Appendix A:
Calibration of a One-Dimensional Hydraulic Model (HEC-RAS) for Simulating Sediment Transport through Three Reservoirs, Lower Susquehanna River Basin, 2008-2011

Attachment A-1:
Additional Information for Susquehanna River at Marietta, PA (01576000), and Conowingo, MD (01578310), and Conowingo Reservoir

Attachment A-2:
Additional Information for Sand Distribution in Conowingo Reservoir

Attachment A-3:
Additional Information for Estimation of Full Sediment Storage Capacity in Conowingo Reservoir

Appendix A - U.S. Army Corps of Engineers Publication, Lower Susquehanna River Watershed Assessment, Maryland and Pennsylvania, Phase 1

Calibration of a One-Dimensional Hydraulic Model (HEC-RAS) for Simulating Sediment Transport through Three Reservoirs, Lower Susquehanna River Basin, 2008-2011

By Michael J. Langland and Edward H. Koerkle

U.S. Department of the Interior
U.S. Geological Survey

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Cover – Susquehanna River at Conowingo Dam

Contents

Figures

Tables

Conversion Factors

Multiply	By	To obtain
acre-foot (acre-ft)	1,233	cubic meter (m^3)
cubic foot per day (ft^3/d)	0.02832	cubic meter per day (m^3/d)
gallon per minute (gal/min)	0.06309	liter per second (L/s)
ton per year (ton/yr)	0.9072	metric ton per year
pound per cubic foot (lb/ft^3)	0.01602	gram per cubic centimeter (g/cm^3)

Temperature in degrees Celsius (°C) may be converted to degrees Fahrenheit (°F) as follows:

°F=(1.8×°C)+32

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

°C=(°F-32)/1.8

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Horizontal coordinate information is referenced to the North American Datum of 1983 (NAD 83).

GLOSSARY – the purpose of this glossary is to provide definitions in general terms for the reader. They are not meant to be complete scientific definitions.

Cohesive sediments – sediments that are less than 0.063 mm in size that represent silts and clays. As the particle size becomes smaller, electrostatic properties of the clays tend to act as a cohesive bond.

Critical Shear Stress – the shear stress required to mobilize and transport sediments. In general, when the shear exceeds the critical shear stress, sediments are mobilized. Conversely, when the shear is less than the critical shear, sediments will deposit. The critical shear varies by particle size, bed embeddedness, and other factors.

Dynamic equilibrium – used in this report to describe the reservoir sediment storage condition. In this condition, little to no sediment storage remains; however, scour events will increase sediment storage for a short period of time, resulting in a reduction in sediment load in the Upper Chesapeake Bay for a short time. In the long-term, sediment will continue to deposit in the reservoirs and be removed with scour-producing flow events.

Fall velocity – the downward velocity of a particle caused by gravity. The velocity is related to the density and viscosity of the fluid, and the density, size, shape, and surface texture of the particle.

Mass Wasting –the down-slope movement of sediment material. As used in this report, mass wasting refers to the process when the bed starts to erode in mass chunks. In this report, this threshold was assumed to occur with flows greater than 390,000 cubic feet per second.

One-dimensional (1-D) modeling – assumes all water flows in the longitudinal direction only. One-dimensional models represent the terrain as a sequence of cross sections and simulate flow to estimate the average velocity and water depth at each cross section.

Shear Stress – the force exerted by water on the sediments in the banks and bottom surface, usually expressed in pascals (standard unit of pressure or stress, English units - pounds per square inch).

Stage-Discharge Rating –A graph showing the relation between the stage and the amount of water flowing in a channel (discharge) that is developed by obtaining a continuous record of stage, making periodic discharge measurements, establishing and maintaining a relation between the stage and discharge, and applying the stage-discharge relation to the stage record to obtain a continuous record of discharge.

Two-dimensional (2-D) modeling – two-dimensional models, water is allowed to move both in the longitudinal and lateral directions, while velocity is assumed to be negligible in the vertical direction. Unlike one-dimensional models, two-dimensional models represent the terrain as a continuous surface through a finite element mesh.

Calibration of a One-Dimensional Hydraulic Model (HEC-RAS) for Simulating Sediment Transport through Three Reservoirs in the Lower Susquehanna River Basin, 2008-2011

By Michael J. Langland and Edward H. Koerkle

Abstract

The U.S. Geological Survey developed a one-dimensional sediment-transport (1-D) model to simulate transport through three reservoirs in the Lower Susquehanna River basin. The primary objective was to produce boundary condition data (daily streamflow, sediment load, and particle size) at a site monitored just upstream of the reservoirs and at the upper end of Conowingo Reservoir. The 1-D model was calibrated with sediment data collected from the downstream site at Conowingo Dam and to bathymetric changes from 2008-2011. The boundary condition data were provided to the U.S. Army Corps of Engineers for use in the calibration and simulation of reservoir dynamics using a two-dimensional model. Due to model limitations identified in this study, two 1-D model simulations were produced, one for the entire modeling period 2008-2011 (representing net deposition) and a second for a high streamflow event September 7-13, 2011 from Tropical Storm Lee (representing net scour). Each simulation used the same model data inputs; however, model parameters were changed to produce results similar to the measured calibration data. The depositional model resulted in a net deposition of 2.1 million tons, while the scour model resulted in a net loss of 1.5 million tons of sediment. The results indicate a difference of about 54 and 57 percent less sediment load, respectively, when compared to the calibration data.

1.0 Introduction

The U.S. Geological Survey (USGS), the Lower Susquehanna River Watershed Assessment (LSRWA) team, and a consortium of federal, State, and private organizations, collaborated on a project to comprehensively forecast and evaluate sediment and associated nutrient loads through a system of three hydroelectric dams located in the lower Susquehanna River above the Chesapeake Bay. The LSRWA team is comprised of staff from the U.S. Army Corps of Engineers (USACE), Baltimore District, the Maryland Department of the Environment, the Maryland Department of Natural Resources, the Susquehanna River Basin Commission, and The Nature Conservancy.

The Susquehanna River is the largest tributary to the Bay and transports about one-half of the total freshwater input and substantial amounts of sediment, nitrogen, and phosphorus to the Bay (Langland, 2009). The loads transported by the Susquehanna River to the Bay are substantially affected by the deposition of sediment and nutrients behind three hydroelectric dams on the lower Susquehanna River near its mouth (Reed and Hoffman, 1996). The three consecutive reservoirs (Lake Clarke, Lake Aldred, and Conowingo Reservoir) that formed behind the three dams (Safe Harbor, Holtwood, and Conowingo) involve nearly 32 miles of the river and have a combined design storage capacity of 510,000 acre-feet (acre-ft) at their normal pool elevations (figure 1). The model area extends just above the pool of the most upstream dam near Marietta, Pennsylvania, to just below the most downstream dam at Conowingo, Maryland, approximately 33 miles. The normal pool elevation is the height in feet above sea level at which a section of a river is to be maintained behind a dam. A fourth dam (York Haven) is located approximately 44 miles above Conowingo Dam. Because of the low head (28 feet) and low storage area (7,800 acre-ft) the sediment retention at York Haven is substantially less than the dams located downstream and is not considered in this project. Safe Harbor Dam, built in 1931 with a dam height of 80 feet, forms the uppermost reservoir with a design capacity of about 150,000 acre-ft and is considered to have reached the capacity to store sediment in the early 1950's (Reed and Hoffman, 1996). Holtwood Dam, built in 1910 with a dam height of 60 feet, is the smallest of the three dams, with a design capacity of about 60,000 acre-ft and is considered to have reached the capacity to store sediment in the mid-1920's (Reed and Hoffman, 1996). Both Lake Clarke and Lake Aldred are considered in dynamic equilibrium. Conowingo Dam is the largest and most downstream; built in 1928 with a dam height of 110 feet, it has a design capacity of about 300,000 acre-ft. Conowingo Reservoir has limited capacity to store sediment and may be in dynamic equilibrium.

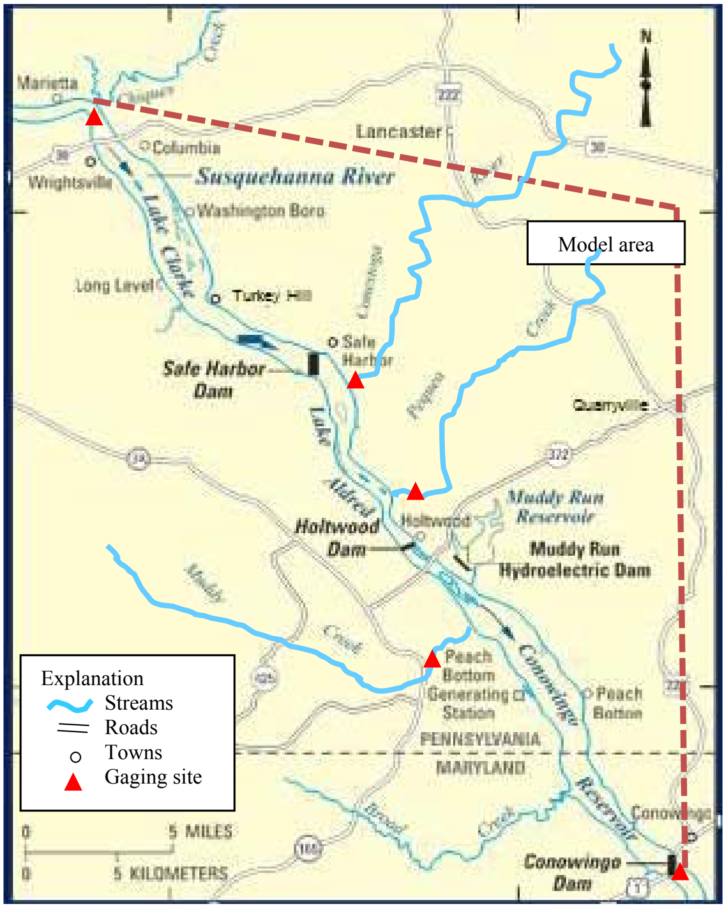

Figure 1. Location map of river reach for the one-dimensional sediment-transport model including the three major reservoirs in the Lower Susquehanna River basin—Lake Clarke, Lake Aldred, and Conowingo Reservoir.

2.0 Background and Previous Studies on the Three Reservoirs

The District of Columbia, the six states with water draining into the Chesapeake Bay (Maryland, Pennsylvania, Virginia, New York, West Virginia, and Delaware), the Chesapeake Bay Commission, and the U.S. Environmental Protection Agency (USEPA) have agreed to a plan to reduce nutrient loads to the Chesapeake Bay in an attempt to restore and protect the estuarine environment of the Bay. The USEPA has established a total maximum daily load (TMDL) which mandates sediment and nutrient allocation goals for each of the six states draining into the Chesapeake Bay (USEPA, 2010).

Previous studies by Ott and others (1991), Hainly and others (1995), Reed and Hoffman (1996), Langland and Hainly (1997), Langland (2009), URS Corporation and Gomez and Sullivan (2012) have documented important information on the lower Susquehanna River reservoirs, including the reservoirs' bottom-sediment profiles, reduced storage capacity, and trap efficiency. Several studies also have determined sediment chemistry (Hainly and others, 1995; Langland and Hainly, 1996; and Edwards, 2006) and the effects of large storm events on the removal and transport of sediment out of the reservoir system and into the upper Chesapeake Bay (Langland and Hainly, 1996; Langland, 2009; URS Corporation and Gomez and Sullivan, 2012). Information from previous reports was useful for the development and calibration of the model for this study.

Langland (2009) provided a historical perspective to reservoir filling rates and projected when sediment storage capacity may be reached in the Conowingo Reservoir. When storage capacity is reached, a dynamic-equilibrium condition will exist between incoming and outgoing sediment and nutrient loads discharged through the reservoir system to the Chesapeake Bay. In the dynamic-equilibrium condition, constituent loads may increase from high flow scour events, thereby affecting the sediment and nutrient allocation TMDL goals set by USEPA and the state of Maryland's water-quality standards for dissolved oxygen, water-clarity, and chlorophyll A. With respect to TMDLs, increased loads may have a greater impact on sediment and phosphorus which tend to be transported in the particulate (solid) phase and less of an impact on nitrogen which tends to transported in the dissolved phase. However, in this dynamic equilibrium condition, loads may also decrease due to increased deposition from a preceding scour event. Hirsch (2012) concludes that the reservoirs are very close to this equilibrium state, and that nutrient and sediment concentrations and loads have been increasing at the Conowingo Dam (the furthest downstream and closest to the Chesapeake Bay) for the past 10-15 years. The report implies increasing concentrations and loads are due to the loss of storage capacity and from a possible decrease in the scour threshold. Reasons for this increase are not certain but likely involve changes in particle fall velocities, increased water velocity, transport capacities, and bed shear.

Dams create a change in hydrological reservoir dynamics affecting sediment transport and deposition. All reservoirs are a sink resulting in hydraulic conditions that reduce the velocity of flows within the reservoir. Due to flow deceleration as the water enters the reservoir, sediment-transport capacity decreases, and the coarser-size fractions of the incoming sediment are trapped and deposited near the upstream end of the reservoir forming a delta near the entrance to the reservoir (figure 2). As the water and sediment continue to flow into the reservoir, the delta continues to extend in the direction of the dam, eventually filling the entire sediment storage volume. The process is usually slow, governed by the amount of incoming sediment, sediment particle size, and flow variability. Generally, low flow results in deposition, while during higher flows some of the sediment is scoured from the upper end of the reservoir and transported downstream with a portion transported out of the reservoir. Large reservoirs receiving runoff with substantial sediment from natural and/or anthropogenic sources typically fill in 50 to 100 years (Mahmood, 1987).

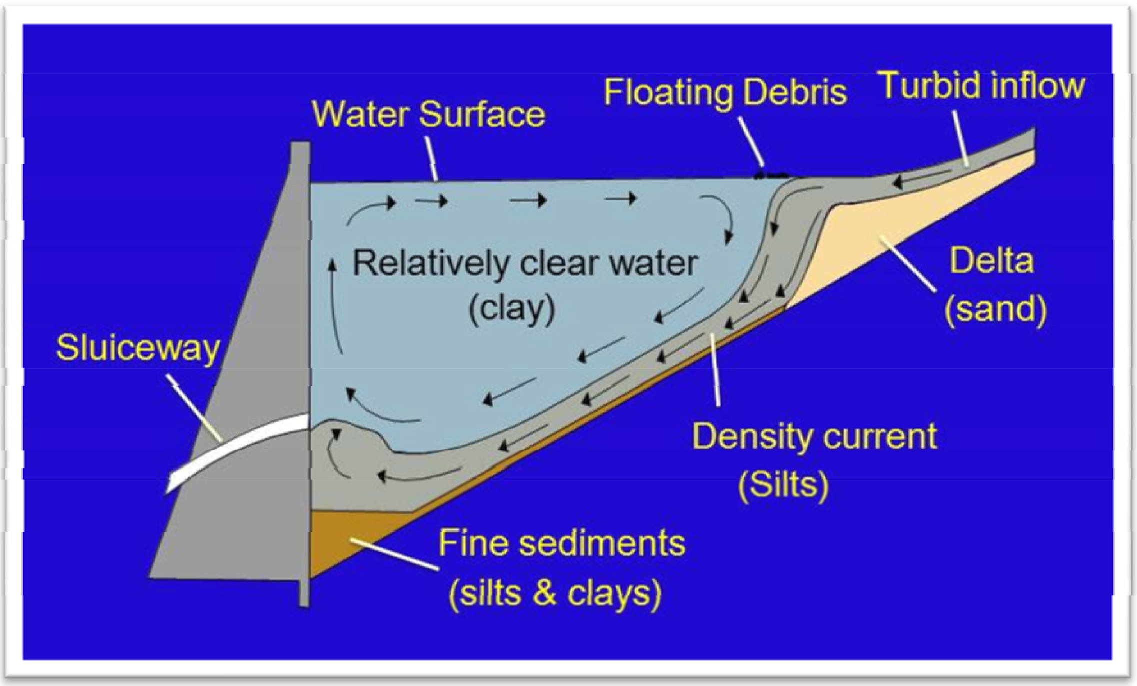

Figure 2. Idealized schematic of a reservoir and the dynamic of circulation and deposition (adapted from Sloff,1997).

3.0 Purpose and Scope

For this study, the primary objective was to produce boundary condition data (daily streamflow, sediment load, and particle size) between the Susquehanna River at Marietta, Pennsylvania streamgage (01576000) and the Susquehanna River at Conowingo, Maryland streamgage (01578310), January 1, 2008 - December 31, 2011. To capture the impacts of transport events on the sediment supply, the USGS selected, developed, and applied a one-dimensional (1-D) U.S. Army Corps of Engineers' **H**ydrologic **E**ngineering **C**enter **R**iver **A**nalysis **S**ystem (HEC-RAS) model to predict sediment discharge, as well as scour and deposition with daily streamflow as an input parameter. The selection was based on existing data, costs to construct and operate the model, new developments in HEC-RAS, and project timeline. This report 1) describes how streamflow and sediment boundary- condition data were developed using the 1-D HEC-RAS model, 2) presents model output to examine calibration and performance, and 3) discusses model limitations. The products of this study were provided to the USACE for the development of a two-dimensional (2-D) model to predict scour and deposition zones, sediment transport, and scenario development for the Conowingo Reservoir and upper Chesapeake Bay. Both the USGS 1-D model and the USACE 2-D model are designed to provide data on reservoir hydrodynamics and sediment transport in the Susquehanna River and to be the basis for sediment inputs into the Chesapeake Bay Program's Chesapeake Bay Environmental Model Package to predict impacts to water quality in the Chesapeake Bay.

4.0 Model Description and Development

Mathematical models have been developed to simulate sediment behavior in reservoirs. All computer sedimentation models include three major components: water routing, sediment routing and special function modules (such as graphical and GIS interfaces). Most models include the option of selecting alternative sediment-transport formulas, but rarely provide the criteria for making that selection. The sediment-transport calculations are performed by grain size fraction thereby allowing the simulation of hydraulic sorting and armoring of the bed. Most 1-D models are based in a rectilinear coordinate system and solve the differential conservation equation of mass and momentum of flow along with the sediment mass continuity equation by using the finite-differences method to predict the parameters of a particular channel, including the velocity, water-surface elevation, bed elevation change, and sediment-transport load (Abood and others, 2009). In addition, many 1-D models also predict the total sediment load and grain size distribution of sediment passing a given cross section.

HEC-RAS is a 1-D movable boundary open-channel flow model designed to simulate and predict changes in river profiles resulting from scour and/or deposition over moderate time periods (years), although single flood events can also be modeled (U.S. Army Corps of Engineers, 2010b). A new beta release of the model was tested for this study (HEC-RAS 4.2 beta 2012-07-19). When paired with a hydrologic record, the model handles hydraulics in a quasi-steady-state mode, which runs as a series of sequential steady-state periods. The HEC-RAS model is largely an enhanced HEC-6 model (U.S. Army Corps of Engineers, 1993) with new and revised algorithms for reservoir simulations and GIS (geographic information system) input/output capabilities using HEC-GeoRAS. HEC-GeoRAS is a GIS extension that provides the user with a set of procedures, tools, and utilities for the preparation of GIS data for import into HEC-RAS and generation of GIS data from RAS output.

The HEC-RAS 1-D model (referred to hereafter as the model) simulates the capability of a stream to transport sediment, both bed and suspended load, based on the yield from upstream sources and current composition of the bed. Using the hydraulic properties of the streamflow and the characteristics of the sediment material (for this study determined by analyzing sediment and core samples), the model can compute the rate of sediment transport. This is accomplished by the user partitioning a continuous streamflow record into a series of steady flows of variable discharges and durations. For each flow, a water-surface profile is calculated thereby providing energy slope, velocity, depth, etc., at each cross section. Potential sediment-transport rates are then computed at each section. These rates, combined with the duration of the flow, permit a volumetric accounting of sediment within each reach. The amount of scour or deposition at each section is then computed and the cross section adjusted accordingly. The computations then proceed to the next flow in the sequence and the cycle is repeated beginning with the updated geometry (U.S. Army Corps of Engineers, 2010b, p. 17-20).

The model calculates sediment-transport rates for 20 particle size classes for grain sizes up to 2048 millimeters (mm). Not all 20 particle size classes are required in the model. If sediment sizes larger than 2048 mm (equivalent to 6.7 feet) exist in the bed, they are used for sorting computations but are not transported. For this study, particle size from sediment core data indicated the largest sediment class to be 8 mm. The user chooses from seven sediment-transport functions (table 1) for bed material load (U.S. Army Corps of Engineers, 2010a). Each transport function was developed based on specific assumptions such as bed type (sand, gravel), hydraulic conditions, and grain size transport. Several transport functions were tested, but Laursen (Copeland) was selected because the dominant particle size in the bed and being transported is silt (discussed later in report).

Bed sorting and armoring methods include Exner 5 and active layer. Exner 5 is a three-layer active bed method capable of forming an armored bed to limit erosion (scour) of deeper material.

Active layer is a two-layer active bed approach with no bed armoring to help increase potential scour (Duan and others, 2008).

Table 1. HEC-RAS 4.1 Sediment-transport functions and general use.

Sediment-Transport Function	General use and Applicability
Ackers-White	Total load function developed for sand to fine gravel. Suspended sediment is a function of shear velocity and bedload is a function of shear stress.
Engelund_Hansen	Total load function developed and limited to sandy rivers.
Laursen (Copeland)	Total sediment load predictor based on excess shear stress and the ratio of excess shear and fall velocity. It outperforms the other transport functions in the silt range.
Meyer-Peter Muller	Designed for bed load transport and not useful for this study
Toffaleti	A modified Einstein total load model generally applicable to sand and gravel beds but tested in large rivers with high suspended sediment loads.
Yang	Developed assuming stream power is dominant factor more useful for sands up to gravel.
Wilcock	Bedload transport function

For deposition and erosion of clay and silt sizes up to 0.0625 mm, fine particle transport can be computed using the selected sediment-transport equation or use of Krone's (1962) method for deposition and Ariathurai and Krone's (1976) adaptation of Parthenaides (1965) method for scour. Additional cohesive sediment data are required when using the above-referenced methods (discussed later in report). The model's default procedure for clay and silt computations allows only deposition using a method based on fall velocity. Cohesive particles are small enough that electrochemical surface forces dominate their behavior more than gravity (fall velocity). The Krone's and Parthenaides methods are functions used to quantify the deposition and erosion of cohesive material in a single process (U.S. Army Corps of Engineers, 2010a).

4.1 Model data

The basic types of data needed to simulate sediment transport are streamflow, bed composition, and the geometric and hydraulic framework, together creating the boundary conditions. The acquisition, development, and assembly of these data are discussed in this section.

4.1.1 Discharge

Continuous (recorded every 15 minutes) and daily-mean streamflow (discharge) data for the Susquehanna River at Marietta, Pennsylvania (USGS 01576000) and the Susquehanna River at Conowingo, Maryland (USGS 01578310) streamgages were obtained from the USGS National Water Information System (NWISWeb) (U.S. Geological Survey, 2002). The Marietta gage served as the upstream boundary condition and the Conowingo gage served as the downstream boundary condition for the period of study and simulation, January 2008-December 2011. A stage-discharge rating curve also was constructed using all available data and both the rating curve and actual discharge values were used in model calibration (figures 3 and 4). Discharge over the 4-year simulation period (figure 5) indicated normal to less than normal flows for the first 3 years with only one daily-mean discharge exceeding 300,000 cubic feet per second (cfs), and flow with a return interval of two years (annual exceedence probability (AEP) of 0.5). The fourth year (2011) was above normal with 8 days exceeding a daily-mean discharge of 300,000 cfs and 4 of those 8 days exceeding 400,000 cfs, the estimated average bed scour threshold (figure 5). The average return interval for flows of 400,000 cfs is every 5 years (AEP 0.2).

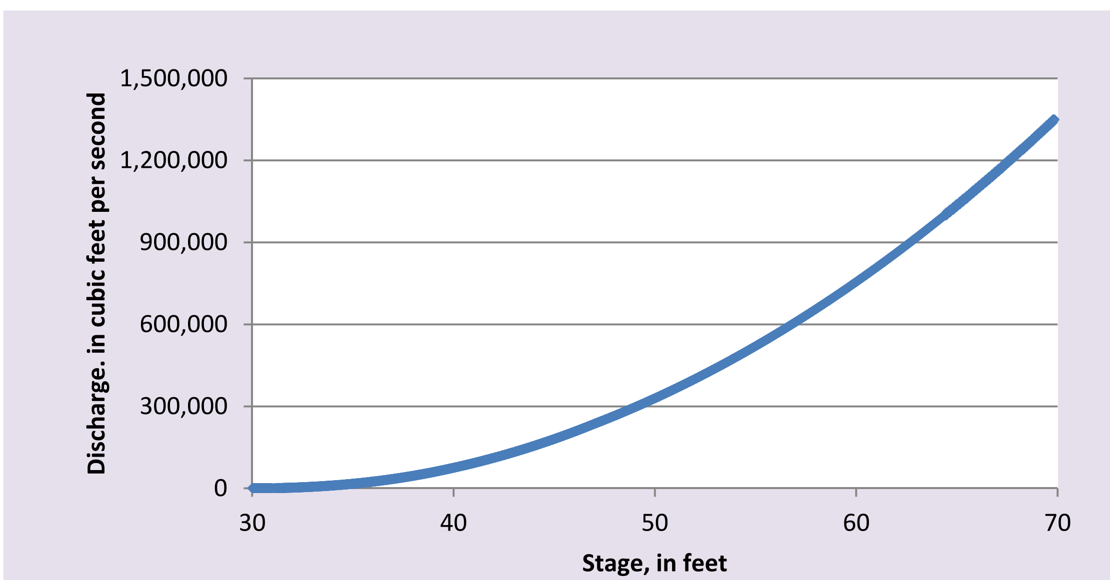

Figure 3. Stage-discharge rating curve for Susquehanna River at Marietta, Pennsylvania (01576000).

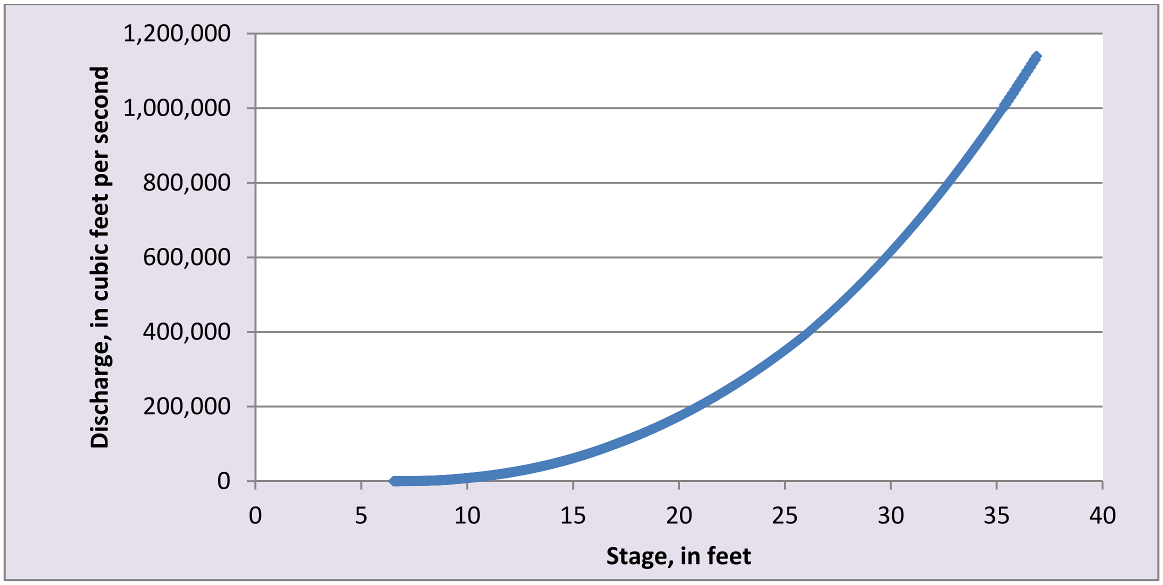

Figure 4. Stage-discharge rating curve for Susquehanna River at Conowingo, Maryland (01578310).

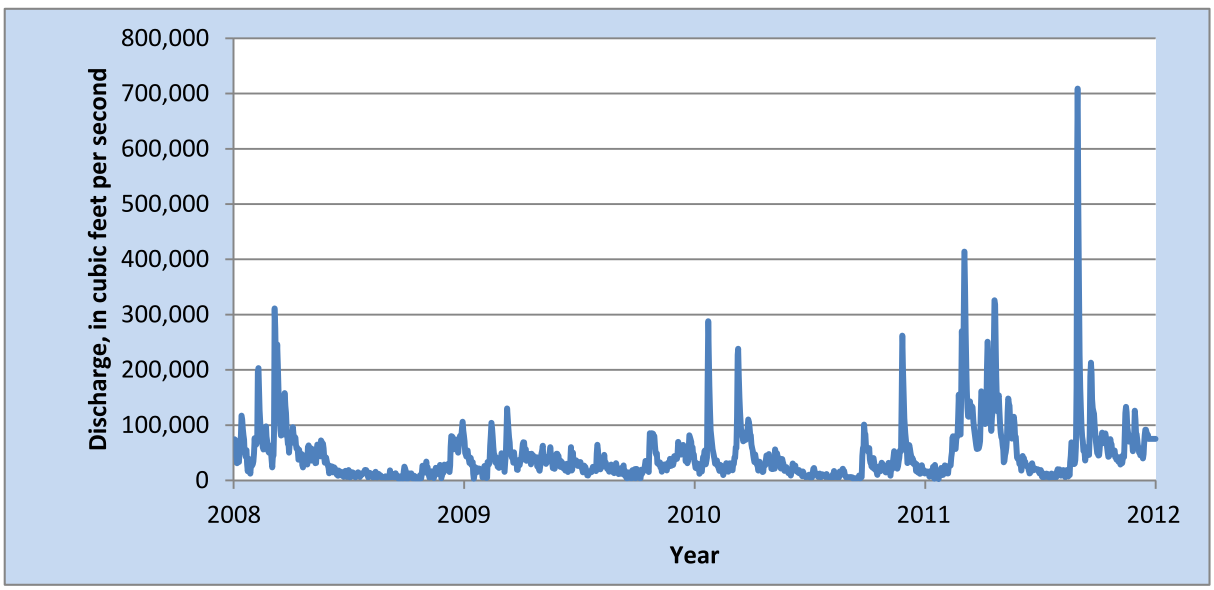

Figure 5. Discharge for Susquehanna River at Conowingo, Maryland (01568310), 2008-2011.

4.1.2 Sediment

Predicting sediment transport through a reservoir is a complex problem. Sediment input, deposition and scour rates in a reservoir mainly depend on water velocities, particle size distribution, and bed shear. Knowledge of sediment particle size distributions in incoming and outgoing water columns, as well as in bottom sediment, aids in the development of a successful sediment-transport model.

Sediment loads entering and leaving a reservoir can be determined from a sediment-rating (transport) curve or from actual concentration data from upstream and/or downstream site(s). In this study, instantaneous suspended-sediment concentrations from above the reservoir system (Susquehanna River at Marietta, Pennsylvania; 01576000) and below the reservoirs (Susquehanna River at Conowingo, Maryland; 01578310) were used to construct sediment transport curves. The sediment-transport curve and actual discharge/concentration data were tested and used in the model calibration (figures 6 and 7). Both figures indicate the occurrence of outliers, the largest being from the September 2011 storm event. Using the R^2 values included in figures 6 and 7, approximately 70 and 61 percent of the variance, respectively, is explained by the equations at the sites. It is important to mention that first, the highest values represented in the graph may need be the "true" maximum concentration because only a small percentage of the storm flow is sampled and second, a direct comparison between the two sediment ratings cannot be made, due to the trapping and release (scour) of the sediments in the three reservoirs.

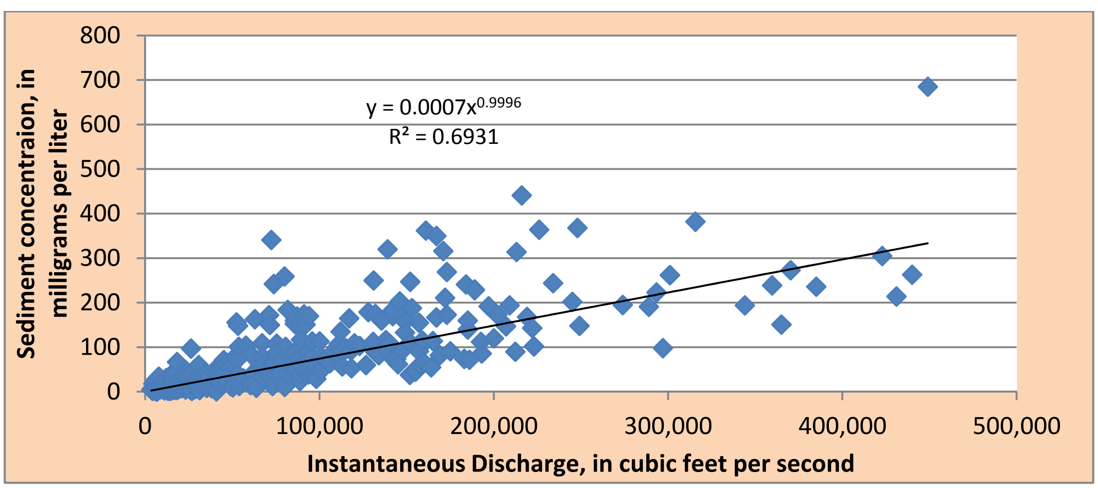

Figure 6. Sediment-transport curve for Susquehanna River at Marietta, Pennsylvania (1987-2011).

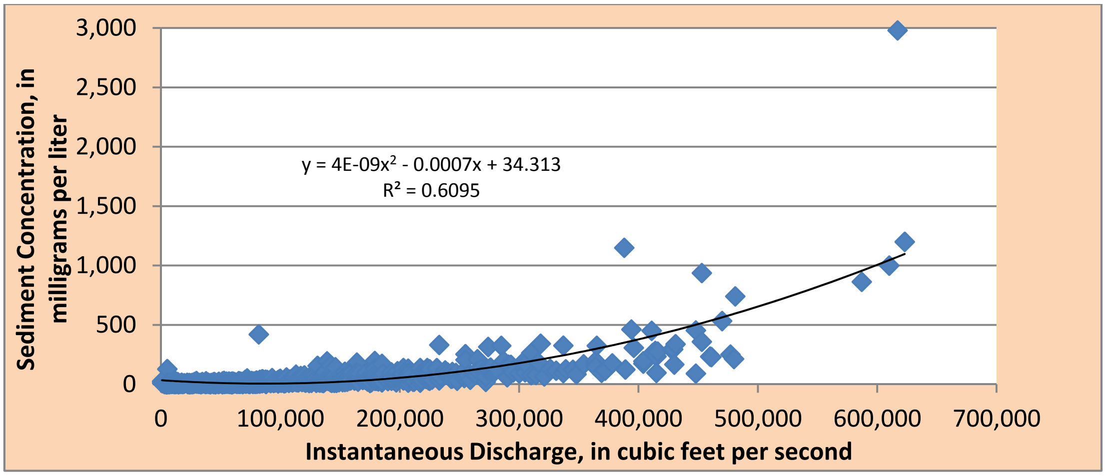

Figure 7. Sediment-transport curve for Susquehanna River at Conowingo, Maryland (1979-2011).

Data on stream bed particle size distributions from sediment corings are available from Hainly and others (1995), Reed and Hoffman (1996), and Edwards (2006) (see attachment B). These data were compiled and analyzed for spatial patterns in each reservoir. Particle size distributions from the 1990-91 and 2000 core data indicated good agreement with size ranges and distributions by depth in all three reservoirs except in the lower portion of Conowingo Reservoir, an area with remaining trapping capacity. Based on sediment cores and historic transport data, 12 particle size classes were simulated in the model, ranging from about 8 mm to less than 0.004 mm. The 1990-91 and 2000 core datasets were averaged and grouped into a total of 12 distinct spatial locations (figure 8), each with unique particle size distributions and bed thickness. The average percentage of sand, silt, and clay for each reservoir is presented in table 2. The percent silt in Lake Aldred was most likely affected by the smaller reservoir size and the dredging of silt-sized coal lasting for several decades until 1972.

Table 2. Average percentage of sediment by sediment type for three reservoirs in the Lower Susquehanna River Basin.

Reservoir	Sand	Silt	Clay
	(Percent)		
Lake Clark	27	44	29
Lake Aldred	61	24	15
Conowingo	16	52	32

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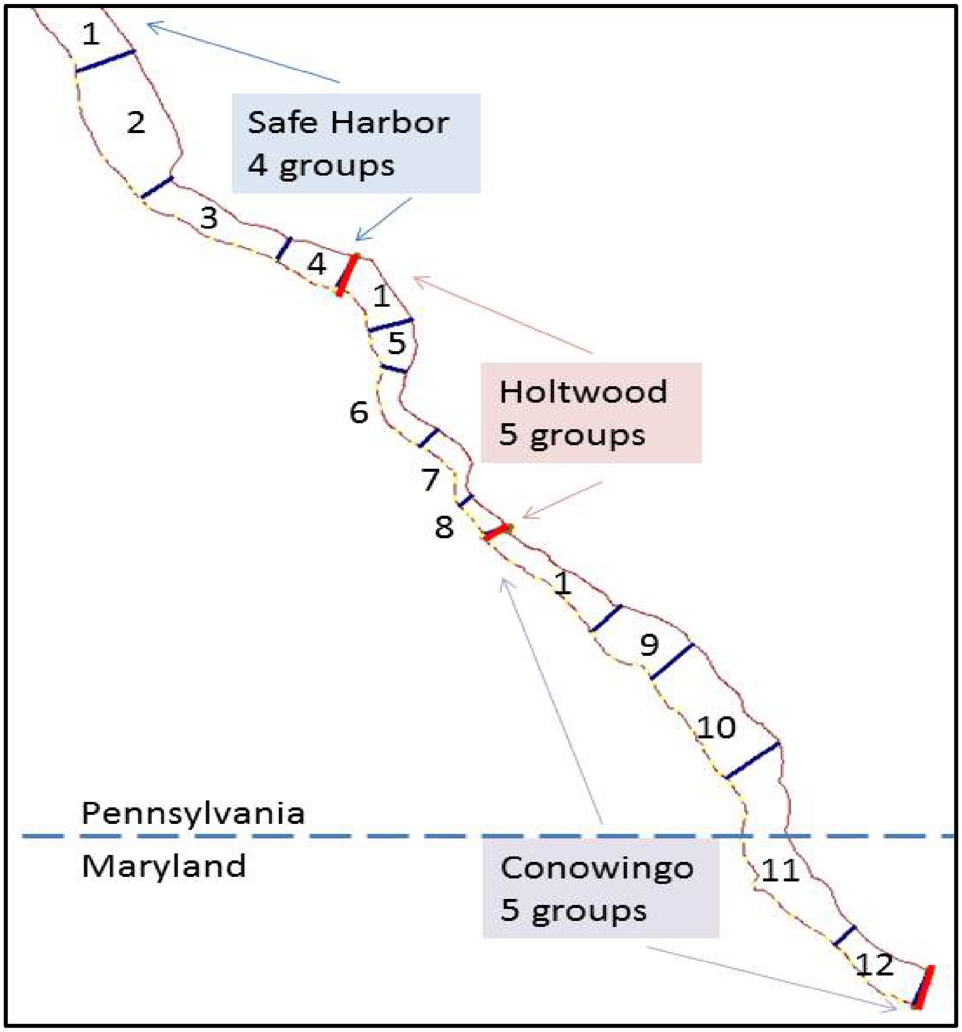


Figure 8. Selected spatial locations (based on particle size and bed thickness) where particle size distribution curves were created for use in the HEC-RAS sediment-transport model

The distribution of particle size classes for each grouping is presented in table 3. Group number 1 is the most sandy and is common at the uppermost portions of each reservoir resulting in three of the locations having equivalent particle size distributions (labeled as group 1), equaling the 12 groups depicted in figure 8 and table 2. Moving downstream within a reservoir, the percent sand generally becomes less, while fines increase due to reservoir transport dynamics (see figure 2, background section) and stratification of the sediments. The data in table 2 were used to construct a continuous particle size distribution curve for each group that was subsequently assigned to corresponding river cross sections in that group. As discussed previously, the HEC-RAS transport equations (table 1) are designed mainly for sand and coarser particles. The bed sediments exhibit a wide variability in the particle size distributions, with sand (greater than 0.0625 mm) as the dominant sediment type in 7 of the 12 groups, generally in the upper and middle sections of each reservoir, and silt (less than 0.0625 mm but greater than 0.004 mm) as the dominant sediment type in the other 5 groups, generally in the lower sections of each reservoir and most prone to be scoured.

Table 3. Particle size distribution for each of the groups used in the HEC-RAS modeled area presented in figure 8. Particle sizes are in percent finer. Group 1 (upper) is used at the uppermost portion of each reservoir. Groups are color coded to match figure 8.

Sediment Type	Particle Size class (mm)	Group Number											
		Upper	Lake Clarke			Lake Aldred				Conowingo Reservoir			
		1	2	3	4	5	6	7	8	9	10	11	12
clay	< .004	2	16	33	20	17	20	5	26	3	16	31	36
silt	< .008	2	23	47	27	23	27	7	35	4	23	42	51
silt	< .016	3	29	61	37	30	35	9	49	4	32	55	70
silt	< .031	3	38	76	48	37	45	11	63	5	42	73	88
silt	< .0625	6	46	87	55	42	58	13	76	7	53	85	96
sand	< .125	21	52	93	62	46	71	20	87	10	63	93	99
sand	< .25	61	60	96	83	59	85	40	96	39	75	97	100
sand	< .5	88	81	99	94	81	95	63	100	70	93	99	100
sand	< 1	98	95	100	99	96	98	78	100	90	97	100	
sand	< 2	100	99	100	100	99	98	88		94	99	100	
pebble	< 4		100		100	100	99	93		98	100		
pebble	< 8						100	100		100			
	Summary												
	Sand	90	38	13	45	58	42	87	24	93	47	15	4
	silt	6	54	54	36	25	37	8	50	3	37	54	60
	clay	2	16	33	20	17	20	5	26	4	16	31	36

4.1.3 Water Temperature

According to Stokes Law, water temperature has a direct effect on the fall velocity (settling) rate of sediment in a reservoir water column (Sullivan and others, 2007). As the temperature decreases, the water becomes more viscous and the fall velocity decreases thereby effecting the distribution of sediment in the water column. In addition, the more viscous (denser) the water becomes, the greater the potential for increase in bed erosion. Therefore, a daily time series of water temperature was generated. Available water temperature data consisted of irregularly spaced measurements during 2005-2011 (165 measurements at Susquehanna River at Marietta, Pennsylvania, 01576000; 105 measurements at Susquehanna River at Conowingo, Maryland, 01578310). Better continuity and distribution of water temperature data was available from Marietta than from Conowingo, but the range of temperatures at the 2 sites was similar. Therefore, the Marietta data was used as the basis for the modeled temperature series (figure 9). A fourth order polynomial (algebraic expression with exponents) was fit to an annual time series of the observed temperature data for the period 2008-2011. Fit of the observed data to the equation was generally within 3 degrees with a few exceptions. Discontinuity in the fit at the December-January boundary was smoothed using the interpolation feature in RAS.

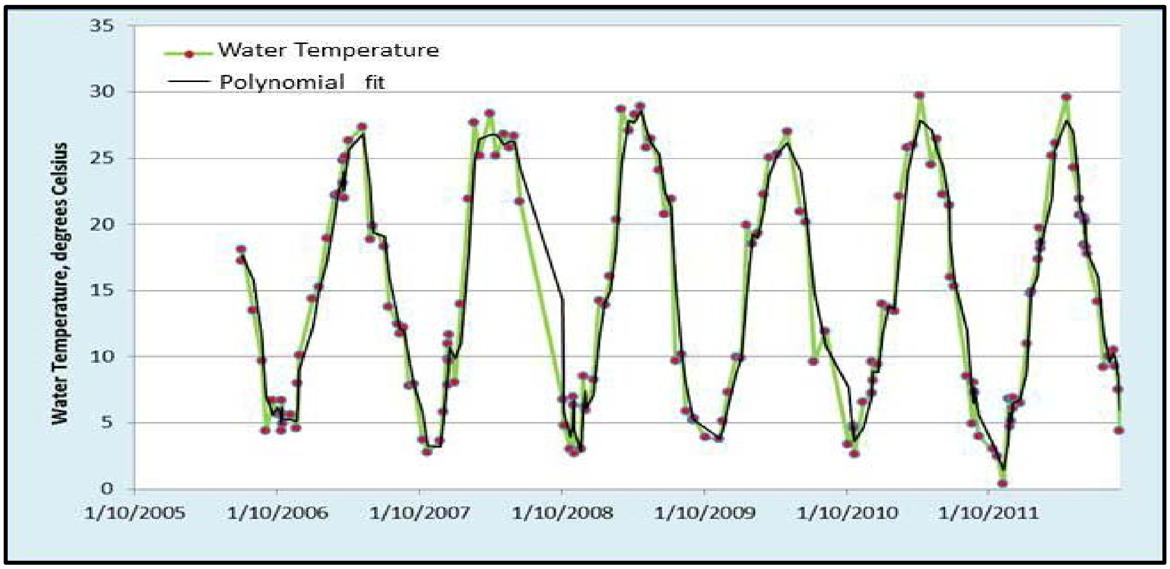


Figure 9. Water temperature data from the Susquehanna River at Marietta, Pennsylvania streamgage used to construct the daily time series for the one-dimensional model.

4.2 Geometry and Hydraulic data

Geometry and flow data are used to calculate steady, gradually varied flow water-surface profiles from energy loss computations (U.S. Army Corps of Engineers, 2010a). Model geometry is specified by a series of channel cross sections and the dam structures. For this study, three options were considered. The options included: (1) using a previous USGS HEC-6 model, (2) converting a flood insurance study (FIS) model completed using HEC-2, and (3) constructing a new model. Due to data limitations, the USGS selected option 3 and assembled new geometry data. Advantages to creating a new model included being able to align cross sections with current bathymetry using the model, using geometry that is better suited for the sediment model (fewer cross sections, no structures), and using Lidar-derived topography for channel banks.

A total of 83 cross sections were developed from the 2008 bathymetry (Langland, 2009) to represent the river system from the Marietta gage to just below Conowingo Dam (figure 10). Each cross section was assigned a numerical identification based on river distance (feet) above the most downstream point and was limited to a maximum of 600 lateral points. The average USGS 2008 bathymetry cross section was 8,000 points. A thinning routine was developed that deleted points based on change over a specific distance while retaining as much detailed bathymetry as possible; however, some loss in detail was unavoidable. Because HEC-RAS is a 1-D model, this loss was considered insignificant. Furthermore, because the river channels are narrow and steep sided, there was little concern for overbank (floodplain) flow.

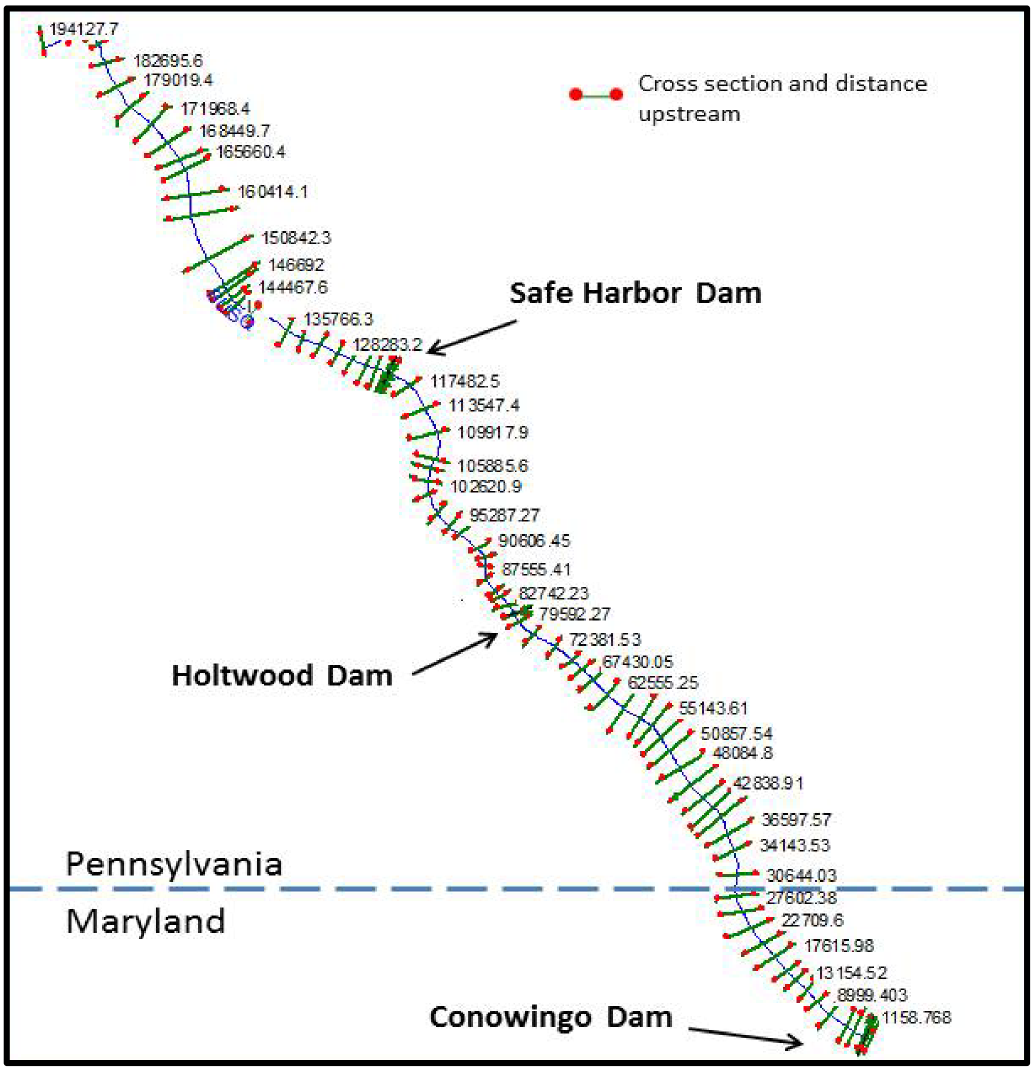


Figure 10. Locations of the cross sections aligned with bathymetry results to produce the geometry files for the HEC-RAS model (river distances in feet).

Flood control gates are designed to release additional water to assist in storage regulation (floods, maintenance) so flow specifications and related changes in reservoir pool elevations need to be considered in the model geometry data. Safe Harbor and Conowingo Dams have flood gates capable of controlling pool elevations over a range of flows. The 31 gates for Safe Harbor and 53 gates for Conowingo (one gate with single flow and 26 gates with flow doubled) were modeled using pass through areas and published gate elevations. There is very limited control of pool elevation at Holtwood (turbine pass through rate and 4.75 feet (ft) high inflatable dam sections are the only controls) therefore, the spillway was simulated as a weir.

Model inputs for the hydraulic simulations included normal water-surface pool elevations with dynamic changes through time representing a hydrograph as levels fluctuate due to power generation, routine maintenance, and changes in incoming water discharge. Gate openings to maintain approximately constant pool elevations for Safe Harbor and Conowingo Dams were determined by multiple steady-state runs covering a range of flows in the 2008-11 period. Gate ratings were subsequently developed and used to estimate gate openings for every day in the 2008-11 simulation period. The bed roughness coefficient (Manning's n) has a major effect on water-surface elevations and is usually one of the primary calibration hydraulic parameters. Several options were available for initial estimates of Manning's n —HEC-RAS defaults, values from a previous USGS HEC-6 model, and values from other HEC 1-D models.

5.0 Model Calibration

The next step in model development is calibration. Calibration can be considered a continuous process. The input parameters that control modeled processes are adjusted during calibration to obtain better agreement between model output and actual observations. For this study, model iterations were made to improve predictions. Prior to calibration, initial boundary conditions were established for discharge, sediment, and geometric and hydraulic parameters.

The streamflow boundary conditions were established using the actual daily-value discharge hydrograph for the Susquehanna River at Marietta, Pennsylvania streamgage as the upstream boundary condition and a stage-discharge rating for daily-value streamflows from the Susquehanna River at Conowingo, Maryland gage as the downstream boundary condition (figure 4). As previously mentioned, instantaneous and daily-mean discharges files and stage-discharge-rating curves were retrieved or developed. Each file was tested in the model and the simulation result that yielded the best hydraulic performance (matching normal pool elevations) was selected. Internal boundaries for the dams were set using time-series of gate openings. Lateral inflows from Conestoga River at Conestoga, Pennsylvania (01576754) and Pequea Creek at Martic Forge, Pennsylvania (01576787) were included. Although other smaller lateral inflows exist (e.g., Muddy Run, Deer Creek, Broad Creek, Conowingo Creek), only Conestoga River and Pequea Creek inflows were included in the model due to their greater volume and agricultural sediment inputs compared to other smaller streams like Muddy Run and Deer Creek.

For the hydraulic boundary conditions, the initial Manning's n values were modified during calibration based on examination of cross section bed movement. Although water-surface elevations respond to changes in n values, sediment transport tends to be fairly insensitive to changes in channel Manning's n values in HEC-RAS (personal communication, Stan Gibson, U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, CA, October, 2012). The average Manning's n for 80 cross sections was 0.034, ranging from 0.012 (level beds) to 0.3 (very rough bedrock and boulders near channel banks and just downstream of each dam). These 80 cross sections, along with the three cross sections representing the dam structures, total 83 modeled cross sections, as previously mentioned.

The target (normal) pool elevations were 227 ft at Safe Harbor, 169.75 ft at Holtwood, and 108.5 ft at Conowingo, all National American Vertical Datum of 1988 (NAVD88). Exact matches to selected (target) normal pool elevations were not achieved in the model on a daily basis with most days differing by less than 5 percent during the 4 year simulation period. In general, gate openings for Safe Harbor and Conowingo were set to produce slightly increasing pool elevations with increasing discharge in lieu of an exact target elevation.

During the 2008-11 simulation period, the largest daily-mean flow event occurred on September 9, 2011 (figure 11). Because Holtwood Dam does not have control gates for pool elevation control, the discharge was simulated to reach the normal and maximum pool elevations. The maximum pool elevation for Holtwood Dam on September 9, 2011 was approximately 183 ft (personal communication, Chris Porse, Pennsylvania Power and Light, 2012). The exact height is uncertain because the water rose higher in the forebay than could be recorded. What is certain is that the elevation did not exceed 184.5 ft, the height of the crestwall. At a height of 183 ft, the water over the spillway would be approximately 17 ft; the calibrated hydraulic simulation resulted in a height of 17.1 ft.

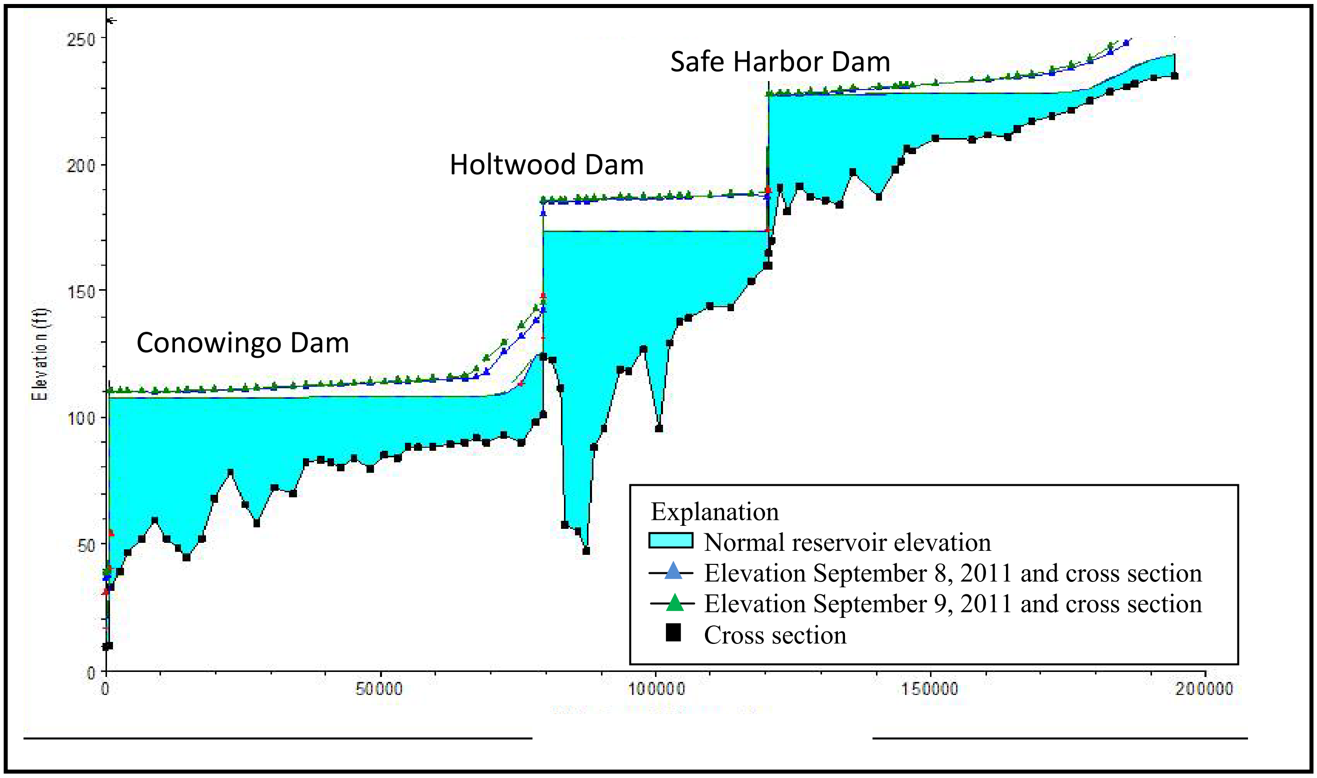


Figure 11. Calibrated water-surface profiles for the three reservoirs at normal pool elevations (light blue shading) and maximum elevation on September 8, 2011 (blue line above shaded areas) and maximum elevations on September 9, 2011 (green line above shaded areas). The dots and triangles represent the model cross sections.

Sediment input boundary conditions were specified at 3 locations in Pennsylvania, Susquehanna River at Marietta, Conestoga River at Conestoga and Pequea Creek at Martic Forge. Together, these three locations account for an average of approximately 97 percent of the monthly inflow into the reservoirs. The boundary conditions consist of daily time series of suspended sediment (USGS parameter code 80154) and loads from the USGS ESTIMATOR model (Cohn and others, 1989). The ESTIMATOR model is a 7-parameter log linear regression model with parameters for flow, season, and time. Although Conestoga and Pequea have much smaller streamflows than the Susquehanna River, the large agricultural sediment loads coming from Conestoga and Pequea add up to 5-10 percent of the total suspended-sediment load entering the reservoirs (figure 12). Note the generally inverse relation between the percentage of the total sediment load from the Conestoga River and Pequea Creek tributaries to the total load transported into the reservoirs, indicating increased influence from the Susquehanna River watershed at higher flows.

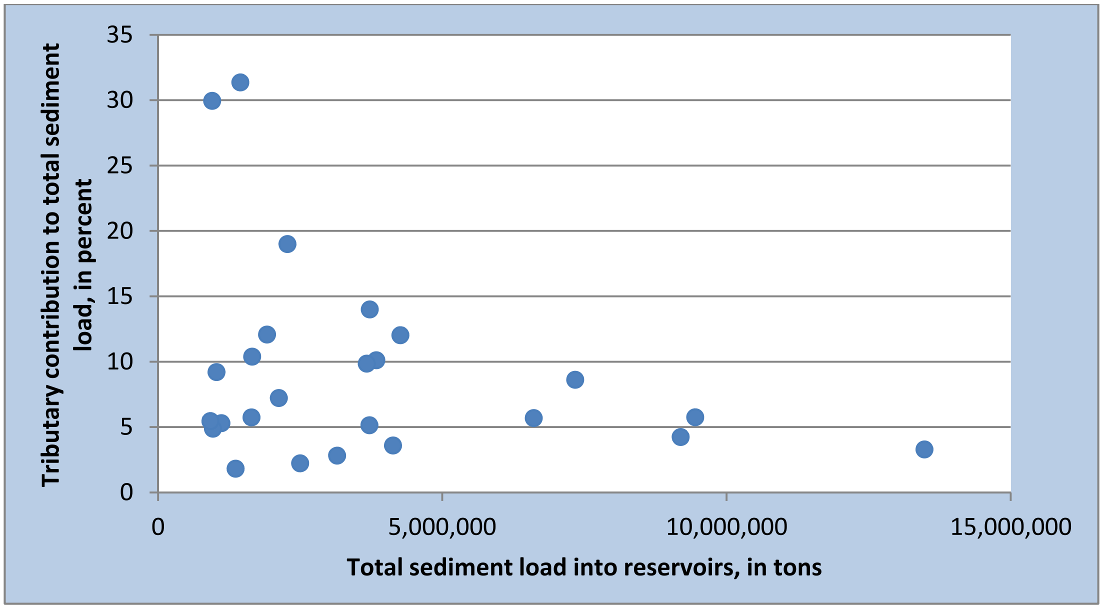


Figure 12. The percent of the total sediment load from the Conestoga River and Pequea Creek tributaries compared to the total sediment load transported into the reservoir system.

A model is calibrated if there is good agreement between model predictions and observed (measured) conditions over the simulation period. Model output was compared to volume changes based on bottom surface profiles from the 2008 and 2011 bathymetry studies, actual daily streamflows and sediment loads for the model time period, and particle size transport data determined from discrete sediment samples collected above and below the reservoirs. Interaction, evaluation, and feedback of boundary-condition data provided to the USACE for the 2-D model also aided in model calibration. The calibration process involved many iterations, each involving some adjustment to one or more model algorithm‘s or parameters and assumptions. For example, the initial model runs indicated scour at low velocities with little to no scour at high velocities, regardless of the critical shear stress resulting in low sediment concentrations and transport. Adjustments were made by changing transport functions and adding cohesive sediment properties.

The sediment-transport analysis in HEC-RAS requires the selection of sediment-transport formulas, maximum erodible depth, sediment bed sorting method, fall velocity method, upstream boundary (flow and sediment) conditions, Manning’s n, information on particle size fractions and additional detailed and specific information on sediment properties. Three of the seven sediment-transport functions were evaluated and Laursen (Copeland) was selected as best predictor. Erodible depths ranged from 0 feet just downstream of each dam where the bed is composed of gravels, boulders, and bed rock to 20 feet in the deepest sediment accumulation areas. Final calibration (input) parameters for each model are presented in table 4. Two simulations (depositional and scour) were performed using different model parameters but the same boundary condition data (more in Results section).

Table 4. Input parameters for the HEC-RAS depositional and scour simulations.

Parameter	HEC-RAS Depositional	HEC-RAS Scour
Sediment-transport function	Laursen (Copeland)	Laursen (Copeland)
Fall velocity method	Ruby	Van Rijn
Cohesive shear (pounds/square ft)	0.018	0.018
Erodible depth (feet)	Variable 0 to 20 ft	Variable 0 to 20 ft
Manning's n	Variable 0.012 to 0.3 (average 0.03)	Variable 0.012 to 0.3 (average 0.03)
Number of size fractions	12	12
Bed sorting	Exner 5	Active Method
Upstream discharge condition	Daily-mean discharge	Daily-mean discharge
Downstream discharge condition	Stage-discharge rating	Stage-discharge rating
Upstream sediment condition	Estimated daily loads	Estimated daily loads
Downstream sediment condition	Calibrate to the estimated daily loads	Calibrate to the estimated daily loads
Length of time steps	1 hour	1 hour
Water temperature	Daily time series	Daily time series

The Laursen (Copeland) transport function was selected as the best total sediment load transport predictor based on performance to transport silt, the most common particle size class in the bed sediments and suspended-sediment data; the selection of sorting methods varied depending on amount of deposition or scour; and the fall velocity method was selected based on temperature compensation and performance with other methods. The fall velocity of a particle depends on the density and viscosity of the fluid, and the density, size, shape, and surface texture of the particle. The "Ruby" method is appropriate for silt, sand, and gravel size grains, while the "van Rijn" method tends to hold the cohesive sediments and fine sands in suspension longer thereby increasing transport capacity (Van Rijn, 1984).

Cohesive critical shear threshold (force needed to initiate movement) and mass wasting thresholds (sediment moved downslope due to gravity) were first run using model defaults and were changed based on sediment data from the USACE SEDflume studies (Perky and others, 2013) using average values and bed mixing routines that were changed between models due to resistance to bed erosion. The Krone/Parthenaides option was selected which requires additional data input to quantify the deposition and erosion of cohesive material in a single process. Final cohesive parameter settings for the 12 groups (presented earlier in report) for bed sediment gradations are presented in table 5. An important model limitation is the model can only accept one non-varying series of cohesive parameters for all 12 groups, although the SEDflume data indicated a wide variability in the parameters.

Table 5. Cohesive parameter settings for bed gradations for the 12 bed sediment groupings.

[lb/ft^{2,} pounds per square foot; lb/ft^2/hr, pounds per square foot per hour];

	Critical Shear Threshold (lb/ft^2)	Erosion Rate (lb/ft^2/hr)	Mass Wasting Threshold (lb/ft^2)	Mass Wasting Rate (lb/ft^2/hr)
Cohesive Parameters	0.0183	33.1	0.31	134.3

In addition, several model computational and tolerance options related to performance (cross section expansion and contraction, critical depth computation, conveyance and energy slope analysis, and number of iterations) were set based on advice from Stan Gibson (personal communication, U.S. Army Corps of Engineers, Hydrologic Engineering Center, Davis, CA, October 4, 2012). The output was daily and the model was run in one hour time steps from January 01, 2008 to December 31, 2011. A sensitivity check was made by using a time and flow varying time step (higher flows equal smaller time steps, with time steps ranging from 24 hours to 1 minute). Because the largest change in hourly flow was only 9,000 cfs in the Conowingo Reservoir, results from time steps less than 1 hour were not discernible.

6.0 Model Uncertainty and Limitations

Because models only approximate natural conditions, they are inherently inexact. The mathematical description can be imperfect and/or understanding of processes may be incomplete. Mathematical parameters used in models to represent real processes are often uncertain because the parameters are empirically determined and represent multiple processes and central tendencies (averages). Additionally, the initial conditions or the boundary conditions in a model may not be well known. The following limitations were observed and documented during this project.

1. Most models include the option of selecting alternative sediment-transport formulas, but few provide the criteria for making that selection. This usually results in many trial and error scenarios, relying on knowledge of the model parameter constraints or additional data collection to help in the validation process, or both. For this study, the selection of the sediment-transport function, Laursen (Copeland), was based on the most common sediment class (silt) in the bed sediments and transported over the Conowingo Dam.
2. Increasing the critical shear resulted in an increase in scour in some cross sections (contradictory effect). In other cross sections, the shear stress exceeded the mass wasting threshold which normally should produce scour, however, only minor scour was indicated. Project staff were not able to resolve these issues.
3. The model is one-dimensional, and while scour and deposition can be simulated in different time steps on the bed surface in each cross section, the model assumes the change occurs evenly across the entire cross-sectional movable bed. Bathymetry data from 2008 and 2011 indicate both deposition and scour occur in the same cross section (figure 13).

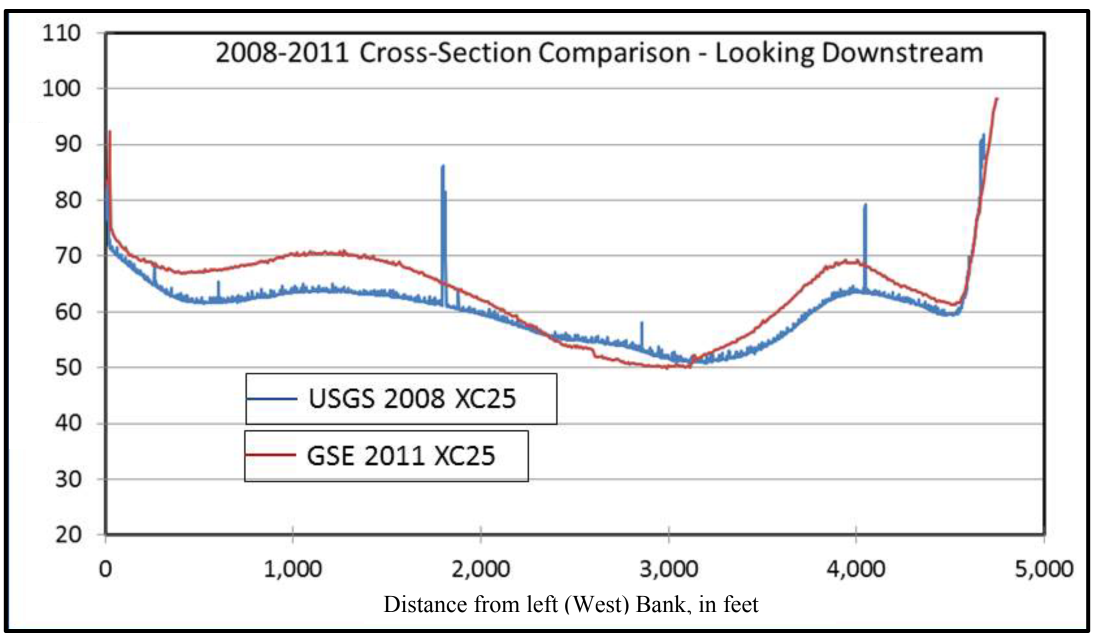


Figure 13. Comparison of cross section 25 (XC25) showing both deposition (red line above blue line) and scour (red line below blue line) for the 2008 U.S. Geological Survey (USGS) and 2011 URS Corporation URS Corporation and Gomez and Sullivan (GSE) bathymetries.

4. There was a lack of information of regarding flocculation size. This could have contributed in modeled fall velocity of the silts and clays being about two times lower (lack of deposition) than expected from literature values and the USACE 2-D model and fall velocity values had limited adjustment capability in the model.
5. The model only allows for one critical shear stress value for cohesive sediments; USACE SEDflume core stress data indicated the potential for wide variability, (Perky and others, 2013).
6. There were substantial differences in particle size distributions across many cross sections. The model cannot account for this lateral variation.
7. The model does not simulate the bed load and suspended load separately, but solves as total load.
8. The model is designed for non-cohesive (sands and course silts) sediment transport with limited capability to simulate processes of cohesive (generally medium silts to fine clays) sediment transport, which may not be suitable for all reservoir simulations, especially in areas of highly variable bed shear, active scour and deposition, and particle size.

7.0 Results

Calibration of the 1-D HEC-RAS model for this application was difficult due to model limitations and the complexity of the system being modeled. Model results were compared to other estimated loads in and out of the reservoir system using the USGS ESTIMATOR model (Cohn and others, 1989). As previously mentioned, the HEC-RAS model is designed for long-term (years) simulations (U.S. Army Corps of Engineers, 2010b), with potential applications to a single, high-flow event. For this study, there was a need to simulate the 2008-11 period and a specific flood event in September 2011. As the calibration proceeded, it became apparent that developing a single model to accurately simulate both deposition and scour was not possible. Therefore, two versions of the model were developed —one to simulate the net depositional change indicated by the 2008 and 2011 bathymetries and another to simulate the net scour that that was estimated to have occurred September 7-13, 2011 (Tropical Storm Lee).

As previously mentioned, bathymetry results indicated net deposition over the simulation period; therefore, model parameters were set to help ensure sediment deposition (Table 4. Many parameter combinations were tested with numerous iterations and calibration checks performed during the simulations (see Calibration section).

Estimated model output was compared to the bathymetry and sediment data, and to estimated data for loads from the USGS ESTIMATOR model and USGS scour regression equation model (table 6 and Attachment A). Using the net deposition model for the simulation period 2008-2011, approximately 22.3 million tons of sediment entered the reservoir system and approximately 20.2 million tons were transported into the upper Chesapeake Bay, resulting in approximately 2.1 million tons (10 percent of total load) being deposited in the reservoirs, with the majority deposited in Conowingo Reservoir (Table 6. The deposition simulated for the period 2008-2011 using the HEC-RAS model was very close (difference less than 5 percent) to the results obtained by summing the estimated annual loads from the USGS ESTIMATOR model for 2008-2011and about 54 percent less the volume when compared to the computed volume difference between the 2008 and 2011 bathymetries. Despite this poor agreement with the estimated change in bathymetry, due to limitations previously discussed, these results are consistent with previously published results from the Rillito River in Arizona (Duan and others, 2004). Duan and others (2004) compared five 1-D models (including two HEC-RAS) to the results based on the bathymetry change, and found all models substantially under predicted the actual deposition. The HEC-RAS model using the Laursen (Copeland) transport equation performed the best, under predicting by about one-half.

Results from the HEC-RAS net deposition model for the high-flow event (Tropical Storm Lee, September 7-13), indicated 200,000 tons of sediment were scoured in the upper two reservoir systems with 500,000 tons deposited in Conowingo. The depositional model results were quite different than results predicted by the USGS ESTIMATOR model (table 6) and the USGS scour equation (Table 6. and attachment A), both of which indicated scour (-3.55 and -3.50 million tons, respectively). The difference in estimates prompted the need for a second simulation for the high flow event in 2011.

Table 6. Results for sediment load transport IN and OUT of the Lower Susquehanna River reservoir system by model type. Numbers in black represent deposition; numbers in red represent scour.

Model	Calendar Year 2008-2011 (tons)	Difference (tons)	Tropical Storm Lee (Sept 7-13, 2011) (tons)	Difference (tons)
HEC-RAS (depositional)				
Marietta IN	22,300,000	--	9,900,000	--
Conowingo IN	22,100,000	200,000	10,100,000	-200,000
Conowingo OUT	20,200,000	1,900,000	9,600,000	500,000
Net change	2,100,000	2,100,000	300,000	300,000
HEC-RAS (scour)				
Marietta IN	22,300,000	--	9,900,000	--
Conowingo IN	24,400,000	-2,100,000	10,300,000	-400,000
Conowingo OUT	25,200,000	-800,000	11,400,000	-1,100,000
Net change	-2,900,000	-2,900,000	-1,500,000	-1,500,000
USGS ESTIMATOR				
Marietta IN	22,300,000	--	9,900,000	--
Conowingo OUT	20,100,000	2,200,000	13,500,000	-3,550,000
USGS Scour Regression Equation	--	--	--	-3,500,000
Bathymetry Change (2008-2011)	**--**	4,500,000	**--**	--

Changes in the bed surface elevations based on the HEC-RAS depositional model suggest deposition occurred in all three reservoirs (figure 14) generally in the middle and lower reaches. The simulated change in bed surface is greatest (between 1.0 and 1.5 feet, areas shown in orange and brown in figure 14) near Safe Harbor and Conowingo Dams. Scour (negative deposition, areas shown in pink and red in figure 14) is indicated in the upper reaches of Safe Harbor Reservoir (Lake Clarke) and in the lower reaches of Holtwood Dam Reservoir (Lake Aldred). No scour was indicated in the Conowingo Reservoir. Little to no change in bed elevation is evident in many areas. Areas mapped in figure 14 correspond well to the 2011 bathymetry for Conowingo in terms of spatial change (deposition) but the modeled sediment mass data is less than predicted when compared to the bathymetry for many cross sections.

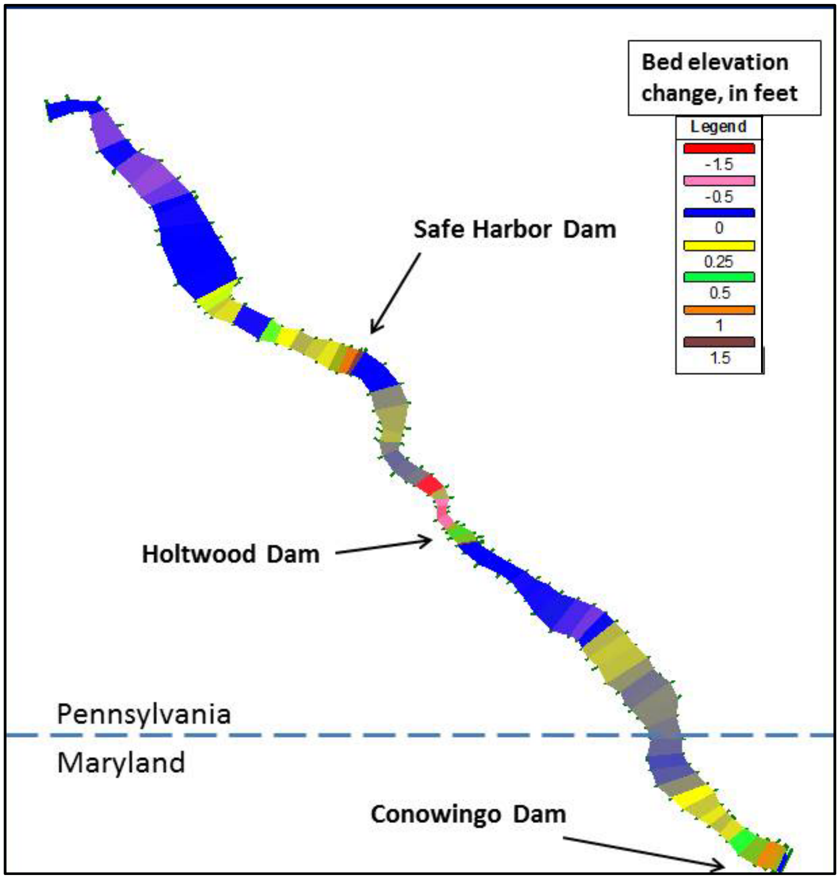


Figure 14. Changes in bed elevation using a HEC-RAS depositional model, 2008-2011.

A second 1-D model simulation (a scour model) was developed using the same 2008-2011 input boundary data to estimate the total scour from the reservoir system for the period September 7-13, 2011. The model parameters for the scour simulation are given in tables 3 and 4. The bed sorting method was changed to an algorithm that was less resistant to erosion and the fall velocity method changed to decrease settling to bed surface, thereby potentially increasing the mass to be scoured (Table 6). For the simulation period September 7-13, 2011, approximately 9.9 million tons of sediment entered the reservoir system (about 44 percent of the entire four year model simulation incoming sediment load) and approximately 11.4 million tons were transported into the upper Chesapeake Bay, resulting in approximately 1.50 million tons being scoured in the reservoirs, the majority (1.1 million tons or approximately 73 percent) was estimated to be from Conowingo Reservoir (Table 6. The simulated scour volume from the HEC-RAS scour model for the high flow event is about 57 percent of the volume computed from the USGS scour prediction and the daily summed USGS ESTIMATOR model loads for September 7-13, 2011. For the 2008-2011 simulation period, the net scour model indicated about 2.9 million tons scoured during the 2008-2011 period, with about 40 percent estimated to originate in Conowingo Reservoir. The net bed elevation change based on the 2008 and 2011 bathymetries indicated 4.5 million tons of deposition.

Changes in the bed surface elevations based on the HEC-RAS scour model indicate scour occurred in all three reservoirs (figure 15), generally occurring throughout the majority of the reservoir cross sections. The greatest change in bed surface elevation depicting scour (about -1.5 ft, areas shown in red in figure 15) occurs in several areas in all three reservoirs, generally related to a natural constriction in the river channel. These large scour spatial areas and depositional areas near Safe Harbor and Conowingo Dams (about 1 to 1.5 ft, areas shown in orange or brown in figure 15) suggest that in all three reservoirs, sediment is both scoured and deposited even at dynamic-equilibrium storage capacity and the upper two reservoirs could contribute one-fourth to one-half of the total scour load from the reservoir system.

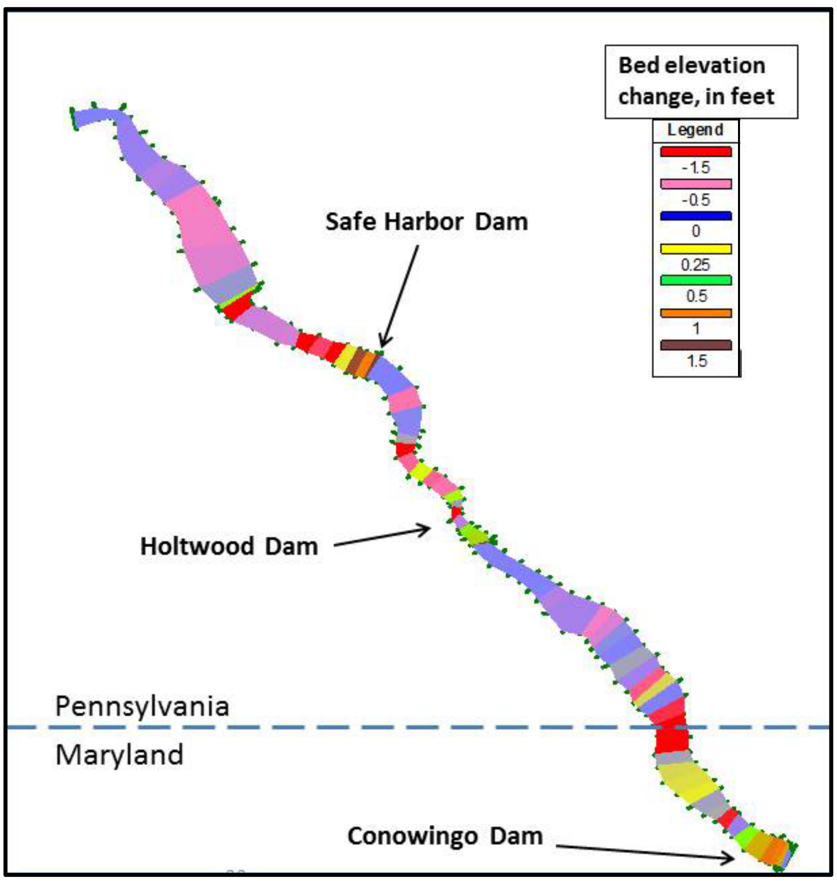


Figure 15. Changes in bed elevation using a HEC-RAS scour model, 2008-2011.

Particle size results from the models for scour and deposition for the 2008-2011 simulation period were compared to historic sediment (sand, silt, and clay) transport (table 7). Twelve sediment particle sizes (7 sand, 4 silt, and 1 clay, from table 2) were used in the bed sorting and sediment-transport routines. The percentages of sediment (sand, silt, and clay) transported in and out of the reservoir system, as simulated in both the depositional and scour models, are in close agreement with historic percentages of sediment transported (table 7). Generally, both simulations suggest little sand is transported to the upper Chesapeake Bay while silts comprise the greater percent of the transported sediment.

The model output data (boundary condition) containing the daily sediment loads by particle size and individual cross sections along with the streamflow data for Susquehanna River at Marietta, Pennsylvania and Conowingo, Maryland were provided to the USACE for use as input or calibration for the 2-D model (Berger and others, 2010). An additional model simulation was completed with no inflowing sediment to the reservoir system in an attempt to quantify the contribution of sediment from the upper two reservoirs. Additional information provided to the USACE included the 2008 and 2011 bathymetries, bed sediment particle size characteristics, temperature data, and Manning's n values for each cross section.

Table 7. Summary of HEC-RAS sediment (sand, silt, and clay) transported into the Susquehanna reservoir system (Marietta), and into and out of the Conowingo Reservoir compared to historic sediment transport.

[N/A; not available]

	Sediment, in percent		Historic sediment, in percent
	2008-2011	TS Lee	
HEC-RAS (depositional)	Sand/Silt/Clay	Sand/Silt/Clay	Sand/Silt/Clay
Marietta IN	10 / 48 / 42	10 / 48 / 42	9 / 47 / 44
Conowingo IN	3 / 47 / 50	5 / 50 / 45	N/A
Conowingo OUT	2 / 46 / 52	4 / 50 / 44	2 / 50 / 48
HEC-RAS (Scour)	Sand/Silt/Clay	Sand/Silt/Clay	Sand/Silt/Clay
Marietta IN	10 / 48 / 42	10 / 48 / 42	9 / 47 / 44
Conowingo IN	2 / 48 / 50	5 / 51 / 44	N/A
Conowingo OUT	1 / 45 / 54	3 / 51 / 46	2 / 50 / 48

8.0 Summary

Boundary-condition data for daily flow, sediment transport, and particle size fractions were constructed from a one-dimensional (1-D) sediment-transport model using two simulations (deposition and scour) and were provided to the USACE for input to the two-dimensional (2-D) model used to simulate processes in the Conowingo Reservoir and output to the upper Chesapeake Bay. The depositional simulation resulted in a net deposition of 2.1 million tons for the 2008-2011 period, while the scour simulation resulted in a net loss of 1.5 million tons of sediment for the Tropical Storm Lee event. The results indicate a difference of about 54 and 57 percent less, respectively, when compared to the calibration data. Each simulation provided a range of probable conditions and also provided a range of uncertainty in the boundary-condition data. The simulations also provide insights into the reservoir sediment dynamics, indicating all three reservoirs are active with respect to scour and deposition even at dynamic-equilibrium storage capacity as is the case in the upper two reservoirs. Silt is the dominate particle size transported from the reservoir system, with little sand (less than 5 percent) transported to the upper Chesapeake Bay. Model limitations were identified and include underestimation of fall velocity, use of non-varying (average) shear, and non-varying cohesive settings to represent highly variable sediment characteristics. These limitations most likely resulted in 1) less than expected deposition for the 2008-2011 simulation and 2) less than expected erosion (scour) for the Tropical Storm Lee seven day event simulation, when compared to other approaches and estimates. In conclusion, because the 1-D model is designed primarily for non-cohesive (sands and course silts) sediment transport with additional but limited capability to simulate processes of cohesive (generally medium silts to fine clays) sediment transport, the model may not be suitable for all reservoir simulations, especially in areas of highly variable bed shear, active scour and deposition, and a lack of information on flocculation size. The boundary-condition data from the 1-D model were helpful in the calibration of the USACE 2-D model, especially by improving information on the inputs into Conowingo Reservoir.

9.0 References

Abood, M.M., Mohammed, T.A., Ghazali, A.H., Mahmudand, A.R., and Sidek, L.M., 2009, Review study and assessment for sedimentation models applied to impounding reservoirs: Journal of Engineering and Applied Sciences, v.4, no. 2, p. 152-160.

Ariathurai, R., Krone, R.B., 1976, Finite element model for cohesive sediment transport: Journal of the Hydraulics Division, ASCE, HY3, p. 323-338.

Berger, R. C., Tate, J. N., Brown, G. L., & Savant, G., 2010), Adaptive hydraulics users manual—Guidelines for solving two-dimensional shallow water problems with the Adaptive Hydraulics Modeling System: Vicksburg, Miss., U.S. Army Engineering Research and Development Center, 98 p.

Cohn, T.A., Delong, L.L., Gilroy, E.J., Hirsch, R.M., and Wells D., 1989, Estimating constituent loads: Water Resources Research, v. 25, no.5, p. 937-942.

Duan, J.G., Acharya, A., Yeager, M., Zhang, S., and Salguero, M., 2008, Evaluation of flow and sediment models for the Rilloto River: Tucson, Ariz., Department of Civil Engineering and Engineering Mechanics, The University of Arizona, 209 p.

Edwards, R. E., 2006, Comprehensive analysis of the sediments retained behind hydroelectric dams of the Lower Susquehanna River: Susquehanna River Basin Commission Pub. 239. (Also available at *http://www.srbc.net/pubinfo/techdocs/Publication_239/ExecutiveSummary.pdf*.)

Hainly, R.A., Reed, L.A., Flippo, H.N., Jr., and Barton, G.J., 1995, Deposition and simulation of sediment transport in the Lower Susquehanna River reservoir system: U.S. Geological Survey Water-Resources Investigations Report 95-4122, 39 p.

Hirsch, R.M., 2012, Flux of nitrogen, phosphorus, and suspended sediment from the Susquehanna River Basin to the Chesapeake Bay during Tropical Storm Lee, September 2011, as an indicator of the effects of reservoir sedimentation on water quality: U.S. Geological Survey Scientific Investigations Report 2012-5185, 17 p. (Also available at *http://pubs.usgs.gov/sir/2012/5185/*.)

Krone, R. B., 1962, Flume studies of the transport of sediment in estuarial shoaling processes: Berkeley, Calif., Hydraulic Engineering Laboratory and Sanitary Engineering Research Laboratory, University of California, 110 p.

Langland, M.J., and Hainly, R.A., 1997, Changes in bottom-surface elevations in three reservoirs on the Lower Susquehanna River, Pennsylvania and Maryland, following the January 1996 flood—

Implications for nutrient and sediment loads to the Chesapeake Bay: U.S. Geological Survey, Water-Resources Investigation Report 97-4138, 34 p.

Langland, Michael J., 2009, Bathymetry and sediment-storage capacity change in three reservoirs on the Lower Susquehanna River, 1996-2008: U.S. Geological Survey Scientific Investigations Report 2009-5110, 21 p. (Also available at *http://pubs.usgs.gov/sir/2009/5110/*.)

Ledvina, J.P., 1962, Holtwood River bed silt survey, Holtwood Dam to Shenk's Ferry, September-November 1961: Holtwood, Pa., Holtwood Steam Electric Station and the Pennsylvania Power and Light Company, 80 p.

Mahmood, Khalid, 1987, Reservoir sedimentation: impact, extent, and mitigation: Washington, D.C., International Bank for Reconstruction and Development, Technical paper no. PB-88-113964/XAB; WORLD-BANK-TP-71, 133 p.

Ott, A.N., Takita, C.S., Edwards, R.E., and Bollinger, S.W., 1991, Loads and yields of nutrients and suspended sediment transported in the Susquehanna River Basin, 1985-89: Susquehanna River Basin Commission Publication no. 136, 253 p.

Parthenaides, E., 1965, Erosion and deposition of cohesive soils: Journal of the Hydraulic Division, ASCE91, HY1, p. 105–139.

Perky, D.W, Smith S.J., and Taylor, M.B, 2013, Cohesive sediment erosion, Conowingo Reservoir Sedflume analysis report: Vicksburg, Miss., Engineer Research and Development Center Coastal and Hydraulics Laboratory, October 2013, 97 p.

Reed, L.A. and Hoffman, S.A., 1996, Sediment deposition in Lake Clarke, Lake Aldred, and Conowingo Reservoir, Pennsylvania and Maryland, 1910-93: U.S. Geological Survey Water-Resources Investigations Report 96-4048, 14 p.

Schuleen, E.T. and Higgins, G.R., 1953, Analysis of suspended-sediment measurements for Lake Clarke, inflow and outflow, 1948-53: Pennsylvania Power and Light Company Report 970, 40 p.

Sloff, C.J., 1997, Modeling reservoir sedimentation processes for sediment management studies *in* Conference on hydropower into the next century, Portoroz, Slovenia, 15-17 Sept. 1997, Proceedings: Sutton, Surrey, Aqua Media International Ltd., p. 513-524.

Sullivan, A.B., Rounds, S.A., Sobieszczyk, S., and Bragg, H.M., 2007, Modeling hydrodynamics, water temperature, and suspended sediment in Detroit Lake, Oregon: U.S. Geological Survey Scientific Investigations Report 2007–5008, 40 p.

U.S. Environmental Protection Agency, 2010, Chesapeake Bay TMDL, Executive summary and appendices, accessed on August 6, 2013, *athttp://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html.*

U.S. Army Corps of Engineers, 2010a, HEC-RAS River Analysis System, Hydraulic reference manual, version 4.1, Hydrologic Engineering Center, CPD-69, 417 p.

U.S. Army Corps of Engineers, 2010b, HEC-RAS River Analysis System, User’s manual, version 4.1, Hydrologic Engineering Center, CPD-68, 790 p.

U.S. Army Corps of Engineers, 1993, HEC-6 Scour and deposition in rivers and reservoirs, User’s manual, Hydrologic Engineering Center, CPD-6, 286 p.

U.S. Geological Survey, 2002, NWISWeb—New site for the Nation’s water data: U.S. Geological Survey Fact Sheet 128–02, 2 p.

URS Corporation and Gomez and Sullivan Engineers. 2012. Sediment introduction and transport study (RSP 3.15) (Appendix F). Kennett Square, PA: Exelon Generation, LLC.

Van Rijn, L.C., 1984, Sediment transport - Part II: Suspended load transport: Journal of Hydraulic Engineering, ASCE, v. 110, no. 11.

Whaley, R.C., 1960, Physical and chemical limnology of Conowingo Reservoir: Baltimore, Md., The Chesapeake Bay Institute, Johns Hopkins University Technical Data Report, 140 p.

Attachment A-1: Additional Information for Susquehanna River at Marietta, PA (01576000), and Conowingo, MD (01578310), and Conowingo Reservoir

Attachment A-1

Additional Information for Susquehanna River at Marietta, Pennsylvania (01576000), Conowingo, Maryland (01578310), and Conowingo Reservoir

The following information is provided to help the Lower Susquehanna River Assessment Project in their efforts to study sediment loads from behind a series of three hydroelectric dams and associated reservoirs, located on the Susquehanna River draining into the northern Chesapeake Bay. Information provided includes recurrence intervals for two U.S. Geological Survey (USGS) streamgages, river and scour sediment transport, and evaluation of streamflow and sediment transport in the reservoirs. The Susquehanna River at Marietta, Pennsylvania and Conowingo, Maryland streamgages are considered to represent the flow and sediment input to and output from the reservoir system. Due to the lack of sediment information from the upper two reservoirs, the flow and sediment results are considered the cumulative effect of all three reservoirs. Information provided in this attachment may be useful to managers when considering a range of management options dealing with flow and sediment dynamics in the Lower Susquehanna River reservoir system.

Recurrence Intervals, Total and Scour Sediment Loads

Expected flows for many recurrence intervals (RI) are presented in table A1. A recurrence interval is a statistical estimate of the likelihood of a given streamflow to occur based on historic data. The annual exceedence probability is the chance of a given flow event to occur in the current year. Figure A1 illustrates the difference between RI and flow at the two USGS Susquehanna River gages representing inflow and outflow from the reservoir system—the Susquehanna River at Marietta, Pennsylvania (01576000) and the Susquehanna River at Conowingo, Maryland (01578310), respectively for 1968-2012. RI's were computed using methods as described in Flynn and others (2006). Flows corresponding to various RI's were computed for this study using methods as described in Flynn and others (2006). Station skew for frequency distribution was used at both stations and historic peak flows prior to 1968 were not used in the analysis. No low outliers were detected. Useful information about short-term streamflow includes the bankfull discharge (RI of about 1.5 years) and the mean peak discharge for the period of record (RI of 2.33 years).

Table A1. USGS estimated recurrence intervals, annual exceedence probabilities, and expected-streamflow estimates for two Susquehanna River streamgages. [cfs, cubic feet per second]

Station 01576000 Susquehanna River at Marietta, Pennsylvania (1968-2012)			Station 01578310 Susquehanna River at Conowingo, Maryland (1968-2012)		
Recurrence Interval (years)	Annual Exceedence Probability	Expected Streamflow Estimate (cfs)	Recurrence Interval (years)	Annual Exceedence Probability	Expected Streamflow Estimate (cfs)
1	0.995	113,100	1	0.995	130,800
1.01	0.99	120,800	1.01	0.99	137,800
1.05	0.95	144,300	1.05	0.95	163,500
1.11	0.9	161,700	1.11	0.9	182,200
1.25	0.8	188,400	1.25	0.8	211,600
1.5	0.667	221,026	1.5	0.6667	247,989
2	0.5	265,400	2	0.5	298,200
2.33	0.4292	287,067	2.33	0.4292	322,790
5	0.2	401,700	5	0.2	436,200
10	0.1	514,200	10	0.1	589,900
25	0.04	684,900	25	0.04	797,500
50	0.02	835,300	50	0.02	984,100
100	0.01	1,008,800	100	0.01	1,202,000
200	0.005	1,206,000	200	0.005	1,455,000
500	0.002	1,514,000	500	0.002	1,857,000

Figure A1 indicates a general coincidence in streamflow between the two Susquehanna River sites up until about the 1.5-year RI (bankfull discharge), then an increasing divergence in RIs as discharge increases. This is most likely due to differences in drainage area between the two sites and flow regulation and storage of three hydroelectric facilities between the streamgages.

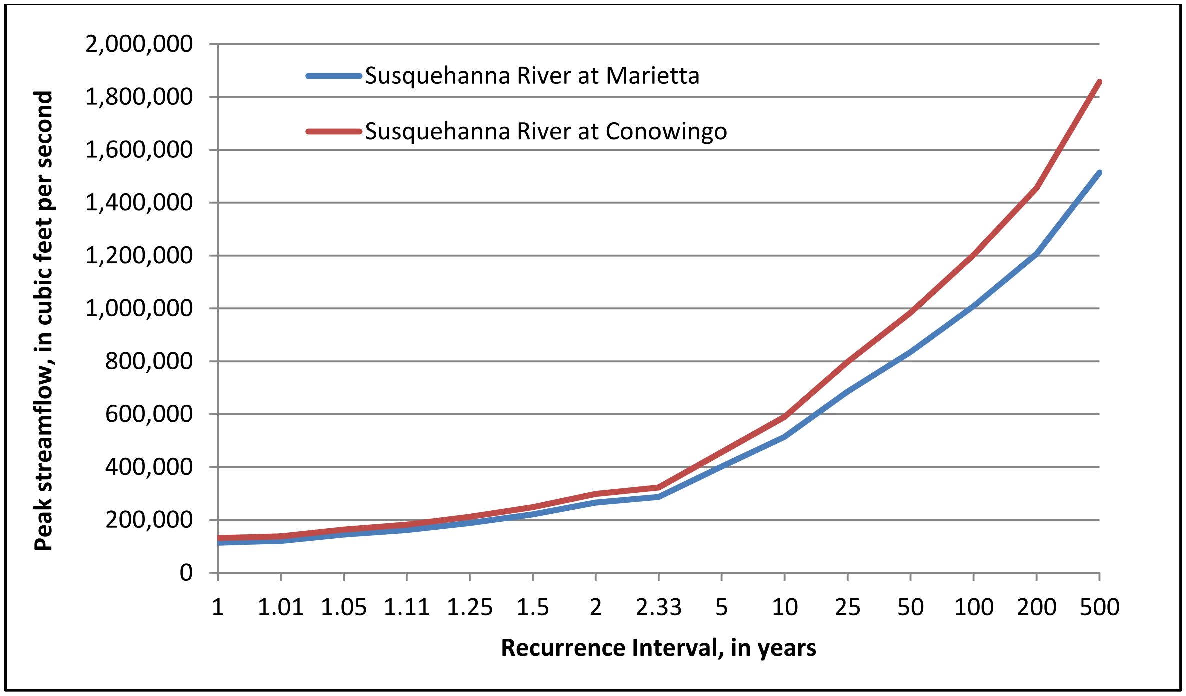


Figure A1. Recurrence Intervals for the Susquehanna River at Marietta, Pennsylvania and Susquehanna River at Conowingo, Maryland streamgages.

The USGS has been estimating sediment loads at the Susquehanna River at Marietta, Pennsylvania and Susquehanna River at Conowingo, Maryland locations since 1987. The annual loads are used to develop a simple in/out model to help predict the mass balance of sediment transport through the reservoir system. The annual loads are used to help calibrate a scour-prediction equation and estimate the sediment deposition and remaining capacity in Conowingo Reservoir.

Since 1972, there have been 11 storms with daily-mean streamflows greater than 400,000 cfs (5-year RI), the flow when an average mass wasting begins for the sediment in the reservoirs. Most likely some of the finer silt and sand particles begin to move before 400,000 cfs. Cohesive sediments such as clays and fine silts may begin to move off the reservoir bottom at flows around 200,000 cfs while the heavier sand and gravels may not move until flows are upwards of 600,000 cfs. Much of the scoured and transported reservoir sediment is re-deposited in the reservoir system. Durations of streamflow at the Susquehanna River at Conowingo, Maryland streamgage are shown in fig. A2. Note the general pattern of rapid increase then on the rising limb to the peak and a more general decrease in flow on the falling limb. This is a typical high flow response in many rivers and indicates that at higher flows the dams do not have the capability to store much water above normal pool elevations and are normally called "run-of-the-river" reservoirs. The number of days above 400,000 cfs ranged from 1 to 5 days; the average was about 3 days. The 1972 event (Tropical Storm Agnes) was the largest flood in the Susquehanna River Basin since 1896, when recording of flow began at Harrisburg, Pennsylvania. The second largest recorded flood event using daily-mean streamflow (discharge) data in the Susquehanna River basin since 1972 was in 2011 (Tropical Storm Lee, figure A2). Note that more than one event is plotted for 1984 and 2011.

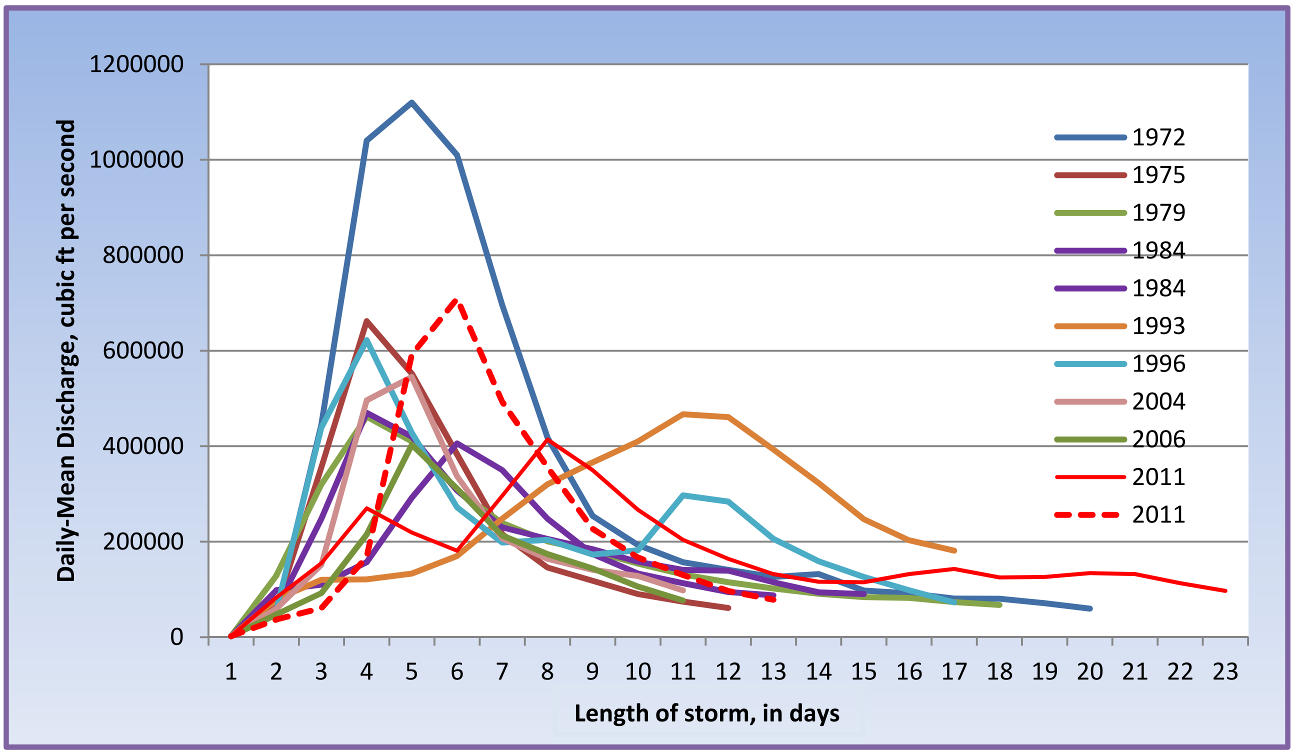
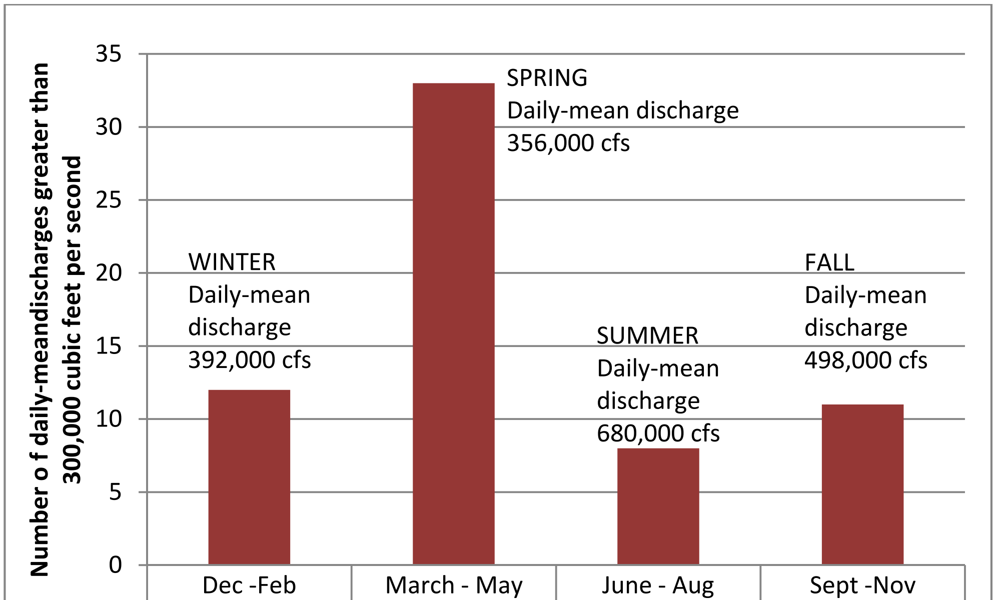


Figure A2. Streamflow (discharge) hydrographs for 11 storms above 400,000 cubic feet per second daily-mean discharge since 1972 at the Susquehanna River at Conowingo, Maryland. X axis units are days.

Streamflow can also be examined on a seasonal basis to help determine the volume and timing of discharge events over a given time period. To increase the number of discharge events, daily-mean discharges greater than 300,000 cfs at Susquehanna River at Conowingo were tabulated and shown in figure A3. Although the highest number of daily-mean discharge events greater than 300,000 cfs was in the March-May (spring) time period, the greatest daily-mean discharges per storm event occurred in June-August (summer) and September-November (fall). The summer season was most likely biased high due the daily-mean discharge of 3 of the 8 events each over 1,000,000 cfs during Tropical Storm Agnes. The higher discharges tend be in the fall season, coinciding with the Hurricane season.



	Dec -Feb	March - May	June - Aug	Sept -Nov
Count	12	33	8	11

Figure A3. Number of daily-mean discharges greater than 300,000 cubic feet per second (cfs) and daily-mean discharge by season at Susquehanna River at Conowingo, Maryland (1967-2013).

The USGS developed a regression equation to predict the sediment scour load for daily-mean discharge at Lower Susquehanna River Reservoirs (figure A4). The equation is based primarily on daily mean discharge and estimated loads from six storm events during 1993-2011 (table A2) from the tow monitoring sites (Susquehanna River at Marietta and Conowingo), on bathymetry (bed-elevation change) data in the reservoirs using the Reed and Hoffman (1996), Langland and Hainly (1997), Langland (2009), URS Corporation and Gomez and Sullivan (Conowingo Reservoir only, 2012) studies, and on a comparison of estimates of sediment inflow and outflow from the reservoirs. Additional information for Tropical Storm Agnes (1972) and Tropical Storm Eloise (1975) (Gross and others, 1978) were used to help calibrate the curve. The regression equation was then used to predict scour loads for an additional three storms prior to 1972 with little to no sediment or bathymetry data for daily-mean discharge greater than 400,000 cubic feet per second (cfs) (table A2) and estimated trapping efficiency.

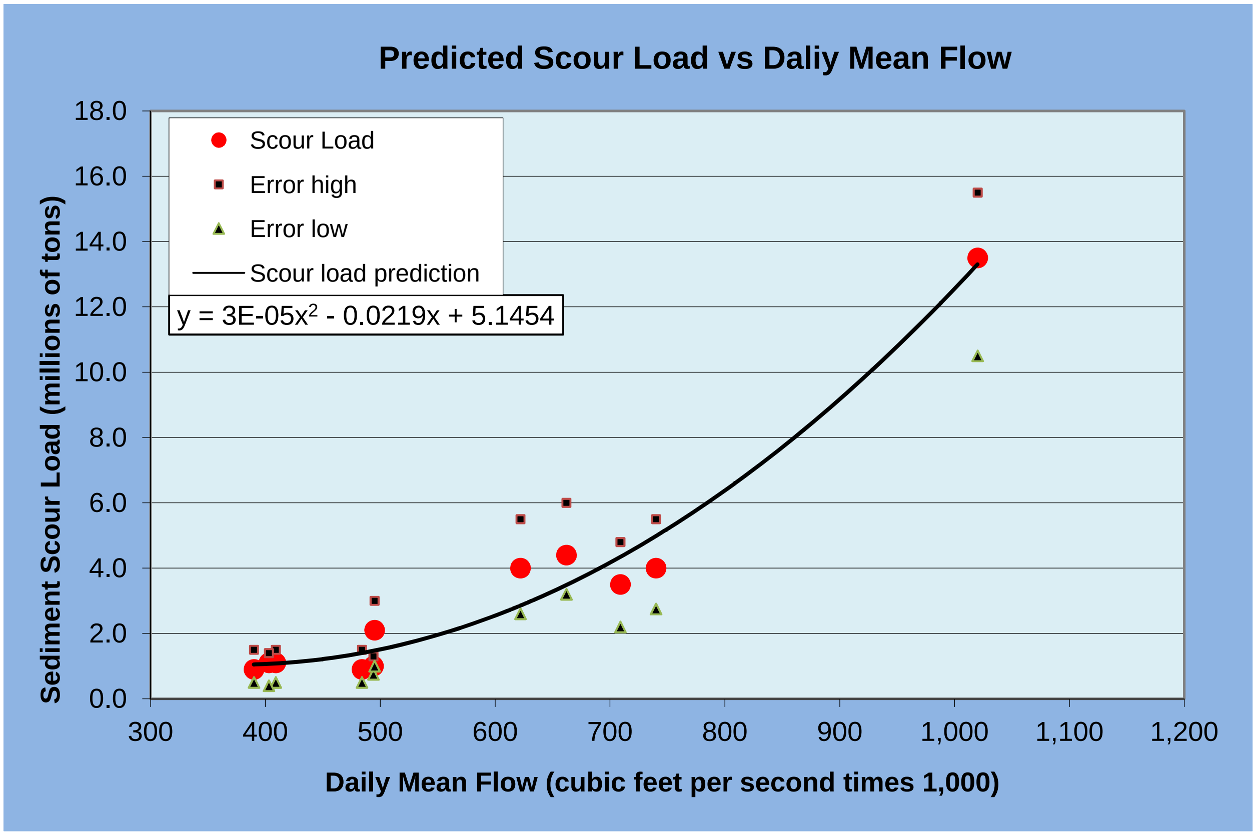


Figure A4. USGS scour equation used to predict scour from discharges generally exceeding 400,000 cubic feet per second in the Lower Susquehanna River reservoir system.

The curve and subsequent scour prediction provides a useful and quick reference for potential scour from the reservoir system to the upper Chesapeake Bay at or soon after flooding events when information may be needed quickly to ascertain potential environmental effects. While not exact as a scour predicting tool, the equation is updated with each flood event resulting in a new, slightly different equation. Complications in the predictions include errors in the methods used to estimate the daily and monthly loads, the amount of sediment entering the reservoir system, and the amount of flow and time above a certain scour threshold, generally 400,000 cfs. In addition, the length of time since a previous scour event which may increase or decrease the amount of scoured sediment, and the changing scour/deposition dynamics resulting from increased velocities as Conowingo Reservoir nears storage capacity, may lower the scour threshold and contribute to scour prediction error.

Table A2. Predicted sediment scour loads from the reservoirs for storms with an average daily-mean discharge at Conowingo, Maryland, greater than 400,000 cubic feet per second (cfs).

Date	Daily-mean Discharge (cfs)	Sediment Scour Load Event (million tons)
Mar-1936[1]	870,000	2.5
May-1946[1]	528,000	0.9
Mar-1964[1]	571,000	1.0
Jun-1972	1,020,000	13.5
Sep-1975	662,000	4.4
Apr-1993	409,000	1.1
Jan-1996	622,000	4.0
Sep-2004	495,000	2.1
Apr-2005	390,000	0.9
Jun-2006	403,000	1.1
Sep-2011	709,000	3.5

[1] Estimated using daily-mean discharge from the Susquehanna River at Harrisburg, Pennsylvania streamgage. The average ratio of streamflow between the daily-mean streamflow data for Susquehanna River at Harrisburg and Marietta streamflow gages was 92 percent using data from 1987 to 2012 with a linear regression r^2 of 0.99.

Using the data from table A1 and converting the annual exceedence probability to percent, changes in bottom surface based on the bathymetry studies, the annual sediment load estimates from Marietta and Conowingo (above and below the reservoirs), plus estimates of scour were combined to produce a range in total sediment transported through the reservoir system and a portioning to source (watershed or scour) for various flows (table A3). The ranges in scour and estimates of total loads transported out the reservoir system allow for differences in season, total volume of potential scour flow, and errors in the estimates. As previously discussed, the flow when mass scour is estimated to begin is approximately 400,000 cfs. Results from the U.S. Army Corps of Engineers 2-D model and a recent USGS report by Hirsch (2012) suggest the threshold has decreased with time. Because figure A4 suggests scour would occur down to 300,000 cfs, table A3 has an estimated scour down to 300,000 cfs. The uncertainty associated in scour estimates below 400,000 cfs is greater than for scour estimates greater than 400,000 cfs.

The percent scour to watershed load based on frequency of flow events ranges from 20 to (average 30 percent) for streamflows of 400,000 to 800,000 cfs. A flow of 800,000 cfs has a recurrence interval of 25 years. As indicated in table A3, streamflows greater than 800,000 cfs generate the greatest amounts of scour and an increasingly higher proportion of total sediment load.

Table A3. Predictions for recurrence intervals, chance of flow event per year, and ranges in scour and total sediment loads in tons and percent for various daily-mean streamflows for Conowingo Reservoir.

Streamflow (cubic feet per second)	Recurrence Interval (years)	Percent chance of flow event per year	Predicted sediment scour (million tons)[1]	Predicted total sediment load (million tons)[2]	Percent scour to total load
1,000,000	60	1.7	10.5 - 15.5	27.1 - 31.1	39 - 49
900,000	40	2.5	6.6 - 11	21.8 - 26.2	30 - 42
800,000	25	4	4.5 -7.5	17.2 - 20.2	26 - 37
700,000	17	5 .9	3.5 - 6	13.1 - 15.6	27 - 38
600,000	10	10	1.8 - 4	7.9 - 10.1	22 - 40
500,000	5.7	17.5	1 - 3	4.9 - 6.9	20 - 42
400,000	4.8	21	0.5- 1.5	2.4 - 3.4	21 - 44
300,000	2.1	52	0 – 0.5	0.5 – 1.5	0 - 33

[1] predicted scour from USGS scour equation, bathymetry results, and literature estimates
[2] predicted total load based on transport regression equation, bathymetry results, and literature estimates.

Volume Change and Total Sediment Deposition.

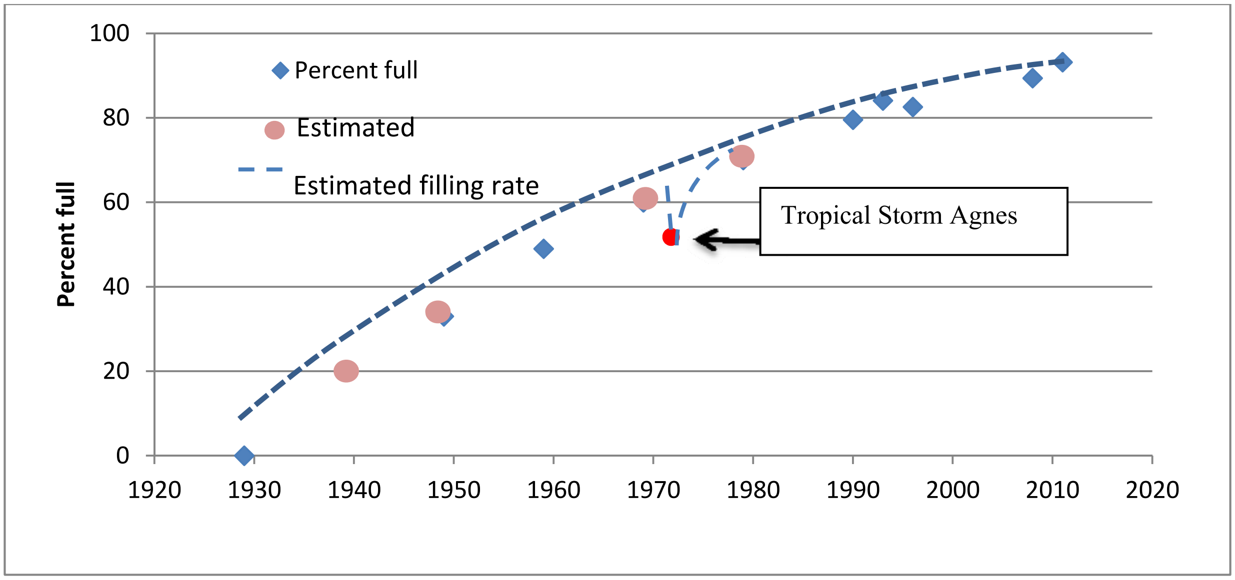
Based on previous studies (Whaley, 1960; Hainly and others, 1995; Reed and others, 1996; Langland and Hainly, 1997; Langland, 2008) URS Corporation and Gomez and Sullivan (2012) capacity and volume change are estimated for six time intervals when bathymetry results were available (table A4 and figure A4). From construction in 1929 to the first survey in 1959 (30 years), the Conowingo Reservoir lost about half of the sediment storage capacity (96 of 194 million tons). Capacity to store sediment was reduced by 30 percent by the next survey 31 years later in 1990 (155 of 194 million tons), indicating a reduction in incoming sediment, a loss of trapping efficiency, or both. The largest flood event occurred during the 1959-1990 time period when in June 1972 Tropical Storm Agnes removed approximately 13.5 million tons of sediment from Conowingo (figure A4). Table A4 indicates that in 2011, the Conowingo Reservoir was about 93 percent filled and that 13 million tons remained to reach an estimated sediment storage capacity of approximately 194 million tons.

Table A4. Storage capacity and volume change in Conowingo Reservoir from bathymetric surveys since construction.

Year	Reservoir capacity (acre feet)	Sediment Deposition (acre feet)	Total Deposition (tons)	Net gain/loss between bathymetries (tons)	percent full
1929	280,000	0	0	--	0
1959	215,000	65,000	96,000,000	96,000,000	49
1990	175,000	105,000	155,000,000	60,000,000	80
1993	169,000	111,000	164,000,000	9,000,000	84
1996	171,000	109,000	161,000,000	-3,000,000	83
2008	162,000	118,000	174,000,000	13,000,000	89
2011	157,000	123,000	181,000,000	7,000,000	92
Equilibrium	146,000*	134,000	198,000,000	17,000,000	100

*Note the equilibrium capacity previously has been reported at 142,000 acre feet. The volume was adjusted after the 2011 bathymetry survey when more detailed information near the dam became available.

Figure A5 shows that the rate of filling continues to follow a non-linear pattern since construction in 1929. Note the estimated impact of Tropical Storm Agnes which removed approximately 13.5 million tons from the reservoir system, which most likely was refilled by the end of the decade. The rate of filling has also slowed, due to a reduction in incoming sediments from the watershed and changes in reservoir scour and deposition dynamics. As the reservoir fills with sediment, the velocity increases, perhaps increasing the bed shear (can result in more scour) and decreasing the amount of residence time for sediments to settle out of the water column thereby reducing deposition. Approximately 7 percent remains of the original 146,000 acre feet of sediment storage capacity (Langland, 2008 with minor adjustment after the 2011 bathymetry). As the capacity is reduced, sediment concentrations and loads may increase to the upper Chesapeake Bay due to an increase in velocity through the reservoirs. Hirsch (2012) indicates that increases in sediment concentrations and loads are occurring and suggests the increases are occurring at lower streamflows.



*Estimated values are from a combination of methods and assuming gradual reduction in long-term trapping efficiency from 75 to 55 percent.

Figure A5. Trend in sediment storage capacity change (percent full) in the Conowingo Reservoir since construction.

Susquehanna River Sediment Transport

Using current and historical streamflow and sediment data from the Susquehanna River at Harrisburg, Pennsylvania until 1985 and streamflow from the Susquehanna River at Marietta, Pennsylvania, sediment loads were estimated from 1930 to 2009 (by decade) at Marietta and considered as input to the reservoirs (figure A6). Loads were greater in the early to mid-1900s, averaging 8.7 million tons per year due to large land disturbance activities including coal extraction and agriculture. In the 1950s, agricultural conservation measures were enacted and sediment loads began to decrease through the 1970s and 1980s as more land reverted back to forest from farm abandonment, a decrease in land disturbance from coal production, and new best-management actions to control sediment were available (table A5). Loads continued to decline to an average of 3.5 million tons per year over the last 20 years. If not for the large decreases in sediment from the watershed, the Conowingo Reservoir may have reached sediment storage capacity resulting in increased loads to the Chesapeake Bay decades ago. Figure A6 highlights the effects of climate when during the 1960's every year was below the normal annual mean streamflow as compared to the 1970's, the wettest decade on record since 1900, marked by two Tropical Storm events (Agnus and Eloise). Tropical Storm Agnus produced the highest streamflows at many locations in the

Susquehanna River basin including Conowingo Dam. The difference in the loads to Reservoirs and to Chesapeake Bay in figure A6 is indicative of decreasing inputs of sediment and potential loss of trapping efficiency over time. Since the 1990's, the decadal mean flow has increased while the decadal sediment loads have continued to decrease, an indication the best-management practices in the Susquehanna watershed may be helping to control sediment from reaching the streams.

In summary, since construction of Conowingo Dam, 1928 to 2012, approximately 470 million tons of sediment was transported by the Susquehanna River Watershed into the reservoir system, approximately 290 million tons were trapped and approximately 190 million tons of sediment was transported to Chesapeake Bay, suggesting a trapping efficiency over the 84 year time span of approximately 60 percent. Using the average estimated scour to total load ratio of 30 percent (table A3), approximately 55 million tons was estimated to be from scour in the reservoirs. Twenty of the storms for which scour is estimated represents approximately 51 million tons or 93 percent of the total scour.

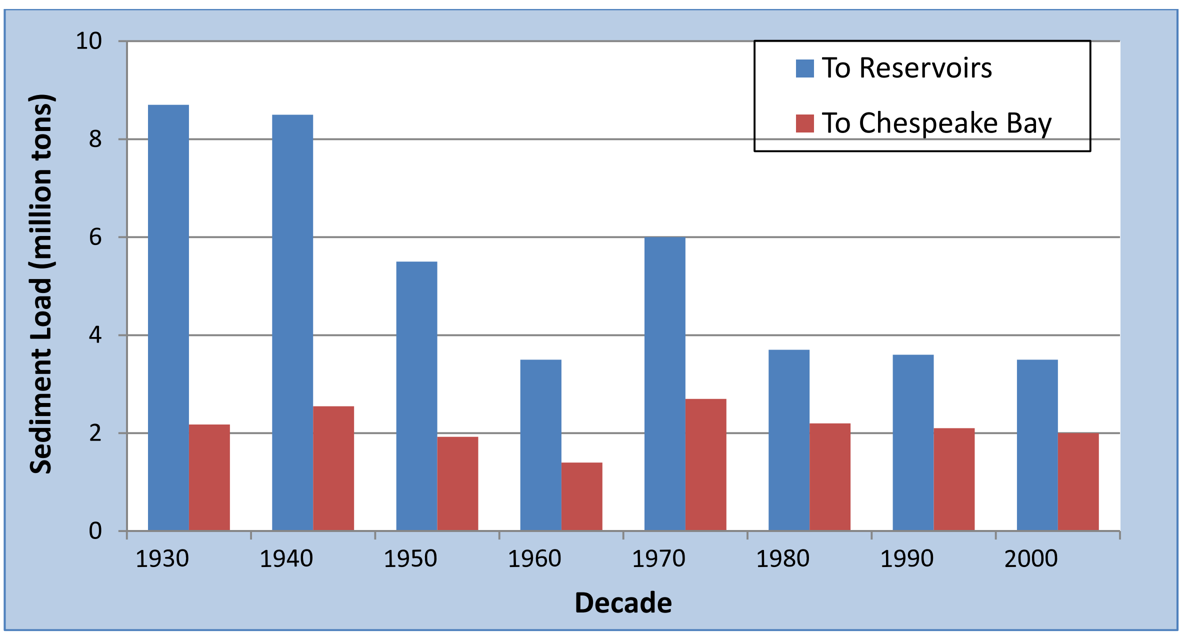


Figure A6. Total estimated sediment transported from the Susquehanna River into the reservoirs and total estimated sediment transport to the Chesapeake Bay.

Table A5. Average annual sediment loads transported into and out of the Lower Susquehanna River reservoir system and estimated trapping efficiency for multiple time periods.

Time Period	Average Annual Sediment Load to reservoirs (million tons/year)	Reservoir Trapping (percent)	Average Annual Sediment Load Trapped (tons)	Average Annual Sediment Load to Bay (million tons/year)
1928-1940	8.7	70-75	6.3	2.4
1941-1950	8.5	65-70	5.8	2.7
1951-1970	4.5	55-60	2.8	1.7
1971-1990[1]	4.9	50-55	2.6	2.3
1991-2012[2]	3.5	45-55	1.3	2.2

[1] Includes Tropical Storms Agnes and Eloise

[2] Includes Tropical Storm Lee

References

Flynn, K.M., Kirby, W.H., and Hummel, P.R., 2006, User's manual for program PeakFQ, Annual flood frequency analysis using Bulletin 17B guidelines: U.S. Geological Survey Techniques and Methods Book 4, Chapter B4, 42 p.

Gross, M.G., Karweit, M., Cronin, W.B., and Schubel, J.R., 1978, Suspended-sediment discharge of the Susquehanna River to northern Chesapeake Bay, 1966-1976: Estuaries, v. 1, p. 106-110.

Hainly, R.A., Reed, L.A., Flippo, H.N., Jr., and Barton, G.J., 1995, Deposition and simulation of sediment transport in the Lower Susquehanna River reservoir system: U.S. Geological Survey Water-Resources Investigations Report 95-4122, 39 p.

Hirsch, R.M., 2012, Flux of nitrogen, phosphorus, and suspended sediment from the Susquehanna River Basin to the Chesapeake Bay during Tropical Storm Lee, September 2011, as an indicator of the effects of reservoir sedimentation on water quality: U.S. Geological Survey Scientific Investigations Report 2012-5185, 17 p. (Also available at *http://pubs.usgs.gov/sir/2012/5185/*.)

Langland, M.J., and Hainly, R.A., 1997, Changes in bottom-surface elevations in three reservoirs on the Lower Susquehanna River, Pennsylvania and Maryland, following the January 1996 flood—Implications for nutrient and sediment loads to the Chesapeake Bay: U.S. Geological Survey Water-Resources Investigation Report 97-4138, 34 p.

Langland, Michael J., 2009, Bathymetry and sediment-storage capacity change in three reservoirs on the Lower Susquehanna River, 1996-2008*:* U.S. Geological Survey Scientific Investigations Report 2009-5110, 21 p. (Also available at *http://pubs.usgs.gov/sir/2009/5110/*.)

Reed, L.A. and Hoffman, S.A., 1996, Sediment deposition in Lake Clarke, Lake Aldred, and Conowingo Reservoir, Pennsylvania and Maryland, 1910-93: U.S. Geological Survey Water-Resources Investigations Report 96-4048, 14 p.

URS Corporation and Gomez and Sullivan Engineers. 2012. Sediment introduction and transport study (RSP 3.15) (Appendix F). Kennett Square, PA: Exelon Generation, LLC.

Whaley, R.C., 1960, Physical and chemical limnology of Conowingo Reservoir: Baltimore, Md., The Chesapeake Bay Institute, Johns Hopkins University, Technical Data Report 32, 140 p.

Attachment A-2:
Additional Information for Sand Distribution in Conowingo Reservoir

Attachment A-2

Additional Information for Sand Distribution in Conowingo Reservoir

The following information is provided to help the Lower Susquehanna River Assessment Project in their efforts to study sediment loads from behind a series of hydroelectric dams and associated reservoirs, located on the Lower Susquehanna River draining into the northern Chesapeake Bay. Information provided includes locations and dates of all cores collected by the U.S. Geological Survey (USGS) in the Conowingo Reservoir. In addition, data concerning particle size percentages and total deposition of sand, silt, and clay for specific locations for multiple time periods are included.

Location of Sediment Cores Collected in Conowingo Reservoir

The locations for 72 USGS cores collected over three time periods are presented in figure B1. Beginning with the 1990-1991 collection (23 locations, Hainly and others, 1995), efforts were made to sample as closely to previous sampling points as possible so comparisons could be made over multiple time intervals. For the 1996 sampling (Langland and Hainly, 1997), 29 cores were collected and for the 2000 sampling (Edwards, 2006), 20 cores were collected. Particle size results have been compiled and are available in Cerco (2012).

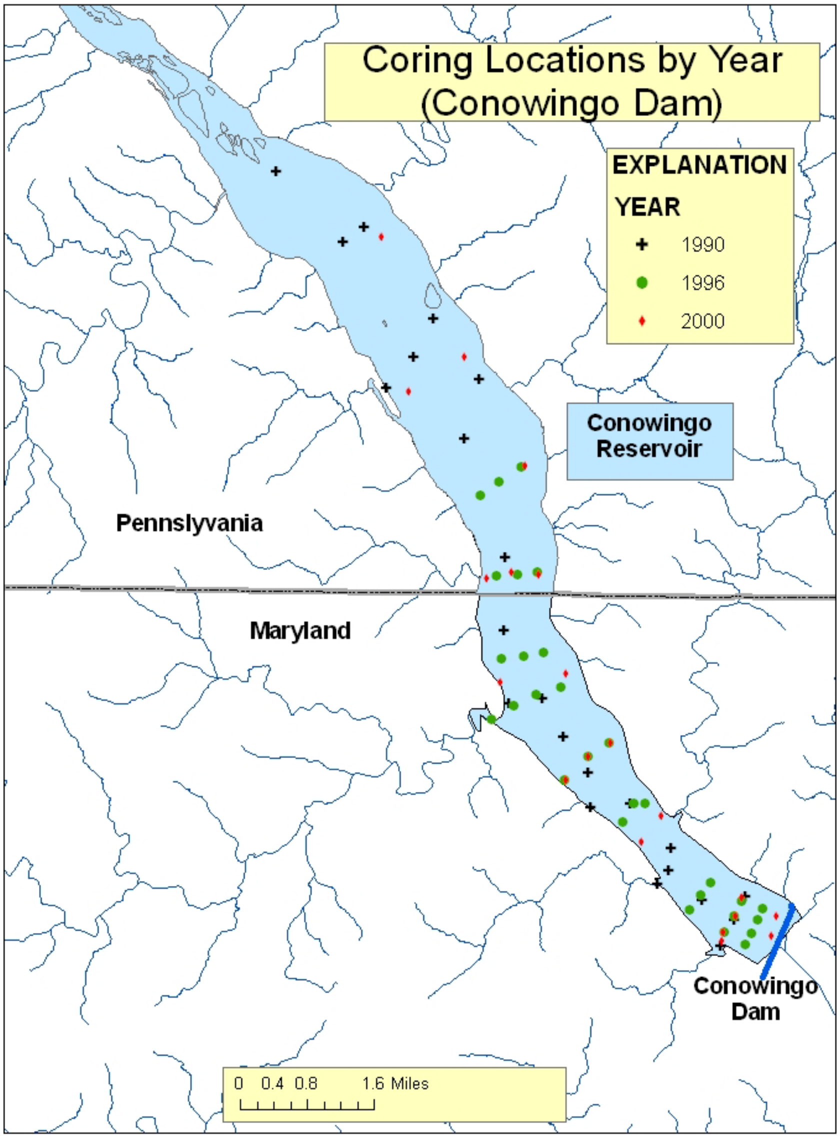


Figure B1. Locations and year for 72 sediment cores collected from Conowingo Reservoir.

The Conowingo Reservoir was divided into 3 sections (upper, middle, and lower) to examine sediment deposition and particle size fractions (figure B2; Langland, 2009). This partitioning was done based on common conveyances, depositional areas, and state of equilibrium. In general, sediment storage capacity in the upper and middle sections is considered in a state of dynamic-equilibrium; in the long-term, the sections are neither net scour or deposit areas. The upper section comprises about 19 percent of the total area of the Conowingo Reservoir, of which about two-thirds is considered to contain very little sediment due to steep channel slopes, high water velocities, and the influence of the Muddy Run hydroelectric pump storage facility near the top of the pool (Hainly and others, 1995). The middle and lower sections of the reservoir comprise approximately 50 and 31 percent of the total area, respectively.

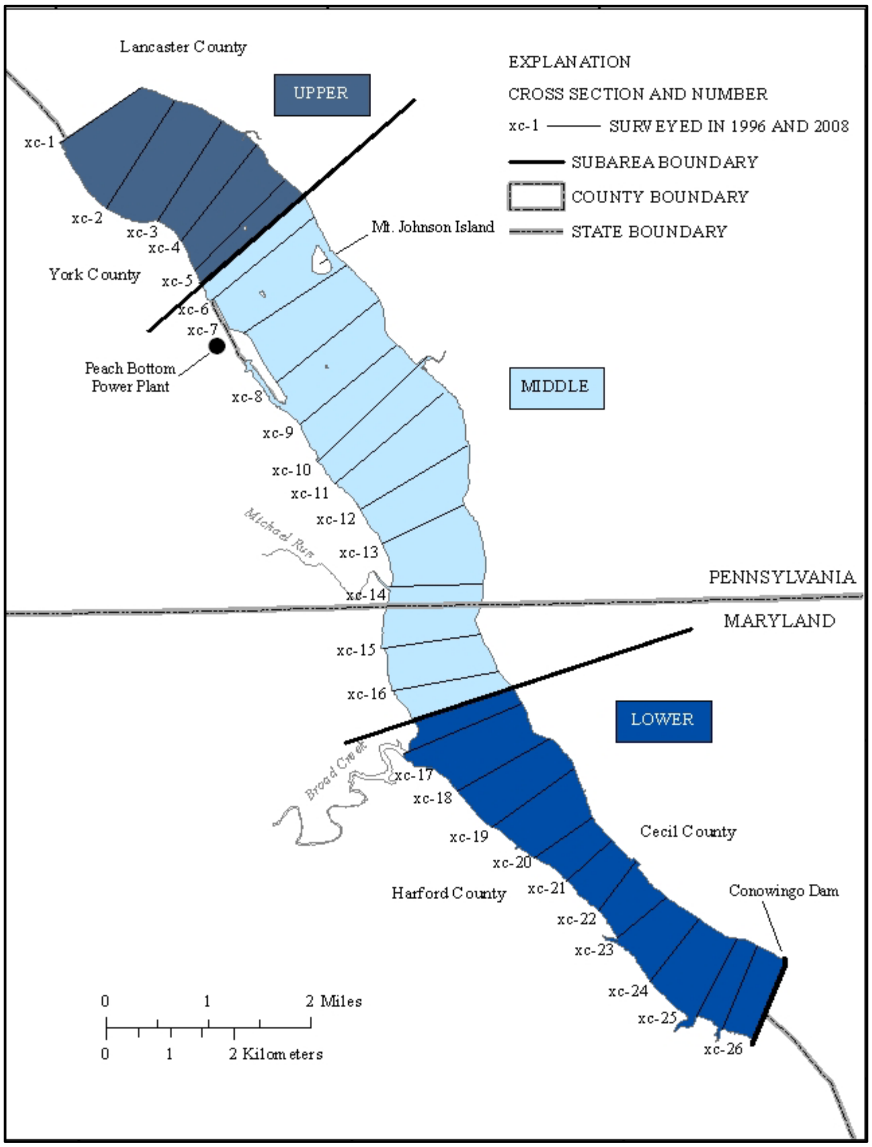


Figure B2. Locations of the Upper, Middle, and Lower sections of Conowingo Reservoir.

Changes in average total sediment deposition and in total sand deposition in the Conowingo Reservoir from the 3 sediment coring studies (1990-01, 1996, and 2000) are presented in table B1. Projections to the year 2012 based on the historical changes and also included in table B1. Percent sand is based predominantly on the uppermost one foot of the sediment cores, areas most prone to bed scour and movement. Results from the sediment cores indicate the highest percentages of sands are in the upper section. This is an area where sands are deposited due to the loss of flow velocity upon entering the top of the impounded reservoir with a general down gradient distribution of sands to fines. Results also suggest minor changes in percent sands in the upper section. Sand increased in the middle section from approximately 39 to 45 percent (1990-2012), due to continual displacement (scour) of fines with sand during high-flow events. The middle area had the greatest amount of sand deposition. The lower section is the active area for deposition and has seen the greatest increase in sand from 5 to 20 percent (1990 – 2012). Clay fractions in the lower section have been reduced from approximately 35 percent in 1990 to 12 percent in 2000, indicating this is also an active area for scouring.

Table B1. Change in grain-size percentage and deposition for 3 sediment coring studies and projected to 2012 for Conowingo Reservoir. Years grouped by color.

Year and Location	Total Sediment Deposition (tons)	Average sand (percent)	Total Sand Deposition (tons)
1990 - Upper	11,000,000	80	8,800,000
1990 - Middle	64,000,000	39	24,000,000
1990 - Lower	80,500,000	5	4,000,000
1996 - Upper	11,200,000	82	9,200,000
1996 - Middle	62,000,000	42	26,000,000
1996 - Lower	89,800,000	8	7,200,000
2000 - Upper	11,500,000	83	9,500,000
2000 - Middle	63,000,000	43	26,000,000
2000 - Lower	103,000,000	15	15,500,000
2012 – Upper (predicted)	11,500,000	84	9,660,000
2012 – Middle (predicted)	64,000,000	45	27,500,000
2012 – Lower (predicted)	108,000,000	20	21,600,000

References

Cerco, C.F. 2012, Data assembly for application of the CBEMP in the Lower Susquehanna River Watershed Assessment: Vicksburg, Miss., U.S. Army Engineer Research and Development Center, 31 p.

Edwards, R. E., 2006, Comprehensive analysis of the sediments retained behind hydroelectric dams of the Lower Susquehanna River: Susquehanna River Basin Commission Pub. 239. (Also available at *http://www.srbc.net/pubinfo/techdocs/Publication_239/ExecutiveSummary.pdf*.)

Hainly, R.A., Reed, L.A., Flippo, H.N., Jr., and Barton, G.J., 1995, Deposition and simulation of sediment transport in the Lower Susquehanna River reservoir system: U.S. Geological Survey Water-Resources Investigations Report 95-4122, 39 p.

Langland, M.J., and Hainly, R.A., 1997, Changes in bottom-surface elevations in three reservoirs on the Lower Susquehanna River, Pennsylvania and Maryland, following the January 1996 flood—Implications for nutrient and sediment loads to the Chesapeake Bay: U.S. Geological Survey Water-Resources Investigation Report 97-4138, 34 p.

Langland, Michael J., 2009, Bathymetry and sediment-storage capacity change in three reservoirs on the Lower Susquehanna River, 1996-2008: U.S. Geological Survey Scientific Investigations Report 2009-5110, 21 p. (Also available at *http://pubs.usgs.gov/sir/2009/5110/*.)

Attachment A-3:
Additional Information for Estimation of Full Sediment Storage Capacity in Conowingo Reservoir

Attachment A-3

Additional Information for Estimation of Full Sediment Storage Capacity in Conowingo Reservoir

The following information is provided to help the Lower Susquehanna River Assessment Project in their efforts to study sediment loads from behind a series of hydroelectric dams and associated reservoirs, located on the lower Susquehanna River draining into the northern Chesapeake Bay. Information provided includes the methodology used for the estimation of a full sediment storage capacity (SSC) condition in the Conowingo Reservoir. An estimation of full SSC condition is presented using 2008 and 2011 bathymetry data in the procedure outlined below.

Procedure for Estimating Conowingo Reservoir Full Sediment Storage Capacity Bathymetry

1) U.S. Geological Survey (USGS) bathymetry data from 2008 (Langland, 2009) URS Corporation and Gomez and Sullivan Engineers (GSE) bathymetry data from 2011 (URS Corporation and Gomez and Sullivan Engineers, 2012) were plotted and compared. An example plot for cross section 25 is shown in figure C1.
2) Full SSC bathymetry was calculated from cross-sectional areas and volumes (depth) previously determined in Reed and Hoffman (1996) using the same transect lengths and widths as used in the previous bathymetry studies (table C1) (Langland, 2009; URS Corporation and Gomez and Sullivan Engineers, 2012).
3) Using the full SSC volume from step #2, the cross-sectional area remains constant so only the depth changes. Changing the depth results in a new estimated volume. The mean depth from the 2011 bathymetry was adjusted to approximate the full SSC for transects 18 through 26, the area of continuing deposition in the Conowingo Reservoir (figure C2). Transects above 18 (upper and middle areas of the reservoir) are considered in a dynamic-equilibrium state and have a limited capacity to store and scour sediment based on the SSC in table C1.
4) Comparing 2008 and 2011 bathymetry data, individual depth readings along each transect were adjusted to approximate the mean depth of sediment deposition (figure C3, table C1) and the SSC.

5) Latitude and longitude data were added.

6) New SSC full condition data set were provided to the U.S. Army Corps of Engineers (USACE), 2/13/2013, for use in the 2-D model for full bathymetry simulations.

The result of the above procedure was to add an additional 6.2 million tons of sediment in the lower section of Conowingo Reservoir. The results of the 2011 bathymetry indicated approximately 7 million tons of sediment were needed to reach 100 percent capacity with sediment (attachment A, table 4).

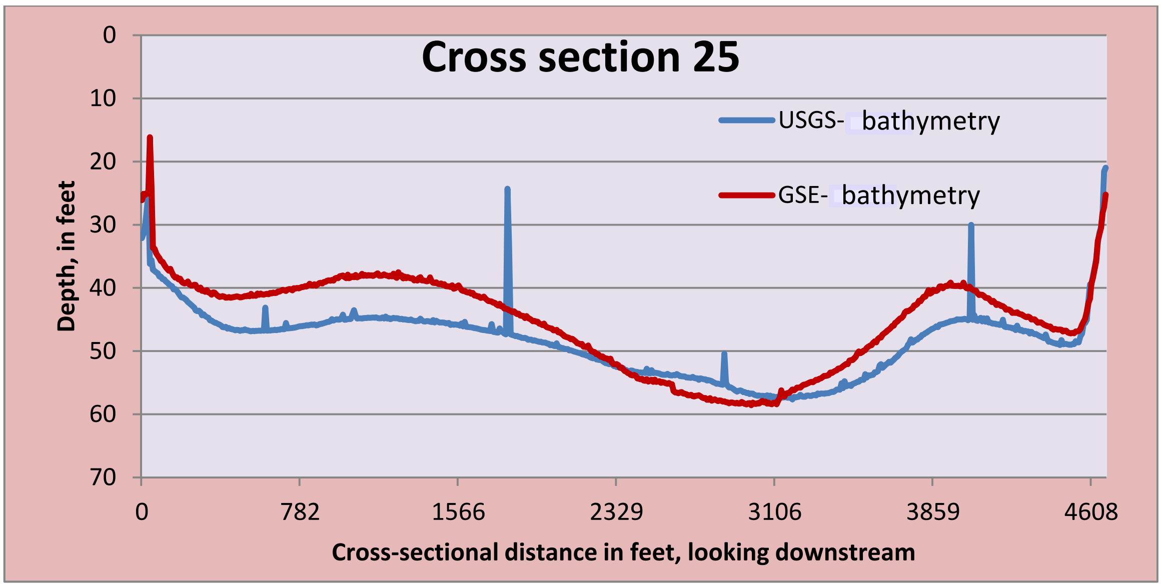


Figure C1. Differences in bathymetry (depth to bottom) comparing a 2008 U.S. Geological Survey (USGS) study (Langland, 2009) and a 2011 URS Corporation and Gomez and Sullivan Engineers (GSE) study (URS Corporation and Gomez and Sullivan Engineers, 2012) for cross section number 25. Red lines above blue lines indicate deposition and red below blue indicate possible scour.

Table C1. Cross-sectional areas and volumes used to estimate the sediment storage capacity (SSC). A blue shaded row indicates change to full depth compared to 2011 depth.
[L; length, W; width, D; depth, ft; feet, ft^2; square feet]

Cross section number	Dimensions			Mean Water Depths and Volumes						Estimated Sediment Storage Capacity (SSC)			
	Length ft	Width ft	L X W ft^2	2008 depth ft	2011 depth ft	2008 area (L X D) ft^2	2011 area (L X D) ft2	2008 volume (acre ft)	2011 volume (acre ft)	SSC	Full depth ft	Full XC area (L X D) ft^2	Full Volume (acre feet)
26	4750	2425	11,518,750	55.5	53.4	263,625	253,650	14,676	14,121	230	48.1	228,4755	12,719
25	4610	1915	8,828,150	49.6	47.3	228,656	218,053	10,052	9,586	200	41.3	190,393	8,370
24	4450	2400	10,680,000	41.7	39.7	185,565	176,665	10,224	9,734	150	33.7	149,965	8,263
23	3520	2175	7,656,000	35.6	34	125,312	119,680	6,257	5,976	110	30.3	110,176	5,325
22	3380	2162	7,307,560	32.1	30.6	108,498	103,428	5,385	5,133	100	29.8	100,724	4,999
21	3350	2085	6,984,750	30.7	29.7	102,845	99,495	4,923	4,762	100	29.7	99,495	4,762
20	3560	2187	7,785,720	29.5	28.1	105,020	99,680	5,273	5,005	100	28.0	100,036	5,022
19	5240	2625	13,755,000	22	21.1	115,280	110,564	6,947	6,663	100	21.1	110,564	6,663
18	5000	2525	12,625,000	21	20.5	105,000	102,500	6,086	5,942	100	20.1	100,500	5,826
17	6180	2550	15,759,000	21	20.8	129,780	128,544	7,597	7,525	110	20.8	128,544	7,525
16	5300	2570	13,621,000	20	19.9	106,000	105,470	6,254	6,223	100	19.9	105,470	6,223
15	5050	2530	12,776,500	21	21	106,050	106,050	6,159	6,159	100	21	106,050	6,159
14	4710	3150	14,836,500	20	20	94,200	94,200	6,812	6,812	98	20	94,200	6,812
13	4700	3175	14,922,500	20	20	94,000	94,000	6,851	6,851	98	20	94,000	6,851
12	6510	3420	22,264,200	16	15.9	104,160	103,509	8,178	8,127	100	15.9	103,509	8,127
11	7600	1900	14,649,000	14	14	106,400	106,400	4,708	4,708	105	14	106,400	4,708
10	6540	1400	9,800,000	15	15	98,100	98,100	3,375	3,375	100	15	98,100	3,375
9	6900	2130	13,930,200	16	15.9	110,400	109,710	5,117	5,085	110	15.9	109,710	5,085
8	6350	2430	16,767,000	14	14.2	88,900	90,170	5,389	5,466	100	14.2	90,170	5,466
7	6810	2775	17,621,250	17	15	115,770	102,150	6,877	6,068	110	16	108,960	6,472
6	6700	2600	17,706,000	15	14.8	100,500	99,160	6,097	6,016	100	14.8	99,160	6,016
SUM	111,210	51,129	271,794,080	526.7	510.8	2,594,061	2,521,178	143,238	139,335	2411	490	2,430,725	134,751
AVERAGE	5,296	2,435	12,942,575	25	24	123,527	120,056	6,821	6,635	115	23.4	116,052	6,433

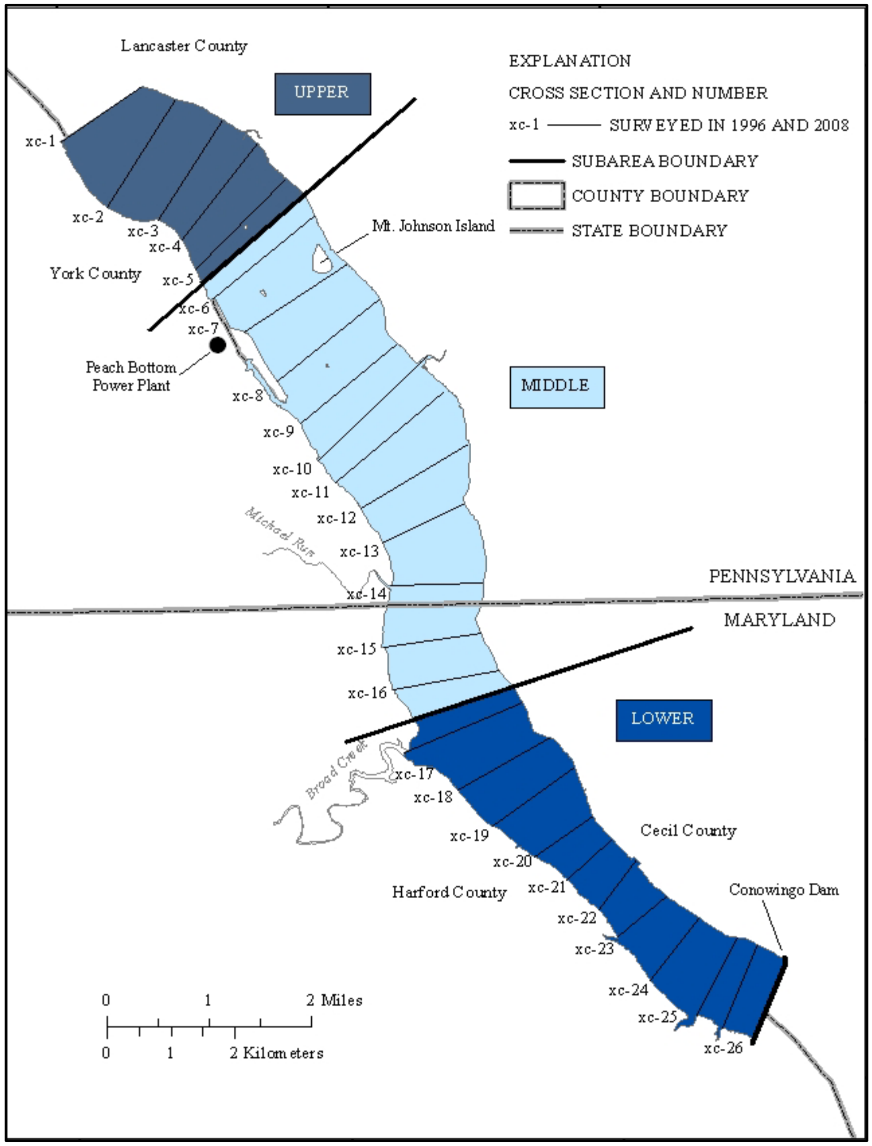


Figure C2. Locations of the surveyed cross sections in relation to the Upper, Middle, and Lower sections of Conowingo Reservoir in 2008 and 2011.

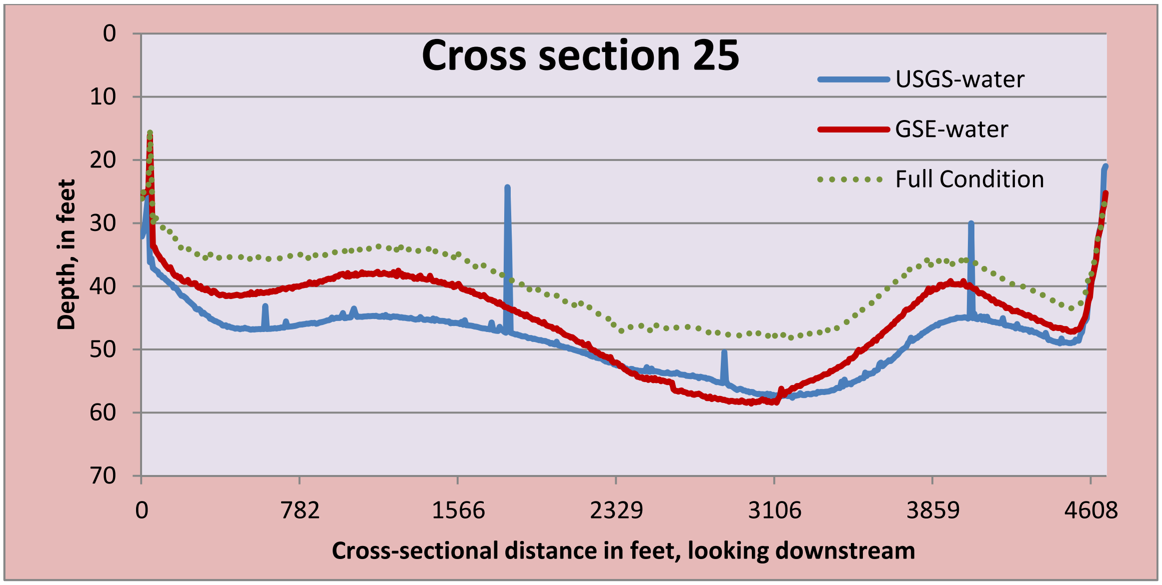


Figure C3. Differences in bathymetry (depth to bottom) comparing a 2008 U.S. Geological Survey (USGS) study (Langland, 2009), a 2011 URS Corporation and Gomez and Sullivan Engineers (GSE) study (URS Corporation and Gomez and Sullivan Engineers, 2012), and the estimated full condition for cross section number 25.

References

URS Corporation and Gomez and Sullivan Engineers. 2012. Sediment introduction and transport study (RSP 3.15) (Appendix F). Kennett Square, PA: Exelon Generation, LLC.

Langland, Michael J., 2009, Bathymetry and sediment-storage capacity change in three reservoirs on the Lower Susquehanna River, 1996-2008: U.S. Geological Survey Scientific Investigations Report 2009-5110, 21 p. (Also available at *http://pubs.usgs.gov/sir/2009/5110/*.)

Appendix B:
Sediment Transport Characteristics of Conowingo Reservoir

Attachment B-1:
Evaluation of AdH Model Simplifications in Conowingo Reservoir Sediment Transport Modeling

Attachment B-2:
SEDflume Erosion Data and Analysis

Attachment B-3:
Change in Deposition and Bed Scour between the 2008 and 2011 Conowingo Reservoir Bathymetry Surveys

Attachment B-4:
Modeling Analysis to Support Agitation Dredging in Conowingo Reservoir

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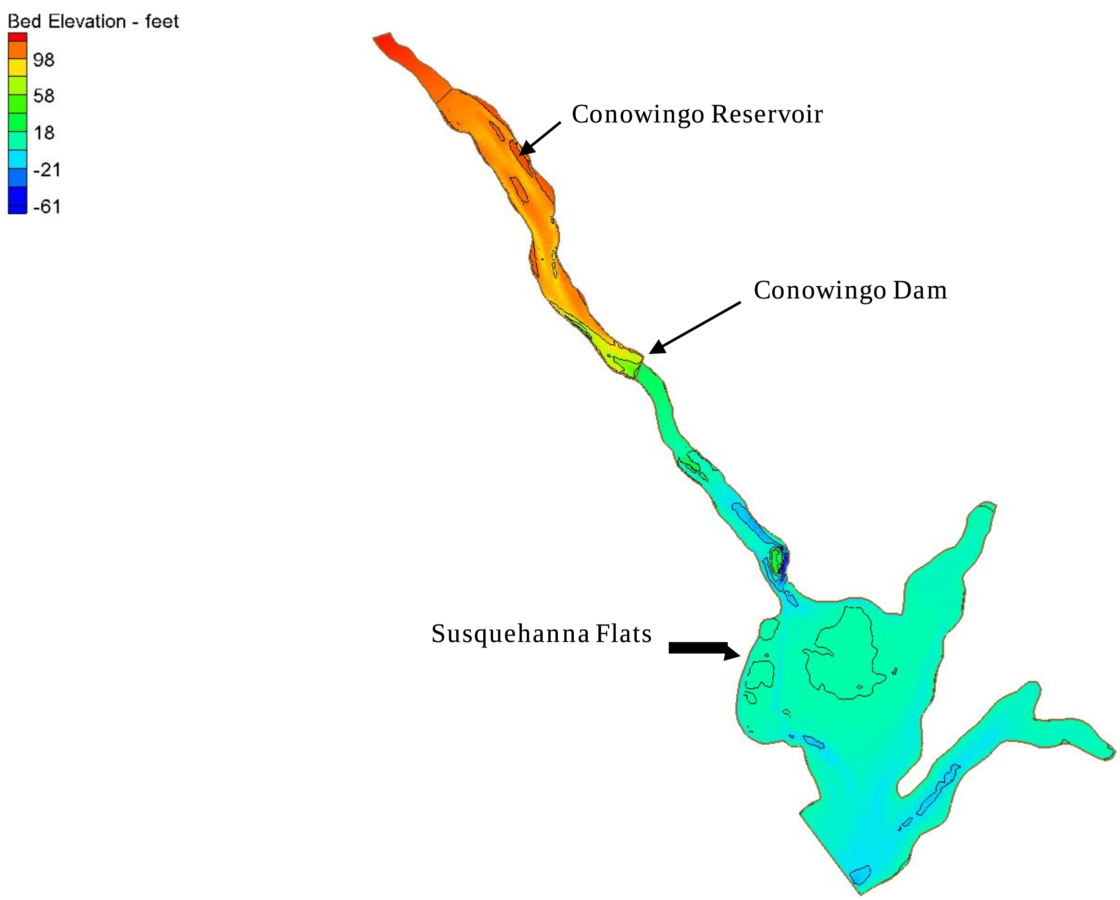
Sediment Transport Characteristics of Conowingo Reservoir

Stephen H. Scott and Jeremy A. Sharp

February 2014



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Sediment Transport Characteristics of Conowingo Reservoir

Stephen H Scott and Jeremy A Sharp

Coastal and Hydraulics Laboratory
US Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180

Final report

Prepared for US Army Corps of Engineers Baltimore District
Baltimore, MA 21202

Monitored by

Coastal and Hydraulics Laboratory
US Army Engineer Research and Development Center
3909 Halls Ferry Road, Vicksburg, MS 39180

Abstract

Three consecutive dam and reservoir systems are located on the lower Susquehanna River; Lake Clarke (uppermost), Lake Aldred, and Conowingo Reservoir (lowermost). The dams associated with these reservoirs produce hydroelectric power for the region. The dams were constructed over the time frame of 1910 – 1931. With the passage of time, Lake Clarke and Lake Aldred have filled with inflowing sediments. These reservoirs are considered to be at full sediment storage capacity, thus they no longer efficiently trap nutrients and sediment. The lowermost reservoir, Conowingo, has very little sediment storage capacity remaining, and is currently near a state of dynamic equilibrium in which sediment transport through the reservoir over time will remain relatively constant.

The Lower Susquehanna River Watershed Assessment (LSRWA) is being conducted by the Baltimore District of the Corps of Engineers to address the sedimentation issues of these lower reservoirs as well as water quality of the lower Susquehanna River and Chesapeake Bay. The Maryland Departments of the Environment and Natural Resources were the non-federal sponsors for the watershed assessment, with The Nature Conservancy and the Susquehanna River Basin Commission as technical contributors. The study described in this report is one of a number of studies sponsored by the LSRWA for evaluating the impacts of sediment and nutrient transport on the water quality of Chesapeake Bay. This report describes the results from a two-dimensional (2D) sediment transport model of Conowingo Reservoir. The impacts of large storms on bed scour were simulated, as well as a number of sediment management alternatives including conventional dredging and agitation dredging. A number alternatives were investigated to evaluate the change in sediment transport in Conowingo over time. Three reservoir bathymetries (1996, 2008, and 2011) were used in the model to evaluate temporal sediment transport trends. Model inflowing sediment boundary conditions were provided by a HECRAS one dimensional model of the three lower Susquehanna River reservoirs developed by the United States Geological Survey (USGS) under the LSRWA effort. Model results indicate reservoir bed scour increases for large storms as the reservoir fills, with decreasing reservoir sedimentation as storage capacity is lost. Additionally, model results indicate that Conowingo Reservoir is near full sediment storage capacity and that it is

currently in a state of dynamic equilibrium. This implies that although the reservoir scours and stores sediment during flood and non-flood periods, overall the net reservoir sediment storage capacity does not change appreciably over time. Thus the bay may be currently experiencing maximum sediment inflows from Conowingo during periodic large flood events.

The 2D modeling results only describe the transp0rt of sediment solids and do not imply a relationship exists between solids transport and fate with nutrient loads.

Contents

Attachment B-3: Change in Deposition and Bed Scour Between the 2008 and 2011 Conowingo Reservoir Bathymetry Surveys

Attachment B-4: Modeling Analysis to Support Agitation Dredging in Conowingo Reservoir

Illustrations

Figures

Tables

Preface

This study was conducted for the U.S. Army Corps of Engineers, Baltimore District under project identification "Sediment Transport Characteristics of Conowingo Reservoir." The Baltimore District team included the study manager Anna Compton, the project manager Claire O'Neill, with technical team members Bob Blama, Tom Laczo, Chris Spaur, and Danielle Szimanski. The Maryland Departments of the Environment and Natural Resources were the non-federal sponsors for the watershed assessment, with The Nature Conservancy and the Susquehanna River Basin Commission as technical contributors.

The work was performed by the River Engineering Branch of the Flood and Storm Protection Division, U.S. Army Engineer Research and Development Center – Coastal and Hydraulics Laboratory. At the time of publication, Dr. Loren L. Wehmeyer was chief of the River Engineering Branch; Dr. Ty V. Wamsley was chief of the Flood and Storm Protection Division; and Mr. Bill Curtis was the technical director for the Flood and Storm Protection Division. The deputy director was Richard Styles and the director was Mr. Jose E. Sanchez.

COL Kevin J. Wilson was the commander and executive director of the U.S. Army Corps of Engineers, Engineer Research and Development Center, and Dr. Jeffery P. Holland was the director.

Unit Conversion Factors

Multiply	By	To Obtain
cubic feet	0.02831685	cubic meters
cubic yards	0.7645549	cubic meters
feet	0.3048	meters
inches	0.0254	meters
microns	1.0 E-06	meters
miles (US statute)	1,609.347	meters
pounds (force)	4.448222	newtons
pounds (force) per square foot	47.88026	pascals
pounds (mass)	0.45359237	kilograms
square feet	0.09290304	square meters
square yards	0.8361274	square meters
tons (long) per cubic yard	1,328.939	kilograms per cubic meter
tons (2,000 pounds, mass)	907.1847	Kilograms
yards	0.9144	Meters

1 Introduction

The Susquehanna River flows through south central New York, central and southern Pennsylvania, and northeastern Maryland, draining a watershed of approximately 27,000 square miles. Three hydroelectric dams and the associated reservoirs are located in series on the lower Susquehanna River within a 35-mile span of the river upstream of Chesapeake Bay. The upper most reservoir, Lake Clarke, is impounded by Safe Harbor Dam located approximately 32 miles upstream of Chesapeake Bay. It was constructed in 1931, with a design water storage capacity of approximately 150,000 acre-feet. The middle reservoir, Lake Aldred, was impounded by Holtwood Dam in 1910, with a water storage capacity of approximately 60,000 acre-feet. It is located approximately 25 miles upstream of Chesapeake Bay. The lowermost reservoir, Conowingo Reservoir, was constructed in 1928 with a water storage capacity of approximately 300,000 acre-feet. Conowingo Dam is located approximately 10 miles upstream of the bay.

Inflowing sediments from the watershed have been depositing in these reservoirs since construction. The inflowing sediment load is dependent on many factors including watershed area, land use, and regional hydrology. In addition to the natural sediment load, coal entered the Susquehanna River system through mining and processing operations. These coal sediments comprise approximately 10 percent of the sediment deposited in the reservoirs (Hainly and others, 1995).

The Susquehanna River is a major tributary to Chesapeake Bay, delivering a substantial amount of sediment and nutrients to the bay. High inflowing nutrient loads, some of which are attached to sediment particles, have resulted in the Chesapeake Bay being listed as water quality impaired under the federal Clean Water Act (CWA). In an effort to mitigate these negative impacts, regulatory agencies responsible for implementing the federal CWA required a TMDL (total maximum daily load) limit for nutrient releases into the bay (USEPA, 2011). To meet the TMDL requirements, sediment and nutrient releases from all Chesapeake Bay tributaries, including the Susquehanna River and the associated Conowingo Dam, must be controlled. If sedimentation processes within the three upstream reservoirs were currently in a steady state condition, a TMDL standard could possibly be enforced. However, the dam/reservoir system has altered the river's hydrology such that sediment deposition and erosion throughout the system is in flux. The top two reservoirs have reached a dynamic equilibrium sediment transport condition in that the capacity to store sediments has been significantly reduced (Langland and others, 2009). In the absence of large flow events, the majority of sediments that enter the two upstream reservoirs transport to the lowermost Conowingo Reservoir. However, large flood events will scour and transport bed sediment deposits in these reservoirs, thus temporarily restoring some incoming sediment storage capacity. Conowingo Reservoir currently is approaching a dynamic equilibrium state and continues to store inflowing sediments during non-flood periods. However, the storage capacity of Conowingo will decrease over time similar to the upstream reservoirs. Eventually, it is assumed that all three reservoirs will be in a dynamic equilibrium condition where the system's overall capacity to store sediments has been significantly reduced and larger flow events cause more frequent sediment scour sediment scour and transport events that temporarily restores some sediment storage capacity. Thus, as the storage capacity decreases over time, the amount of sediment and nutrients delivered to the bay may increase to some degree.

The hydrodynamic and sediment transport processes in the reservoirs are complex and unsteady in nature. Thus a thorough understanding of both sediment deposition and erosion processes is required for evaluating how the system currently functions and how it will function in the future. Although sediment transport in Conowingo Reservoir is dominated by deposition during low flow periods, bed scour does occur during large flow events, and significant amounts of sediment can potentially be scoured, mobilized, and transported through the reservoir system and ultimately into the bay. To facilitate analysis of the reservoir system, a 2D numerical model of reservoir hydrodynamics and sediment transport was developed and utilized to evaluate sediment transport through the reservoir, as well as evaluate sediment management alternatives necessary to control or mitigate sediment releases.

This report presents a description of the model, how it was applied, and model results for a number of sediment transport scenarios designed to evaluate storm scour potential and sediment management alternatives. The 2D modeling results only describe the transp0rt of sediment solids and do not imply a relationship exists between solids transport and fate with nutrient loads.

2 Background

The USGS has performed a number of significant sediment transport and bathymetric studies on the three reservoirs. Their study findings indicate that top two reservoirs are in a dynamic equilibrium status, with Conowingo Reservoir currently having some capacity to store incoming sediment load. The USGS predicts that Conowingo Dam has approximately 10 to 15 years of sediment storage capacity remaining (USGS 2009). Data presented by the USGS studies show the average inflowing sediment into the reservoir system as well as the Conowingo Reservoir deposition rate over time. Figure 1 presents the average sediment delivery to the system by decade, along with the estimated sediment deposition in Conowingo Dam. The estimated sediment deposition in Conowingo was determined by interpolating data presented in the 2009 USGS publication referenced above.

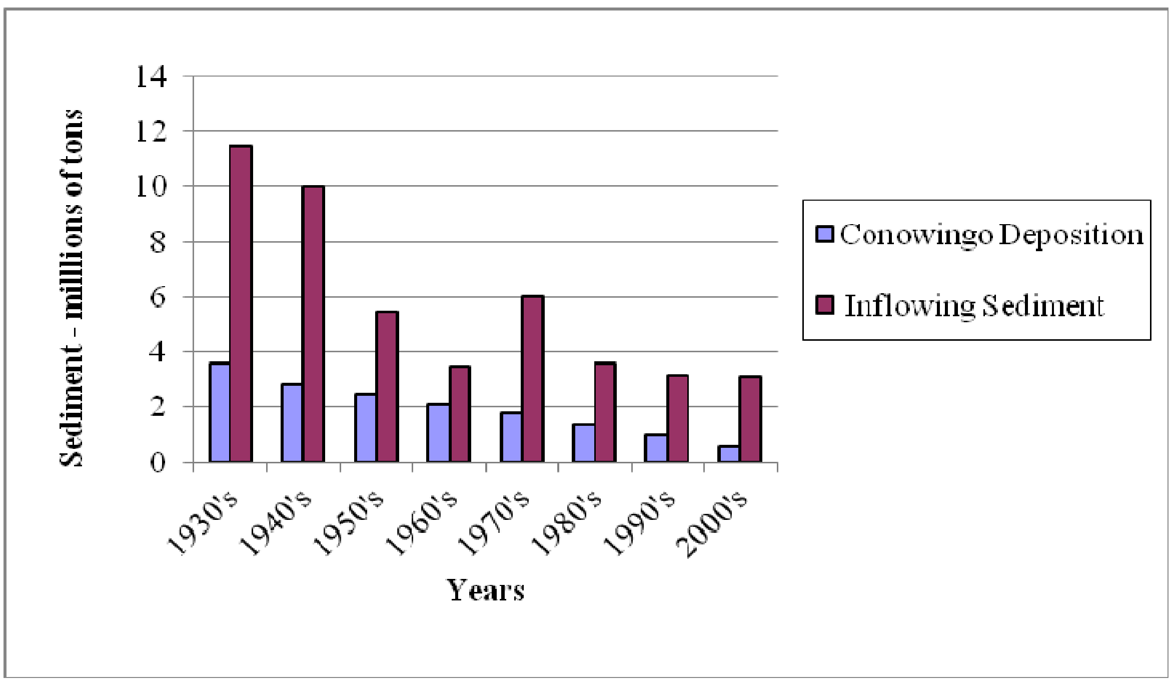


Figure 1 Average annual Inflowing sediment into the lower Susquehanna along with Conowingo Reservoir deposition (provided by USGS)

From 1929 to 1959, all three reservoirs were actively trapping sediments. (USGS, 2009) The inflowing loads from the watershed during that period were much higher. By approximately 1959, the two uppermost reservoirs had become less efficient in trapping sediment, and the inflowing sediment load to Conowingo Reservoir remained relatively constant at about 3.2 million tons per year, with the exception of the 1970's which was impacted by Hurricane Agnes. During this time of relatively constant average sediment inflow (1960 to present), the average deposition of sediment in Conowingo Reservoir has been decreasing. A constant sediment inflow combined with a reduction in sediment deposition indicates a possible decrease in trap efficiency with a resulting increase in sediment outflow from the reservoir.

The USGS estimates that the average inflow of sediment is about 3.2 million tons per year into Conowingo Reservoir, with deposition ranging from 1.0 to 2.0 million tons per year. A similar reservoir with adequate storage capacity can have a trap efficiency ranging from 70 to 80 percent. Although the data indicate that, on the average, the trap efficiency of Conowingo Dam is decreasing, large flow events can temporarily increase trap efficiency by scouring existing bed sediments out of the reservoir into the bay. The USGS indicates that flow events on the order of 400,000 cfs (cubic feet per second) will result in scour of reservoir bed sediments. This flow is approximately a 5-year return flood (Figure 2). To put this flow in perspective, a 1-year return flood on the lower Susquehanna is approximately 130,000 cfs, with a 100-year return flood approaching 900,000 cfs.

Two sediment transport numerical modeling studies were conducted on the lower Susquehanna reservoirs. In 1995, the USGS conducted a HEC-6 one dimensional model study (Hainly and others 1995). The modeling results indicated that the HEC-6 model significantly under-predicted the trap efficiency (35 percent as opposed to the measured efficiency of 76 percent). They found that the model was capable of reproducing the measured trap efficiency if the inflowing sediment size classes included more coarse grained sediments. In addition, Exelon Corporation revised the USGS HEC-6 model and conducted a series of simulations to evaluate scour potential of the three reservoirs (Exelon, 2012 RSP 3.15). Their results indicated that for flood flows greater than 400,000 cfs (scour threshold flows), Conowingo Reservoir was net depositional. A summary of both studies is presented in the Exelon report cited above.

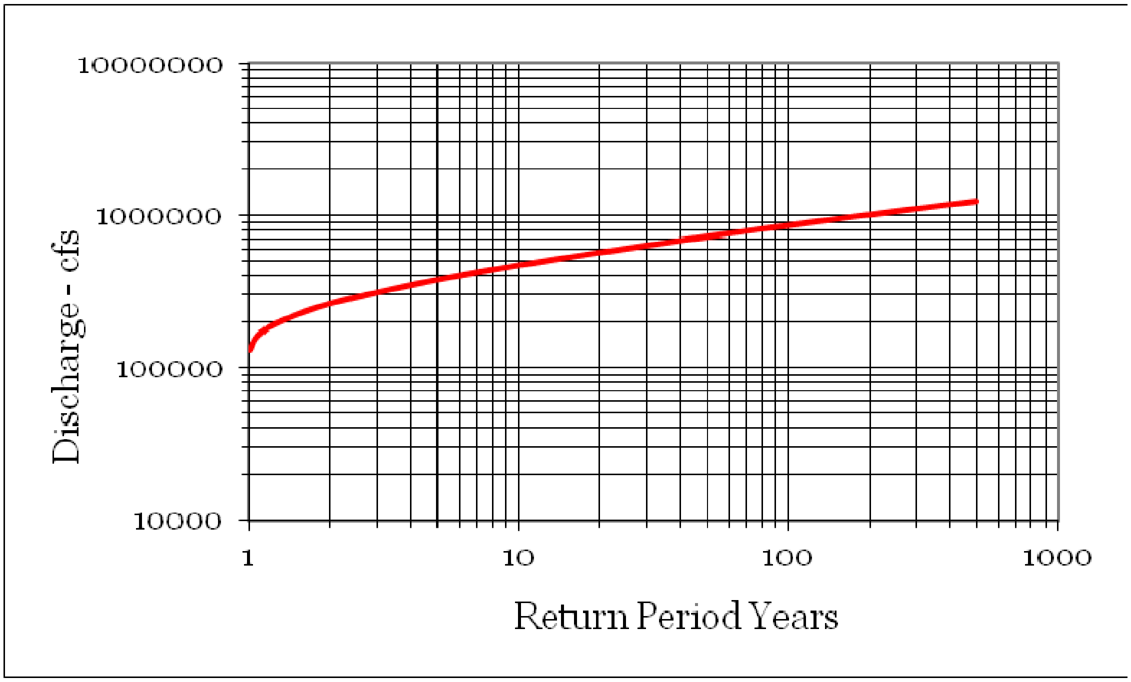


Figure 2 Return flood flows for the Susquehanna River

3 Study Approach and Goals

For this study, the 2D model was used to simulate a number of alternatives that were designed to provide an estimate of the impact of low, moderate, and flood flows on sediment transport dynamics in Conowingo Reservoir. The complexity of reservoir hydrodynamics and sediment transport dictate that a physics-based model be applied to the problem. The appropriate model must contain either physical or empirical formulations that will adequately simulate the processes found in the domain. The 2D Adaptive Hydraulics (AdH) numerical model developed by the ERDCWES is a finite element, implicit scheme model utilizing an unstructured mesh (Berger, 2012). It provides a fully unsteady solution of system hydrodynamics and sediment transport. The sediment transport model is capable of simulating coarse sediment transport (sand size or greater), fine sediment transport (silt and clay sizes) or mixed sediment transport. Multiple bed layers can be simulated, with sorting of mixed load due to variable erosion and deposition processes. The model contains sediment transport capacity functions for the coarse sediment transport. However, silt and clay deposits in reservoirs will most likely display cohesive behavior due to consolidation. Functions that describe the prototype sediment behavior can be directly input into AdH to describe the erosion and deposition characteristics. For the LSRWA study, the bed sediments in the reservoirs were sampled and analyzed in the laboratory to develop erosion rate functions specific to the sediments in the reservoir. The AdH model utilizes this data to compute the erosion rate and critical shear stress for erosion of the cohesive fine sediment bed.

The AdH numerical mesh used for the Conowingo study consisted of approximately 20,000 elements and 10,000 nodes. The mesh density for the entire Conowingo Reservoir is depicted in Figure 3, with Figure 4 presenting the mesh density in the lower reach of the reservoir. The mesh was designed to provide an adequate number of computational elements and associated nodes to capture details of the reservoir bathymetry and to provide highly resolved model results. The model solution is generated at the computational nodes and interpolated across the element area to create a solution over the entire problem domain. For this study, a number of reservoir surveys were mapped to the mesh for analysis. The USGS provided reservoir surveys from 1996 and 2008, with Exelon

Corporation providing the most recent 2011 survey. The 2011 survey was modified by the USGS to represent a full sediment capacity condition.

The model simulations were designed to provide insight into how the reduction in sediment storage capacity over time affects sediment discharge from Conowingo Dam, and determine the effectiveness of proposed sediment management techniques designed to reduce the overall sediment load to Chesapeake Bay. The model output parameters of interest include net reservoir sedimentation, net bed scour as a function of sediment grain size, and total load to the bay. All simulations were conducted with the same Susquehanna River flow and inflowing sediment boundary conditions. The 4-year flow period from 2008 to 2011 was simulated in the model. The flow and sediment entering the upstream model boundary (channel below the dam on Lake Aldred) were provided by the USGS from HEC-RAS (Hydrologic Engineering Center-River Analysis System) model simulations of the 4-year flow record. These simulations included all three reservoirs, thus the sediment output from HEC-RAS included bed sediment scour from the upper two reservoirs. The sediment rating curve in the HEC-RAS simulations was developed by the USGS from suspended sediment measurements in the Susquehanna River above the reservoir system.

The following were the six main study goals:

- Evaluate the uncertainty associated with applying a 2D model to Conowingo Reservoir;

- Measure the critical shear stress and erosion rate of bed sediments in Conowingo Reservoir for input into the 2D model;

- Evaluate how Conowingo Reservoir sediment transport responds to low, moderate, and flood flows for different reservoir bathymetries representing temporal changes in sediment storage capacity (1996, 2008, and 2011 years);

- Determine how Conowingo Reservoir sediment transport responds to low, moderate, and flood flows for a full reservoir capacity scenarios;

- Evaluate how effective sediment management techniques would be for reducing sediment loads passing through Conowingo into Chesapeake Bay (conventional dredging, agitation dredging, and sediment bypassing impacts);

- Provide model output to the CBEMP (Chesapeake Bay Environmental Modeling Package) which will evaluate the impact of the 2D AdH output on water quality in Chesapeake Bay.

Figure 3 Numerical Mesh of Conowingo Reservoir

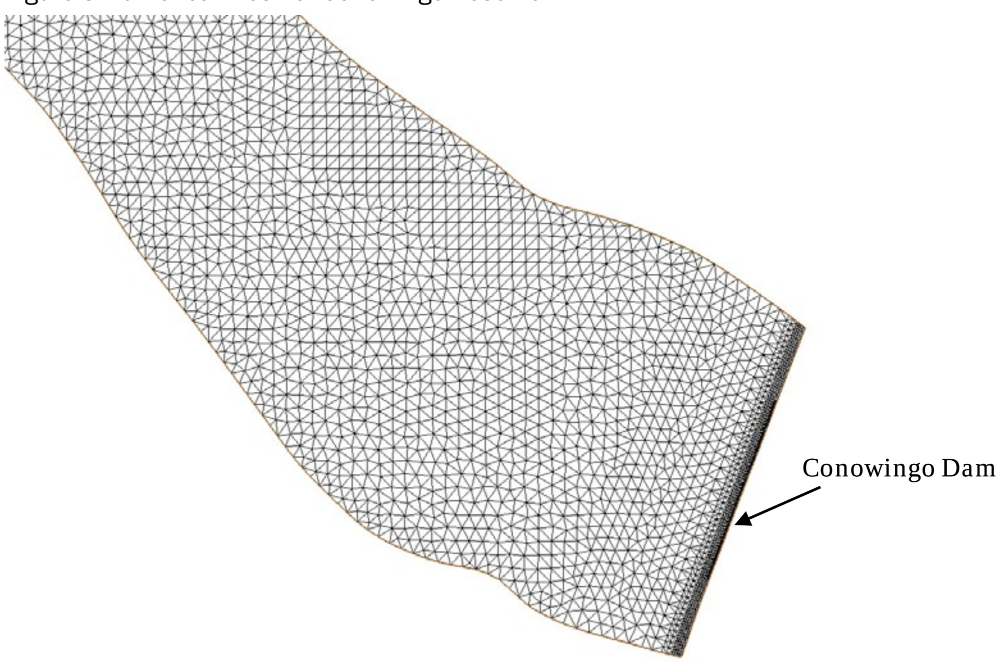


Figure 4 Detail of numerical mesh in lower Conowingo Reservoir

4 Description of Modeling Uncertainties

Numerical models are valuable tools for describing complex flow and sediment interactions. However, as with any analytical method, they contain a number of uncertainties that can influence results. The decision of which model to use depends on many factors, including problem dimensionality and required resolution. One dimensional models are typically utilized when depth and laterally averaged conditions can provide adequate resolution to the problem. When lateral sediment transport conditions need to be resolved, a 2D model is more appropriate. In this case, the model results are depth averaged, with model results available throughout the domain area. The most complex model to apply to a problem is the 3D model. It provides problem resolution in all three dimensions (depth, lateral, and longitudinal). However, these models are computationally intensive and require long periods of simulation time to run relatively short problem durations.

4.1 Modeling uncertainties

Hydrodynamic and sediment transport numerical models have a number of inherent uncertainties. The mathematical computation methods add uncertainty, with additional uncertainties due to bathymetry surveys used to populate the model and field data used for model boundary conditions. The choice of a sediment transport model to apply to reservoirs depends on the conditions that will be modeled. If the goal of a particular study is to better understand reservoir stratification in low flow, low turbulence conditions, then a three-dimensional model (3D) will be required to differentiate the vertical properties. However, if the item of interest in the reservoir occurs during well-mixed, turbulent conditions, a 2D depth-averaged model will be adequate. A 3D model can also be applied to well-mixed problems, but the computational requirements (run time) are excessive. Two dimensional models can be used to simulate sediment transport over years or decades, thus they are better suited for long-term simulations.

Reservoirs are primarily depositional at low to moderate flows. When a reservoir is initially constructed the sediment trap efficiency is high, approaching 80 percent or more. As the reservoir fills with sediment, coarser sediments begin to deposit in the upper reaches of the reservoir, with the finer fractions depositing in the downstream reaches or passing through the dam. Over time, the upper reservoir reach becomes shallower due to deposition, thus the transport capacity increases with inflowing sediment transporting further downstream. Eventually a delta forms within the reservoir at its upstream end that encroaches on the deeper, lower reaches of the reservoir and gradually decreases sediment storage capacity (Sloff, 1997). When the reservoir no longer has sediment storage capacity, it is assumed to be in equilibrium in that sediment that flows into the reservoir eventually is passed through the dam. Reservoir equilibrium is not a static condition, rather an ongoing dynamic change of state. The sediment deposits during low flows and scours during flood flows, and the net result is that the sediment entering the reservoir eventually leaves the reservoir. The changes in hydrology created by the dam thus changes both the timing and the quantity of sediment transport below the dam.

Modeling such a dynamic system requires an extensive set of model boundary conditions such as suspended sediment inflow concentrations and fine sediment bed properties. Suspended fine sediments can either exist as primary silt and clay particles, or in low energy systems such as reservoirs, form larger particles in the water column due to flocculation. Particles that flocculate are larger and have higher settling velocities, thus their fate in the reservoir can be quite different than the lighter primary particles (Ziegler, 1995).

When fine sediment particles deposit on the reservoir bed, they compact consolidate over time. As they consolidate, the yield stress increases, meaning that the resistance to erosion becomes greater. Higher flows and subsequent bed shear stresses are required to scour the consolidated bed. Laboratory results show that sediments that erode from consolidated beds may have larger diameters than the primary or flocculated particles (Banasiak, 2006). Scour may result in re-suspension of large aggregates that re-deposit in the reservoir and do not pass through the dam. To add to the complexity of this phenomenon, the large aggregate particles scoured from the bottom during a high flow event can break down to smaller particles in highly turbulent conditions. Thus the fate of inflowing sediment particles in the reservoir is highly variable and difficult to capture with current modeling techniques.

Reservoir dam operations can significantly impact the fate of inflowing sediments. Conowingo Reservoir discharges water through the power plant on the western end of the dam. At a flow greater than 86,000 cfs, the 52 flood gates that span the dam begin to open (Exelon, 2012 RSP 3.29). Each flood gate generally has the capability to pass up to about 15,000 cfs. The power plant water intake is located near the reservoir bed whereas the flood gates remove near surface waters. With the lower elevation water intake, the power plant has the potential to pass coarser materials that transport near the bottom whereas the flood gates may pass finer materials. Reservoir surveys indicate that during floods, the bed scours just upstream of the power plant intake and the adjacent flood gates. During a large flood that requires the majority of the gates to open, the spatial distribution of discharge shifts from the western side of the dam where the power plant resides, to the center of the channel. This shift in flow distribution and subsequent sediment load causes the sediment load on the eastern side of the reservoir to increase resulting in a high deposition rate in this area. Thus depending on the reservoir inflows, the spatial and quantitative fate of sediment in Conowingo Reservoir can be quite variable and difficult to simulate with current modeling methods.

In summary, of all the modeling uncertainties that exist, three are most critical for interpreting the Conowingo Reservoir modeling results. These include the potential for flocculation of sediments flowing into the reservoir, the potential for large sediment aggregates to erode from cohesive beds, and dam operations. Because of these uncertainties the AdH model may potentially over-predict to some degree transport of scoured bed sediment through the dam.

A report was prepared for the LSRWA effort that discusses modeling uncertainties. This report is attached in Attachment B-1.

5 Model Flow and Sediment Boundary Conditions

5.1 Susquehanna River inflows

The Susquehanna River inflows for all but one of the AdH simulations used flows from the four year time period from 2008 to 2011. The model inflow and downstream water surface elevation were the same for each simulation for comparison purposes. The sediment management simulation for agitation dredging used a number of steady state flows ranging from 30,000 to 400,000 cfs.

The 2008-2011 time period was chosen for the model simulations because it included periods of low flows where sediment was depositing in the reservoir, medium flows that transport more sediment to the lower reaches of the reservoir, and high flood flows that scour the bed. The first two years of flow allowed the bed to build whereas the last two years had flows that reached or surpassed the scour threshold flow of 400,000 cfs.

The simulation flow data are presented in Figure 5. The first 2 years of this flow record contained relatively low flows with peak flows of approximately 300,000 cfs, whereas the final 2 years had flows exceeding 400,000 cfs, which is considered the approximate bed scour threshold discharge. The scour threshold discharge indicates when mass bed erosion occurs, not low erosion rates of thin surface layers of low density material. The top layer of Conowingo Reservoir sediments consists of a low density unconsolidated layer that may mobilize at lower flows. Tropical Storm Lee occurred in September 2011 with a peak discharge of approximately 700,000 cfs. The downstream water surface elevation boundary condition at the dam was 109.0 feet for all simulations.

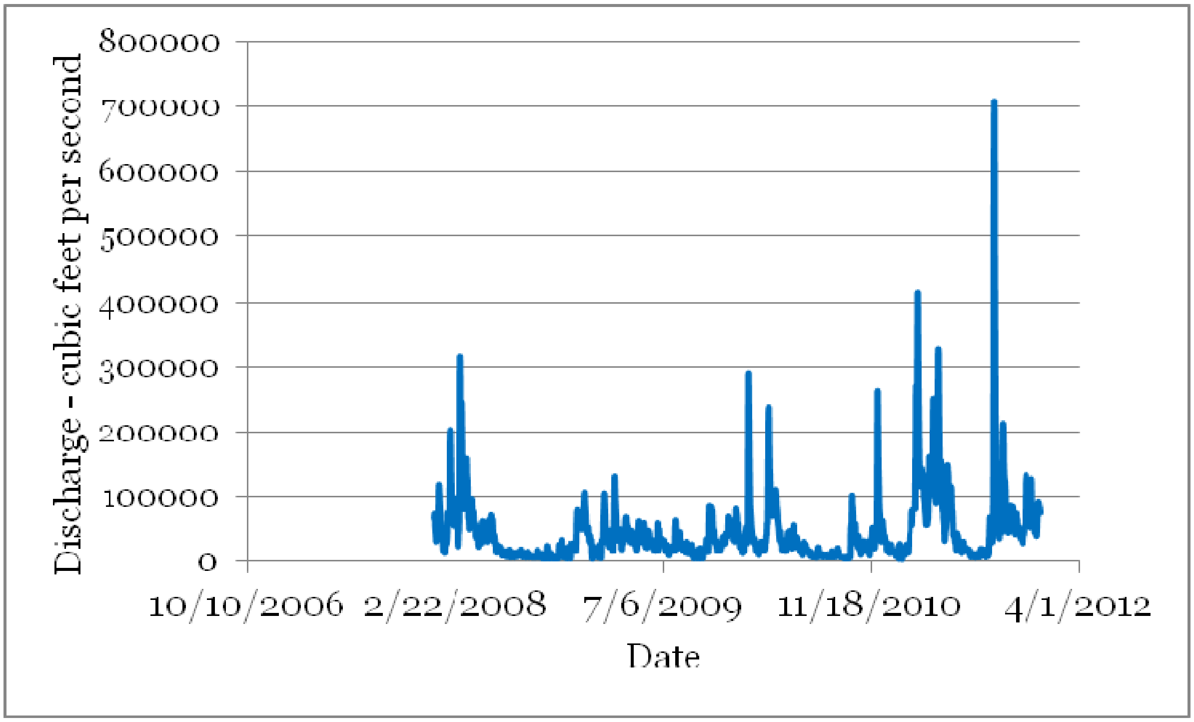


Figure 5 Flow boundary condition for AdH simulations

5.2 HECRAS output sediment rating curve / AdH input

The USGS provided the inflowing sediment load for the AdH model by simulating sediment transport through all three reservoirs with the HEC-RAS one-dimensional (1D) model. The USGS created a sediment rating curve for the Susquehanna River based on historical suspended sediment measurements for 10 sediment grain sizes. The HEC-RAS model was run for the 4-year flow record, 2008 to 2011. Hydraulic and sediment output data from HEC-RAS just below Lake Aldred (upstream boundary of Conowingo Reservoir) was used as input to the 2D model of Conowingo Reservoir based on maximum scour potential from Lake Clarke and Lake Aldred.

The HECRAS simulations produced two sediment inflow scenarios. The first scenario indicated no scour from the upper two reservoirs. The total inflow into Conowingo for this scenario was approximately 22.0 million tons. The second scenario was for approximately 1.8 million tons of scour from the upper two reservoirs, for a total Conowingo inflow load of approximately 24 million tons. For the AdH model runs, the maximum scour load from the upper two reservoirs is needed because the maximum load may influence transport capacity in Conowingo, and thus impact bed scour potential. Therefore the 24 million ton HECRAS load was increased by 10 percent to reflect a potential maximum scour load from the upper reservoirs . Thus the total sediment load entering Conowingo Reservoir was 26.2 million tons for the 4-year flow event simulation in the 2D model. The inflowing sediment rating curve for AdH is presented in Figure 6, with the clay, silt, and sand fraction in Figure 7 for the 2008 – 2011 inflow. Figures 6 and 7 show loads increasing exponentially after the 400,000 cfs scour threshold, with clay sediments dominating the inflow at lower discharges, with coarser sediments (silts and sands) increasing with flow. The USGS 1D model effort is summarized in a separate report to the LSRWA.

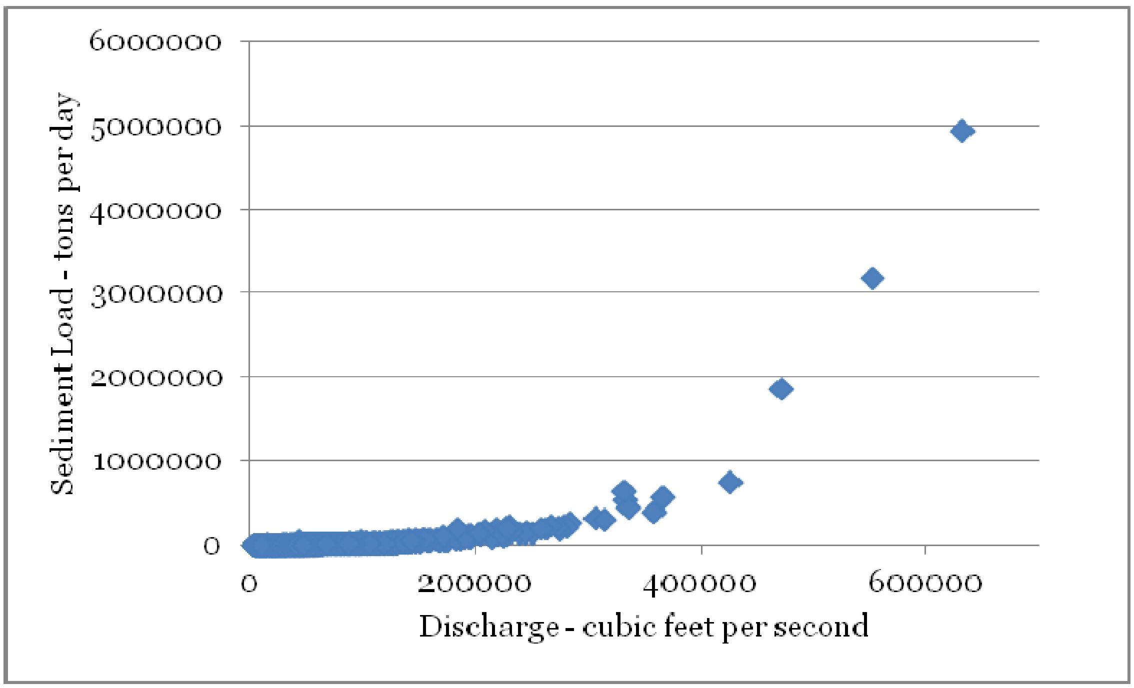


Figure 6 AdH input sediment rating curve

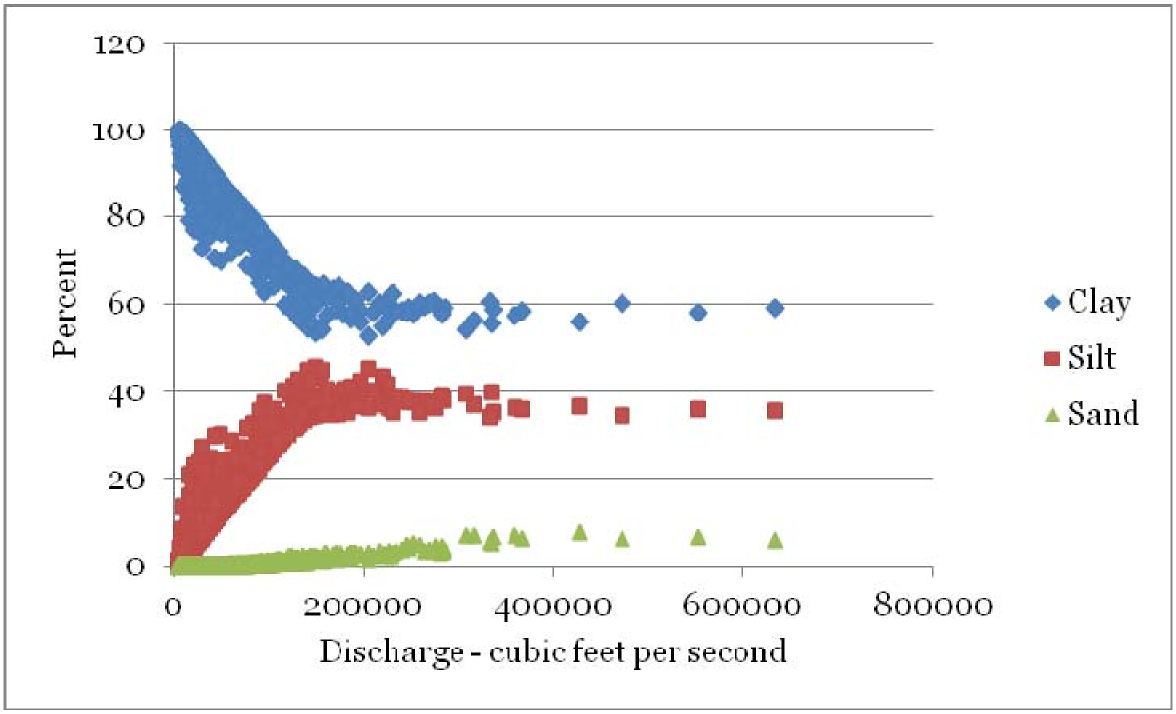


Figure 7 Percent of clay, silt, and sand in Conowingo inflow

5.3 SEDflume analysis of bed sediments

The AdH sediment model requires bed sediment properties for each layer in the bed. If the sediment bed has more than 10 percent fines (silts and clays), it is considered cohesive. For fine sediments, these properties include sediment bulk density, sediment particle size fraction, critical shear stress for erosion, and erosion rate.

Eight bed core samples were taken from Conowingo Reservoir for analysis (Figure 8). The sample locations were determined through evaluation of potential scour and deposition areas, as well as spatial considerations (distance from the dam). The bed was sampled to a maximum depth of only one foot because the resistance of the more consolidated sediments at deeper depths. These samples were analyzed in the SEDflume, a laboratory-scale flume that subjects the core samples to varying flows to determine the inception of erosion (critical shear stress for erosion), and the erosion rate. The SEDflume apparatus is presented in Figure 9, with the full SEDflume laboratory report and bed property summary found in Attachment B-2. The SEDflume data developed in the Laboratory was used to populate the model bed. Six material zones were established in the model (Figure 10). For each of the zones, critical bed shear stress for erosion and erosion rates were defined based on the laboratory data.

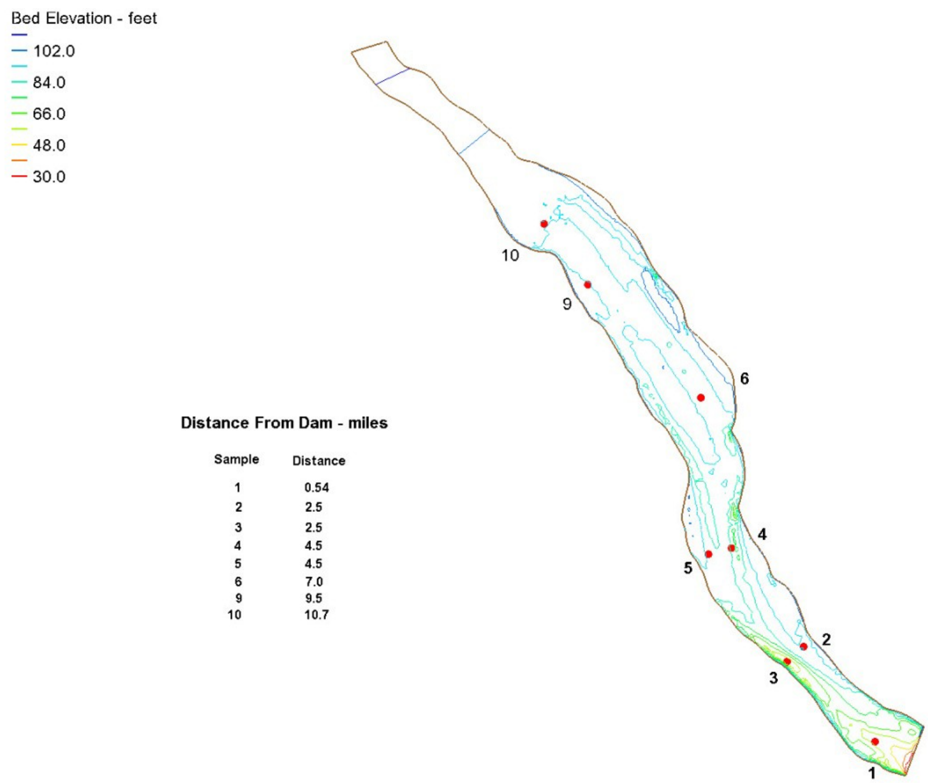
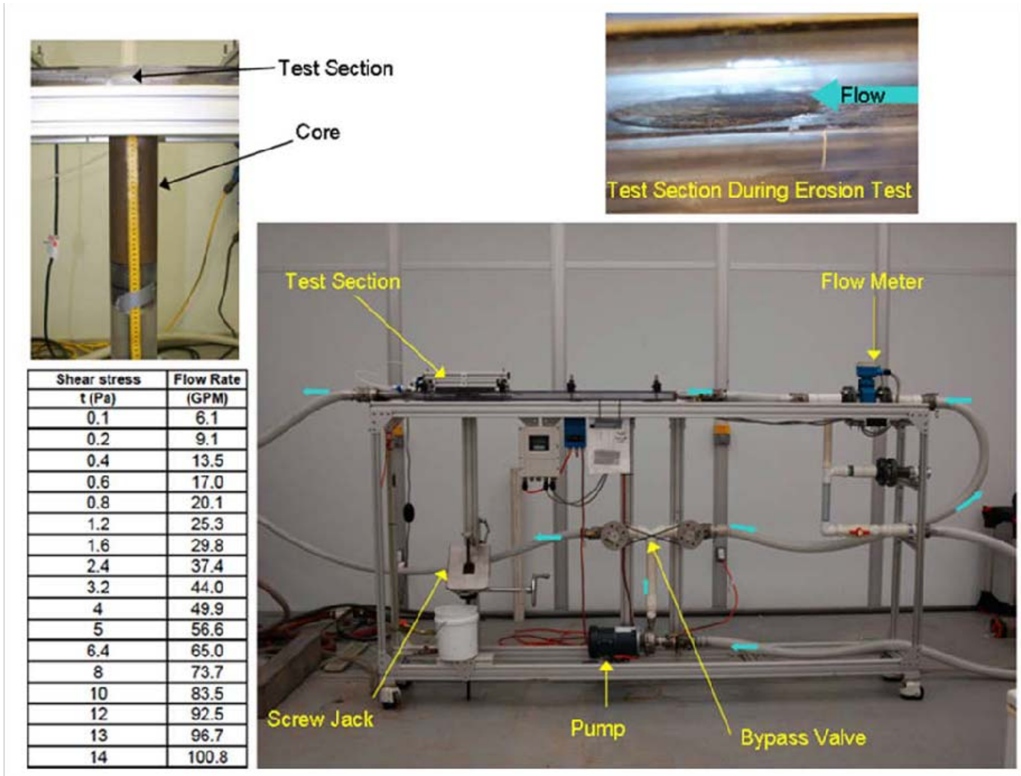


Figure 8 Core sample locations in Conowingo Reservoir for SEDflume studies



Shear stress t (Pa)	Flow Rate (GPM)
0.1	6.1
0.2	9.1
0.4	13.5
0.6	17.0
0.8	20.1
1.2	25.3
1.6	29.8
2.4	37.4
3.2	44.0
4	49.9
5	56.6
6.4	65.0
8	73.7
10	83.5
12	92.5
13	96.7
14	100.8

Figure 9 SEDflume apparatus

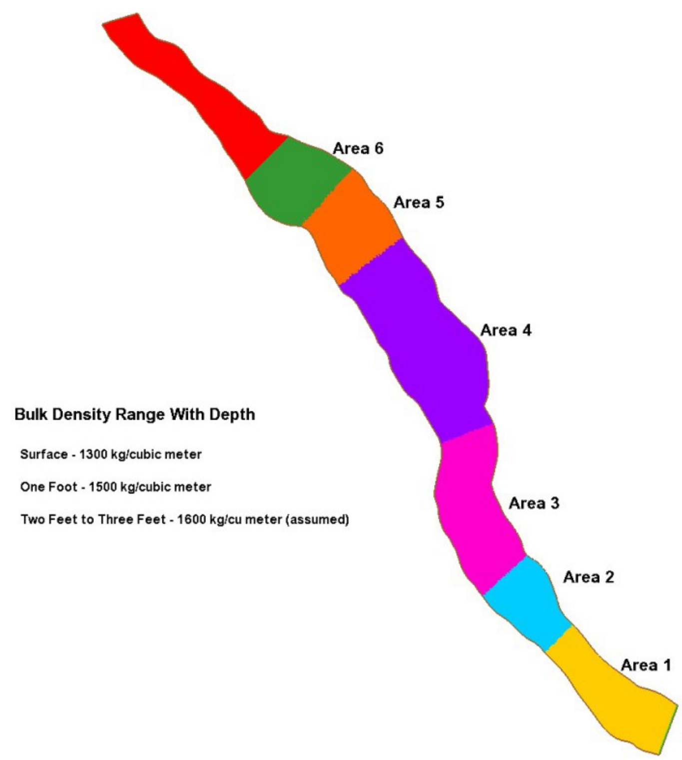


Figure 10 AdH sediment model material zones for assigning bed properties

6 Model Validation

Generally, there are two methods for evaluating model capability for reproducing field conditions; model calibration or model validation. Model calibration is conducted by comparing model output to a set of measured boundary conditions such as water surface elevations, velocity measurements, and inflowing and out-flowing sediment concentrations. The model parameters are then set to match, within reason, the actual data that was measured over a range of flows. A calibrated model can then be used to predict outcomes into the future. This is the preferable model application, however, large field data sets are often times non-existent, difficult to collect, and prohibitively expensive, or they cannot be collected within the timeframe of the project.

The alternative to a fully calibrated model is a model validation exercise. This is the method used for this AdH 2D modeling effort. Generally, a sediment transport model validation insures that the model can adequately replicate sediment transport characteristics of the system for which it is applied. Typically, a model validation is conducted when there are minimal or no directly measured boundary conditions. The model is compared to either analytical or empirical study results such as historical suspended sediment loads collected by the USGS below Conowingo dam. Model parameters are varied accordingly to generally match the results. Typically, a range of model parameters are varied to determine a lower and upper bound for sediment transport characteristics. This type of model is better suited for comparing existing and alternative project conditions rather than predicting model results into the future.

Minimum amounts of data were available for this modeling effort. The inflowing sediment load into Conowingo was provided from HEC-RAS output and not direct measurements. Suspended sediment samples were collected below the dam over time, however, very few were taken over the Tropical Storm Lee flood event simulated in the model. A total of eight bed sediment samples were taken from Conowingo Reservoir for analysis of critical bed shear stress for erosion and erosion rate. The maximum sample depth was only about 12 inches due to highly consolidated sediments in deeper layers preventing penetration of the sampling tube. In addition to the uncertainty of bed sediment erosion properties and inflowing sediment load, dam operations could not be simulated in the model. Efforts were made to simulate power plant discharge as well as flood discharge through the 52 flood gates. The hydrodynamics of the flood gate system was successfully modeled; however, sediment transport through the dam was not successful and could not be implemented for this project. Thus sediment transport characteristics (scour and deposition) near the dam may not be representative.

Because of the uncertainty of measured model boundary conditions, the AdH 2D model was validated by comparing model output to the total suspended sediment sample measurements below Conowingo Dam, the empirical studies of sediment mass balance through Conowingo Reservoir by the USGS, the fraction of sand, silt, and clay in the outflow below Conowingo Dam, and the scour and deposition change in Conowingo computed from surveys taken in 2008 and 2011. The bed roughness was 0.03 Manning's n for the reservoir with the exception of the upper 3.0 miles of the reservoir where the roughness ranged from 0.05 to 0.04 Manning's n. The Manning's n is a coefficient that describes the roughness of the bed, which is directly related to the computed water surface elevations and velocities.

6.1 Validation model description

For the validation exercise, the AdH model bathymetry was based on the 2008 survey. The USGS sediment rating curve was utilized as the inflowing sediment for the period 2008–2011 (26.2 million tons), with bed material properties taken from the SEDflume laboratory study. Generally, the sand, silt, and clay fractions ranged from about 10, 80, and 10 percent, respectively, near the dam, to about 50, 44, and 6 percent, respectively, in the upper reaches of the reservoir about 7 to 11 miles above the dam (Figure 11). The critical shear stress for erosion ranged from a low of 0.006 pounds per square foot (psf) within the top 0.5 inch of the core to a maximum of about 0.04 psf at a core depth of 1 foot. Most of the cores were less than 1 foot in length. The sampling tube could not penetrate the substrate indicating highly consolidated sediments. Although the samples only represented the top foot of material, the sediment bed in the AdH model was approximately 3 feet. The properties of the lower two feet were estimated from literature values. The general trend in bed properties was a coarsening of sediment size and subsequent increasing critical shear stress with distance from the dam. Although the bulk of sand was found in the upper reach of the reservoir, layers of sand were found in the cores taken in the lower reaches indicating transport of sand during high flow events to lower reaches of the reservoir.

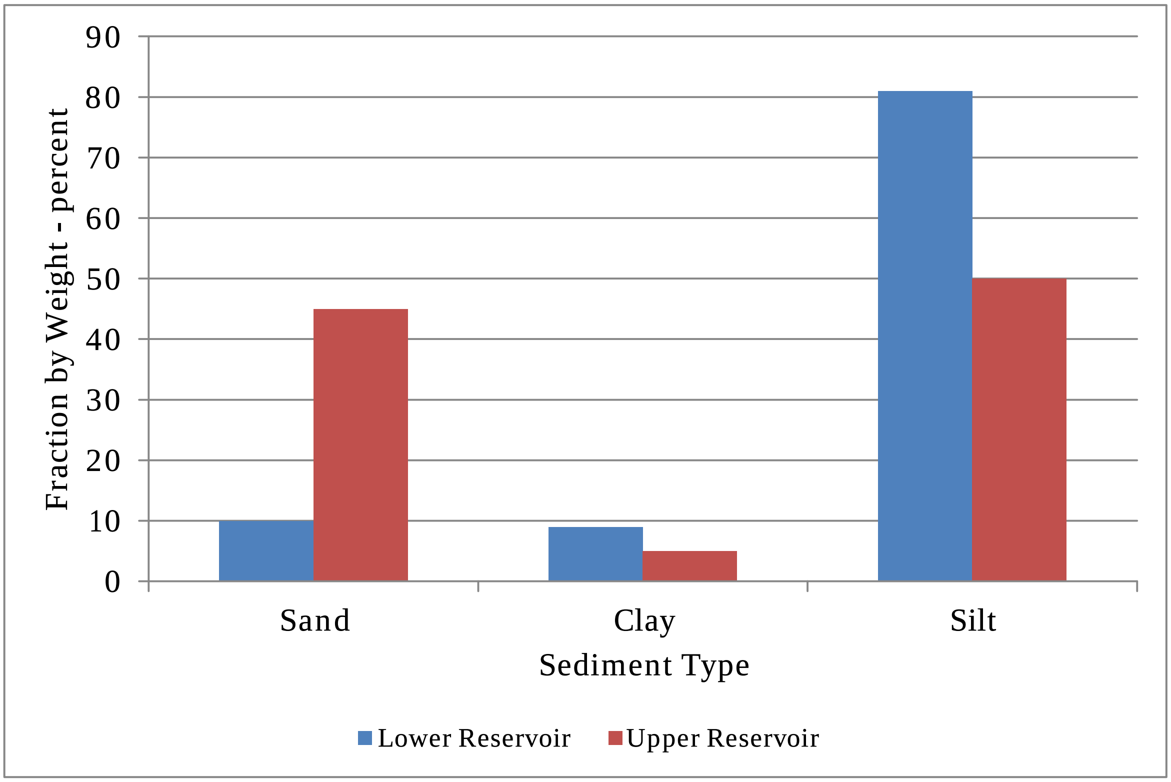


Figure 11 General particle size distribution for upper and lower Conowingo Reservoir

6.2 Total suspended solids measurements below Conowingo Dam

The measured suspended sediment data are presented in Figure 12 (USGS, 2011). The data show an increasing scatter with discharge indicating the effects of high flows. For a storm hydrograph, the magnitude of a suspended sediment measurement is highly dependent on when the measurement is taken. The highest suspended sediment concentrations are found on the ascending leg of the hydrograph, whereas the descending leg typically has lower values. This is referred to as the hysteresis effect. As the flow increases during the ascending leg, the available sediment is scoured and mobilized with peak sediment discharge. On the descending leg of the hydrograph, sediment supply is less, thus suspended sediment concentrations are lower. The peak concentration on Figure 11 was one data point taken on the ascending leg of the Tropical Storm Lee hydrograph (about 600,000 cfs). No further data could be collected because of dangerous conditions adjacent to the dam. Because large storms are more difficult and dangerous to sample, and occur less frequently, few suspended sediment samples are included in the data set for the higher flow ranges.

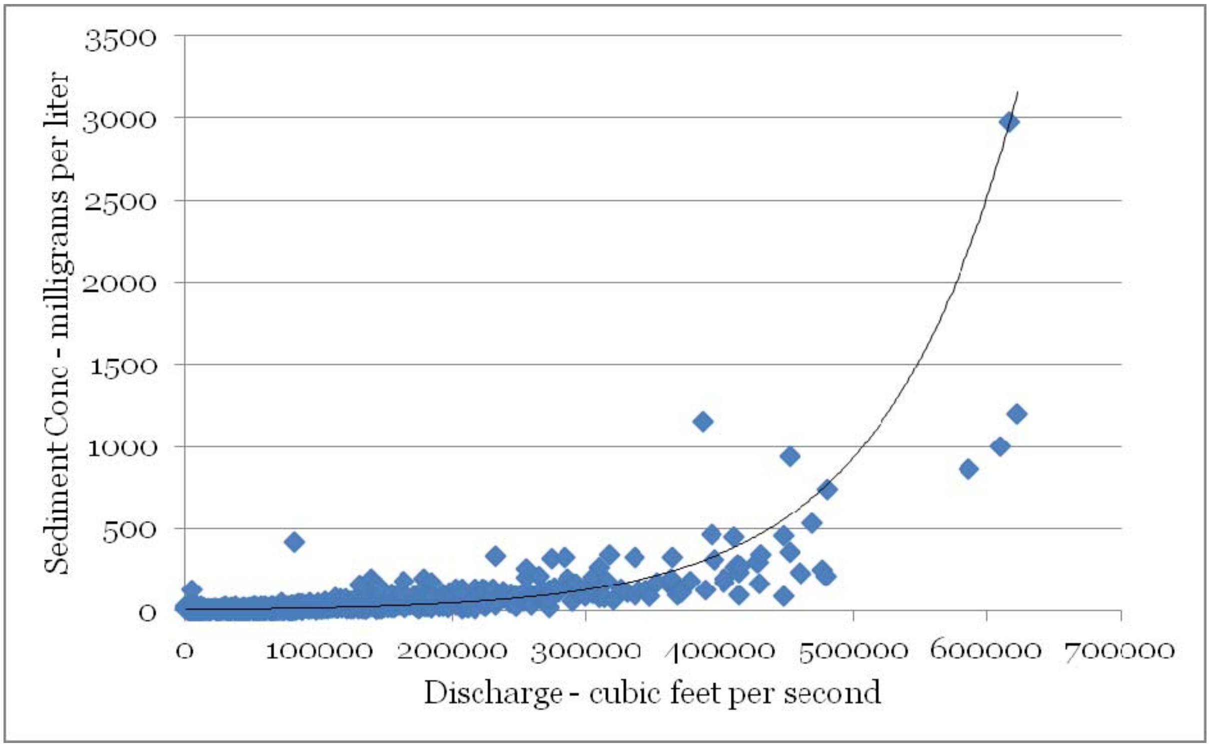


Figure 12 Suspended sediment concentrations measured below Conowingo Dam

6.3 USGS estimation of bed scour as a function of discharge

The USGS has performed numerous studies on changes in sediment storage capacity of Conowingo Reservoir (summarized in Langland and others, 2009). Based on these studies, they developed a scour prediction curve which estimates the amount of bed scour load that will occur in the lower Susquehanna River reservoirs as a function of mean daily discharge. The prediction curve is presented in Figure 13 along with upper and lower bounds. Note that at 630,000 cfs (mean daily flow for Tropical Storm Lee), the predicted scour load is about 3.3 million tons.

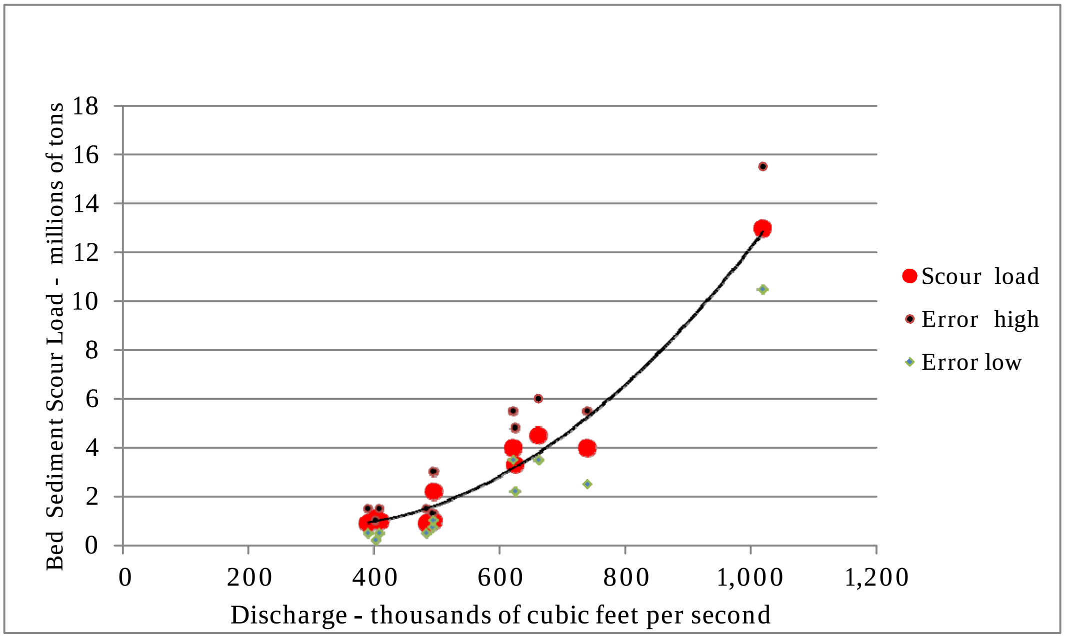


Figure 13 USGS predicted scour as a function of discharge in Conowingo Reservoir (provided by USGS)

6.4 Suspended sediment grain size distribution measurements

The total suspended sediment samples collected below Conowingo Dam were analyzed for sand, silt, and clay fractions. Figure 14 presents the data as a function of discharge (USGS 2001). Generally, at low flows, clay is the dominant sediment that is scoured. However, the silt fraction increases with increasing flow, along with the sand fraction. This reflects the increasing transport capacity with discharge. Overall, the sand fraction is less than 10 percent. These data were from suspended sediment samples taken below the dam and not computed by the model.

6.5 Change in deposition and bed scour from survey comparisons

Bathymetric surveys of Conowingo Reservoir were taken in 2008 and 2011. The 2011 survey was taken just after Tropical Storm Lee occurred. The impact of Tropical Storm Lee can be determined from evaluating the bed elevation change between the surveys. A computational mesh was created in the graphical user interface for the AdH model, the Surface Water Modeling System (SMS). This mesh contained 25,000 nodes and 48,000 elements. Each survey was interpolated to the mesh, with the 2008 mesh subtracted from the 2011 mesh. The difference is change in bed elevation, with positive change reflecting deposition and negative change reflecting bed scour. A summary report of these computations is provided in Attachment B-3. Approximately 8.6 million tons of sediment deposited between 2008 and 2011, with 5.4 million tons of scour. The reservoir was net depositional 3.2 million tons. The major trend was that most of the scour (50 percent) occurred in the upper one third of the reservoir (7-10 miles from the dam), with decreasing scour in the lower reaches of the reservoir. These sediments contained up to 50% sand. Approximately 120,000 tons scoured from the dam to a point one mile upstream. Deposition increased with distance from the upper reservoir to the dam, with 69 percent of deposition occurring in the lower half of the reservoir (from the dam to about 5 miles upstream). A significant amount of sediment was deposited just upstream of the Eastern end of the dam. This deposit contained approximately 26 percent of the total deposition in about 3 percent of the reservoir area.

Although the change in survey computations do not address how much scour material leaves Conowingo dam, they do show the potential for re-deposition of bed scour within the reservoir. The area with the maximum bed scour contains 50 percent sand. Samples taken below Conowingo dam indicate sand concentrations of 10 percent or less passing through the dam for large floods, thus the potential is high for these sandy sediments to re-deposit and not leave through the dam. The high depositional area found on the eastern side of the dam may be the result of dam operations during floods. The flood gates re-align the sediment laden flow to the middle of the reservoir, with low velocity circulation occurring upstream of the Eastern side of the dam. This low velocity circulation will encourage sedimentation in this area during the flood.

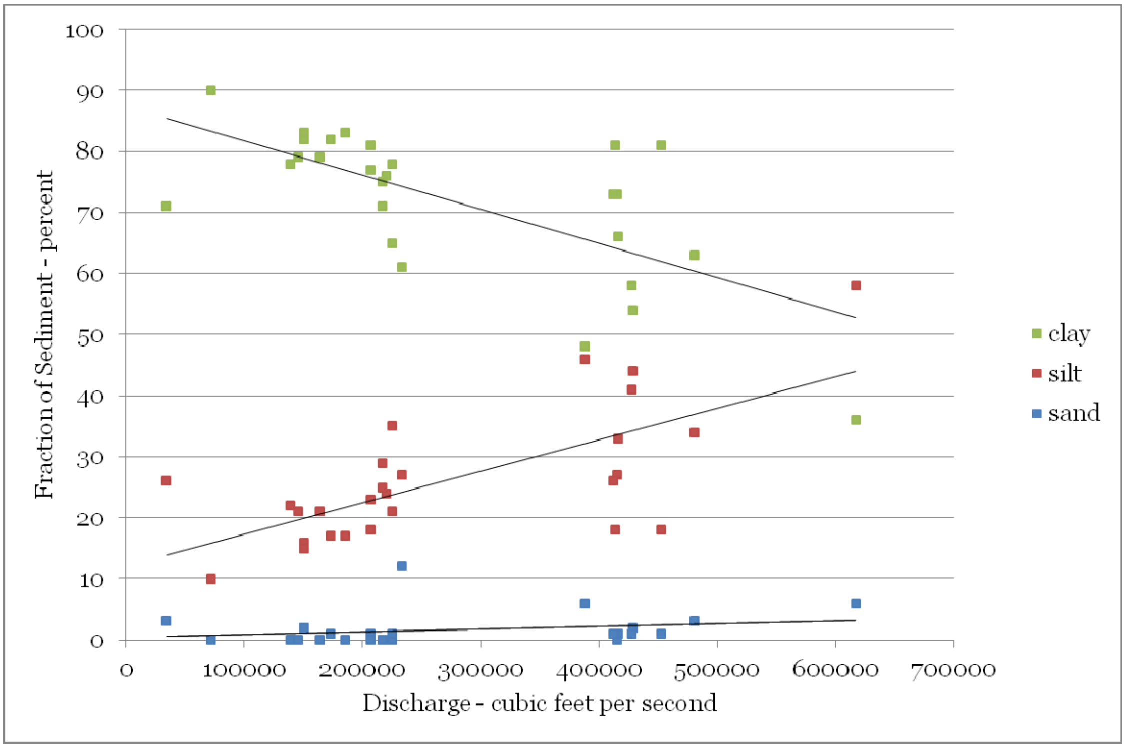


Figure 14 Measured clay, silt, and sand fractions as a function of discharge below Conowingo Dam

6.6 AdH model validation simulations and comparisons

A relatively small number of bed samples were taken from Conowingo Reservoir. Eight samples were used to represent the entire domain. Analysis of these samples revealed how the sediment size distribution coarsened with distance from the dam, and the subsequent variation of the critical shear stress and erosion rate. With such a small data set, it was necessary to conduct a parametric model study in which the variables were varied or adjusted to reflect the potential variation in bed properties. Variables include bed bulk density, critical bed shear stress, erosion rate, and depth of available bed sediment. After each parametric model run, the data were compared to the USGS scour load prediction, sediment size distribution of samples collected below the dam, and the change in survey computations. Each run was made with the same hydraulic and sediment boundary conditions (2008–2011 Susquehanna River flow and inflowing sediment rating curve). Ultimately, the most representative model formulation would reflect a net deposition of 3.0 to 4.0 million tons over the 2008 – 2011 simulation period, sediment retention of about 1.0 to 1.5

million tons per year during the non-storm periods, and outflow of 10 percent or less sand from the reservoir.

The model calculated a bed scour load through the model ranging from 5. 5 million tons to 2.0 million tons based on simulations containing varying estimates of critical shear stress, bed bulk density, erosion rate, and available bed material.

The upper range, 5.5 million tons, was within the upper error bound of the USGS scour prediction curve, however, the simulation resulted in a net scour bathymetry, which is not in agreement with the change in survey calculations. Additionally, sand fractions higher than 10 percent passed through the model.

Estimated increases in critical bed shear stress for erosion for deeper bed layers resulted in a calculation of 4.0 million tons of bed scour passing through the model with a net depositional bathymetry of about 1.0 million tons.   This net deposition is somewhat lower than that computed by the change in survey calculations. Additionally, sand fractions greater than 10 percent passed through the model.

Higher critical shear stress values from literature were assigned to the model based on the bulk density of the sediments (Whitehouse, 2000). This simulation calculated a bed scour load of 2.9 million tons, with a net depositional bathymetry of 4.4 million tons, which is in approximate agreement with the change in survey computations, with sand fractions passing through the dam less than 10 percent (Figure 15). The average annual non-storm deposition during the initial years of simulation (2008 – 2010) was about 1.3 million tons.

To obtain a lower end estimate of bed scour passing through the dam, the depth of sediment available for scour was limited to one foot which represents the sampling depth limit. Approximately 2.0 million tons of sediment passed through the model.

The AdH model and USGS scour predictions are found in Figure 16, with SEDflume parameters used in the simulations summarized in Table1 (full description in Attachment B-2).

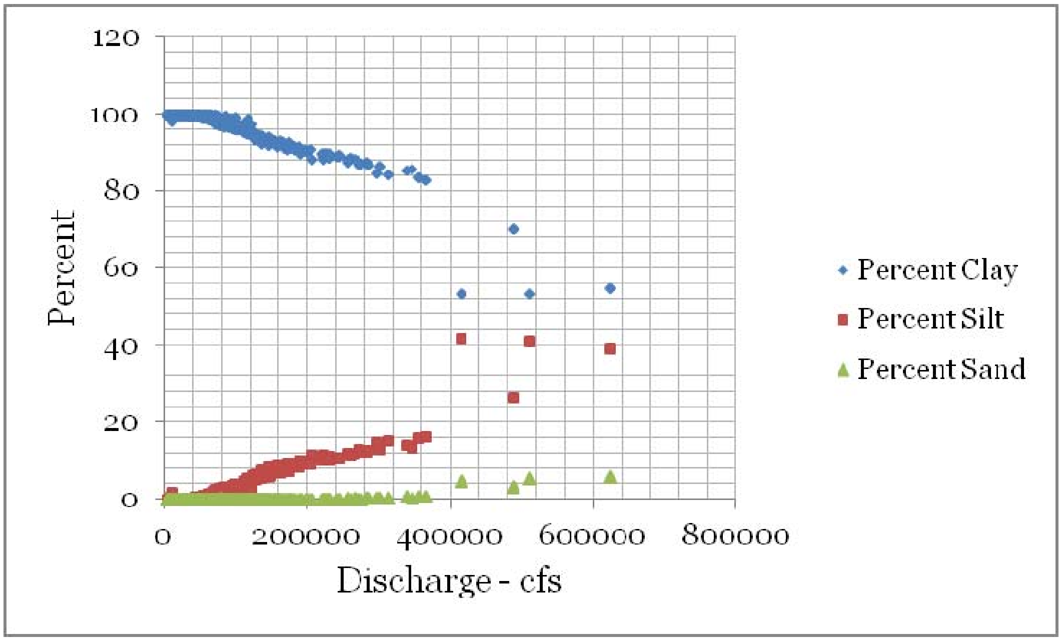


Figure 15 Model output of clay, silt, and sand fractions passing through Conowingo Dam

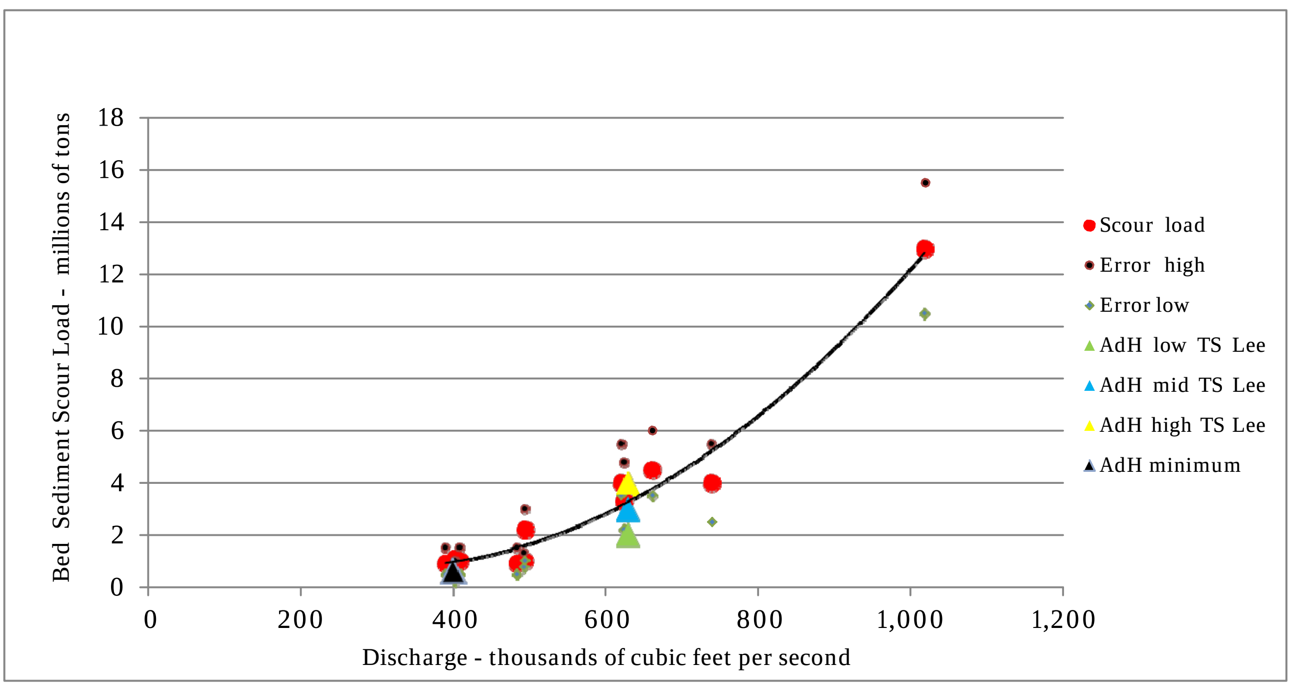


Figure 16 Scour load predictions by the USGS with AdH model results

The parameters in Table 1 are used to compute erosion rate from the following equation:

$$E = M\left(\frac{\tau}{\tau_c} - 1\right)^n$$

With τ_c the critical bed shear stress for initiation of erosion, τ the bed shear stress calculated by the model, M the erosion coefficient and n the expo- nent.

Table 1. SEDflume data for validation simulations – scour load in millions of tons

Simulation	Bed Depth - ft	Critical Shear – lb/ft^2	Coefficient M	Exponent n	Scour Load
1	0-1	0.005 – 0.04	0.01-0.08	1.0 – 1.3	5.5
	1-2	0.04	0.08	1.3	
	2-3	0.04	0.08	1.3	
2	0-1	0.005 – 0.04	0.01-0.08	1.0 – 1.3	4.0
	1-2	0.06	0.08	1.3	
	2-3	0.10	0.08	1.3	
3	0-1	0.03 – 0.06	0.01-0.08	1.0 – 1.3	2.9
	1-2	0.10	0.08	1.3	
	2-3	0.14	0.08	1.3	
4	0-1	0.03 – 0.06	0.01 – 0.08	1.0 – 1.3	2.0

6.7 Discussion

Based on the AdH validation simulations, along with the computed changes in the 2008 and 2011 bed surveys, it is estimated that the potential range of bed scour that leaves the reservoir during the Tropical Storm Lee event is within the range of 2.0 to 4.0 million tons, with this bed scour range based on the impact of varying the bed bulk density, critical shear stress for erosion of bed layers, and the quantity of bed material available for erosion.

Based on the above model runs and analysis, the model formulation that predicts 2.9 million tons of bed scour load was chosen for the following alternative simulations. It is a more conservative calculation that better correlates bed scour and deposition to system hydraulics.

7 Model Simulations – Impact of Temporal Change in Sediment Storage Capacity

The AdH model was utilized to investigate a number of scenarios designed to provide guidance on how variations in sediment storage capacity impacts sediment transport through Conowingo reservoir. Although significant uncertainty exists with the model simulations, the uncertainty is reduced to a manageable level by comparing existing versus alternative model simulations. With this approach, an existing condition simulation is performed for a given problem. Then a change is made to the model to represent the alternative condition. This could be a change to the model bathymetry such as removing sediment representing a dredging operation. All of the other variables remain the same as for the existing condition. The alternative condition is simulated and directly compared to the existing condition simulation to evaluate the impact of the change in condition.

Three reservoir bathymetries were simulated in the model for comparison purposes (1996, 2008, and 2011). For all three simulations, the same sediment and flow boundary conditions were utilized (the 2008–2011 flow record with USGS sediment inflows). Each simulation contained the same model variables with the exception of the model bathymetry. The cumulative change in sediment storage in the reservoir over the 4-year timeframe was computed by subtracting the sediment load discharged from the reservoir from the inflowing sediment load. A positive loading trend represents deposition with a negative loading trend representing a reduction of storage due to bed scour. For all of the sediment storage plots, the Tropical Storm Lee flood event occurred on day 1348 (significant decrease in sediment storage trend). The bed scour load passing through the dam was computed, along with net sedimentation in the reservoir. The reservoir sediment storage was then compared for each of the simulations (1996, 2008, 2011, and full reservoir storage).

7.1 General flow and bed shear distribution in Conowingo Reservoir

Before presenting the sediment transport results, it is informative to show system hydrodynamics for two flow events, a 150,000 cfs flow which approximately represents a one year return flow event for the

Susquehanna River, and a 400,000 cfs flood event which represents a five year return flow event. Model hydrodynamic output are presented in Figures 17-20 which describe the distribution of flow and bed shear stress for both events. The bathymetry used for this simulation was based on the most recent 2011 reservoir survey. The 150,000-cfs flow event is presented in Figures 17 and 18. The upper 3.0 miles of the reservoir has the steepest channel slope (0.001 feet/feet) thus it had the highest velocity and bed shear. This channel was not included in the bathymetry surveys (USGS and Exelon), however, some bathymetric data were available that described the general channel shape and slope. At 150,000 cfs, the maximum velocity in the reservoir is about 1.0 foot per second, with a bed shear less than the critical bed shear stress for erosion from the SEDflume studies (0.004 psf) over much of the reservoir. Generally, the flow distribution and velocity are highest in the deeper channels within the reservoir. The 400,000-cfs event is presented in Figures 19 and 20. Velocities in the reservoir exceed approximately 3.0 feet per second over much of the reservoir area, with bed shear stresses exceeding the critical shear stress for erosion as defined by the SEDflume studies. The 400,000 cfs event is considered the threshold for mass erosion of the reservoir bed.

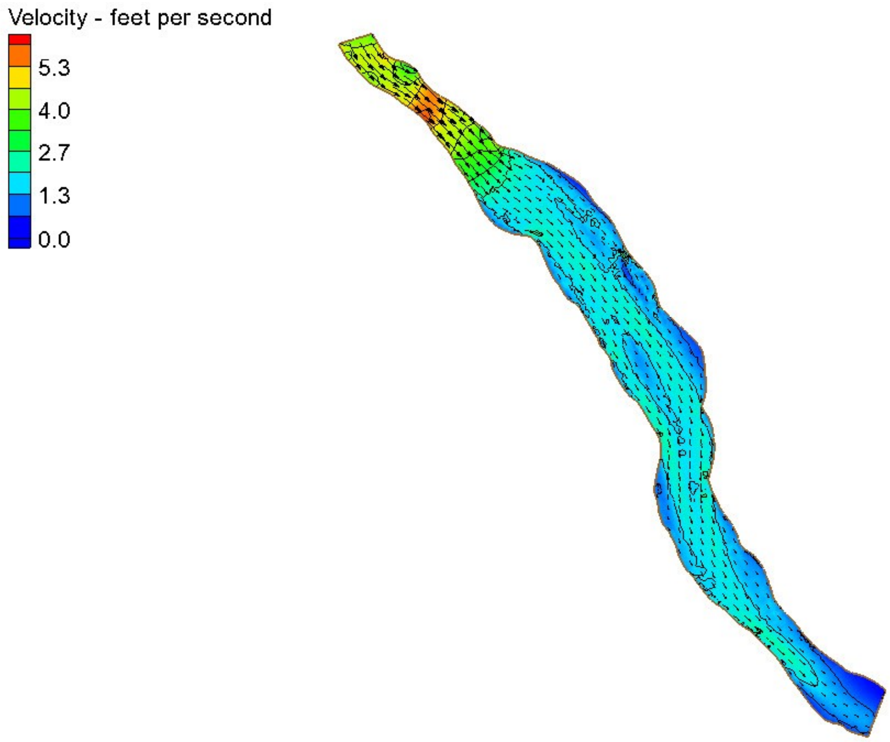


Figure 17 Conowingo Reservoir velocity at a discharge of 150,000 cfs

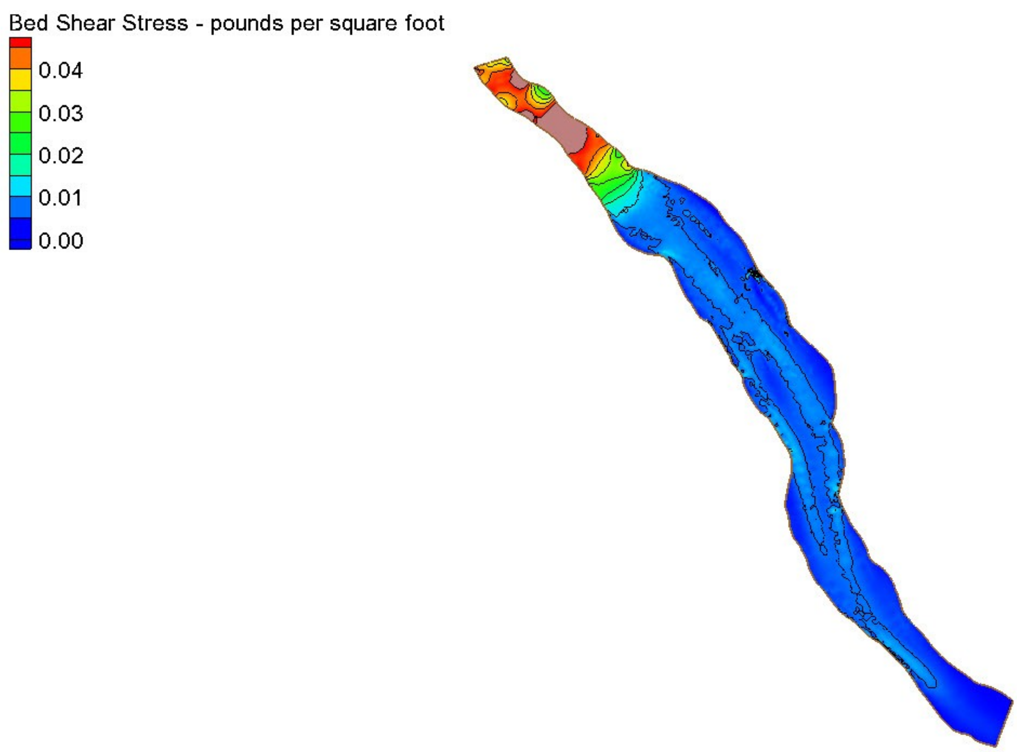


Figure 18 Conowingo Reservoir bed shear stress for a discharge of 150,000 cfs

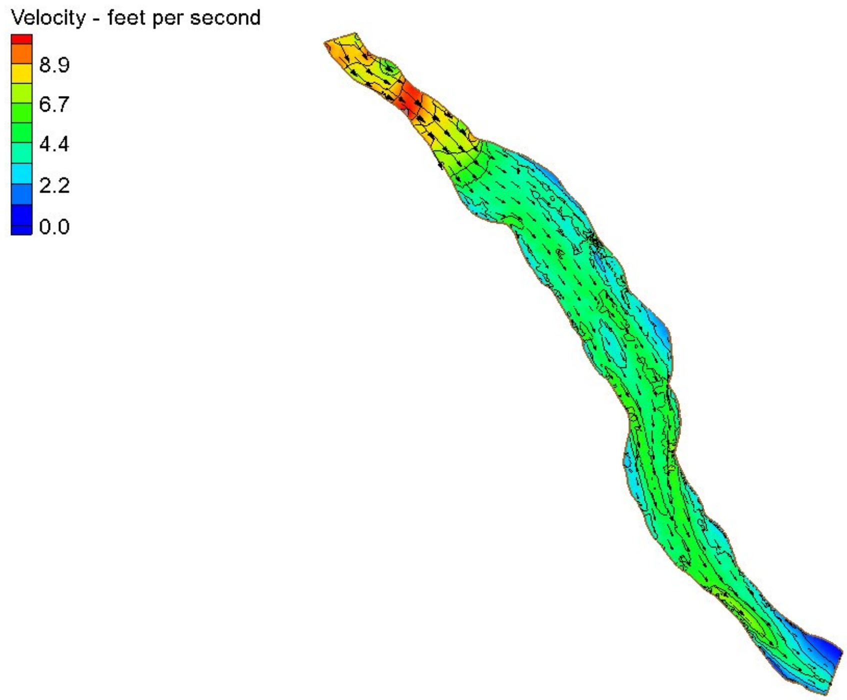


Figure 19 Conowingo Reservoir velocity for a discharge of 400,000 cfs

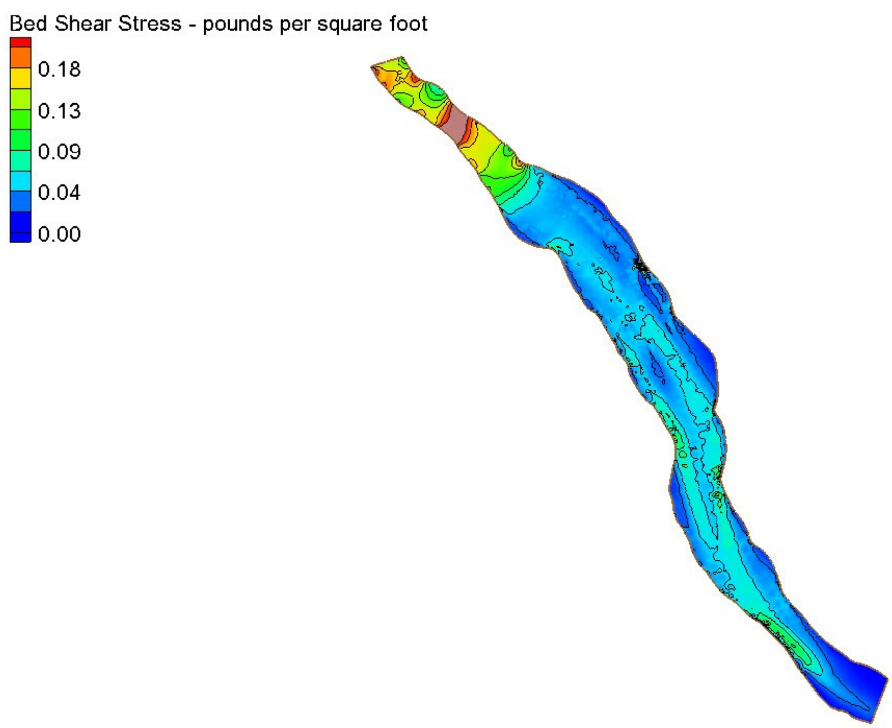


Figure 20 Conowingo Reservoir bed shear stress at a discharge of 400,000 cfs

7.2 Sediment Transport Simulation Utilizing the 1996 bathymetry

The 1996 bathymetry was simulated in the AdH model for the 4-year flow record (2008–2011). The cumulative change in sediment storage in the reservoir is presented in Figure 21. The total sediment load discharged below the dam was 20.3 million tons, with bed scour from Tropical Storm Lee comprising 9.0 percent of the load (1.8 million tons). The net deposition in the reservoir was 6.0 million tons. The 1996 bathymetry is depicted in Figure 22.

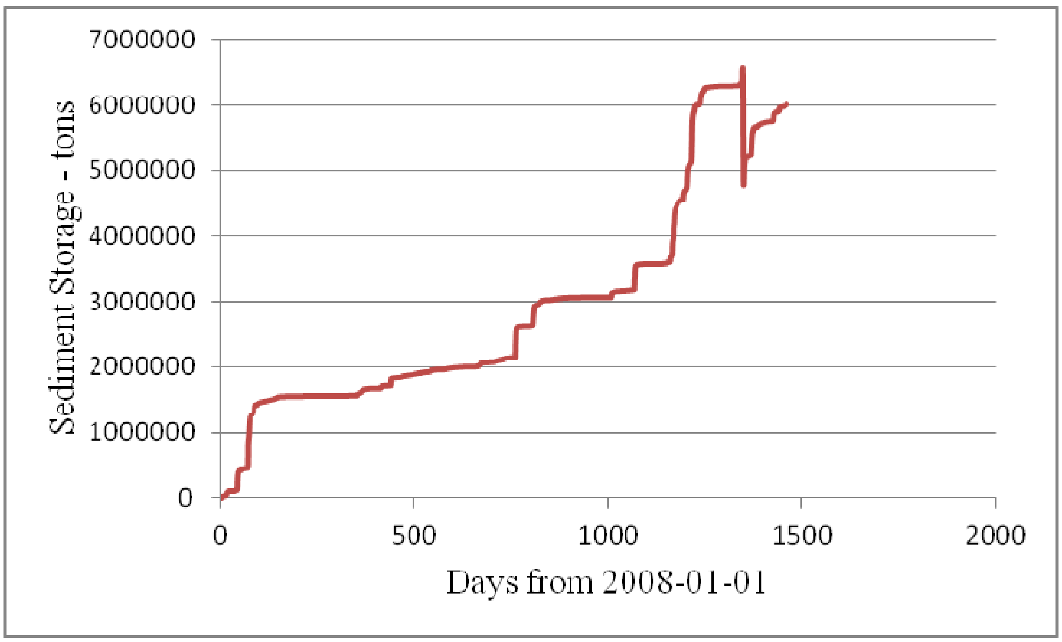


Figure 21 Sediment storage in Conowingo Reservoir for the 1996 bathymetry simulation

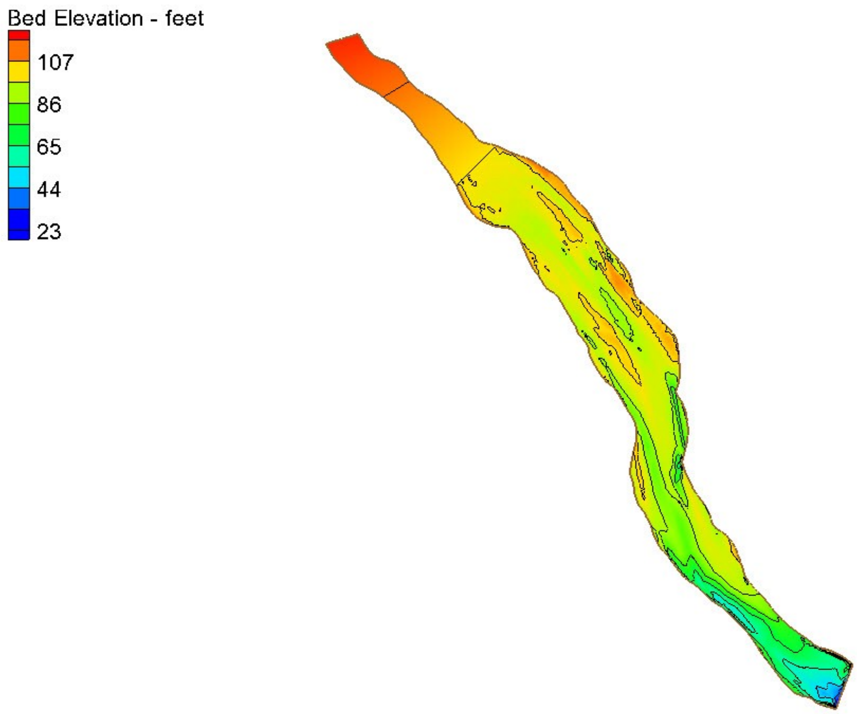


Figure 22 The 1996 model bed elevation

7.3 Simulation of the 2008 bathymetry

The 2008 bathymetry was simulated in the AdH model for the 4-year flow record (2008–2011), with the cumulative storage of sediment presented in Figure 23. The total sediment load discharged below the dam was 21.9 million tons, with a Tropical Storm Lee scour load of 2.9 million tons (13 percent of the total load). The net deposition in the reservoir was 4.4 million tons. The 2008 bathymetry is depicted in Figure 24.

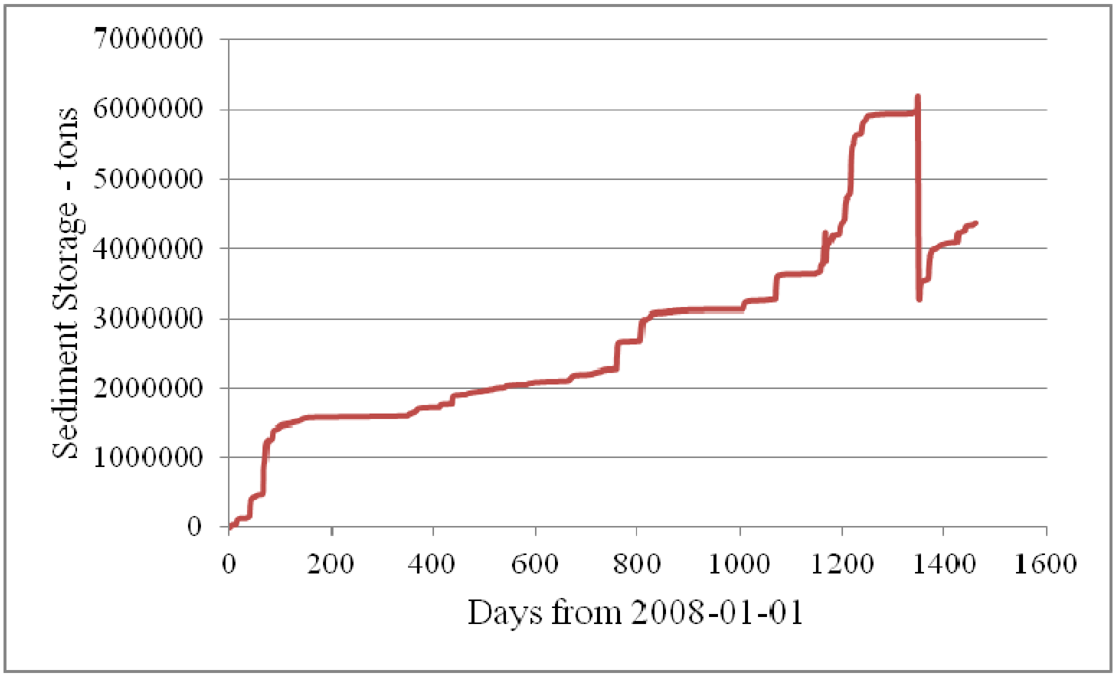


Figure 23 Sediment storage in Conowingo Reservoir for the 2008 bathymetry simulation

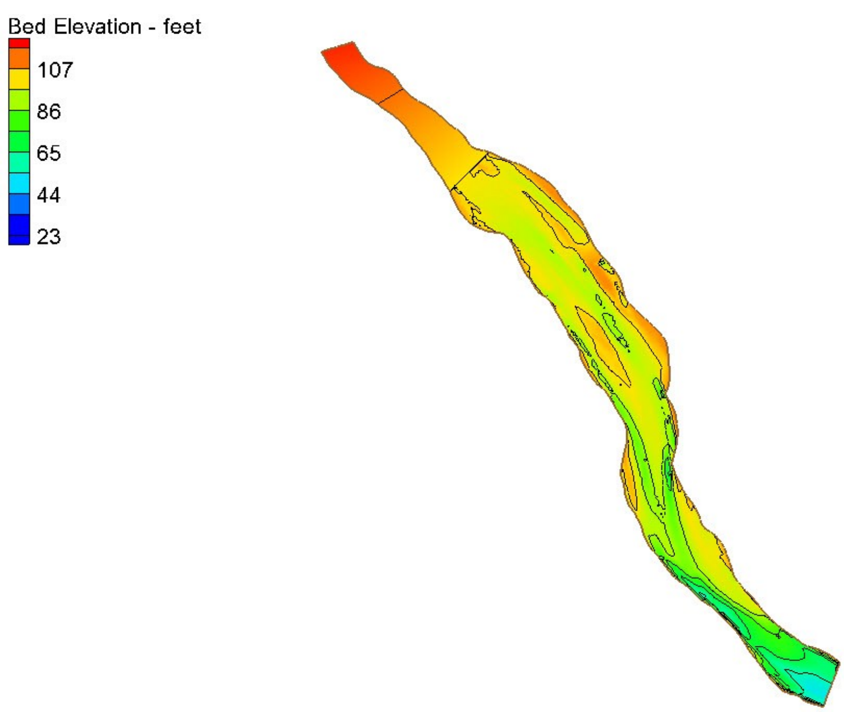


Figure 24 The 2008 model bed elevation

7.4 Simulation of the 2011 bathymetry

The 2011 bathymetry was simulated in the AdH model for the 4-year flow record (2008-2011). The cumulative storage of sediment is presented in Figure 25. The total sediment load discharged below the dam was 22.3 million tons, with a Tropical Storm Lee scour load of 3.0 million tons (13 percent of the total load). The net deposition in the reservoir was 4.0 million tons. The 2011 bathymetry is depicted in Figure 26.

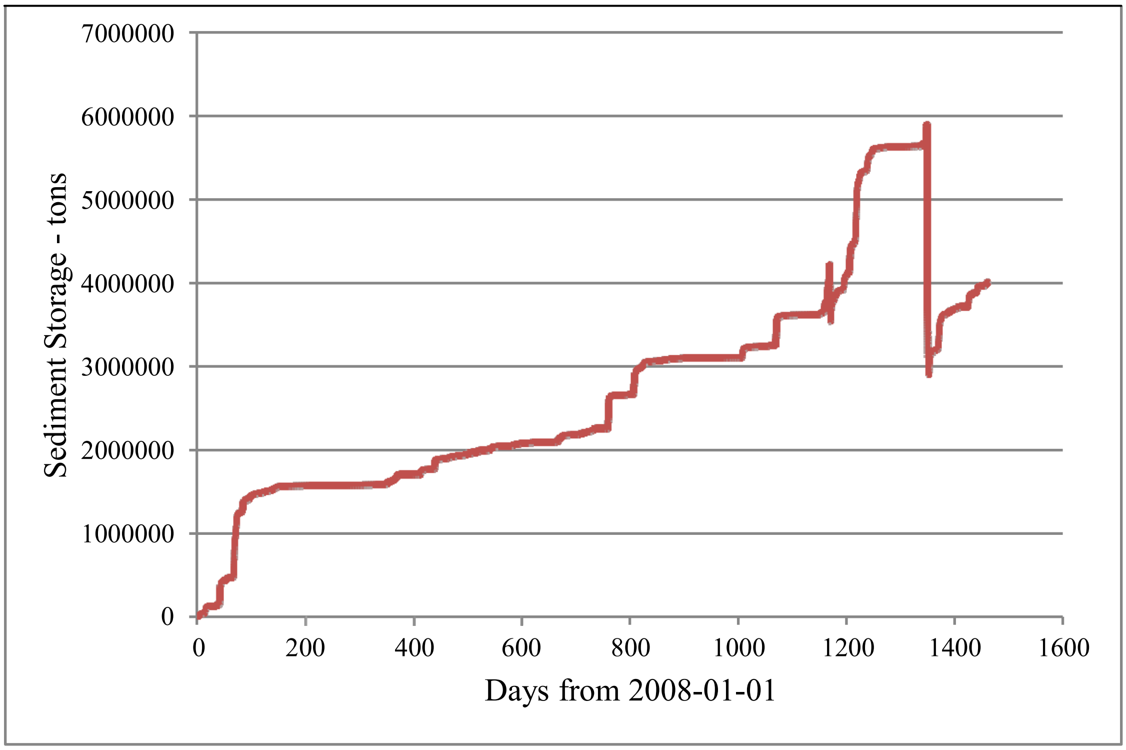


Figure 25 Sediment storage in Conowingo Reservoir for the 2011 bathymetry

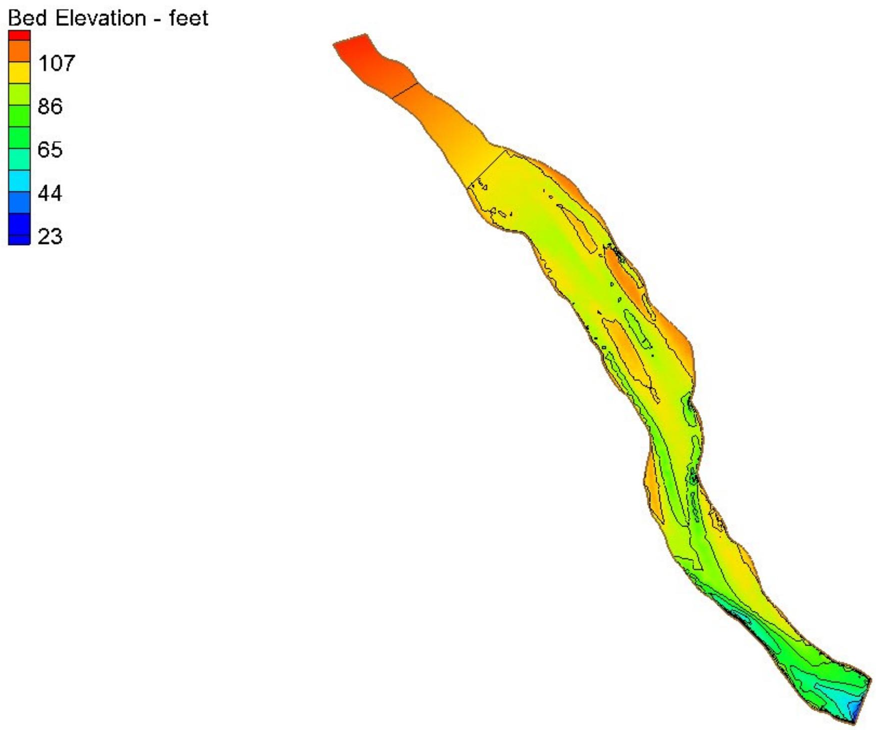


Figure 26 The 2011 model bed elevation

7.5 Simulation of the full reservoir bathymetry

The 2011 bathymetry was modified to reflect a full reservoir condition with minimum remaining sediment storage capacity. The USGS provided the remaining reservoir storage volume which was added to the 2011 model bathymetry. The cumulative storage of sediment is presented in Figure 27, with the full storage bathymetry presented in Figure 28. The location and magnitude of this additional volume (approximately 7.0 million cubic yards) is presented in Figure 29. This full reservoir condition model was simulated for the 4-year flow record. The results indicate an outflow load of 22.2 million tons, with a Tropical Storm Lee scour load of 3.0 million tons (13 percent of the total load). The net deposition in the reservoir was 4.1 million tons.

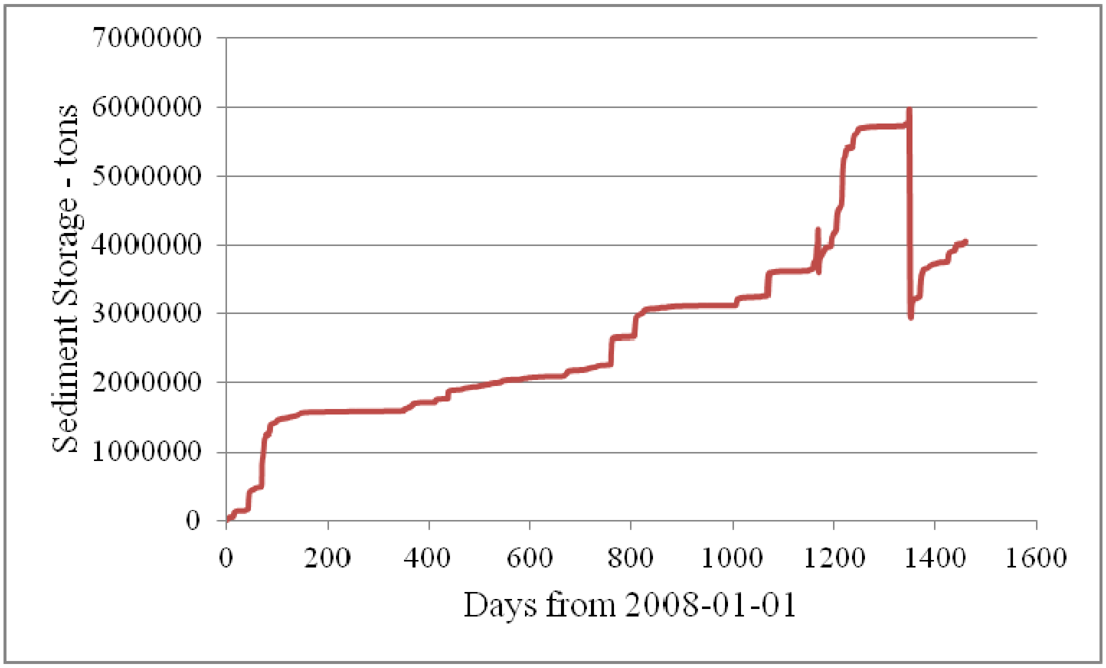


Figure 27 Sediment storage in Conowingo Reservoir for the full reservoir simulation

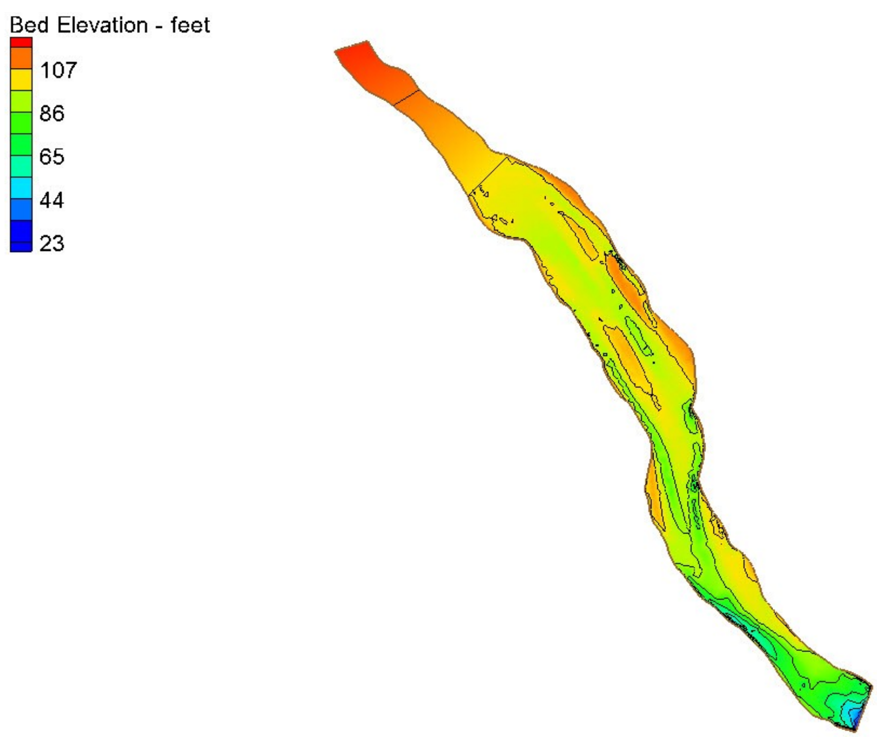


Figure 28 The full reservoir model bed elevation

Figure 29 Additional sediment depth added to the 2011 bathymetry for the full reservoir simulation

7.6 Discussion

Summary data for the four bathymetric simulations are found in Table 2. The impact of decreasing sediment storage capacity with time on sediment transport is revealed by a comparison of the 1996 and 2011 model results. A comparison of the 1996 and 2011 surveys not presented in this report indicate that approximately 25 million tons of sediment have deposited in Conowingo Reservoir between 1996 and 2011 (approximately 31 million cubic yards assuming a consolidated bulk density of 1600 kilograms per cubic meter). The model results for this 4-year simulation indicate that the decrease in reservoir capacity has resulted in a 10-percent increase in total load to the bay (20.3 to 22.3 million tons), a 66-percent increase in bed scour (1.8 to 3.0 million tons), and a 33-percent decrease in reservoir sedimentation (6.0 to 4.0 million tons).

Table 2 Summary of AdH 2D Model Simulation (Millions of Tons)

Bathymetry	Inflow Load	Outflow Load	Bed Scour Load	Net Deposition
1996	26.3	20.3	1.8	6.0
2008	26.3	21.9	2.9	4.4
2011	26.3	22.3	3.0	4.0
Full Condition	26.3	22.2	3.0	4.1

The reservoir will have more storage capacity, however, the large periodic storms like Tropical Storm Lee will continue to transport large quantities of sediment to the Bay which are much higher than the reduced scour loads resulting from sediment removal operations.

Results for the 2011 and full bathymetry model runs indicate minimal differences in bed scour and net sedimentation, indicating that Conowingo Reservoir is currently at or very near the maximum sediment storage capacity. The additional storage capacity in Conowingo Reservoir is within a reach two miles upstream of the dam. This is a deep area, with relatively lower velocities and bed shear stress, thus the potential for bed scour is low. These simulations reinforce the opinion that Conowingo Reservoir is currently in a dynamic equilibrium state.

The impact of Tropical Storm Lee on total load passing through the dam is shown in Table 3. For all simulations, Tropical Storm Lee provided about 65 percent of the total outflow load for the four year simulation (about 14.5 million tons of the 22.3 million-ton 2011 bathymetry outflow load). The scour load during Tropical Storm Lee comprises about 20 percent of the Tropical Storm Lee total load (about 3.0 million tons of the 14.5 million tons). For the total outflow load to the bay, bed scour passing through

Conowingo Dam comprises 13 percent of the total load, with 87 percent of the load originating from the watershed and the reservoirs upstream of Conowingo.

These results are based on a maximum scour load potential from the upper two reservoirs (26.3 million ton inflow load over the 2008 – 2011 time period). For a lower Conowingo inflow load scenario, the outflow load will be less, along with the Tropical Storm Lee load, thus the scour fraction presented in Table 2 can potentially be as high as 30 percent of the Tropical Storm Lee load.

Table 3 Summary of AdH 2D Model Simulation –Tropical Storm Lee (loads in millions of tons)

Bathymetry	Outflow Load	Total Lee Load	Lee Percent of Outflow	Scour Load	Scour Percent of Lee
1996	20.3	13.1	65	1.8	14
2008	21.9	14.4	66	2.9	20
2011	22.3	14.5	65	3.0	21
Full Condition	22.2	14.6	66	3.0	21

8 Simulation of Sediment Management Alternatives

Three sediment management modeling scenarios were simulated. The first alternative was simulated to evaluate the impact of sediment removal in a sediment deposition area upstream of the dam. The goal of the simulation was to determine how effective dredging would be for reducing scour during storms and reducing the overall total sediment transport to the bay. The second management scenario investigated the potential application of agitation dredging to Conowingo Reservoir. The goal of this simulation was to determine the minimum flow condition for which agitation dredging would be effective for transporting sediments through the dam. The third scenario was designed to evaluate the impact of bypassing sediments below the dam.

8.1 Dredging alternative

The impact of sediment removal activities on reservoir sediment transport was investigated with the model. It was assumed that 3.0 million cubic yards (2.4 million tons) were removed by dredging from an area above the dam that is depositional for all flows (Figure 30). The 2011 model bathymetry was lowered approximately 5.0 feet in this area to simulate a post-dredging bed elevation. The altered 2011 bathymetry was simulated over the same 4-year flow record and compared back to the unaltered 2011 simulation. The cumulative reservoir storage plots are found in Figure 31. The total outflow load to the bay was reduced by about 1.4 percent from 22.3 to 22.0 million tons, the scour load decreased by 10 percent (from 3.0 to 2.7) and the net reservoir sedimentation increased by about 5.0 percent (4.1 to 4.3 million tons). For this simulation, the scour load decreased approximately 3.3 percent for every million cubic yards removed.

Although changing the dredging area location will likely influence model results, removing such a relatively small quantity of sediment will have a minimal impact on total load delivered to the Bay when large flood events occur.

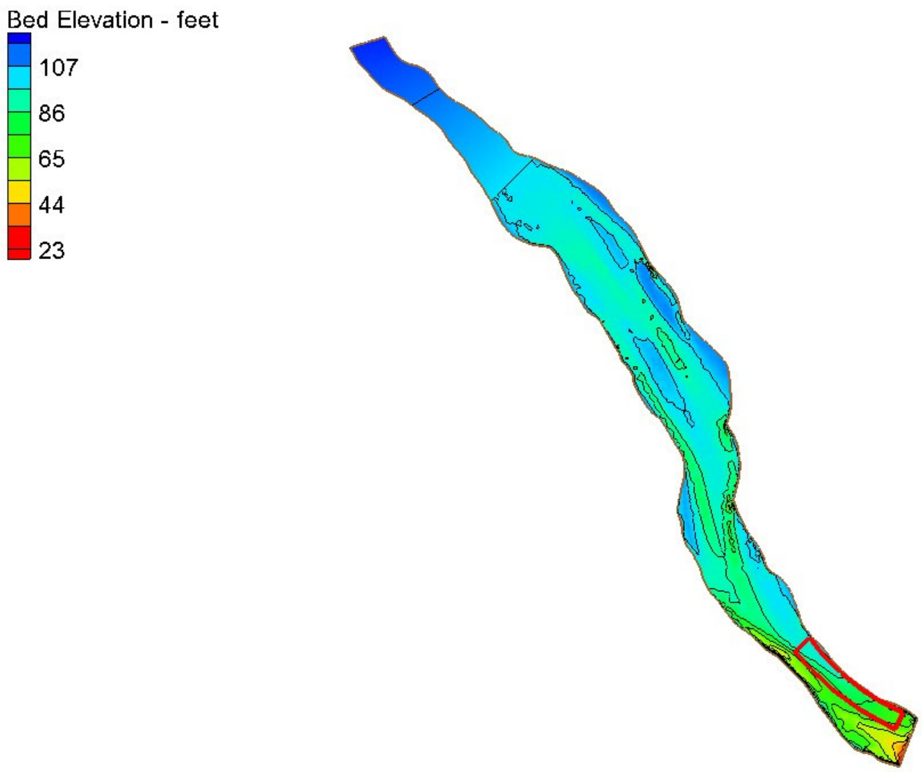


Figure 30 Area of reservoir for dredging simulation (outlined in red)

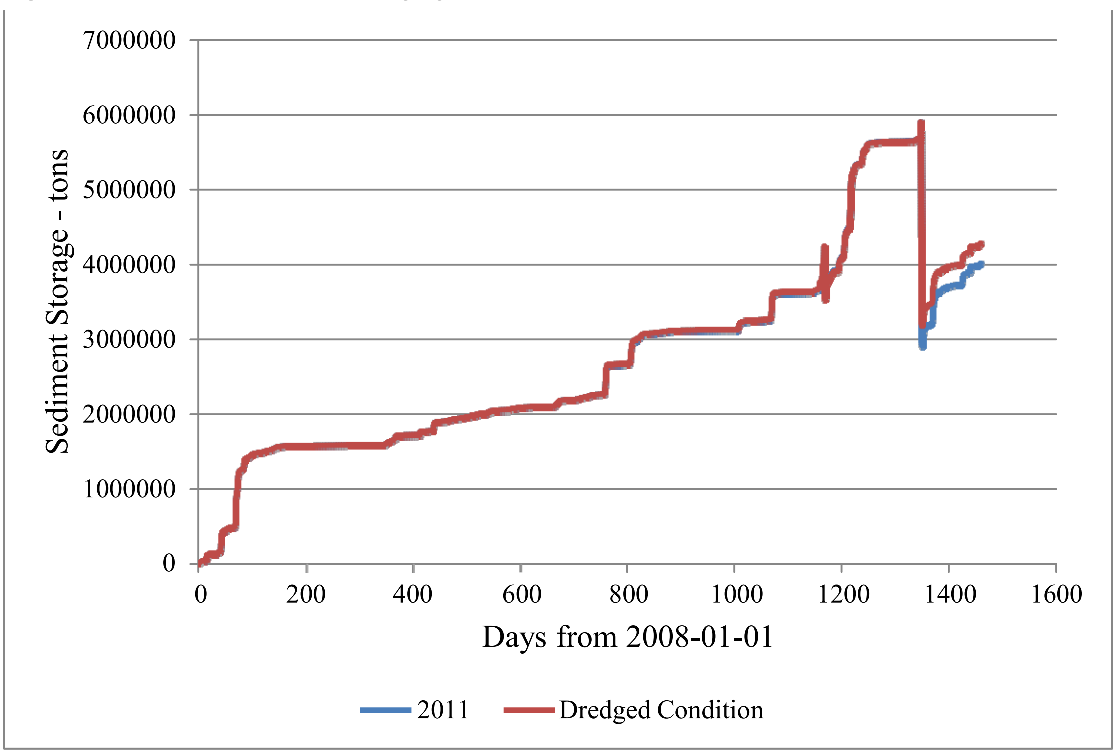


Figure 31 Comparison of pre-dredge and dredged reservoir sediment storage

8.2 Agitation dredging alternative

An alternative to dredging bed sediments and transporting them out of the reservoir is agitation dredging. Agitation dredging is mechanically or hydraulically re-suspending bed sediments which are then entrained in the water column and transported out the dam with the currents. For this sediment removal technology to be successful, adequate flow velocities in the reservoir are required to transport the re-suspended sediments through the system. The AdH model was used to evaluate the feasibility of such a system in Conowingo Reservoir. A number of steady state discharges were simulated in the model to evaluate the flow velocity and turbulence required to transport re-suspended sediments through Conowingo Dam. A flow range from 30,000 cfs to 400,000 cfs was investigated. A mean sediment grain size 0f 0.1 mm (millimeters) was assumed based on the size distribution in the reservoir bed and the potential size of cohesive bed sediment agitated from the bed. The potential for sediment to transport as a function of turbulence and particle fall velocity was determined. The study results indicated that a minimum flow of 150,000 cfs was required to transport agitated sediment through the dam. A report on the agitation dredging analysis is found in Attachment B-4.

8.3 Sediment bypassing alternative

The sediment bypassing study was not conducted with the AdH 2D model. It was a desk study with sediment bypassing quantities provided by the Baltimore District. The study consisted of two parts. Part 1 assumed that 2.4 million tons of sediment were transported below the dam and discharged into the channel over a 90-day period. Part 2 of the study assumed that 2.4 million tons of sediment were transported below the dam and discharged into the channel over a 270-day period. The goal of the studies was to determine the impact to suspended sediment concentrations below the dam.

The total suspended sediment load for the bypassing study consisted of the total Susquehanna River load passing through the dam plus the bypassed sediment load from the dredging operation. It was assumed that the average Susquehanna River flow during the winter months was 60,000 cfs, approximately twice that of the median flow of about 30,000 cfs. At

60,000 cfs, the average suspended sediment measurement below the dam was assumed to be about 12.0 milligrams per liter, which equates to about 1490 tons of sediment passing per day through the dam.

The dredging load discharged below the dam for the 90-day period was 26,700 tons per day with a dredge discharge of about 61.0 cubic feet per second. The dredging load discharged below the dam for the 270-day period was 8,900 tons per day. Thus the total solids loading per day below the dam for the 90- and 270-day scenarios was 28,200 and 10,400 tons, respectively. Analysis indicates that the 90 day loading resulted in an increase in total solids concentration from 12 to 174 milligrams per liter, whereas the 270 day loading resulted in an increase in concentration from 12 to 66 milligrams per liter.

8.4 Discussion

The dredging scenario results indicate a relatively small reduction in scour load (3.0 percent per million cubic yards removed), with a 1.4-percent reduction in total load to the bay (scour reduction and slight increase in reservoir deposition). Although the bed scour load is reduced, it is a relatively small contribution to the overall total load dominated by watershed and upstream dam sources. The previous comparison of the 1996 and 2011 bathymetry simulations indicated that removal of 31.0 million cubic yards produced only a 10.0-percent reduction in total sediment to the bay for the 4-year simulation, therefore dredging relatively small amounts will have a minimal impact to total sediment discharged to the bay.

The agitation dredging scenario is only effective for flows of 150,000 cfs or greater. These flows occur on the average 12 days out of the year. Although agitation dredging is feasible, operations will be limited due to flow restrictions and will not be effective for significantly reducing overall sediment transport to the bay.

Bypassing sediment around Conowingo Dam will increase suspended sediment loading to the lower channel and Susquehanna Flats, with the 90-day bypass scenario increasing suspended sediment concentrations by a factor of 15 (12 to 174 milligrams per liter) and the 270-day bypass scenario increasing concentrations by a factor of 5 (12 to 64 milligrams per liter).

9 Impact of Conowingo Reservoir Water and Sediment Releases on Susquehanna Flats

An AdH model of the lower Susquehanna River channel and Susquehanna Flats area was constructed. The model domain bathymetry is presented in Figure 32. The model contains approximately 16,000 elements and 8,600 nodes. Bathymetric surveys of approximately 4 miles of channel below Conowingo Dam were provided by Exelon Corporation from a previous 2D model water quality study (Exelon, 2012 RSP 3.16). The remaining bathymetry data in the model was digitized from NOAA depth charts, with bed elevation converted from water depth to mean low lower water elevations, and then finally to the Maryland State Plane coordinate system.

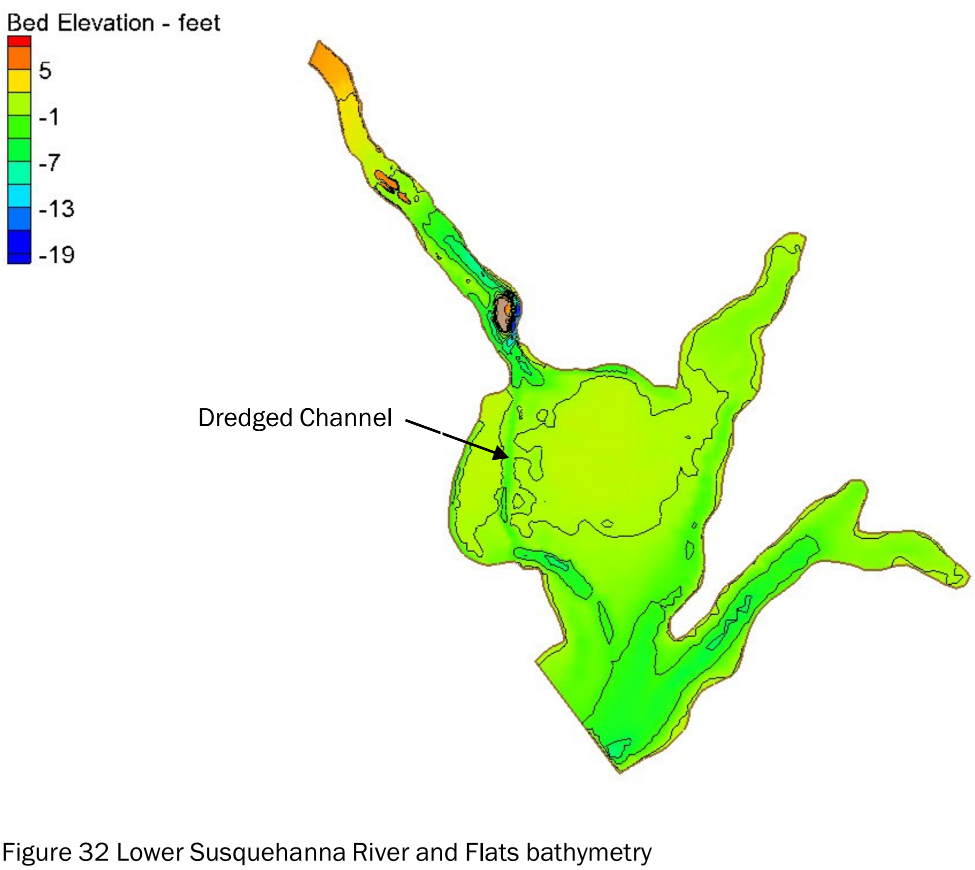


Figure 32 Lower Susquehanna River and Flats bathymetry

The model contains the Susquehanna Flats area. The submerged aquatic vegetation (SAV) in the flats is represented in the model. The SAV areas were defined from maps provided by Virginia Institute for Marine Sciences (Orth, 2012) and are presented in Figure 33. The SAV presence is seasonal, occurring from about April through October. These areas were defined as specific material types in the model mesh with specific properties. The AdH model has the capability to simulate the influence of both submerged and unsubmerged aquatic vegetation on total roughness (resistance to flow). The relationship of submerged vegetation height and water depth to total roughness is found in Figure 34. Bed size gradations were determined from samples taken in the lower channel and flats area by the Maryland Department of Natural Resources.

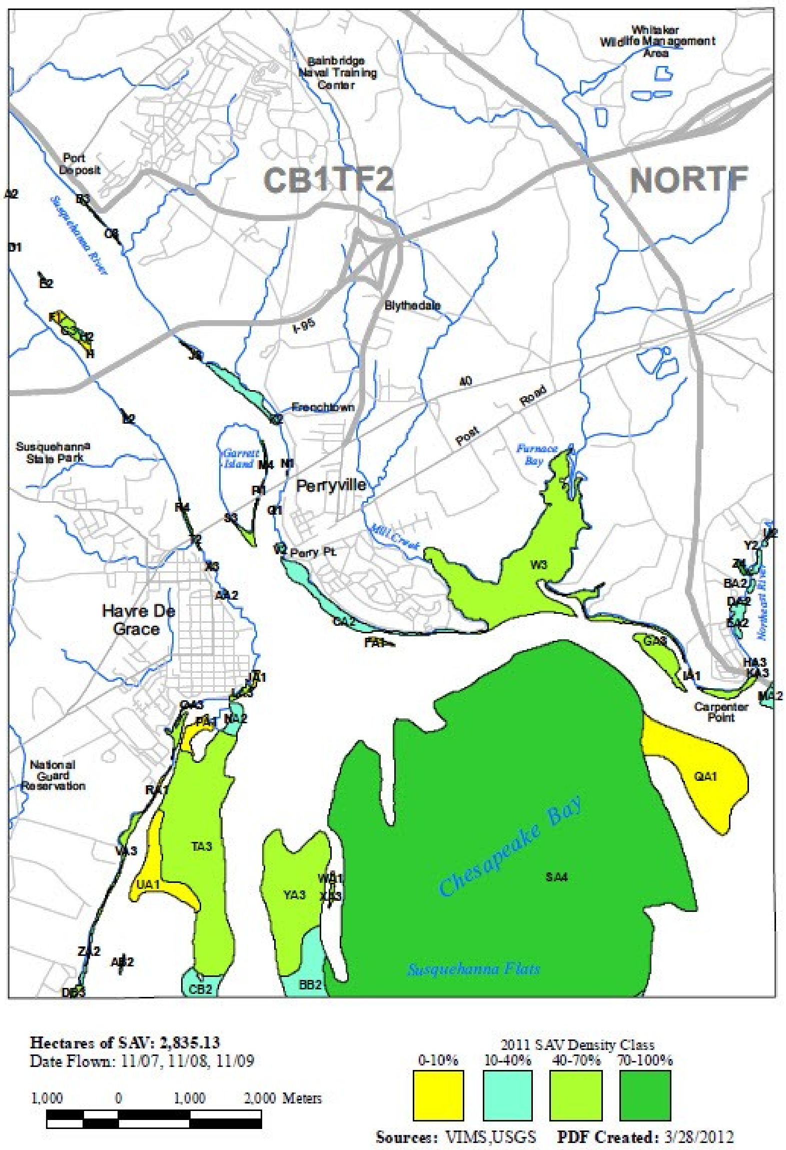


Figure 33 Submerged aquatic vegetation (SAV) areas in Susquehanna Flats

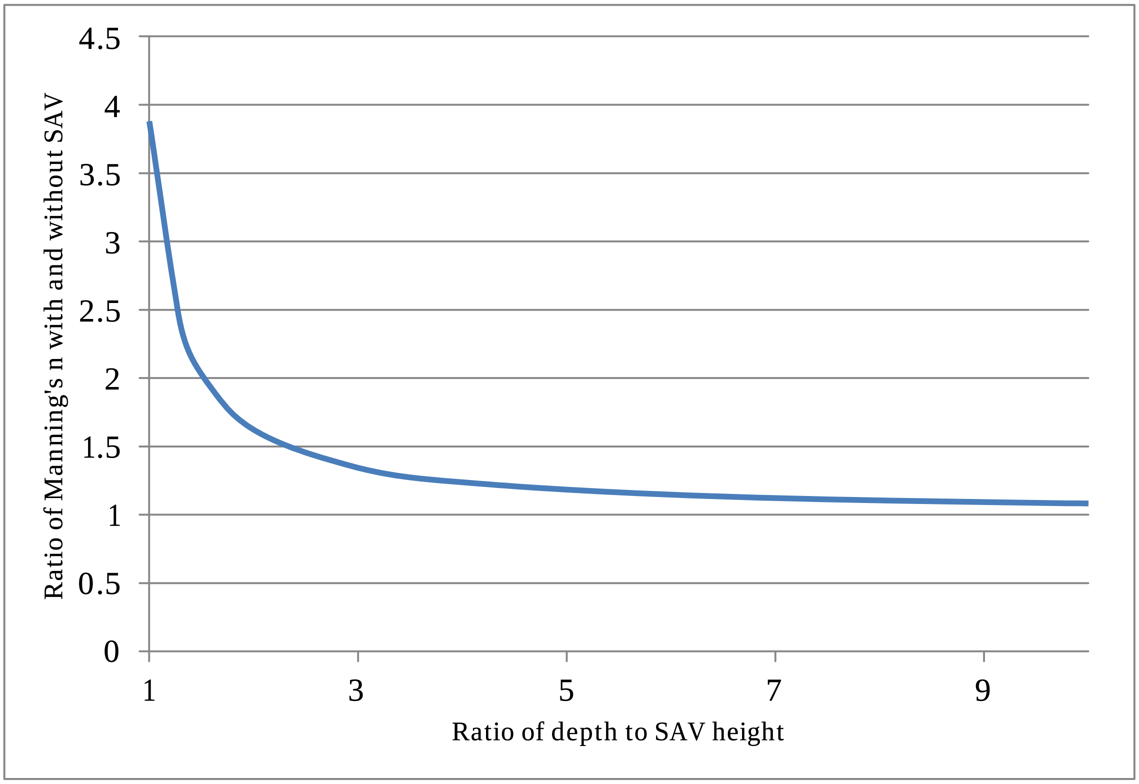


Figure 34 Ratio of Manning's n roughness coefficient with and without SAV to the ratio of water depth to SAV height (Berger et al, 2012)

9.1 Hydrodynamic modeling results

An inflow similar to the Tropical Storm Lee event was applied to the model. Figure 35 presents the flow velocity near the peak of the event (600,000 cfs). Velocities exceed 5.0 feet per second in the channel below the dam, however, in the flats area, flow is routed around the shallow flats through the dredged channel. Velocities in the dredged navigation channel below Havre de Grace are approximately 5.0 feet per second.

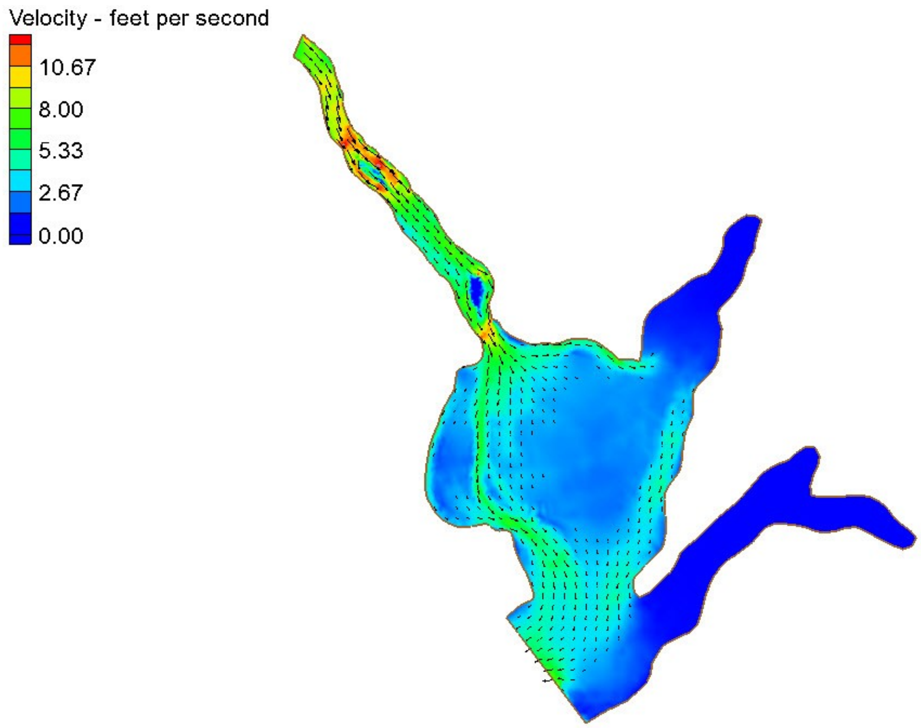


Figure 35 Velocity in Susquehanna Flats for a discharge of 600,000 cfs

9.2 Sediment modeling results

Bed scour at the peak flow of the simulation is presented in Figure 36. The bed scour and deposition pattern reflects the routing of flow around the flats area due to the resistance of flow from the relatively shallow SAV area containing vegetation.

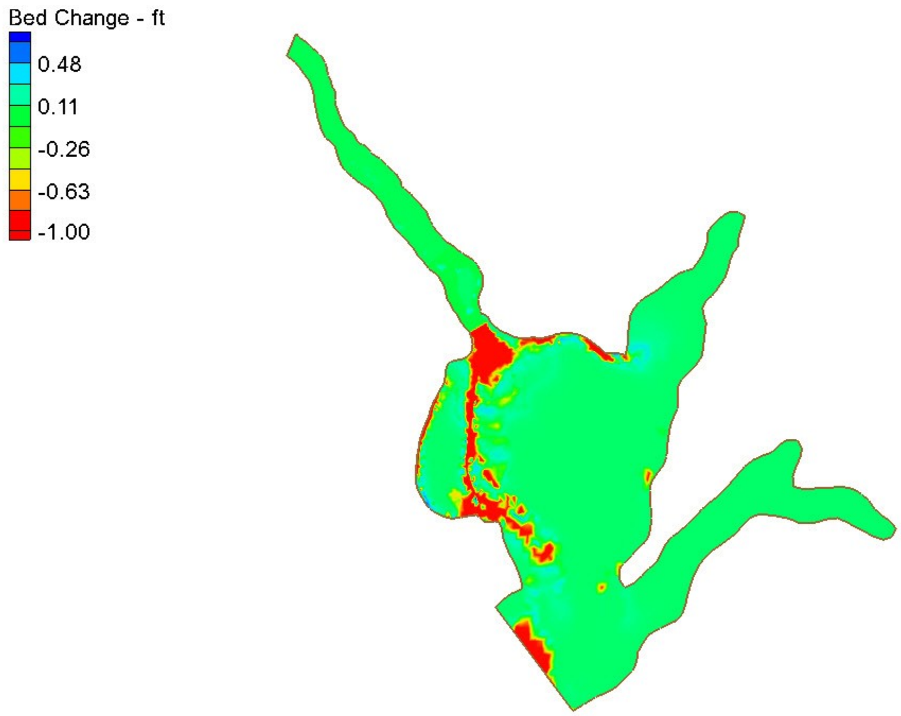


Figure 36 Bed change in Susquehanna Flats area for 600,000 cfs

9.3 Discussion

The SAV in the Susquehanna Flats area will increase resistance to flow thus change the specific discharge through the area, with the highest concentration of flow in the dredged channel. Inflowing sediment will be routed around the flats, with scour occurring in the dredged channel at high flows. When the SAV dies back in the winter, the flats area will be vulnerable to higher flows and possibly scour. However, the relatively higher bed roughness of the shallow flats will tend to continue to route the majority of the flow through the dredged navigation channel below Havre de Grace. Thus, discharge of sediment from Conowingo Dam due to bypassing or flushing operations will have minimal impact on the flats area, with sedimentation occurring in the dredged navigation channel or below the flats area.

10 Conclusions

A number of conclusions can be drawn from the modeling study. Although the uncertainty of the modeling is high due to the uncertainty of sediment boundary conditions and model limitations, the existing versus alternative approach to the simulations revealed the relative change in sediment transport based on the alternative condition scenario. The conclusions are as follows:

10.1 Modeling to evaluate temporal changes in sediment transport

The simulation and comparison of the various model bathymetries (1996, 2008, and 2011) for the Susquehanna flow record of 2008–2011 revealed an increase in scour and decrease in reservoir sedimentation in the 15-year period between 1996 and 2011. The bed scour load increased by 66 percent (1.8 million tons to 3.0 million tons) while deposition decreased by 33 percent (6.0 million tons to 4.0 million tons). The results imply that if 31 million cubic yards were removed from the present day reservoir (back to the 1996 condition), the reduction of total sediment discharged to the bay would be about 10.0 percent due to a reduction in bed scour and increase in net sedimentation). Although the scour increase from 1996 to 2011 appears significant, it only represents a relatively small fraction of the total load resulting from Tropical Storm Lee.

A comparison of the present day (2011 bathymetry) model results with the projected full bathymetry model results indicates that sediment transport through Conowingo Reservoir does not appreciably change, indicating that the reservoir is currently in a state of dynamic equilibrium in which the net change in sedimentation (deposition during low flows and scour during floods) will remain relatively constant into the future. This implies that the bay is currently experiencing the maximum periodic sediment loading from Conowingo Reservoir.

Tropical Storm Lee contributed approximately 65 percent of the total load discharged to the bay over the 2008–2011 flow record (14.5 of 22.3 million tons); with bed scour contributing about 20 percent of the total Tropical Storm Lee load. These results imply that the watershed and upstream reservoirs are providing 80 percent of the load during Tropical Storm Lee.

Overall, bed scour contributes about 13 percent of the total load to the bay based on the 4-year model simulation (3.0 of 22.3 million tons) with the remaining 87 percent originating from the watershed and upstream reservoirs. The estimated range of bed scour load that passed through the model for the Tropical Storm Lee event is 2.0 to 4.o million tons which is within the prediction error of the USGS scour regression curve.

10.2 Modeling to evaluate dredging (removing sediment out of the reservoir)

Dredging limited quantities from depositional areas in the reservoir has a minimal impact on total sediment load transported to the bay. Model results for the 2008 – 2011 flow scenario indicate that for 3.0 million cubic yards removed, a 10-percent reduction of scour is achieved (from 3.0 million tons to 2.7 million tons). This reduction represents only a 1.4-percent reduction of total load delivered to the bay (reduction of bed scour and increase in net sedimentation) over the 2008 – 2011 simulation period. Large periodic flood flows dominate sediment transport dynamics in Conowingo Reservoir. The amount of sediment passed through the dam during floods is significantly higher than the estimated bed scour load, thus small reductions in bed scour due to dredging operations will not provide any substantial benefit to the bay over time.

10.3 Modeling to evaluate agitation dredging effectiveness

Agitation dredging is possible in Conowingo Reservoir, but it requires sufficient currents for transporting re-suspended sediments through the dam. Model and analytical results indicate that a Susquehanna River flow of 150,000 cfs is required to maintain re-suspended sediments in suspension and transport them out of the reservoir. The 150,000 flow occurs approximately 12 days out of the year thus there is a narrow window for operations.

10.4 Sediment bypassing impacts to sedimentation below Conowingo Dam

Bypassing sediment around Conowingo Dam will temporarily increase suspended sediment concentrations below the dam. Assuming an average Susquehanna River flow of 60,000 cfs and concentration of 12 milligrams per liter, bypassing 2.4 million tons of sediment below the dam over a 90-day period will result in an increase in average suspended sediment concentration from 12.0 to 174.0 milligrams per liter. If the same mass of sediment is bypassed over 270 days, the increase is from 12.0 to 64.0 milligrams per liter.

10.5 Susquehanna Flats sedimentation impacts

The Susquehanna flats area is shallow and contains submerged aquatic vegetation. These characteristics increase resistance to flow. Because of these characteristics, the deeper dredged navigation channel to the east of the flats passes the majority of the flow and sediment, and thus is most vulnerable to sedimentation impacts (erosion and sedimentation).

10.6 Interpretation of AdH sediment transport model results

The AdH sediment transport model results only estimate the transport and fate of sediments that enter the reservoir and scour from the bed. The model does not predict nutrient transport and does not imply any predictive relationship exists between nutrients and sediment transport.

11 Recommendations to Improve Future Modeling Efforts

This model study contains significant uncertainty due to limited sediment boundary conditions as well as limited model representation of dam operations. The initial plan for the model was to simulate dam operations by releasing flows less than or equal to 86,000 cfs through the power plant (western side of the dam), with the 52 flood gates releasing water based on their operations rating curve. The hydrodynamics were successfully implemented in AdH; however, the model was not capable of passing sediment through the gates, therefore, for this study the dam was modeled as an open boundary with downstream control represented by the water surface elevation at the dam. This limitation impacted how sediment was spatially distributed in the lower reach of Conowingo Reservoir near the dam. It is recommended that dam operations be incorporated in the Conowingo model for future studies.

Sediment transport models in general do not have a sophisticated approach to simulate fine sediment flocculation. The AdH model has the capability to relate flocculation to concentration, but not to other variables such as shear stress which determine flock particle size and overall fate. The ability to predict flocculation dynamics is critical to track the fate of sediment in a reservoir system. More sophisticated methods need to be developed to provide this capability.

Field data collection needs to continue both upstream and downstream of Conowingo Dam to provide more information on reservoir mass balance. Currently, the suspended sediment samples are collected from one location near the power plant. Because of the danger of sampling during large storms, samples are not currently collected for the peak of the largest storms. Field methods are required for sampling storm concentrations or turbidity over the entire storm hydrograph to verify estimations of bed scour during large storms.

12 References

Banasiak, R. and Verhoeven, R., Quantification of the Erosion Resistance of Undisturbed and Remoulded Cohesive Sediment, Journal of Water, Air, and Soil Pollution, Vol. 6, P. 17-27, (2006)

Berger et. al, Adaptive Hydraulics, a Two Dimensional Modeling System Developed by the Coastal and Hydraulics Laboratory, Engineer Research and Development Center, Users Manual, April 2012.

Exelon Corporation, Updated Study Report: Effect of Project Operations on Downstream Flooding, RSP 3.29, Conowingo Hydroelectric Project, Prepared by URS Corporation and Gomez and Sullivan Engineers.

Exelon Corporation, Updated Study Report: In stream Flow Habitat Assessment Below Conowingo Dam, RSP 3.16, Conowingo Hydroelectric Project, Prepared by URS Corporation and Gomez and Sullivan Engineers.

Exelon Corporation, Updated Study Report: Sediment Introduction and Transport Study, RSP 3.15, Conowingo Hydroelectric Project, Prepared by URS Corporation and Gomez and Sullivan Engineers.

Hainly R.A. et al, “Deposition and Simulation of Sediment Transport in the Lower Susquehanna River Reservoir System”, U.S. Geological Survey Water Resources Investigations Report 94 – 4122, 1995

Langland M.J., “Bathymetry and Sediment-Storage Capacity Change in Three Reservoirs on the Lower Susquehanna River, 1996 – 2008”, U.S Geological Survey Scientific Investigations Report 2009 – 5110.

Orth, R.J., et. al., 2012 Distribution of Submerged Aquatic Vegetation in Chesapeake Bay and Coastal Bays, Special Scientific Report No. 155, Virginia Institute of Marine Sciences, October 2013.

Sloff, C.J., 1997, Modeling Reservoir Sedimentation Processes for Sediment Management Studies, Proc. Conf. “Hydropower into the next century”, Portoroz, Slovenia, 15-17 Sept. 1997, p. 513-524

USEPA, 2011, Clean Water Act Section 303(d): Notice for the Establishment of Total Maximum Daily Load (TMDL) for the Chesapeake Bay, Federal Registration Number EPA-Ro3-OW-2010-0736-0776, posted January 5, 2011.

U.S. Geological Survey, 2001, National Water Information System data available on the World Wide Web (Water Data for the Nation, accessed June 2012 at URL http://waterdata.usgs.gov/nwis/

Whitehouse, et. al., Dynamics of Estuarine Muds, A manual for practical applications, HR Wallingford, Thomas Telford Publishing, 2000.

Ziegler, C.K. and Nisbet B.S., Long Term Simulation of Fine Grained Sediment Transport in Large Reservoirs, Journal of Hydraulic Engineering, November 1995, P. 773-781.

Attachment B-1:
Evaluation of AdH Model Simplifications in Conowingo Reservoir Sediment Transport Modeling

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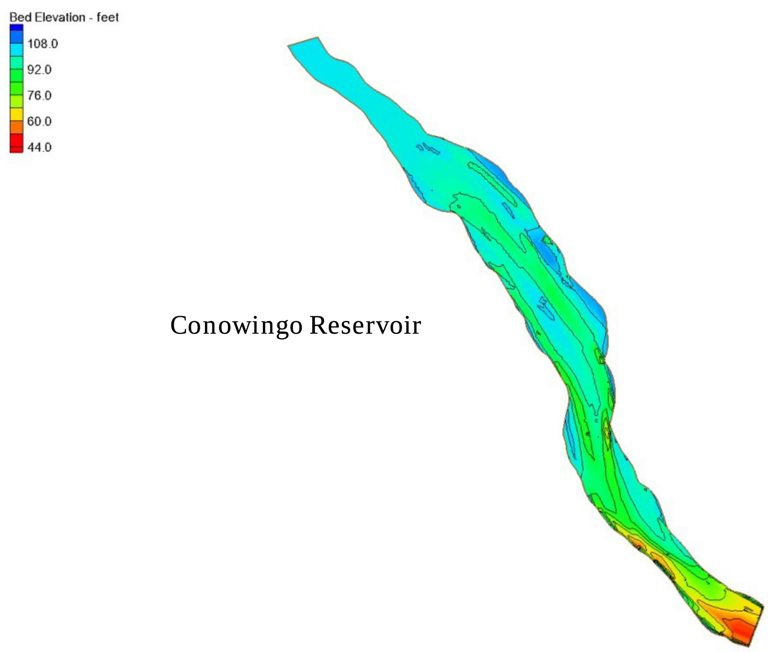
October 2012

Lower Susquehanna River Watershed Assessment

Evaluation of AdH Model Simplifications in Conowingo Reservoir Sediment Transport Modeling

Stephen H. Scott



Coastal and Hydraulics Laboratory
U.S. Army Engineer Research and Development Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Final Report

Prepared for Baltimore District Corps of Engineers

1.0 STUDY GOAL

The goal of this paper is to detail the uncertainties involved with the simulation of hydrodynamics and sediment transport through Conowingo Reservoir. Uncertainties in the modeling process include approximation of reservoir bathymetry and estimation of hydrodynamic and sediment modeling parameters. However, the type (dimensionality) of model to apply is based primarily on the model's ability to capture the dominant hydrodynamic and sediment transport mechanisms. Reservoirs are typically exposed to both low and high inflow conditions that will impact the transport and fate of inflowing sediments. The ability of a sediment particle to transport suspended in the water column or transport near or along the bed is determined by the ratio of the force that tends to cause the particle to settle (gravity) and the force that tends to keep it in suspension (turbulence). Depending on the inflow condition, the sediments may be stratified in the water column (low flow, low turbulence) or well mixed (high flow, high turbulence). This paper presents the potential uncertainties involved in modeling varying reservoir conditions, along with the potential impact of Conowingo Dam operations. Model capabilities are presented, with discussion of the application of one, two, and three dimensional models for reservoir sediment transport modeling.

2.0 INTRODUCTION

The basic governing equations involved in modeling reservoir sedimentation processes are the same as for river or estuarine systems. However, other factors unique to reservoirs may influence the distribution of inflowing sediments and re-distribution of bed sediments during large flow events.

The circulation of water and sediment in reservoirs is generally multi-dimensional, non-uniform, and unsteady in nature (USBR 2006). It can be affected by a number of processes including river inflow rates, wind driven circulation, density gradients in the water column due to temperature stratification, ice and debris, and dam operations during low flow and flood events. Cooler water is denser and will displace the warmer, less dense water. Sediment concentrated in these higher density layers will displace with the water, resulting in vertical sediment stratification. All these effects may have an impact on sedimentation processes, sediment trap efficiency, and distribution of sediments in the reservoir.

Sediment transport processes are highly dependent on hydrodynamics. Reservoir hydraulics directly influences the transport, deposition, and scour of sediment consisting of widely varying grain sizes (clay to sand sizes). Generally, coarse sediments such as gravels (greater than 4 mm) will only transport as bed load. Sand-sized material can transport as both suspended load and bed load, while the finer sediments such as silts and clays primarily transport as suspended load. The flow velocity in reservoirs is the primary sediment transport mechanism. The ability of a sediment particle to stay in suspension is directly proportional to the degree of turbulence generated by the flow within the system. However, for low flow conditions in reservoirs with low flow velocities, the dominant transport processes may not be due to inflows. Wind driven events may increase surface velocities and influence spatial deposition patterns. Vertical density stratification due to temperature differences in the water column may also induce currents that will transport suspended sediments in the form of density currents. This gravity-driven sediment transport is the result of temperature difference in the impounded and inflowing waters.

The type of sediment transport model to apply to reservoirs is based on the expected flow distribution and sediment mixing potential. Two-dimensional (2D) and one-dimensional (1D) models are generally used for engineering applications which include computing total sediment discharge along with scour and deposition potential within the reservoir. For relatively narrow reservoirs where flow is channelized and is generally well mixed, 1D models are applicable. However, if the reservoir pool is wide with a widely varied lateral flow distribution, the multi-dimensional model is more applicable (Haun 2012). If 3D effects are a significant aspect of the study, a 3D model may be applicable. However, 3D models are computationally intensive and thus have limited capability for long term simulations (simulation of years of record). Generally, these models are applied to very specific areas to evaluate the effects of 3D water circulation (vertical velocities and accelerations). For example, hydrodynamics and sediment transport in the immediate vicinity of a dam where vertical circulation is expected and complex sediment deposition and scour patterns may occur.

3.0 BACKGROUND

The Engineering Research and Development Center at Waterways Experiment Station is applying the 2D Adaptive Hydraulics model (AdH) to Conowingo Reservoir for the Lower Susquehanna River Watershed Assessment. The goal of the sediment transport modeling is to simulate sediment transport processes within the reservoir for widely varying flow conditions, including very low flows that typically occur during the summer months, and large flood flows due to inland storm events and occasional coastal storm events that influence the watershed.

There are areas and flow conditions in the reservoir that can impact the spatial distribution of sediment deposits. The flow patterns in the vicinity of Conowingo Dam vary due to dam operations, power plant water intake, and other potentially 3D flows near structures. Additionally, in Conowingo reservoir there are low inflow conditions where flow velocity is at a minimum, water residence time is high, and sediments are stratified in the water column. However, during these low flow periods, sediment transport into the reservoir is at a minimum. Thus, although forces other than advection may be a factor in how sediment moves through the reservoir and ultimately deposits, the amount of sediment under this influence has been determined to be negligible for low flow conditions.

The following sections will discuss the effects of various modeling simplifications and quantify the low flow sediment load into Conowingo Reservoir.

4.0 IMPACT OF CONOWINGO DAM ON HYDRAULICS AND SEDIMENT TRANSPORT

The presence of the dam creates a backwater effect, reducing the energy slope, thus reducing velocities and encouraging sedimentation. In the area adjacent to Conowingo dam, circulation of water and sediment is directly impacted by both the dam face and how the water is discharged through the dam. For low flows less than 86,000 cfs, the water is released through the power plant on the eastern side of the dam. The reservoir pool is generally maintained at an elevation of 109.2 feet NGVD 29, with the power plant intakes located over a depth range of 58 feet (from elevation 11.2 to 69.2 feet NGVD 29). For flows exceeding 86,000 cfs, both the power plant and flood gates pass flow. There are 53 flood gates with a crest elevation of 89.2 feet NGVD 29. Both the power plant and floodgates pass flow up to approximately 400,000 cfs. At higher flows the power plant is shut down with all flow passing through the gates.

For lower flows with less turbulence and more sediment stratification in the water column, the higher near-bed sediment concentrations will pass through the power plant. Density currents that flow through the reservoir may display this type of behavior.

These currents are formed from inflows that are cooler and denser than the reservoir waters. These sediment laden flows transport through the reservoir below the warmer, less dense water. For low turbulence conditions, these flows may remain near the bed, and transport through the power plant intake.

For higher, more turbulent flows, flow passes through both the power plant intake and through flood gates which have a crest elevation approximately 67 feet above the power plant intake. Under these flow conditions, the majority of the sediment transports as suspended load with the water column considered well mixed. However, the power plant intake that is located near to the bed will likely pass higher concentrations of sand bed load.

The presence of the dam, flood control gates, and hydropower intakes will result in changes in hydrodynamics and sediment transport. The stream-wise transport of bed-load is impeded by the dam, with 3D flows occurring adjacent to the structures. Both scour and deposition are possible near the dam due to dam operations.

5.0 SIGNIFICANCE OF LOW FLOW SEDIMENT TRANSPORT

During low inflow conditions, sediment may be stratified in the water column and forces other than stream-wise flow velocity may act to re-distribute sediment in the reservoir. Wind and wave action may impact how sediment moves through the reservoir system. However, during low flow conditions, the sediment inflow is generally low.

To evaluate the sediment transport potential for Conowingo Reservoir during low flow conditions, the Susquehanna River flow duration and sediment inflow must be analyzed, along with consideration of Conowingo Reservoir water residence time.

The water residence time or flushing rate can be defined as the time that it takes for a particle of water entering the reservoir to exit out the dam. For Conowingo Reservoir, the residence time is described by Figure 1. These data were generated by the Exelon Corporation during a study of Conowingo Dam operations (Exelon 2009). This figure indicates an exponential drop in residence time with flow, ranging from a high of 80 days for a river discharge of 1,000 cubic feet per second (cfs) to 1 day for a discharge of 100,000 cfs.

The flow-duration curve for the Susquehanna River at Marietta, Pennsylvania, is presented in Figure 2 (USGS station 0157600). This curve was created from 40 years of flow record from 1970 to 2010. The flow duration curve is a plot that shows the percentage of time that flow in a river is likely to equal or exceed a specific discharge (volumetric flow rate of water). The median Susquehanna River flow (50 percent exceeded) is approximately 26,000 cfs, and has a residence time of six days in Conowingo Reservoir.

Generally, the sediment load entering a river or reservoir is described with a sediment rating curve which represents the sediment load in tons per day as a function of discharge. A sediment rating curve was developed for the Susquehanna River from previous sediment transport studies conducted by the USGS (USGS 1994). Recently, Exelon Corporation used this rating curve to evaluate sediment transport through the lower three Susquehanna River reservoirs (Lake Alred, Lake Clark, and Conowingo Reservoir) (Exelon 2011). This curve is presented in Figure 3. For example, the inflowing sediment load for the median flow of 26,000 cfs is approximately 2500 tons of sediment per day.

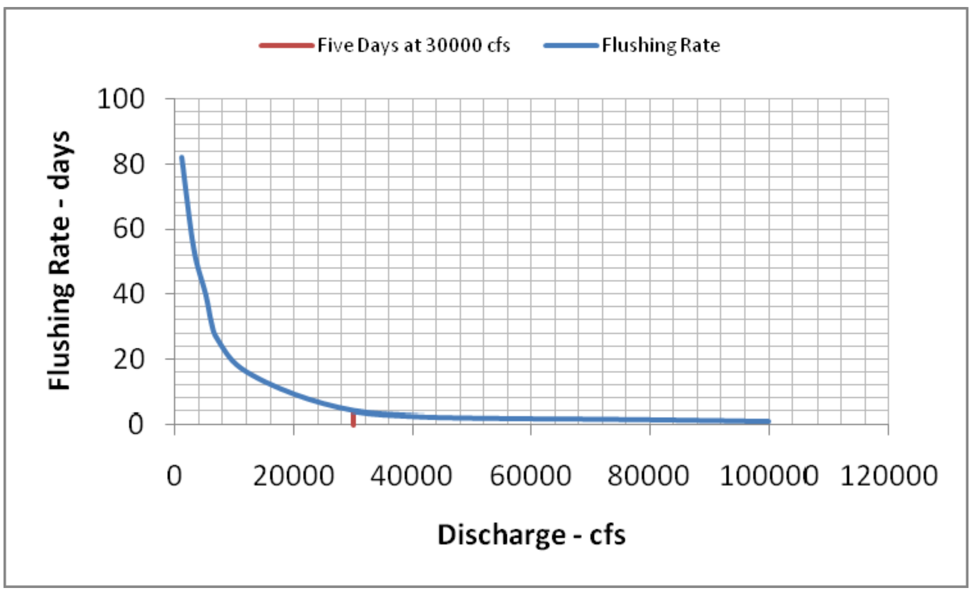


Figure 1. Residence time for Conowingo Reservoir

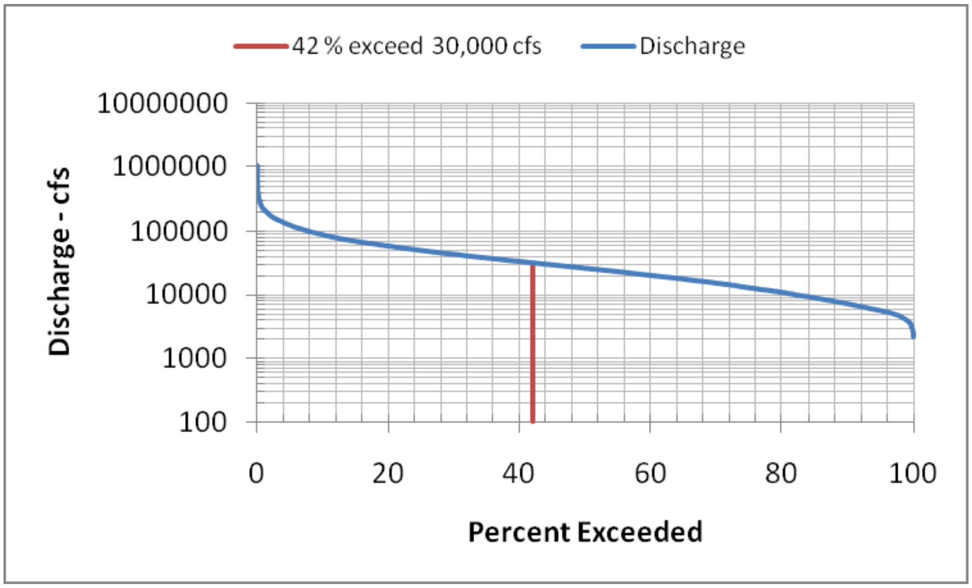


Figure 2. Flow duration curve for the Susquehanna River at Marietta, Pennsylvania

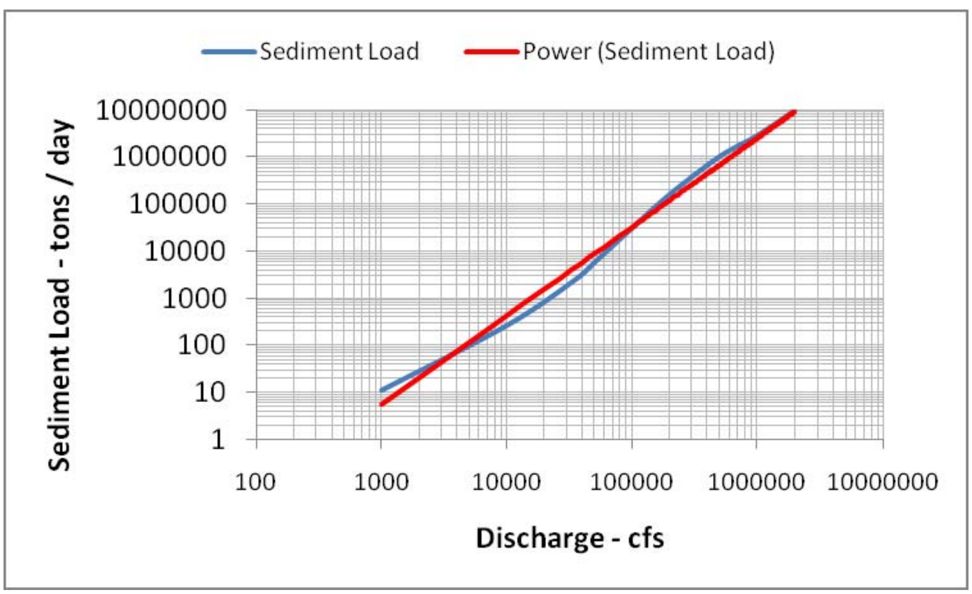


Figure 3. Sediment rating curve for the lower Susquehanna River

5.1 Sediment Delivery Analysis

To determine the annual sediment yield delivered by the Susquehanna River to the three lower reservoirs, the flow duration curve is integrated with the sediment rating curve. The flow duration curve is a graphical representation of the percentage of time in the historical record that a flow of any given magnitude has been equaled or exceeded. Integrating this curve with the sediment rating curve will provide not only the total estimated annual sediment yield, but will also demonstrate the cumulative sediment yield to the lower reservoirs as a function of discharge. The result of this integration is presented in Figures 4 and 5. Figure 4 shows the cumulative annual sediment yield in tons as a function of discharge and Figure 5 presents the cumulative percentage of annual sediment yield as a function of discharge. The total estimated annual sediment yield delivered to the downstream reservoirs is approximately 4,200,000 tons.

From the Conowingo Reservoir water residence time plot (Figure 1), a river discharge of 30,000 cfs requires approximately four days to transit through the reservoir. If one assumes all flows less than the median flow of 30,000 cfs to be low flows with a potentially higher degree of sediment stratification in the water column, the cumulative percent of delivered sediment per year for these low flows is approximately 5 percent. In other words, only 5 percent of the total annual sediment load is delivered during these low flow periods. Thus sediment delivery during median to low Susquehanna River flows is not significant to the overall sediment delivery into the system of reservoirs on the lower Susquehanna River.

The analysis presented in the following section will provide insight on sediment stratification as a function of discharge in Conowingo Reservoir.

5.2 Analysis of Transport Capability at 30,000 cfs – Rouse Number Calculation

The ability of a sediment particle to transport suspended in the water column or transport near or along the bed is determined by the ratio of the force that tends to cause the particle to settle (gravity) and the force that tends to keep it in suspension (turbulence). Small particles such as silts and clays require less flow-generated turbulence to keep particles in suspension, whereas sand-size particles require higher flows to maintain in suspension. Clay and fine silt-sized particles less than 10 microns in diameter may remain in suspension and pass through the system as wash load without interacting with the bed.

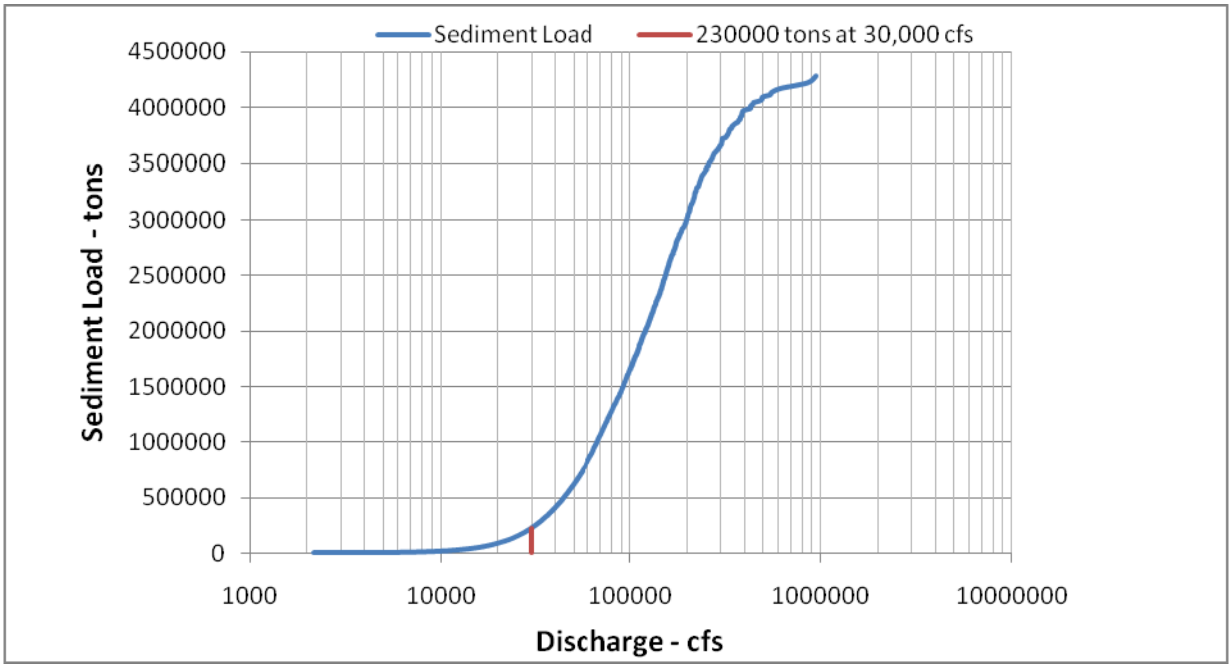


Figure 4. Annual cumulative sediment yield for the lower Susquehanna River

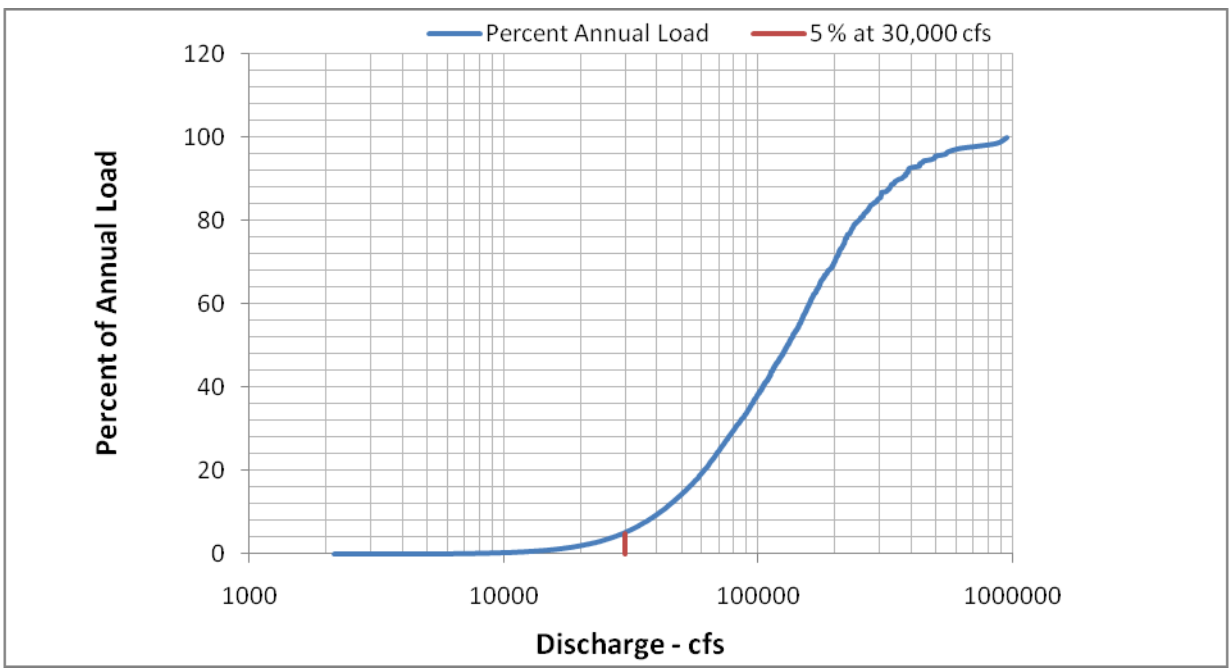


Figure 5. Percent of average annual yield for the lower Susquehanna River

The Rouse Number is a dimensionless number that is used to evaluate the potential of sediment to stratify in the flow (Rouse 1937). It is the ratio of the sediment fall velocity and the shear velocity which is a function of bed shear stress:

$$R = \frac{U_p}{k\left(\frac{\tau_b}{\rho}\right)^{0.5}}$$

With U_p the particle fall velocity, k the Von Karman Constant, τ_b bed shear stress, and ρ the water mass density.

The AdH 2D model was used to evaluate the sediment transport capability for a discharge of 30,000 cfs in Conowingo Reservoir. The bed shear stress resulting from the calculation was used to calculate the Rouse Number across the entire model domain assuming a medium silt particle size (Figure 6). A silt sediment particle size was chosen for the analysis because the silt fraction of the incoming load represents approximately 60 percent of the total load. The results indicate that velocity and subsequent bed shear stress is high enough to maintain a medium silt in suspension throughout the lower reaches of the reservoir (Rouse number of < 0.8). Only in the upper reach of the reservoir (blue contour on Figure 6) is the flow velocity and bed shear low enough for stratification (50% settled out, 50% in suspension). These Rouse Number simulation results validate the assumption that flows greater than 30,000 cfs will have sufficient velocity to transport silt sized sediments and that any three dimensional affects due to secondary flow processes will potentially be negligible in comparison.

5.3 AdH Model Treatment of Suspended Sediment Profiles

Due to the way AdH treats Suspended Sediment Profiles, the uncertainty due to stratification is not as great as it might have been. Suspended sediment transport is an inherently three dimensional process (Brown 2010). In low flow conditions with little or no sand transport, fine sediments such as silts can stratify vertically in the water column. During higher, more turbulent flows, the fines are generally well mixed in the profile, with larger, sand sized sediments exhibiting some degree of stratification in the water column. Typically 2D models utilize a general depth averaged advection diffusion equation to account for suspended sediment transport. To account for this 3D stratification, AdH computes a correction factor to simulate quasi 3D suspended sediment transport. These correction factors, based on work by Rouse (1937), yield an approximate concentration profile for both equilibrium and non-equilibrium conditions. This profile is then integrated to compute mass flux, with a mass flux correction factor applied assuming a logarithmic velocity profile. In addition, when transport equations are depth averaged, the dispersion of sediment concentration based on varying velocities within the vertical profile is not accounted for. To correct for this, AdH assumes a logarithmic velocity profile, and computes a correction factor by integrating the difference in the velocity at a given depth and the depth averaged velocity.

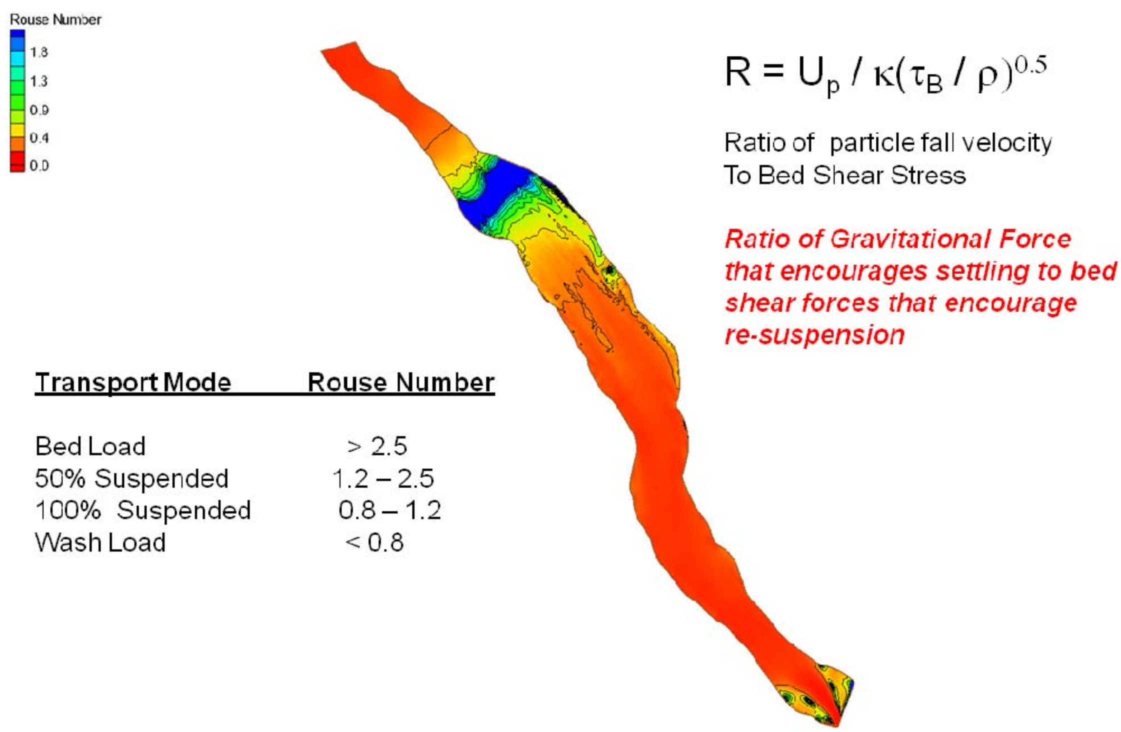


Figure 6. Rouse Number calculation for a medium silt sediment particle at 30,000

6.0 DISCUSSION AND CONCLUSIONS

The transport of sediments through Conowingo Reservoir can be affected by a number of phenomena including stratification due to temperature, wind-driven circulation, and dam operations. Conowingo Dam passes all flows less than 86,000 cfs through the power house on the western edge of the dam, with high flows passing through flood gates along the dam length. Thus reservoir operations add additional uncertainties to the modeling process, with highly variable sediment processes (scour and deposition) likely in the vicinity of the flood gates, hydropower intake, and the dam itself.

This sediment load analysis indicates that approximately 5 percent of the total annual load is accounted for by flows equal to or less than 30,000 cfs. Thus the bulk of the annual sediment load is passed into the reservoir for the higher flows for which the water column is relatively well mixed and stream-wise velocity is the dominant transport process. For this flow condition, 1D and 2D models can provide adequate resolution of sediment processes.

Based on the findings of this study, the application of the AdH 2D sediment transport model to Conowingo reservoir is adequate for simulating general reservoir sediment scour and deposition modeling scenarios (flows that define the reservoir morphology). Although there are 3D effects in the reservoir that occur during certain flow conditions and dam operations, they are not significant enough to warrant a 3D model application.

7.0 REFERENCES

Brown, Gary, “A Quasi-3D Suspended Sediment Model Using a Set of Correction Factors Applied to a Depth Averaged Advection Diffusion Equation”, presentation to IIHR 3rd International Shallow Flows Symposium, University of Iowa, 2012.

Exelon Corporation, “Revised Study Plan for the Conowingo Hydroelectric Project”, FERC No. 405, December 22, 2009.

Exelon Corporation, “Sediment Introduction and Transport Study”, RSP 3.15, Conowingo Hydroelectric Project, FERC No. 405, May 2011.

Haun, Stefan, et al, “Three-dimensional Numerical Modeling of the Flushing Process at Kalik Gandaki Hydropower Reservoir”, Lakes and Reservoir: Research and Management 2012, Vol 17, pp 25-33.

Rouse, H. (1937), “Modern conceptions of the mechanics of fluid turbulence”, transactions of the American Society of Civil Engineers, Vol. 102 pp 463-554.

US Geological Survey (USGS), “Deposition and Simulation of Sediment Transport in the Lower Susquehanna River Reservoir System”, Water Resources Investigations Report 94 – 4122, November 3, 1994.

US Bureau of Reclamation (USBR) Publication, “Erosion and Sedimentation Manual”, November 2006, Chapter 2.

Attachment B-2:
SEDflume Erosion Data and Analysis

Attachment B-2

Sedflume Erosion Data and Analysis

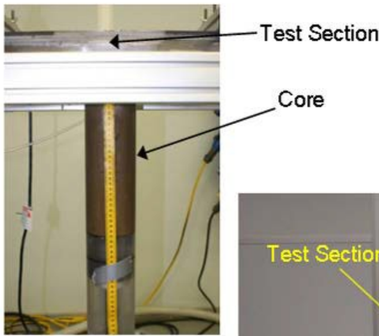
The Conowingo Reservoir sediment bed is composed of cohesive sediments. Non-cohesive sediment (sand and gravel) erosion and settling can be generally estimated from grain size distribution and mineral density. Cohesive sediment transport processes are dominated by other factors. Cohesive sediments are generally a mixture of sand, silt, and clay sized particles.

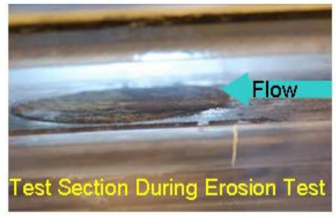
A general definition for cohesive sediment is sediment for which the erosion rate cannot be estimated by standard sand/gravel transport methods. In these cases, cohesive forces are equivalent to or are greater than the gravitational forces that dominate sand transport. Cohesive sediment erosion characteristics are highly dependent upon factors such as particle size distribution, particle coatings, fine sediment mineralogy, organic content, bulk density, gas content, pore-water chemistry, and biological activity. Erosion rate and critical shear stress for erosion can vary significantly with small changes in only one of these interdependent parameters. It has been well demonstrated that critical stress and erosion rates for cohesive sediment can vary over several orders of magnitude for sediments with only slightly differing properties. Therefore, the influence of cohesion on sediment processes is significant. Qualitatively, it is understood which properties most significantly influence erosion. However, there are no quantitative methods available to determine erosion rate from cohesive sediment properties. Therefore, due to the sensitivity and wide range of influencing parameters, erosion characteristics of cohesive sediments are determined by site-specific analysis of erosion with erosion flumes.

Several flumes are available to parameterize site-specific cohesive sediment erosion algorithms. Most of these devices operate over a range of low shear stress (<2 Pa) and are consequently capable of measuring only surface sediment erosion. Sedflume is an erosion device with capability to impose bed stresses in the range of 0.1 to 12 Pa and measures erosion rates from sediment cores taken from the field (for in-situ or stratified bed conditions) or prepared in the laboratory (for assessing disturbed sediments such as dredged material). Sedflume is designed to quantify erosion rates for surface and sub-surface sediments. These measurements permit description of the vertical variation of erosion rate within the bed. It should be noted that even if sediments are well mixed, cohesive sediment bed erosion will change with depth due to the influence of consolidation (bed density) on erosion rate. Erosion rate can vary by several orders of magnitude between surficial sediments and sediment buried less than 30 cm below the surface. Sedflume was selected to quantify erosion rate and erosion rate variation with depth (density) for this study.

Methods

This section describes the field experiments, sampling and experimental methods, and data analysis methods used in determining cohesive sediment erosion within Conowingo Reservoir. Background and technical information about the experimental device is presented first, followed by description of how these devices were deployed during field experiments to meet the study objectives.





Shear stress t (Pa)	Flow Rate (GPM)
0.1	6.1
0.2	9.1
0.4	13.5
0.6	17.0
0.8	20.1
1.2	25.3
1.6	29.8
2.4	37.4
3.2	44.0
4	49.9
5	56.6
6.4	65.0
8	73.7
10	83.5
12	92.5
13	96.7
14	100.8

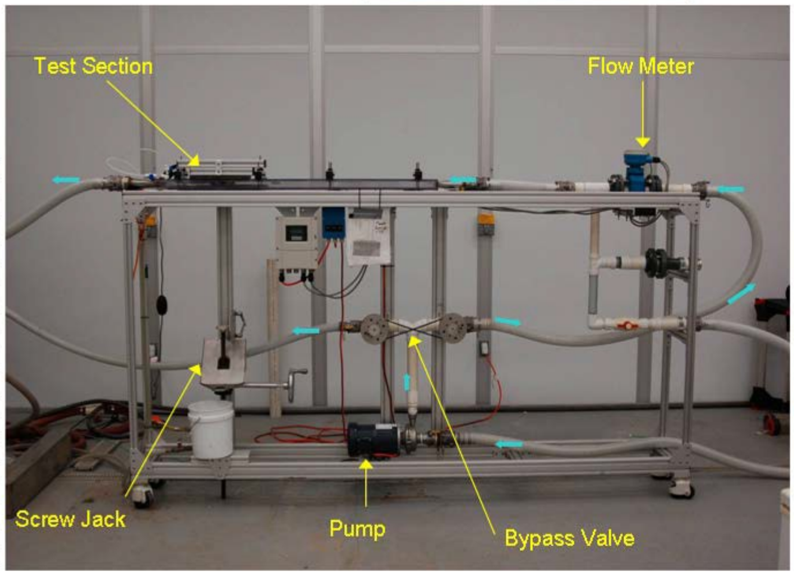


Figure 1. Sedflume erosion flume (lower right). Core inserted into test section (upper left). Core surface flush with bottom of flow channel (upper right). Table of shear stress associated with channel flow rates (lower left).

Sedflume

Sedflume is a field- or laboratory-deployable flume for quantifying cohesive sediment erosion. The USACE-developed Sedflume is a derivative of the flume developed by researchers at the University of California at Santa Barbara (McNeil et al. 1996). The flume includes an 80-cm-long inlet section (Figure 1) with cross-sectional area of 2 × 10 cm for uniform, fully developed, smooth-turbulent flow. The inlet section is followed by a 15-cm-long test section with a 10 × 15 cm open bottom (the open bottom can accept cores with rectangular cross-section (10 × 15 cm) or circular cross-section (10-cm diameter)). Coring tubes and flume test section, inlet section, and exit sections are constructed of clear polycarbonate materials to permit observation of sediment-water interactions during the course of erosion experiments. The flume includes a port over the test section to provide access to the core surface for physical sampling. The flume accepts sediment cores up to 80-cm in length.

Erosion Experiments

Prior to the erosion experiment, descriptions of the core are recorded, including length, condition of the core surface, biological activity, and any visual evidence of layering. Cores are inserted into the testing section of Sedflume and a screw jack is used to advance the plunger such that the core surface becomes flush with the bottom wall of the flume. Flow is directed over the sample by diverting flow from a

3-hp pump, through a 5-cm inner diameter hose, into the flume. The flow through the flume produces shear stress on the surface of the core. (Numerical, experimental, and analytical analyses have been performed to relate flowrate to bottom shear stress.) Erosion of the surface sediment is initiated as the shear stress is increased beyond the critical stress for erosion, τ_{cr}. As sediment erodes from the core surface, the operator advances the screw jack to maintain the sediment surface flush with the bottom wall of the erosion flume. Figure 1 includes a photograph of the flume, a close-up photograph of the test section, and a table of flow rate/shear stress relationships.

Erosion rate is determined from the displacement of the core surface over the elapsed time of the experiment. Generally, erosion experiments are performed in repeating sequences of increasing shear stress. Operator experience permits sequencing of erosion tests to allow greater vertical resolution of shear stress/erosion rate data where required. The duration of each erosion experiment at a specified shear stress is dependent on the rate of erosion and generally is between 0.25 and 15 minutes. Shear stresses that induce no measurable erosion are also recorded. The range of shear stress for each cycle is determined by the operator based on the previous erosion sequences and erosion behavior during the ongoing sequence.

Sediment Bulk Properties

Physical samples for bulk sediment property measurements are taken at approximately 3-5 cm intervals during erosion experiments, generally at the end of each shear stress cycle. Physical samples are collected by draining the flume channel, opening the port over the test section, and extracting a sample from the sediment bed. Properties measured include bulk density and grain-size distribution, and separate samples were collected from the core surface for these analyses. These properties strongly influence erosion; therefore, understanding their variation with depth is important in interpreting the erosion data.

Bulk Density Measurements. Bulk sediment density of physical samples is determined by a wet-dry weight analysis. Physical samples are extracted from the saturated core surface and placed in a pre-weighed aluminum tray. Sample weight is recorded immediately after collection and again after a minimum of 12 hours in an 90° C (194° F) drying oven. Wet weight of the sample was calculated by subtracting tare weight from the weight of the sample. The dry weight of the sample was calculated as the tare weight subtracted from the weight after drying. The water content w is then given

$$w = \left(\frac{m_w - m_d}{m_d} \right) \tag{1}$$

where m_W and m_d are the wet and dry weights, respectively. A volume of saturated sediment, V, consists of both solid particles and water and can be written as

$$V = V_s + V_w \tag{2}$$

where V_S is the volume of solid particles and V_W is the volume of water. If the sediment particles and water have density ρ_S and ρ_W, respectively, the water content of the sediment can be written as

$$w = \frac{\rho_w V_w}{\rho_s V_s} \tag{3}$$

A mass balance of the volume of sediment gives

$$\rho V = \rho_s V_s + \rho_w V_w \tag{4}$$

where ρ is the bulk density of the sediment sample.

(1)-(4) are used to derive an explicit expression for the bulk density of the sediment sample, ρ, as a function of the water content, w, and the densities of the sediment particles and water. This equation is

$$\rho = \rho_s + \frac{w\rho_s\left(\rho_w - \rho_s\right)}{\rho_w + w\rho_s} \tag{5}$$

For the purpose of these calculations, $\rho_s = 2.65\ \mathrm{g\cdot cm^{-3}}$ and ρ_w is calculated for measured pore water at sample temperature.

<u>Particle-Size Distribution.</u> Samples collected during erosion experiments were transported to the Sediment Transport Processes Lab at ERDC for grain size analysis. A Beckman-Coulter LS 13-320 laser particle-sizer was used to measure the particle-size distributions in sub-samples collected from the cores. The LS 13-320 measures particle size over the range 0.4 to 900 µm. Particle size distributions were measured by first removing and sieving particles larger than 850 µm. The passing portion of the sample was added to a small volume of water (approximately 150 mL) and sonicated using a high-powered laboratory sonicator to disperse the sediment. The dispersed solution was placed in the particle sizer fluid module. The sample is pumped and recirculated through the optical module. The optical module includes a spatial filter assembly containing a laser diode and laser beam collimator. The diffraction detector assembly contains a custom photodetector array that is used for the measurement of light scattering by the suspended particles. The distribution of grain sizes and median grain sizes is derived from this light scattering measurement. The size distribution of fines passing the 850 µm sieve is scaled to account for the sediment mass retained on the sieve. Organic material was not oxidized before grain size analysis was performed; therefore grain size distributions include organic material.

Multivariate Erosion Rate Prediction

The goal of erosion data analysis is to determine appropriate parameterization of erosion processes for numerical modeling studies. For this study, the erosion data are to be described in the SEDZLJ model. SEDZLJ is flexible in the form of the erosion equation, and the effects of bulk density, depth, and applied shear stress may be represented as indicated by the erosion data. Analysis of the erosion data from Conowingo Reservoir suggested that the erosion algorithm should be of the following form:

$$\begin{aligned} E &= 0; && (\tau < \tau_c) \\ E &= A\tau^n; && (\tau_c < \tau < \tau_m) \\ E &= A\tau_m^n; && (\tau > \tau_m) \end{aligned} \tag{6}$$

where E represents erosion rate ($\mathrm{cm\cdot s^{-1}}$) from the bed, τ is bed shear stress, τ_c is critical stress for erosion, A is an empirical constant, n is an empirical exponent, and τ_m is bed stress at which erosion rate becomes constant. Solution of Equation (6) to data requires solving for three parameters, τ_c, A, and n. Bed stress for the upper limit of erosion rate is determined by examining the data. The best fit of Equation (6) to measured data is accomplished through an iterative, multi-parameter, least-squares method on the linear transform of Equation (6).

Field Experiments

Field experiments were conducted from April 11 through April 16 of 2012. Field experiments included core collection, physical sampling, and cohesive sediment erosion experiments.

Core Collection

On April 11, 2012, eight 10-cm (4-inch) diameter cores were collected from eight locations (Figure 2, Table 1) within Conowingo Reservoir for the purpose of erosion experiments. The eight core collection locations were provided to ERDC by the United State Geological Survey (USGS), in Maryland State Plane North American Datum (NAD) 83 northing and easting. A gravity corer was used to collect a core from each location.

Table 1. Core Summary

Core ID	Northing	Easting	Collection Method	Collection Date	Sample Depth (cm below sediment surface)
Station 1	728720	1541780	Gravity	11 April 2012	20
Station 2	737040	1535500	Gravity	11 April 2012	36
Station 3	735660	1534110	Gravity	11 April 2012	26.5
Station 4	743790	1530280	Gravity	11 April 2012	18
Station 5	743520	1528760	Gravity	11 April 2012	30.5
Station 6	757140	1527370	Gravity	11 April 2012	19.5
Station 9	766460	1518910	Gravity	11 April 2012	17.5
Station 10	772540	1514680	Gravity	11 April 2012	19.5

The ERDC gravity corer (Figure 3A) is constructed of steel and weighs approximately 32 kg (70 lbs). The gravity corer consists of a core barrel, check valve, fins, and cable harness. The gravity corer is lowered to the bottom and penetrates the bed by its own weight and momentum. The check valve serves to create a seal above the core to prevent the captured sediment core from slipping out of the core tube. Once the core is retrieved to the vessel, a plunger with Bentonite paste (for sealing and lubrication) is inserted into the bottom of the core and each end of the core is sealed with end caps (Figures 3B-C). Each core was labeled, logged, and stored submerged in water on the vessel deck.

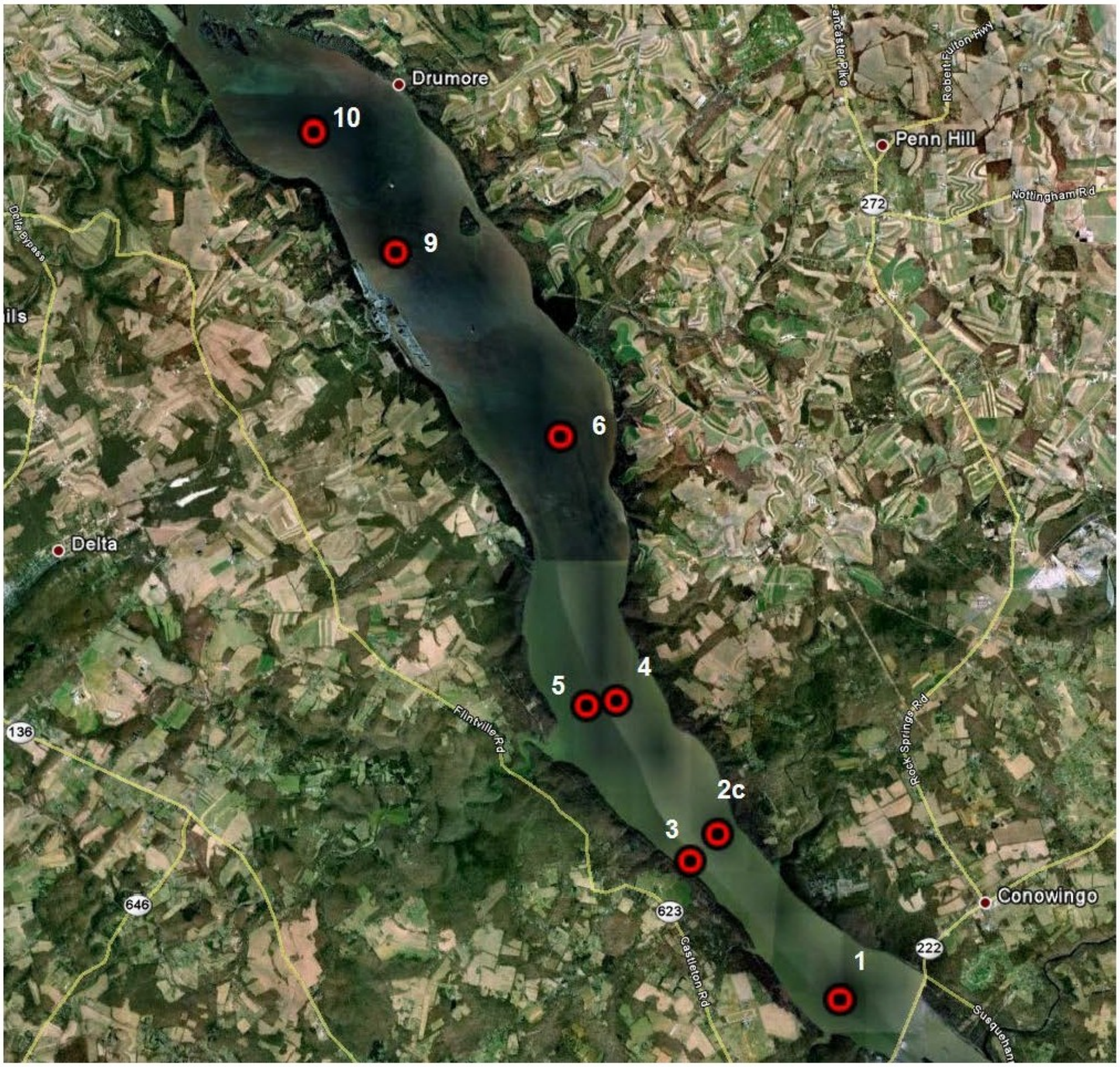


Figure 2. Coring locations in Conowingo Reservoir, MD.

B) Plungers with Bentonite paste

A) Gravity Corer

C) Core with plunger in

Erosion Experiments

Cores collected were transported by vessel to the ERDC-CHL Field Sediment Laboratory (located on Conowingo Reservoir at the Glen Cove Marina site). Erosion experiments were conducted 13 April through 16 April 2012, in the field laboratory following the Sedflume methods presented earlier in this report. During the time of erosion experiments, sediment cores were stored in a shaded barrel, filled with site water.

Results and Discussion

Cohesive sediment transport process data collected during the field study were analyzed to determine SEDZLJ model parameterizations for cohesive sediment erosion and settling velocity. This section presents results of the data analysis, model parameterization, and general observation with discussion. This report presents physical descriptions of each core including:, bed density profiles, grain size analysis, and erosion analysis of each core, including definition of bed layers that erode similarly.

Cohesive Sediment Erosion

Analysis of cohesive sediment erosion data obtained from undisturbed field cores is inherently complex. Cohesive sediment erosion is sensitive to slight changes in bed density, deposit mineralogy, gas content, organic content, biological activity, debris and a host of other factors. In many cases, these factors change significantly at relatively small vertical scales (such as depositional bed sequences). Consequently, measured cohesive sediment erosion rates from field cores are notoriously variable. To compensate for the large variance in measured erosion rates, field erosion experiments are conducted in a manner to produce a large sample from which to derive statistically representative relationships for various numerical erosion algorithms. To ensure high quality in the data analysis, data and associated experimental notes are evaluated to identify outliers in the dataset. Outliers are rejected based on comparisons between adjacent data points and experimental log notes.

Cores 1-5 (from the downstream half of the reservoir) were composed primarily of silt and clay and the sediment composition was fairly uniform with depth aside from the occasional increase in leafy organic matter or the occasional sand lens. Sand content generally increased upstream of Core 6 and sediment composition became more variable with depth. The composition of Core 10 was highly variable with depth, with as much as 80% sand content.

Erosion Parameterization

Erosion rate data were evaluated for relationships between erosion rate, bed density, and applied shear stress. In general, the erosion behavior of the cores gradually varied with depth. The occasional sand lens or change in organic content occasionally produced distinctly different erosion behavior. The erosion data were grouped in layers to account for the changing critical erosion depth and erosion rates with depth.

The erosion data from Core 1 will be presented here to illustrate the parameterization of the erosion data from Conowingo Reservoir. The composition of Core 1 was very uniform and was predominantly silt (80-85% silt from the physical samples). Figure 3 presents the erosion data with depth. First, the erosion data were grouped vertically within cores. This grouping was accomplished by reviewing the erosion notes and erosion rate relationships to depth, density, and shear stress. At the sediment water interface, there is typically a thin, low-density layer that erodes more easily than the more highly consolidated sediments deeper in the sediment bed. This was observed for Core 1 between depths of 0 – 4 cm into the core with a critical shear stress of 0.2 Pa, which is defined as Layer Core01_L1. Beneath the surface layer was a layer from 5 – 10 cm that had a critical shear stress of 0.4 Pa, and reduced erosion rate associated with the increase in bed density with depth into the core. Core01_L3 (10-14 cm depth) was associated with an increase in critical shear stress to 0.8 Pa and further reduction of erosion rates with depth into the core.

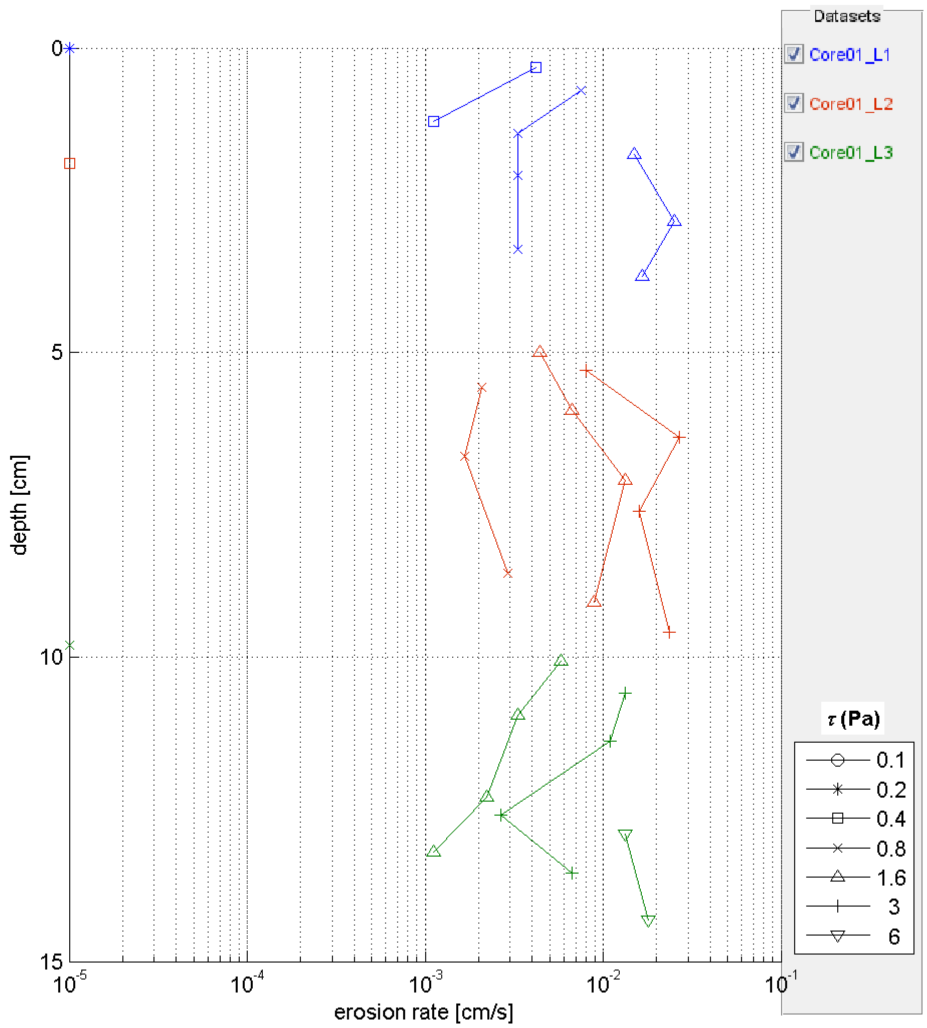
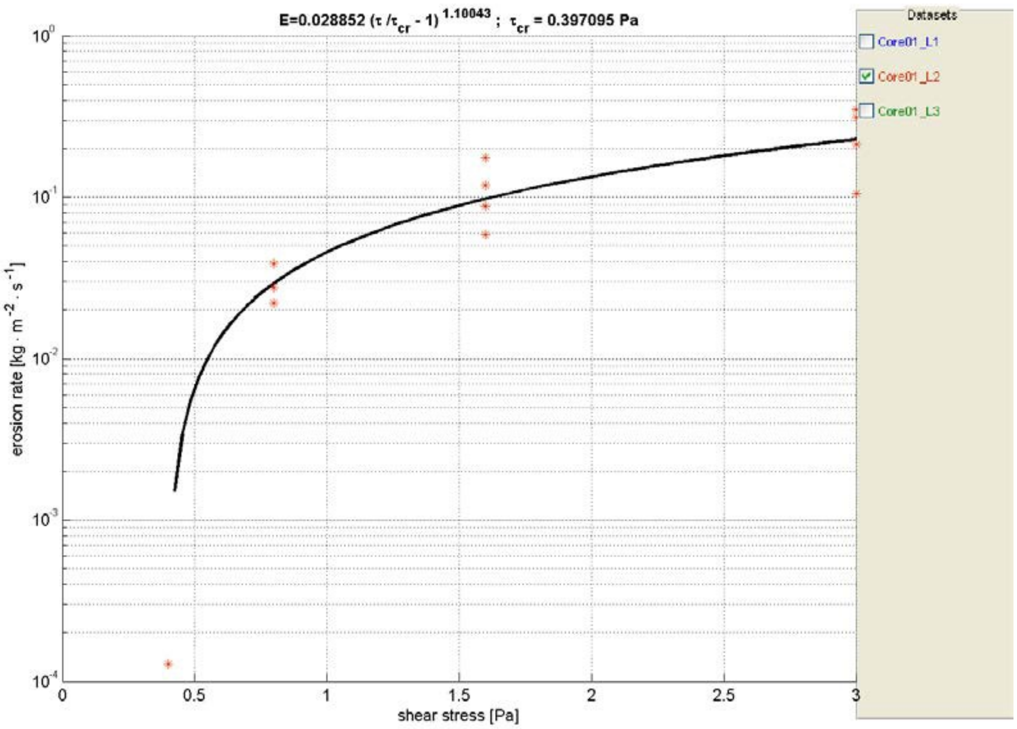


Figure 3. Erosion rate data of Core 1. For erosion rate data set, colors indicate the layers of the core as inferred from erosion data visual observations and physical properties

A multivariate, least-squares fit of erosion rate to shear stress for the standard form of the Partheniades erosion equation (Core 01, Layer 2) is presented in the upper plot of Figure 4. In the bottom plot of Figure 4, a parameterization of the piece-wise linear form of the Partheniades implementation in HEC-RAS is presented. Erosion parameterization for each layer in each core is provided in Table 2 (Full Partheniades) and Table 3 (HEC-RAS Partheniades). For instances where the range of erosion measurements was nearly linear, the second limb of the HEC-RAS parameterization is not provided.



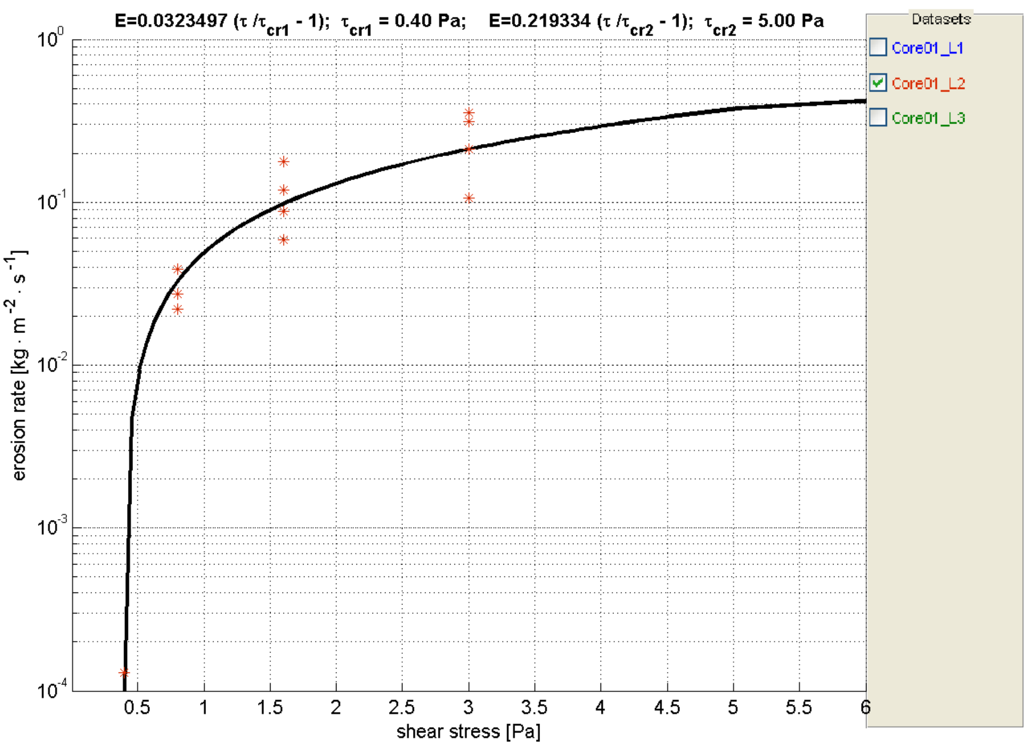


Figure 4. Erosion parameterization for Core 1, Layer 2. (Upper) best-fit line to Partheniades' erosion

All cores collected exhibited cohesive erosion behavior. Critical shear stress for erosion generally increased with depth and erosion rates at a given shear stress decreased with depth. These are common observations associated with stronger bonding with increased sediment consolidation and density.

Table 2. Cohesive Sediment Erosion Parameterization

Layer ID	Depth (cm)	Critical Shear (τ_{cr})	Erosion Rate Constant (M)	Erosion Rate Exponent (n)
		Pa	-	-
Core01_L1	0-4	0.20	2.02E-02	1.14
Core01_L2	5-10	0.40	2.89E-02	1.10
Core01_L3	10-14	0.80	3.52E-02	0.96
Core02_L1	0-10	0.20	1.01E-01	1.05
Core02_L2	10-17	0.40	5.98E-02	1.52
Core02_L3	17-24	0.80	3.73E-02	1.36
Core02_L4	24-32	1.60	9.18E-02	0.92
Core02_L3&4	17-32	0.80	3.86E-02	0.92
Core03_L1	0-2.5	0.20	9.90E-03	0.98
Core03_L2	2.5-22	0.80	8.08E-02	1.00
Core04_L1	0-2	0.20	1.04E-02	1.21
Core04_L2	2-11	0.80	3.23E-02	0.90

Table 2. Cohesive Sediment Erosion Parameterization				
		Critical Shear (τ_{cr})	Erosion Rate Constant (M)	Erosion Rate Exponent (n)
Layer ID	Depth (cm)	Pa	-	-
Core05_L1	0-5	0.20	1.20E-02	1.04
Core05_L2	5-12	0.78	2.17E-02	1.37
Core05_L3	12-24	1.60	9.80E-02	0.99
Core06_L1	0-2	0.10	1.48E-02	0.90
Core06_L2	2-14	1.60	3.31E-02	1.04
Core09_L1	0-2	0.20	8.20E-03	1.41
Core09_L2	2-9	1.52	2.32E-02	1.36
Core10_L1	0-8	0.18	3.40E-02	1.31
Core10_L2	8-16	1.14	1.70E-02	1.61

Table 3. Cohesive Sediment Erosion Parameterization for HEC-RAS

Layer ID	Depth (cm)	Shear Threshold		Erosion Rate		Mass Wasting Threshold		Mass Wasting Rate	
		Pa	lb/ft2	kg/m2/s	lb/ft2/hr	Pa	lb/ft2	kg/m2/s	lb/ft2/hr
Core01_L1	0-4	0.2	0.0042	2.02E-02	14.9	1	0.0209	0.263	193.9099
Core01_L2	5-10	0.4	0.0084	3.24E-02	23.9	-	-	-	-
Core01_L3	10-14	0.8	0.0167	3.39E-02	25.0	-	-	-	-
Core02_L1	0-10	0.2	0.0042	1.04E-01	76.7	-	-	-	-
Core02_L2	10-17	0.4	0.0084	6.32E-02	46.6	0.9	0.0188	0.323	238
Core02_L3	17-24	0.8	0.0167	4.62E-02	34.1	-	-	-	-
Core02_L4	24-32	1.6	0.0334	8.86E-02	65.3	-	-	-	-
Core02_L3&4	17-32	0.8	0.0167	3.53E-02	26.0	-	-	-	-
Core03_L1	0-2.5	0.2	0.0042	9.60E-03	7.08	-	-	-	-
Core03_L2	2.5-22	0.8	0.0167	8.07E-02	59.5	-	-	-	-
Core03_L1&2	0-22	0.2	0.0042	1.09E-02	8.04	2	0.0418	0.237	175
Core04_L1	0-2	0.2	0.0042	1.20E-02	8.85	0.8	0.0167	0.087	64.1
Core04_L2	2-11	0.8	0.0167	2.82E-02	20.8	-	-	-	-
Core05_L1	0-5	0.2	0.0042	1.28E-02	9.44	-	-	-	-
Core05_L2	5-12	0.8	0.0167	2.22E-02	16.4	2	0.0418	0.125	92.2

Table 3. Cohesive Sediment Erosion Parameterization for HEC-RAS									
Layer ID	Depth (cm)	Shear Thresh-old		Erosion Rate		Mass Wasting Threshold		Mass Wasting Rate	
		Pa	lb/ft2	kg/m2/s	lb/ft2/hr	Pa	lb/ft2	kg/m2/s	lb/ft2/hr
Core05_L3	12-24	1.6	0.0334	9.76E-02	72.0	-	-	-	-
Core06_L1	0-2	0.1	0.0021	1.32E-02	9.73	-	-	-	-
Core06_L2	2-14	1.59	0.0332	3.41E-02	25.1	-	-	-	-
Core09_L1	0-2	0.2	0.0042	1.25E-02	9.22	0.8	0.0167	0.102	75.2
Core09_L2	2-9	1.58	0.033	3.43E-02	25.3	-	-	-	-
Core10_L1	0-8	0.19	0.004	5.08E-02	37.5	-	-	-	-
Core10_L2	8-16	1.19	0.0249	1.95E-02	14.4	2.8	0.0585	0.139	102

Summary

United States Army Corp of Engineers, Baltimore District commissioned the ERDC to conduct cohesive sediment erosion testing services for the purpose of defining erosion rates of reservoir bottom sediments at Conowingo Reservoir, Maryland. ERDC-CHL conducted the erosion testing in April 2012.

Eight, 4-inch (10-cm) diameter sediment cores were collected from the locations throughout Conowingo Reservoir. The cores were eroded in the Field Sediment Transport Laboratory that was operated at the Glen Cove Marina. During erosion experiments, the cores were visually described, eroded, and subsampled for physical properties. Erosion data were analyzed by the layers evident in each core and later grouped by core layers that demonstrated similar erosion characteristics. Empirical coefficients were determined for modeling cohesive sediment bed erosion for individual core layers and groups of core layers that had similar erosion behavior.

Acknowledgements

Mr. Michael Langland from the United States Geological Survey (USGS) provided background information on Conowingo Reservoir and recommended sediment sampling locations for the field data collection and analysis. Mr. Mike and Tommy Kirklin (contractors for USACE-CHL) assisted with core collection, erosion experiments, and sample analysis.

References

Jepsen, R., Roberts, J, and Lick, W. 1997a. 'Effects of bulk density on sediment erosion rates', Water, Air, and Soil Pollution, 99, 21-31.

Core Physical Properties

Figure A-1a. Core 1 Surface Photograph, Sample 1.

Figure A-1b. Core 1 Surface Photograph, Sample 2.

Figure A-1c. Core 1 Surface Photograph, Sample 3.

Figure A-1d. Core 1 Surface Photograph, Sample 4.


Figure A-1e. Core 1 Surface Photograph, Sample 5.

Table A-1b. Physical Sample Properties (Core 1)								
Sample	Depth (cm below surf)	Bulk density (g/cm^3)	D10(µm)	D50(µm)	D90(µm)	Percent Sand	Percent Silt	Percent Clay
Surface	0.00	-	5.08	18.33	74.94	14.10	80.33	5.57
1	0.98	1.28	4.79	15.89	53.64	8.62	85.29	6.09
2	4.25	1.32	4.89	16.22	55.10	9.11	84.99	5.90
3	8.10	1.33	4.46	14.91	59.10	10.12	82.76	7.13
4	11.83	1.33	4.00	13.10	44.72	6.45	84.63	8.92
5	16.15	1.33	4.44	14.74	53.76	8.88	83.94	7.18

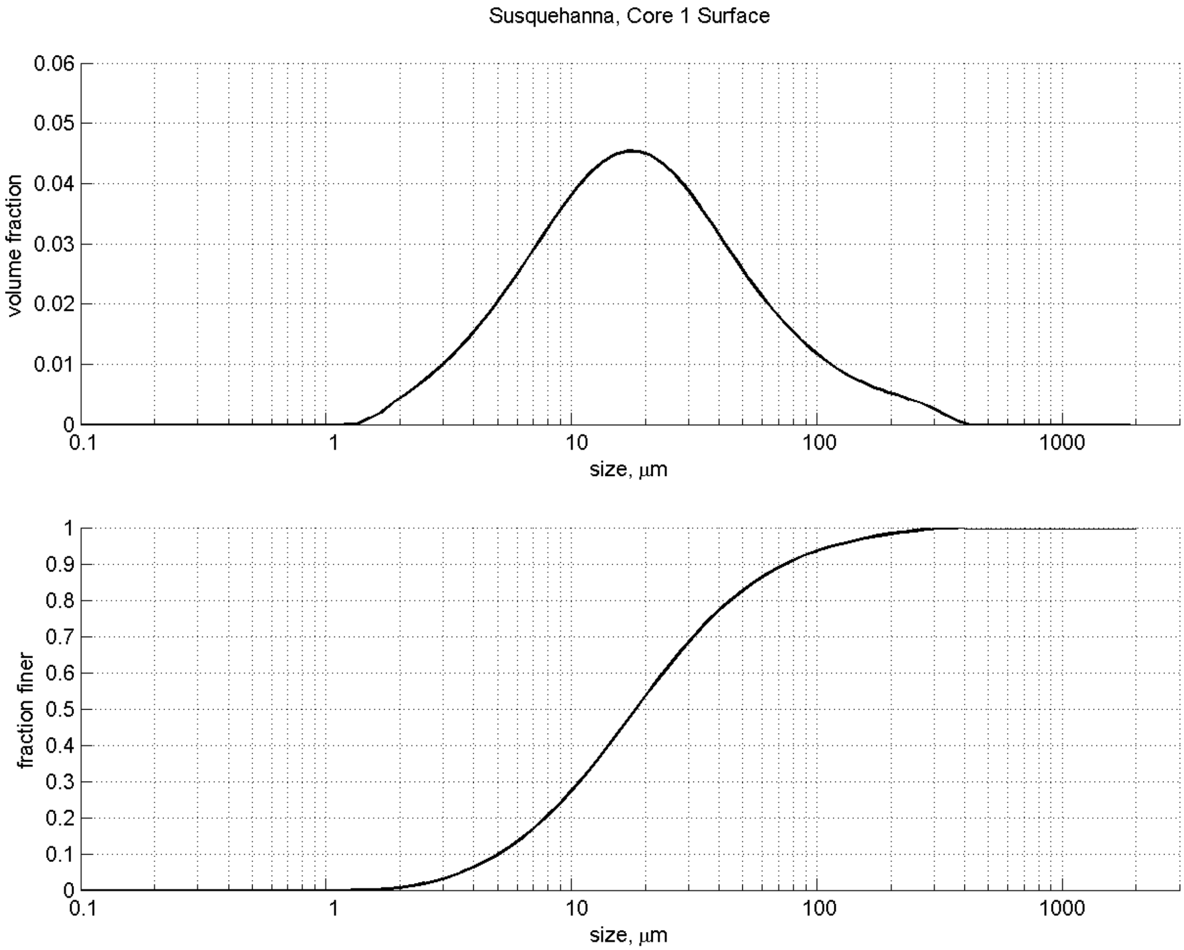


Figure A-2a. Grain Size Distribution for Core 1, Physical Sample.

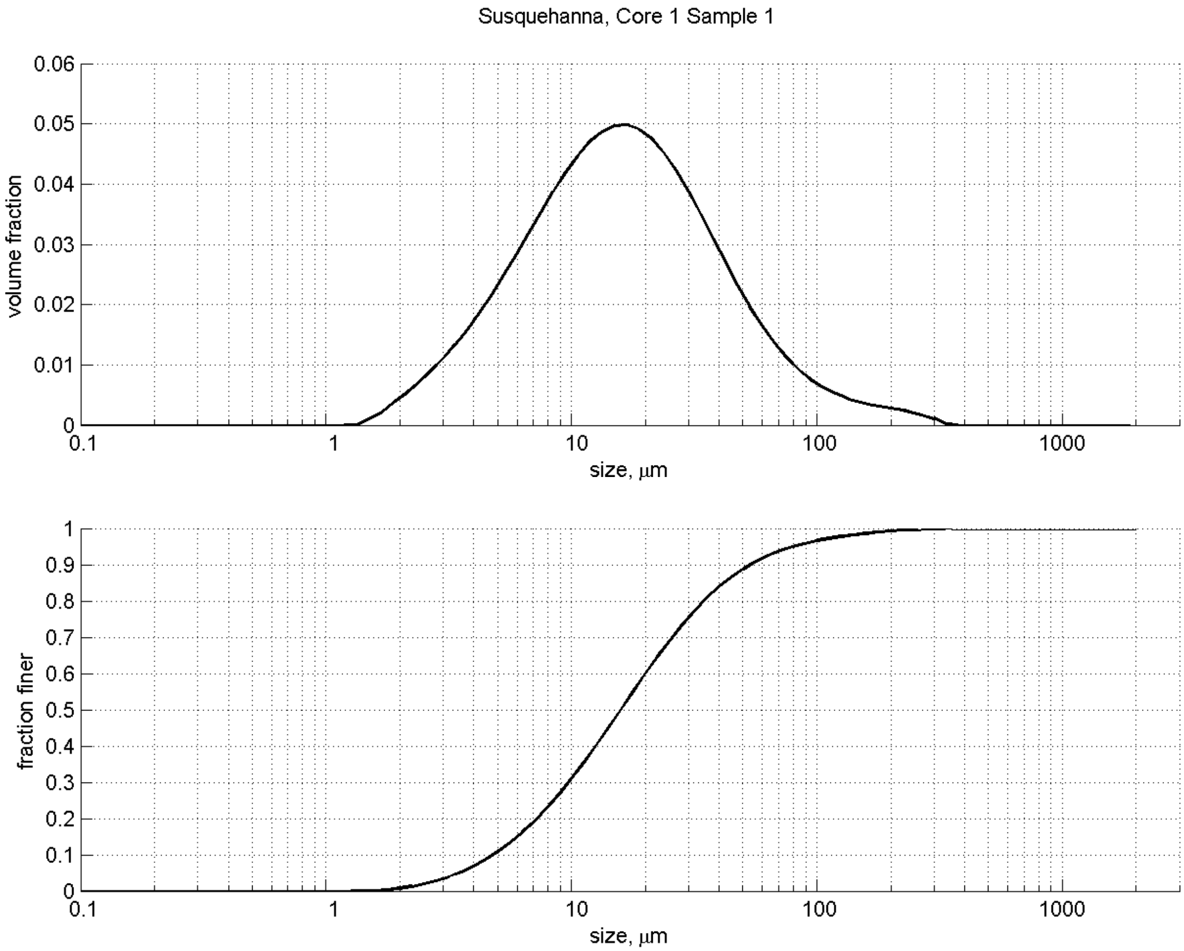


Figure A-2b. Grain Size Distribution for Core 1, Physical Sample.

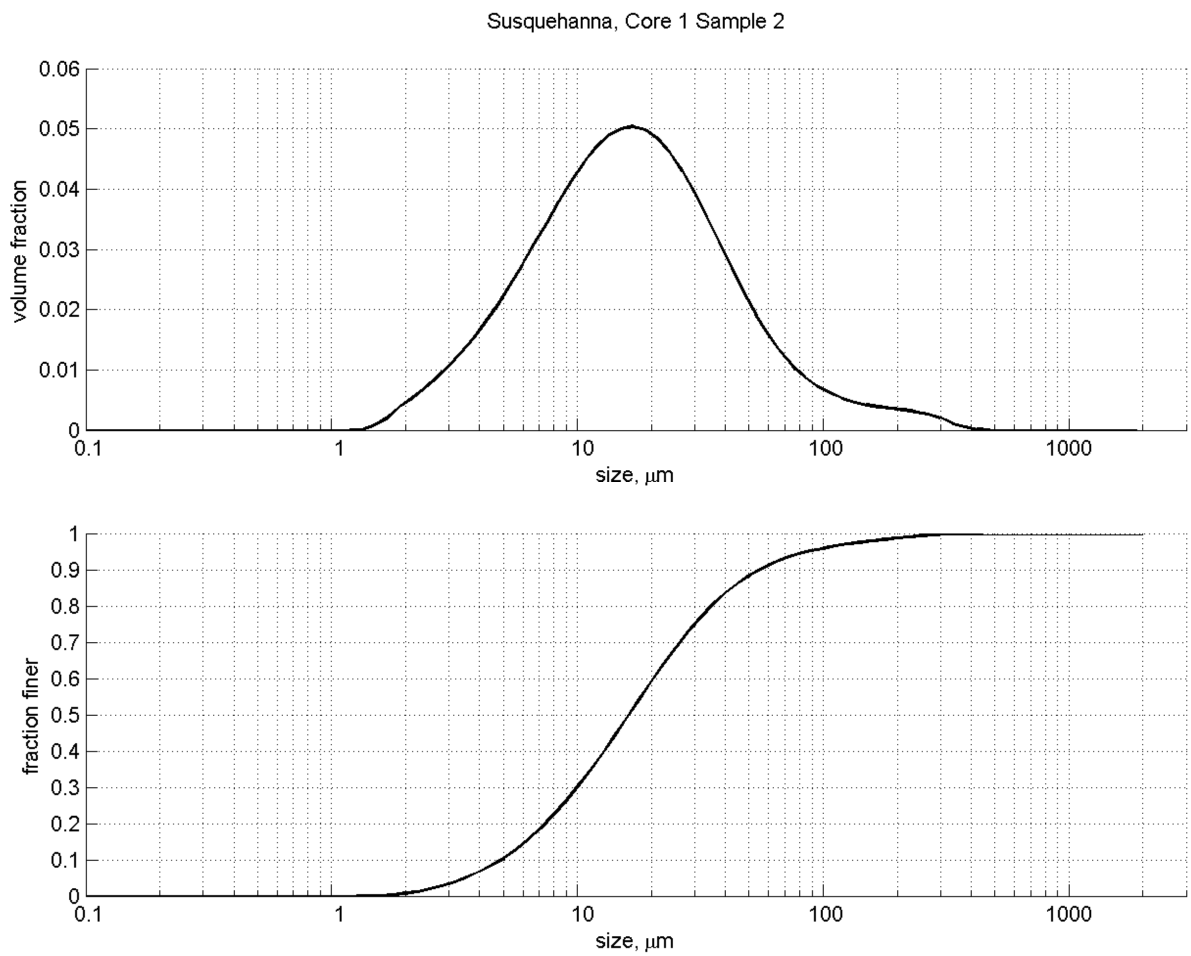


Figure A-2c. Grain Size Distribution for Core 1, Physical Sample.

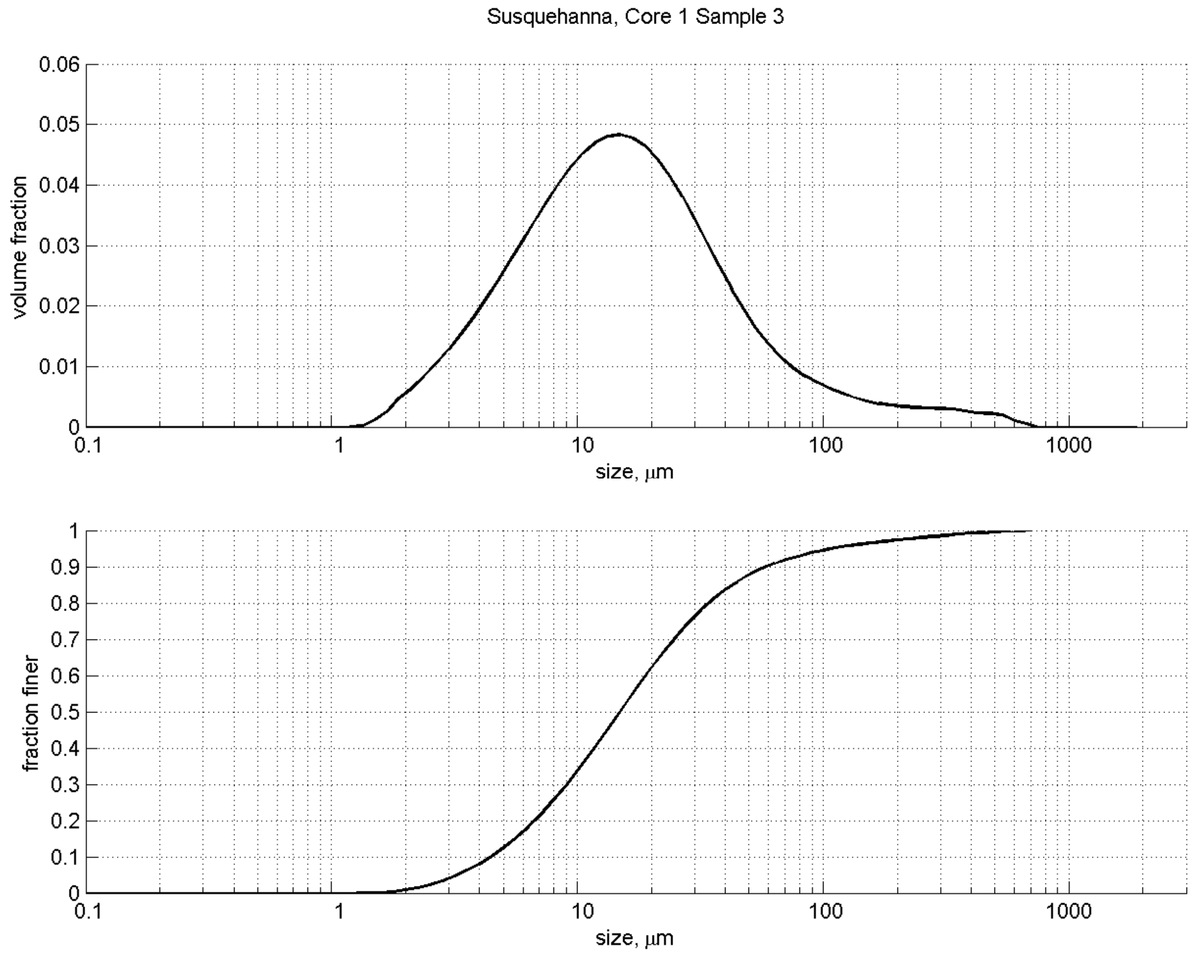


Figure A-2d. Grain Size Distribution for Core 1, Physical Sample.

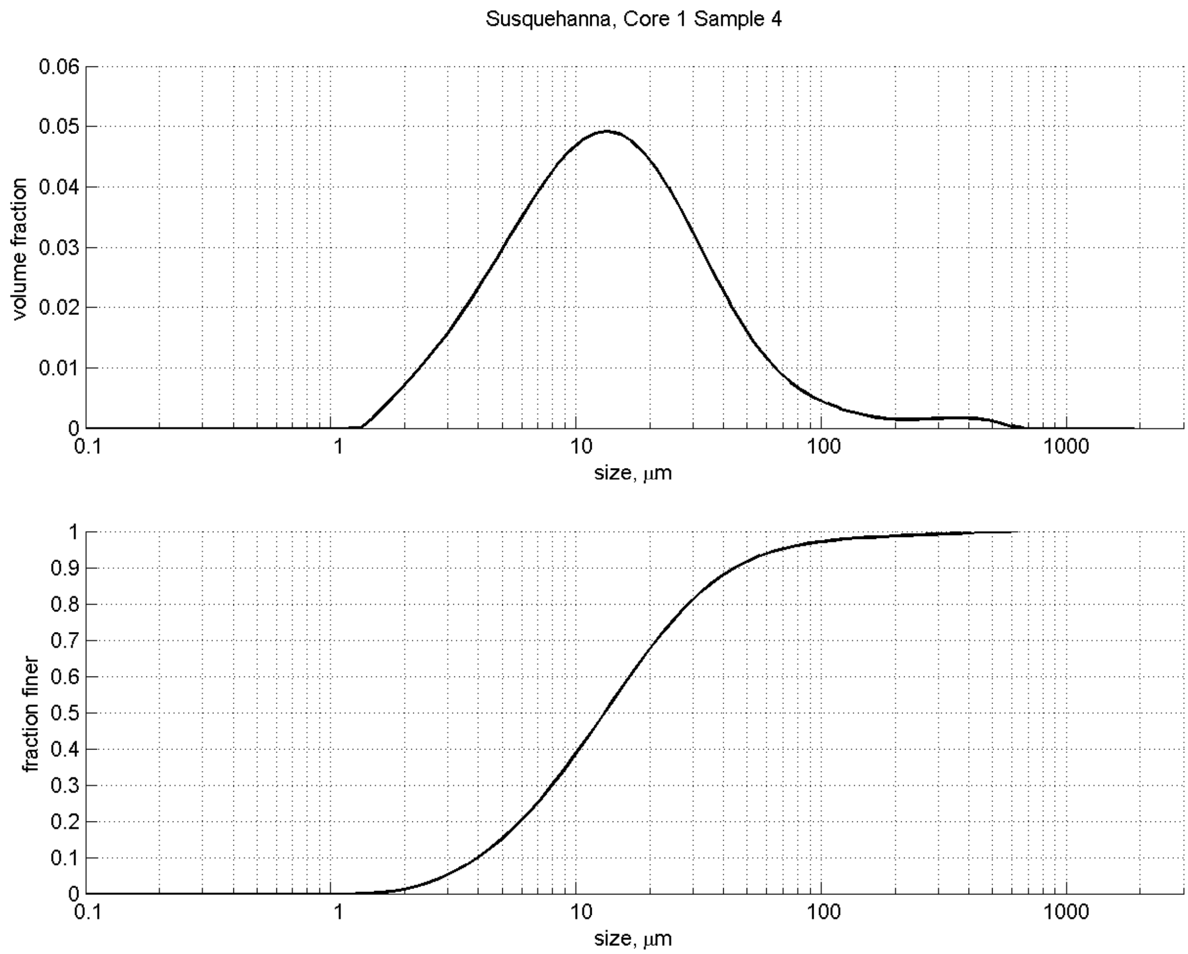


Figure A-2e. Grain Size Distribution for Core 1, Physical Sample.

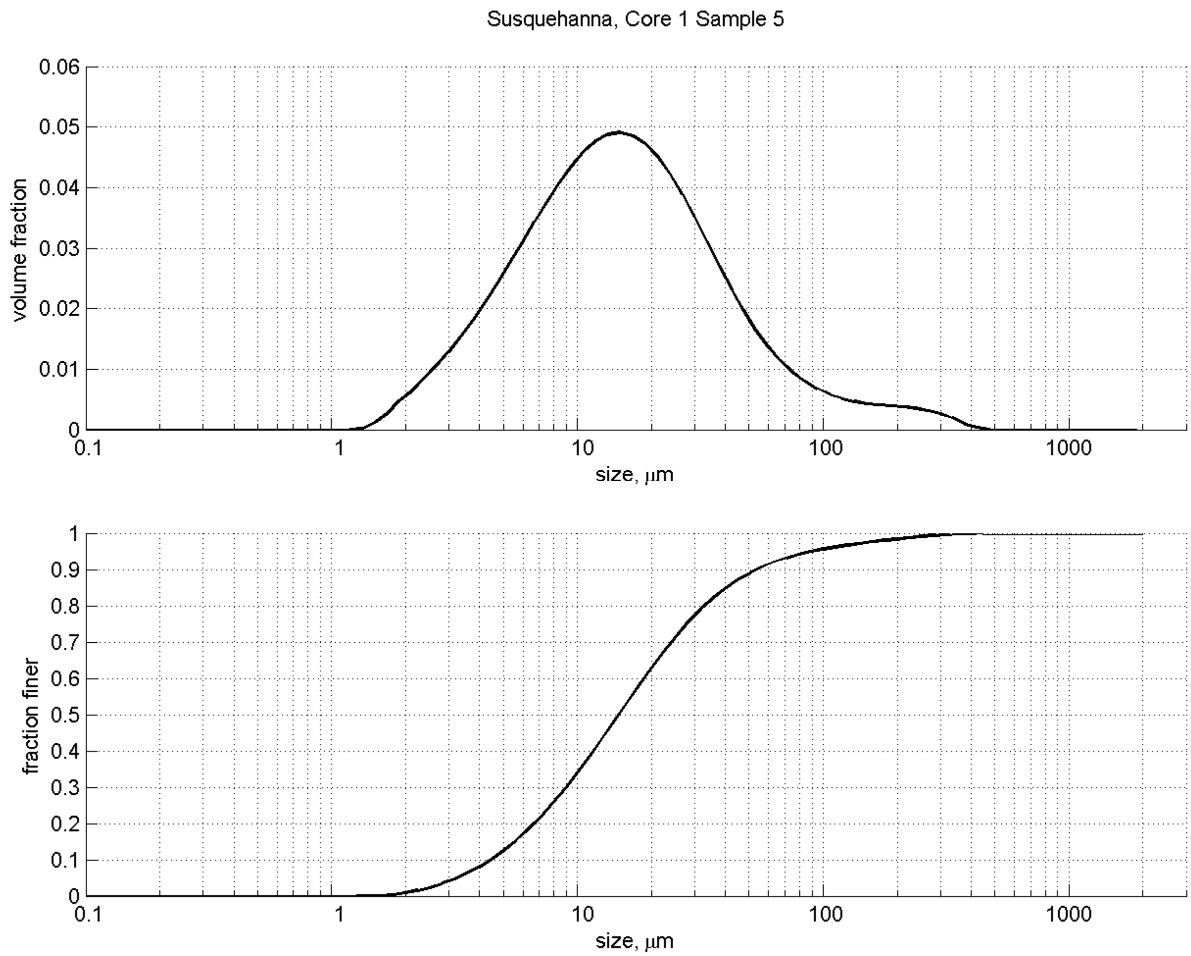


Figure A-2f. Grain Size Distribution for Core 1, Physical Sample.

Table A-2b. Physical Sample Properties (Core 2c)								
Sample	Depth (cm below surf)	Bulk den-sity (g/cm^3)	D10(µm)	D50(µm)	D90(µm)	Percent Sand	Percent Silt	Percent Clay
Surface	0.00	-	9.24	218.00	787.16	63.38	34.45	2.17
1	1.05	1.42	10.64	294.46	934.12	69.76	28.36	1.88
2	4.95	1.62	111.06	545.72	1113.57	95.84	3.95	0.20
3	9.63	1.67	7.71	70.78	589.44	52.74	44.44	2.83
4	13.80	1.38	5.73	23.96	98.95	21.78	73.66	4.56
5	17.30	1.30	5.72	20.25	78.32	15.36	80.31	4.33
6	20.80	1.39	6.00	24.57	103.06	22.36	73.56	4.08
7	25.80	1.38	5.62	22.32	96.57	19.99	75.40	4.62
8	30.60	1.44	6.61	26.44	115.64	24.59	72.17	3.24
9	32.63	1.43	5.27	21.99	96.87	19.85	74.85	5.31

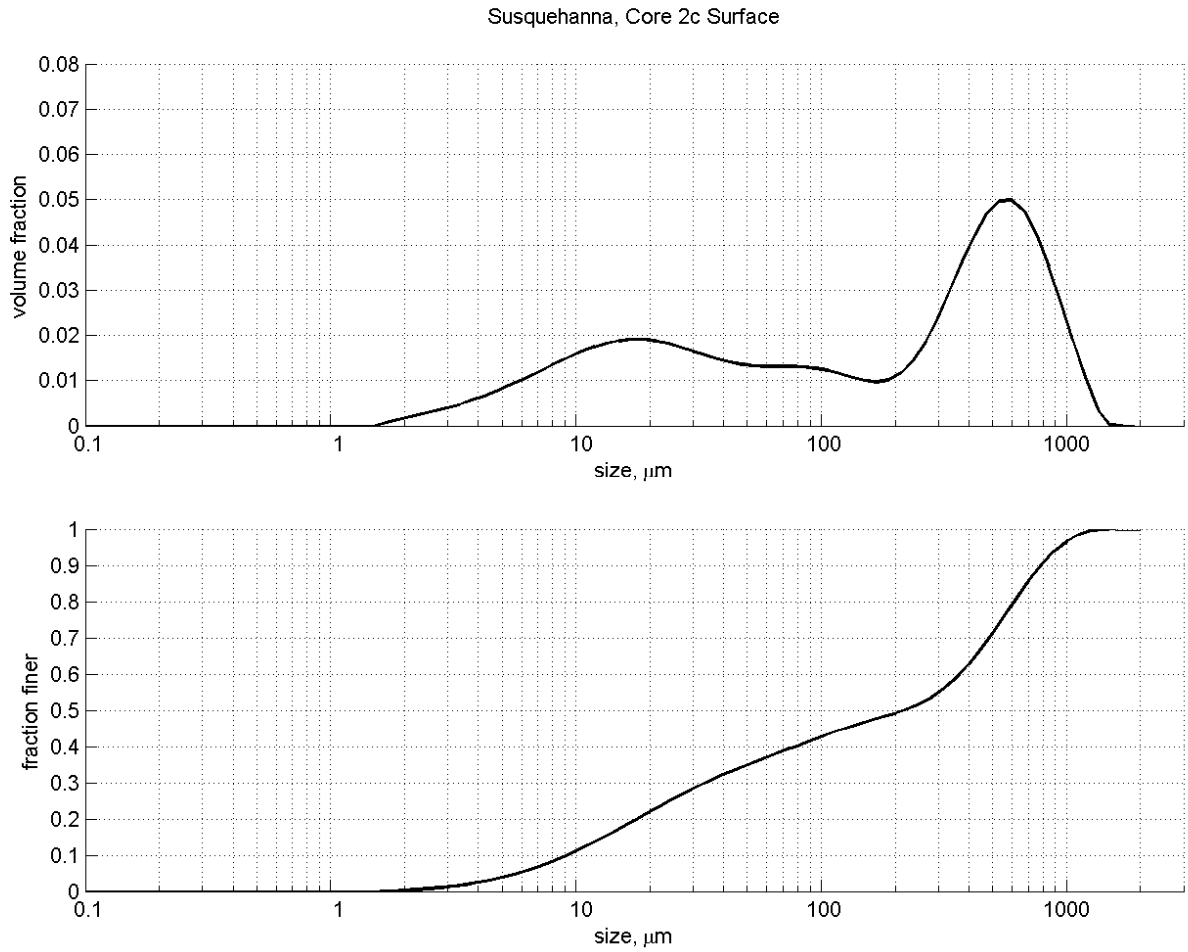


Figure A-4a. Grain Size Distribution for Core 2c, Physical Sample.

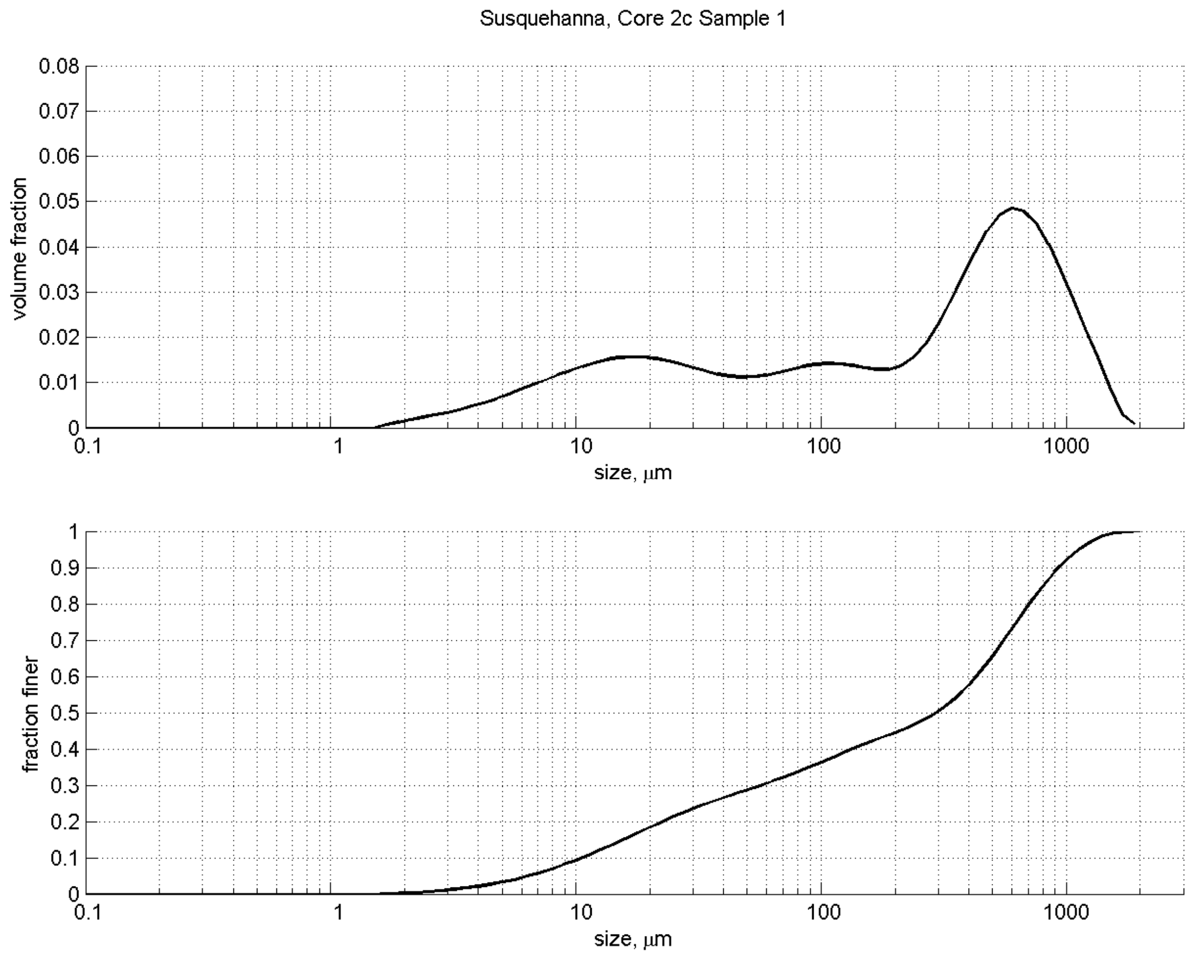


Figure A-4b. Grain Size Distribution for Core 2c, Physical Sample.

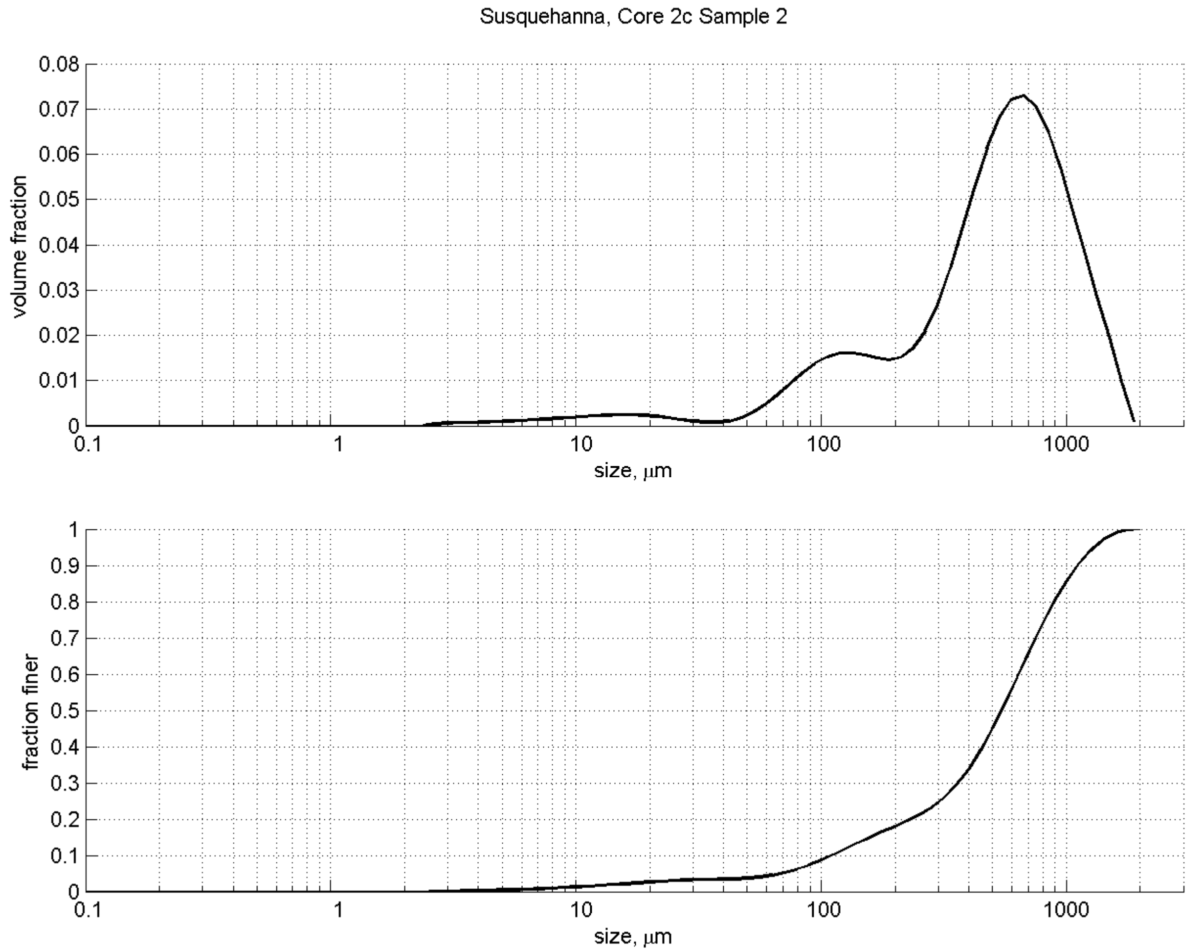


Figure A-4c. Grain Size Distribution for Core 2c, Physical Sample.

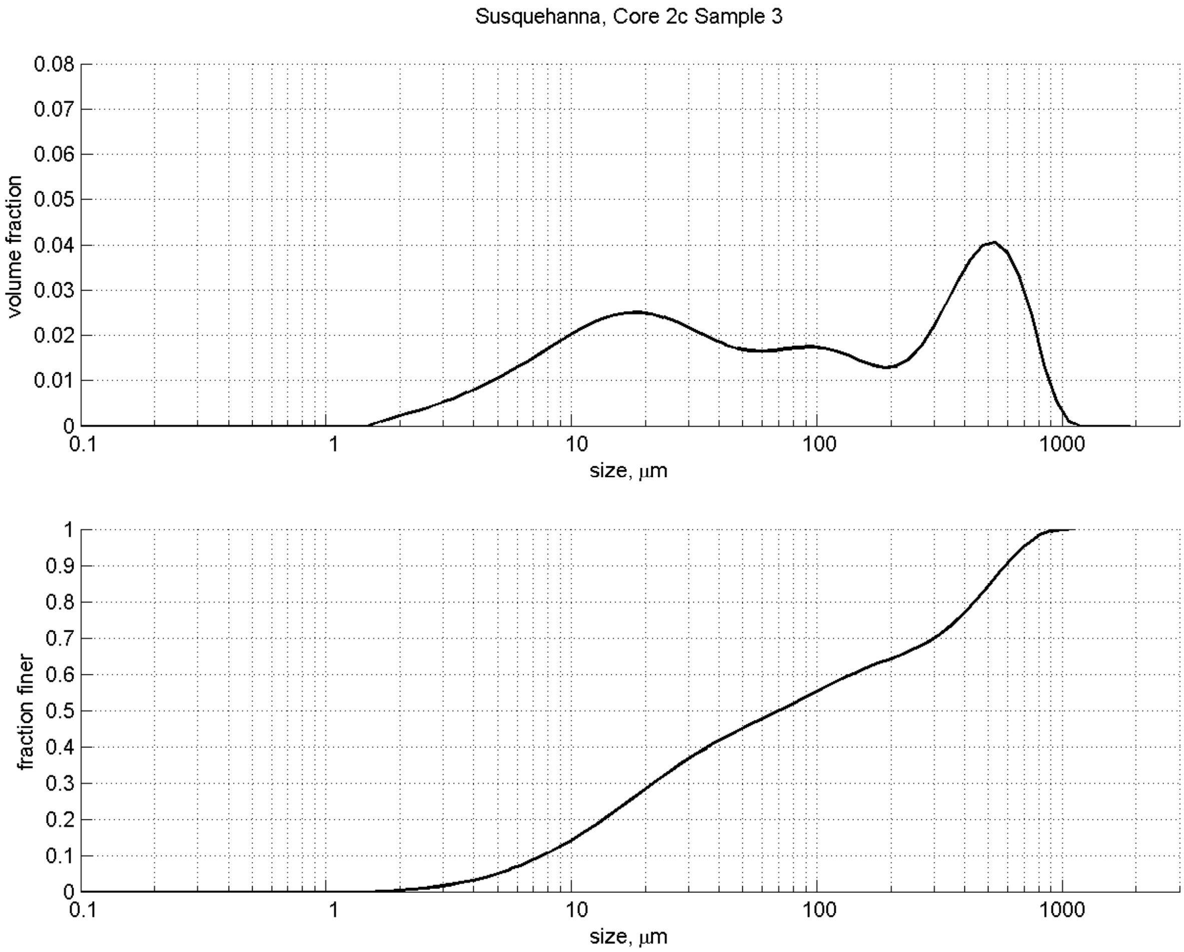


Figure A-4d. Grain Size Distribution for Core 2c, Physical Sample.

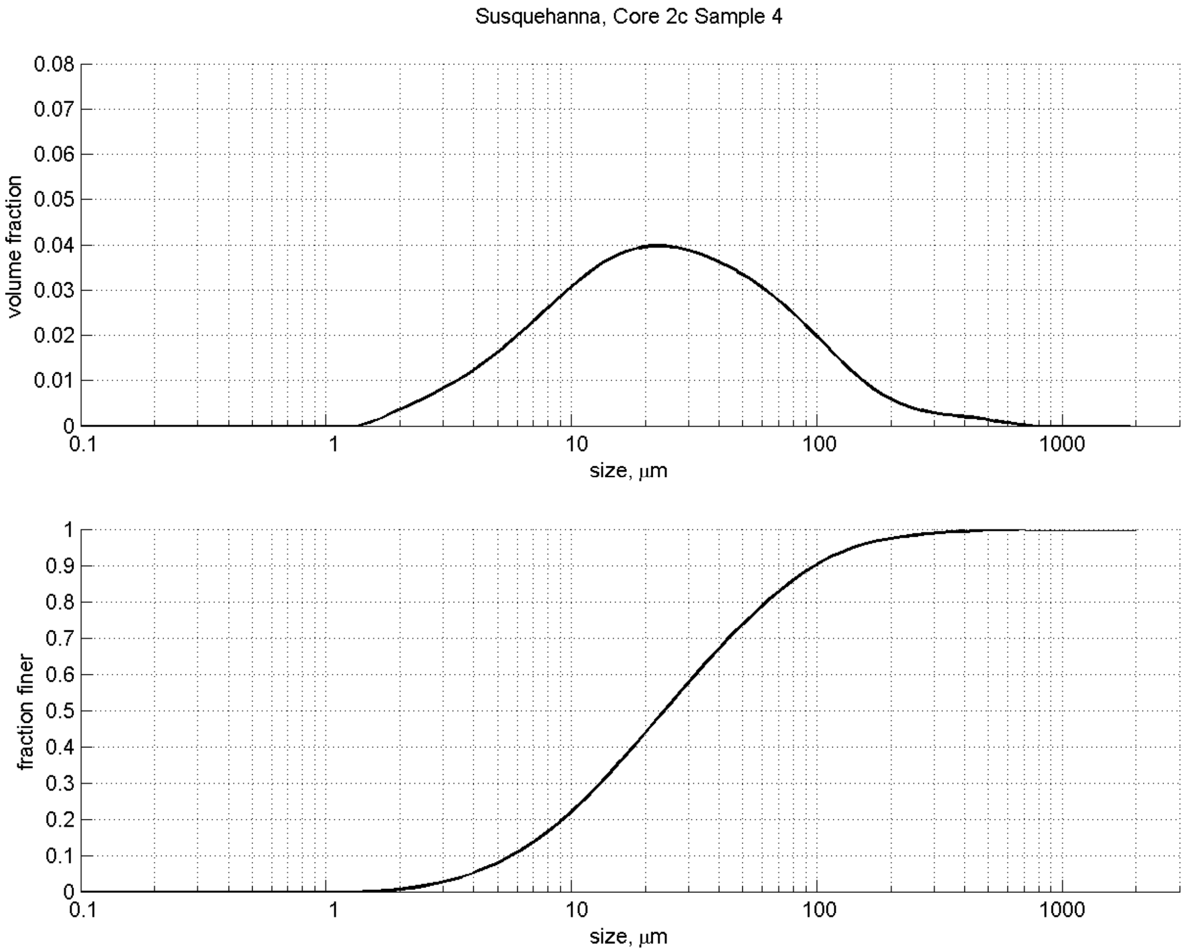


Figure A-4e. Grain Size Distribution for Core 2c, Physical Sample.

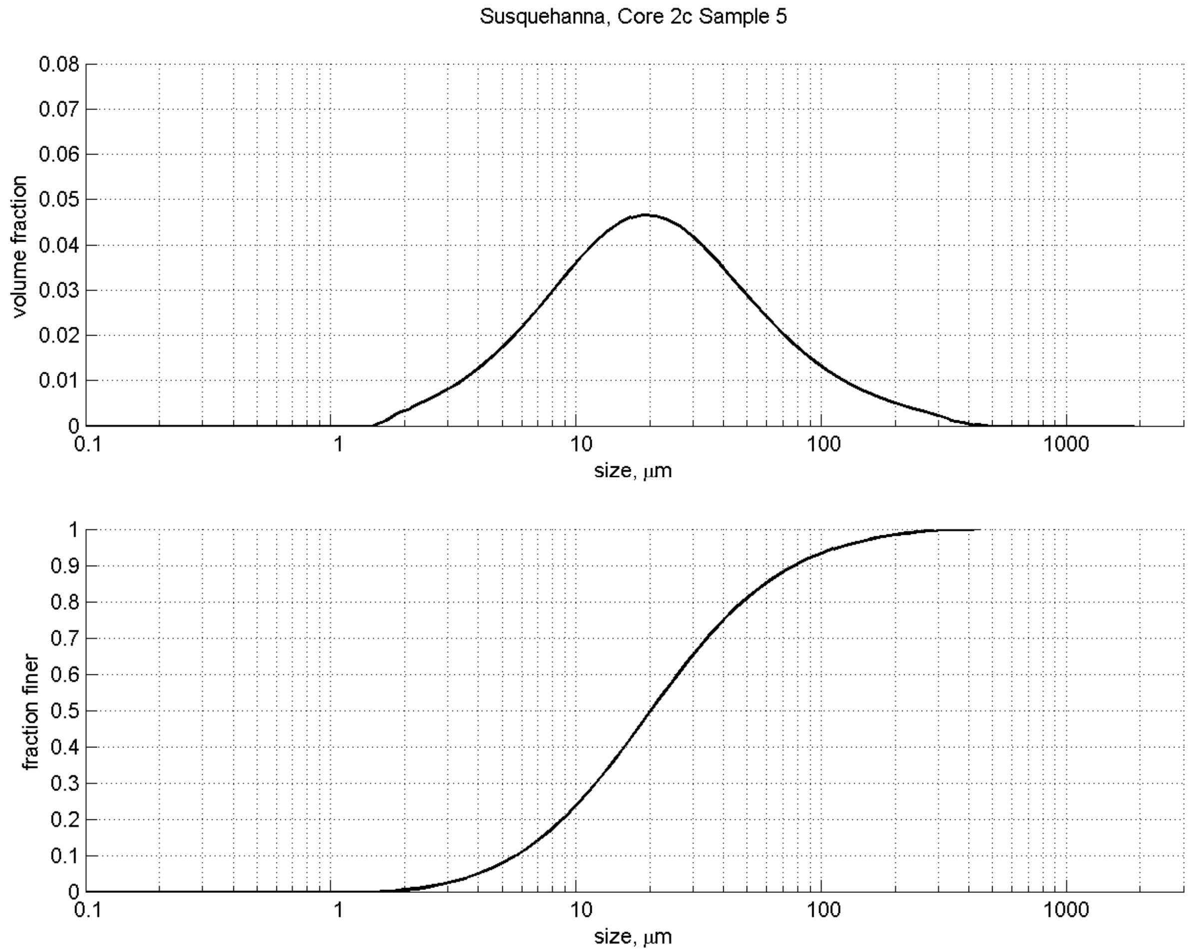


Figure A-4f. Grain Size Distribution for Core 2c, Physical Sample.

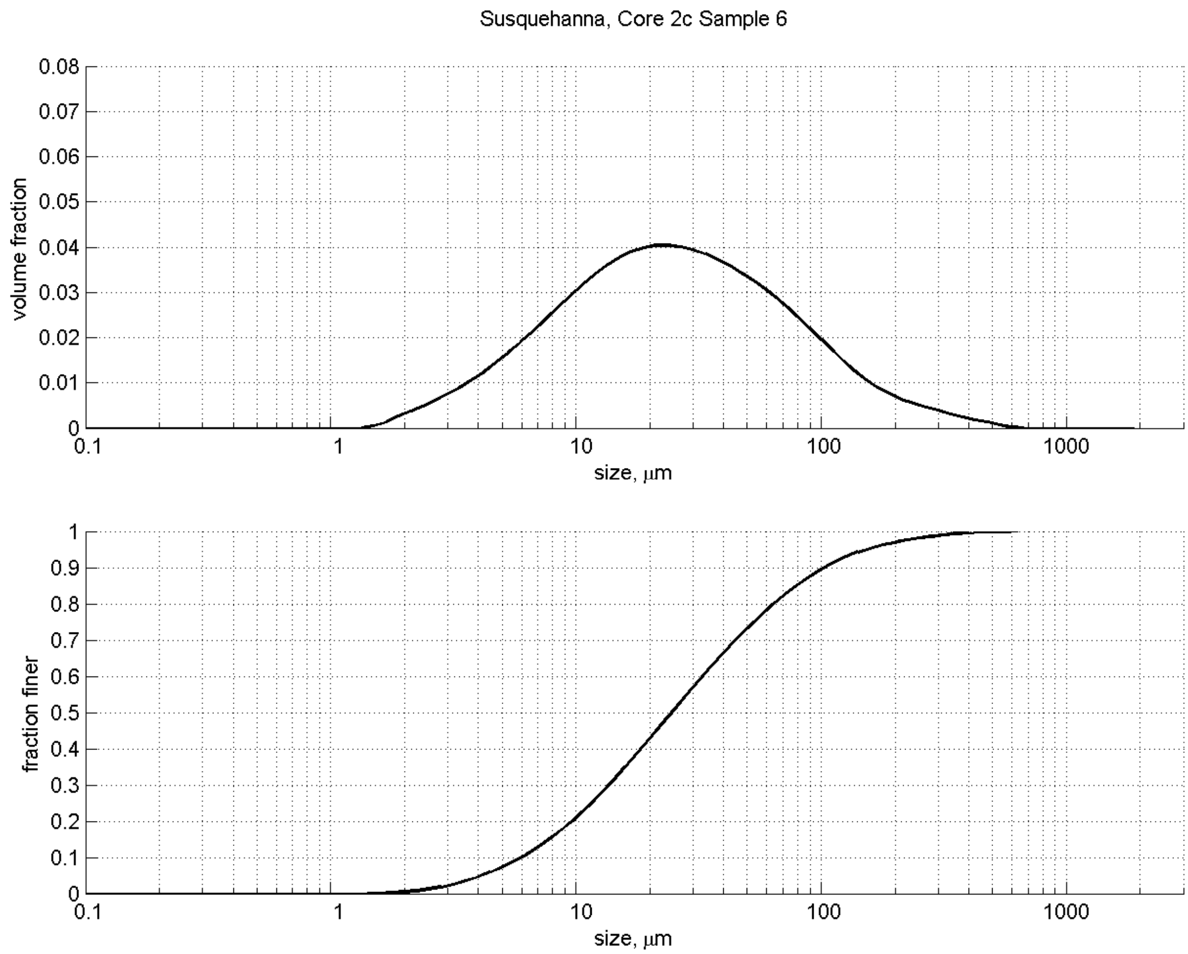


Figure A-4g. Grain Size Distribution for Core 2c, Physical Sample.

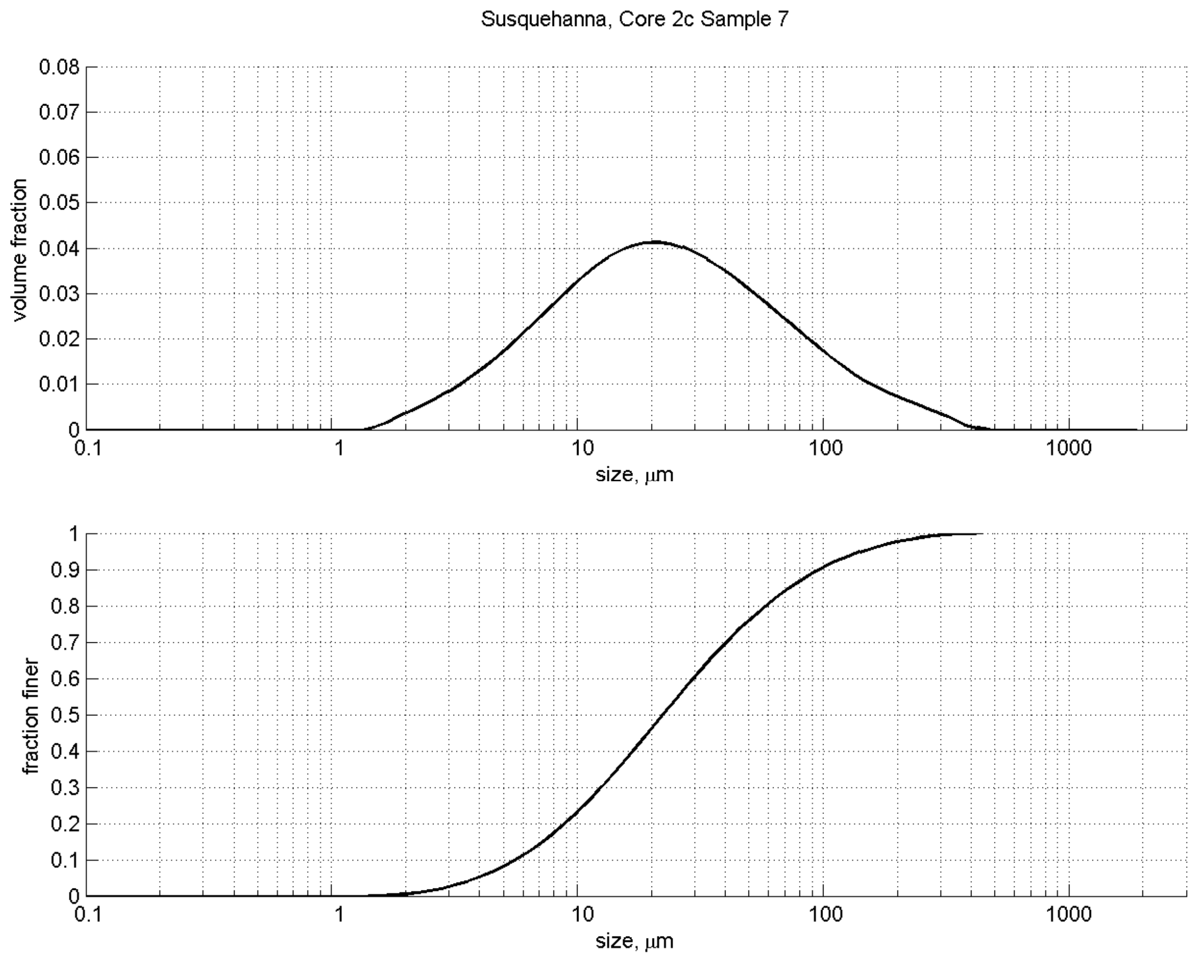


Figure A-4h. Grain Size Distribution for Core 2c, Physical Sample.

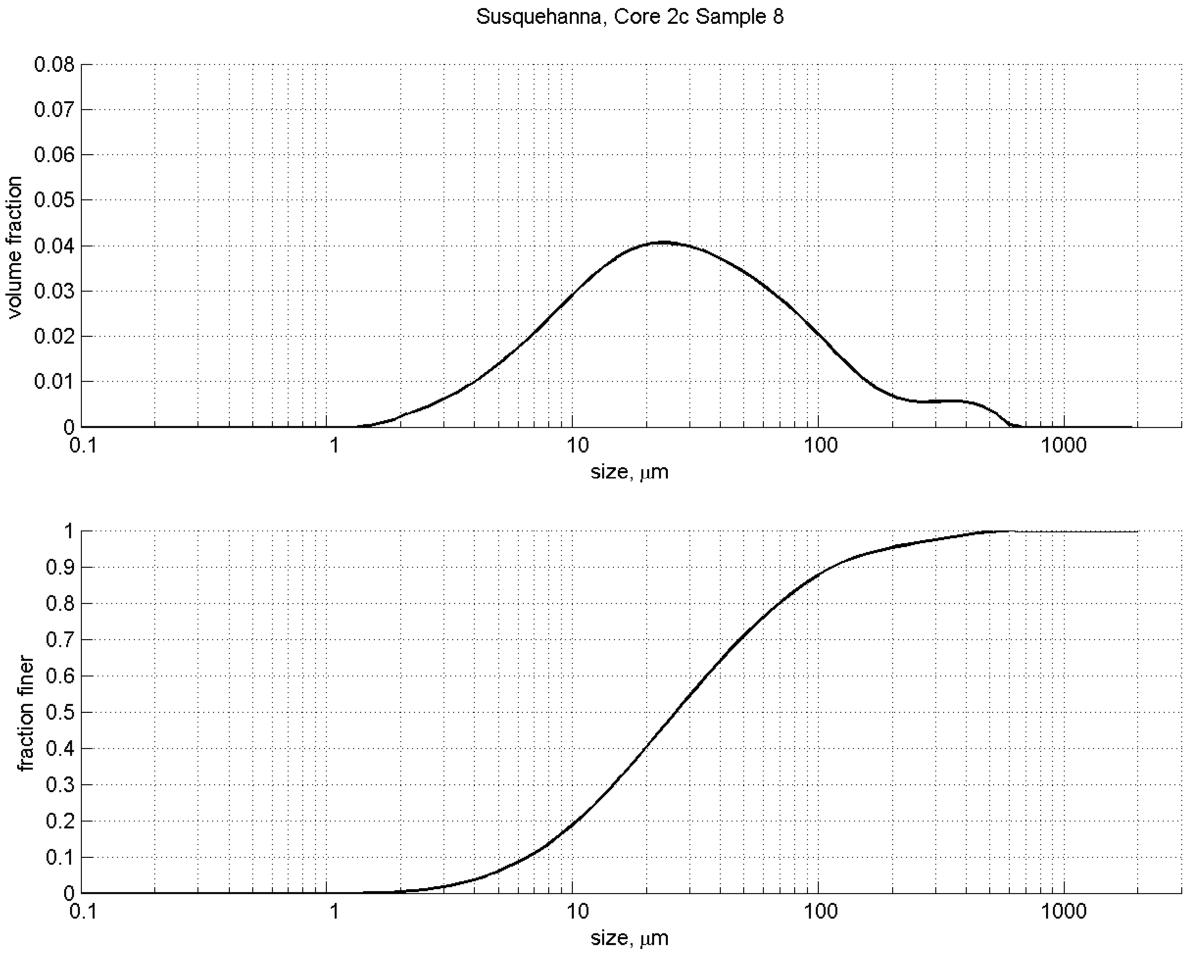


Figure A-4i. Grain Size Distribution for Core 2c, Physical Sample.

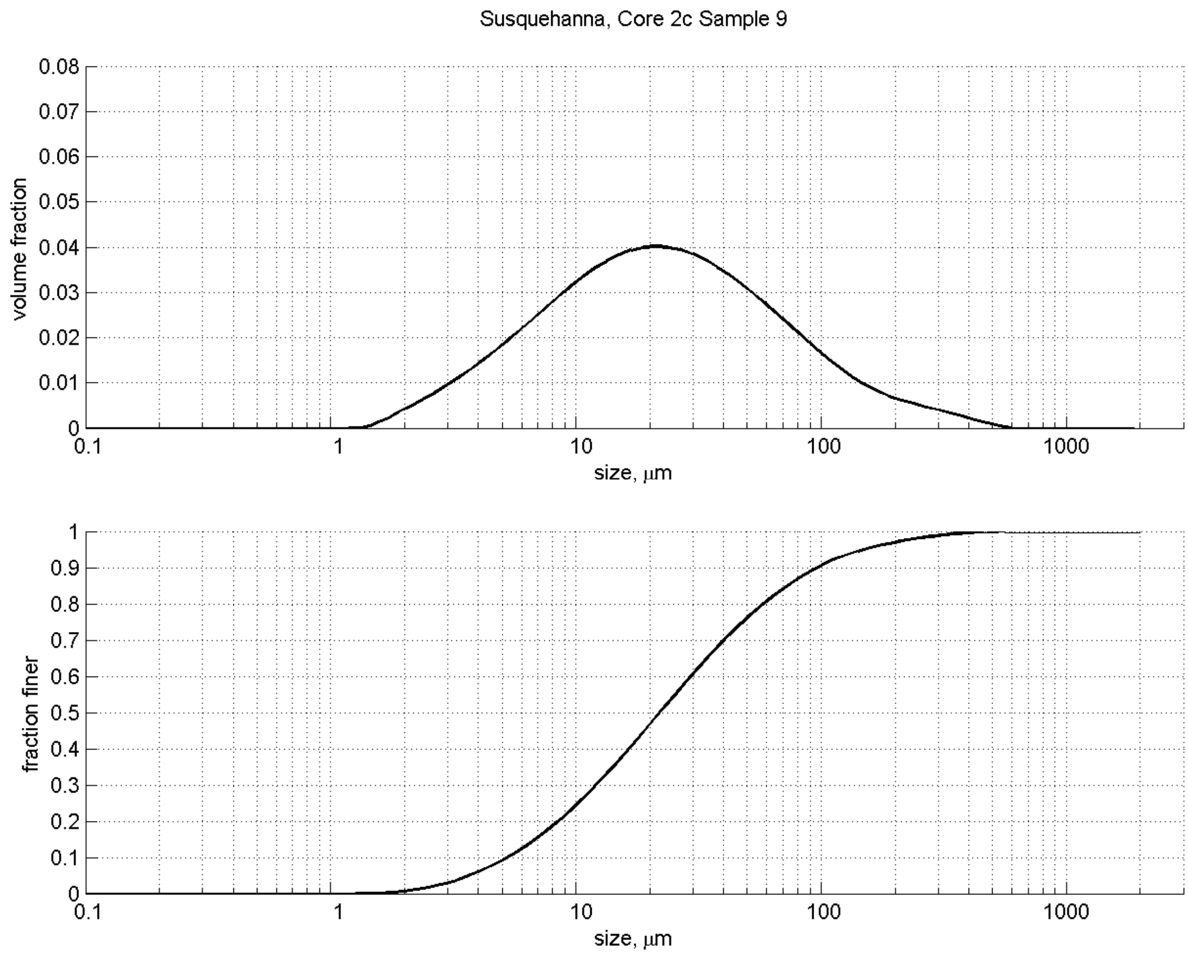


Figure A-4j. Grain Size Distribution for Core 2c, Physical Sample.

Table A-3b. Physical Sample Properties (Core 3)								
Sample	Depth (cm below surf)	Bulk density (g/cm^3)	D10(µm)	D50(µm)	D90(µm)	Percent Sand	Percent Silt	Percent Clay
Surface	0.00	-	5.43	21.43	103.07	19.98	75.10	4.92
1	0.90	1.29	5.97	21.97	101.41	19.43	76.69	3.89
2	4.30	1.34	5.29	20.23	97.87	18.73	76.17	5.09
3	8.98	1.36	5.20	16.86	62.54	11.00	84.01	4.99
4	13.40	1.35	4.70	18.65	167.89	24.05	69.55	6.39
5	18.35	1.36	5.62	26.92	192.94	31.32	64.01	4.67
6	23.00	1.36	5.52	23.48	155.38	26.53	68.84	4.63

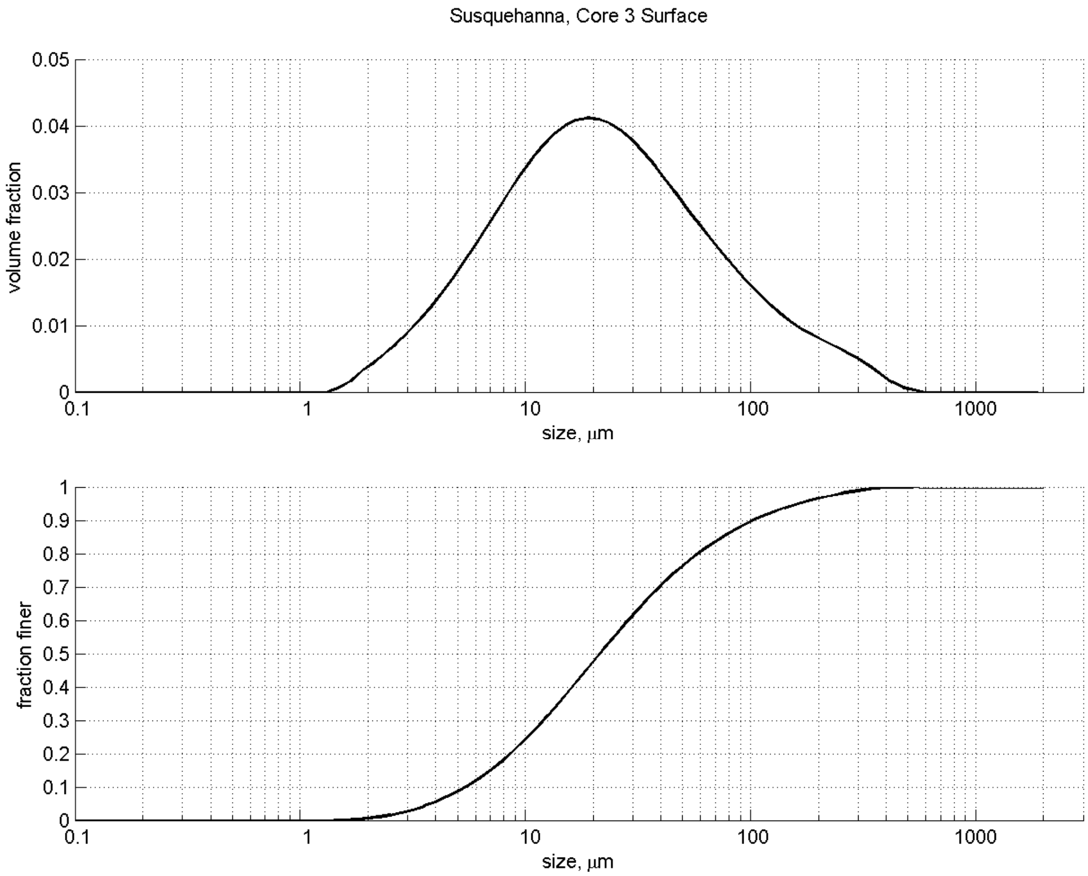


Figure A-6a. Grain Size Distribution for Core 3, Physical Sample.

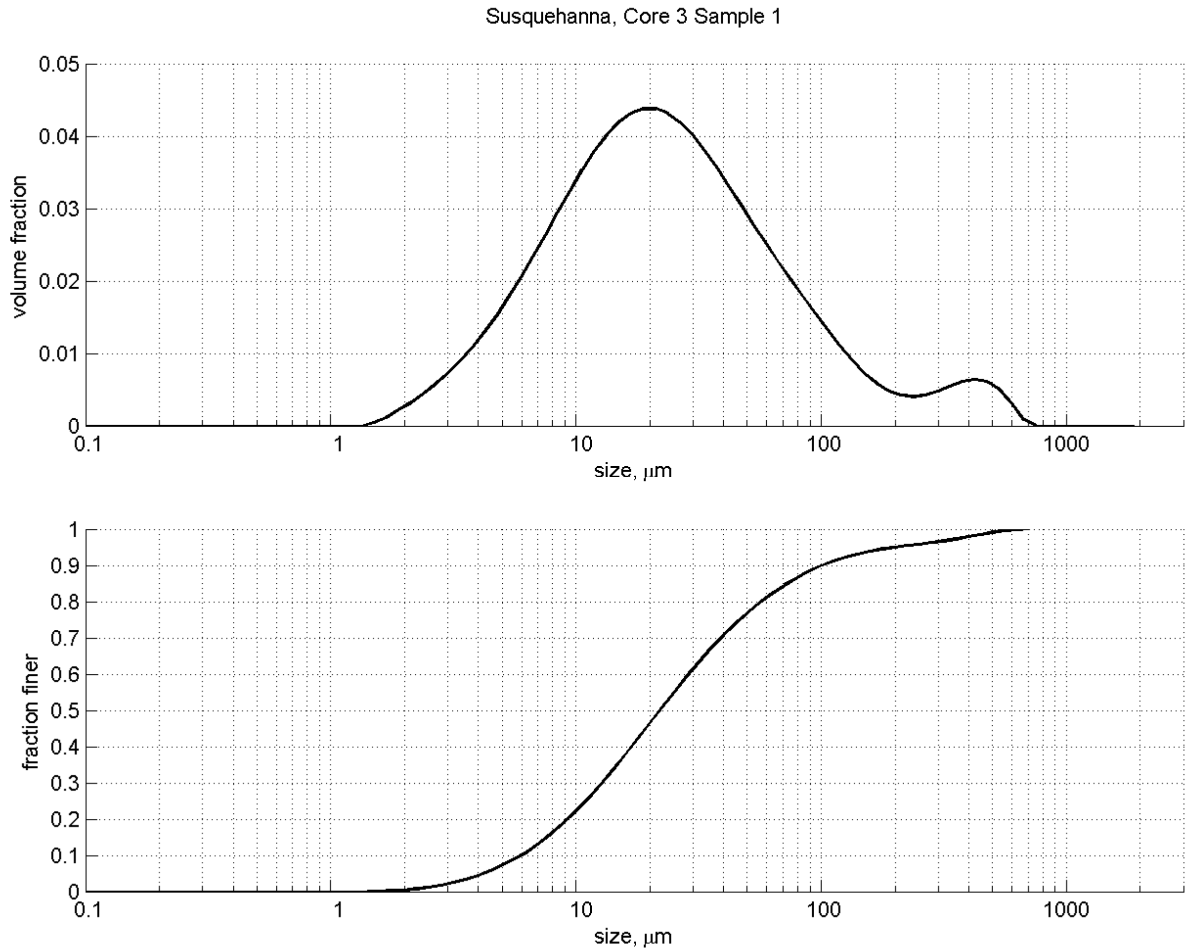


Figure A-6b. Grain Size Distribution for Core 3, Physical Sample.

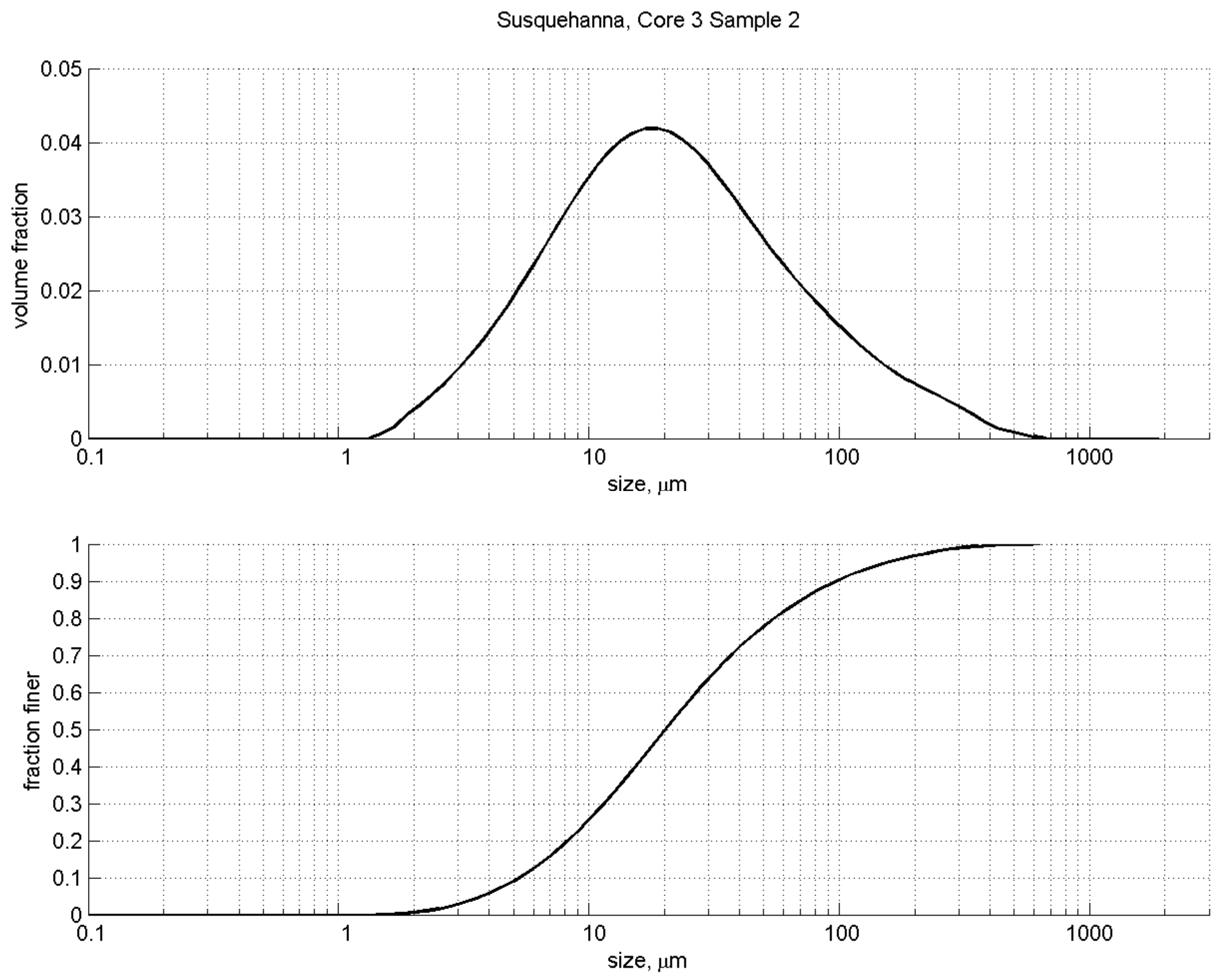


Figure A-6c. Grain Size Distribution for Core 3, Physical Sample.

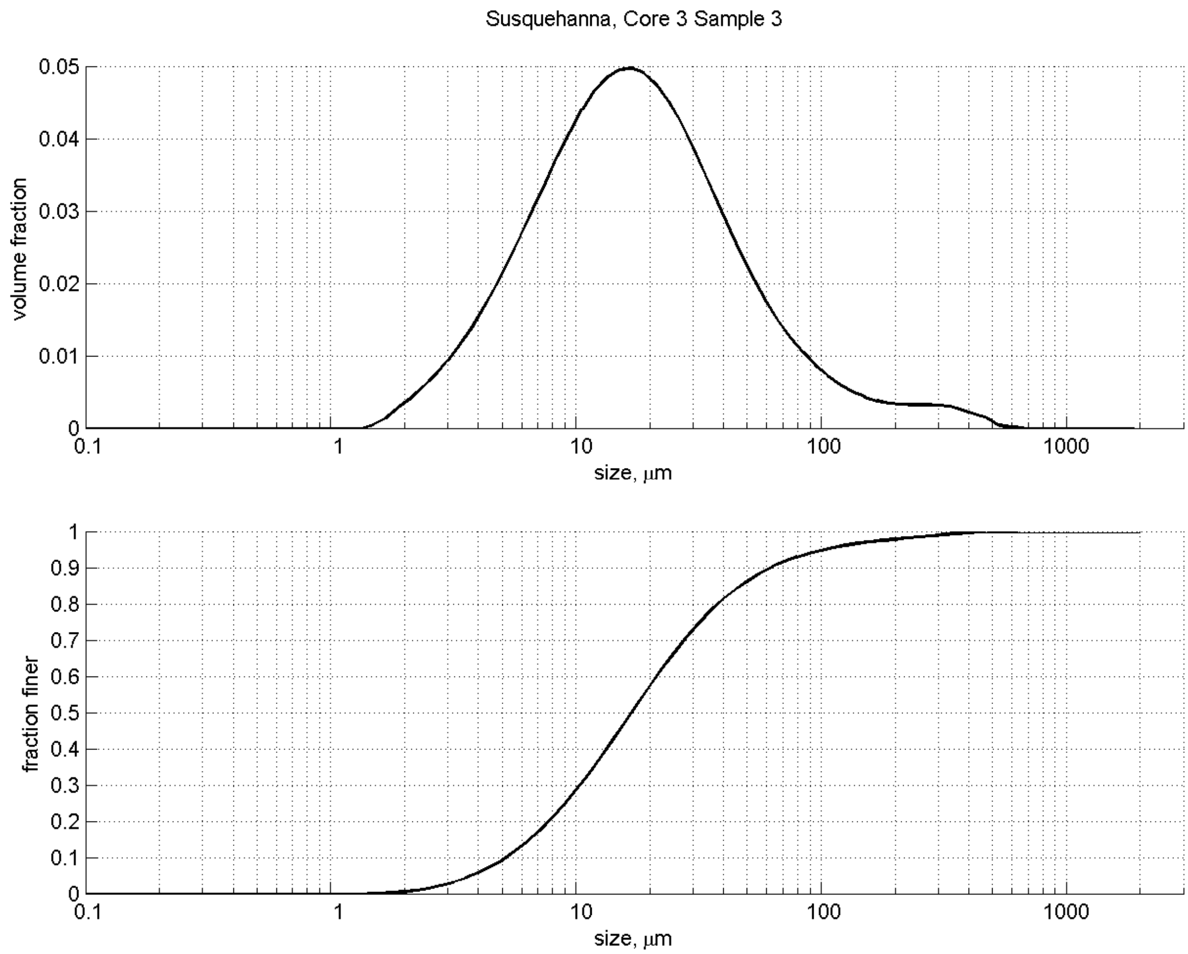


Figure A-6d. Grain Size Distribution for Core 3, Physical Sample.

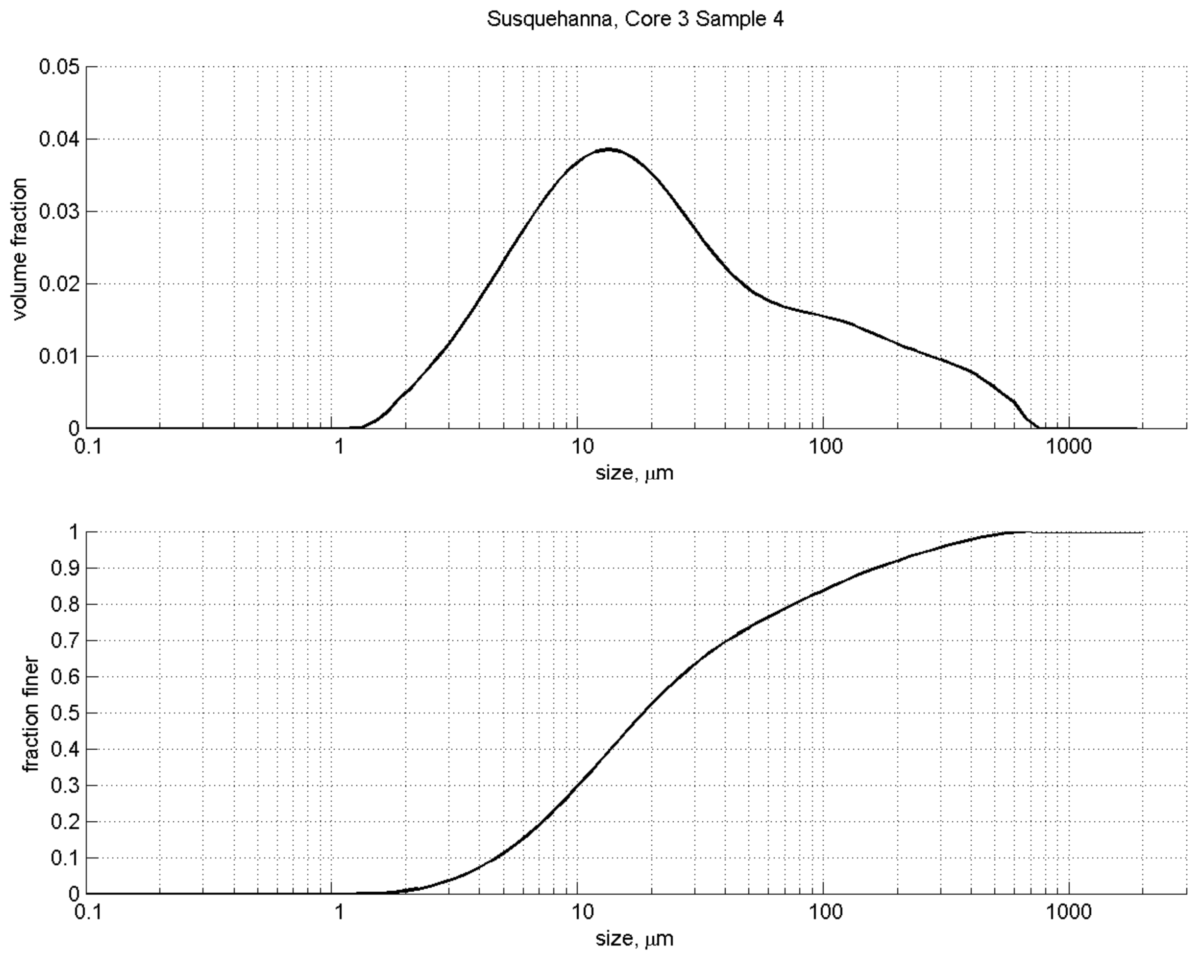


Figure A-6e. Grain Size Distribution for Core 3, Physical Sample.

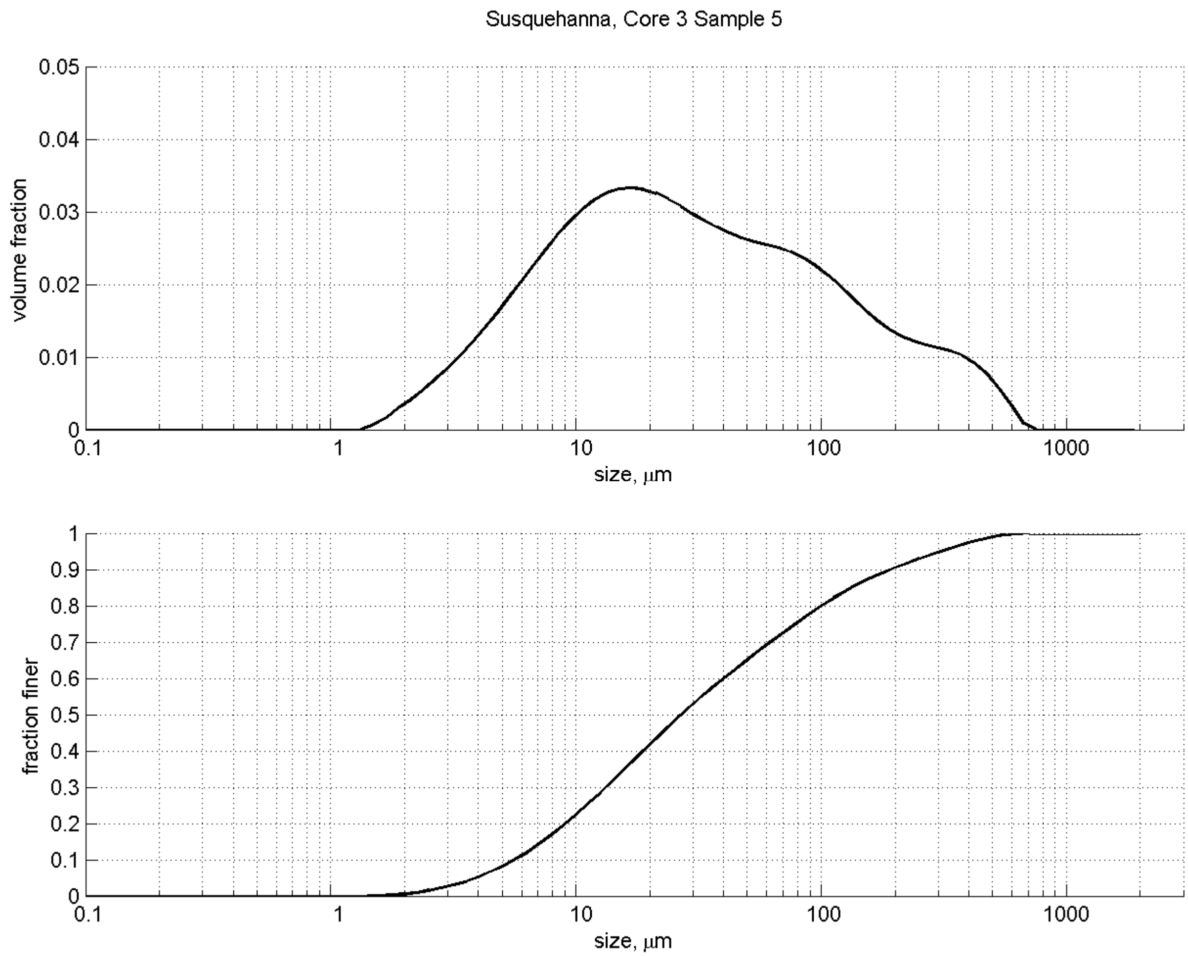


Figure A-6f. Grain Size Distribution for Core 3, Physical Sample.

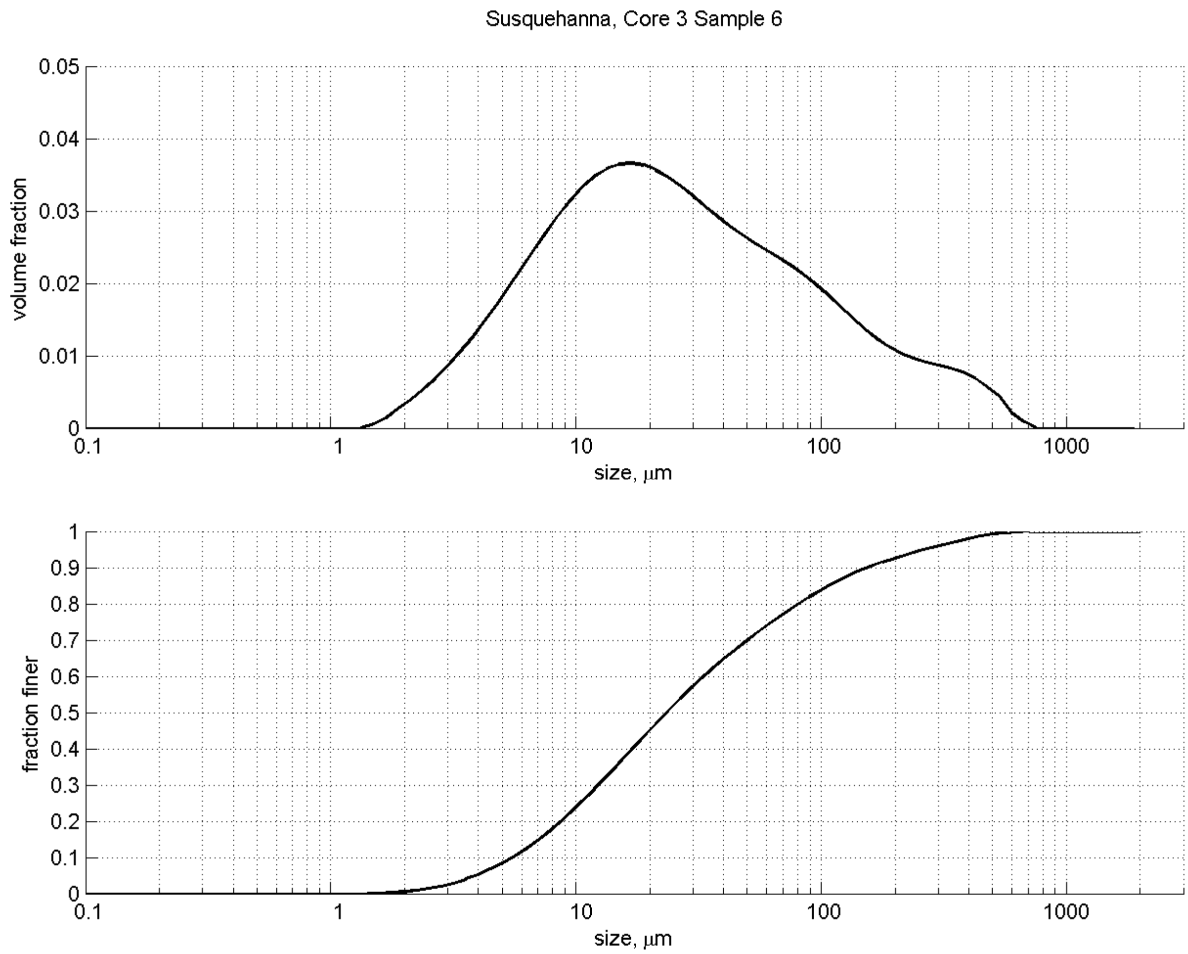


Figure A-6g. Grain Size Distribution for Core 3, Physical Sample.

Table A-4b. Physical Sample Properties (Core 4)								
Sample	**Depth (cm below surf)**	**Bulk density (g/cm^3)**	**D10(µm)**	**D50(µm)**	**D90(µm)**	**Percent Sand**	**Percent Silt**	**Percent Clay**
Surface	0.00	-	5.57	21.01	85.43	17.29	78.03	4.69
1	0.88	1.43	5.56	29.41	98.38	24.59	70.36	5.05
2	4.05	1.33	4.97	20.55	124.06	21.77	72.33	5.90
3	8.55	1.40	4.67	15.82	56.06	9.37	84.13	6.50
4	13.10	1.46	4.34	15.84	68.63	12.43	79.99	7.58

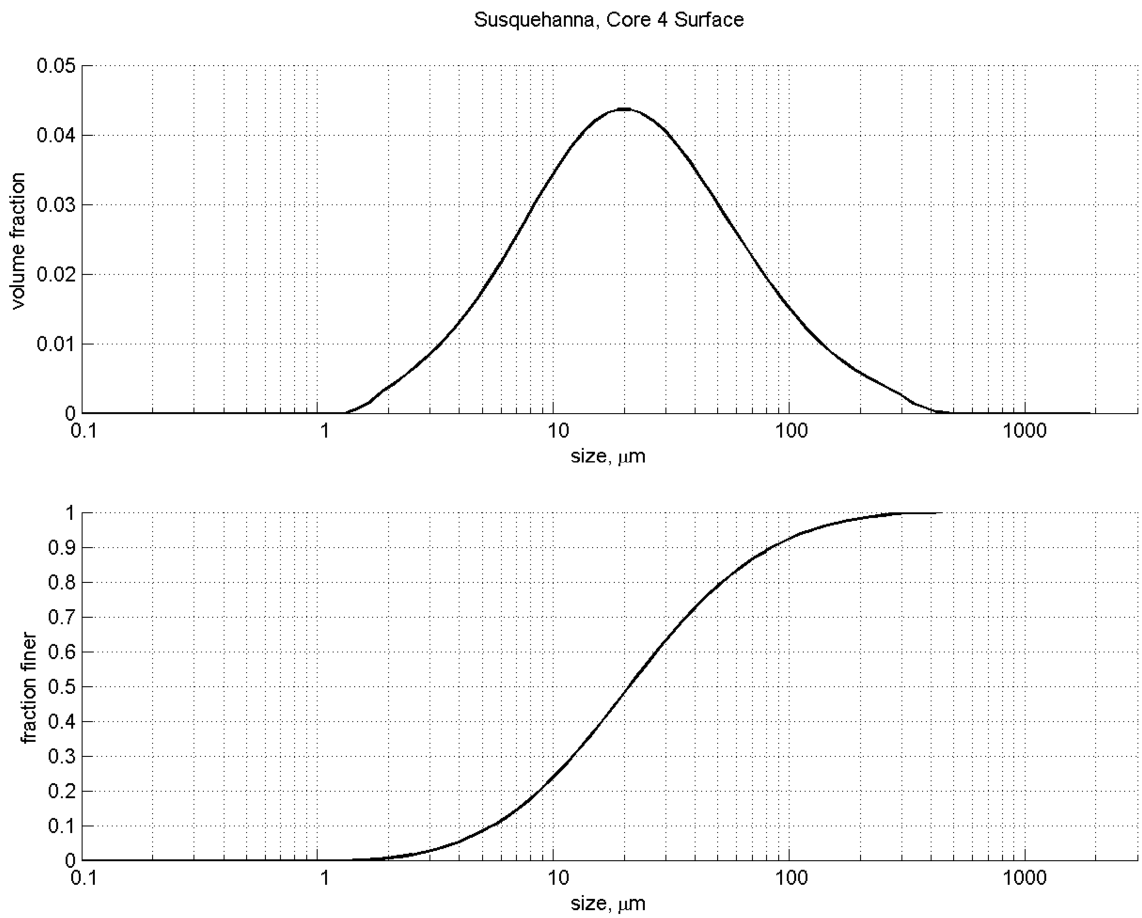


Figure A-8a. Grain Size Distribution for Core 4, Physical Sample.

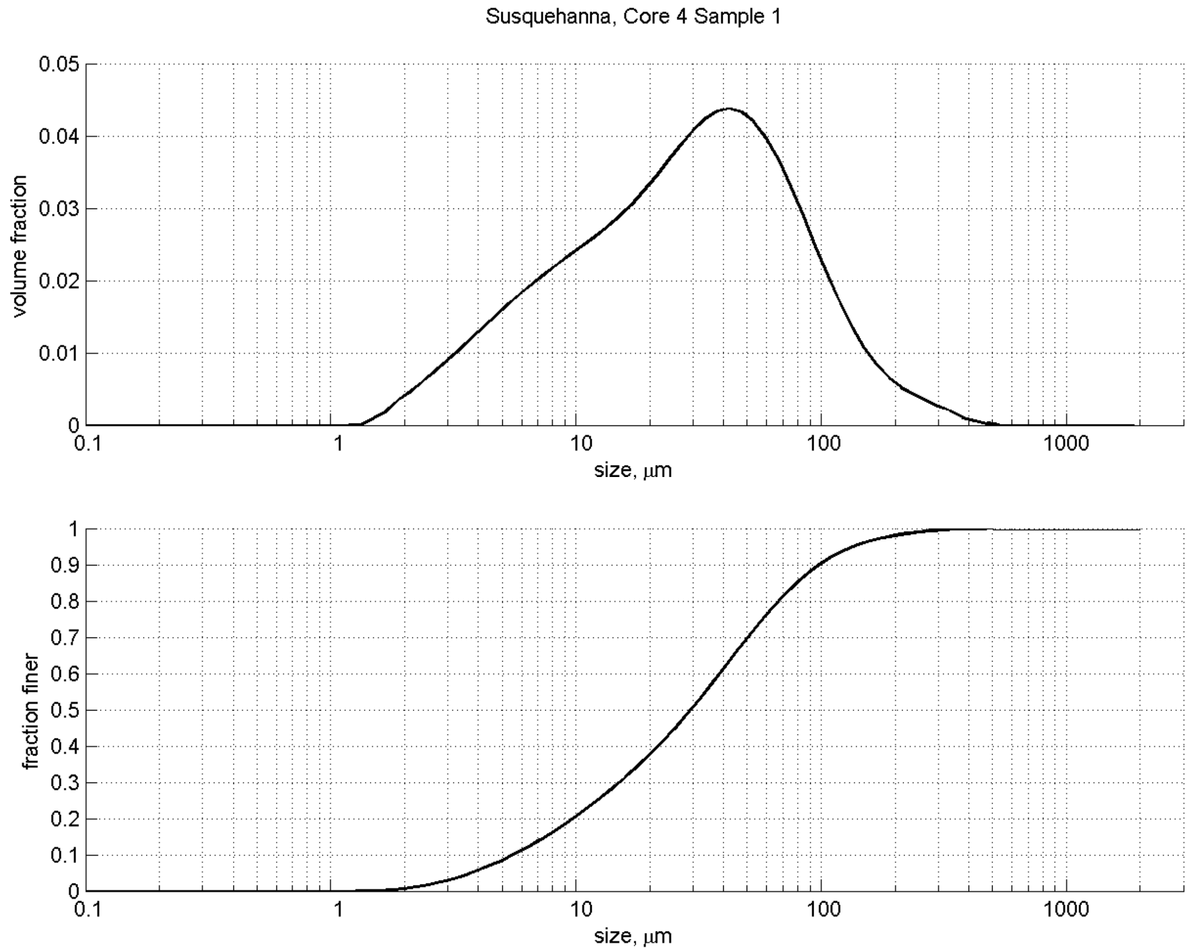


Figure A-8b. Grain Size Distribution for Core 4, Physical Sample.

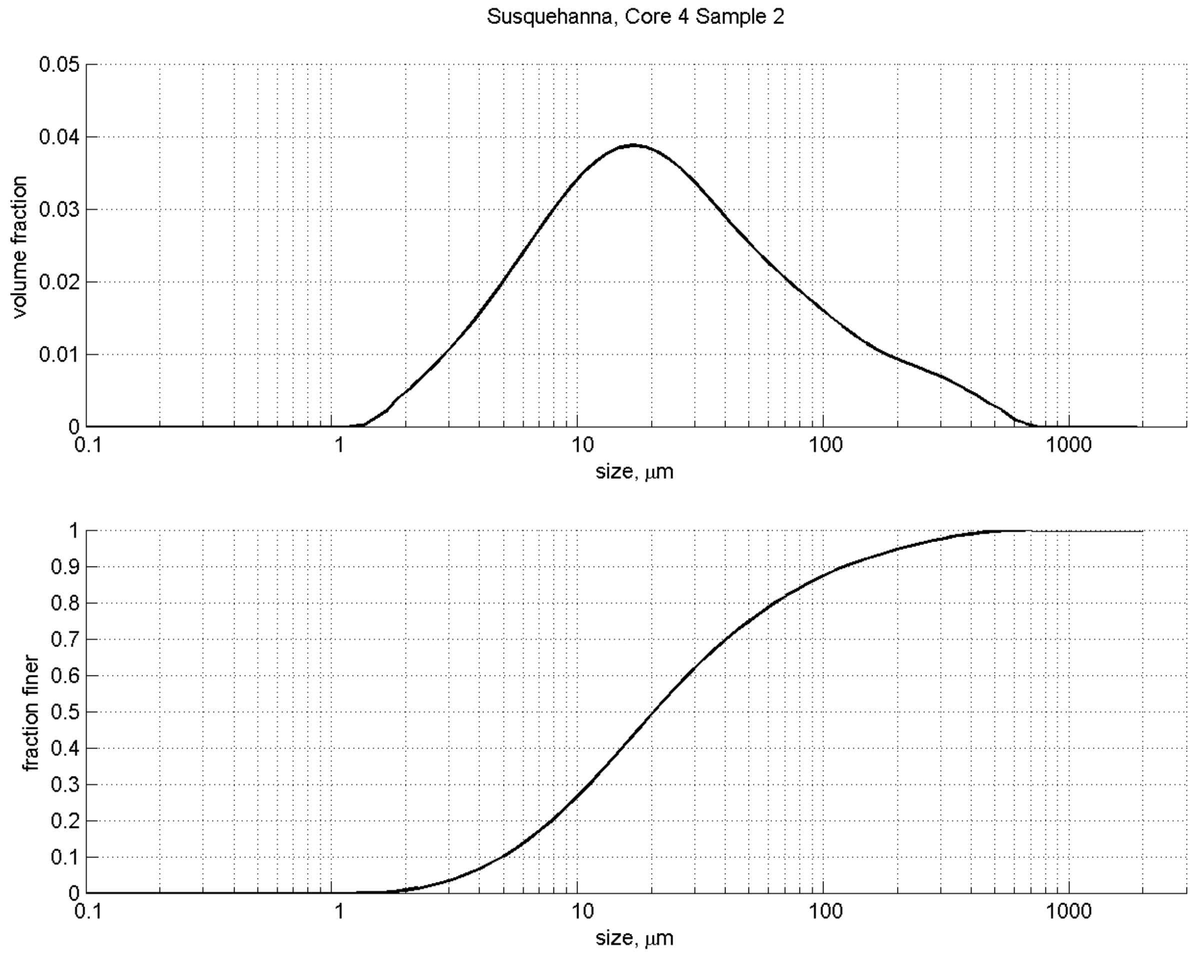


Figure A-8c. Grain Size Distribution for Core 4, Physical Sample.

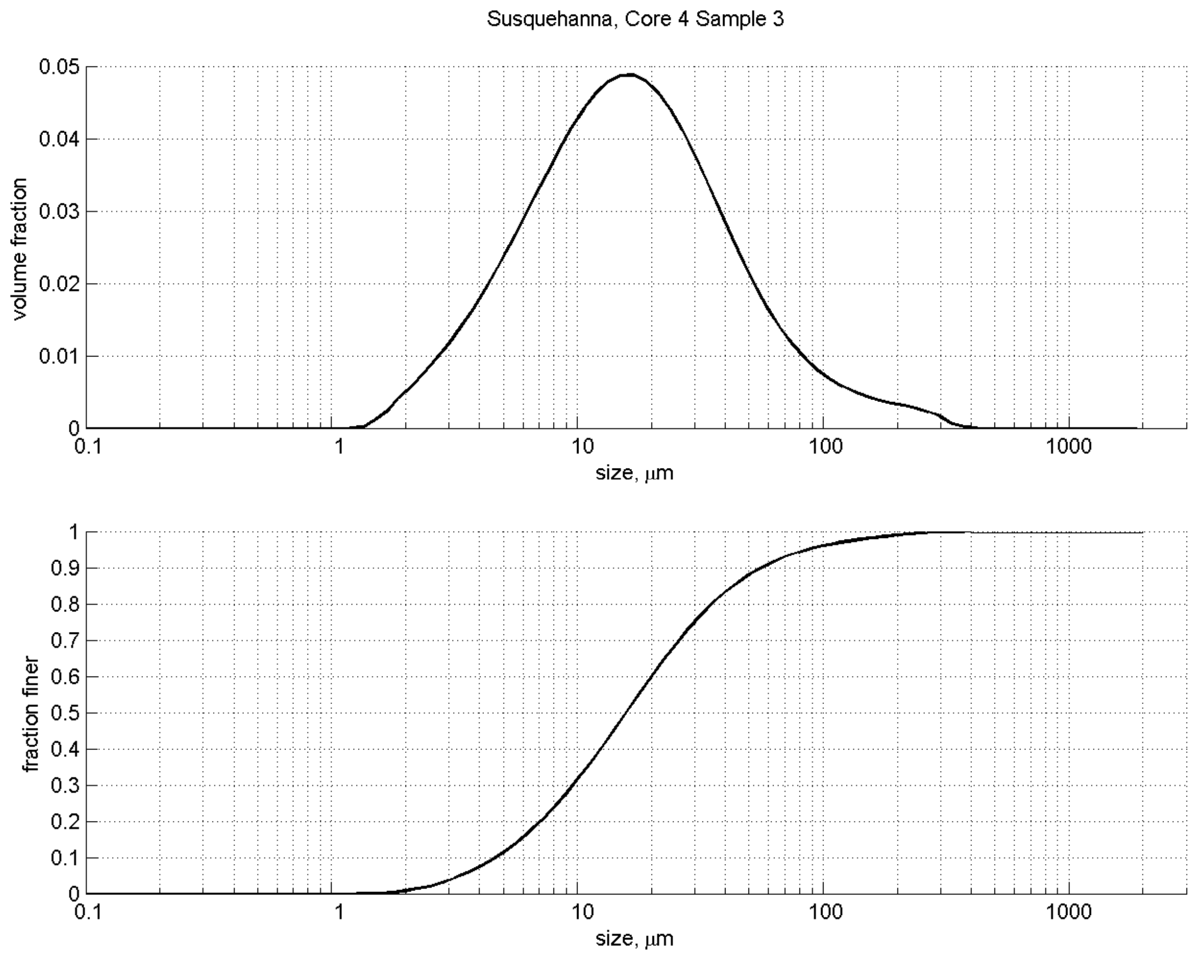


Figure A-8d. Grain Size Distribution for Core 4, Physical Sample.

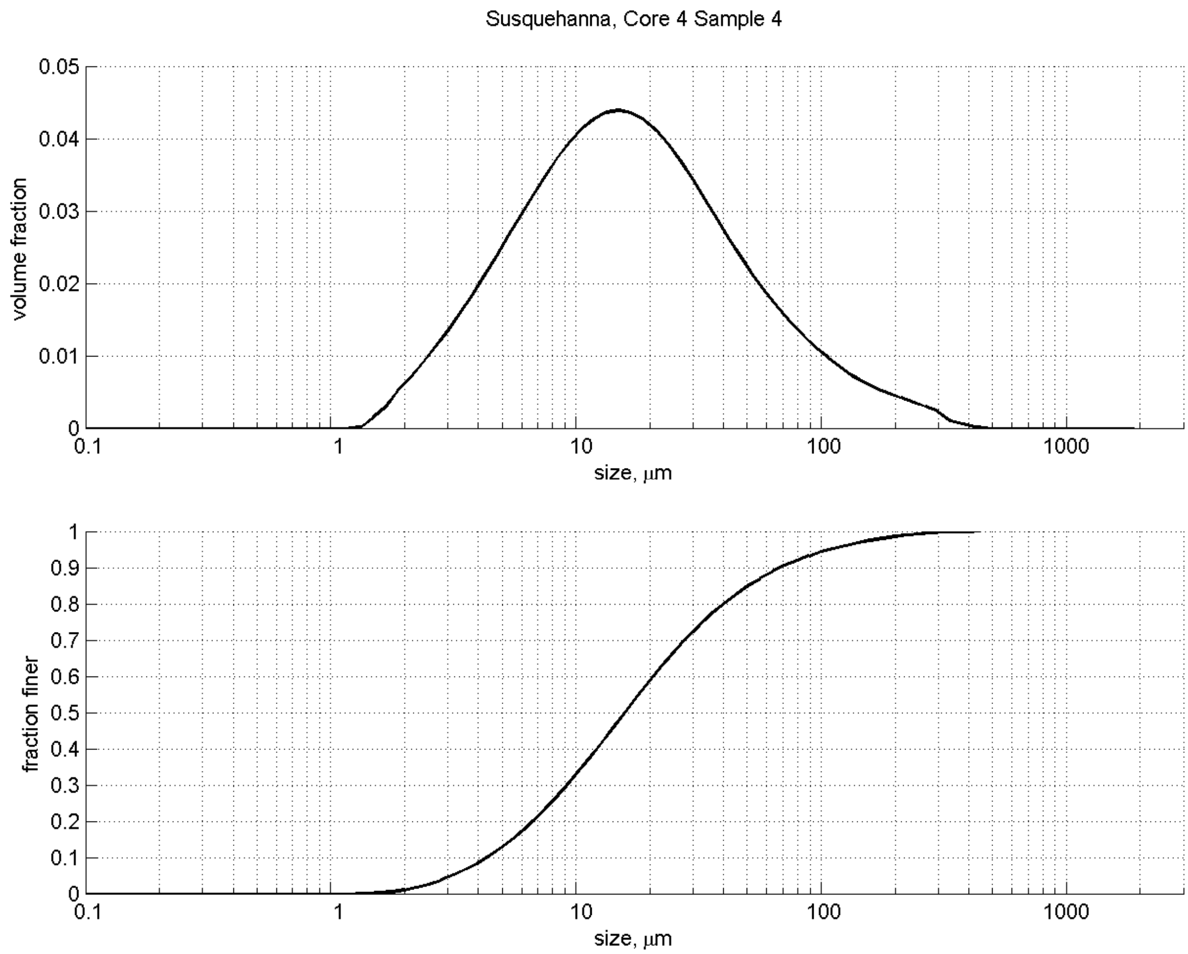


Figure A-8e. Grain Size Distribution for Core 4, Physical Sample.

Table A-4b. Physical Sample Properties (Core 5)								
Sample	Depth (cm below surf)	Bulk density (g/cm^3)	D10(μm)	D50(μm)	D90(μm)	Percent Sand	Percent Silt	Percent Clay
Surface	0.00	-	5.91	26.01	219.90	30.47	65.35	4.17
1	1.10	1.41	6.48	32.47	331.62	37.28	59.38	3.35
2	5.08	1.31	5.76	25.21	140.55	27.60	68.10	4.30
3	8.60	1.37	5.34	21.69	107.11	21.46	73.45	5.09
4	14.60	1.38	5.38	20.38	79.11	16.31	78.71	4.99
5	19.73	1.35	5.60	21.13	83.03	17.30	78.08	4.62
6	23.90	1.36	5.99	22.61	82.48	17.66	78.32	4.02

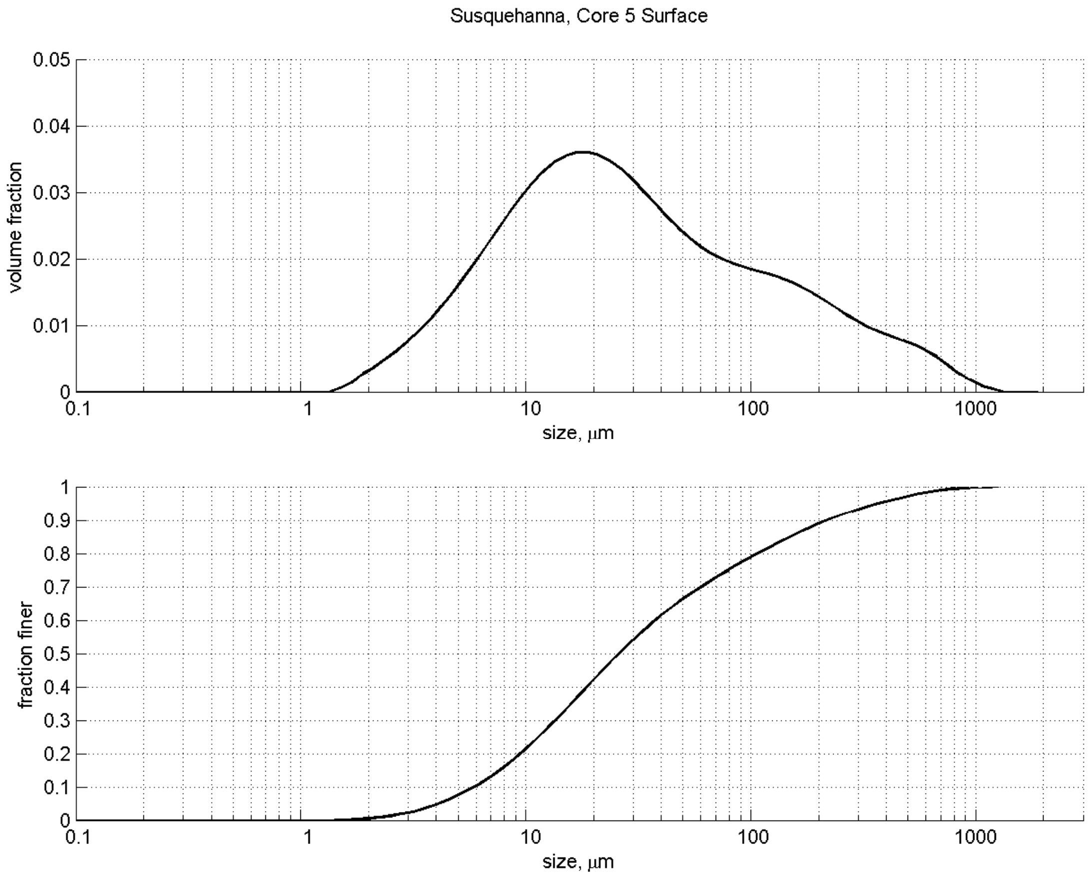


Figure A-10a. Grain Size Distribution for Core 5, Physical Sample.

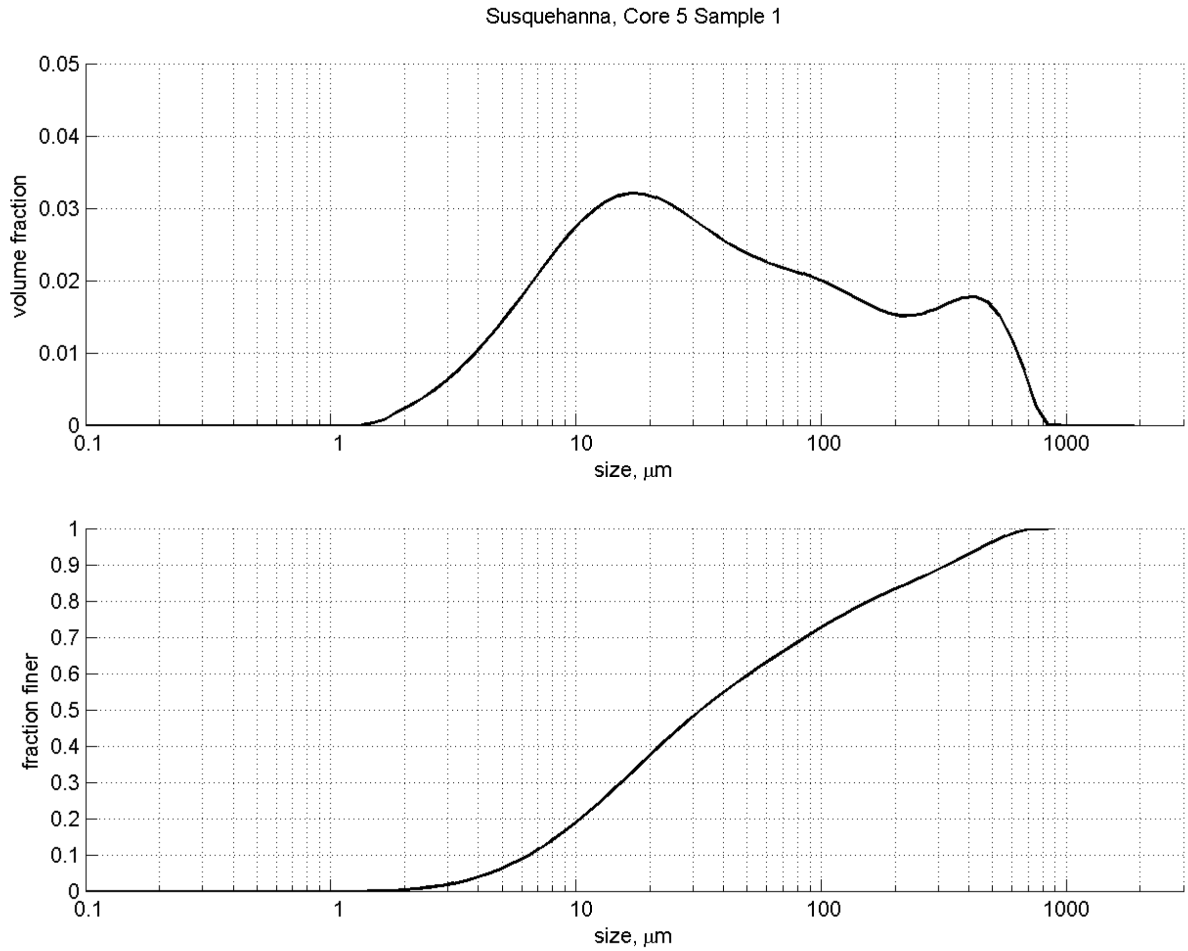


Figure A-10b. Grain Size Distribution for Core 5, Physical Sample.

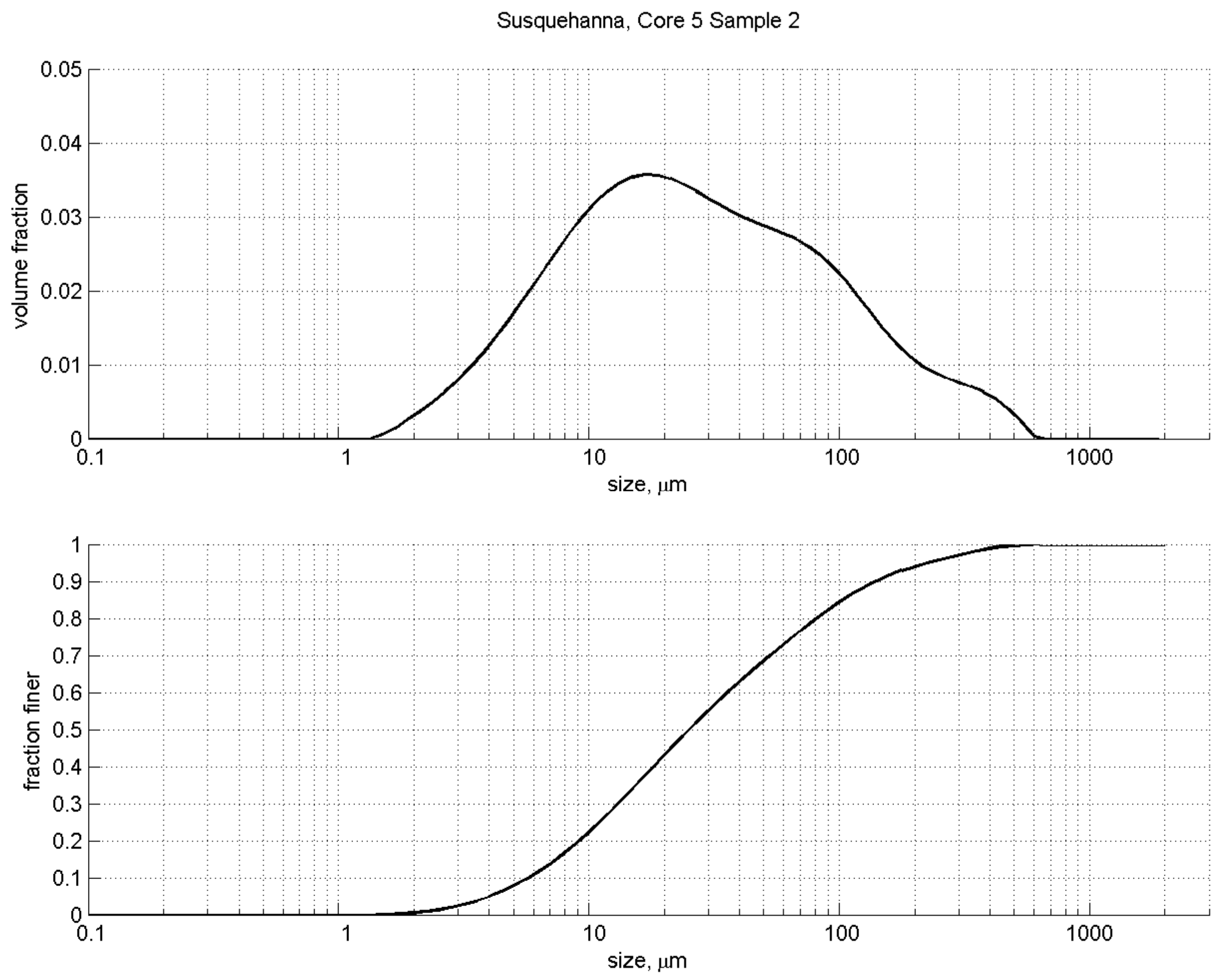


Figure A-10c. Grain Size Distribution for Core 5, Physical Sample.

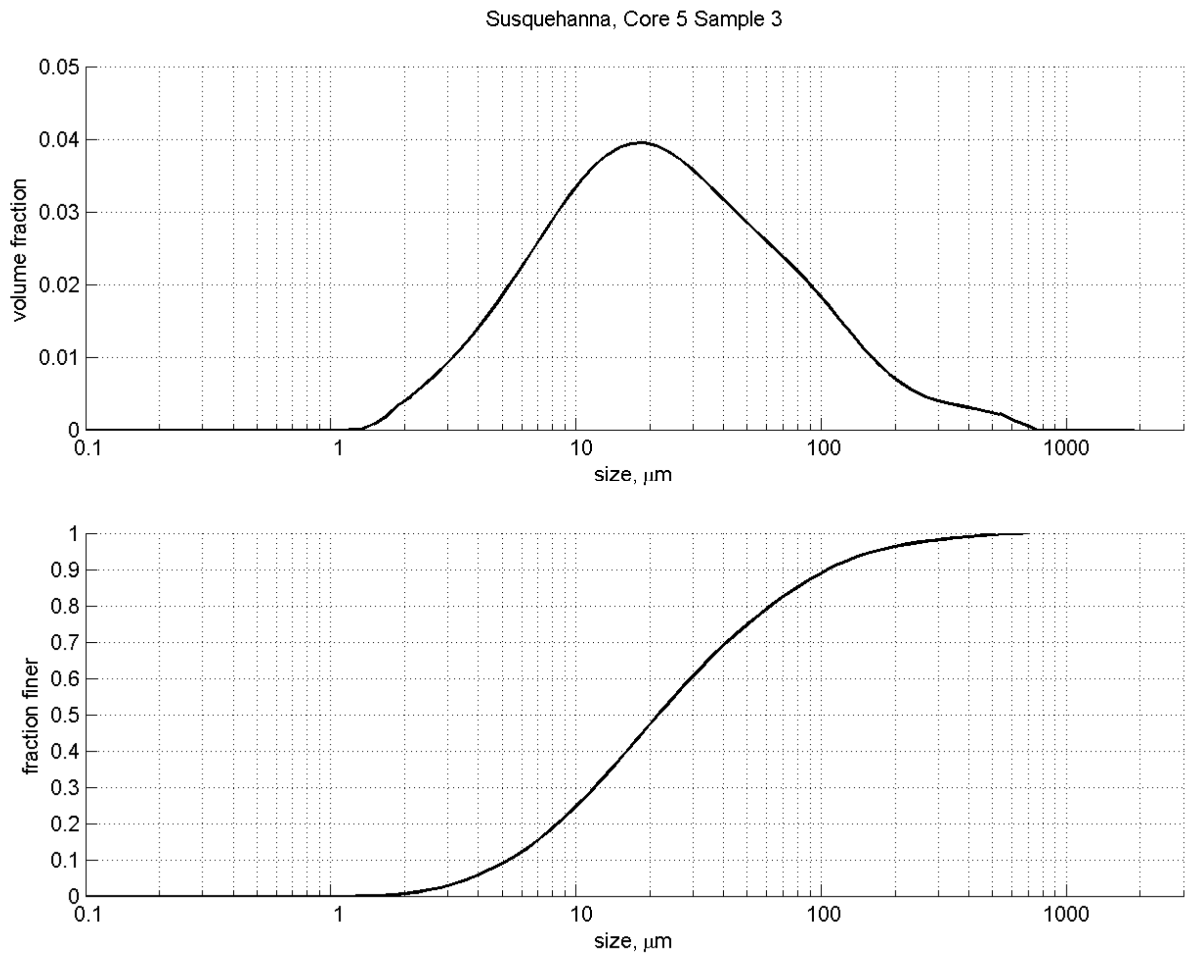


Figure A-10d. Grain Size Distribution for Core 5, Physical Sample.

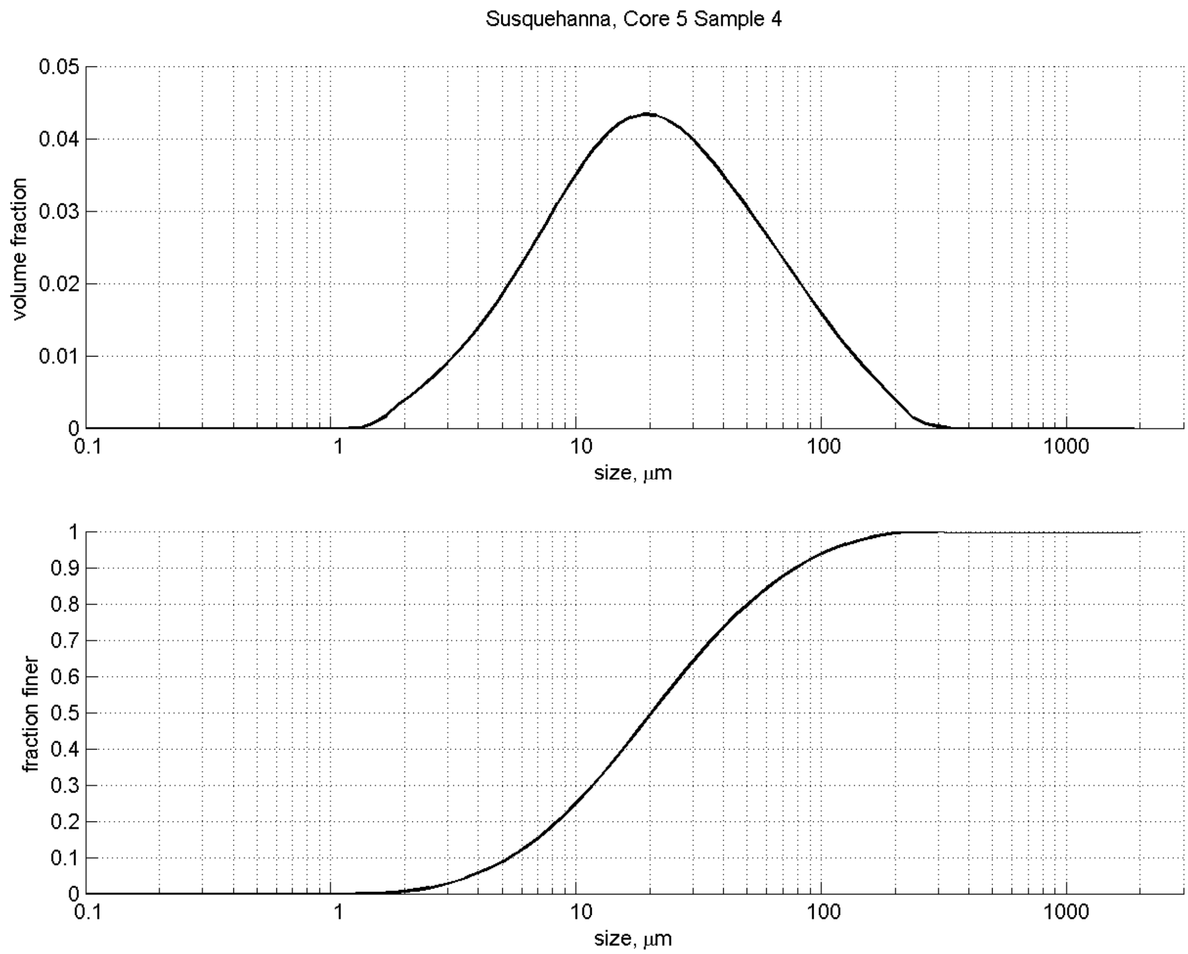


Figure A-10e. Grain Size Distribution for Core 5, Physical Sample.

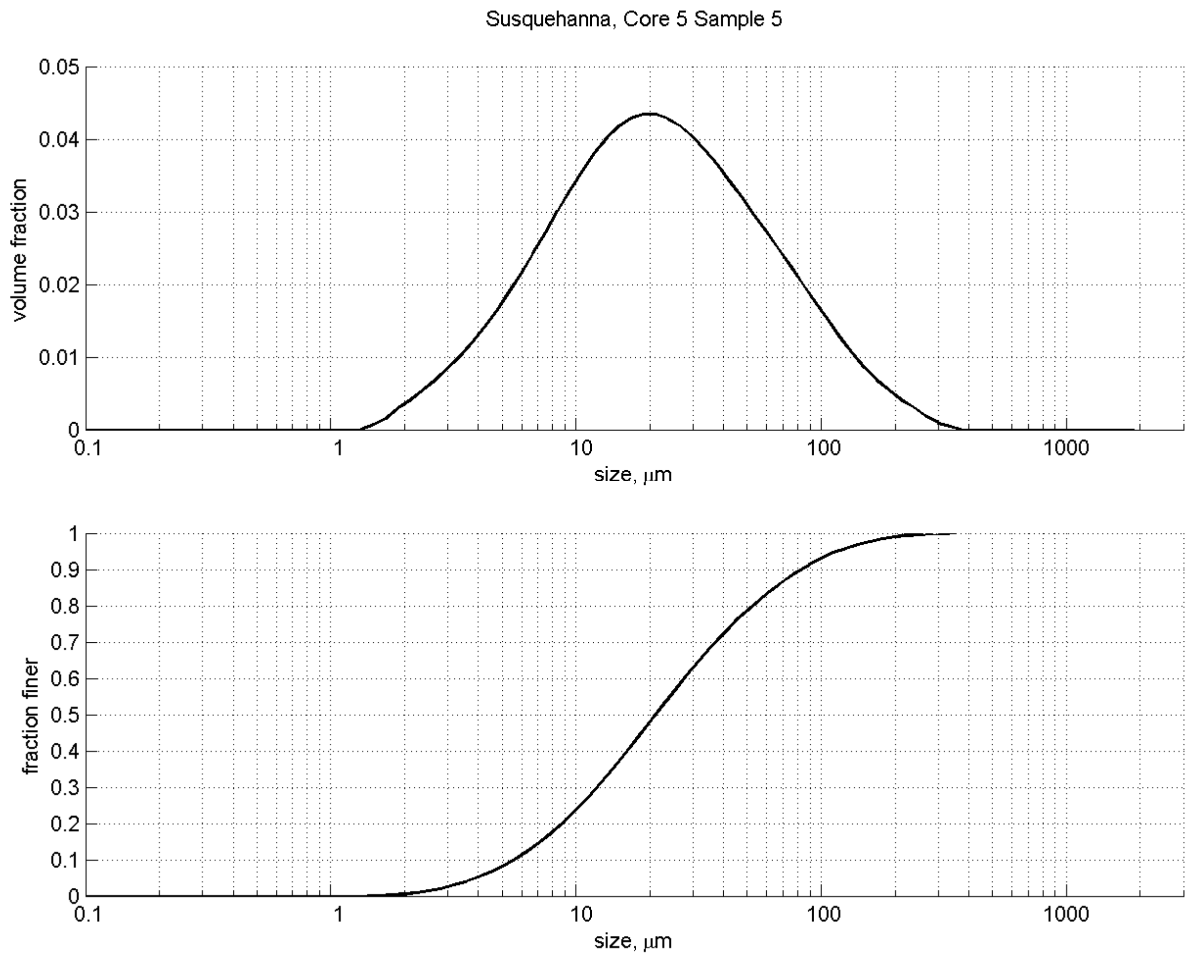


Figure A-10f. Grain Size Distribution for Core 5, Physical Sample.

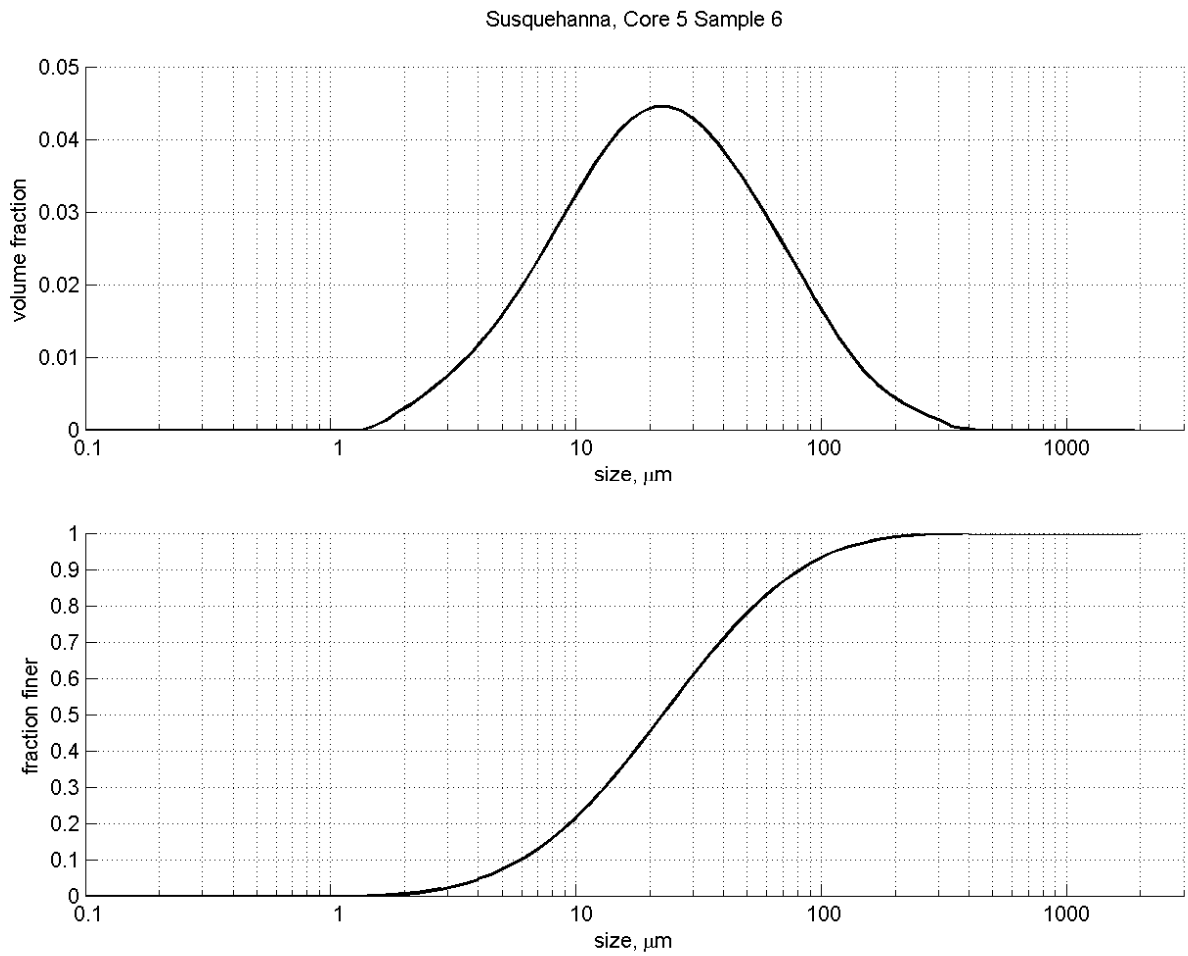


Figure A-10g. Grain Size Distribution for Core 5, Physical Sample.

Table A-6b. Physical Sample Properties (Core 6)								
Sample	Depth (cm below surf)	Bulk density (g/cm^3)	D10(μm)	D50(μm)	D90(μm)	Percent Sand	Percent Silt	Percent Clay
Surface	0.00	-	7.82	159.13	450.74	56.59	40.68	2.74
1	1.60	1.53	4.41	19.90	197.12	24.45	68.07	7.48
2	5.43	1.46	4.72	22.68	124.51	25.69	67.79	6.52
3	10.25	1.52	5.62	30.94	156.51	32.98	62.15	4.87
4	13.95	1.57	5.62	30.73	168.99	34.46	60.79	4.75

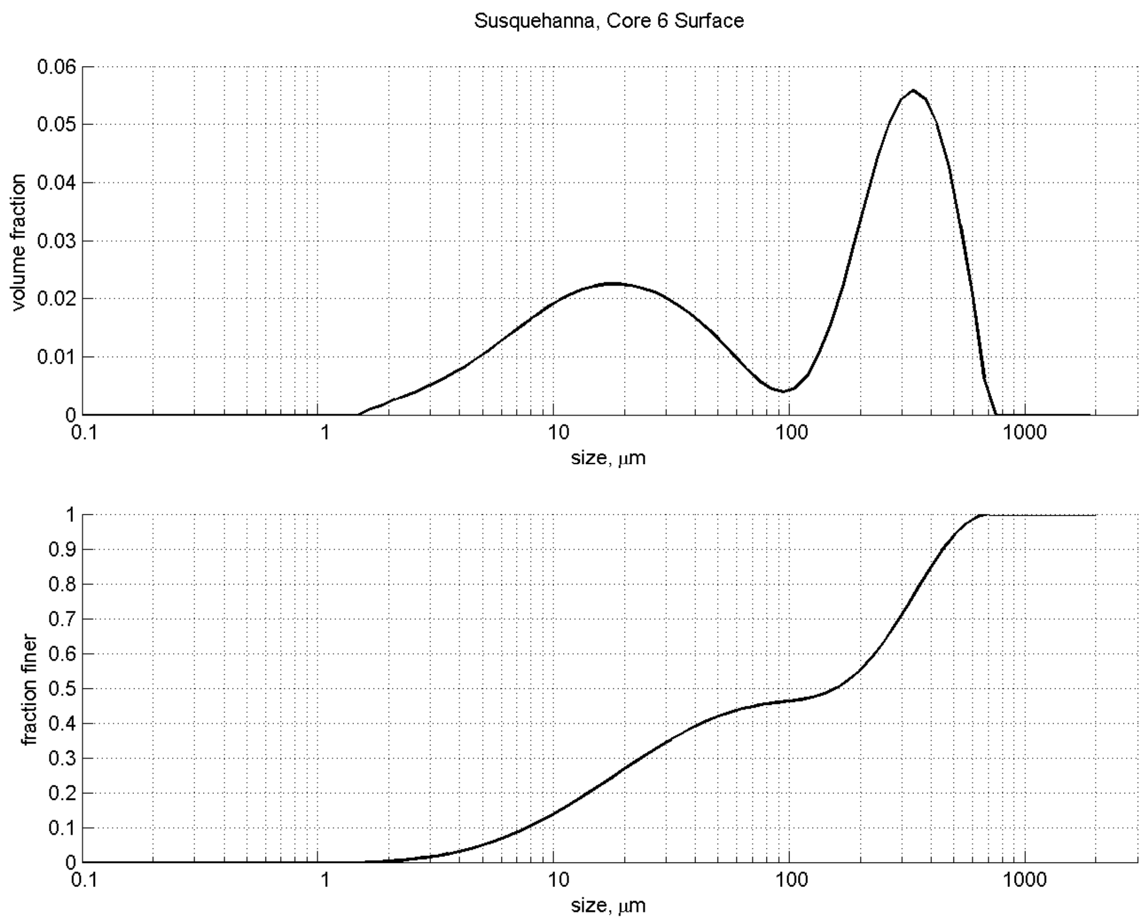


Figure A-12a. Grain Size Distribution for Core 6, Physical Sample.

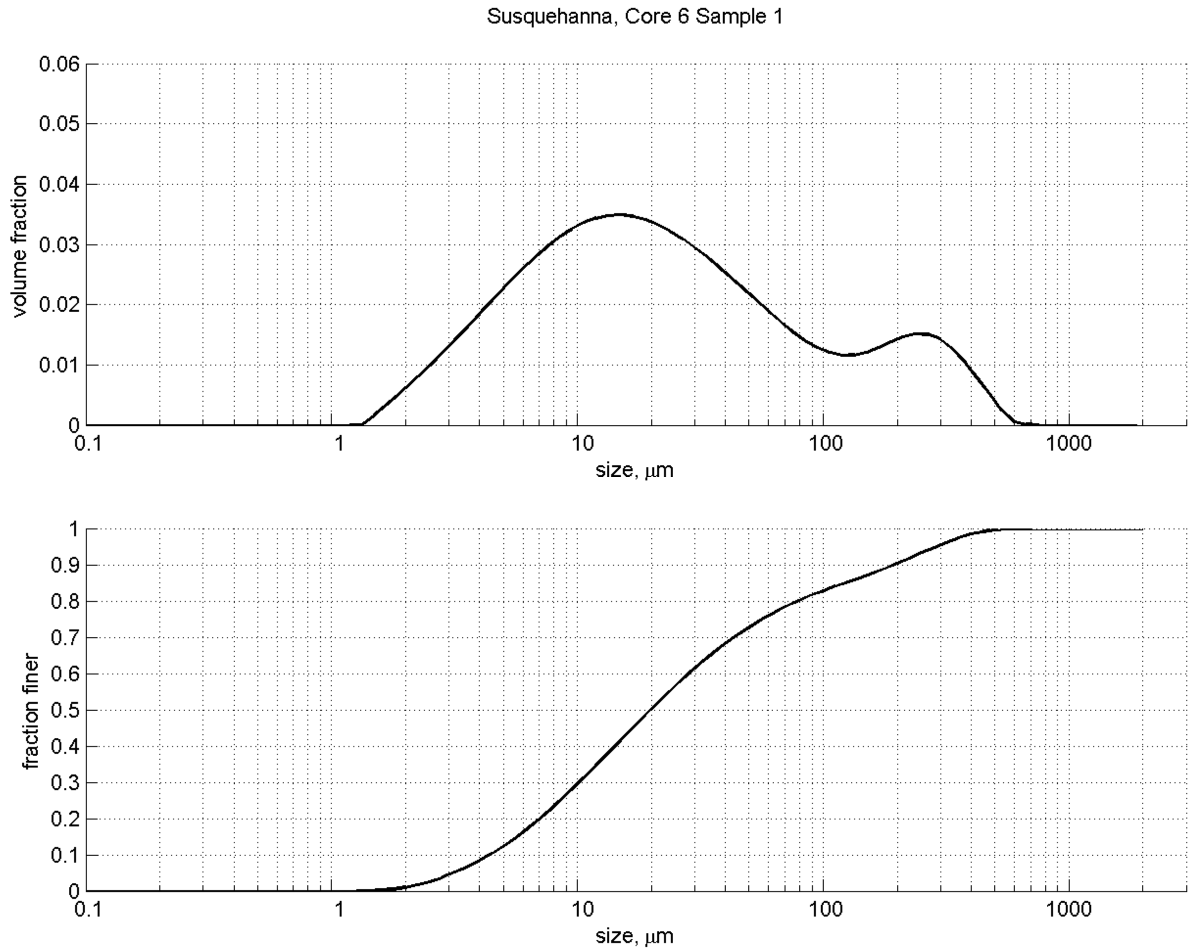


Figure A-12b. Grain Size Distribution for Core 6, Physical Sample.

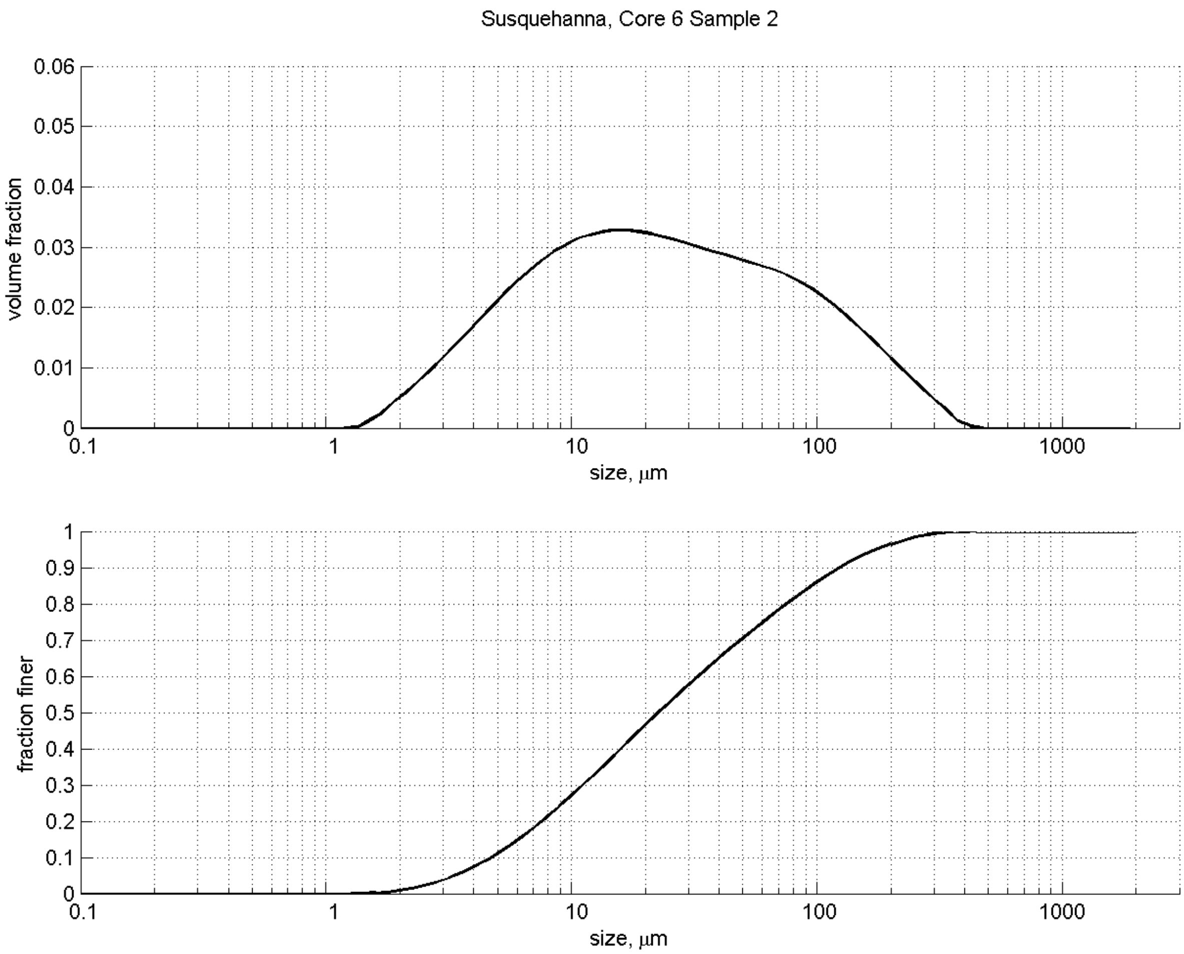


Figure A-12c. Grain Size Distribution for Core 6, Physical Sample.

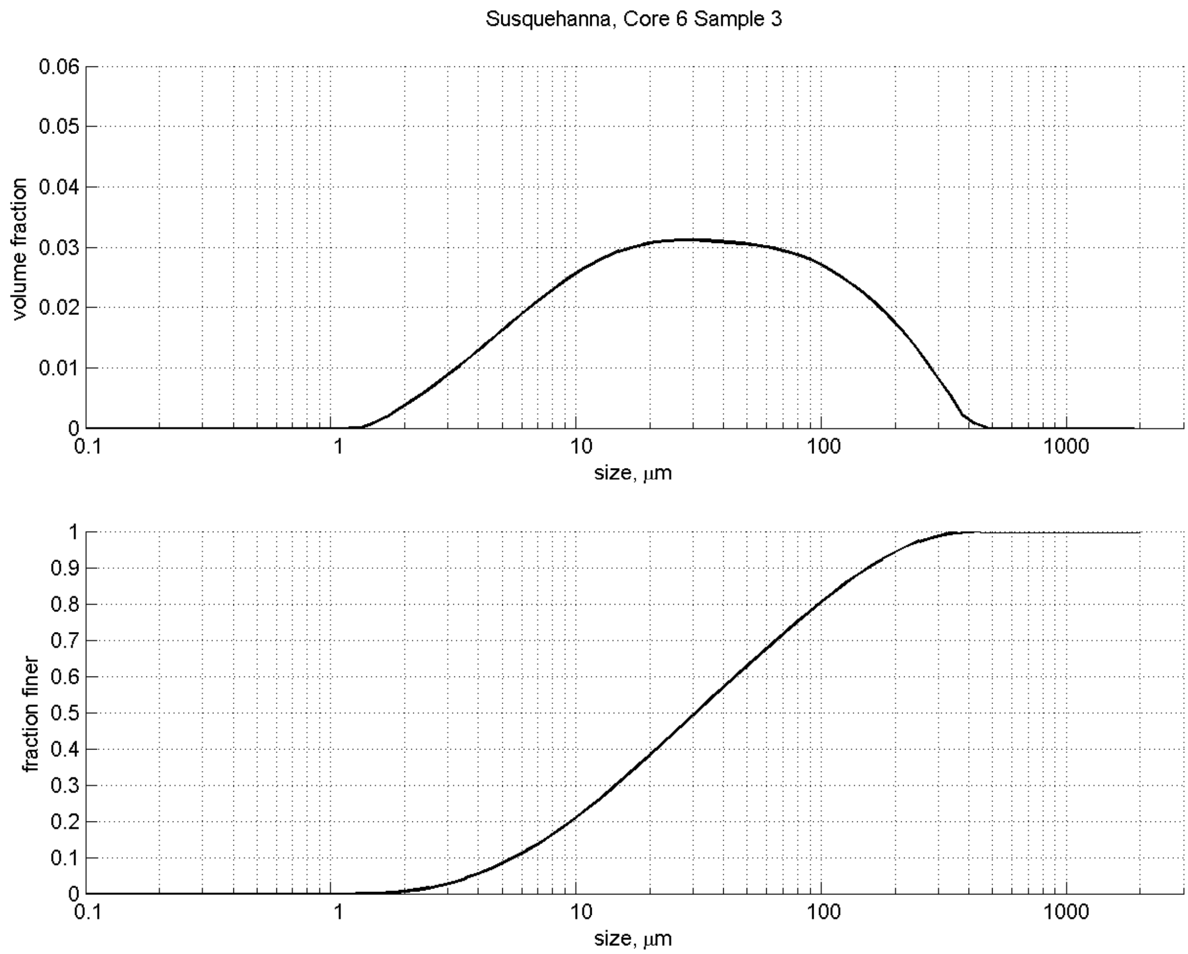


Figure A-12d. Grain Size Distribution for Core 6, Physical Sample.

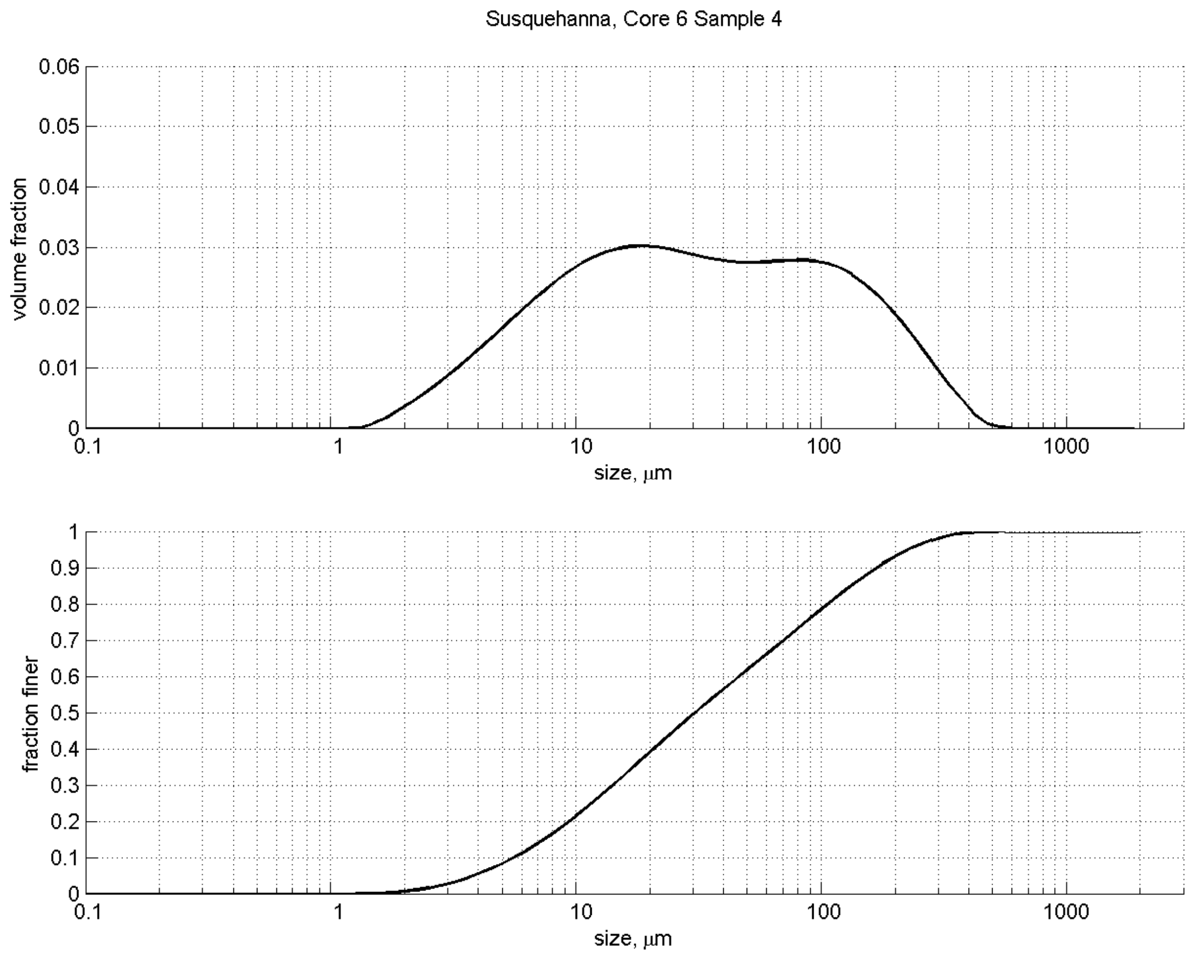


Figure A-12e. Grain Size Distribution for Core 6, Physical Sample.

Table A-7b. Physical Sample Properties (Core 9)								
Sample	Depth (cm below surf)	Bulk density (g/cm^3)	D10(μm)	D50(μm)	D90(μm)	Percent Sand	Percent Silt	Percent Clay
Surface	0.00	-	4.73	22.48	105.09	22.58	70.87	6.54
1	1.18	1.54	3.91	14.93	66.79	12.04	78.60	9.36
2	1.95	1.55	4.01	14.69	58.43	9.98	81.14	8.88
3	5.20	1.53	3.43	13.02	61.23	10.65	77.29	12.05
4	9.60	1.55	4.22	17.97	83.25	16.57	75.35	8.08

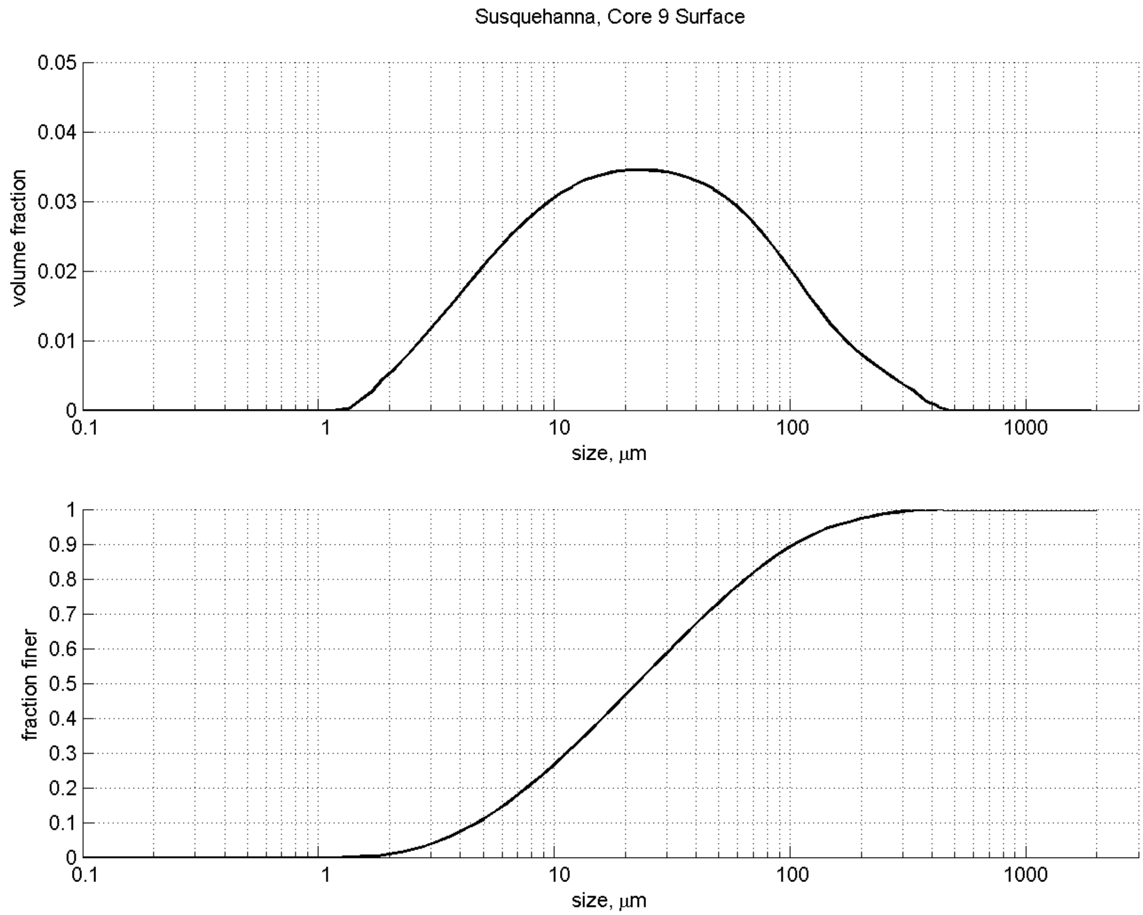


Figure A-14a. Grain Size Distribution for Core 9, Physical Sample.

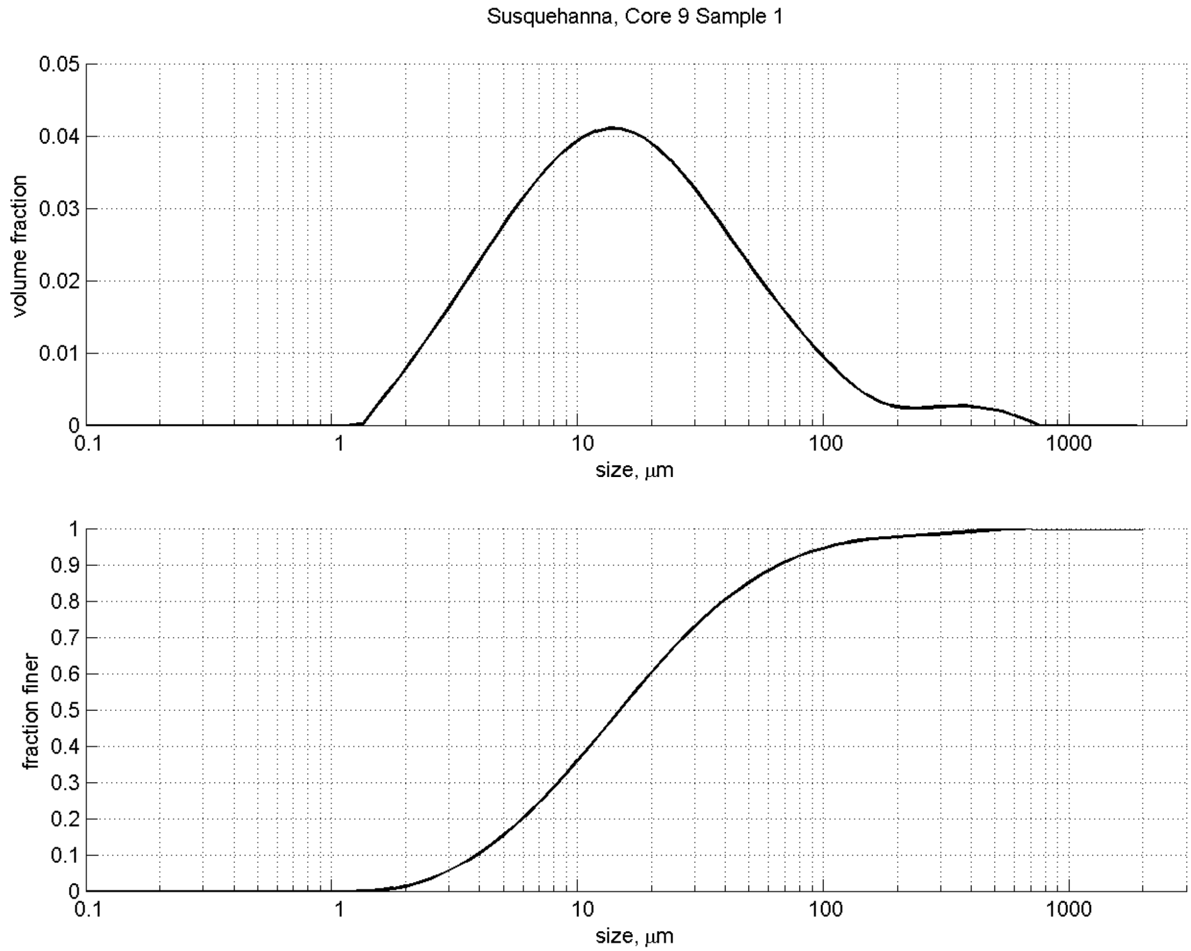


Figure A-14b. Grain Size Distribution for Core 9, Physical Sample.

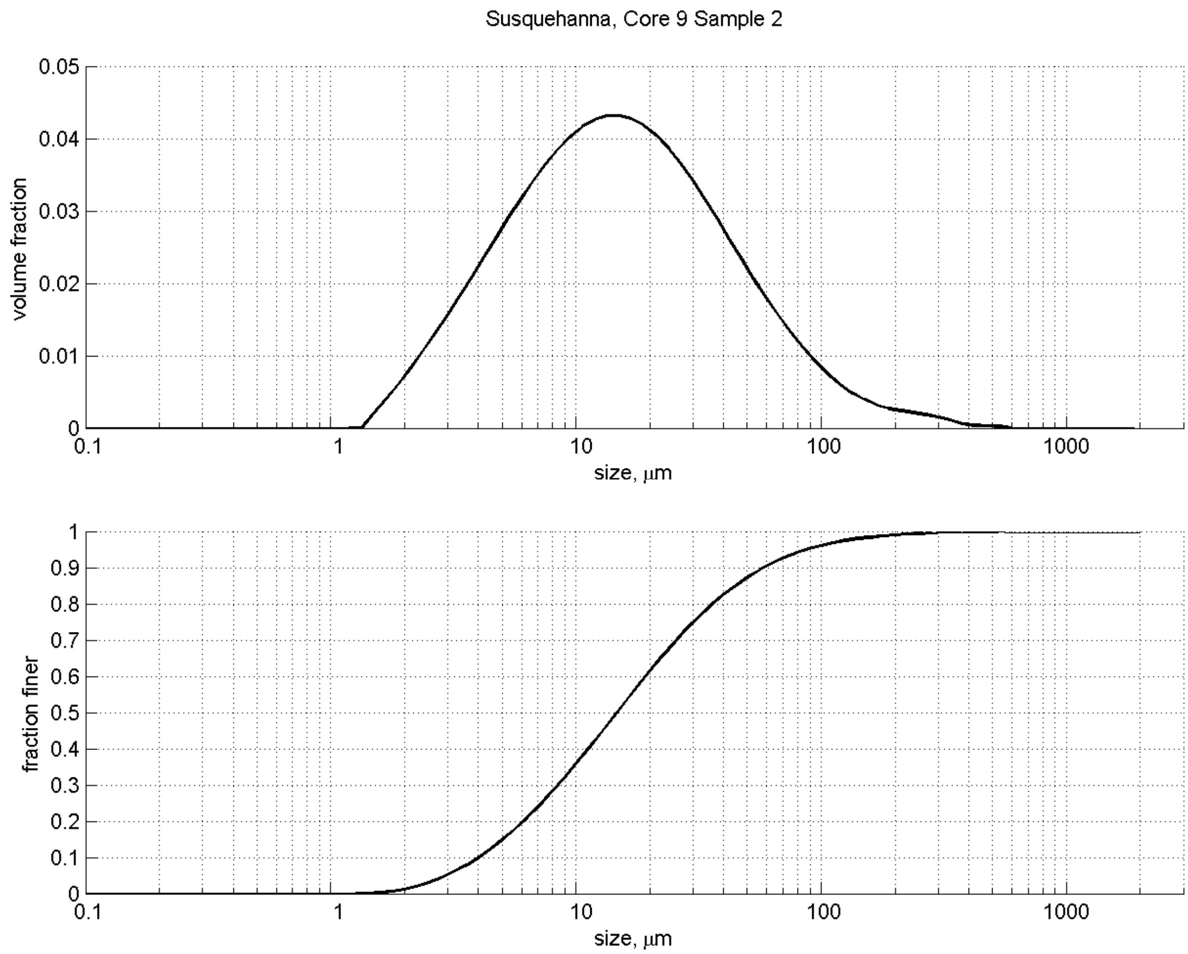


Figure A-14c. Grain Size Distribution for Core 9, Physical Sample.

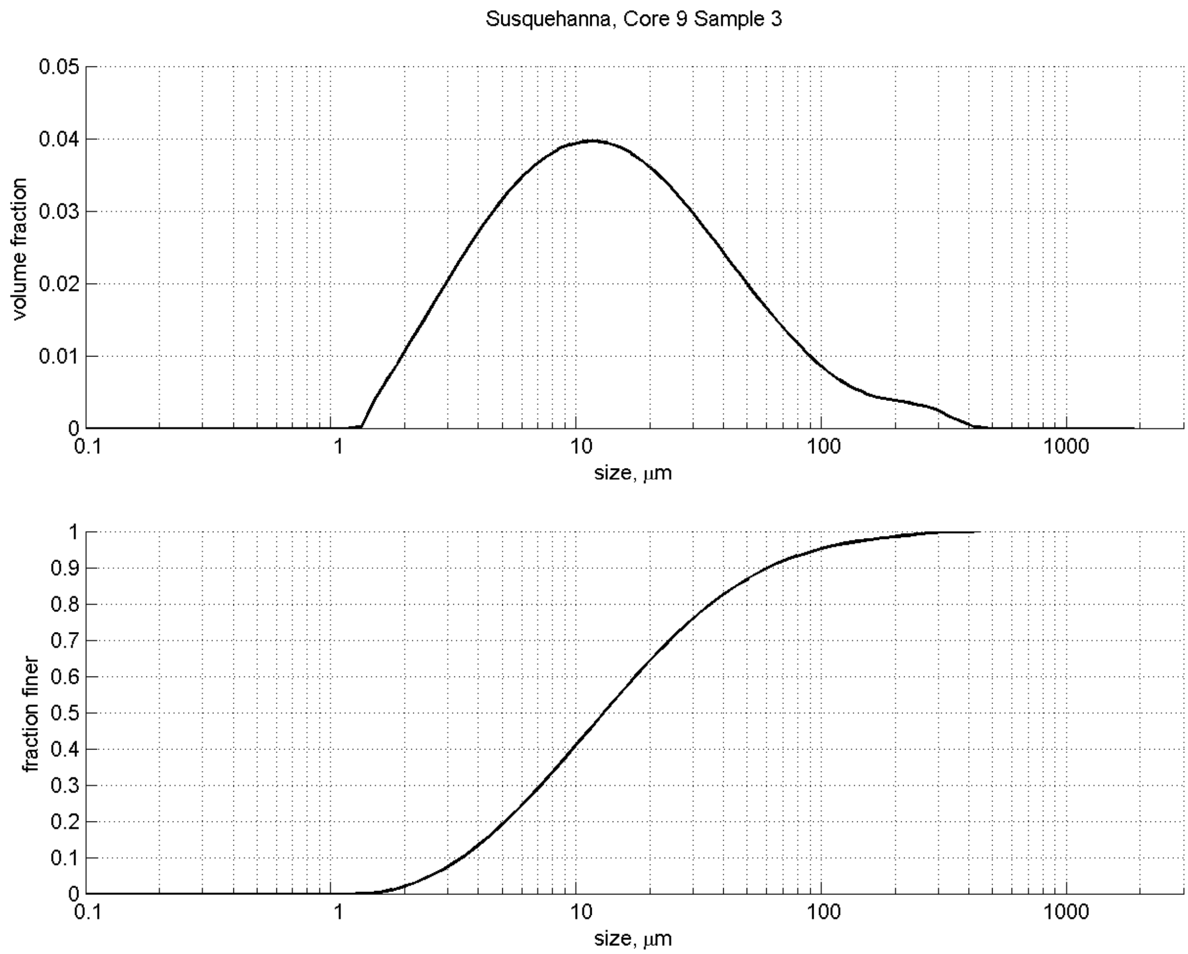


Figure A-14d. Grain Size Distribution for Core 9, Physical Sample.

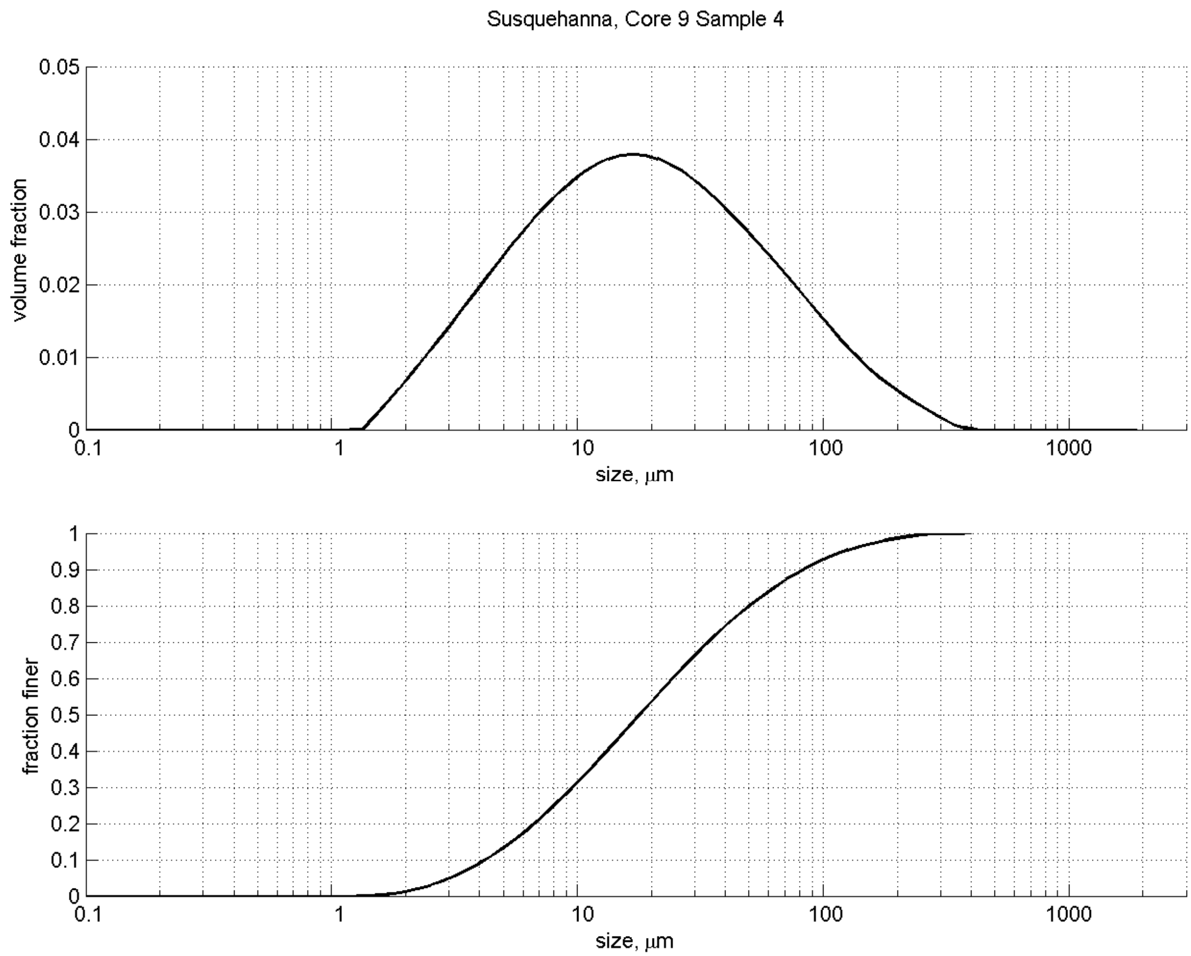


Figure A-14e. Grain Size Distribution for Core 9, Physical Sample.

Table A-8b. Physical Sample Properties (Core 10)								
Sample	Depth (cm below surf)	Bulk density (g/cm^3)	D10(μm)	D50(μm)	D90(μm)	Percent Sand	Percent Silt	Percent Clay
Surface	0.00	-	7.92	53.53	382.76	47.76	49.52	2.72
1	0.73	1.67	10.07	118.55	536.26	64.75	33.01	2.24
2	5.20	1.77	17.57	300.76	725.76	80.06	18.40	1.54
3	8.15	1.40	5.35	26.99	234.51	30.70	64.07	5.23
4	12.00	1.47	4.91	21.67	97.31	20.22	73.67	6.11
5	15.55	1.53	4.79	23.31	120.45	24.24	69.23	6.53

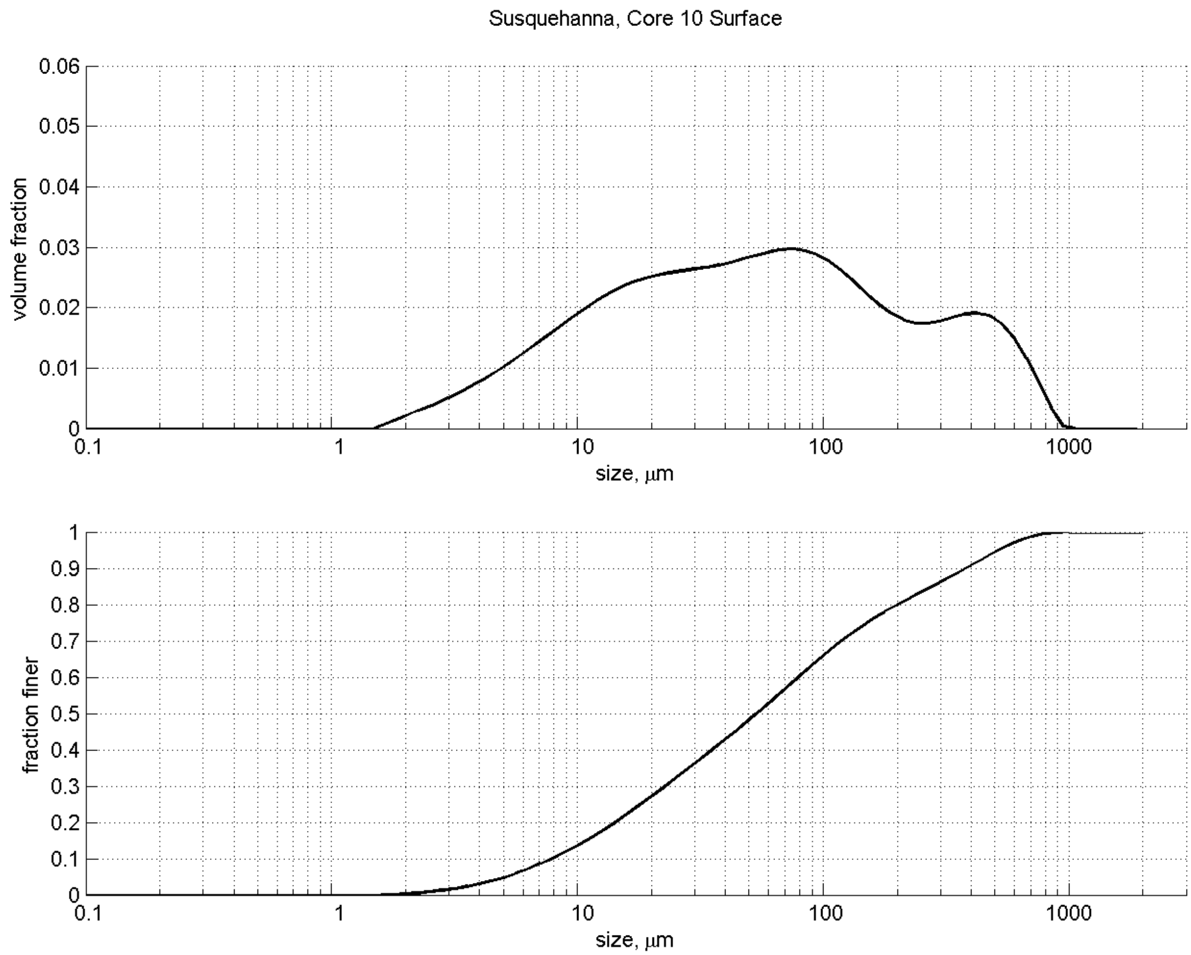


Figure A-15a. Grain Size Distribution for Core 10, Physical Sample.

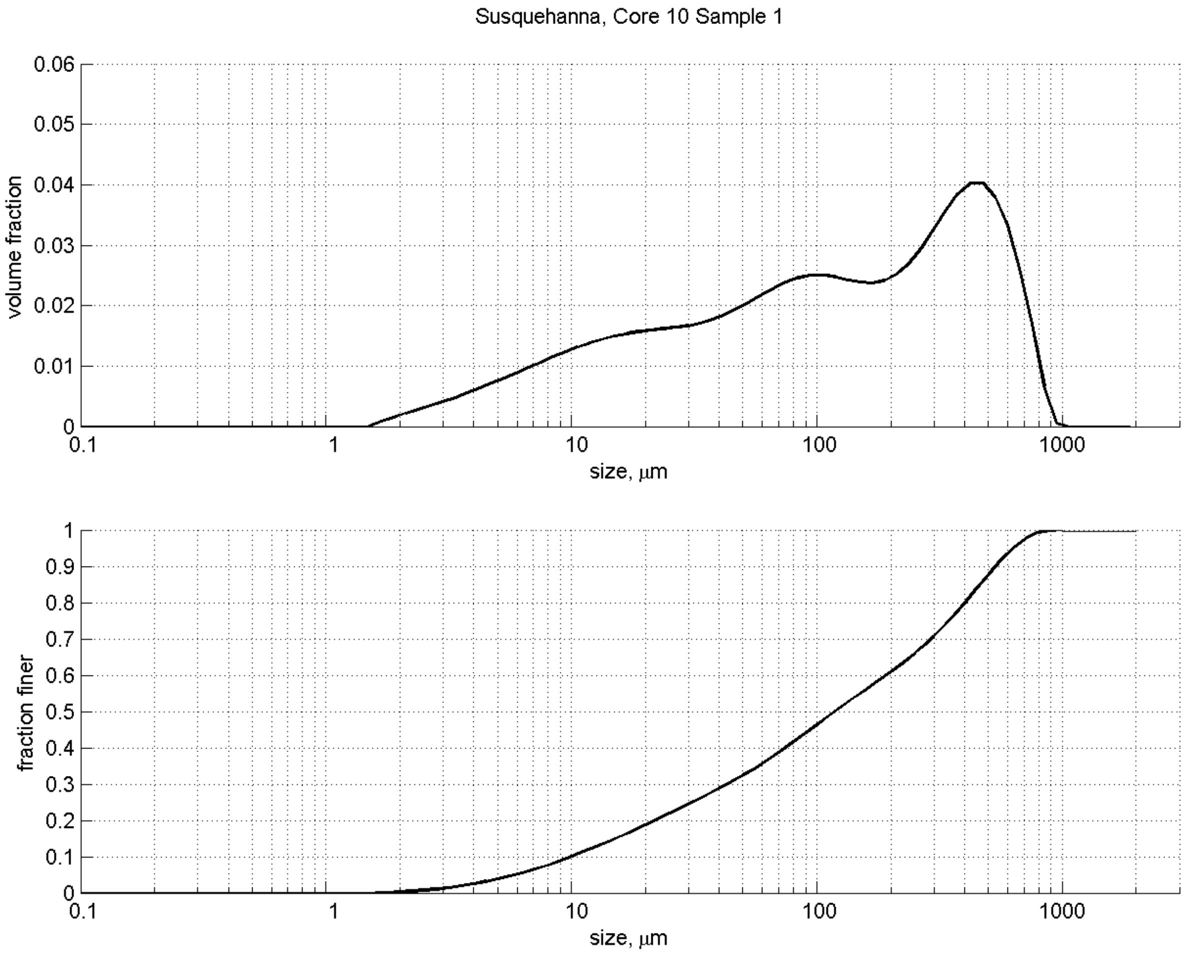


Figure A-15b. Grain Size Distribution for Core 10, Physical Sample.

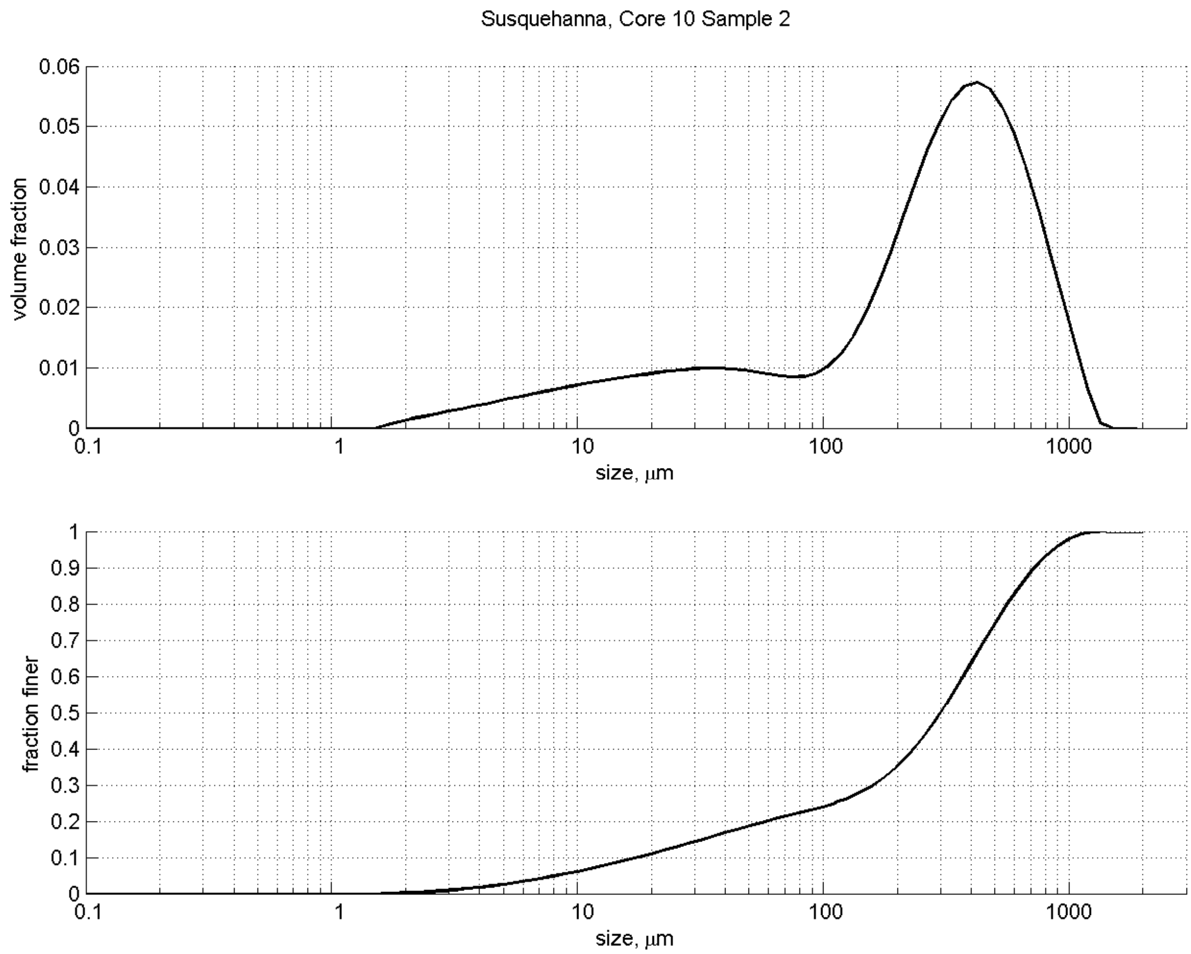


Figure A-15c. Grain Size Distribution for Core 10, Physical Sample.

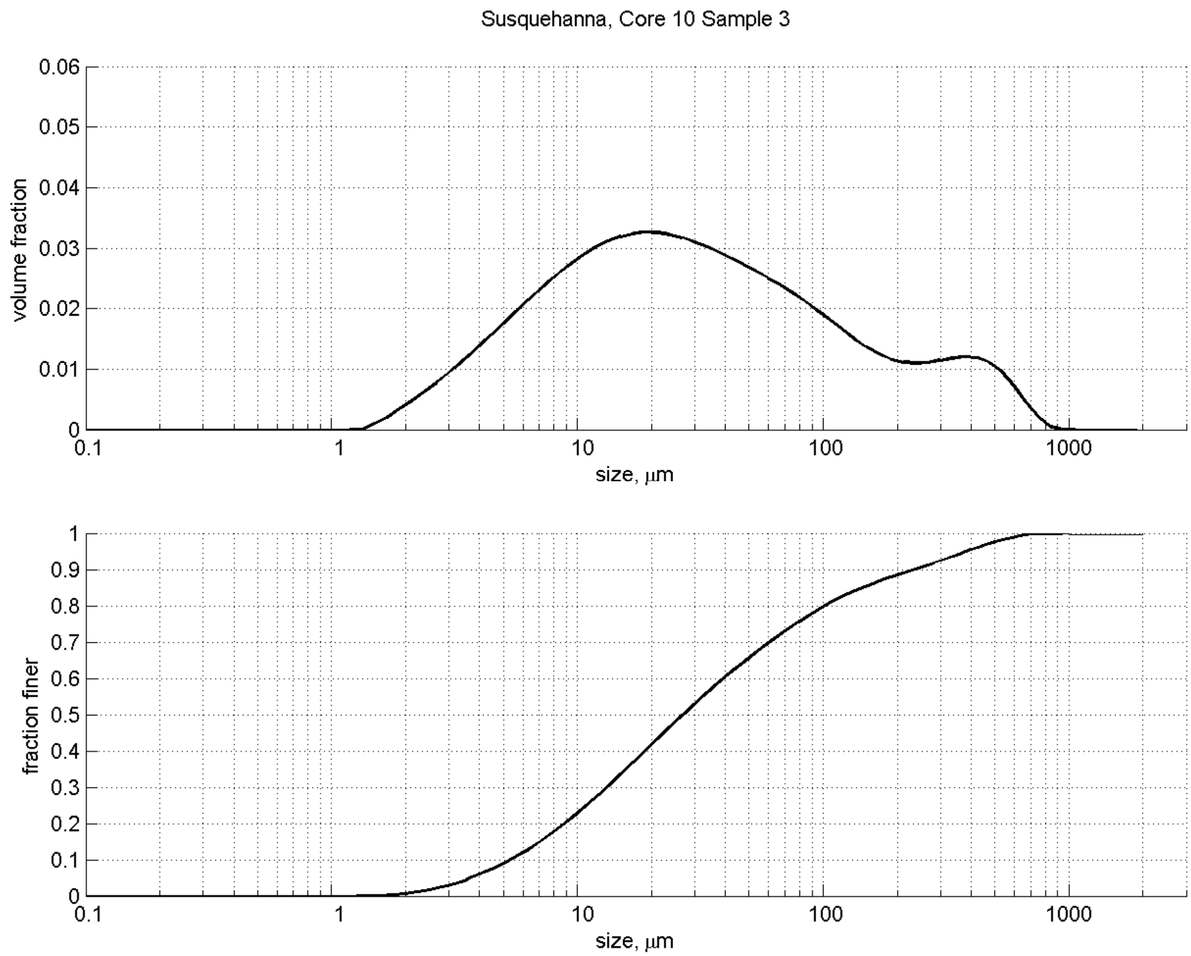


Figure A-15d. Grain Size Distribution for Core 10, Physical Sample.

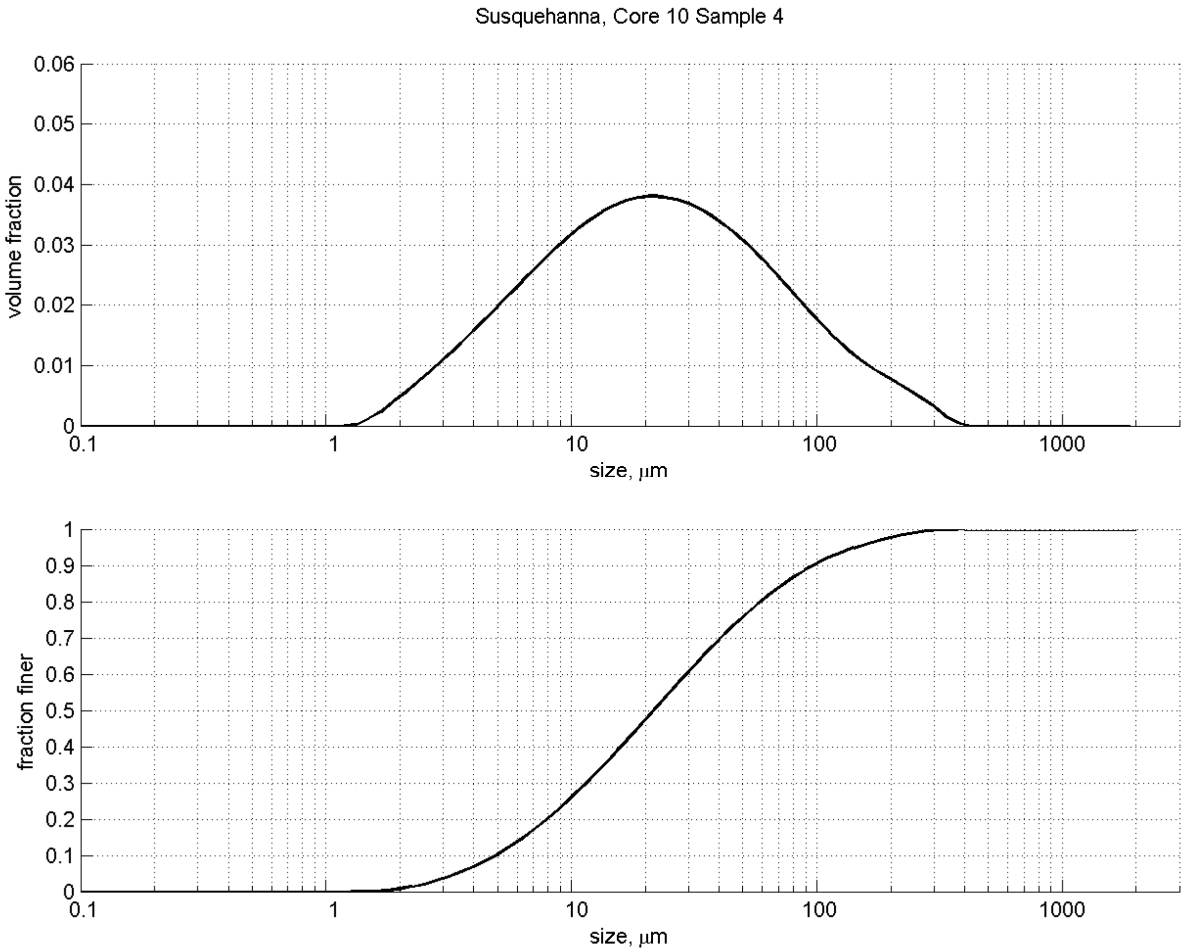


Figure A-15e. Grain Size Distribution for Core 10, Physical Sample.

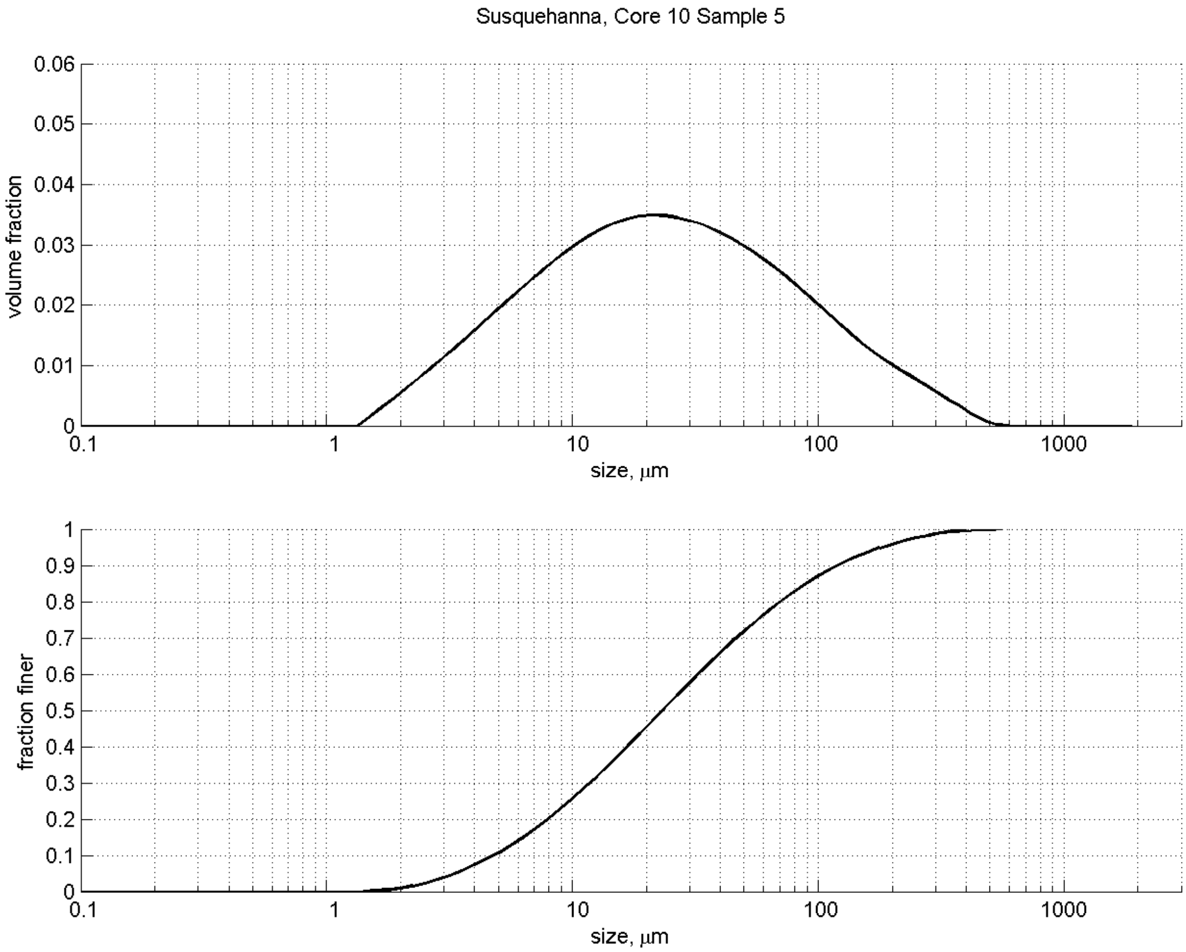


Figure A-15f. Grain Size Distribution for Core 10, Physical Sample.

Erosion versus Depth

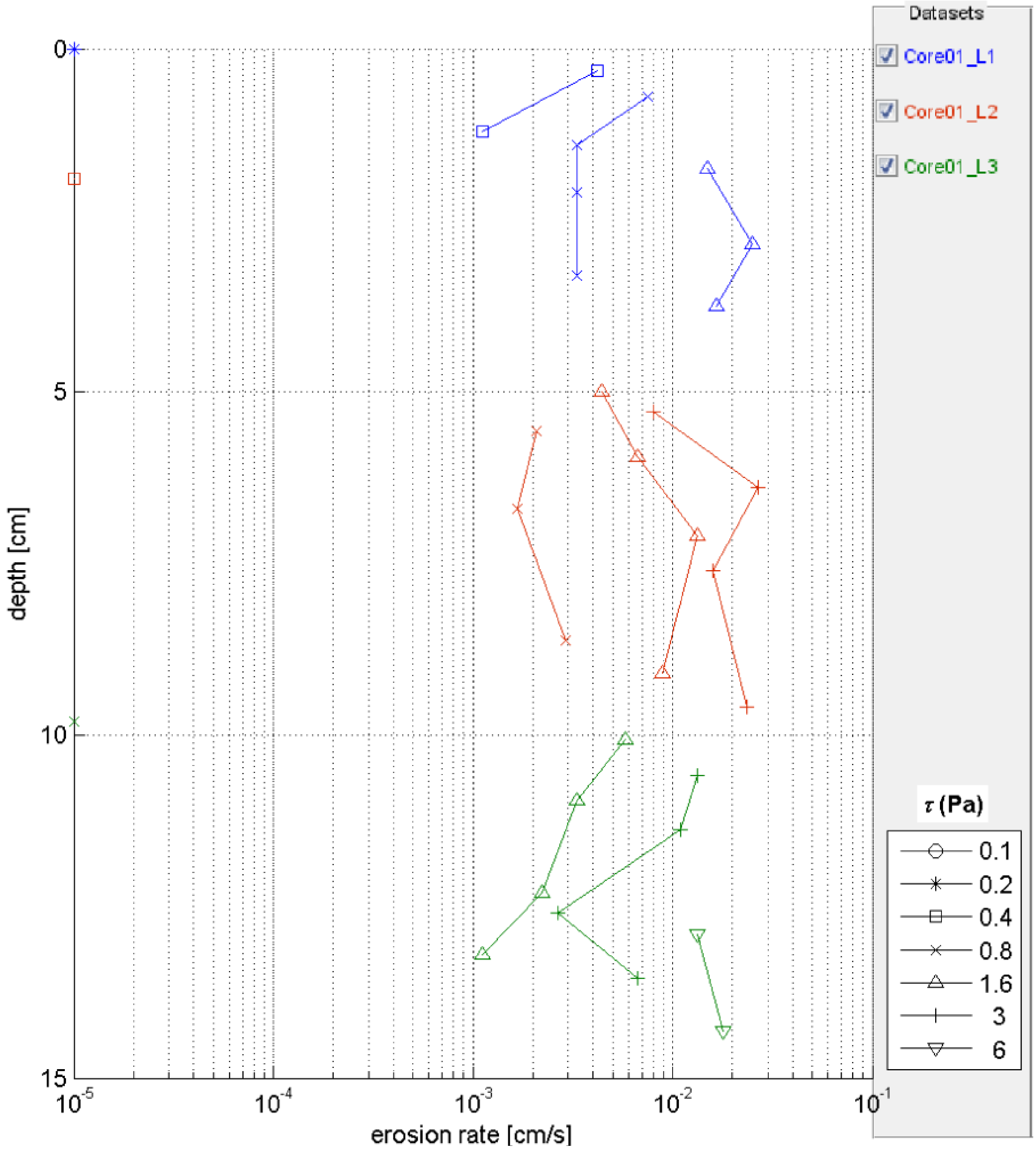


Figure B-1. Erosion versus depth for core 1. Colors indicate bed layers, symbols indicate applied shear stress.

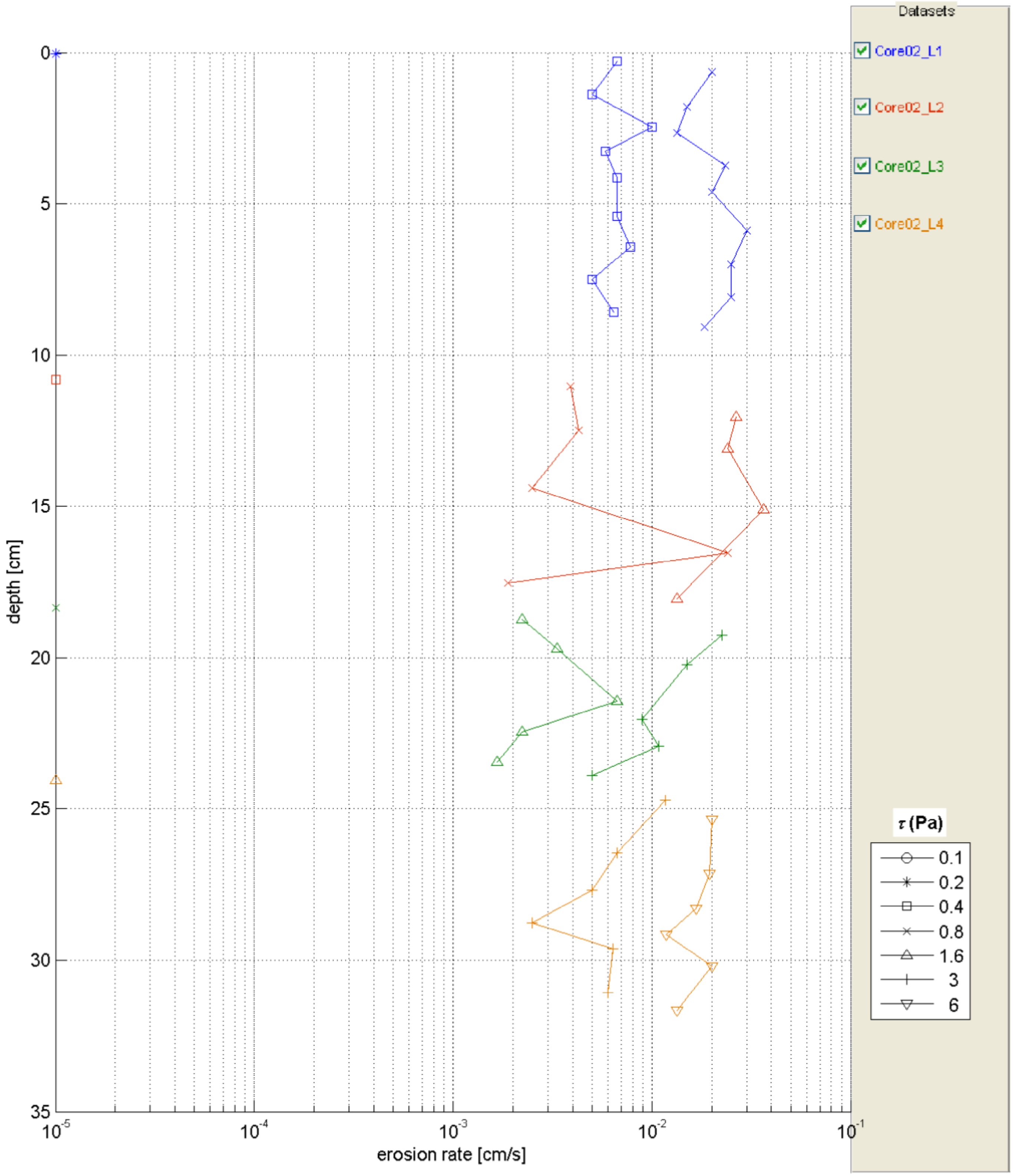


Figure B-2. Erosion versus depth for core 2. Colors indicate bed layers, symbols indicate applied shear stress.

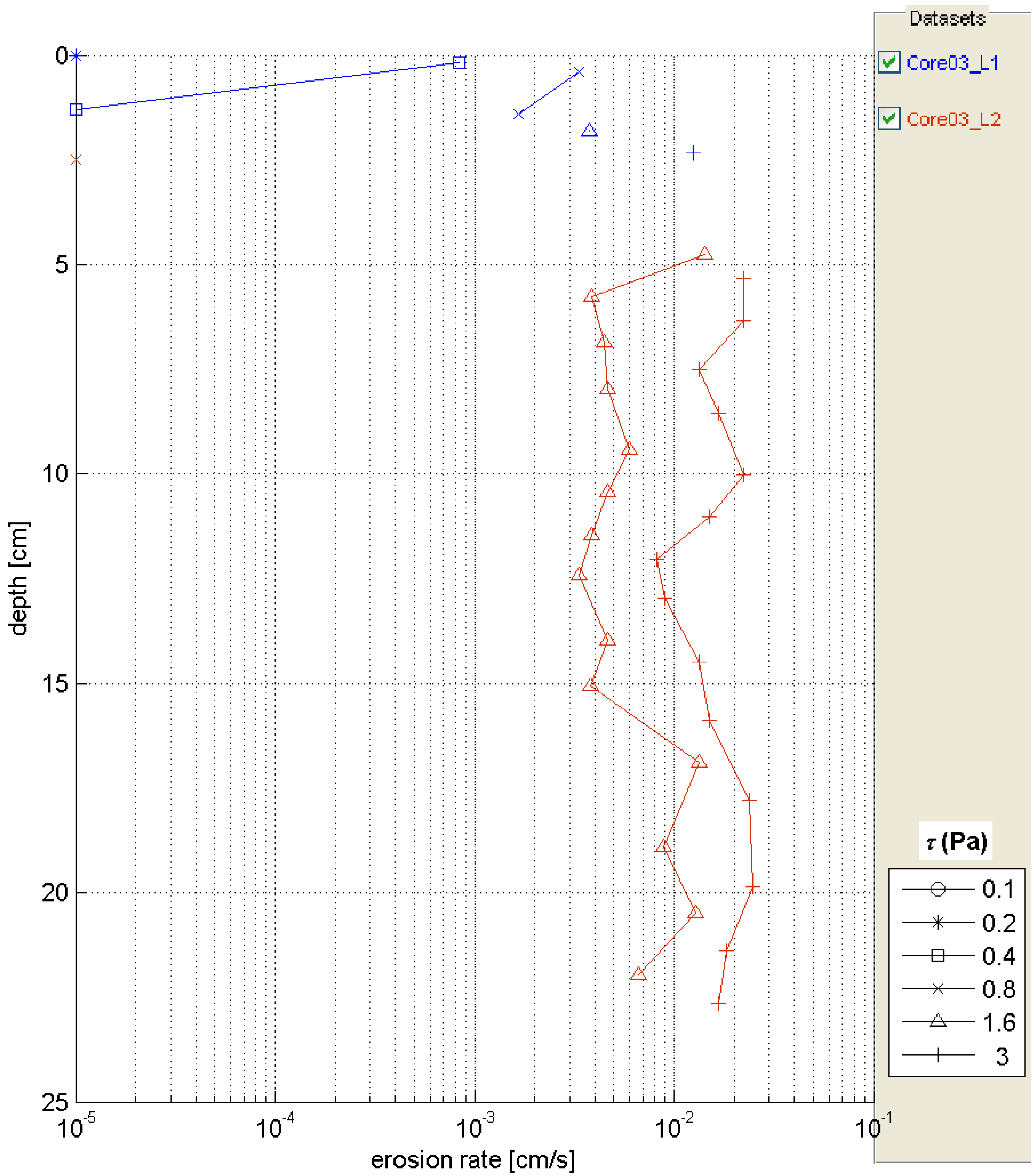


Figure B-3. Erosion versus depth for core 3. Colors indicate bed layers, symbols indicate applied shear stress.

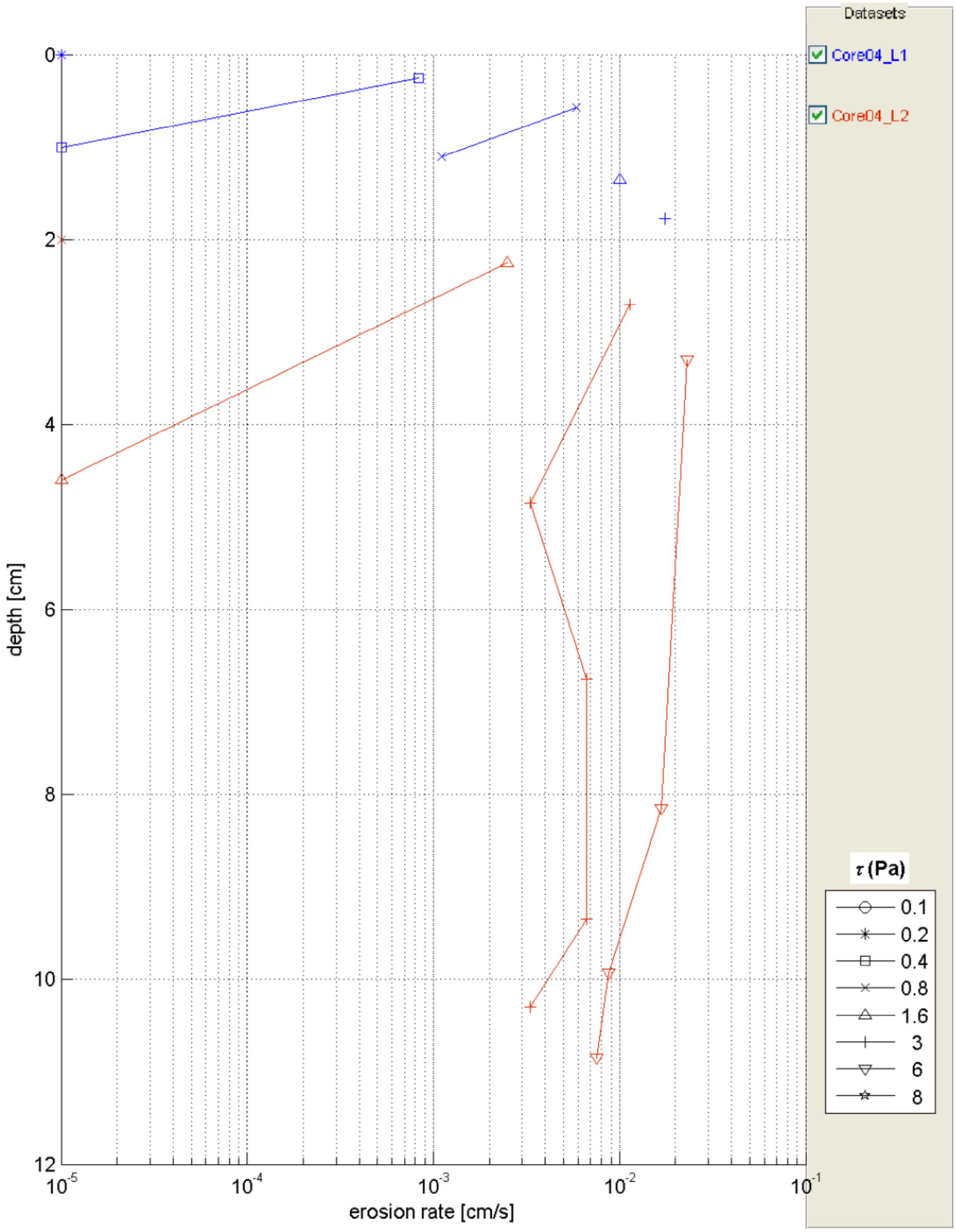


Figure B-4. Erosion versus depth for core 4. Colors indicate bed layers, symbols indicate applied shear stress.

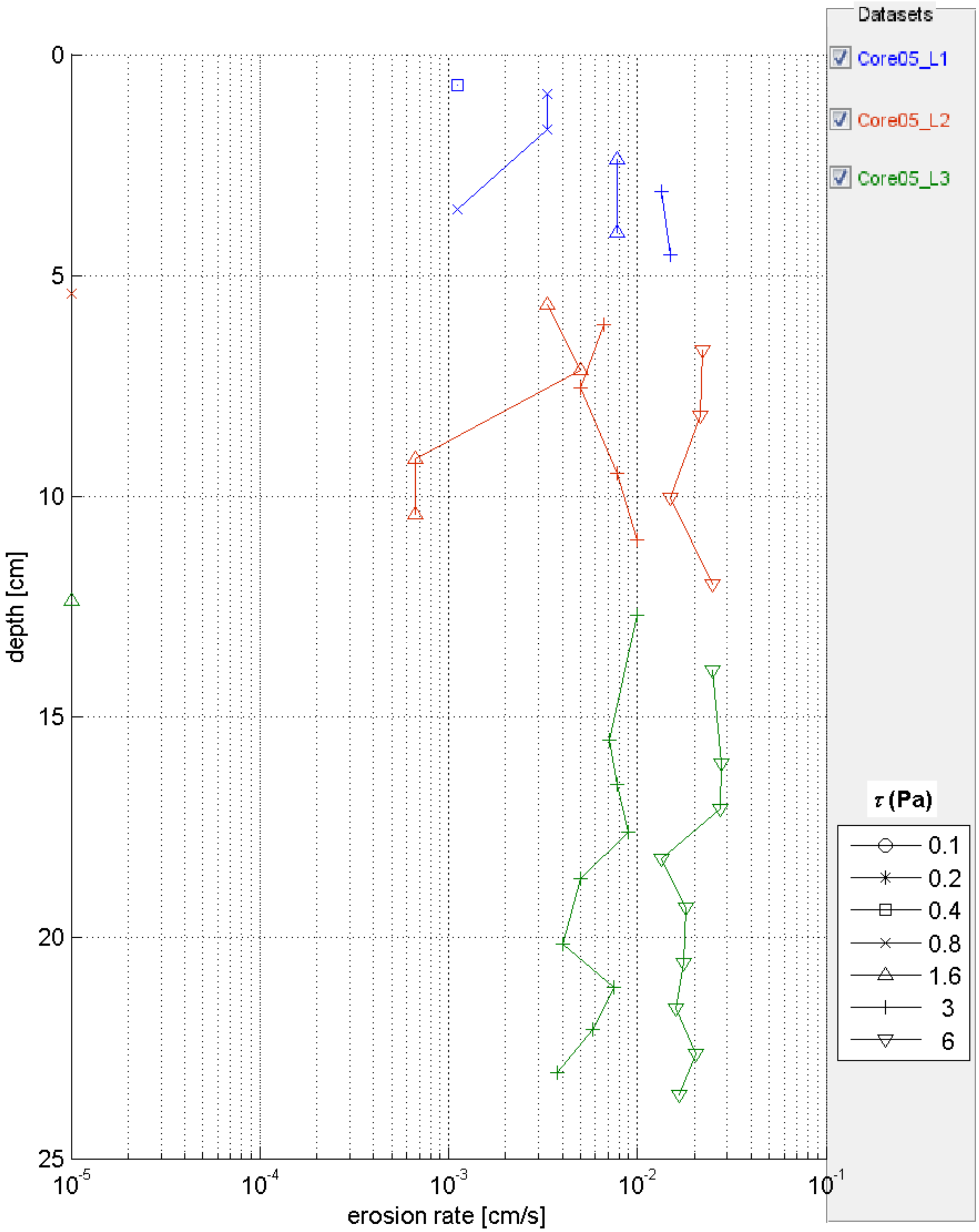


Figure B-5. Erosion versus depth for core 5. Colors indicate bed layers, symbols indicate applied shear stress.

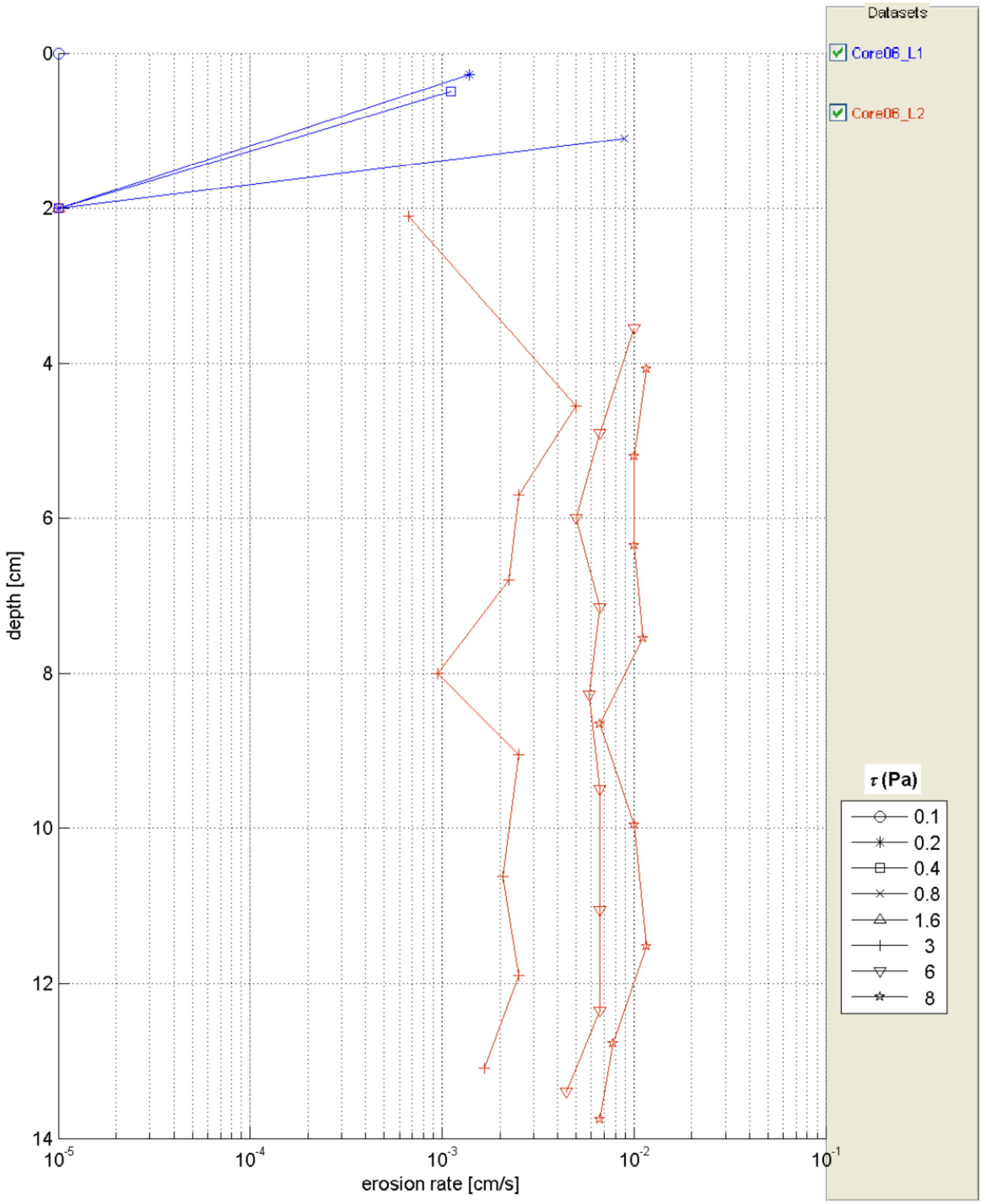


Figure B-6. Erosion versus depth for core 6. Colors indicate bed layers, symbols indicate applied shear stress.

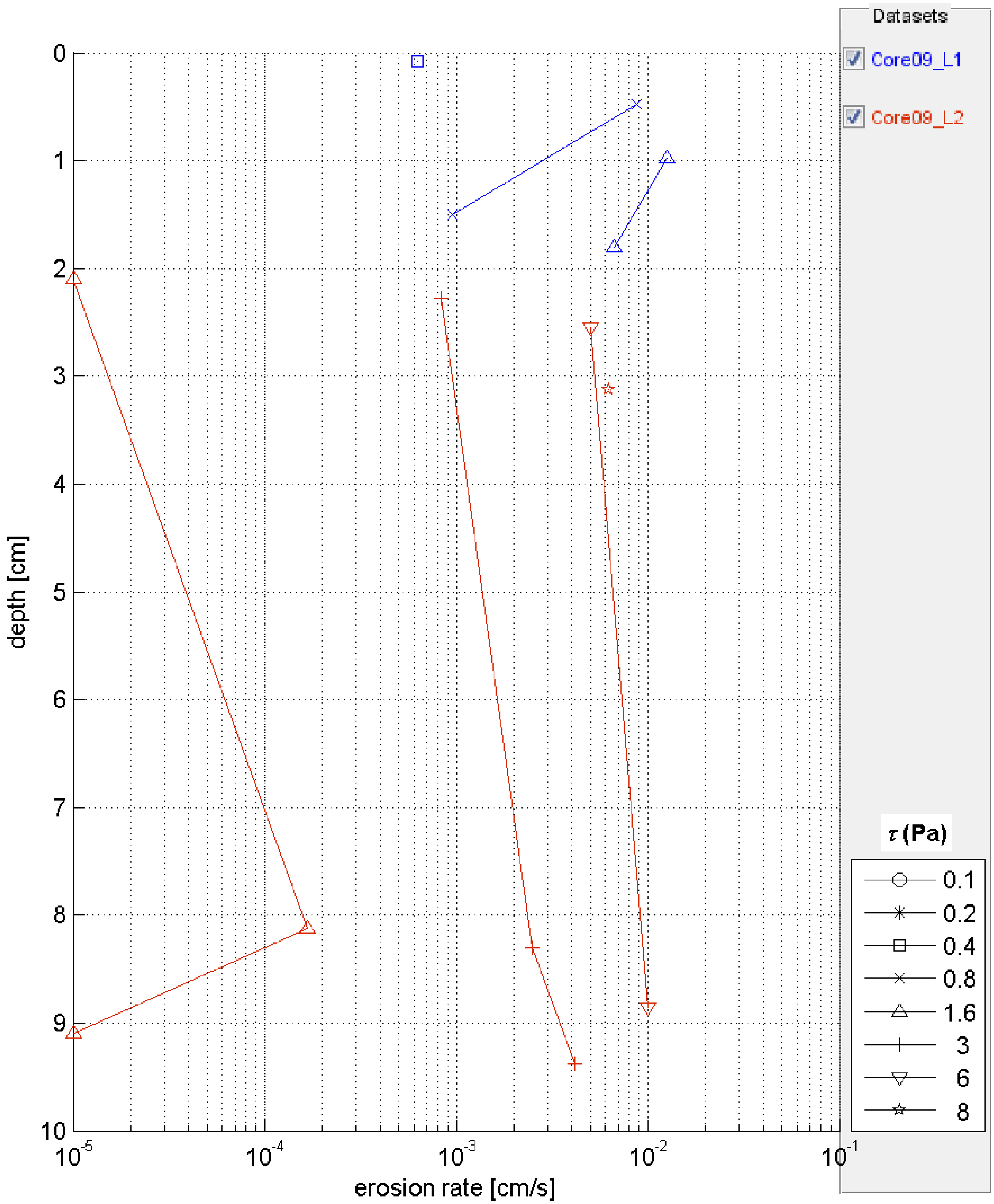


Figure B-7. Erosion versus depth for core 9. Colors indicate bed layers, symbols indicate applied shear stress.

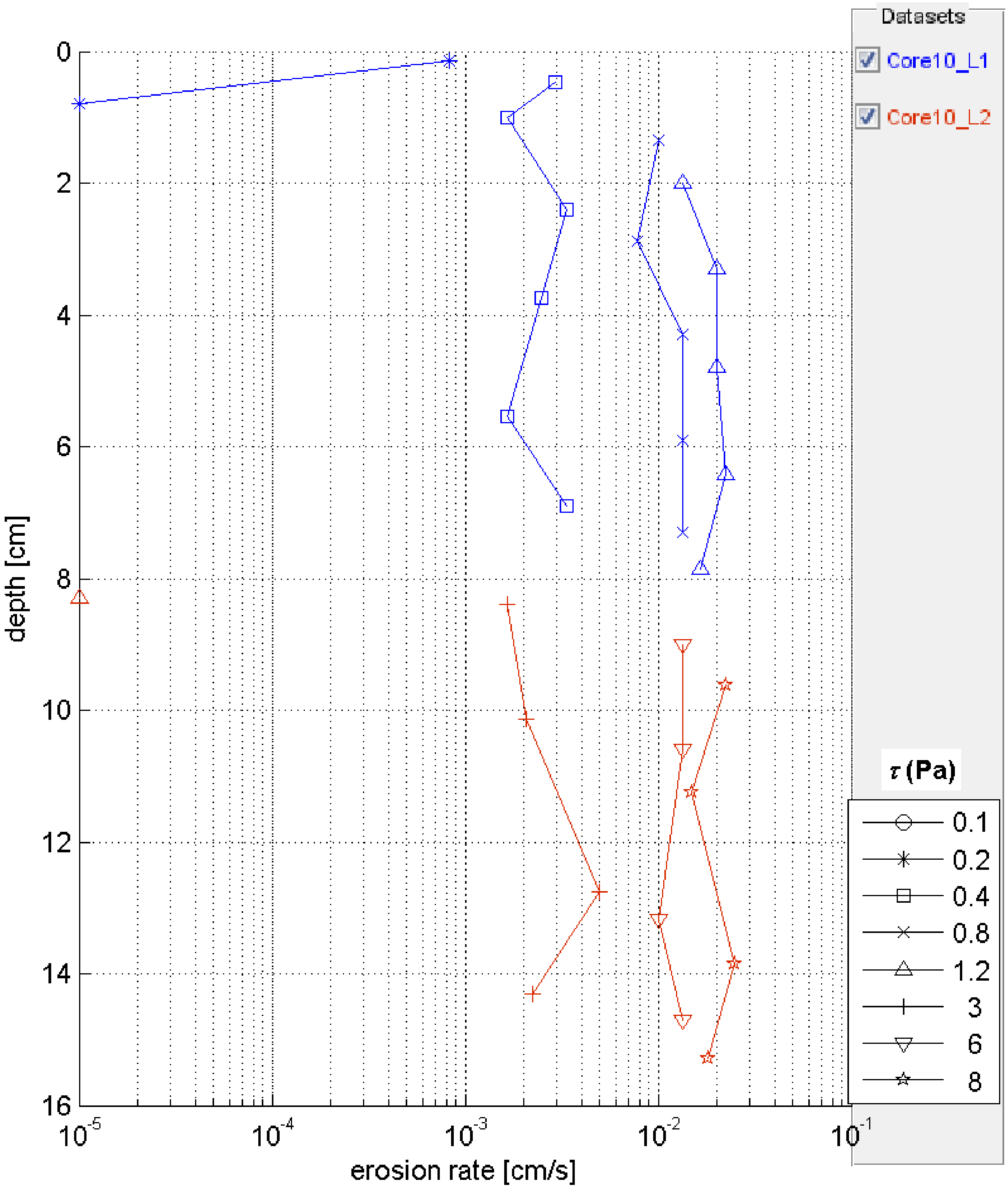


Figure B-8. Erosion versus depth for core 10. Colors indicate bed layers, symbols indicate applied shear stress.

Erosion versus shear stress (Partheniades)

Core 1

Table B-1. Cohesive Sediment Erosion Parameterization				
		Critical Shear (τ_{cr})	Erosion Rate Constant (M)	Erosion Rate Exponent (n)
Layer ID	Depth (cm)	Pa	-	-
Core01_L1	0-4	0.20	2.02E-02	1.14
Core01_L2	5-10	0.40	2.89E-02	1.10
Core01_L3	10-14	0.80	3.52E-02	0.96

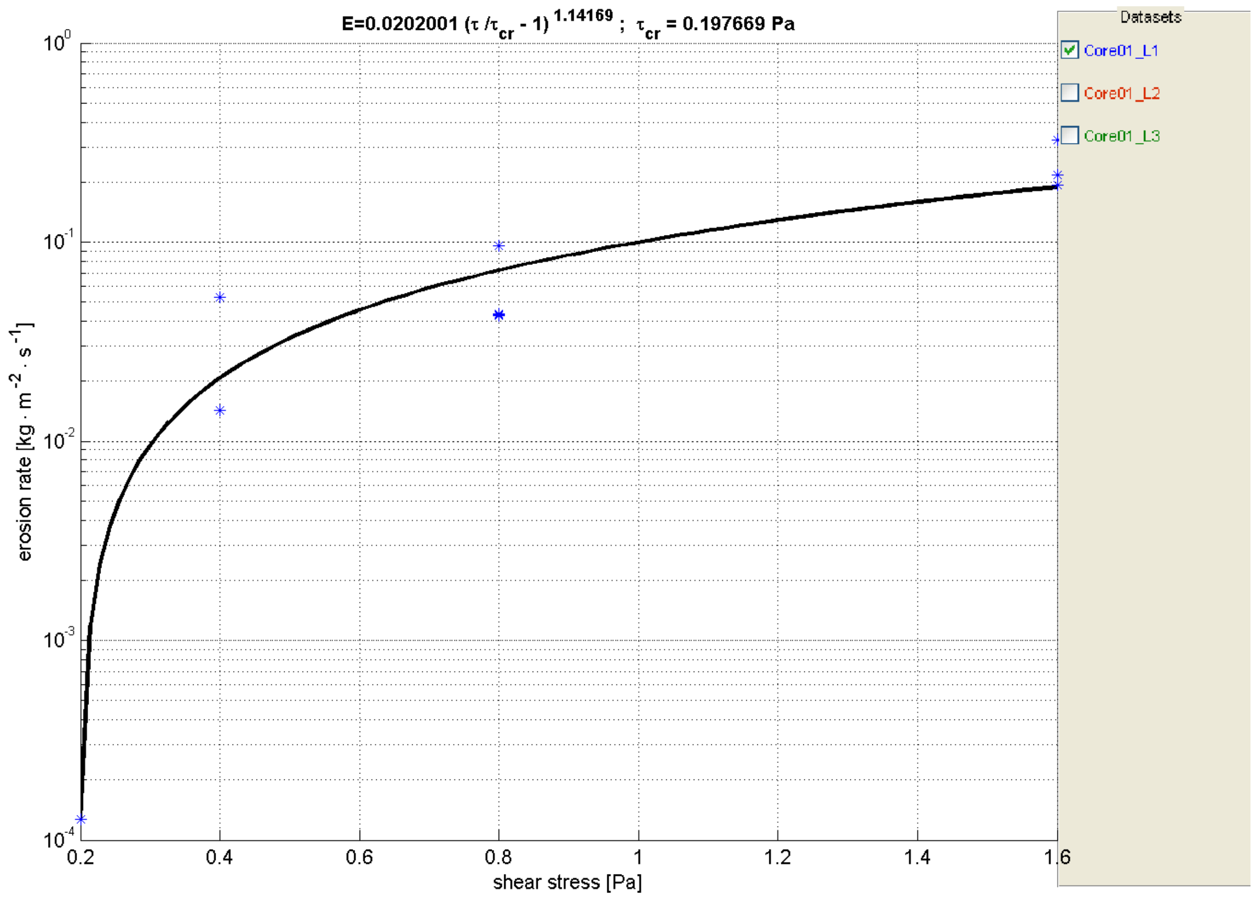


Figure B-9. Erosion versus applied shear stress for core 1, Layer 1. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

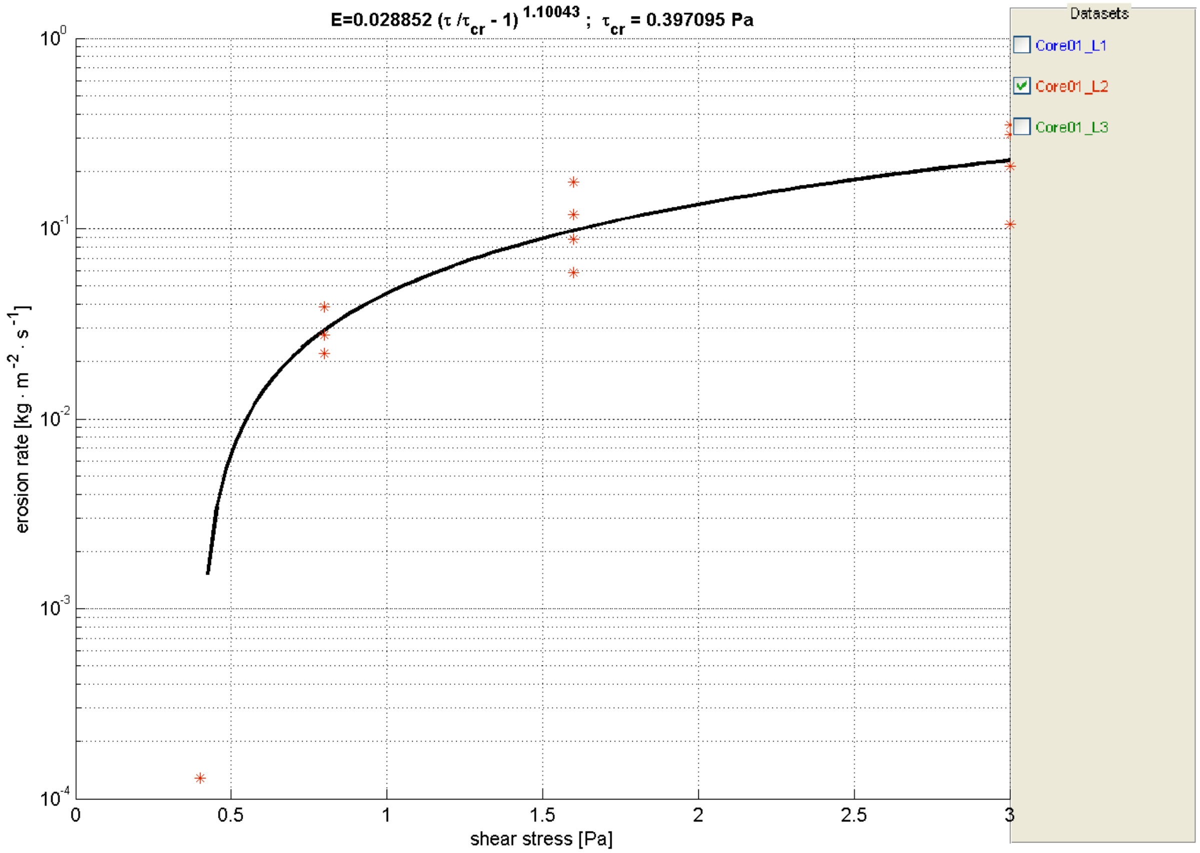


Figure B-10. Erosion versus applied shear stress for core 1, Layer 2. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

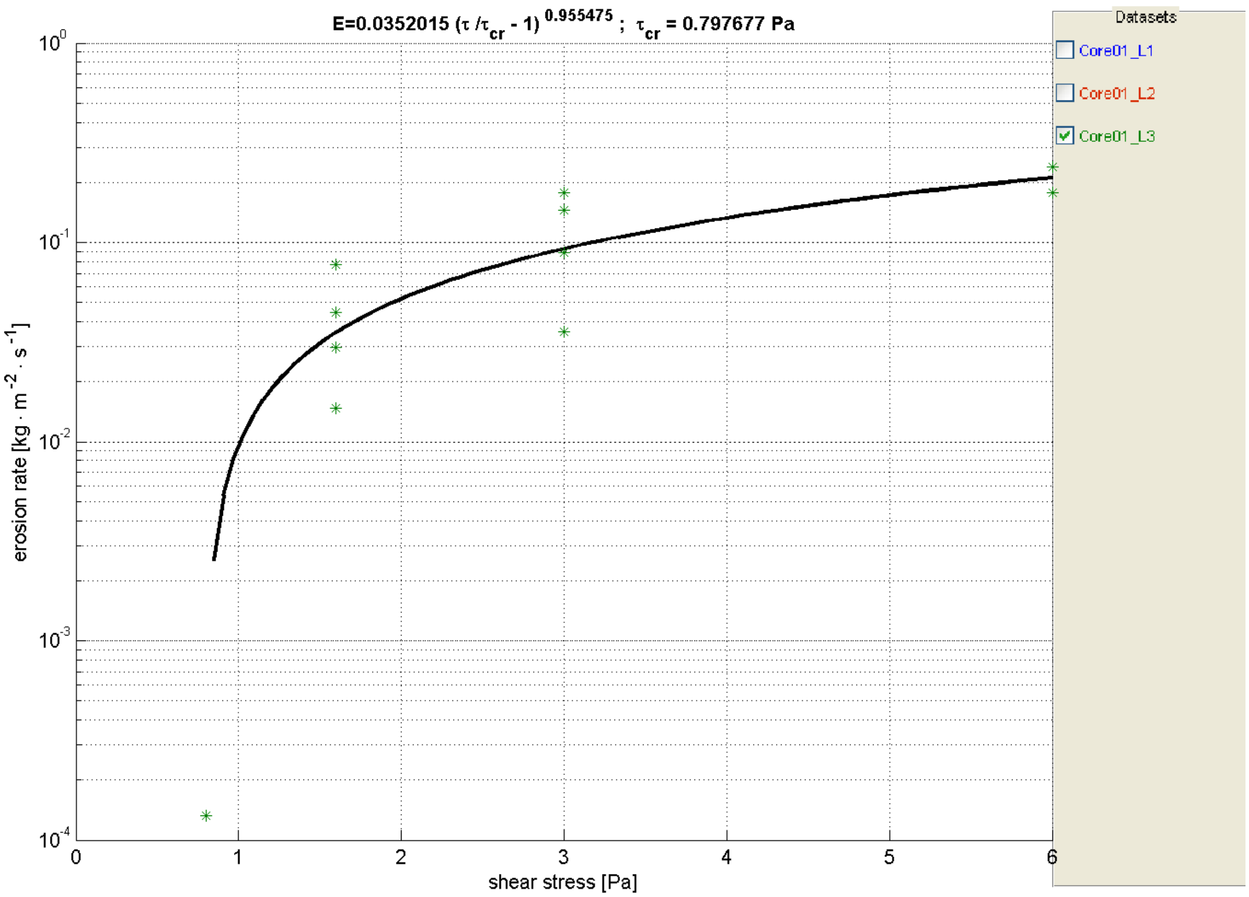


Figure B-11. Erosion versus applied shear stress for core 1, Layer 3. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 2

Table B-2. Cohesive Sediment Erosion Parameterization

Layer ID	Depth (cm)	Critical Shear (τ_{cr})	Erosion Rate Constant (M)	Erosion Rate Exponent (n)
		Pa	-	-
Core02_L1	0-10	0.20	1.01E-01	1.05
Core02_L2	10-17	0.40	5.98E-02	1.52
Core02_L3	17-24	0.80	3.73E-02	1.36
Core02_L4	24-32	1.60	9.18E-02	0.92
Core02_L3&4	17-32	0.80	3.86E-02	0.92

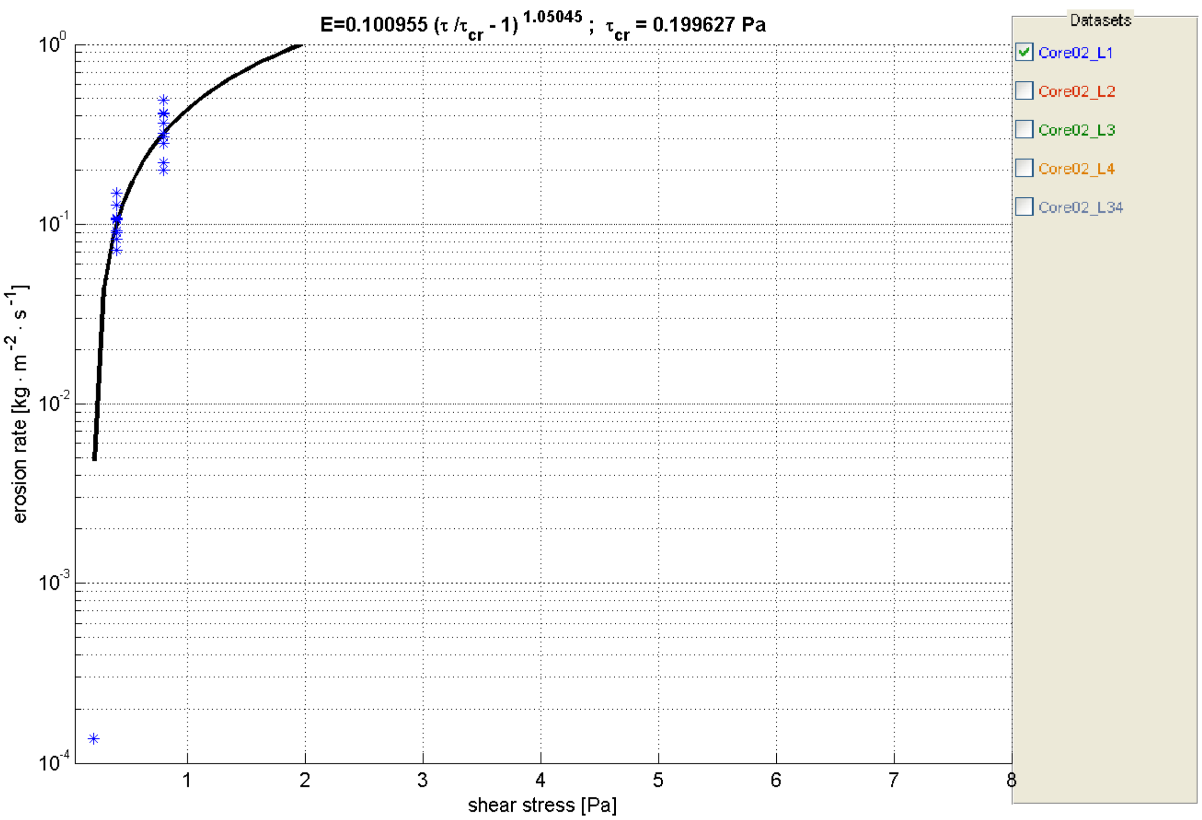


Figure B-12. Erosion versus applied shear stress for core 2, Layer 1. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

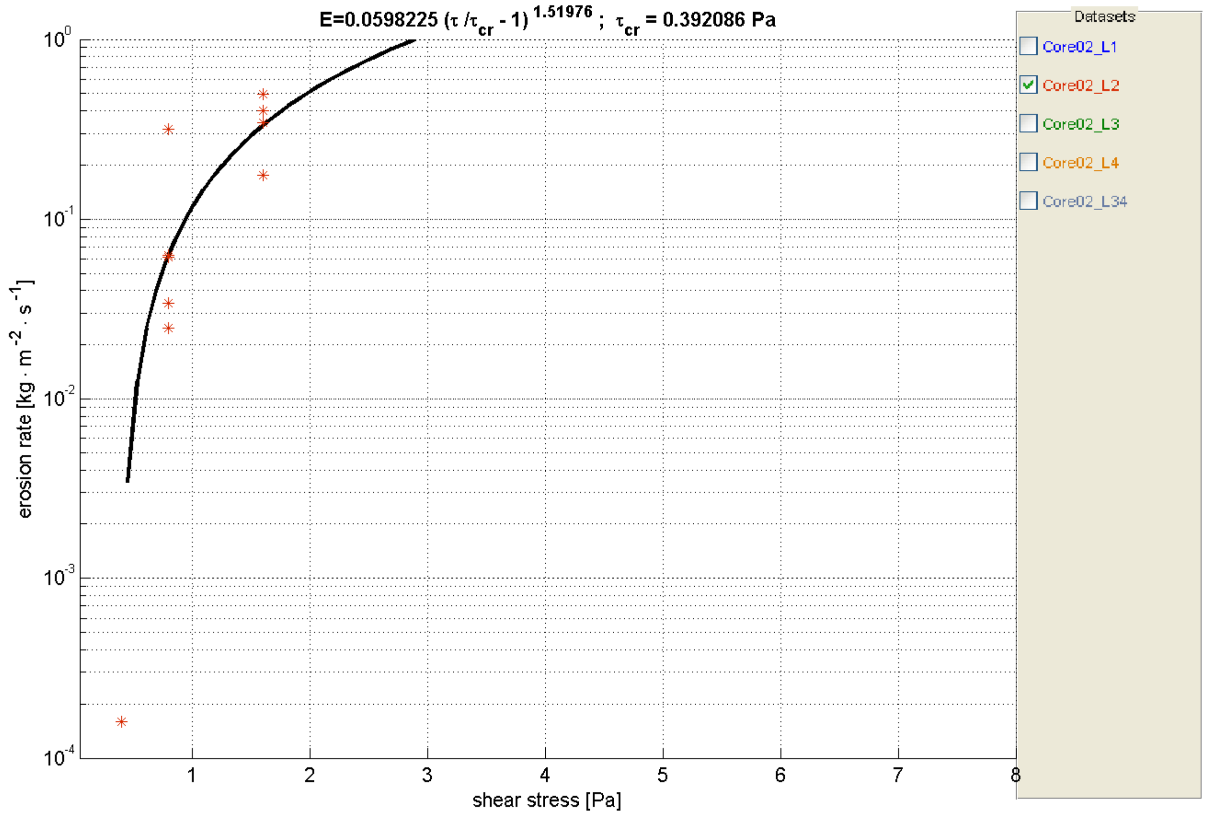


Figure B-13. Erosion versus applied shear stress for core 2, Layer 2. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

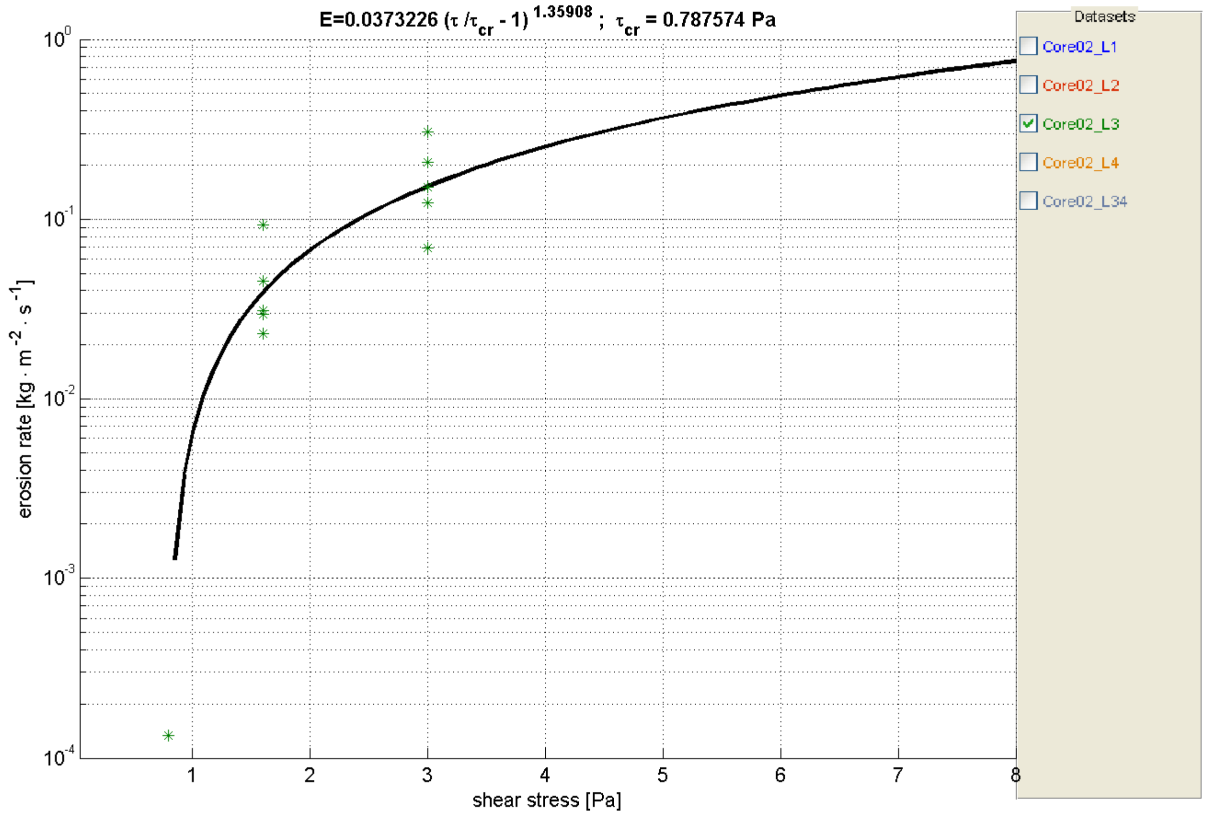


Figure B-14. Erosion versus applied shear stress for core 2, Layer 3. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

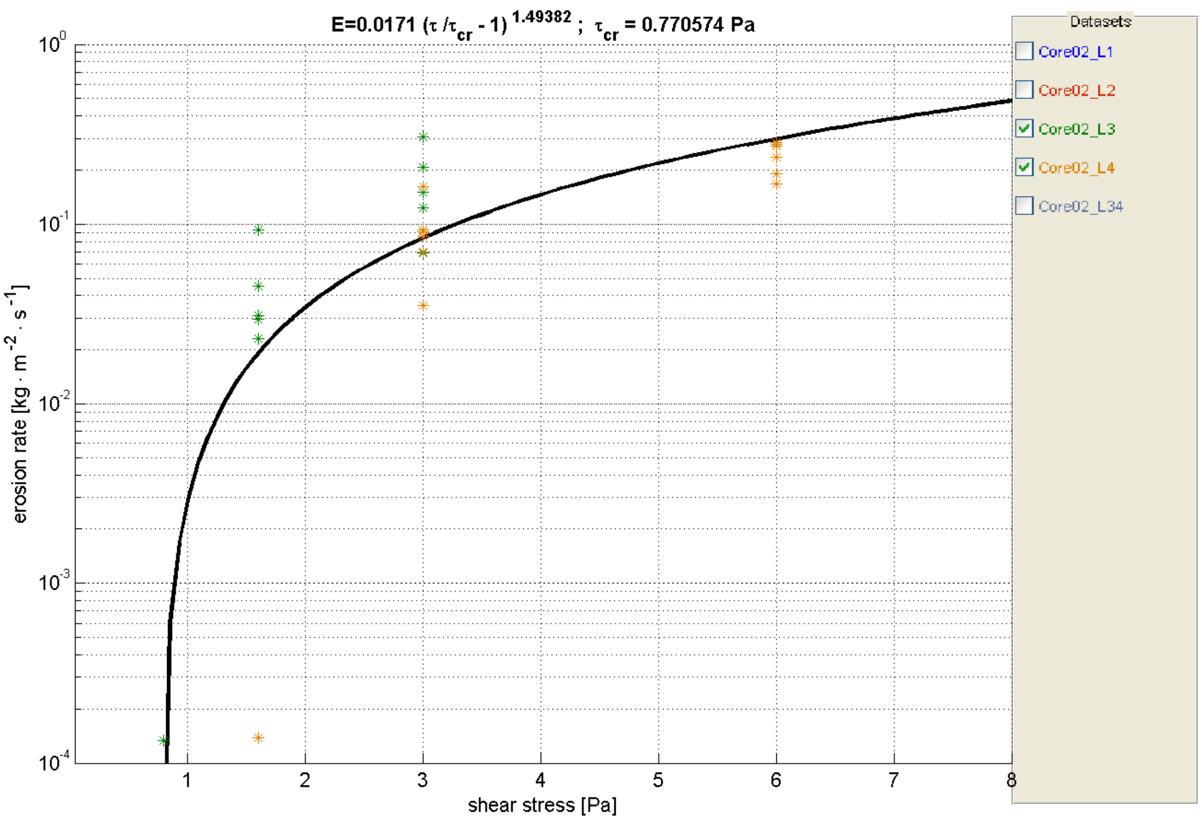


Figure B-15. Erosion versus applied shear stress for core 2, Layer 4. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

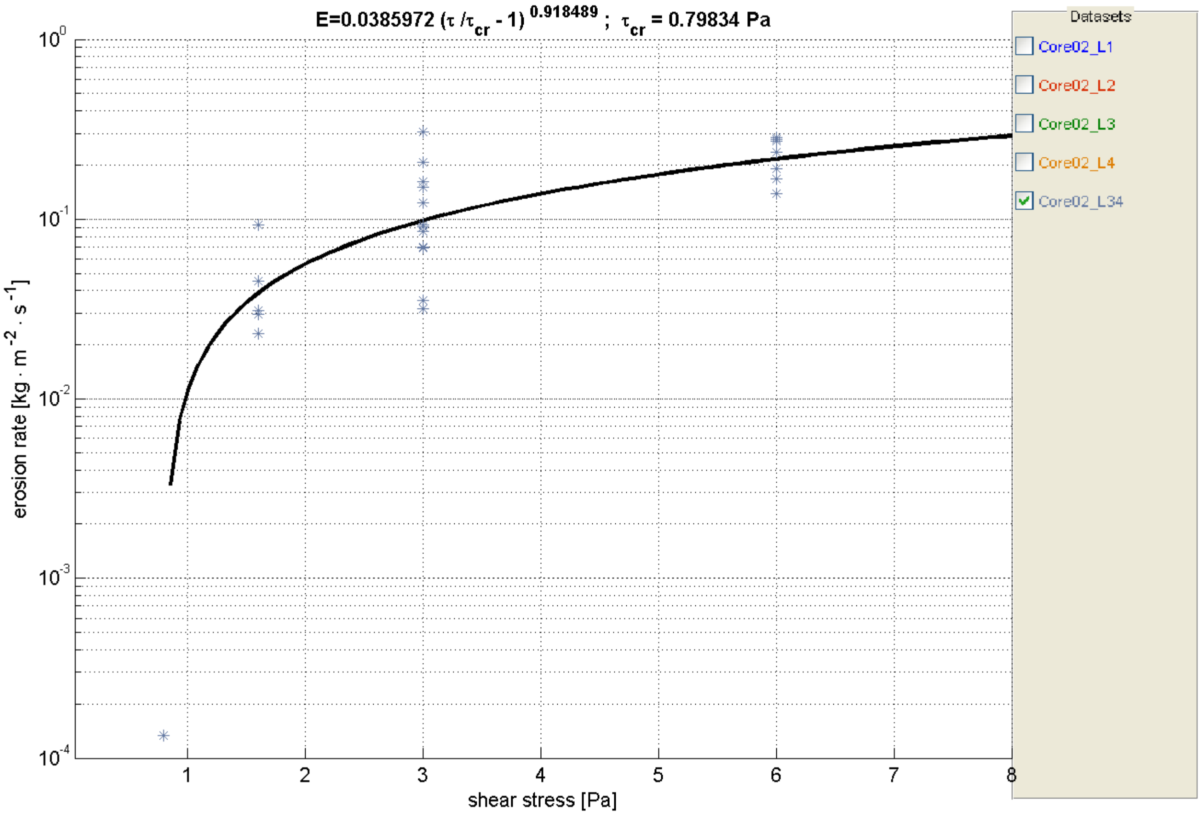


Figure B-16. Erosion versus applied shear stress for core 2, Layer 3 and Layer 4. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 3

Table B-3. Cohesive Sediment Erosion Parameterization				
		Critical Shear (τ_{cr})	**Erosion Rate Constant (M)**	**Erosion Rate Exponent (n)**
Layer ID	**Depth (cm)**	**Pa**	**-**	**-**
Core03_L1	0-2.5	0.20	9.90E-03	0.98
Core03_L2	2.5-22	0.80	8.08E-02	1.00

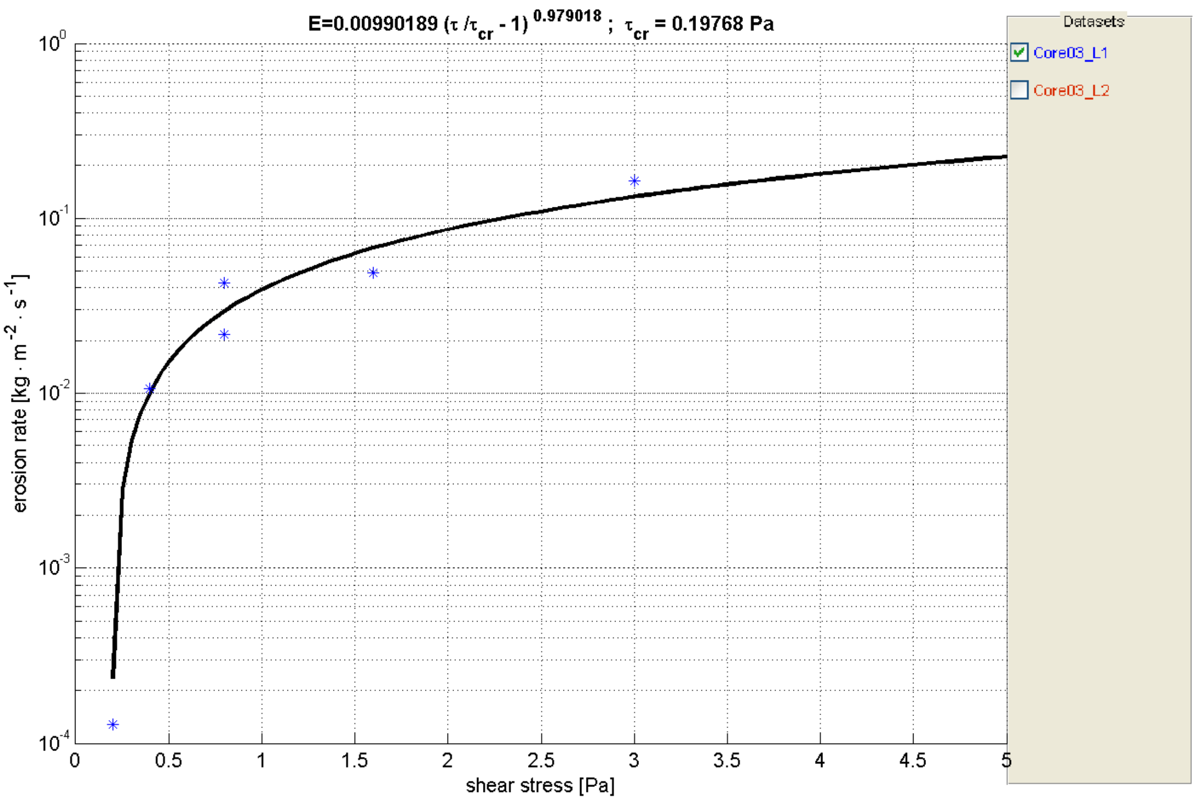


Figure B-17. Erosion versus applied shear stress for core 3, Layer 1. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

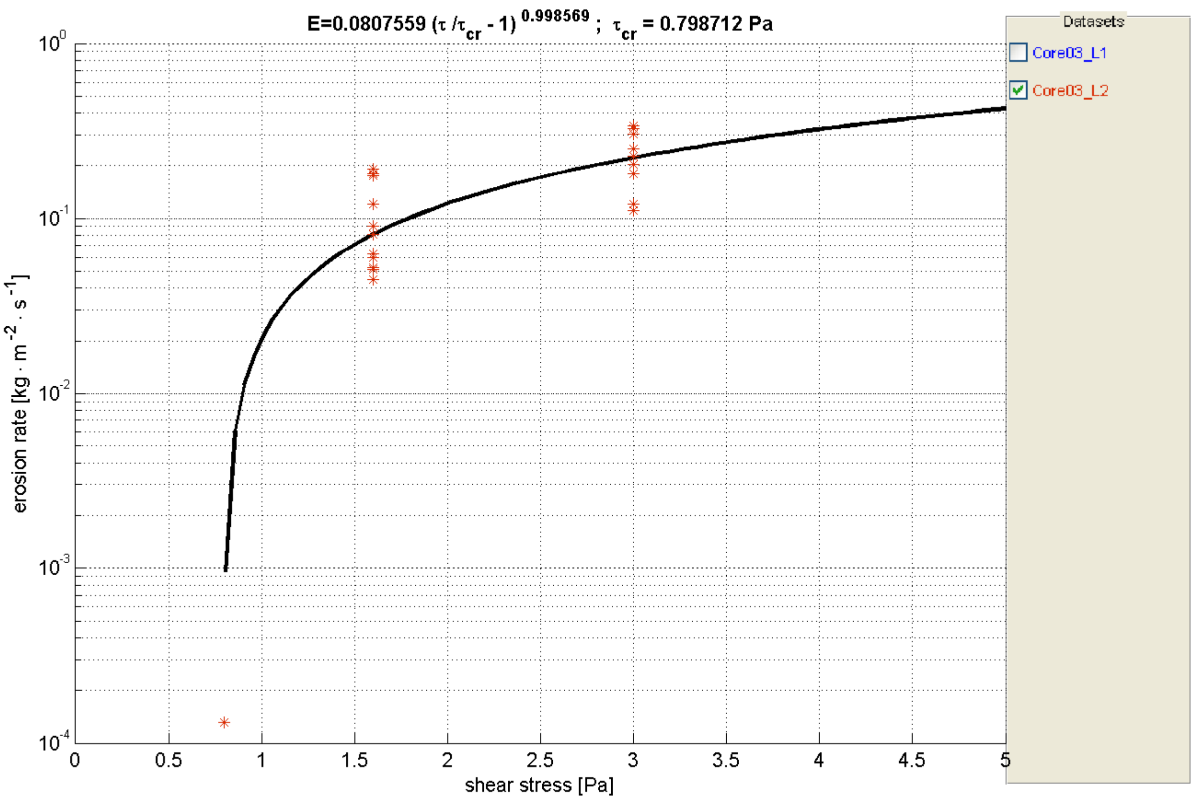


Figure B-18. Erosion versus applied shear stress for core 3, Layer 2. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 4

Table B-4. Cohesive Sediment Erosion Parameterization				
		Critical Shear (τ_{cr})	Erosion Rate Constant (M)	Erosion Rate Exponent (n)
Layer ID	Depth (cm)	Pa	-	-
Core04_L1	0-2	0.20	1.04E-02	1.21
Core04_L2	2-11	0.80	3.23E-02	0.90

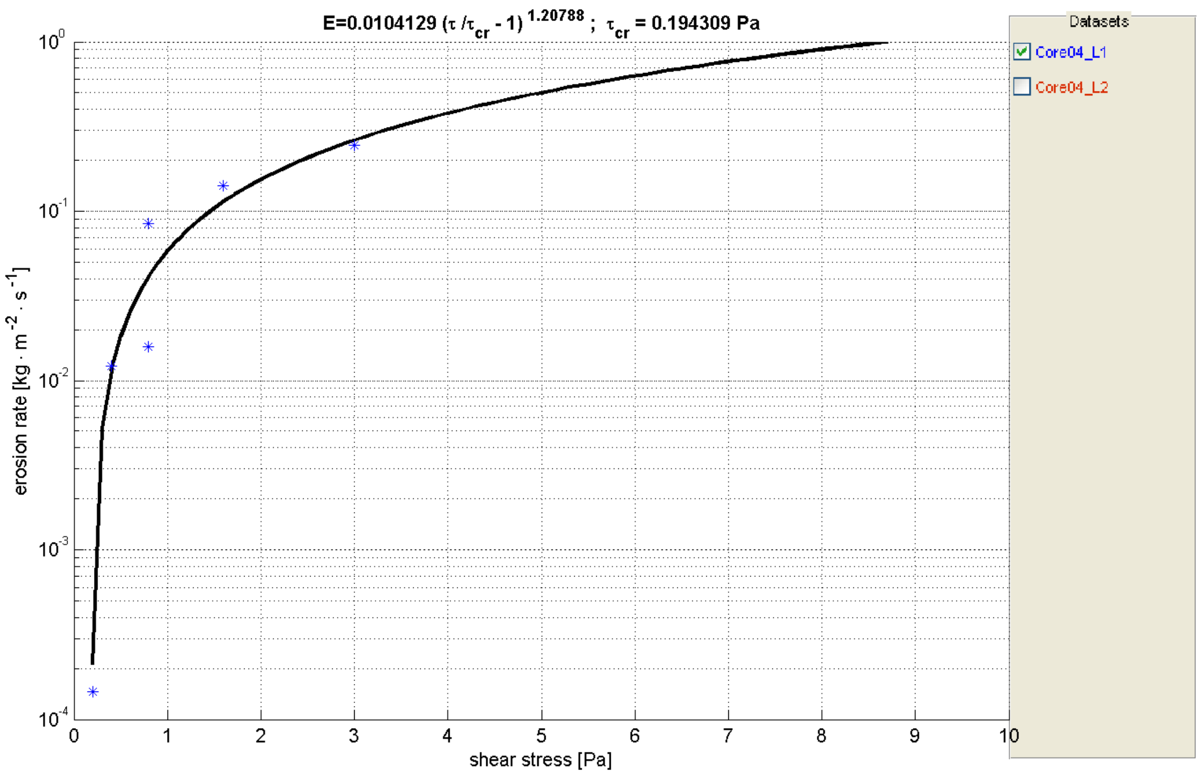


Figure B-19. Erosion versus applied shear stress for core 4, Layer 1. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

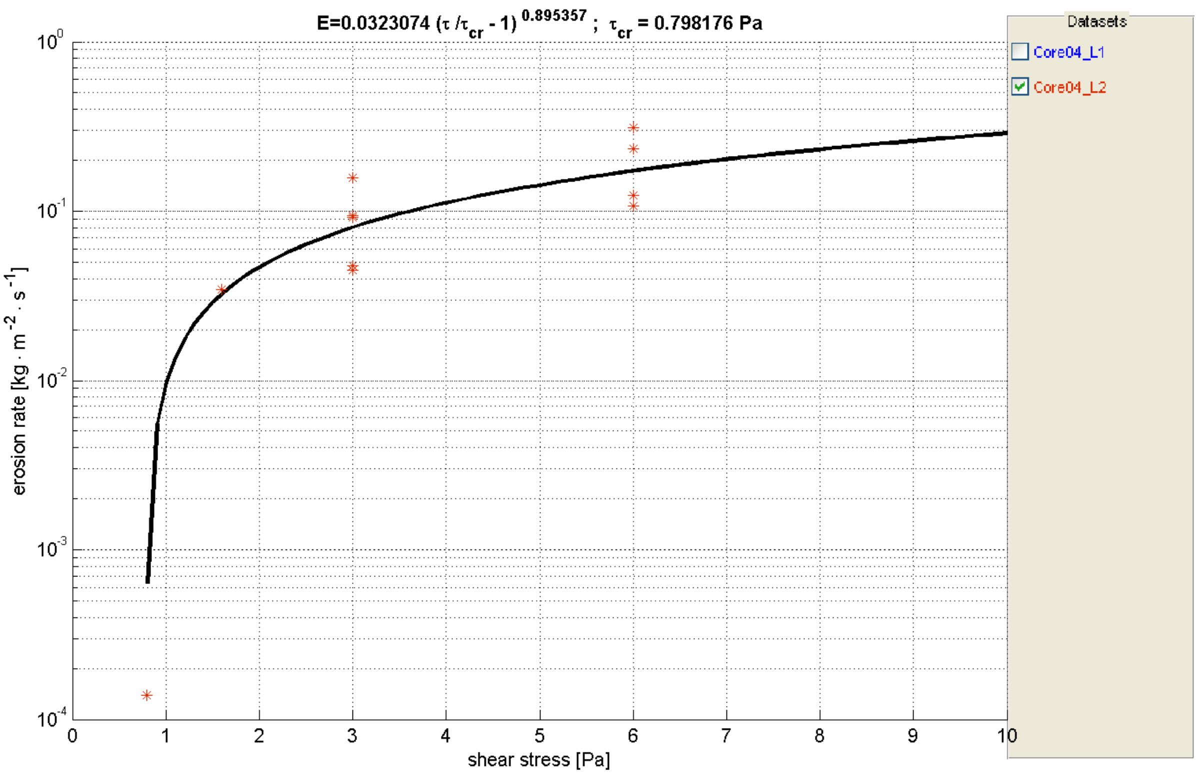


Figure B-20. Erosion versus applied shear stress for core 4, Layer 2. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 5

Table B-5. Cohesive Sediment Erosion Parameterization				
		Critical Shear (τ_{cr})	Erosion Rate Constant (M)	Erosion Rate Exponent (n)
Layer ID	Depth (cm)	Pa	-	-
Core05_L1	0-5	0.20	1.20E-02	1.04
Core05_L2	5-12	0.78	2.17E-02	1.37
Core05_L3	12-24	1.60	9.80E-02	0.99

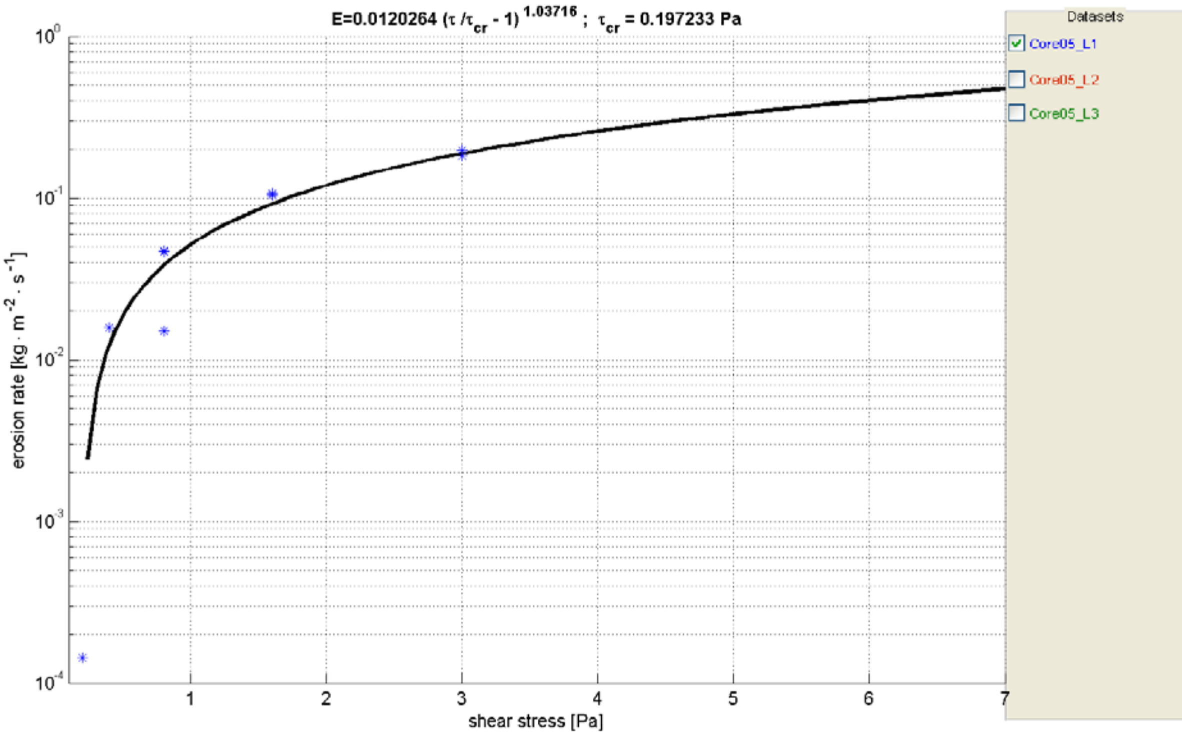


Figure B-21. Erosion versus applied shear stress for core 5, Layer 1. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

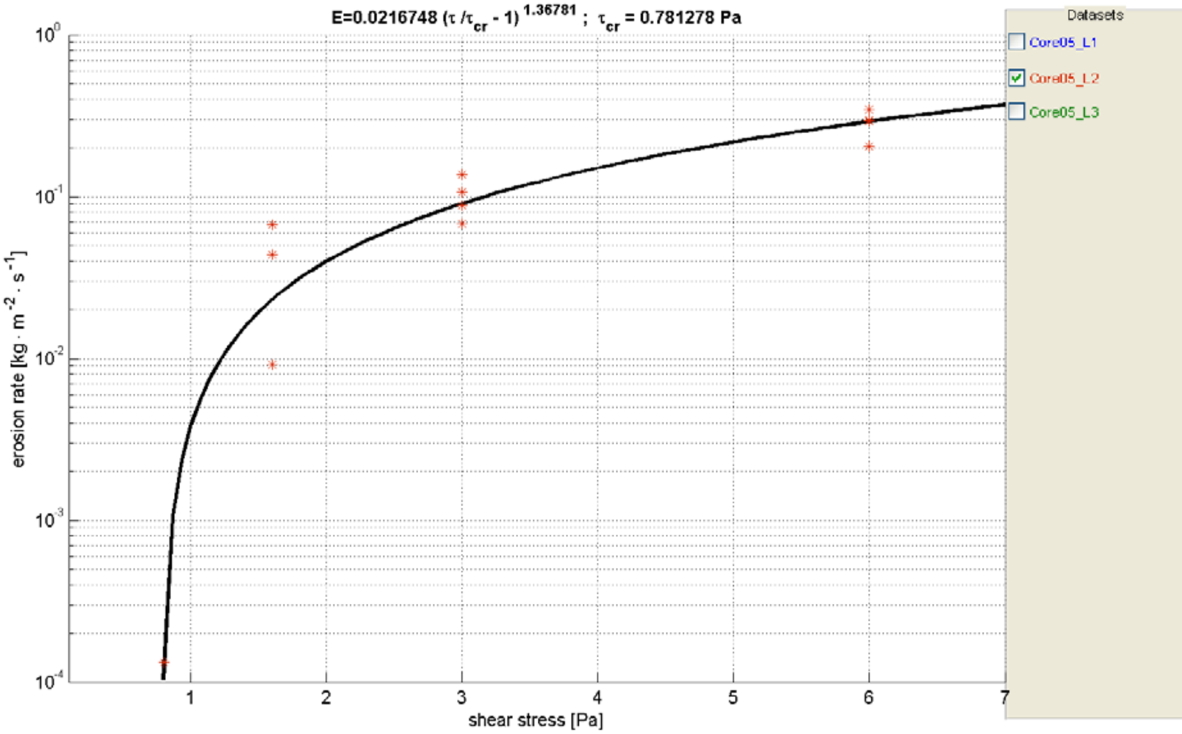


Figure B-22. Erosion versus applied shear stress for core 5, Layer 2. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

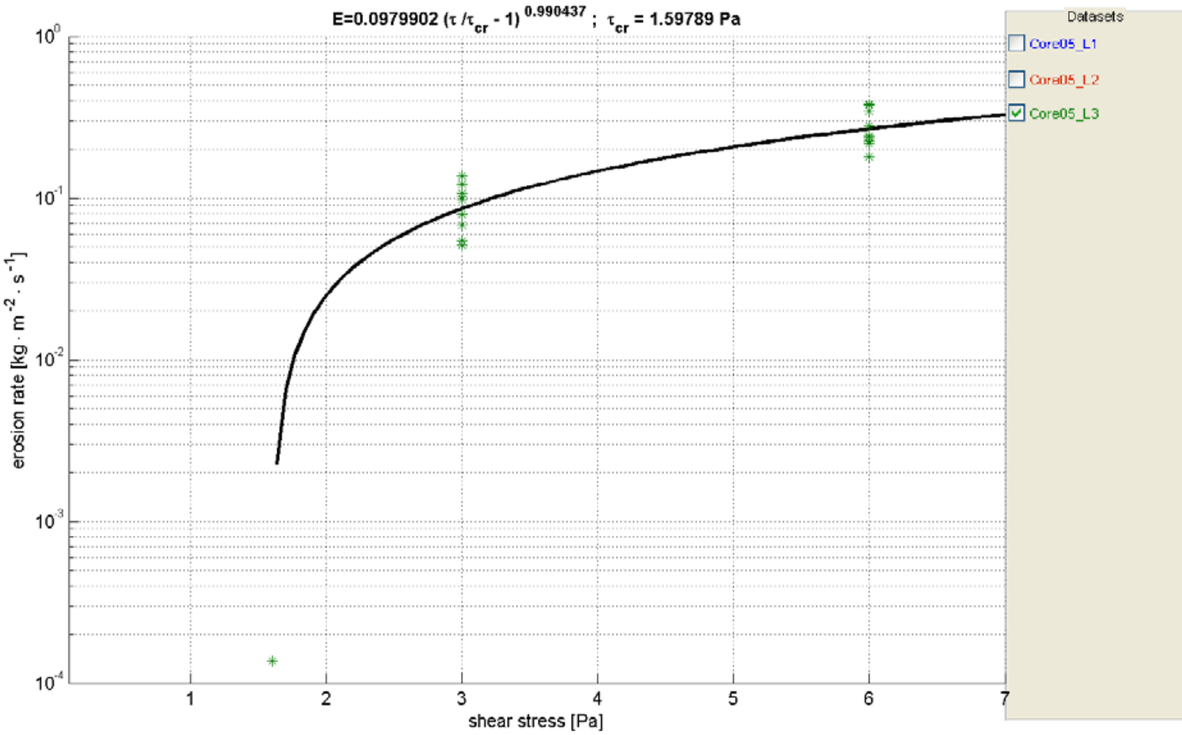


Figure B-23. Erosion versus applied shear stress for core 5, Layer 3. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 6

Table B-6. Cohesive Sediment Erosion Parameterization				
Layer ID	Depth (cm)	Critical Shear (τ_{cr})	Erosion Rate Constant (M)	Erosion Rate Exponent (n)
		Pa	-	-
Core06_L1	0-2	0.10	1.48E-02	0.90
Core06_L2	2-14	1.60	3.31E-02	1.04

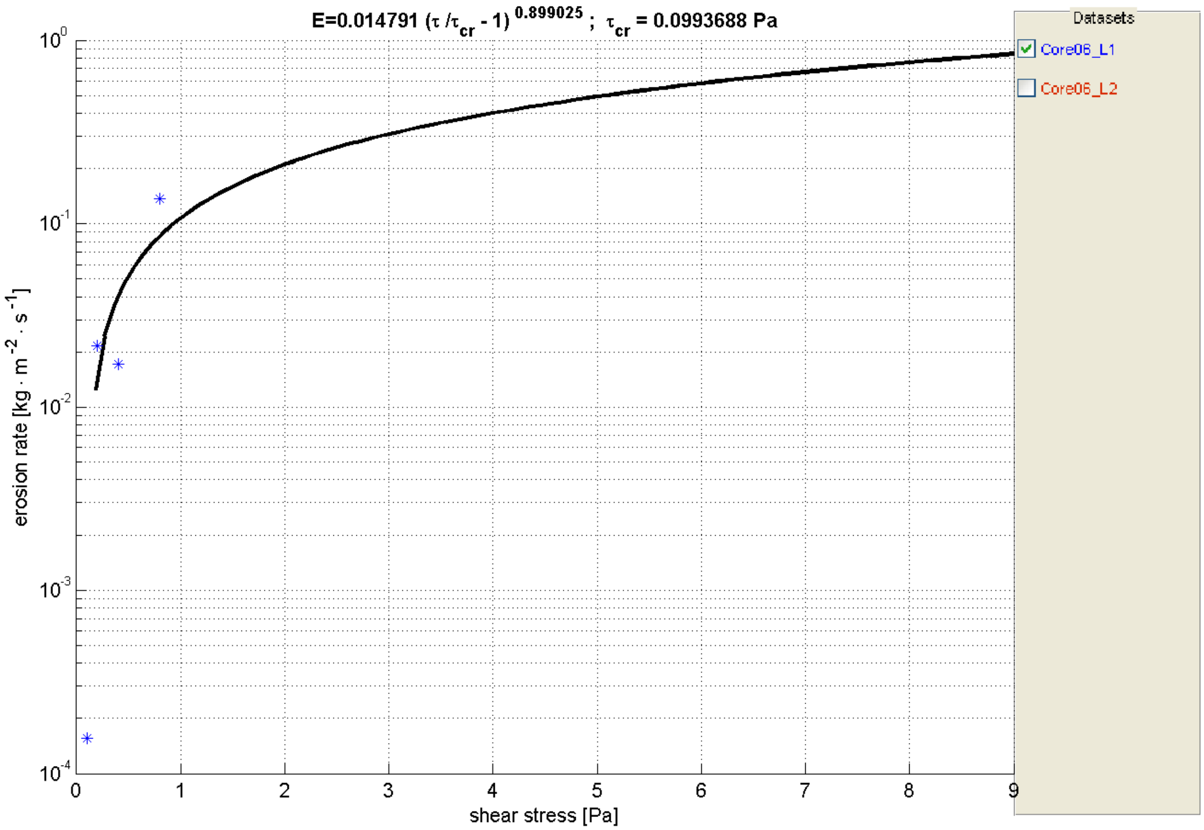


Figure B-24. Erosion versus applied shear stress for core 6, Layer 1. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

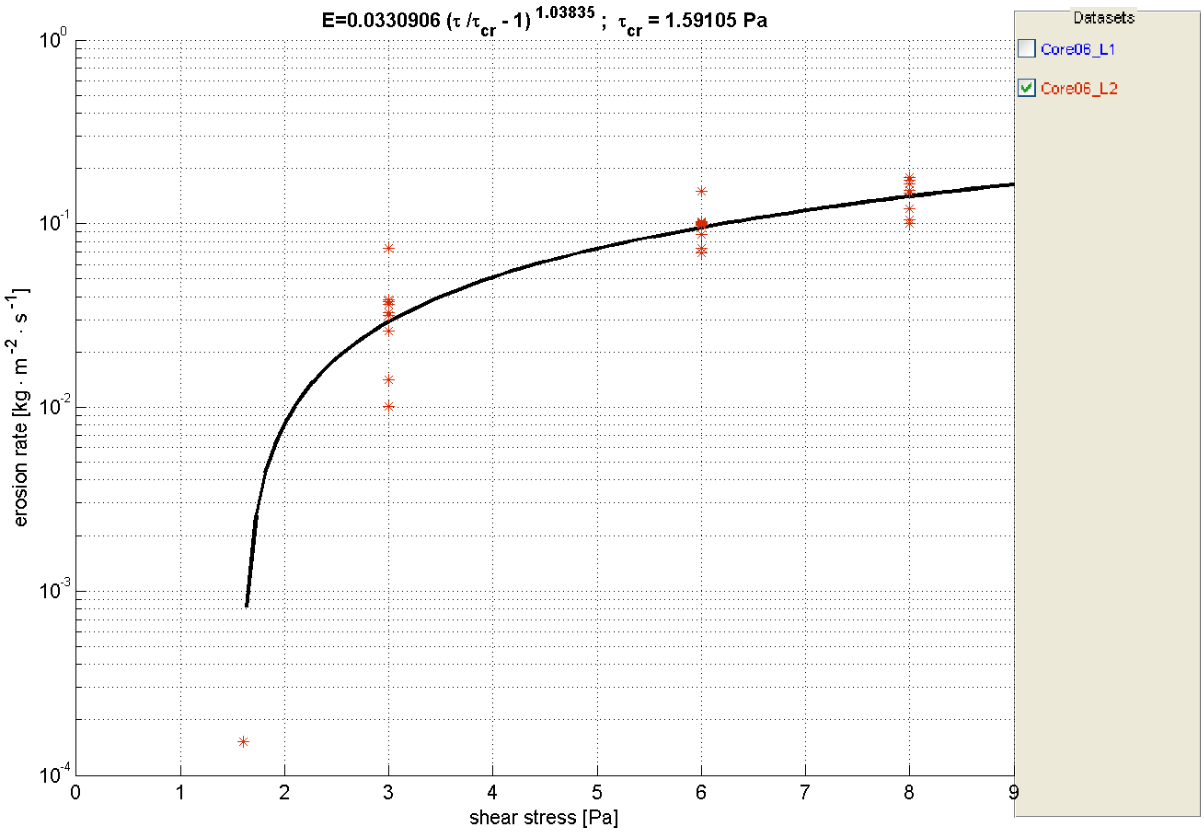


Figure B-25. Erosion versus applied shear stress for core 6, Layer 2. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 9

Table B-7. Cohesive Sediment Erosion Parameterization				
		Critical Shear (τ_{cr})	Erosion Rate Constant (M)	Erosion Rate Exponent (n)
Layer ID	Depth (cm)	Pa	-	-
Core09_L1	0-2	0.20	8.20E-03	1.41
Core09_L2	2-9	1.52	2.32E-02	1.36

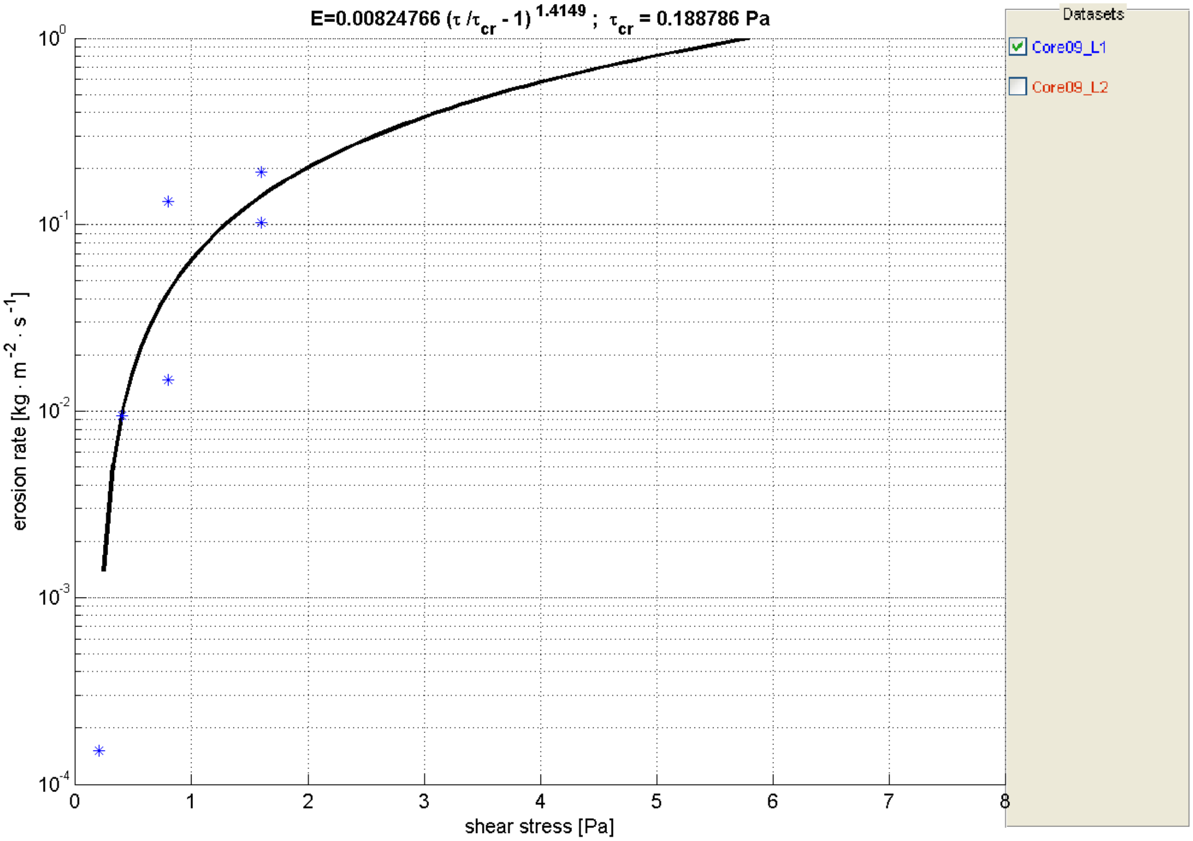


Figure B-26. Erosion versus applied shear stress for core 9, Layer 1. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

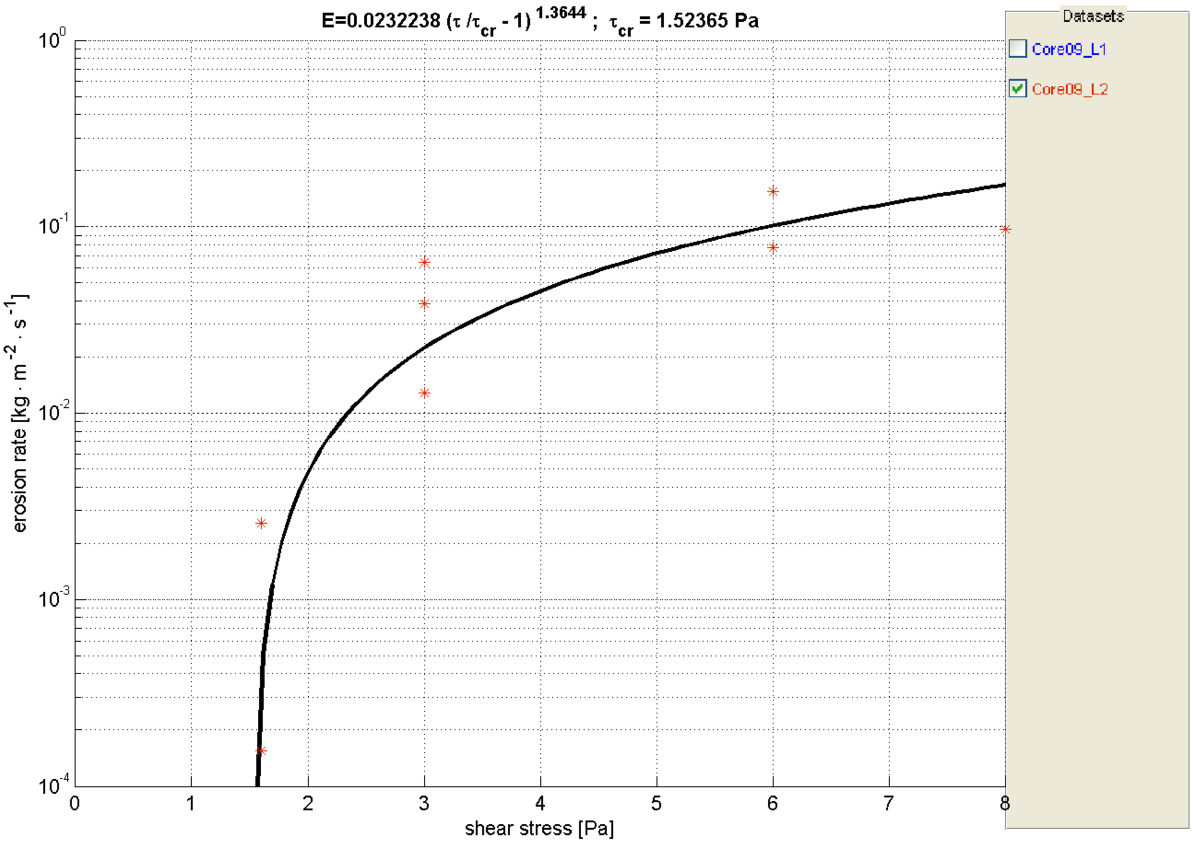


Figure B-27. Erosion versus applied shear stress for core 9, Layer 2. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 10

Table B-8. Cohesive Sediment Erosion Parameterization				
		Critical Shear (τ_{cr})	Erosion Rate Constant (M)	Erosion Rate Exponent (n)
Layer ID	Depth (cm)	Pa	-	-
Core10_L1	0-8	0.18	3.40E-02	1.31
Core10_L2	8-16	1.14	1.70E-02	1.61

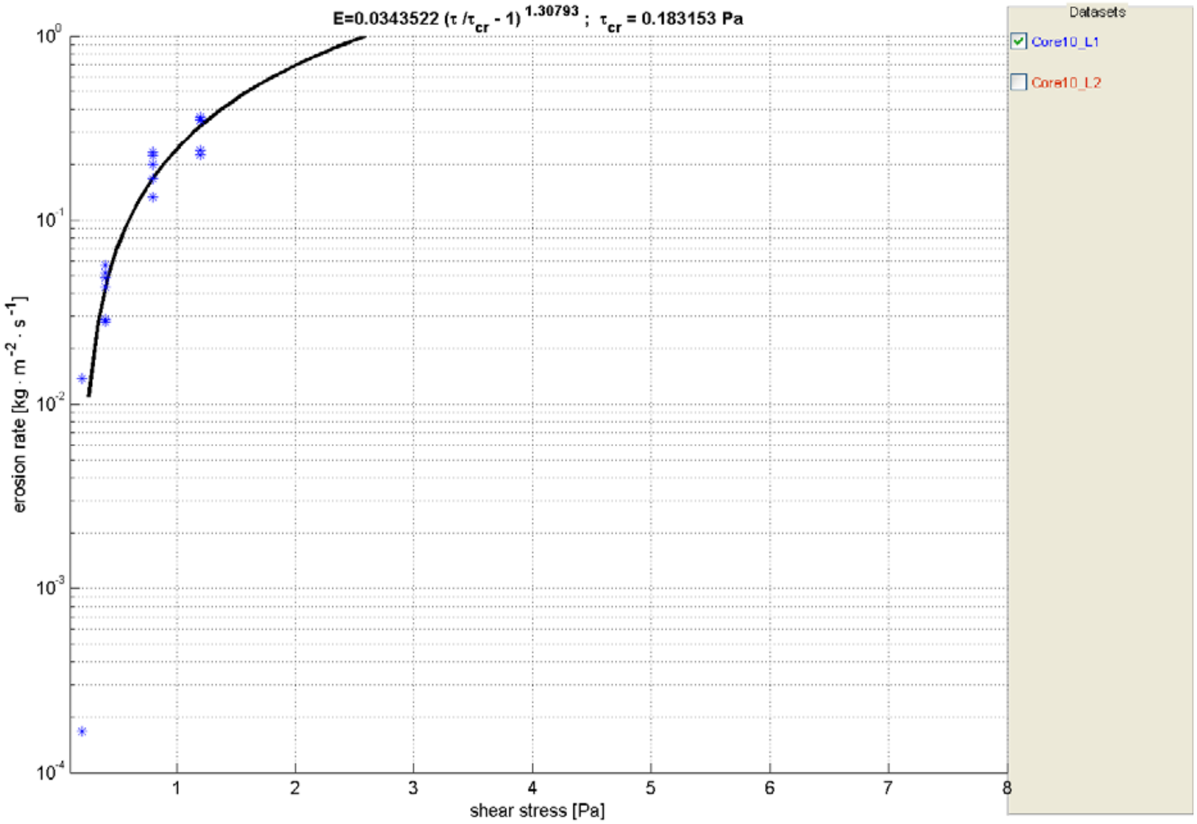


Figure B-28. Erosion versus applied shear stress for core 10, Layer 1. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

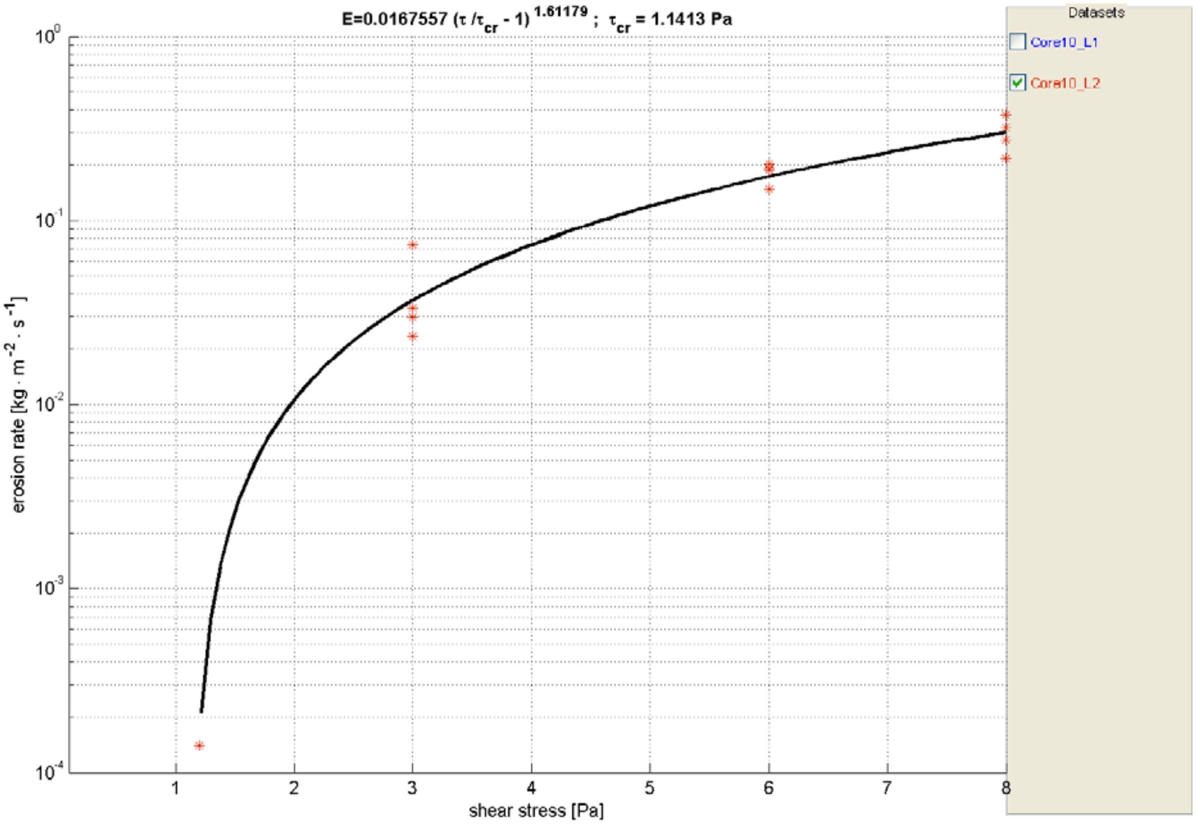


Figure B-29. Erosion versus applied shear stress for core 10, Layer 2. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Erosion versus shear stress (HEC-RAS fit to Partheniades)

Core 1

Table B-9. Cohesive Sediment Erosion Parameterization for HEC-RAS									
		Shear Thresh-old		Erosion Rate		Mass Wasting Threshold		Mass Wasting Rate	
Layer ID	Depth (cm)	Pa	lb/ft^2	$kg/m^2/s$	$lb/ft^2/hr$	Pa	lb/ft^2	$kg/m^2/s$	$lb/ft^2/hr$
Core01_L1	0-4	0.2	0.0042	2.02E-02	14.9	1	0.0209	0.263	193.9
Core01_L2	5-14	0.4	0.0084	3.24E-02	23.9	-	-	-	-
Core01_L3	10-14	0.8	0.0167	3.39E-02	25.0	-	-	-	-

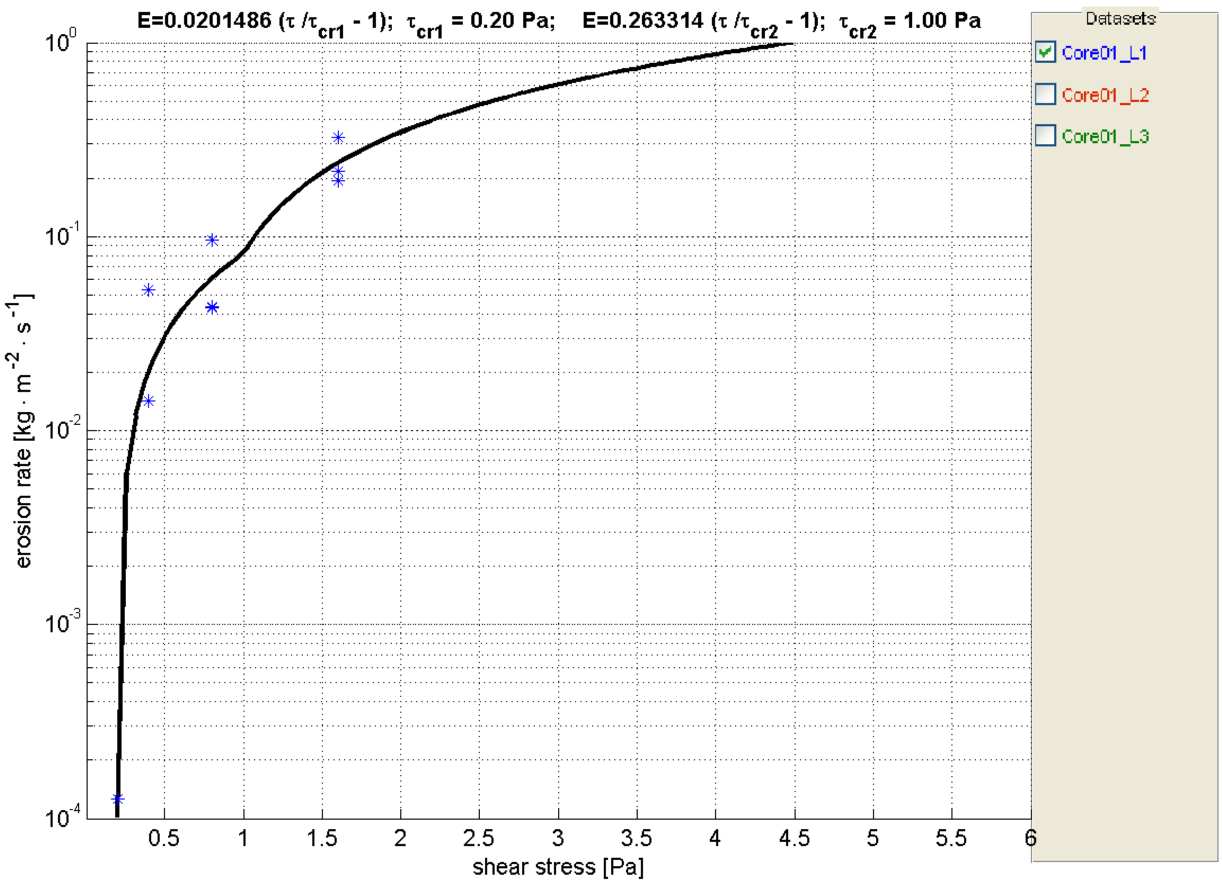


Figure B-30. Erosion versus applied shear stress for core 1, Layer 1. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

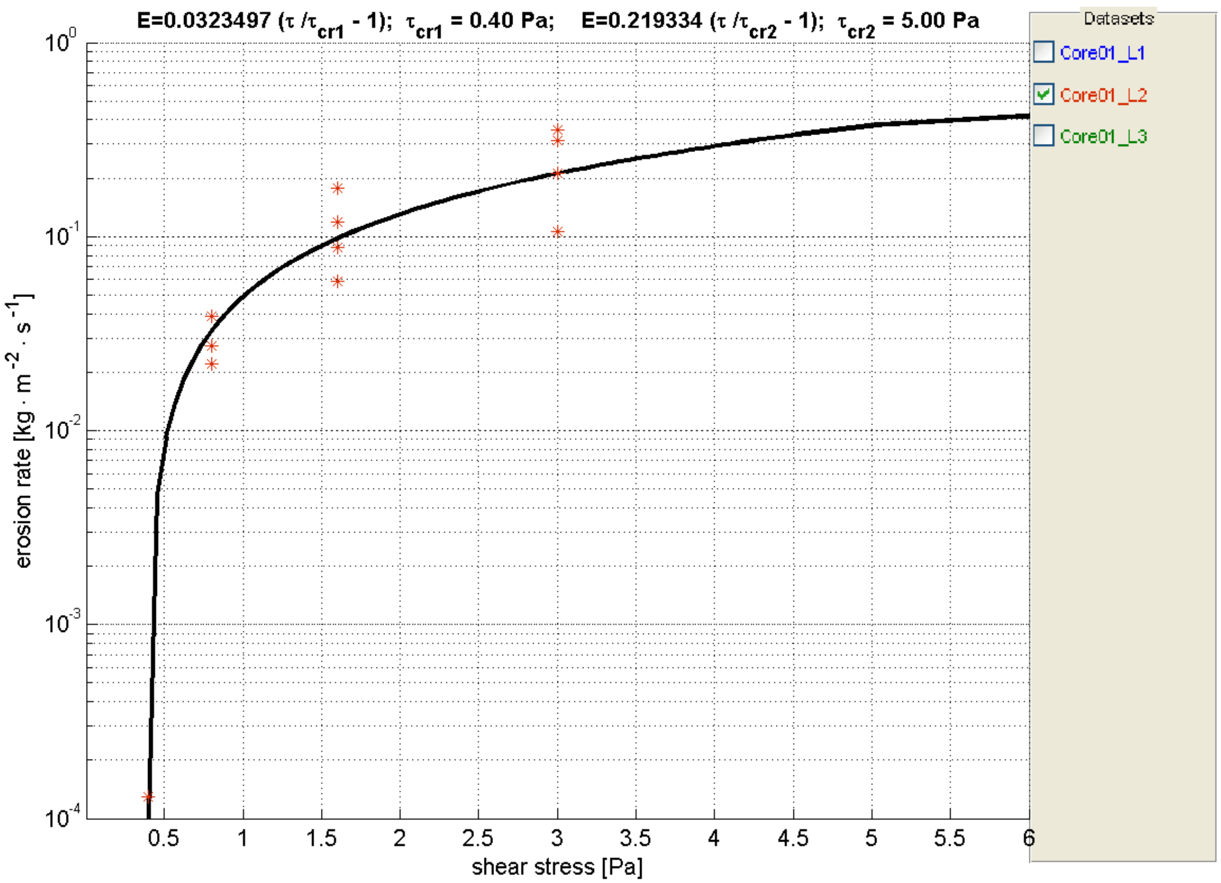


Figure B-31. Erosion versus applied shear stress for core 1, Layer 2. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

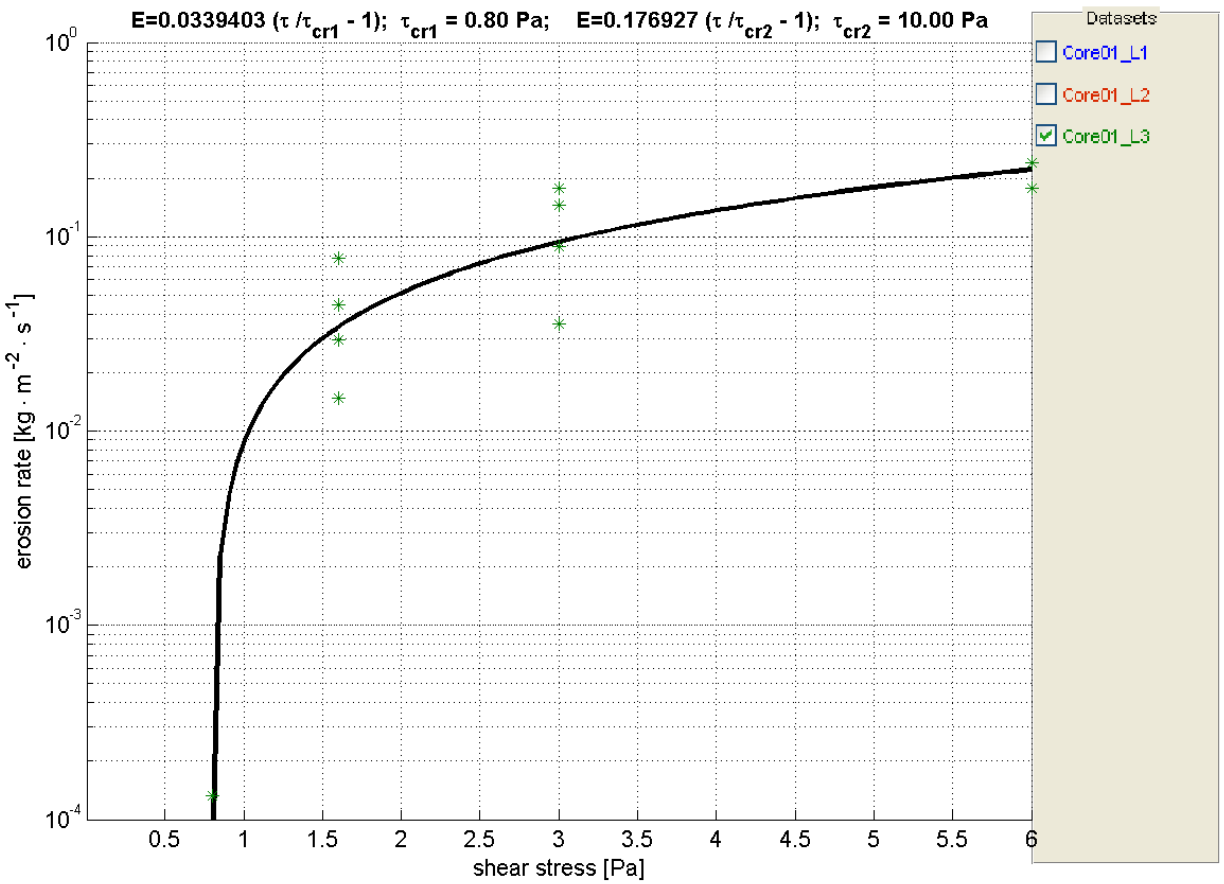


Figure B-32. Erosion versus applied shear stress for core 1, Layer 3. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 2

Table B-10. Cohesive Sediment Erosion Parameterization for HEC-RAS									
		Shear Thresh-old		Erosion Rate		Mass Wasting Threshold		Mass Wasting Rate	
Layer ID	Depth (cm)	Pa	lb/ft^2	kg/m^2/s	lb/ft^2/hr	Pa	lb/ft^2	kg/m^2/s	lb/ft^2/hr
Core02_L1	0-10	0.2	0.0042	1.04E-01	76.7	-	-	-	-
Core02_L2	10-17	0.4	0.0084	6.32E-02	46.6	0.9	0.0188	0.323	238
Core02_L3	17-24	0.8	0.0167	4.62E-02	34.1	-	-	-	-
Core02_L4	24-32	1.6	0.0334	8.86E-02	65.3	-	-	-	-
Core02_L3&4	17-32	0.8	0.0167	3.53E-02	26.0	-	-	-	-

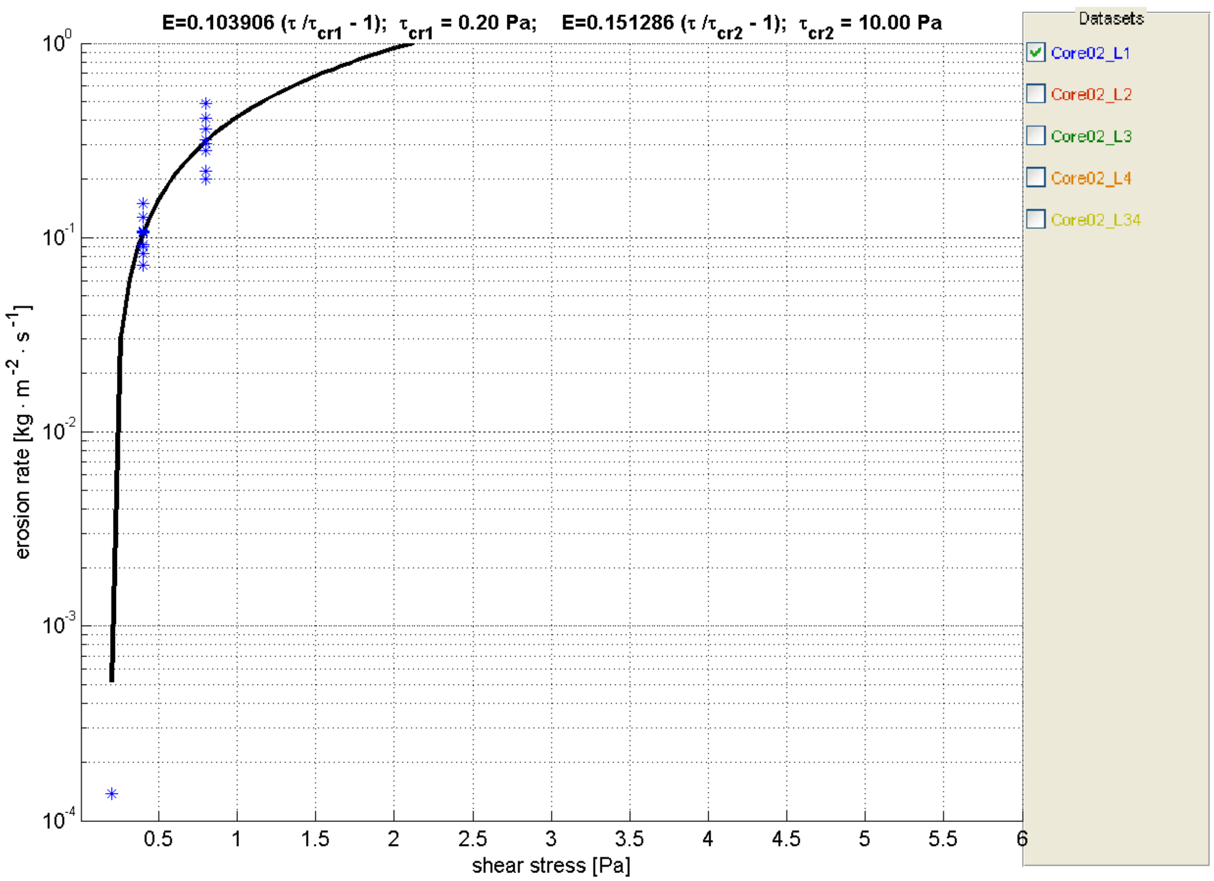


Figure B-33. Erosion versus applied shear stress for core 2, Layer 1. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

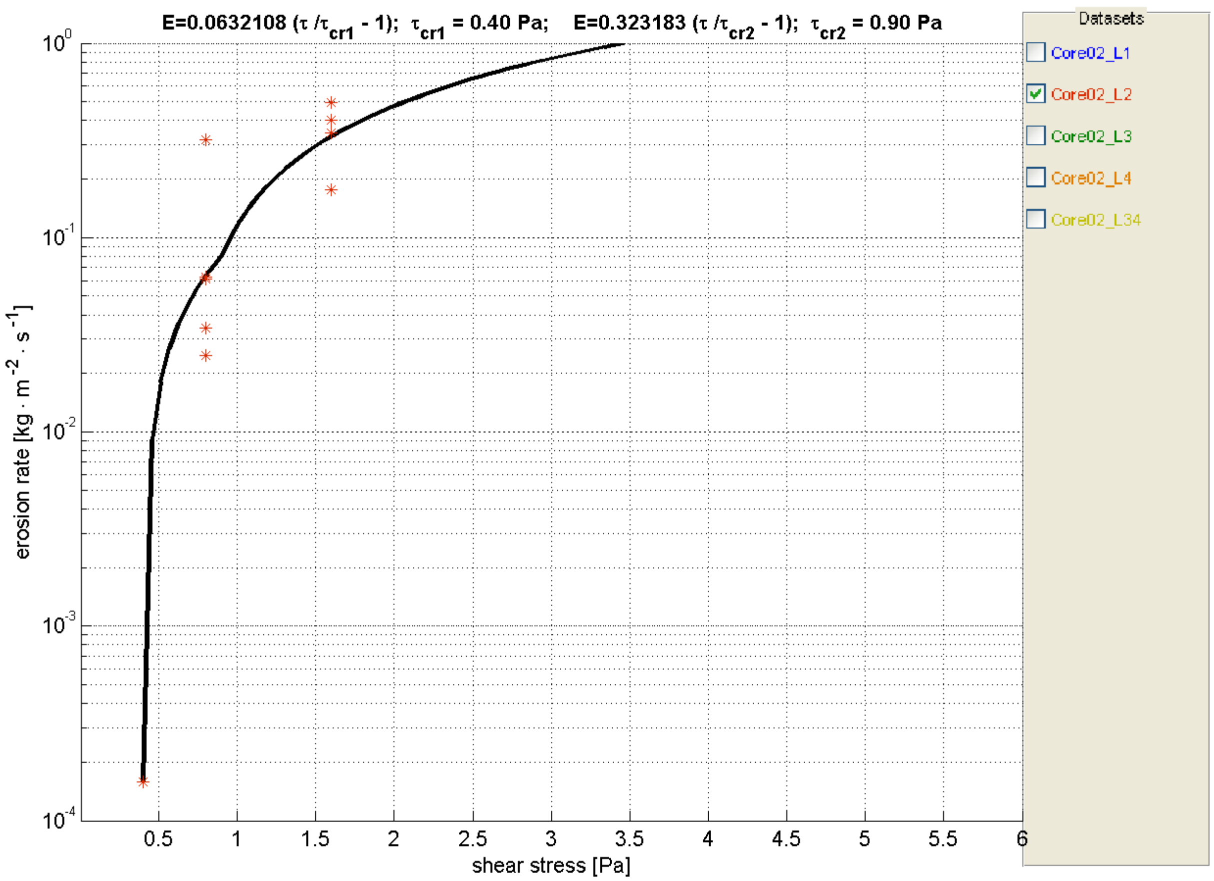


Figure B-34. Erosion versus applied shear stress for core 2, Layer 2. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

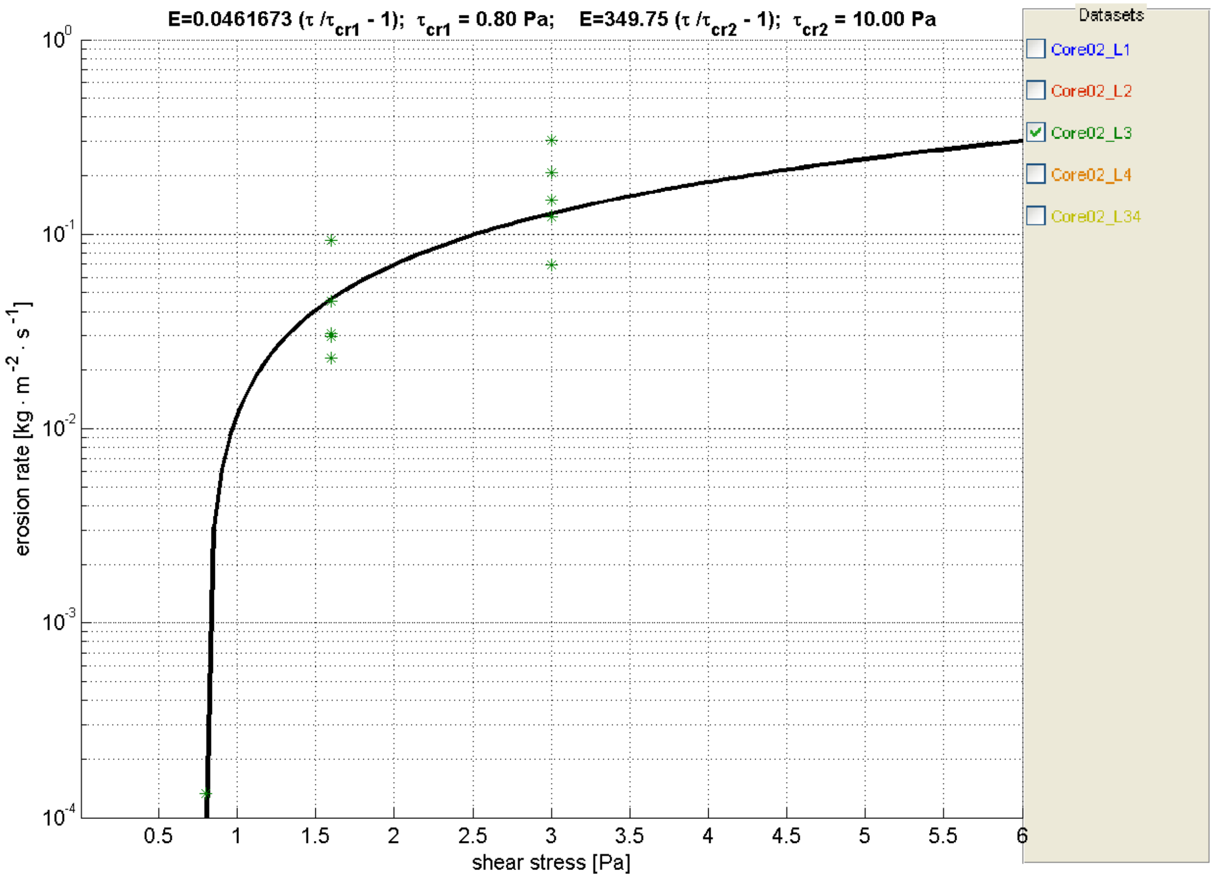


Figure B-35. Erosion versus applied shear stress for core 2, Layer 3. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

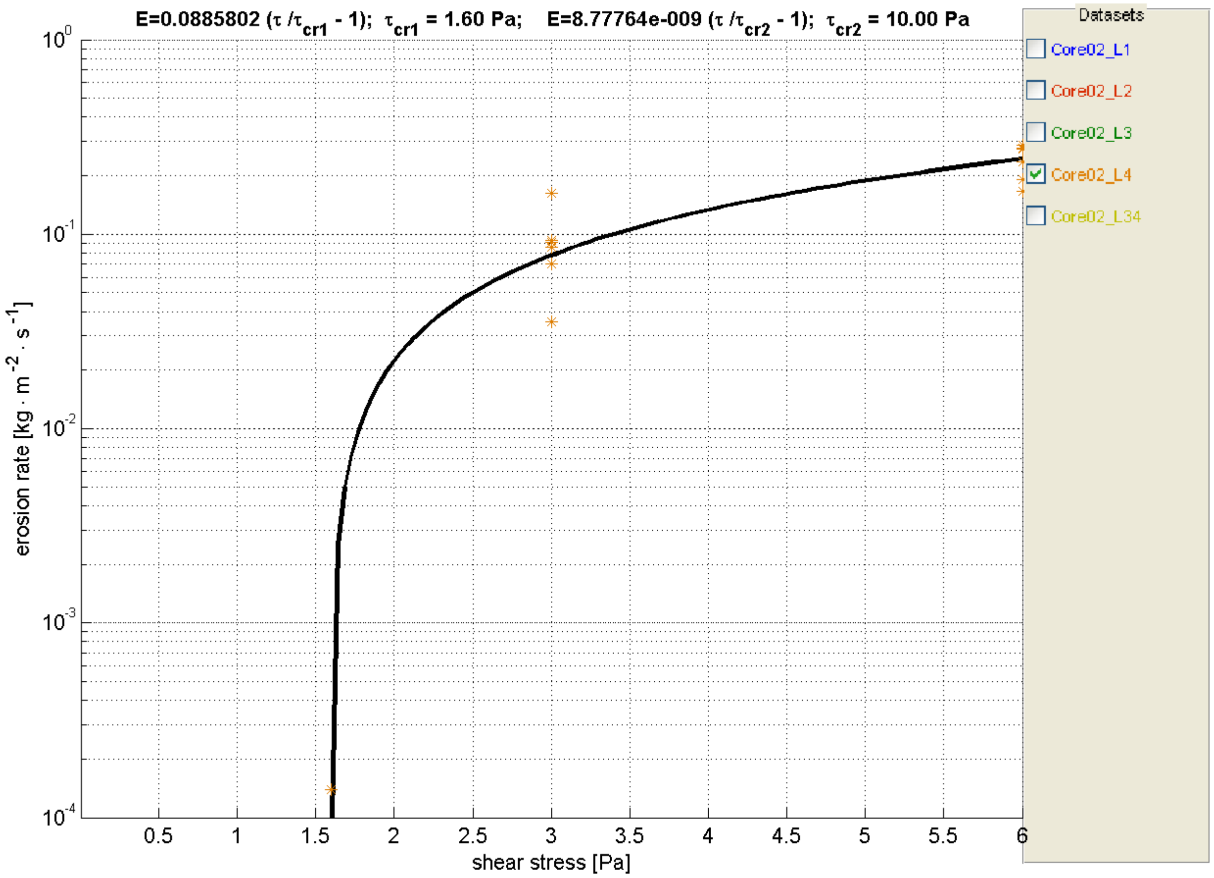


Figure B-36. Erosion versus applied shear stress for core 2, Layer 4. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

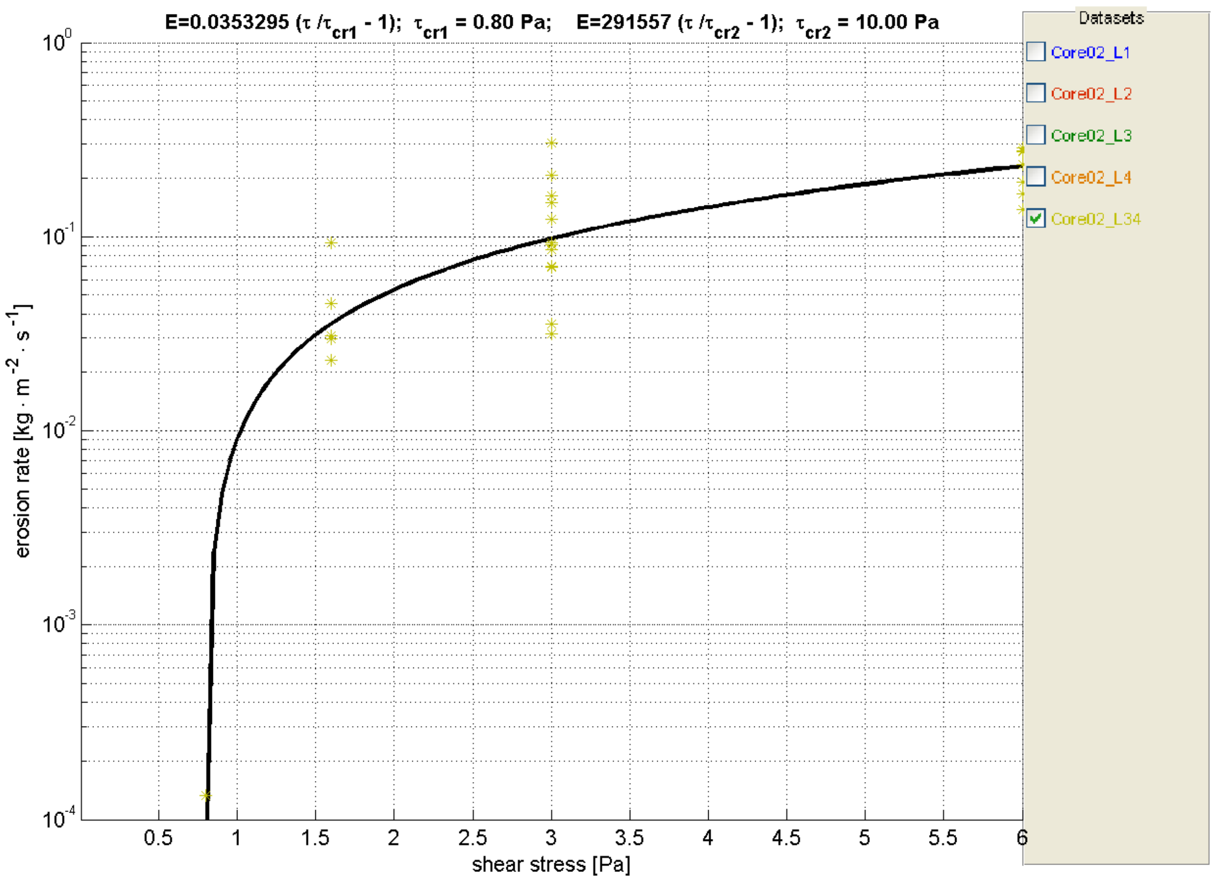


Figure B-37. Erosion versus applied shear stress for core 2, Layer 3 and Layer 4. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 3

Table B-11. Cohesive Sediment Erosion Parameterization for HEC-RAS									
Layer ID	Depth (cm)	Shear Threshold		Erosion Rate		Mass Wasting Threshold		Mass Wasting Rate	
		Pa	lb/ft^2	kg/m^2/s	lb/ft^2/hr	Pa	lb/ft^2	kg/m^2/s	lb/ft^2/hr
Core03_L1	0-2.5	0.2	0.0042	9.60E-03	7.08	-	-	-	-
Core03_L2	2.5-22	0.8	0.0167	8.07E-02	59.5	-	-	-	-
Core03_L1&2	0-22	0.2	0.0042	1.09E-02	8.04	2	0.0418	0.237	175

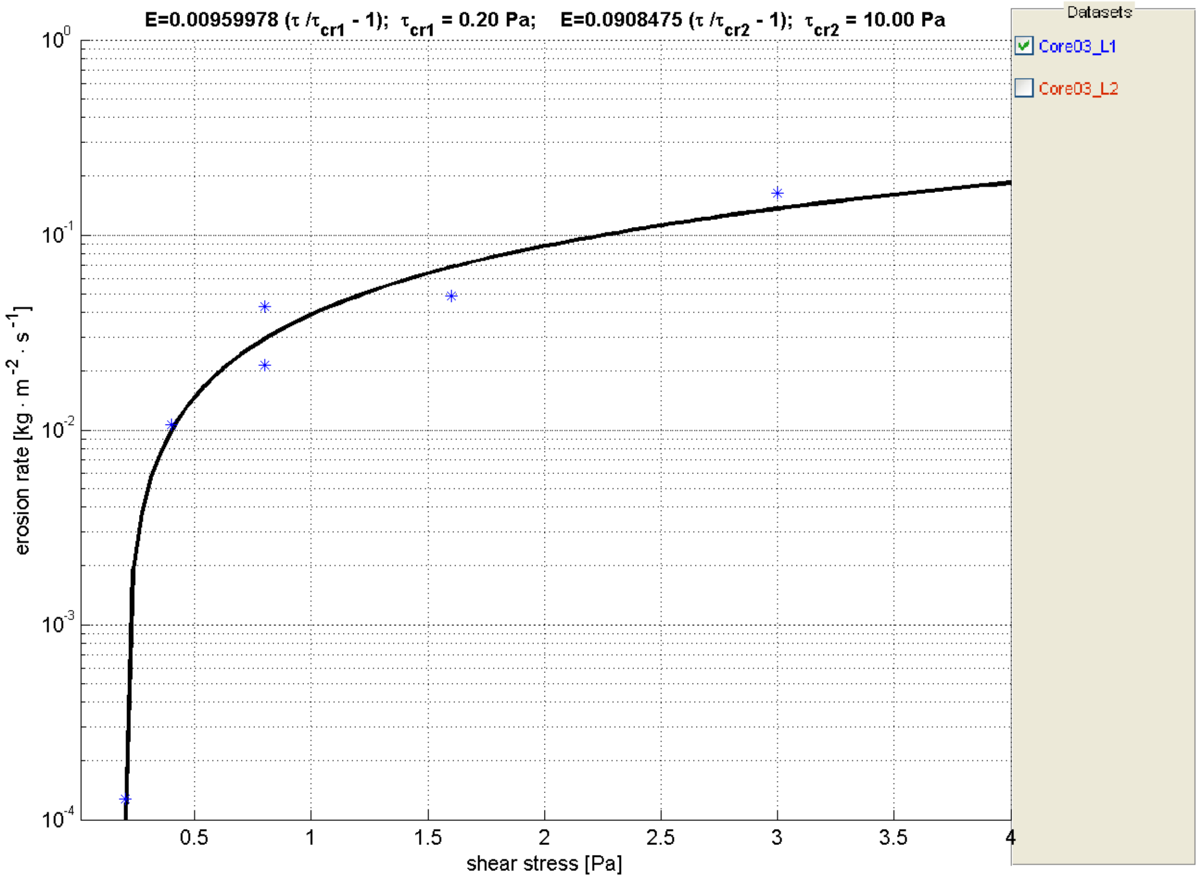


Figure B-38. Erosion versus applied shear stress for core 3, Layer 1. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

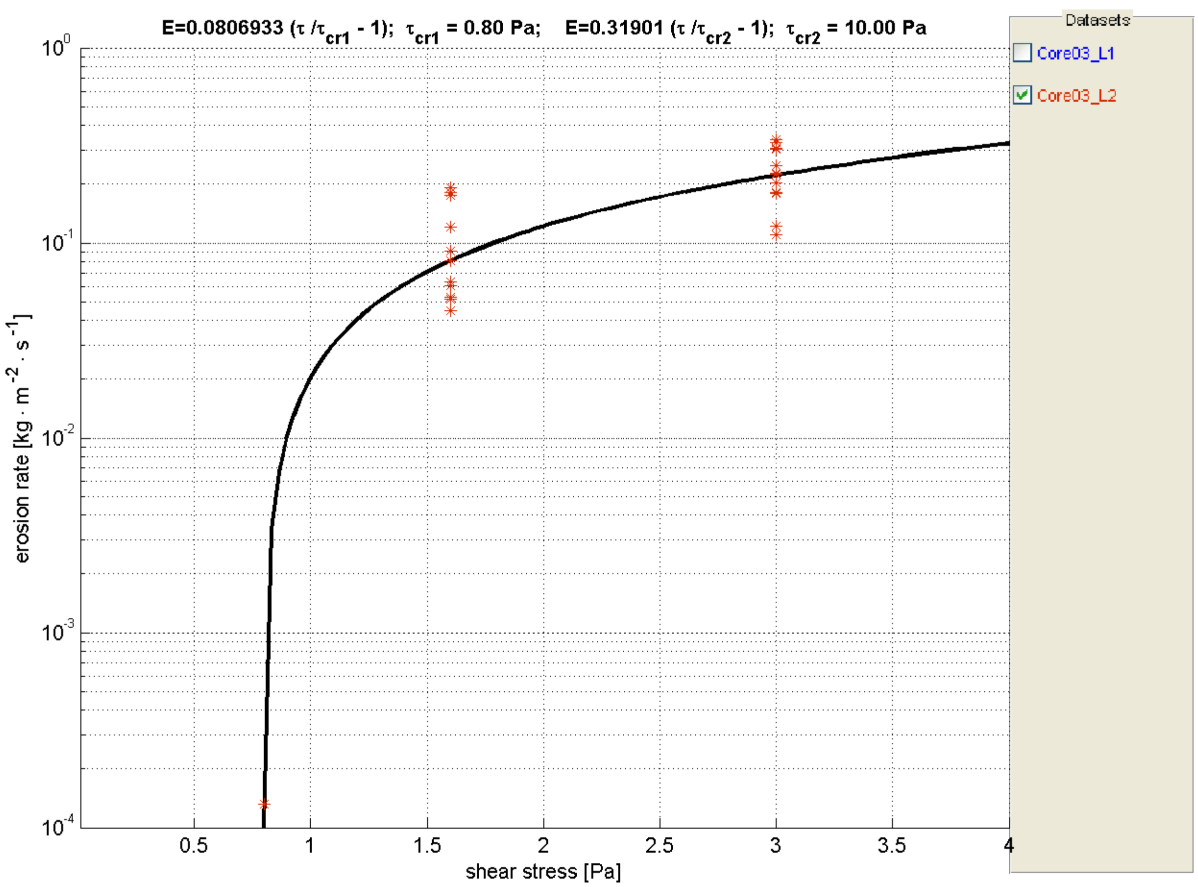


Figure B-39. Erosion versus applied shear stress for core 3, Layer 2. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

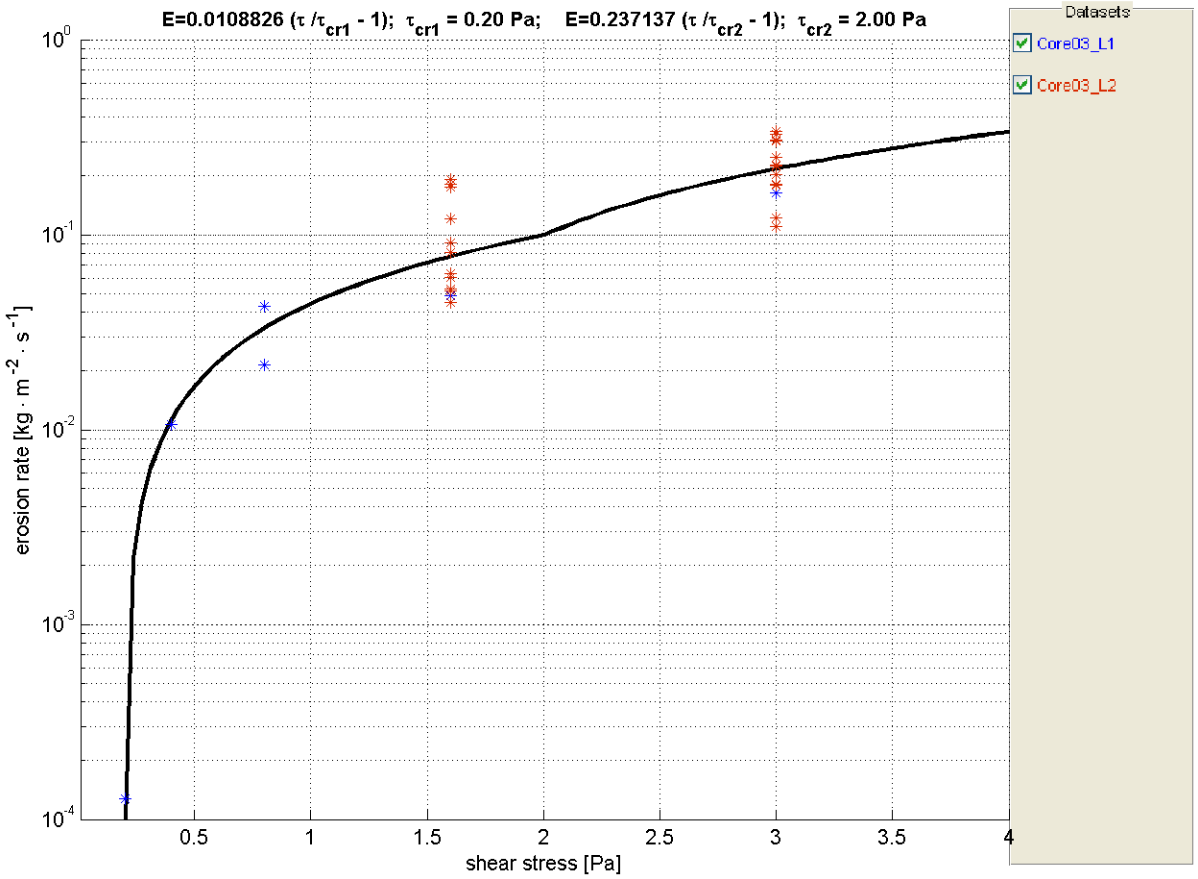


Figure B-40. Erosion versus applied shear stress for core 3, Layer 1 and Layer 2. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 4

Table B-12. Cohesive Sediment Erosion Parameterization for HEC-RAS									
		Shear Thresh-old		Erosion Rate		Mass Wasting Threshold		Mass Wasting Rate	
Layer ID	Depth (cm)	Pa	lb/ft^2	$kg/m^2/s$	$lb/ft^2/hr$	Pa	lb/ft^2	$kg/m^2/s$	$lb/ft^2/hr$
Core04_L1	0-2	0.2	0.0042	1.20E-02	8.85	0.8	0.0167	0.087	64.1
Core04_L2	2-11	0.8	0.0167	2.82E-02	20.8	-	-	-	-

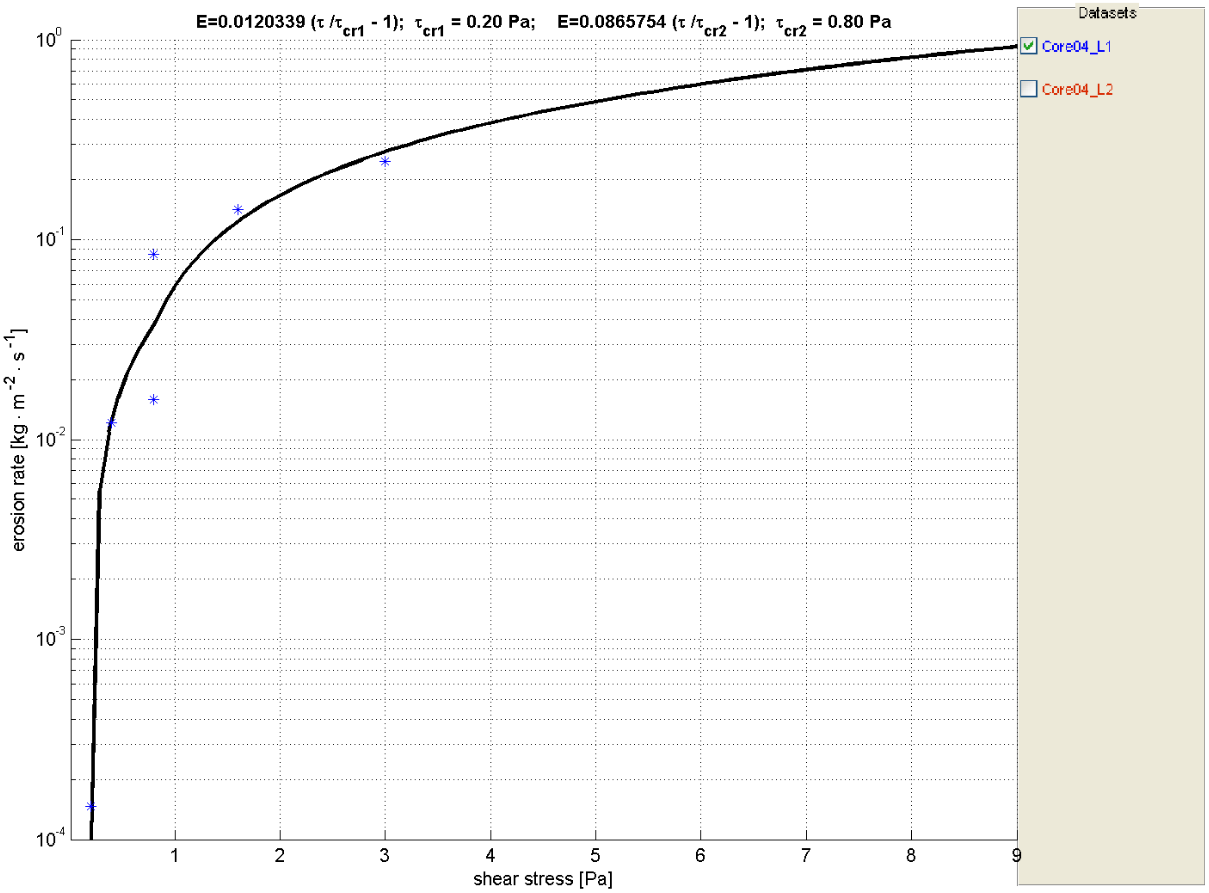


Figure B-41. Erosion versus applied shear stress for core 4, Layer 1. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

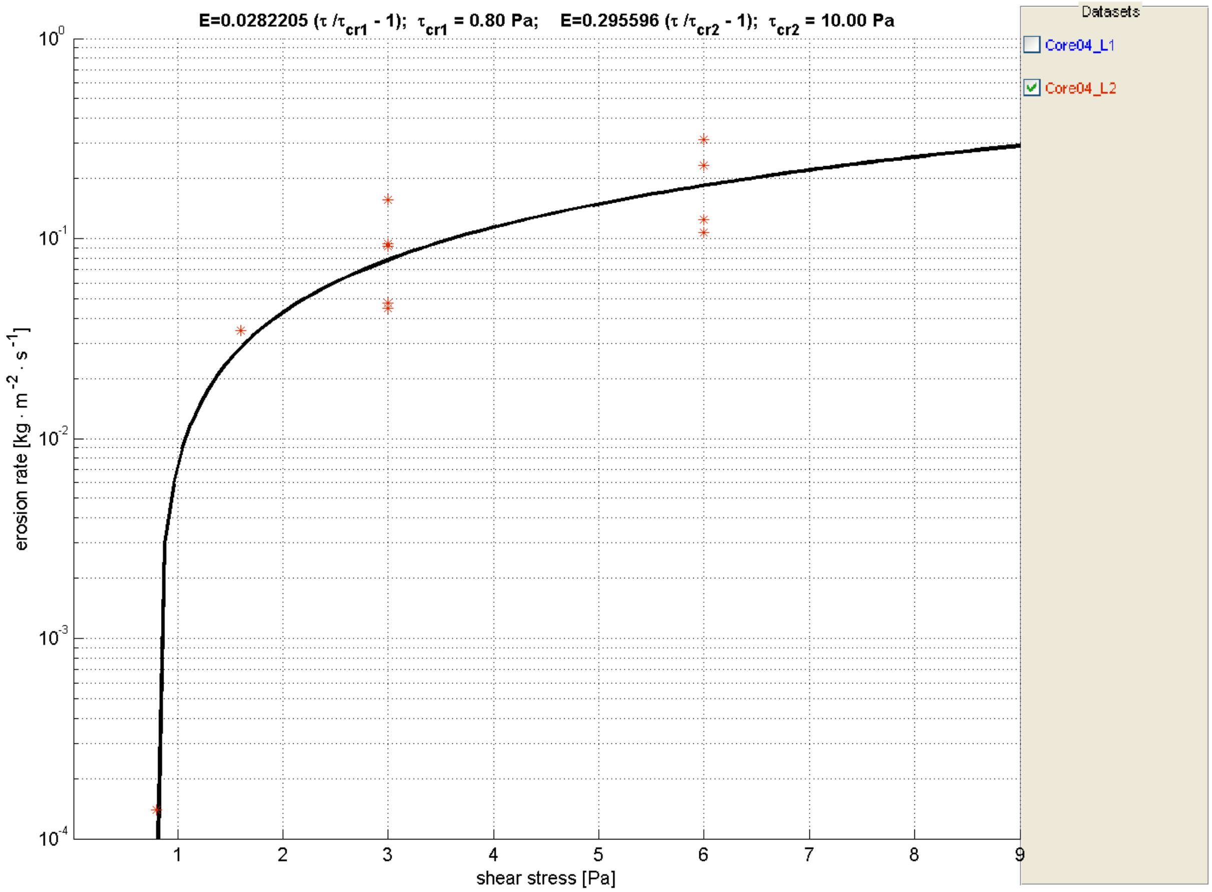


Figure B-42. Erosion versus applied shear stress for core 4, Layer 2. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 5

Table B-13. Cohesive Sediment Erosion Parameterization for HEC-RAS									
		Shear Thresh-old		Erosion Rate		Mass Wasting Threshold		Mass Wasting Rate	
Layer ID	Depth (cm)	Pa	lb/ft^2	kg/m^2/s	lb/ft^2/hr	Pa	lb/ft^2	kg/m^2/s	lb/ft^2/hr
Core05_L1	0-5	0.2	0.0042	1.28E-02	9.44	-	-	-	-
Core05_L2	5-12	0.8	0.0167	2.22E-02	16.4	2	0.0418	0.125	92.2
Core05_L3	12-24	1.6	0.0334	9.76E-02	72.0	-	-	-	-

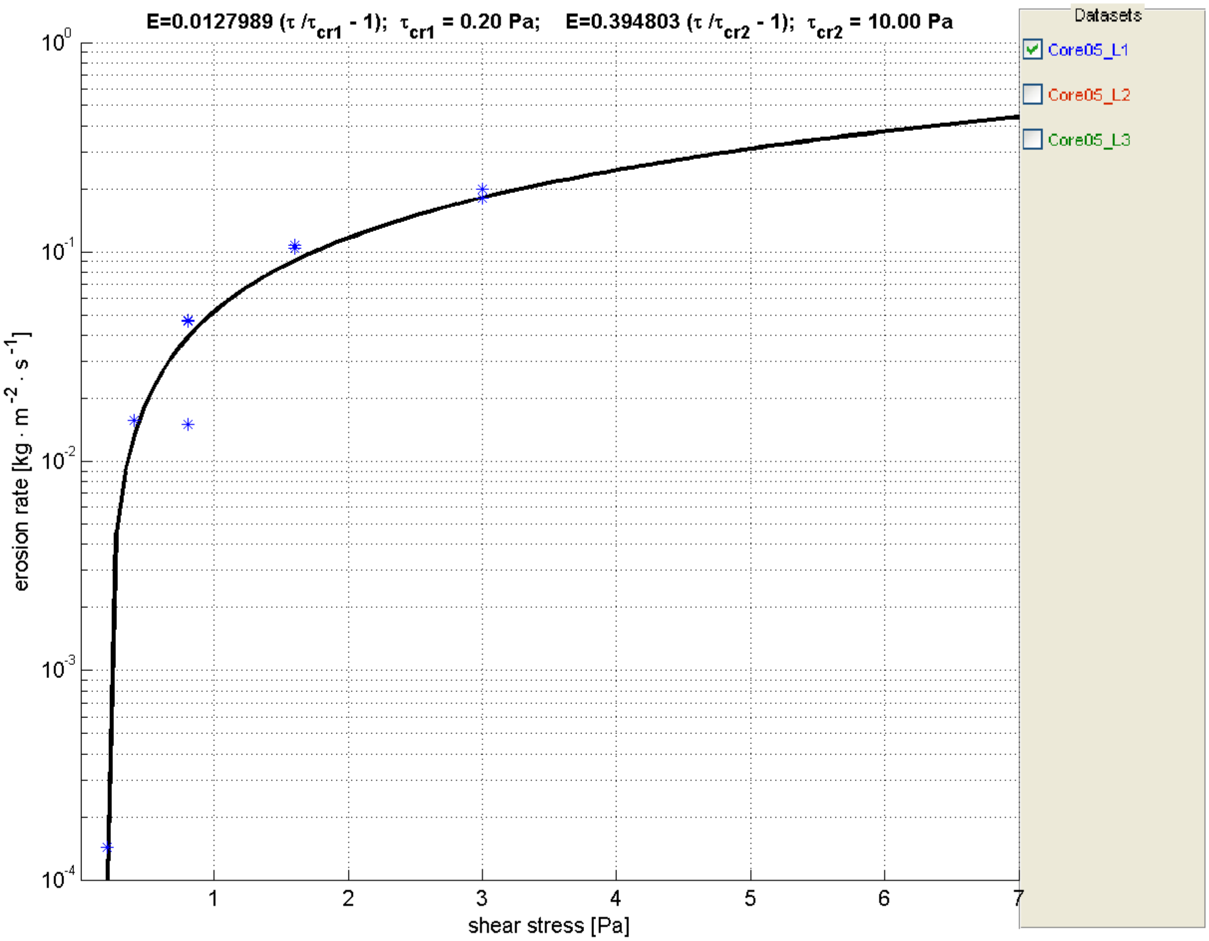


Figure B-43. Erosion versus applied shear stress for core 5, Layer 1. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

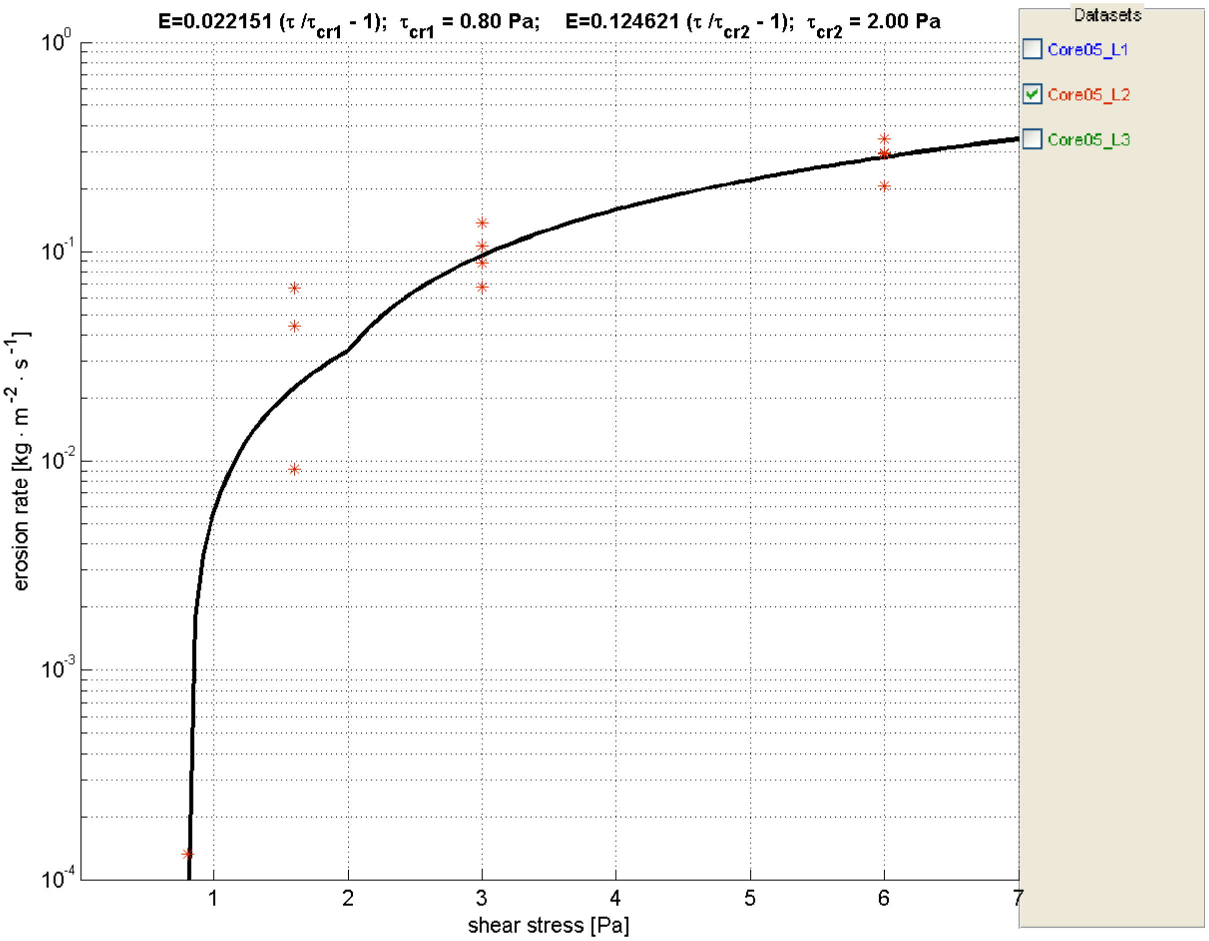


Figure B-44. Erosion versus applied shear stress for core 5, Layer 2. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

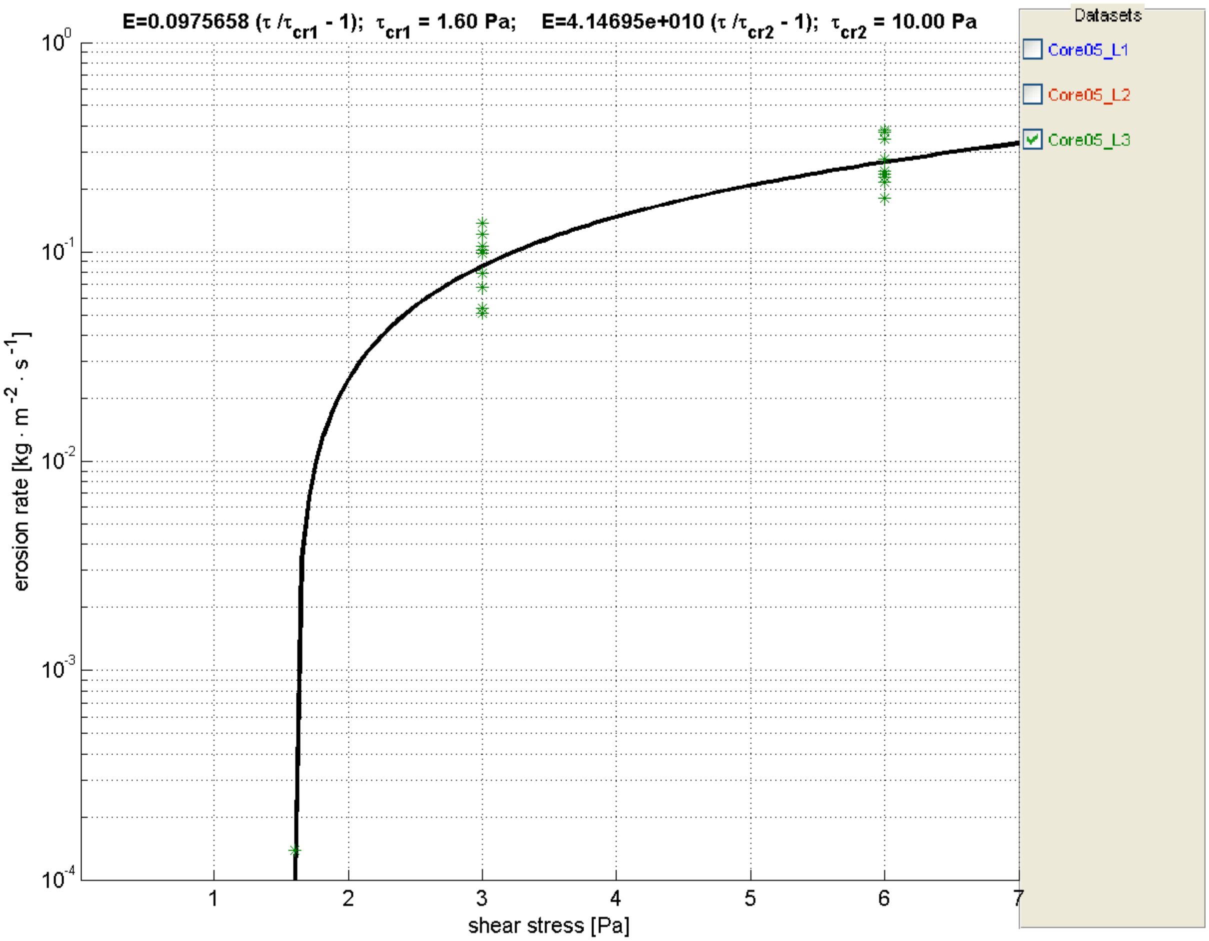


Figure B-45. Erosion versus applied shear stress for core 5, Layer 3. Colors indicate bed layers, Lines represent best-fit line to HEC-RAS implementation of Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 6

Table B-14. Cohesive Sediment Erosion Parameterization for HEC-RAS									
		Shear Thresh-old		Erosion Rate		Mass Wasting Threshold		Mass Wasting Rate	
Layer ID	Depth (cm)	Pa	lb/ft^2	$kg/m^2/s$	$lb/ft^2/hr$	Pa	lb/ft^2	$kg/m^2/s$	$lb/ft^2/hr$
Core06_L1	0-2	0.1	0.0021	1.32E-02	9.73	-	-	-	-
Core06_L2	2-14	1.59	0.0332	3.41E-02	25.1	-	-	-	-

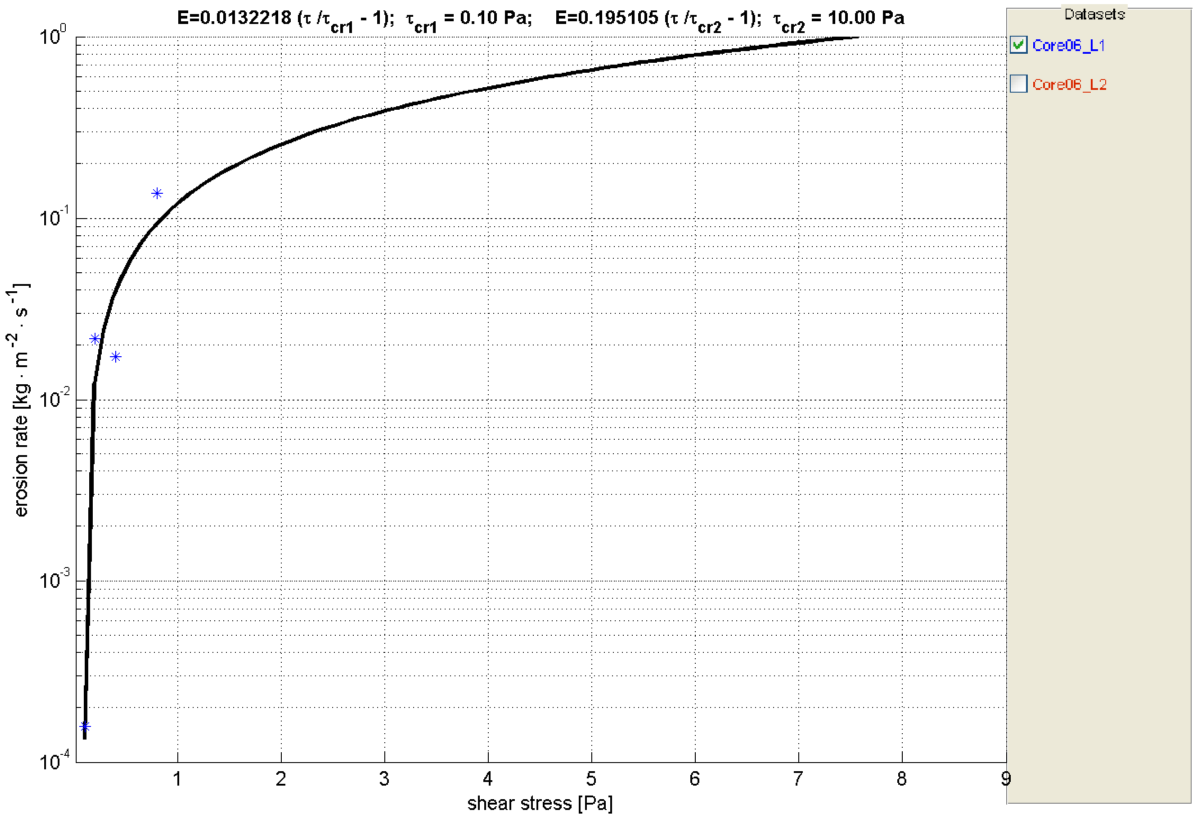


Figure B-46. Erosion versus applied shear stress for core 6, Layer 1. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

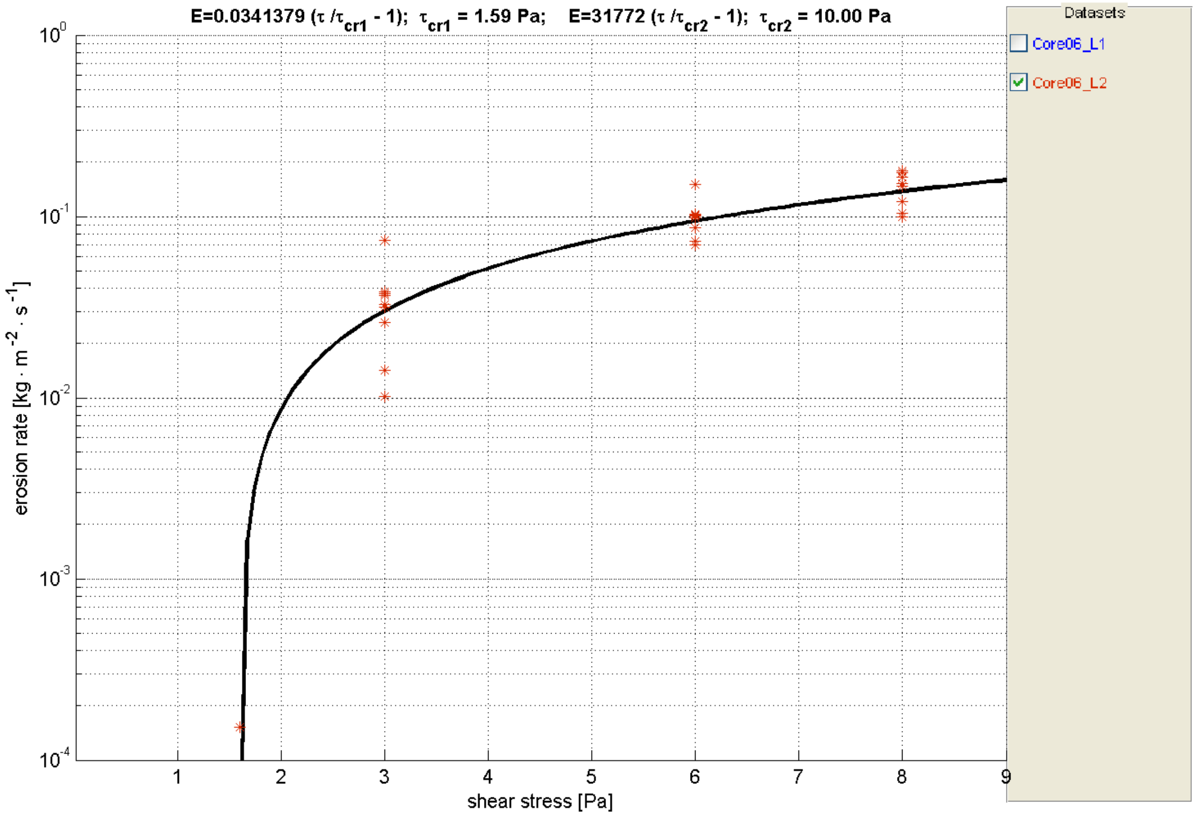


Figure B-47. Erosion versus applied shear stress for core 6, Layer 2. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 9

Table B-15. Cohesive Sediment Erosion Parameterization for HEC-RAS									
		Shear Threshold		Erosion Rate		Mass Wasting Threshold		Mass Wasting Rate	
Layer ID	Depth (cm)	Pa	lb/ft^2	$kg/m^2/s$	$lb/ft^2/hr$	Pa	lb/ft^2	$kg/m^2/s$	$lb/ft^2/hr$
Core09_L1	0-2	0.2	0.0042	1.25E-02	9.22	0.8	0.0167	0.102	75.2
Core09_L2	2-9	1.58	0.033	3.43E-02	25.3	-	-	-	-

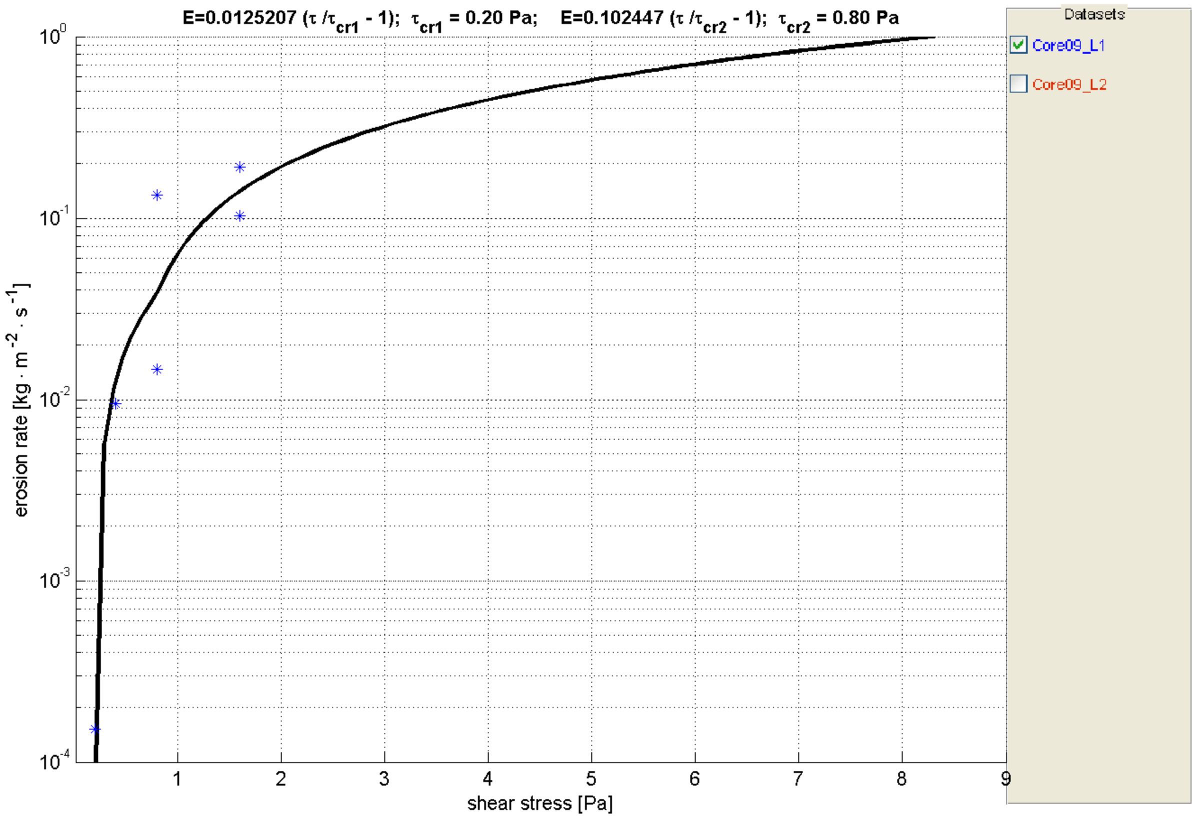


Figure B-48. Erosion versus applied shear stress for core 9, Layer 1. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

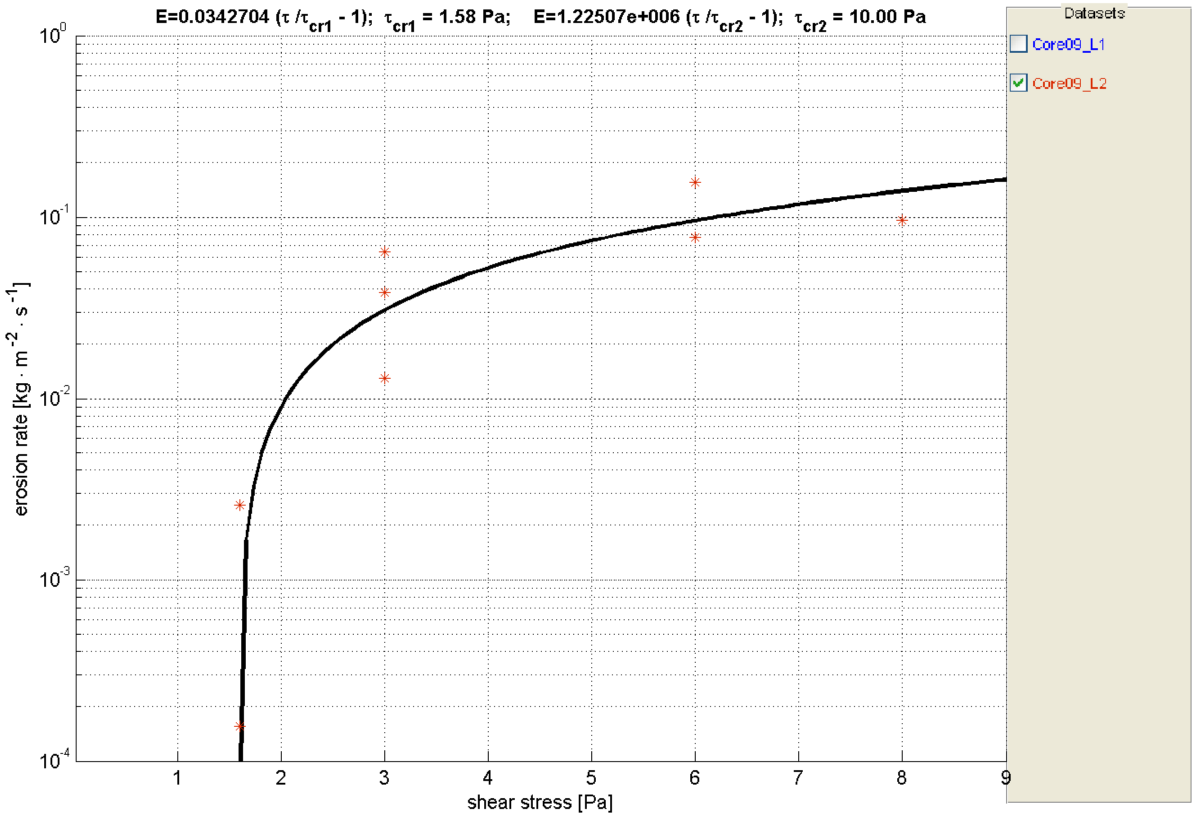


Figure B-49. Erosion versus applied shear stress for core 9, Layer 2. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Core 10

Table B-16. Cohesive Sediment Erosion Parameterization for HEC-RAS									
Layer ID	Depth (cm)	Shear Thresh-old		Erosion Rate		Mass Wasting Threshold		Mass Wasting Rate	
		Pa	lb/ft^2	$kg/m^2/s$	$lb/ft^2/hr$	Pa	lb/ft^2	$kg/m^2/s$	$lb/ft^2/hr$
Core10_L1	0-8	0.19	0.004	5.08E-02	37.5	-	-	-	-
Core10_L2	8-16	1.19	0.0249	1.95E-02	14.4	2.8	0.0585	0.139	102

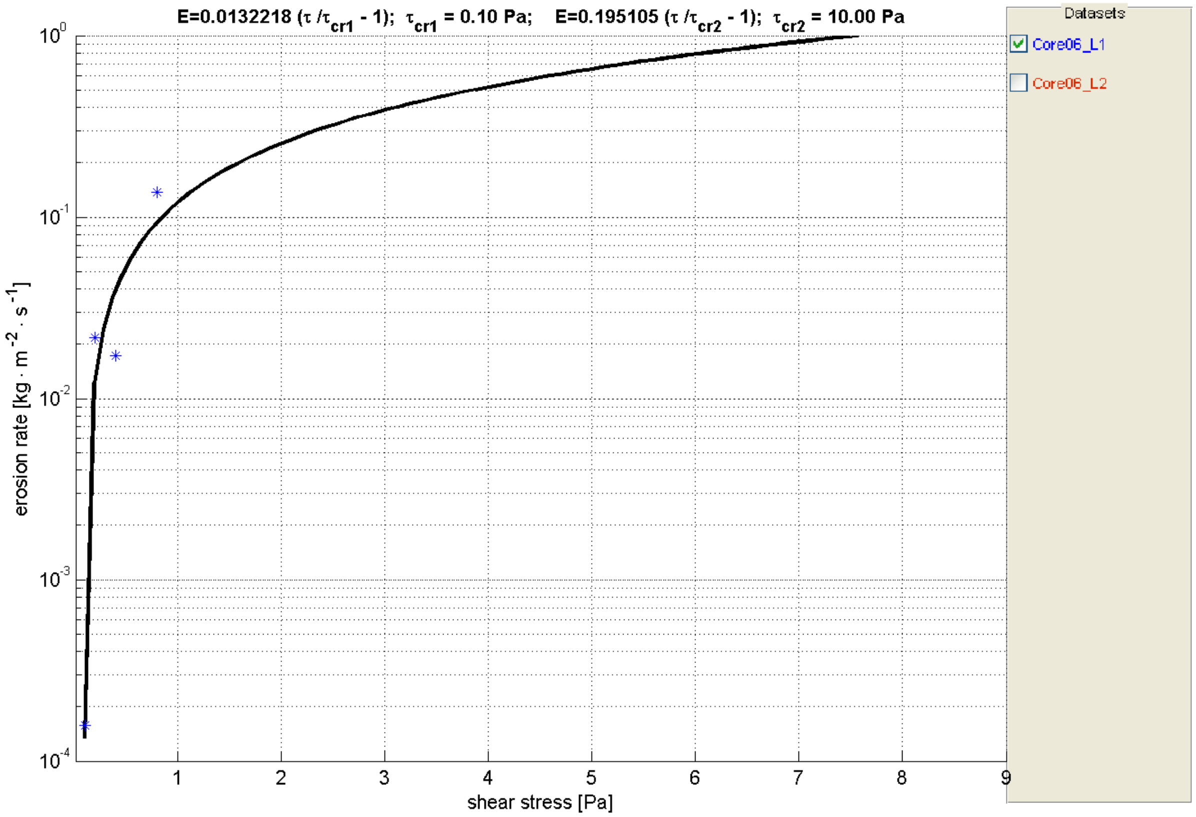


Figure B-50. Erosion versus applied shear stress for core 10, Layer 1. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

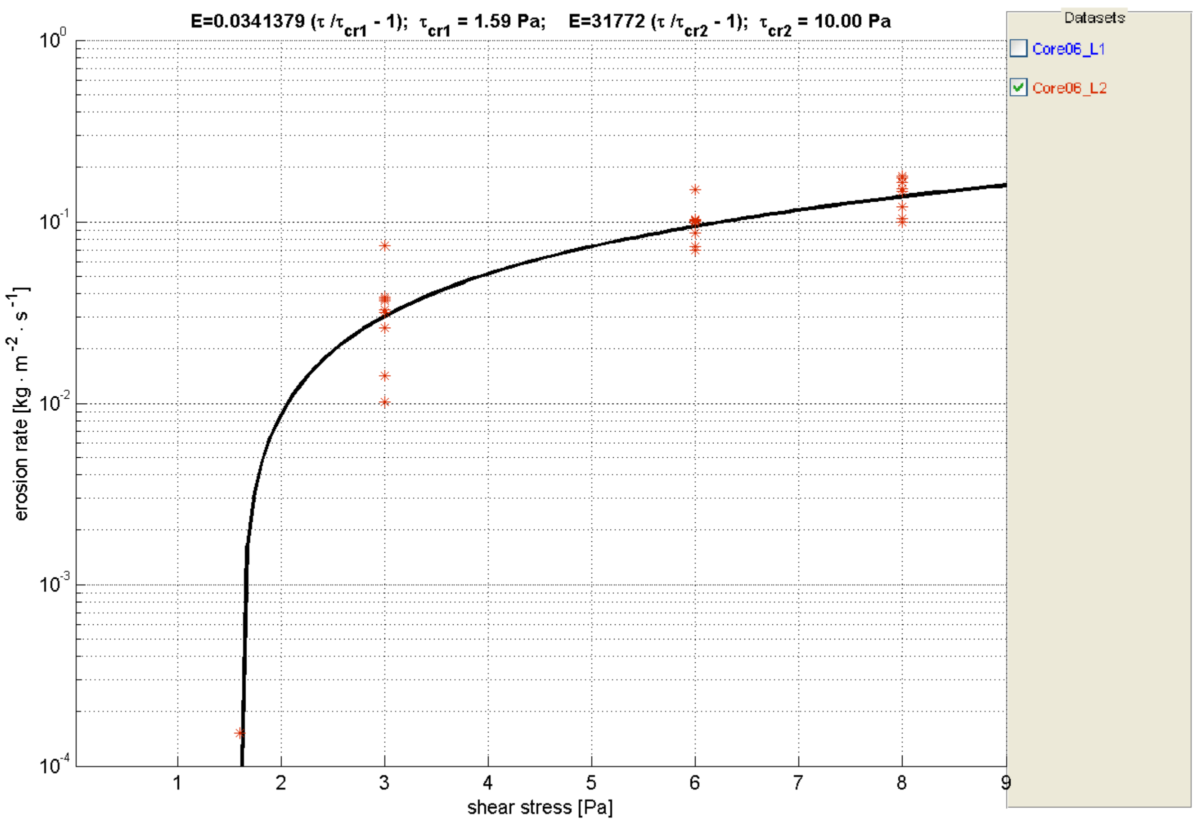


Figure B-51. Erosion versus applied shear stress for core 10, Layer 2. Colors indicate bed layers, Lines represent best-fit line to Partheniades' erosion function. Erosion equation parameters provided at top of figure.

Attachment B-3:
Change in Deposition and Bed Scour between the 2008 and 2011 Conowingo Reservoir Bathymetry Surveys

Attachment B-3

Change in Deposition and Bed Scour Between the 2008 and 2011 Conowingo Reservoir Bathymetry Surveys

Change in Deposition and Bed Scour Between the 2008 and 2011 Conowingo Reservoir Bathymetry Surveys

Background

This document describes the change in bed elevation that occurred between the 2008 and 2011 bathymetry surveys of Conowingo Reservoir. To support this calculation, a high resolution mesh of Conowingo Reservoir was constructed using the SMS modeling graphical user interface. This mesh contained 25,000 nodes and 48,000 elements. Each of the surveys was interpolated to this mesh, with the 2008 interpolated bed elevation subtracted from the 2011 interpolated bed elevation. The result was the difference in bed elevation, with sediment deposition indicated by positive change in elevation and bed scour indicated by negative change in bed elevation. Figure 1 describes how the survey transect data were interpolated to the mesh, with Figure 2 showing the resolution of the mesh in the lower reservoir.

Results

The bed elevation change is depicted in Figure 3. The total deposition was 8.8 million tons assuming a bed bulk density of 1600 kg/m^{3}. The total bed scour was 5.6 million tons also assuming a bed bulk density of 1600 kg/m^{3}. The reservoir was net depositional 3.2 million tons. Figures 4 and 5 show deposition and bed scour respectively, with the color contour representing the variable in question, with the other variable not contoured (white areas). Figure 4 indicates that deposition increases with distance from the upper reservoir, with 69 percent of the deposition occurring in the lower half of the reservoir. A relatively large amount of deposition (26 percent of the total deposition) is located in a relatively small area from the dam to a point about 2 miles upstream on the eastern side of the reservoir (see notation on Figure 4).

Figure 5 shows the bed scour depth, as well as spatial variation of scour. The bed scour trend is opposite of the deposition trend. The most bed scour is found in the top one-third of the reservoir, with a decreasing trend downstream. Approximately 73 percent of the total bed scour occurs in the top half of the reservoir. In the lower reservoir, approximately 120,000 tons scours from just upstream of the dam (see notation on Figure 5).

Discussion

The bed elevation change calculations for the 2008 and 2011 survey comparison show distinct trends in deposition and erosion. The 2011 survey was taken just after the Tropical Storm Lee event, which had a peak instantaneous discharge of 700,000 cfs, which is 75 percent greater than the scour threshold discharge of 400,000 cfs. Significant changes occurred in reservoir morphology due to this storm. Fifty percent of the scour occurred in the top one third of the reservoir which contained up to 50 percent sand. Suspended sediment samples taken below the dam indicate that 10 percent or less sand transported through the dam during Tropical Storm Lee, thus the remaining sand scoured from the upper reservoir is likely re-depositing in the lower reservoir reaches.

The lower half of the reservoir is net depositional, with a relatively large quantity of sediment deposited just upstream of the dam along the eastern shore of the reservoir. This deposit depicted on Figure 4 contains 26 percent of the total deposition over just 3 percent of the reservoir area. This area is on the opposite side of the reservoir from the power plant intake. The excessive accumulation of sediment in this area is likely due to reservoir operations during the flood. As the gates open to release floodwaters, sediment laden flows re-align to the middle of the channel, with the area along the eastern shore experiencing lower velocities and secondary circulation. Thus this area is subjected to constant sedimentation when the gates are releasing flood flows. Sediment scoured from upstream may enter this sedimentation zone and re-deposit.

Conclusions

Analysis of sedimentation and bed scour that occurred in Conowingo Reservoir between 2008 and 2011 indicates potential re-deposition of bed scour material in the lower reaches of the reservoir. Sand sized sediments scoured from the upper reservoir do not exit the reservoir in their entirety, and a depositional zone along the eastern shore of the reservoir just upstream of the dam contains a significant quantity of sediment given the area it occupies in the reservoir.

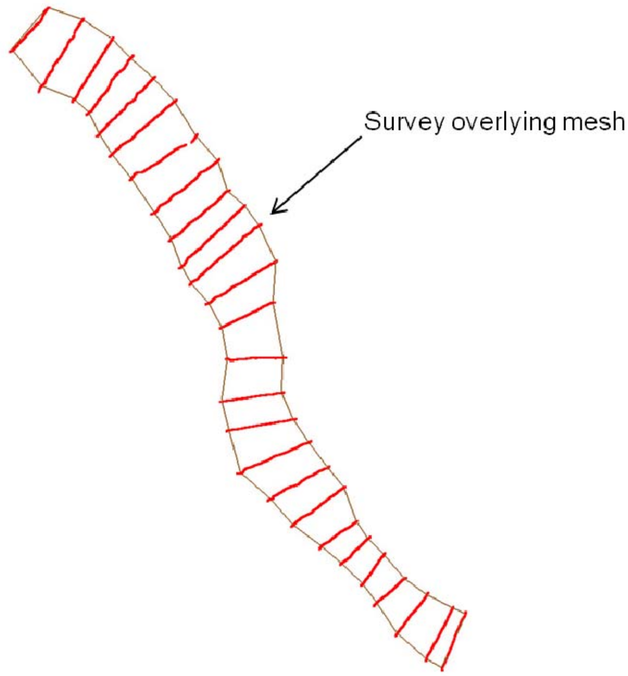


Figure 1. Bathymetric survey overlying the reservoir mesh

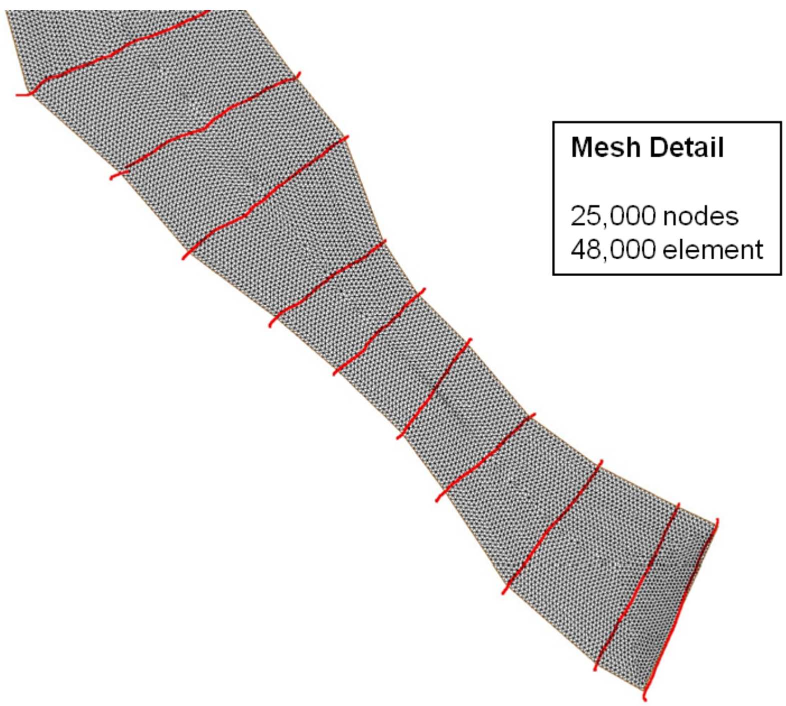


Figure 2. Bathymetric survey overlying reservoir mesh with details

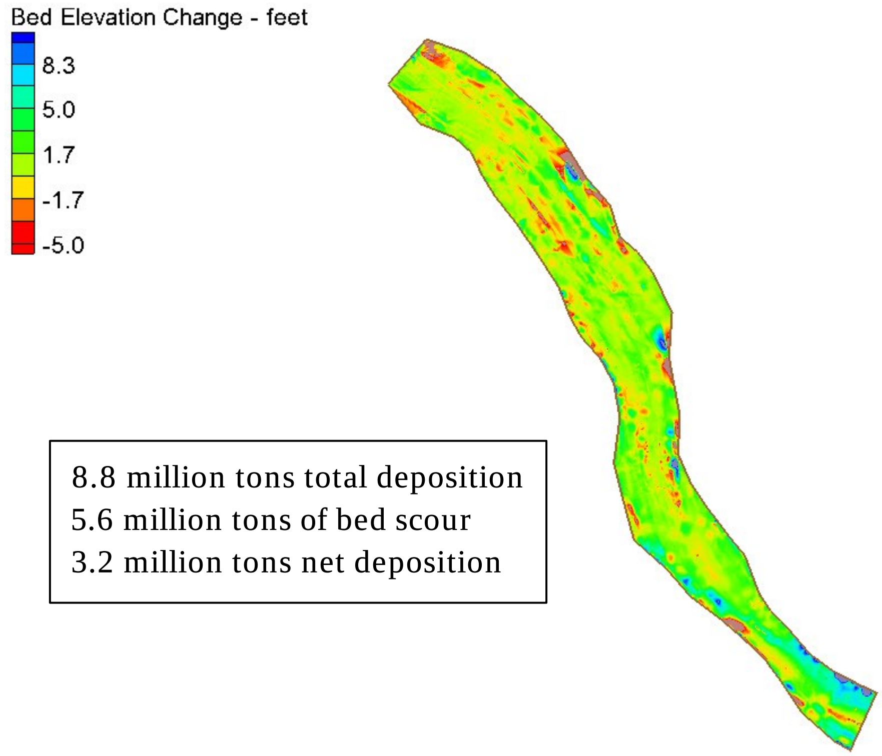


Figure 3. Bed elevation change between the 2011 and 2008 surveys

Figure 4. Change in deposition depth between the 2011 and 2008 surveys

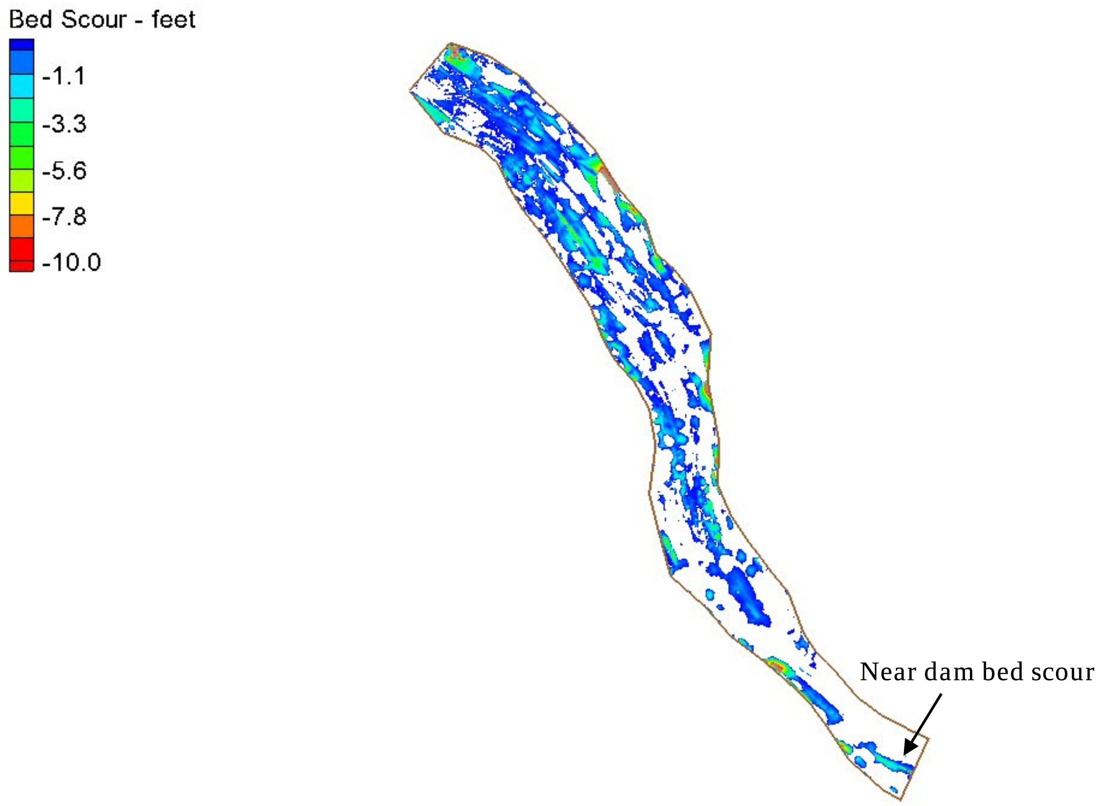


Figure 5. Change in bed scour depth between the 2011 and 2008 surveys

Attachment B-4:
Modeling Analysis to Support Agitation Dredging in Conowingo Reservoir

Attachment B-4

Modeling Analysis to Support Agitation Dredging in Conowingo Reservoir

Modeling Analysis to Support Agitation Dredging in Conowingo Reservoir

By

Steve Scott

Engineering Research and Development Center

Coastal and Hydraulics Laboratory

May 30, 2013

BACKGROUND

The feasibility of agitation dredging in Conowingo Reservoir is currently being evaluated. The agitation dredging process involves re-suspending reservoir bed sediments into the water column using either high pressure water jets or mechanical agitation methods. The re-suspended sediment is then transported through to the dam by the currents in the reservoir.

This report presents a two dimensional (2D) model study of the flow velocity and bed shear stress generated by a number of inflows into Conowingo Reservoir. Model output data were used to evaluate the potential for system hydrodynamics to adequately transport re-suspended sediments through the dam.

The potential for sediment to transport in suspension is directly related to sediment particle size, density, and the degree of turbulence in the flow. Sediment can transport as bed load, suspended load, or mixed load. Bed load transport can occur in relatively low energy (low velocity) systems for finer sediments (fine sands), or in higher energy systems with larger sediments such as gravels. Bed load is sediment transported near the bed or in contact with the bed. Suspended load is transported in suspension with minimal contact with the bed. Mixed load transport implies sediment transport in both bed load and suspended load regimes. As flow through the reservoir increases, turbulence increases, thereby increasing the potential for the transport of suspended load. For fine sediments such as silts and clays, the turbulence requirements are lower than for coarse sediments because the particle sizes and resulting fall velocities are smaller. For larger particles such as sands, higher flows are required to keep the sediment in suspension.

An analysis of historical deposition in Conowingo Reservoir revealed that the reservoir is almost full to capacity for sediment, with the remaining sediment storage capacity located in the lower two miles of the reservoir. Thus the highest potential for increasing sediment storage capacity through agitation dredging is in the lower two miles. The bed sediments in the lower two miles consist of primarily silts, with some clay and sand (81 percent silt, 9 percent clay, and 10 percent sand). These sediments are cohesive in nature, and will consolidate over time in the bed. As the sediments consolidate, the clay and silt particles are tightly packed and become resistant to erosion. Because of the cohesive properties of silts and clays, disturbance of the sediment bed by agitation dredging most likely will result in re-suspension of fine sediment aggregates instead of primary silt and clay particles. These fine sediment aggregates will have higher fall velocities than the primary silt and clay particles, thus higher flows in the reservoir will be required to transport the re-suspended sediments through the dam.

ANALYSIS METHODOLOGY

The potential for sediments to transport in suspension can be evaluated by the ratio of the shear velocity to the sediment particle fall velocity. The shear velocity defines the turbulence intensity due to the flow, and is defined as:

$$U^* = \sqrt{\frac{\tau}{\rho}}$$

where U^* is the shear velocity, τ is the bed shear stress, and ρ is the water density. The particle fall velocity of primary silt and clay particles ranges from about 0.00002 – 0.003 meters per second. However, fine sediment aggregates can be much larger in size and have higher settling velocities. For the purpose of this study, it is assumed that the average fine sediment aggregate re-suspended from the bed in the lower two miles of the reservoir is approximately 0.1 millimeter, which represents fine sand with a fall velocity of 0.00347 meters per second.

Julien (1995) presents the ratio of suspended load to total load as a function of the ratio of the shear velocity to the particle fall velocity. A representative data curve is presented in Figure 1. As the shear velocity increases due to higher flows (increased turbulence), the percentage of suspended sediment load increases. Figure 1 indicates that at a shear velocity to particle fall velocity ratio of about 3.0, the load is fully suspended. At a ratio of 2.0 about 60 percent is suspended, and at a ratio of 1.8 about 15 percent of the load is suspended. Assuming a constant fall velocity for the agitated sediments, the percent of suspended load as a function of bed shear stress is presented in Figure 2. These data were used to evaluate the effectiveness of agitation dredging as a function of discharge in Conowingo Reservoir. Over the bed shear stress range of 0.07 – 0.10 Pascals, about 92 – 100 percent of the sediments will transport as suspended load.

APPROACH AND RESULTS

The goal of this study was to determine the required discharge through Conowingo Reservoir to transport the majority of sediment suspended from the agitation dredging process through the dam. The study concentrated on the lower three miles of the reservoir. Six 2D model simulations were conducted using the AdH model. Discharges of 33,000, 50,000, 75,000, 100,000, 120,000, and 150,000 cubic feet per second (cfs) were simulated in the model. For each simulation, the bed shear stress, flow velocity, and depth were analyzed along a longitudinal profile (Figure 3) from the dam to a point three miles upstream. Figure 4 shows the bed shear stress along the longitudinal profile for each of the simulations. The minimum bed shear stress occurs between 0.5 and 2.0 miles from the dam, referred to in this document as the area of concern. This is the deepest area of the reservoir that contains the remaining sediment storage capacity. The 120,000 cfs discharge event shows a minimum bed shear stress in the area of concern of about 0.07 Pascals, which from Figure 2 indicates about 92 percent of the sediment will remain in suspension. The

150,000 cfs discharge event has a minimum bed shear stress in the area of concern of over 0.1 Pascals. At 0.1 Pascals, Figure 2 predicts 100 percent of sediment will remain in suspension. The lower flow events show a reduced suspended sediment load, indicating that agitation dredging would be inefficient at these flows. Table 1 presents the percent of suspended sediment as a function of flow for each event. Figure 5 shows the corresponding velocity. The velocity range that an agitation dredge would encounter at the 150,000 cfs flow would be about 1 – 1.75 feet per second through the proposed dredging area. Figures 6 – 11 present the spatial distribution of velocity, depth, and bed shear stress for the 120,000 and 150,000 cfs simulations.

Table 1. Percent of suspended sediment as a function of discharge

Flow Event – cubic feet per second	**Percent Suspended Sediment**
33,000	0.0
50,000	0.0
75,000	1.0
100,000	58.0
120,000	92.0
150,000	100.0

CONCLUSIONS

Analysis of Conowingo Reservoir hydrodynamics for varying discharge scenarios indicates that a flow of 150,000 cfs will result in all of the 0.1 millimeter or smaller agitated sediment transporting in suspension through the dam. Sediment particles larger than the assumed size (0.1 millimeter) will likely deposit within the reservoir. In addition, re-suspended sediments, including those smaller than 0.1 millimeter that transport to lower energy areas of the lower reservoir, will likely deposit before reaching the dam.

REFERENCES

Julien, P.Y., 1995, "Erosion and Sedimentation", Cambridge University Press, page 187.

LIST OF FIGURES

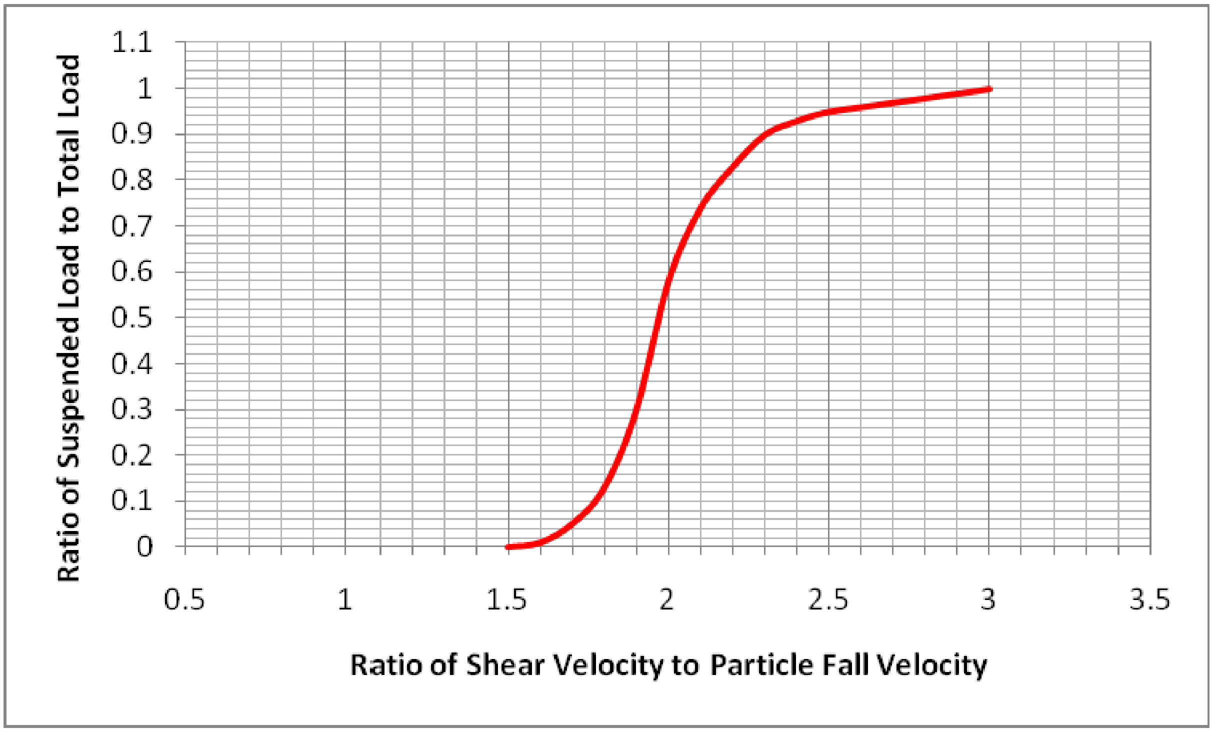


Figure 1. Ratio of suspended load to total load as a function of the ratio of shear velocity to particle fall velocity

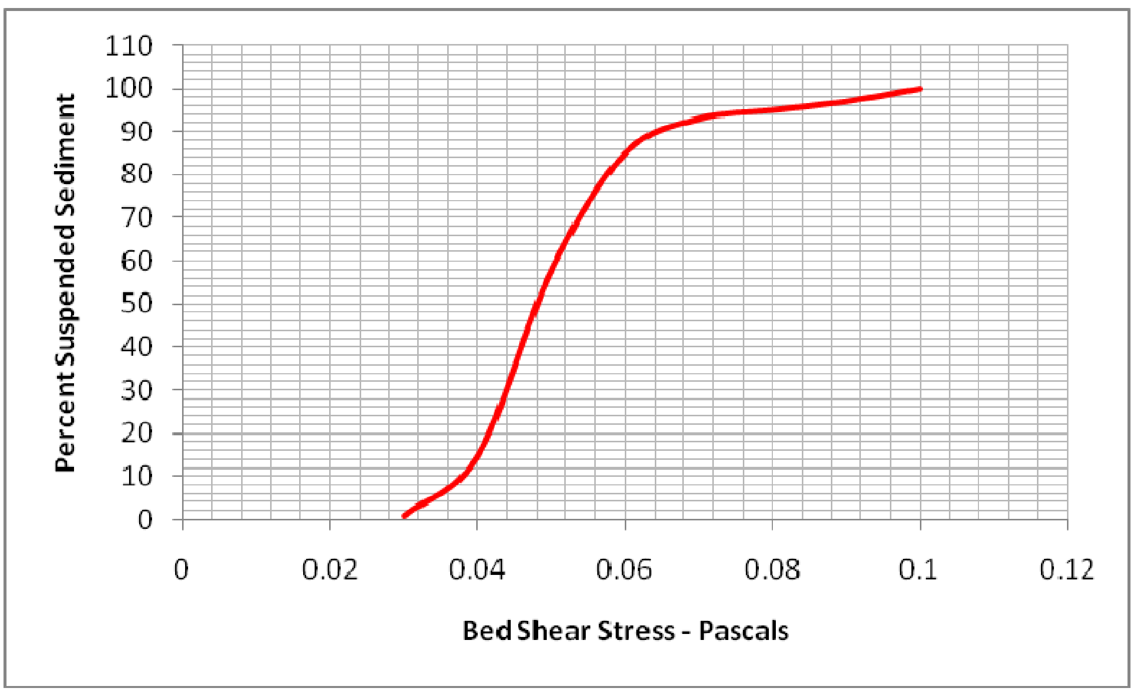


Figure 2. The percent of sediment in suspension as a function of bed shear stress

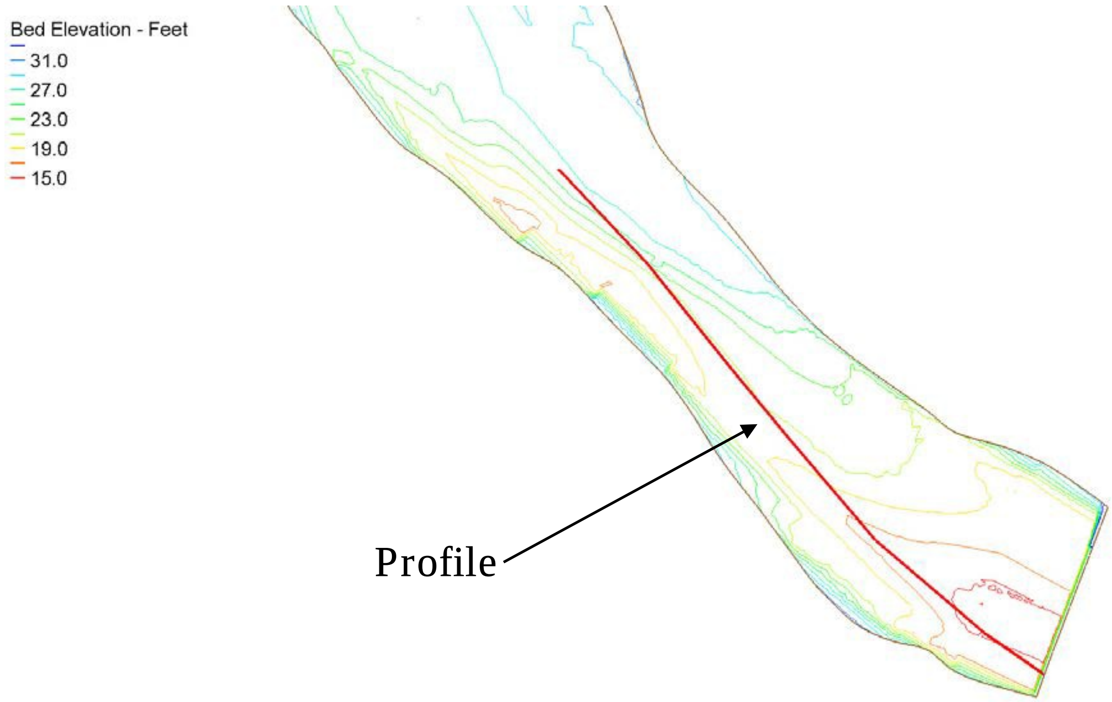


Figure 3. Agitation dredging study area including longitudinal profile used for data analysis

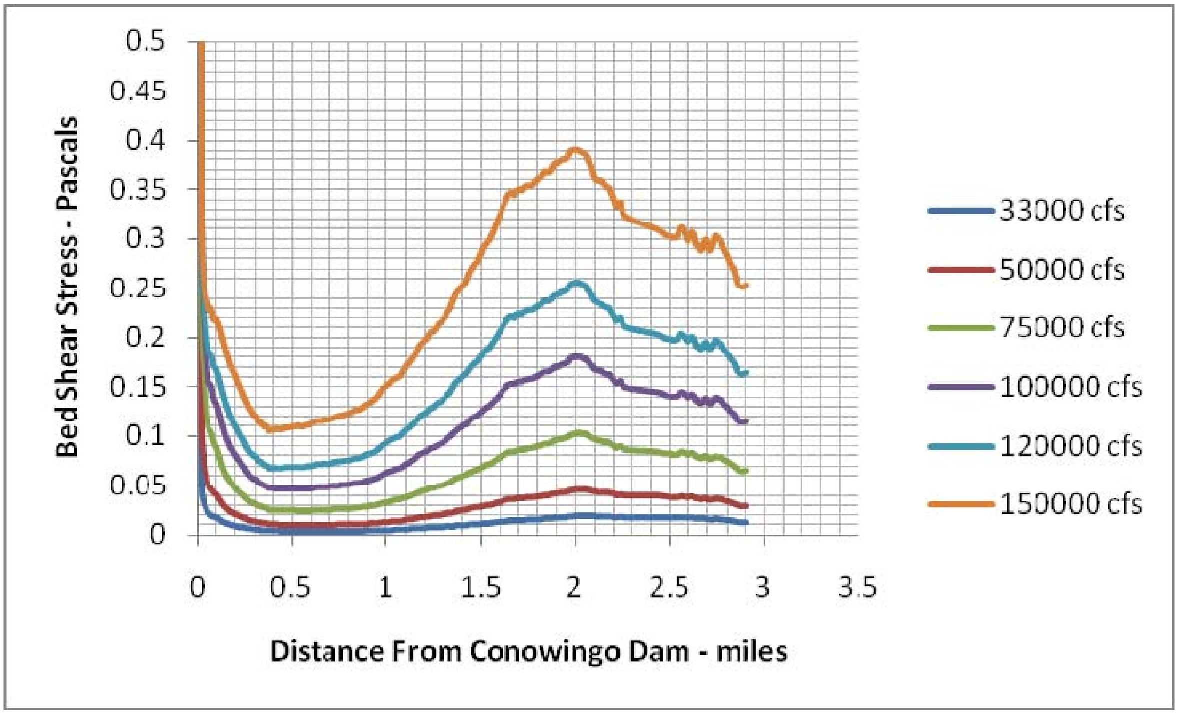


Figure 4. Bed shear stress profile upstream of Conowingo Dam for selected flow events

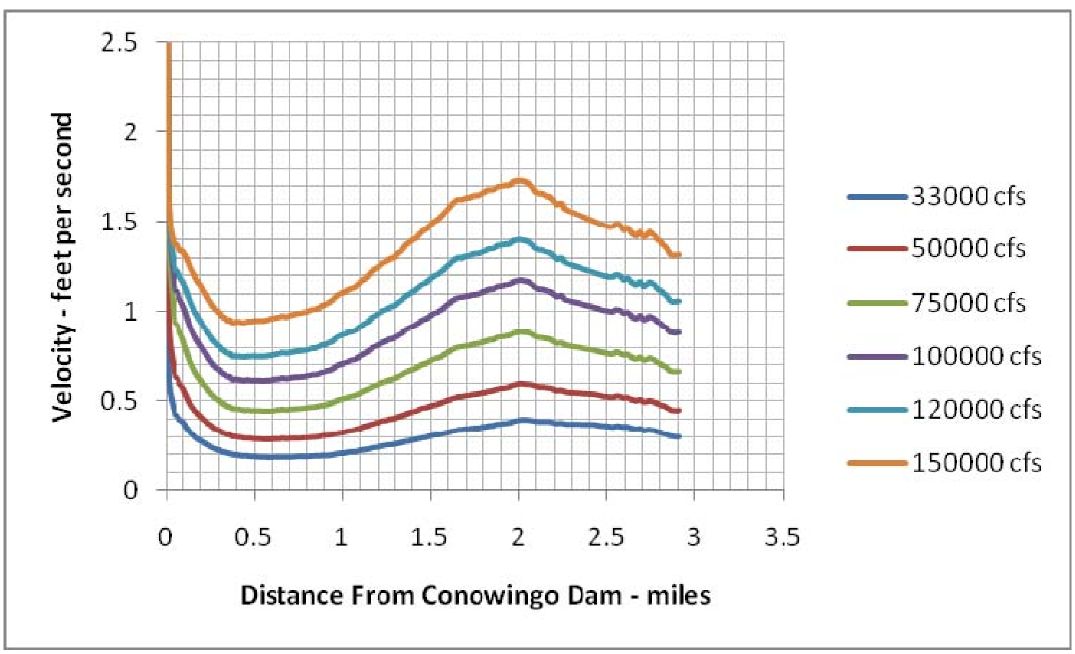


Figure 5. Flow velocity profile upstream of Conowingo Dam for selected flow events

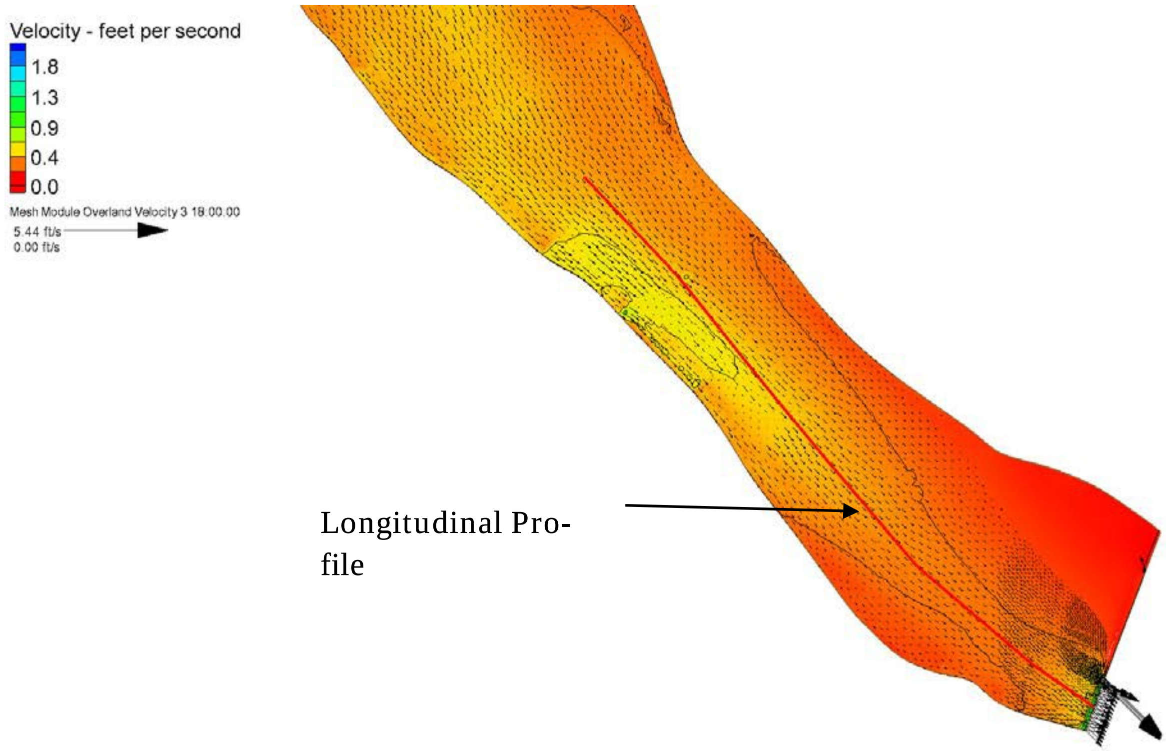


Figure 6. Velocity contour and direction for 120,000 cfs flow

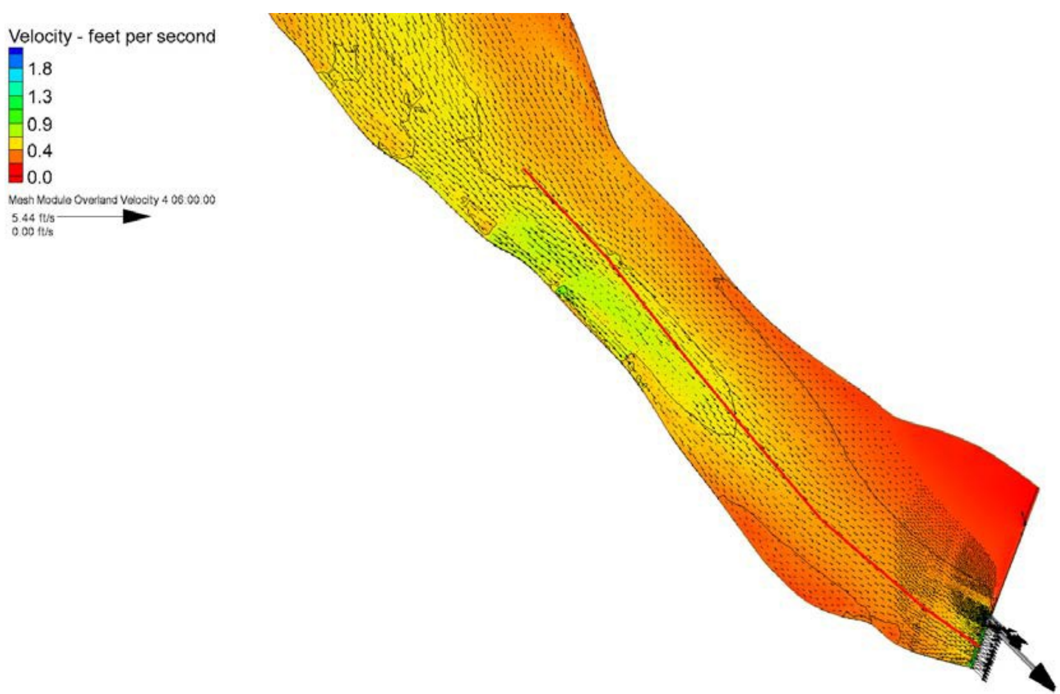


Figure 7. Velocity contour and direction for 150,000 cfs flow

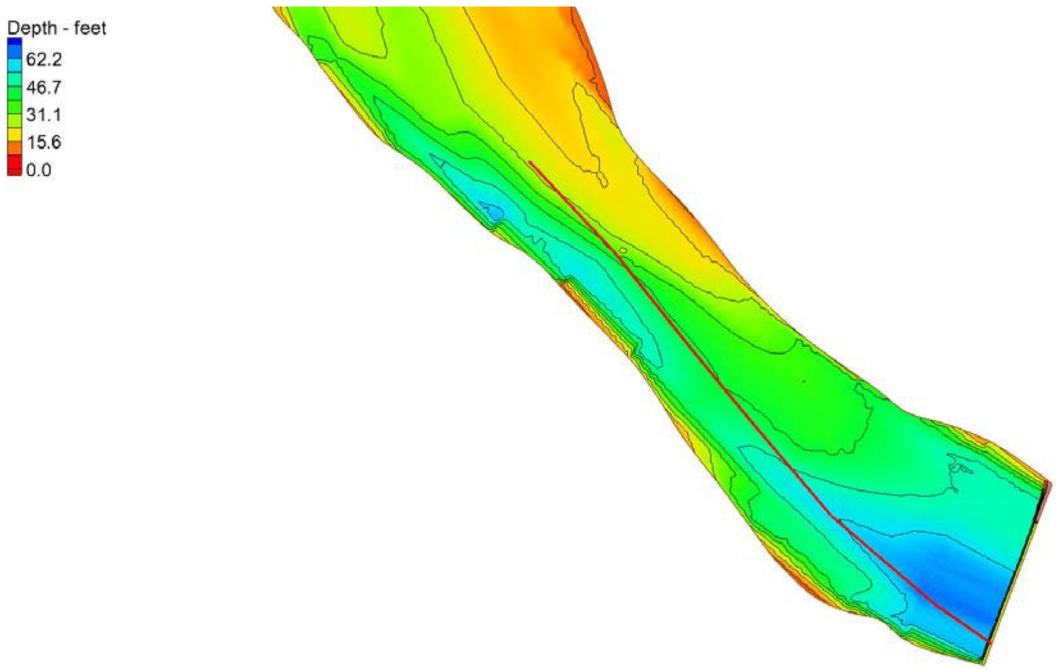


Figure 8. Depth contours for 120,000 cfs flow

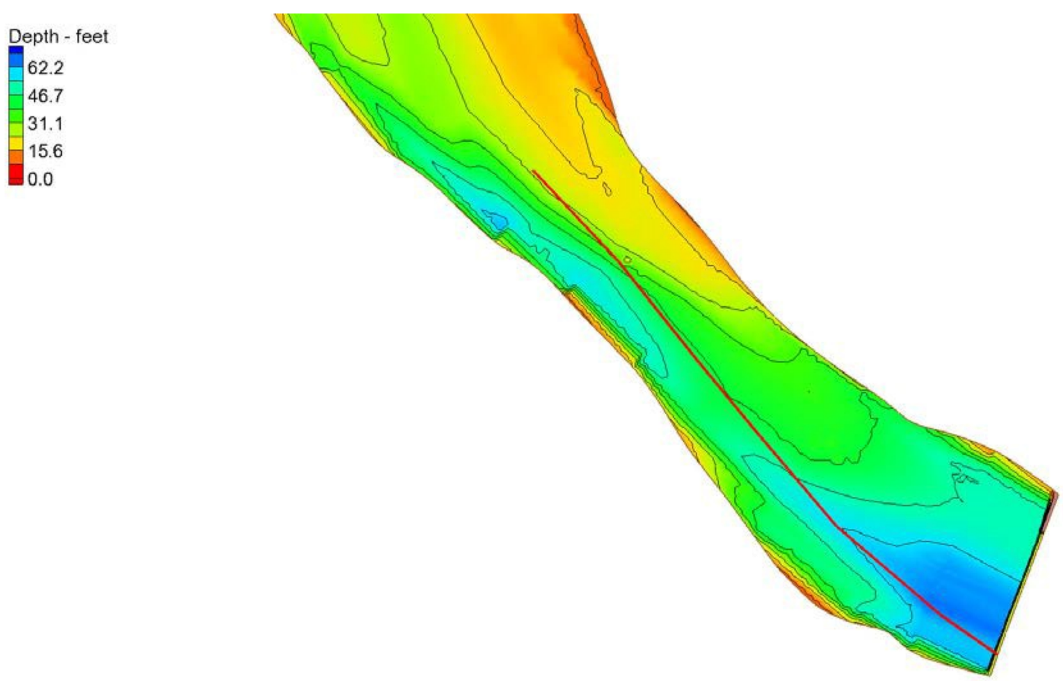


Figure 9. Depth contours for 150,000 cfs flow

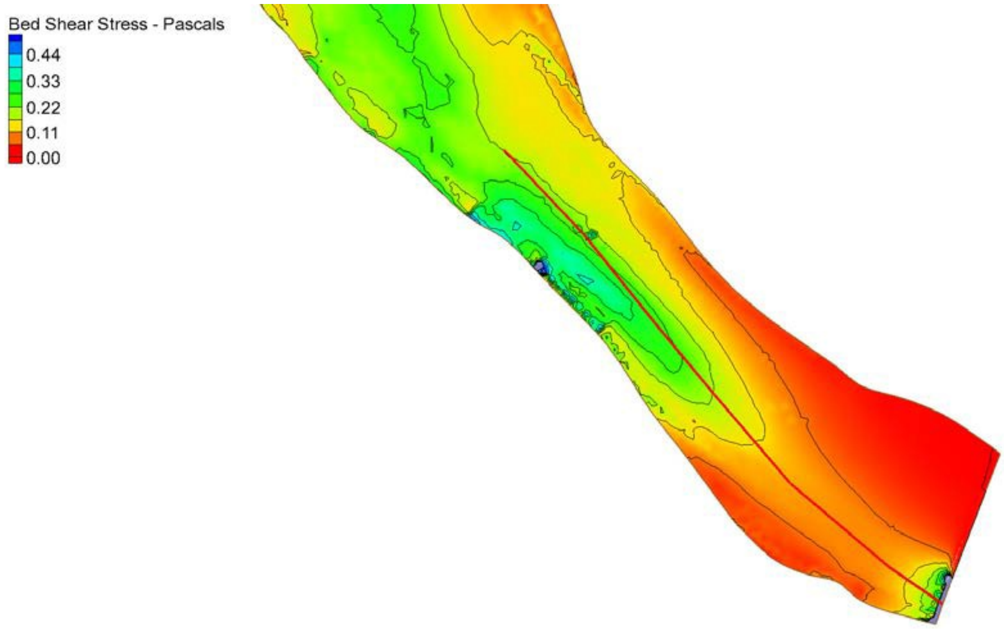


Figure 10. Bed shear stress contours for 120,000 cfs flow

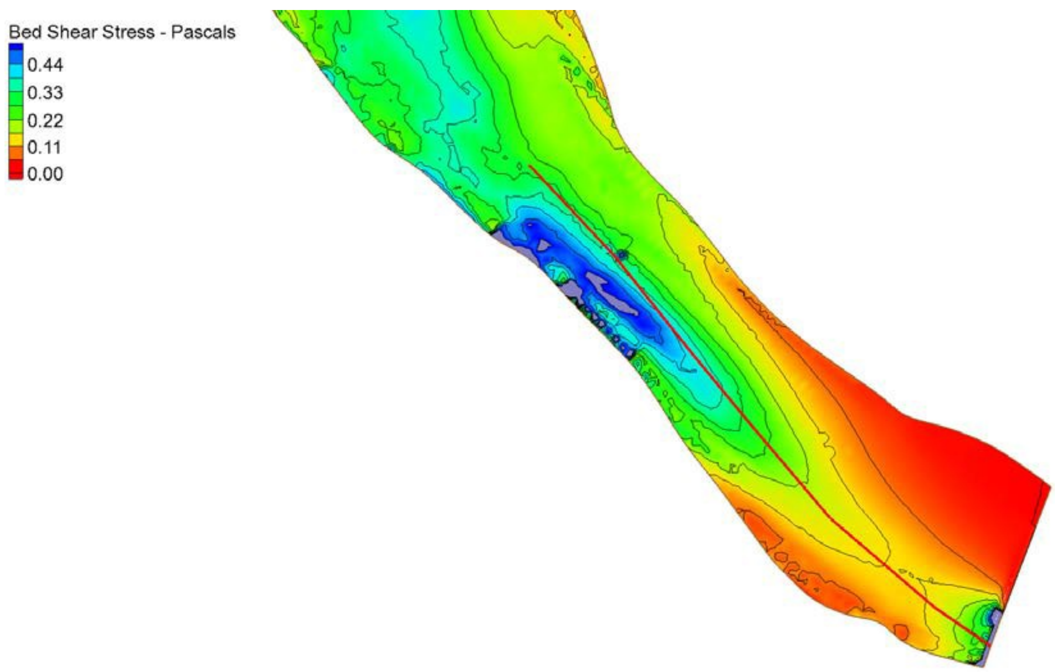


Figure 11. Bed shear stress contours for 150,000 cfs flow

Appendix C:
Application of the Chesapeake Bay Environmental Model Package to Examine the Impacts of Sediment Scour in Conowingo Reservoir on Water Quality in the Chesapeake Bay

Attachment C-1:
Data Assembly for Application of the CBEMP in the Lower Susquehanna River Watershed Assessment

Attachment C-2:
Individual Results for Each Chesapeake Bay Environmental Model Package in the LSRWA

(Not Included – Contact USACE-Baltimore District)

Application of the Chesapeake Bay Environmental Model Package to Examine the Impacts of Sediment Scour in Conowingo Reservoir on Water Quality in Chesapeake Bay

A Report to the U.S. Army Corps of Engineers, Baltimore District

September 2014 Final Report

Carl F. Cerco, Mark R. Noel

US Army Engineer Research and Development Center, Vicksburg MS

Abstract

The Susquehanna River empties into the northernmost extent of Chesapeake Bay and provides more than half of the freshwater flow to the estuarine system. A series of dams and reservoirs at the lower terminus of the river regulates flow and influences dissolved and suspended material loads into the Bay. Considerable sedimentation has occurred in the reservoirs since the dams were constructed. The two upper-most reservoirs have lost all sediment storage capacity while Conowingo Reservoir, situated immediately upstream of the Bay, was reported to have lost 60% to 70% of its storage capacity by 1997. Loss of the remaining sediment storage could have environmental consequences for the Chesapeake Bay, especially the portion immediately below the dam. Sediments which pass over the dam and enter the Bay, instead of settling to the reservoir bottom, may increase light attenuation, with adverse consequences for submerged aquatic vegetation. Nutrients associated with the sediments may contribute to ongoing eutrophication. Loss of storage may counter or negate load reductions planned under a recently-completed total maximum daily load (TMDL) program which assumes continued deposition in Conowingo Reservoir at the rate which prevailed from 1991 to 2000.

This report examines the impact of reservoir filling on water quality in Chesapeake Bay. Emphasis is placed on three quantities which form the basis of Bay water quality standards: chlorophyll, water clarity, and dissolved oxygen. Scenarios are presented which examine the impact of scour from a large storm on the Bay and which examine benefits from potential sediment management efforts. The Chesapeake Bay Environmental Model Package was the primary tool used to complete these investigations. Scenarios examined the impact of scour under alternate reservoir bathymetries, the effect of storms occurring at different times of the year, the potential ecosystem benefits of the dam, the potential benefits of removing sediments from the reservoir, and the potential impact of sediment bypassing. One over-arching conclusion from the scenarios is that the suspended solids loads are not the major threat to Bay water quality. For most conditions examined, solids scoured from the reservoir bottom settle out before the period of the year during which light attenuation is critical. The nutrients associated with the solids are more damaging. The nutrients settle to the estuary bottom and are mineralized in bottom sediments. The nutrients are recycled to the water column and stimulate algal production. Subsequent decay of algal organic matter consumes oxygen in the classic eutrophication cycle.

The computed impact of storm scour associated with a January 1996 flood event on TMDL conditions is small in magnitude relative to projected ambient conditions although the area affected may be extensive. Averaged over the SAV growing season, the median increase in growing-season light attenuation is less than 0.01 m^{-1}. Computed chlorophyll increases by 0.1 to 0.3 mg m^{-3} over a widespread area extending into the lower Potomac River and below the mouth of the Potomac in the mainstem bay. Bottom-water dissolved oxygen declines up to 0.2 g m^{-3} although the decline is 0.1 g m^{-3} or less when averaged over the summer season.

Point of Contact

Carl F. Cerco, PhD, PE
Research Hydrologist
US Army ERDC
3909 Halls Ferry Road
Vicksburg MS 39180 USA
601-634-4207
Carl.F.Cerco@usace.army.mil

Table of Contents

1 Introduction

The Susquehanna River empties into the northernmost extent of Chesapeake Bay and provides more than half of the freshwater flow to the estuarine system. A series of dams and reservoirs (Figure 1-1) at the lower terminus of the river regulates flow and influences dissolved and suspended material loads into the Bay. The most upstream reservoir, Lake Clarke, forms behind Safe Harbor Dam. Holtwood Dam forms Lake Aldred which sits below Lake Clarke. Conowingo Reservoir, the largest of the three, forms behind Conowingo Dam which is situated roughly six kilometers above the Chesapeake Bay head of tide.

Considerable sedimentation has occurred in the reservoirs since the dams were constructed circa 1910 – 1930. Lakes Clarke and Aldred have filled to the extent that they are in equilibrium with sediment loads coming down the river. Gravitational particle settling is balanced by erosion in these shallow systems so that no net accumulation of sediments occurs. The quantity of suspended solids entering each reservoir is essentially balanced by the quantity leaving. Conowingo Reservoir was reported to have lost 60% to 70% of its storage capacity by 1997 (Langland and Hainly, 1997). At that time, the period for the reservoir to fill to capacity was estimated at roughly 17 years. The Langland and Hainly report projected substantial increases in loadings of sediment and sediment-associated phosphorus to Chesapeake Bay resulting from loss of storage capacity in the reservoir. Recent analysis of loads from the reservoir to the Bay associated with the 2011 Tropical Storm Lee event suggest storm-generated loads are now substantially higher than in previous years (Hirsch, 2012). The increase in loadings projected in 1997 may be presently in effect.

Loss of sediment storage in Conowingo Reservoir could have environmental consequences for the Chesapeake Bay, especially the portion immediately below the dam. Sediments which pass over the dam and enter the Bay, instead of settling to the reservoir bottom, may increase light attenuation, with adverse consequences for submerged aquatic vegetation. Nutrients associated with the sediments may contribute to ongoing eutrophication. Loss of storage may counter or negate load reductions planned under a recently completed total maximum daily load (TMDL) program (USEPA, 2010) which assumes continued deposition in Conowingo Reservoir at the rate which prevailed during the hydrologic period used in determination of the TMDL (1991 to 2000).

The U.S. Army Corps of Engineers, Baltimore District (USACE), and the state of Maryland (MDE) have entered into a cost-share agreement to conduct Phase I of the Lower Susquehanna River Watershed Assessment (LSRWA). Phase I will:

- Forecast and evaluate sediment loads to the system of hydroelectric dams located on the Susquehanna River,
- Analyze hydrodynamic and sedimentation processes and interactions within the lower Susquehanna River watershed,
- Consider structural and non-structural strategies for sediment management, and
- Assess cumulative impacts of future conditions and sediment management strategies on Chesapeake Bay.

Critical components of the Phase I Watershed Assessment (USACE, 2011) include:

- Identification of watershed-wide sediment management strategies,
- Use of engineering models to link incoming sediment and associated nutrient projections to in-reservoir processes at the hydroelectric dams and forecast impacts to living resources in the upper Chesapeake Bay,
- Use of the Chesapeake Bay Environmental Model Package (CBEMP), a cooperative effort of the US Environmental Protection Agency Chesapeake Bay Program and the US Army Engineer Research and Development Center, to assess cumulative impacts of the various sediment management strategies to the upper Chesapeake Bay, and
- Integration of the Maryland and Pennsylvania Watershed Implementation Plans for nitrogen, phosphorus, and sediment reduction, as required to meet Chesapeake Bay TMDL's.

The present document reports on the use of the CBEMP in partial fulfillment of the goals stated above.

The Model Suite

This investigation involves the use of numerous predictive environmental models and the transfer of information between the models (Figure 1-2). Various and, occasionally, alternate acronyms are used to describe the individual models and combination of models. Water quality in the Bay is computed by the CBEMP which consists of three independent models: a watershed model (WSM), a hydrodynamic model (HM), and a water quality or eutrophication model (WQM). The WSM (Shenk and Linker, 2013) incorporates the entire Chesapeake Bay watershed and provides daily computations of flow, solids loads, and nutrient loads at the Conowingo outfall, at the heads of other tributaries and along the shoreline below the tributary inputs. Daily flows from the WSM are one set of inputs to the Computational Hydrodynamics in Three Dimensions (CH3D) hydrodynamic model (Johnson et al., 1993; Kim, 2013). CH3D computes surface level, three-dimensional velocities, and vertical diffusion on a time scale measured in minutes for the tidal Chesapeake Bay system. Daily nutrient and solids loads from the WSM and hourly transport processes from CH3D drive the Corps of Engineers Integrated Compartment Water Quality Model (CE-QUAL-ICM or simply ICM) of the Bay and tributaries (Cerco et al., 2010). ICM computes, in three dimensions, physical properties including suspended solids, algal production, and elements of the aquatic carbon, nitrogen, phosphorus, silica, and oxygen cycles. These are computed on time scales of minutes although computations averaged up to longer time periods, hours to one day, are more representative of observations. A predictive sediment diagenesis component (DiToro, 2001), a submerged aquatic vegetation component (Cerco and Moore, 2001), and a bivalve filtration component (Cerco and Noel, 2010) are attached to and interact with the model of the water column.

The HM and the WQM operate on a 50,000-cell computational grid which extends from the mouth of the Bay to the heads of tide of the Bay and major tributaries (Figure 1-3). Computational cells are quadrilateral (≈1 km x ≈1 km x 1.5m) and vary in number from 1 to 19 in the vertical in order to represent bathymetric variations. The primary application period for the two models covers the decade from 1991 to 2000. The 1991 to 2000 hydrologic record is retained for this study and the hydrodynamics for all but a few model runs are transferred directly from Cerco et al. (2010). (Two additional hydrodynamic simulations were completed as described in a subsequent chapter of this report.) The WQM is exactly as calibrated and described by Cerco at al. (2010) and as employed by the EPA Chesapeake Bay Program in development of the 2010 TMDL (USEPA, 2010).

WSM Phase 5.3.2, the most recent implementation, provided daily solids and nutrient loads for this study. The WSM provided two series of outputs for subsequent use in the WQM. The "2010 Progress Run" was based on land use, management practices, waste-loads, and atmospheric deposition from the year 2010 and represented current conditions. The "TMDL" run employed projected land use, management practices, waste-loads, and atmospheric deposition upon which the TMDL was based. The TMDL was developed from WSM Phase 5.3.0, however, so small differences exist between the loads used herein and the published regulatory TMDL.

Two other models were associated with this study and provided information utilized directly or indirectly in the CBEMP. A detailed Adaptive Hydrodynamics (ADH) model computed two-dimensional hydrodynamics and sediment transport in Conowingo Reservoir (Scott and Sharp, 2013). Sediment erosion or scour from the bed of Conowingo under various conditions was computed in ADH and added to the loads at Conowingo computed by the WSM and employed by the WQM. Since the ADH application period was 2008 to 2011 while the CBEMP application period was 1991 to 2000, an algorithm described in a subsequent chapter was applied to adjust calculated scour from the ADH application for use in the CBEMP. Solids loads to Conowingo Reservoir, for use in the ADH model, were based on a "rating curve" which was informed by an application of the Hydrologic Engineering Center River Analysis System (HEC-RAS) to the three-reservoir system from Lake Clarke through Conowingo (Langland, 2013).

A Word about Units

This report employs SI units throughout, with rare exceptions. Tons comprise 1,000 kg unless "English" tons, 1000 lbs., are specified.

References

Cerco, C., and Moore, K. (2001). “System-wide submerged aquatic vegetation model for Chesapeake Bay,” *Estuaries*, 24(4), 522-534.

Cerco, C., and Noel, M. (2010). “Monitoring, modeling, and management impacts of bivalve filter feeders in the oligohaline and tidal fresh regions of the Chesapeake Bay system,” *Ecological Modelling,* 221, 1054-1064.

Cerco, C., S-C Kim, and M. Noel. (2010). “The 2010 Chesapeake Bay eutrophication model,” A Report to the U.S. Environmental Protection Agency Chesapeake Bay Program and to the U.S. Army Corps of Engineers Baltimore District. http://www.chesapeakebay.net/publication.aspx?publicationid=55318

DiToro, D. (2001). *Sediment Flux Modeling*, John Wiley and Sons, New York.

Hirsch, R. (2012). “Flux of nitrogen, phosphorus, and suspended sediment from the Susquehanna River basin to the Chesapeake Bay during Tropical Storm Lee, September 2011, as an indicator of the effects of reservoir sedimentation on water quality,” Scientific Investigations Report 2012-5185, US Geological Survey, Reston VA.

Johnson, B. H., Kim, K., Heath, R., Hsieh, B., Butler, L. (1993). “Validation of a three-dimensional hydrodynamic model of Chesapeake Bay,” *Journal of Hydraulic Engineering*, 119, 2-20.

Kim, S-C. (2013). “Evaluation of a three-dimensional hydrodynamic model applied to Chesapeake Bay through long-term simulation of transport processes,” *Journal of the American Water Resources Association,* 49(5), 1078-1090.

Langland, M., and Hainly, R. (1997). “Changes in bottom-surface elevations in three reservoirs on the lower Susquehanna River, Pennsylvania and Maryland, following the January 1996 flood -Implications for nutrient and sediment loads to Chesapeake Bay,” Water-Resources Investigations Report 97-4138, US Geological Survey, Lemoyne PA.

Langland, M. (2013). “Sediment transport simulation of three reservoirs in the lower Susquehanna River basin, Pennsylvania and Maryland,” a report to the U.S. Army Corps of Engineers, Baltimore District.

Shenk, G., and Linker, L. (2013). “Development and application of the 2010 Chesapeake TMDL watershed model,” *Journal of the American Water Resources Association,* 49(5), 1042-1056.

Scott, S., and Sharp, J. (2013). “Sediment transport characteristics of Conowingo Reservoir,” a report to the U.S. Army Corps of Engineers, Baltimore District.

USEPA. (2010). "Chesapeake Bay total maximum daily load for nitrogen, phosphorus and sediment," US Environmental Protection Agency Region 3. http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html

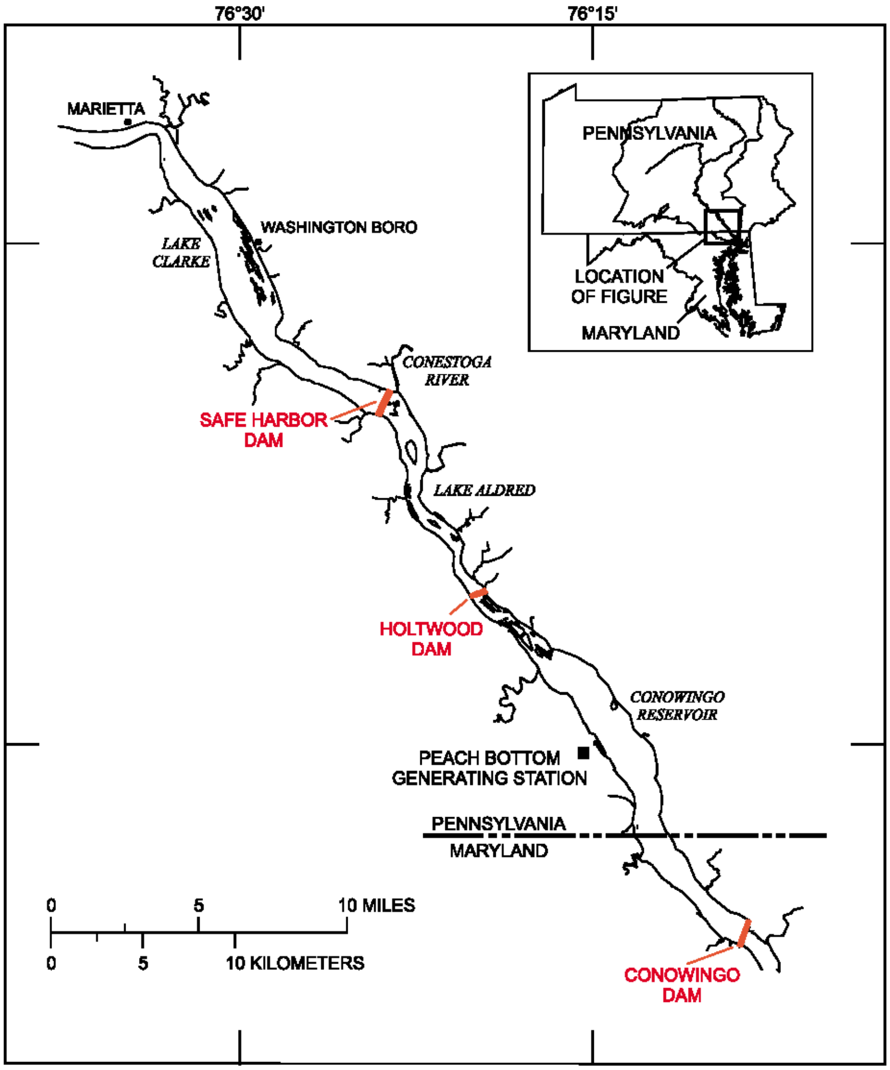


Figure 1-1. Lower Susquehanna River reservoir and dam system (extracted from USGS, 2003).

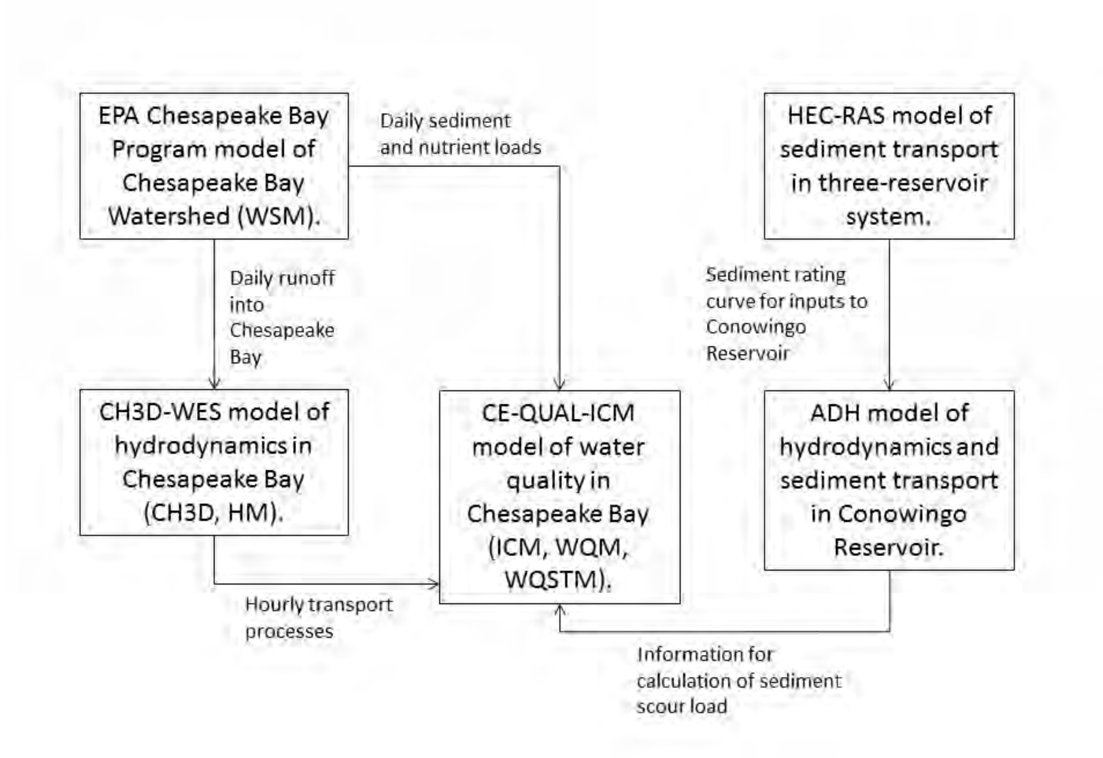


Figure 1-2. Flow chart for models applied in this study.

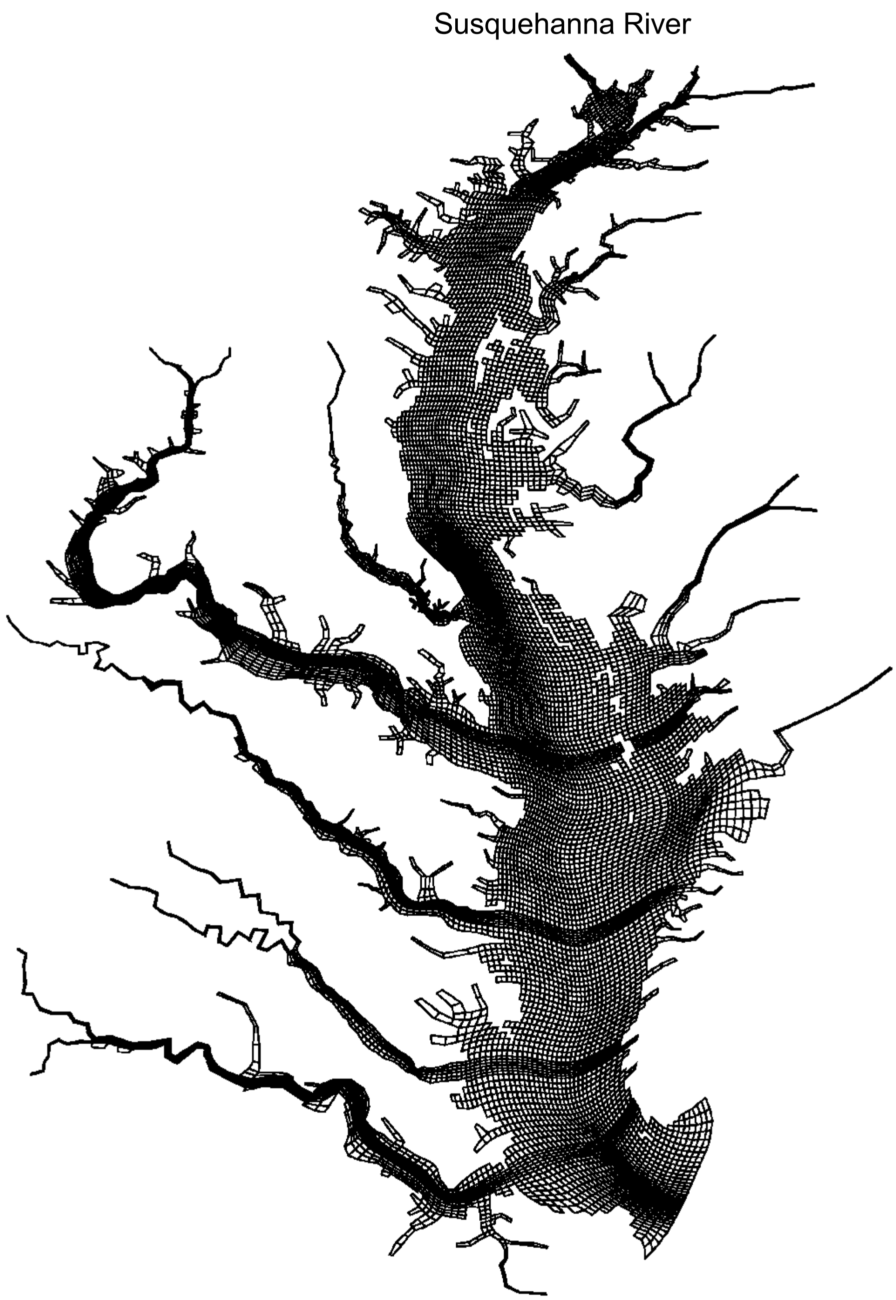


Figure 1-3. Plan view of the Chesapeake Bay computational grid.

2 Analytical and Conceptual Models

Suspended solids transport through the Conowingo Reservoir is a dynamic process involving flow and storage in the water column and erosion, deposition, and storage in the sediment bed. Realistic simulation of suspended solids transport in this system requires application of complex hydrodynamic and sediment transport models. While these models can be highly accurate, interpretation of model results is complicated by the myriad processes represented in the model framework. The application of basic analytical models provides insight which aids in understanding of complex model results. We developed the analytical model below to aid in interpretation of model results presented in succeeding chapters. The analytical model leads to the presentation of a conceptual model of suspended solids transport in and out of the reservoir.

Analytical Model

Consider the reservoir to be a well-mixed system at steady state and containing sediments of a single size class (Figure 2-1). Sources of sediment to the water column include loading from the watershed and erosion from the bottom. Sediment sinks are reservoir discharge and deposition. At steady state, reservoir volumetric inflow must equal volumetric outflow and sediment sources must equal sediment sinks:

$$Q \cdot Cin + E \cdot A = Q \cdot C + W \cdot A \cdot C \qquad (2\text{-}1)$$

in which:

Q = volumetric flow (L^3/T)
Cin = inflow solids concentration (M/L^3)
E = erosion rate ($M/L^2/T$)
A = surface area (L^2)
C = solids concentration in water column (M/L^3)
W = settling velocity (L/T)

Solving for C yields:

$$C = \frac{Cin + \frac{E \cdot A}{Q}}{1 + \frac{W \cdot A}{Q}} \qquad (2\text{-}2)$$

At this level of analysis, solids concentration is independent of reservoir depth. Rather, the dimension of importance is surface area.

Consider erosion to be proportional to excess bottom shear stress:

$$E = B \cdot \frac{\tau - \tau c}{\tau c} \qquad \text{for } \tau > \tau c \qquad (2\text{-}3)$$
$$E = 0 \qquad \text{otherwise}$$

in which:

B = base erosion rate ($M/L^2/T$)
τ = bottom shear stress ($M/L/T^2$)
τc = critical shear stress required to initiate erosion ($M/L/T^2$)

Bottom shear stress is the product of shear velocity, u_*, and fluid density, ρ:

$$\tau = \rho \cdot u_*^2 \qquad (2\text{-}4)$$

Shear velocity is considered proportional to mean velocity in the water column:

$$u_* = \alpha \cdot u \qquad (2\text{-}5)$$

in which:

u = velocity in water column
α = proportionality constant

Velocity is not a property of the well-mixed reactor. In an open channel, mean velocity would be obtained by dividing flow by cross-sectional area, width x depth. Consider a characteristic width to be proportional to the square root of surface area. In that case, a characteristic velocity is:

$$u = \frac{Q}{H \cdot \sqrt{A}} \qquad (2\text{-}6)$$

in which:

H = depth (L)

The expression for bottom shear stress becomes:

$$\rho \cdot u_*^2 = \rho \cdot \left[\frac{\alpha \cdot Q}{H \cdot \sqrt{A}}\right]^2 = \varepsilon \cdot \frac{Q^2}{H^2 \cdot A} \qquad (2\text{-}7)$$

The constant ε incorporates the density and the proportionality constant between bulk velocity and shear velocity.

Substituting the relationship for bottom shear stress, Equation 2-7, into the relationship for erosion rate, Equation 2-3, yields:

$$E = \frac{B \cdot \frac{\varepsilon \cdot Q^2}{H^2 \cdot A} - \tau c}{\tau c} \qquad (2\text{-}8)$$

and the solution for concentration, Equation 2-2, becomes:

$$C = \frac{Cin + \frac{B \cdot A}{Q} \cdot \left[\frac{1}{\tau c} \cdot \frac{\varepsilon \cdot Q^2}{H^2 \cdot A} - 1\right]}{1 + \frac{W \cdot A}{Q}} \qquad (2\text{-}9)$$

Parameter Values

Parameter values for use in Equation 2-9 were obtained from publications on Conowingo Reservoir and from values used in other lakes. Table 2-1 presents parameter values, their source, and brief explanations.

The value for τc is obtained by noting, from Eq. 2-9, that erosion occurs when

$$\frac{1}{\tau c} \cdot \frac{\varepsilon \cdot Q^2}{H^2 \cdot A} > 1 \qquad (2\text{-}10)$$

Then

$$\tau c = \frac{\varepsilon \cdot Qe^2}{H^2 \cdot A} \qquad (2\text{-}11)$$

in which:

Qe = volumetric flow at which bottom erosion is initiated (L^3/T)

The value of Qe is widely recognized to be ≈ 11,000 m^3 s^{-1} (Hirsch, 2012 and references therein). Substitution of appropriate parameter values (Table 2-1) in Equation 2-11 yields τc = ≈ 0.7 P.

Results from Analytical Model

The expression for concentration, Equation 2-9, has multiple independent variables. The solution is illustrated (Figure 2-2) for continuous values of Q and discrete values of H. Concentration is normalized by a characteristic value of Cin, 10 g m^{-3}. When the ratio C/Cin > 1, reservoir concentration is greater than inflowing concentration, indicating the occurrence of net erosion.

The following insights can be gleaned from the derivation of the analytical model and from the illustrated solution:

When volumetric flow is below the erosion threshold, the solids concentration in the reservoir is independent of depth. This result is derived from Equation 2-2 with E = 0. The reservoir concentration, and hence the outflowing concentration, is always less than the inflowing concentration. The difference between inflowing and outflowing sediment loads is deposition which is also independent of depth. By this analysis, deposition is continuous and the reservoir is never full. This situation cannot continue indefinitely, however.

As reservoir depth decreases, the flow required to initiate erosion, Qe, diminishes. This result follows from Equation 2-11 which can be rearranged to yield:

$$Qe = H \cdot \sqrt{\frac{A}{\varepsilon} \cdot \tau c} \tag{2-12}$$

The flow required to initiate erosion is linearly proportional to depth. This result can also be seen in Figure 2-2. For a reservoir of 9 m depth, flow required to initiate erosion is ≈ 13,000 m^3 s^{-1} versus ≈ 7,000 m^3 s^{-1} at 5 m depth.

When the erosion threshold is exceeded, the sediment concentration in the outflow is inversely proportional to depth. Effectively, for any flow rate sufficient to initiate erosion, more sediment will flow from a shallow reservoir than a deep reservoir. This result can be readily seen from Figure 2-2. At a flow rate of 12,000 m^3 s^{-1}, the ratio of C/Cin is ≈ 2 for a reservoir of 7 m depth; the ratio increases to C/Cin ≈ 7 at the same flow rate for a reservoir of 5 m depth.

Conceptual Model

Insights from the analytical model as well as from numerous reports on the reservoir system allow for the formulation of a conceptual model of Conowingo Reservoir (Figure 2-3). One significant insight is that the reservoir is never completely filled. Solids accumulate continuously until an erosion event occurs. As the reservoir fills, however, the flow threshold to initiate an erosion event diminishes. Erosion events become more frequent and severe.

The concept of equilibrium between solids loads into and out of Conowingo Reservoir is used in this report and elsewhere although the precise definition of the equilibrium condition is lacking. Equilibrium does not imply equality of suspended solids inflows and outflows on a daily basis or similar time scale. As used here, equilibrium implies a balance between suspended solids inflows and outflows over a time period defined by erosion events. Solids which accumulate between events are washed away after which accumulation begins anew. No net storage or filling occurs in the reservoir. The conventional threshold for erosion of ≈ 11,000 m^3 s^{-1} has a recurrence interval of five years (Langland, 2013) implying the equilibrium exists over roughly that period. If we believe the threshold for erosion is below 11,000 m^3 s^{-1}, then the recurrence interval and the equilibrium tine scale are shorter. The concept of equilibrium remains applicable over a period of years, however, rather than an instantaneous equality between inflows and outflows.

References

Bailey, M., and Hamilton, D. (1997). “Wind induced sediment resuspension: a lake-wide model,” *Ecological Modeling*, 99, 217-228.

Fisher, H., List, E., Koh, R., Imberger, J., and Brooks, N. (1979). “Mixing in rivers.” *Mixing in inland and coastal waters*. Academic Press, New York, 136-138.

Hawley, N., and Lesht, B. (1992). "Sediment resuspension in Lake St. Clair," *Limnology and Oceanography*, 37(8), 1720-1737.

Hirsch, R. (2012). "Flux of nitrogen, phosphorus, and suspended sediment from the Susquehanna River basin to the Chesapeake Bay during Tropical Storm Lee, September 2011, as an indicator of the effects of reservoir sedimentation on water quality," Scientific Investigations Report 2012-5185, US Geological Survey, Reston VA.

James, W., Barko, J., and Butler, M. (2004a). "Shear stress and sediment resuspension in relation to submersed macrophyte biomass," *Hydrobiologia*, 515, 181-191

James, W., Best, E., and Barko, J. (2004b). "Sediment resuspension and light attenuation in Peoria Lake: Can macrophytes improve water quality in this shallow system?," *Hydrobiologia*, 515, 193-201.

Langland, M. (2013). "Sediment transport simulation of three reservoirs in the lower Susquehanna River basin, Pennsylvania and Maryland," a report to the U.S. Army Corps of Engineers, Baltimore District.

Luettich, R., Harleman, D., and Somlyody, L. (1990). "Dynamic behavior of suspended sediment concentrations in a shallow lake perturbed by episodic wind events," *Limnology and Oceanography*, 35(5), 1050-1067.

Scott, S., and Sharp, J. (2013). "Sediment transport characteristics of Conowingo Reservoir," prepared for U.S. Army Corps of Engineers Baltimore District by Engineer Research and Development Center, Vicksburg MS.

Table 2-1
Parameter Values for Analytical model

Parameter	Value	Derivation	References
A	33×10^6 m^2	Reported as 12.8 mi^2.	Hainly et al., 1995
Volume	2.34×10^8 m^3	Reported capacity in 1990 was 190,000 acre-feet.	Hainly et al., 1995
H	7.3 m	Obtained from volume divided by area.	
ε	10 kg m^{-3}	The density of water is 1000 kg m^{-3}. Shear velocity is 10% of mean velocity.	Fisher et al., 1979
τc	0.688 P (= kg m m^{-2} s^{-2})	Bottom erosion occurs at 11,000 m^3 s^{-1} (400,000 ft^3 s^{-1}). See text. Critical shear stress measured in cores collected from Conowingo is 0.19 to 2.87 P.	Hirsch, 2012; Scott and Sharp, 2013
B	0.019 g m^{-2} s^{-1}	Typical values for lakes range from 500 to 10,000 g m^{-2} d^{-1}.	Luettich et al., 1990; Bailey and Hamilton, 1997; Hawley and Lesht, 1992; Janes et al., 2004a; James et al., 2004b
W	1.16×10^{-4} m s^{-1}	Order of magnitude range for lakes is 10^0 to 10^2 m d^{-1}.	Luettich et al., 1990; Bailey and Hamilton, 1997; Hawley and Lesht, 1992; Janes et al., 2004a; James et al., 2004b

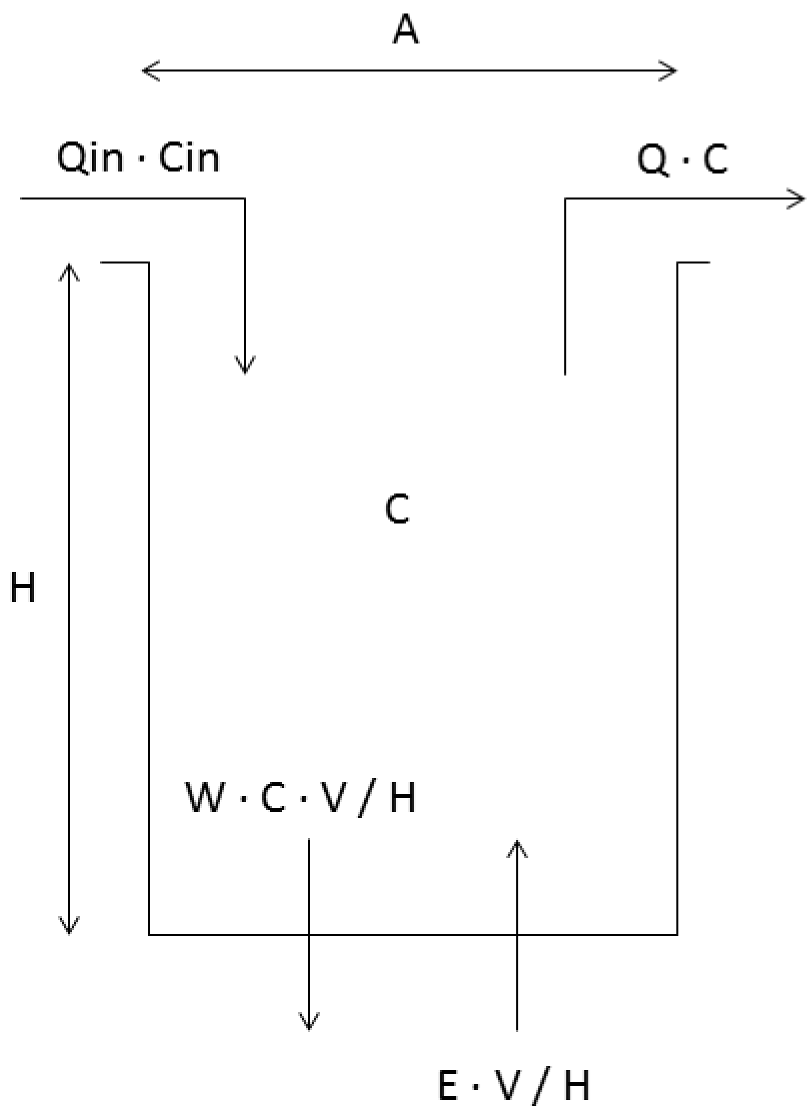


Figure 2-1. Schematic diagram for the Conowingo Reservoir represented as a well-mixed system of depth H, surface area A, and volume V. Note that concentration within the reservoir is equivalent to outflowing concentration.

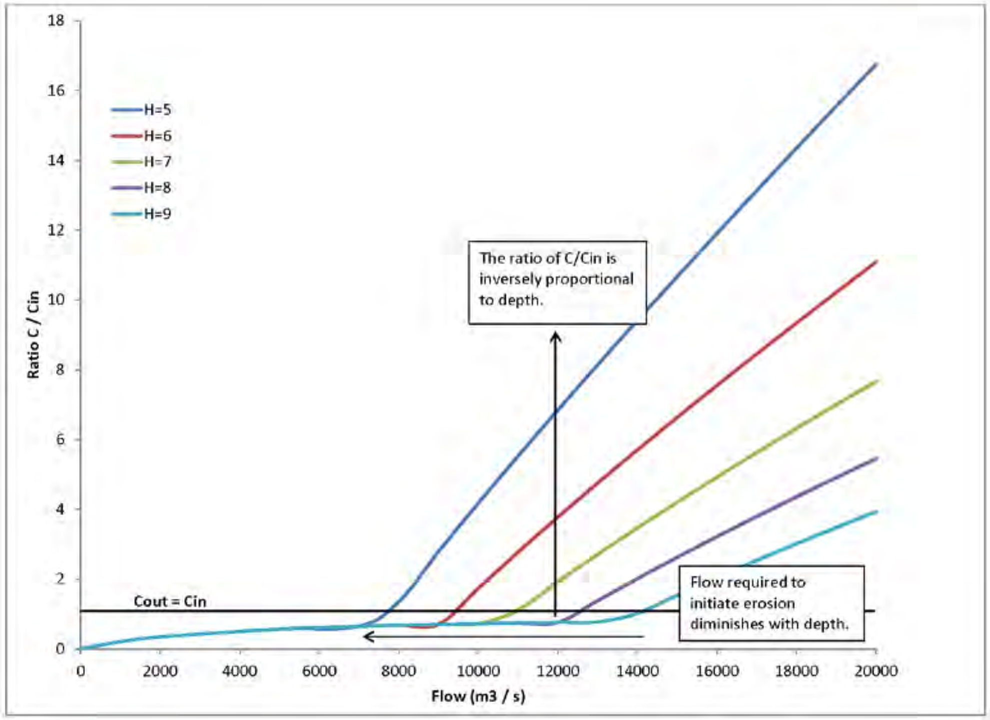


Figure 2-2. Analytical solution (Equation 2-9) for sediment concentration, C, as a function of flow and depth, H.

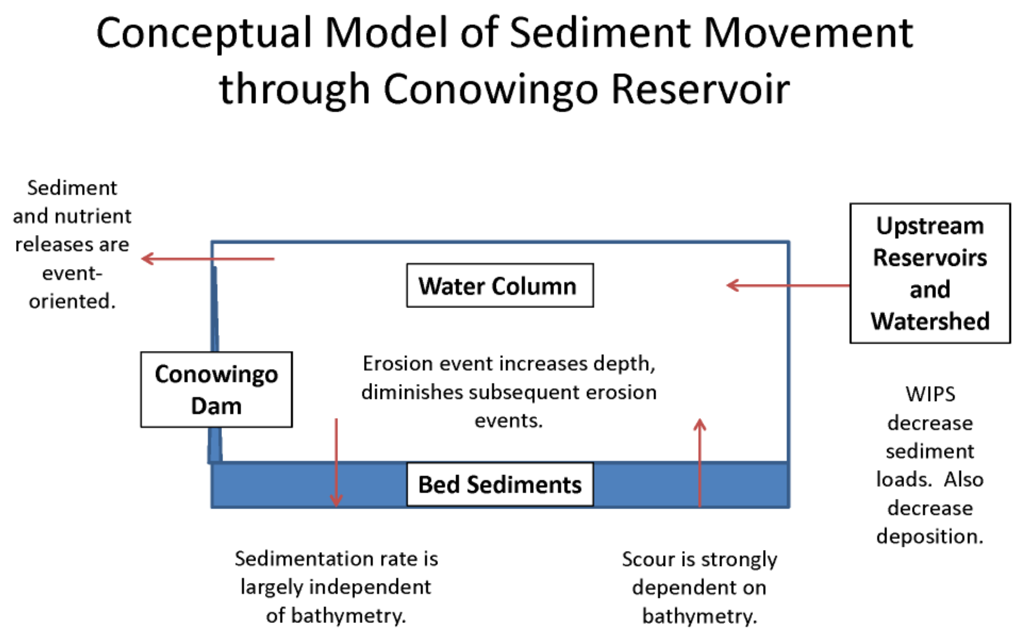


Figure 2-3. Conceptual model for solids transport and erosion in Conowingo Reservoir.

3 Scenario Procedure and Listing

Overview

The LSRWA makes use of existing tools and methodologies as well as new tools and applications developed specifically for this study. The use of existing models and practices is advantageous to the study since these tools could not be developed within the time and budget limitations of the LSRWA. The individual models within Chesapeake Bay Environmental Model Package (Watershed Model, Hydrodynamic Model, and Water Quality Model) are documented, have been extensively reviewed, and have lengthy application histories. The use of these existing tools provides some disadvantages and constraints, however, notably in the period emphasized in their application.

The ADH model, which computed sediment fate and transport in the Conowingo Reservoir, was a new application created especially for this study. ADH was applied over the period 2008 – 2011, in order to take advantage of recent data collected in the reservoir. The application included the Tropical Storm Lee event, which resulted in notable scour and provided an excellent opportunity for model calibration and validation. This period was not represented in the CBEMP, however, for which the primary application period was 1991 – 2000. The resources necessary to acquire raw observations, create model input decks, execute and validate the individual models within the CBEMP for the years 2008 – 2011 was beyond the scope of the LSRWA. Consequently, means were required to transfer information from the 2008 – 2011 ADH application to the 1991 – 2000 CBEMP. The crucial transfer involved combining scour computed by ADH for TS Lee with watershed loads computed by the WSM model for a January 1996 flood and scour event represented by the CBEMP.

The WSM provides computations of volumetric flow and associated sediment and nutrient loads throughout the watershed and at the entry points to Chesapeake Bay. Flow computations are based on precipitation, evapotranspiration, snow melt, and other processes. Loads are the result of land use, management practices, point-source wasteloads and additional factors. The loads computed for 1991 – 2000 are no longer current and are not the loads utilized in the TMDL computation. To emphasize current conditions, a synthetic set of loads was created from the WSM based on 1991 – 2000 flows but 2010 land use and management practices. The set of loads is designated the “2010 Progress Run.” The TMDL loads are a second set of synthetic loads created with the WSM. In this case, the 1991 – 2000 flows are paired with land uses and management practices sufficient to meet the TMDL limitations.

The ADH model provides computations of sediment load due to bottom scour, but not the load of associated nutrients. Limited observations of sediment-associated nutrients are available at the Conowingo outfall during the 1996 flood event. The composition of solids eroded from the bottom are difficult to glean from these observations, however, since samples at the outfall represent the mixture of solids washed down from the watershed and eroded from the bottom. And, as with the watershed loads, these observations may no longer represent current conditions. Consequently, the nutrients associated with scoured solids for use in scenarios was derived from observations of nutrients in the bottom sediments of Conowingo Reservoir.

Major storm events occur at different times of the year. In order to examine the effect of seasonality of storm loads on Chesapeake Bay, the January 1996 storm was moved, within the model framework, to June and to October. The loads were moved directly from January to the other months. No adjustment was made for the potential effects of seasonal alterations in land uses. New Chesapeake Bay hydrodynamic model runs were completed based on the revised flows, to account for alterations in flow regime and stratification within the Bay.

Scenario Procedure

Scenarios that examine the effect on Chesapeake Bay of sediment erosion in Conowingo Reservoir are ten years in duration and incorporate the hydrologic record that occurred from 1991 to 2000. This record consists of daily freshwater flows at the heads of all tributaries as well as runoff from the adjacent watershed directly to Bay and tributary waters. All freshwater flows are provided by the CBP WSM. This is the record employed in calibration of the CBEMP and incorporates the critical years 1993 to 1995. The TMDL was determined based on maintenance of water quality standards during these three years. The record (Figure 3-1) includes a major scour event in Conowingo Reservoir which occurred in January 1996 (Figure 3-2). The January 1996 event included the second highest daily flow observed at Conowingo since the inception of the modern management era in 1985, 17,600 $m^3 s^{-1}$, as well as three of the top ten daily flows in that period. The 11,000 $m^3 s^{-1}$ (400,000 $ft^3 s^{-1}$) threshold for scour was exceeded on January 20, 21, and 22. The threshold for scour was also exceeded in early April 1993 although the peak flow, 13,200 $m^3 s^{-1}$, was lower and the event did not receive the notoriety of the 1996 event.

The 1996 flood was caused by an unusual convergence of events (Langland, 1998). Heavy rainfall and warm temperature enhanced melting of snow cover which had accumulated in the Susquehanna watershed. The combined volume of rain and snowmelt caused a rapid rise in river level and breakup of ice cover in the Susquehanna River and tributaries. Ice jams caused even greater rise in river level and accumulation of large volumes of water behind the jams. When the jams broke, an enormous volume of water pushed through the reservoir system and was released through Conowingo Dam. Peak instantaneous flow was 25,000 $m^3 s^{-1}$ (Langland, 1998).

Runoff at major tributary inputs, lesser distributed flows, solids loads and nutrient loads for the scenarios all originate with the CBP WSM. These are input to the CBEMP on a daily basis, according to the watershed area contributing to each surface cell in the CBEMP computational grid. The hydrologic record is the same in all scenarios with the exception of alterations to examine the effects of seasonality of storm events. Solids and nutrient loads are based on alternate combinations of land use in the watershed. Loads computed in the 2010 Progress Run are based on 2010 land uses and management practices and represent current loading conditions. Loads computed in the TMDL scenario are based on projected future land uses and management practices which meet the loading restrictions imposed by the TMDL.

Each scenario is preceded by a ten-year spin-up sequence. The spin-up is required to generate initial conditions in the water column and in the sediment bed. The spin-up is a ten-year repetition of hydrodynamics, daily flows, and daily loads for the year 1992, a year of typical hydrology in the Susquehanna River. Following the spin-up, conditions in the water column and sediments are considered to be in equilibrium with the imposed sediment and nutrient loads.

The scenarios incorporate scour loads from Conowingo Reservoir generated based on alternate bathymetry configurations. Most scenarios employ the "existing" bathymetry, based on a 2008 survey. The "equilibrium" bathymetry is the bathymetry projected to result when sediment loads in and out of the reservoir are in dynamic equilibrium and no net deposition occurs. The "1996" bathymetry is based on a survey completed after the scour event and represents a reservoir with enhanced volume relative to present conditions. The "dredged" bathymetry is derived from existing bathymetry less 2.3×10^6 m^3 (3×10^6 yd^3) of material removed as a management action.

Roughly thirty scenarios were conducted although all are not reported here. A number of scenarios conducted early in the study were supplanted as improved information and understanding developed. The significant scenarios are listed in Table 3-1. Space considerations limit the information presented in this report. An appendix entitled "Individual Results for each Chesapeake Bay Environmental Model Package Scenario" is available upon request from the first author or from the Planning Division, US Army Engineer District, Baltimore.

References

Langland, M. (1998). "Changes in sediment and nutrient storage in the three reservoirs in the lower Susquehanna River basin and implications for the Chesapeake Bay," USGS Fact Sheet 003-98, USGS Pennsylvania Water Science Center, Lemoyne PA.

Table 3-1
Scenario List

Code	Land Use	Bathymetry	Description
LSRWA_4	2010 Progress	Existing	The base scenario for the 2010 Progress Run. No scouring in Conowingo.
LSRWA_3	TMDL	Existing	The base TMDL scenario. No scouring in Conowingo.
LSRWA_5	2010 Progress	Existing	The 2010 Progress Run with Conowingo Reservoir removed from the system. Loads computed by the WSM to the reservoir are routed directly to Chesapeake Bay. This scenario examines the role of Conowingo Reservoir under existing conditions.
LSRWA_6	TMDL	Existing	The TMDL scenario with Conowingo Reservoir removed from the system. Loads computed by the WSM to the reservoir are routed directly to Chesapeake Bay. This scenario examines the role of Conowingo Reservoir under projected TMDL conditions.
LSRWA_20	2010 Progress	Existing	The 2010 Progress Run with added solids and nutrient loads from scour in Conowingo Reservoir. The nutrients associated with the solids are based on observations collected during Tropical Storm Lee in 2011.
LSRWA_21	TMDL	Existing	The TMDL scenario with added solids and nutrient loads from scour in Conowingo Reservoir. The nutrients associated with the solids are based on observations collected during Tropical Storm Lee in 2011.
LSRWA_31	TMDL	1996	The TMDL scenario with added solids and nutrient loads from scour in Conowingo Reservoir. The nutrients associated with the solids are based on observations collected during Tropical Storm Lee in 2011.
LSRWA_18	2010 Progress	Equilibrium	The 2010 Progress Run with added solids and nutrient loads from scour in Conowingo Reservoir. The nutrients associated with the solids are based on observations collected during Tropical Storm Lee in 2011.
LSRWA_30	TMDL	Equilibrium	The TMDL scenario with added solids and nutrient loads from scour in Conowingo Reservoir. The nutrients associated with the solids are based on observations collected during Tropical Storm Lee in 2011.
LSRWA_22	TMDL	Existing	The TMDL scenario with added solids and nutrient loads from scour in Conowingo Reservoir. The nutrients associated with the solids are based on observations collected during the January 1996 scour event.
LSRWA_23	TMDL	Existing	The TMDL scenario with the January 1996 storm removed from the hydrologic record, from the load record, and from the hydrodynamics.
LSRWA_24	TMDL	Existing	The TMDL scenario with the January 1996 storm moved to June 1996. The transfer includes the hydrologic record, the load record, and the hydrodynamics. The nutrients associated with the solids are based on observations collected during Tropical Storm Lee in 2011.

LSRWA_25	TMDL	Existing	The TMDL scenario with the January 1996 storm moved to October 1996. The transfer includes the hydrologic record, the load record, and the hydrodynamics. The nutrients associated with the solids are based on observations collected during Tropical Storm Lee in 2011.
LSRWA_26	TMDL	Existing	The TMDL scenario with the January 1996 storm moved to June 1996. The transfer includes the hydrologic record, the load record, and the hydrodynamics. The nutrients associated with the solids are based on observations collected during the January 1996 scour event.
LSRWA_27	TMDL	Existing	The TMDL scenario with the January 1996 storm moved to October 1996. The transfer includes the hydrologic record, the load record, and the hydrodynamics. The nutrients associated with the solids are based on observations collected during the January 1996 scour event.
LSRWA_28	TMDL	Dredged	The TMDL scenario with added solids and nutrient loads from scour in Conowingo Reservoir. The nutrients associated with the solids are based on observations collected during Tropical Storm Lee in 2011.
LSRWA_29	TMDL	Dredged	The TMDL scenario with added solids and nutrient loads from scour in Conowingo Reservoir. The nutrients associated with the solids are based on observations collected during Tropical Storm Lee in 2011. Three million cubic yards of solids and associated nutrients, assumed to be the by-product of dredging, are bypassed during the months of December – February for each of ten scenario years.

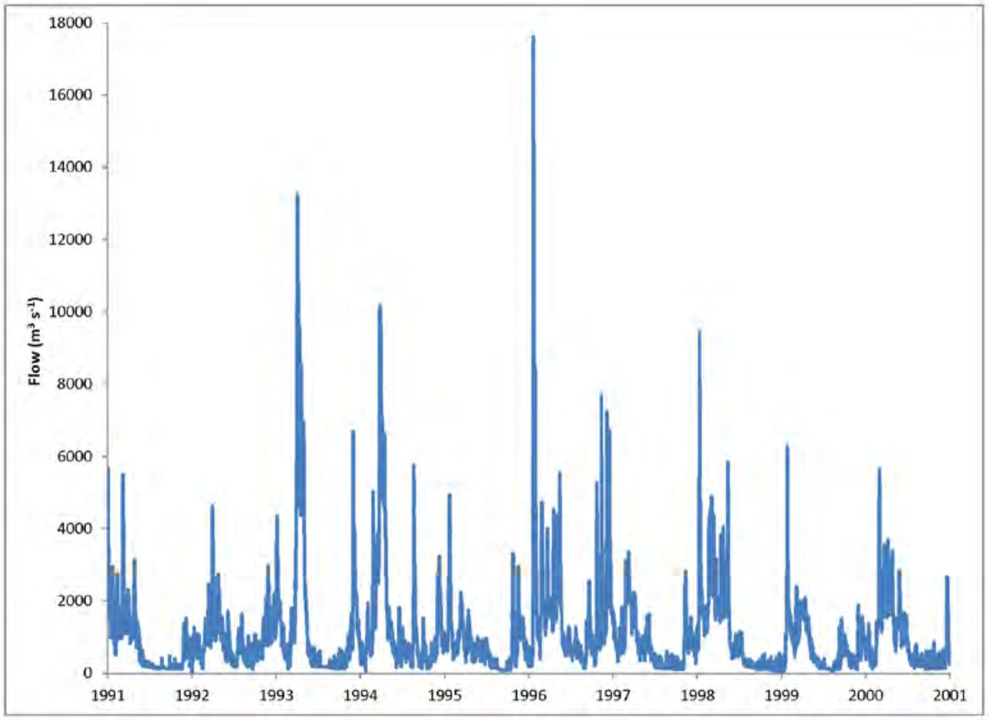


Figure 3-1. Observed flows at Conowingo Dam outfall 1991 – 2000. Scour occurs at ≈ 11,000 m^3 s^{-1}.

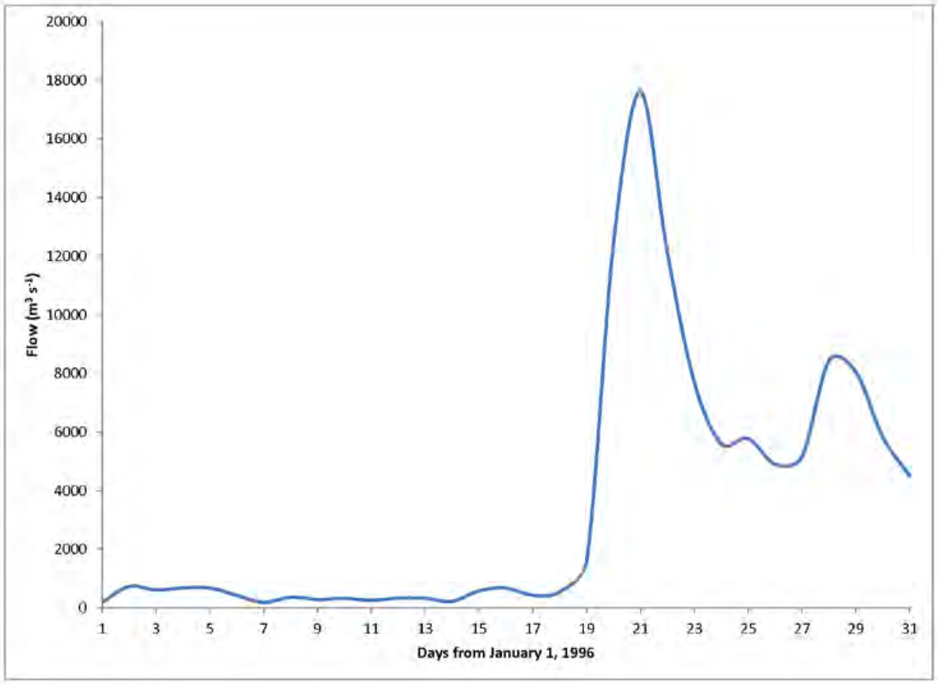


Figure 3-2. Observed flows at Conowingo Dam outfall, January 1996. Scour occurs at ≈ 11,000 $m^3\ s^{-1}$.

4 Load Computation and Summary

Loads from the Watershed

Sediment and nutrient loads from the Susquehanna River employed in Chesapeake Bay scenario runs are influenced by hydrology, by land use and management practices in the watershed, and by the configuration of the reservoir system at the watershed terminus. Loads from the watershed are calculated by the CBP WSM for two configurations: existing conditions (2010 Progress Run) and total maximum daily load (TMDL). The WSM routes watershed loads computed above the three reservoirs through Lake Clarke, Lake Aldred, and Conowingo Reservoir. The loads at the head of the reservoir system are supplemented by inputs from the local watersheds immediately adjacent to the reservoirs. The routing process includes calculation of the effects of settling, erosion, and biological transformations within the reservoirs. Several scenarios were completed in which the calculated loads to Conowingo Reservoir were routed directly to Chesapeake Bay without modeling of processes in the reservoir. These scenarios were originally conducted as “reservoir full” scenarios based on the supposition that under reservoir-full conditions material would pass through the reservoir swiftly and completely. This supposition was supplanted as an improved picture of the reservoir under equilibrium between inputs and outputs became available. The scenario results are retained, however, since they provide an illustration of the conditions expected if the river emptied directly into the bay. A summary of loads to the bay from the Susquehanna River, with and without the dam, calculated for the period 1991 – 2000 is presented in Table 4-1.

The WSM represents multiple nitrogen forms including ammonium, nitrate, and organic nitrogen. The individual forms have been combined into total nitrogen here and in subsequent tables. The organic nitrogen variable is also reported individually since scoured nutrient loads are incorporated into this classification. The WSM represents multiple phosphorus forms including dissolved inorganic phosphorus, particulate inorganic phosphorus, and organic phosphorus. The individual forms have been combined into total phosphorus here and in subsequent tables. The organic phosphorus and particulate inorganic phosphorus variables are also combined and reported as particulate phosphorus since scoured nutrient loads are incorporated into this classification.

Coupling the Bay Model and the Watershed Model

Particulate nutrients suspended in Susquehanna River water and eroded from the bottom of Conowingo Reservoir exist in multiple organic and inorganic forms. No definitive laboratory analysis or suite of analyses describes all these forms. Neither is there a universal suite of model variables for the particulate nutrients. The state variable suite in the WSM differs from the WQM. In particular, the WQM incorporates a more elaborate suite of organic and inorganic particles. WSM variables are “mapped” into WQM variables during preparation of the WQM input files. Nutrients associated with solids eroded from the Conowingo Reservoir bed are routed into WQM variables in the same process. The mapping procedure is sketched in Figure 4-1 and quantified in Table 4-2. Details are found in Cerco and Noel (2004) and Cerco et al. (2010).

Loads from Bottom Erosion

The WSM incorporates algorithms to calculate particle settling and erosion in Conowingo Reservoir. The algorithms are parameterized empirically to optimize agreement between computed and observed sediment and nutrient concentrations flowing over Conowingo Dam. During the course of this study, we determined that little or no scouring of bottom material was calculated during the January 1996 flood event. As a consequence, computed solids concentrations (Figure 4-2) and, potentially, particulate nutrient concentrations were less than observed. Solids and nutrient loads from erosion were calculated independently, based on computations from the ADH model for Conowingo Reservoir, and added to the WSM loads for this event.

The terms “erosion” and “scour” are used interchangeably in this report. A significant point to remember is that both these terms refer to <u>net</u> erosion or scour. “Net scour” is the amount of material scoured from the bottom of Conowingo Reservoir <u>and</u> carried over the Conowingo outfall. Net scour does not include material scoured from the bottom and re-deposited within the reservoir. Net scour is computed on a daily basis as the excess of suspended solids leaving via the outfall over suspended solids entering the reservoir.

Solids Loads from Bottom Erosion

The ADH application period, 2008 – 2011, differed from the WQM application period, 1991 – 2000. A procedure to apply ADH calculations to the 1996 storm was developed based on the volumetric flow in excess of the threshold for scour, ≈ 11,000 $m^3 s^{-1}$. The year 2011 contained two erosion events, an un-named event in March and Tropical Storm Lee, in late August. The excess volume (Figure 4-3) for each event was computed by integrating flow over time for the period during which flow exceeded 11,000 $m^3 s^{-1}$. The amount of solids eroded during each event was taken as the difference between computed loads entering and leaving Conowingo Reservoir. Solids loads leaving the reservoir in excess of loads entering were taken as evidence of net erosion from the bottom. Net erosion for January 1996 was calculated by linear interpolation of the two 2011 events, using excess volume as the basis for the interpolation (Figure 4-4). The analysis was conducted for three major sediment classes employed in the WQM: clay, silt, and sand. The total scour load for the 1996 event was apportioned to individual days based on flows and inspection of the 2011 record. The solids concentrations resulting from the combination of WSM loads and estimated erosion showed remarkable agreement with solids concentrations observed at the dam outfall in January 1996 (Figure 4-2).

Nutrient Loads from Bottom Erosion

Nutrient loads associated with bottom erosion were calculated by assigning a fractional nitrogen and phosphorus composition to the eroded solids. The initial fractions assigned, 0.3% nitrogen and 0.1% phosphorus, were based on analyses of sediment cores removed from the reservoir (Cerco, 2012). These fractions were consistent with data collected at the Conowingo outfall during 2011 as part of this study (Table 4-3). We found, however, that addition of these nutrient loads to the WSM loads resulted in nutrient concentrations in excess of values observed in January 1996 (Figures 4-5, 4-6, Table 4-4).

The solids nutrient fractions observed at Conowingo in 2011 were determined via direct particle analysis. No direct analyses were conducted in 1996 but nutrient fractions can be obtained by differencing of filtered and unfiltered samples:

$$\%N = 100 \cdot \frac{(TKNw - TKNf)}{SS} \qquad (4\text{-}1)$$

in which:

%N = nitrogen associated with sediment particles (% mass fraction)
TKNw = whole total Kjeldahl nitrogen (g m^{-3})
TKNf = filtered total Kjeldahl nitrogen (g m^{-3})
SS = suspended sediment (g m^{-3})

An analogous relationship holds for the particulate phosphorus fraction, %P.

Comparison of the particle composition in 1996 (Table 4-4) and 2011 (Table 4-3) indicates the compositions are distinctly different and the nutrient fractions are much less in 1996 than in 2011 (Figures 4-7, 4-8). The reason (or reasons) for the differences cannot be definitively identified. The 1996 and 2011 storms occurred in different seasons (January versus August) and differences in properties of material washed from the land surface are expected. The mechanisms behind the floods also differed. The 2011 flood was primarily a meteorological event while the 1996 flood was partly due to the build-up and release of water trapped behind ice dams. The unique origin of the 1996 flood and the dam operation intended to release the flood waters may have caused bottom erosion from a different portion of the reservoir than in 2011.

Employment of the 1996 nutrient composition to characterize the nutrients associated with sediment eroded in 1996 results in reasonable agreement between observed and computed nutrients at the Conowingo outfall (Figures 4-5, 4-6) but presents a dilemma. Which nutrient fractions should be used in subsequent scenario analysis? The 1996 composition, which accompanied the 1996 event and was observed during the 1991 – 2000 scenario period? Or the 2011 composition which is more recent and characterizes a typical tropical storm event? In view of the dilemma, several key scenarios have been run with alternate composition, presenting a range of potential outcomes.

Erosion Loads under Different Bathymetries

The amount of material scoured from the bottom of the reservoir depends, in part, upon the reservoir bathymetry. Observations (Langland and Hainly, 1997) and theory (Chapter 2) indicate scour is inversely related to reservoir depth. The ADH model was run for several bathymetry sets including:

- Existing (2008) bathymetry
- Equilibrium bathymetry
- Bathymetry following 1996 storm
- Bathymetry resulting from dredging 2.3 x 10^6 m^3 (3 million cubic yards)

The existing bathymetry was based on surveys conducted in 2008. The equilibrium bathymetry was based on the estimated configuration after the reservoir achieves long-term equilibrium between solids inflows and outflows. The bathymetry following the 1996 storm was also based on surveys. Following the erosion associated with this event, the reservoir volume was 21 x 10^6 m^3 (28 million cubic yards) greater than existing volume. This configuration allowed assessment of depth effects on scour and served as an endpoint for dredging scenarios. The bathymetry resulting from dredging 3 million cubic yards from a depositional area near the dam was employed in sediment management scenarios.

In all cases, the procedure for determining the scour load followed the same steps:

- Solids loads into and out of Conowingo Reservoir using the hydrologic record for the period 2008 to 2011were provided by the ADH model.
- Solids scour for two events in 2011 was determined by the excess of outflowing solids loads over inflowing solids loads.
- Scour for the 1996 hydrologic record was estimated by interpolation based on excess volume.
- Nutrient composition was assigned to the scoured solids based on 2011 observations.
- For key scenarios, an alternate set of nutrient loads was constructed based on 1996 observed nutrient fractions.

The scour loads for alternate bathymetric configurations and solids composition are presented in Table 4-5.

References

Cerco, C., and Noel, M. (2004). “The 2002 Chesapeake Bay eutrophication model,” EPA 903-R-04-004, US EPA Chesapeake Bay Program, Annapolis MD.

Cerco, C. (2012). “Data assembly for application of the CBEMP in the lower Susquehanna River watershed assessment,” A report to the U.S. Army Corps of Engineers Baltimore District, Baltimore MD. (Available from the author carl.f.cerco@usace.army.mil)

Cerco, C., Kim, S.-C., and Noel, M. (2010). “The 2010 Chesapeake Bay eutrophication model,” A report to the US Environmental Protection

Agency Chesapeake Bay Program and to the US Army Engineer Baltimore District, US EPA Chesapeake Bay Program, Annapolis MD. http://www.chesapeakebay.net/content/publications/cbp_55318.pdf

Langland, M., and Hainly, R. (1997). “Changes in bottom-surface elevations in three reservoirs on the lower Susquehanna River, Pennsylvania and Maryland, following the January 1996 flood -Implications for nutrient and sediment loads to Chesapeake Bay,” Water-Resources Investigations Report 97-4138, US Geological Survey, Lemoyne PA.

Table 4-1 Summary of Watershed Model Loads from the Susquehanna River for 1991 to 2000 Hydrologic Record

		Flow, $m^3 s^{-1}$	Total Nitrogen, kg d^{-1}	Organic Nitrogen, kg d^{-1}	Total Phosphorus, kg d^{-1}	Particulate Phosphorus, kg d^{-1}	Total Suspended Solids, kg d^{-1}
2010 Progress Run	1991 to 2000 daily average	1,170	147,949	62,931	6,314	5,222	3,056,623
	daily maximum	13,382	1,981,500	1,387,800	154,330	116,028	181,910,000
TMDL	1991 to 2000 daily average	1,175	104,067	46,058	4,718	3,872	2,307,352
	daily maximum	13,367	1,421,600	1,010,300	113,490	86,797	134,960,000
2010 Progress Run, No Conowingo Efffects	1991 to 2000 daily average	1,171	161,569	73,648	7,697	6,495	4,113,782
	daily maximum	13,415	2,093,500	1,498,200	268,870	263,249	483,100,000
TMDL, No Conowingo Effects	1991 to 2000 daily average	1,183	114,959	53,757	5,779	4,818	3,196,639
	daily maximum	13,411	1,603,500	1,125,100	227,470	222,041	393,000,000
2010 Progress Run, January 1996 Storm	January 19 to 25 daily average	9,292	1,178,697	496,847	100,562	71,920	74,115,571
	storm total	65,041	8,250,880	3,477,930	703,931	503,440	518,809,000
TMDL, January 1996 Storm	January 19 to 25 daily average	9,260	842,820	354,771	73,726	49,248	57,837,429
	storm total	64,822	5,899,740	2,483,400	516,081	344,739	404,862,000

Table 4-2 Routing WSM Variables into WQM Variables		
Watershed Model	**goes to**	**Water Quality Model**
Organic Nitrogen		Up to 0.16 g m^{-3} is considered Dissolved Organic Nitrogen. The remainder is considered Refractory Particulate Organic Nitrogen.
Organic Phosphorus plus Particulate Inorganic Phosphorus		Up to 0.005 g m^{-3} is considered Dissolved Organic Phosphorus. 58% of the remainder is considered Particulate Inorganic Phosphorus. 42% of the remainder is considered Refractory Particulate Organic Phosphorus.
Clay		Up to 4 g m^{-3} is considered fine clay. The remainder is clay.

Table 4-3 Particle Composition Observed at Conowingo Outfall 2010 to 2011[1]

Date	Flow, $m^3 s^{-1}$	Phosphorus, ppm	Fe, %	Mn, ppm	TOC,%	PN, %	Susp. Sediment, $g\ m^{-3}$
10/3/2010	2861	1500	3.6	2500			
12/3/2010	7819	1400	4.7	3000	4.1	0.47	141
3/8/2011	7762	1400	5	3400	4.2	0.4	129
3/12/2011	12833	1200	4.2	2100	5.1	0.36	937
3/12/2011	12833	1200	4.4	2200	4.9	0.34	937
9/8/2011	17479	1100	4.4	1900	3.2	0.26	2980
9/8/2011	17479	1100	4.3	2000	3.2	0.27	2980
9/10/2011	13626	900	5.3	1900	2.2	0.18	741
9/11/2011	10992	960	4.9	1800	2.5	0.2	1150
9/12/2011	6600	940	5.4	1800	1.9	0.19	332
avg	11028	1170	4.6	2260	3.5	0.30	1147
max	17479	1500	5.4	3400	5.1	0.47	2980
min	2861	900	3.6	1800	1.9	0.18	129

[1]Data provided by Jeffrey Chanat, USGS MD-DE-DC Water Science Center. The samples from September 2011 reflect Tropical Storm Lee.

Table 4-4 Observed and Derived Concentrations at Conowingo Outfall, January 1996[2]

Date	Flow, $m^3 s^{-1}$	Total Nitrogen, $g m^{-3}$	Ammonium + Organic Nitrogen, whole, $g m^{-3}$	Ammonium + Organic Nitrogen, filtered, $g m^{-3}$	Phosphorus, whole, $g m^{-3}$	Phosphorus, filtered, $g m^{-3}$	Suspended Sediment, $g m^{-3}$	Organic Carbon, $g m^{-3}$	Particulate Nitrogen, $g m^{-3}$	Particulate Phosphorus, $g m^{-3}$	Particulate Nitrogen, %	Particulate Phosphorus, ppm
1/17/96	431	2.4	0.2	0.3	0.02	0.011	3	3.6		0.009		3000
1/20/96	12436	2.3	0.6	0.4	0.09	0.021	194	5.5	0.2	0.069	0.10	356
1/21/96	17620	2.8	1.3	0.7	0.29	0.007	1200	9.7	0.6	0.283	0.05	236
1/21/96	17620						1000					
1/21/96	17620	2.8	1.3	0.7	0.29	0.007	863		0.6	0.283	0.07	328
1/22/96	12125	2.0	0.6	0.4	0.13	0.013	533	7.0	0.2	0.117	0.04	220
1/22/96	12125	2.1	0.7	0.3	0.20	0.008	462	11.0	0.4	0.192	0.09	416
1/22/96	12125	2.0	0.6	0.3	0.13	0.009	451	12.0	0.3	0.121	0.07	268
1/23/96	7705	1.8	0.4	0.3	0.10	0.024	315	4.3	0.1	0.076	0.03	241
1/23/96	7705	1.9	0.5	0.3	0.11	0.01	254	4.3	0.2	0.100	0.08	394
1/24/96	5609						105					
1/24/96	5609	2.0	0.6	0.2	0.20	0.01	118	3.8	0.4	0.190	0.34	1610
1/25/96	5779						111					
1/25/96	5779	1.9	0.3	0.3	0.06	0.01	87	4.9	0	0.050	0.00	575
1/26/96	4901	2.1	0.5	0.3	0.15	0.016	96	3.7	0.2	0.134	0.21	1390
1/29/96	8045	2.3	0.6	0.4	0.17	0.023	130	4.1	0.2	0.147	0.15	1131
1/31/96	4504	2.0	0.4	0.2	0.08	0.01	63	7.6	0.2	0.070	0.32	1111

avg		2.2	0.6	0.4	0.1	0.0	352	6.3	0.3	0.132	0.12	805
max		2.8	1.3	0.7	0.3	0.0	1200	12.0	0.6	0.283	0.34	3000
min		1.8	0.2	0.2	0.0	0.0	3	3.6	0.0	0.009	0.00	220

[2]Data provided by Joel Blomquist, US Geological Survey, Baltimore MD. Particulate nitrogen and phosphorus are derived from the original data as described in the text.

Table 4-5 Scour Loads Computed for January 1996 as a Result of Alternate Reservoir Bathymetries

Bathymetry	Clay, metric ton	Silt, metric ton	Sand, metric ton	Total Suspended Solids, metric ton	Particulate Nitrogen, metric ton	Particulate Phosphorus, metric ton
Existing	1,143,996	1,117,128	110,926	2,372,050	7,116	2,372
Equilibrium	1,154,277	1,106,496	106,557	2,367,330	7,102	2,367
After Dredging 2.3 x 10^6 m^3 (3 million cubic yards)	1,015,964	554,083	34,975	1,605,021	4,815	1,605
After 1996 Scour Event	754,660	531,278	27,934	1,313,872	3,942	1,314
Existing, 1996 Nutrient Composition	1,143,996	1,117,128	110,926	2,372,050	1,637	712

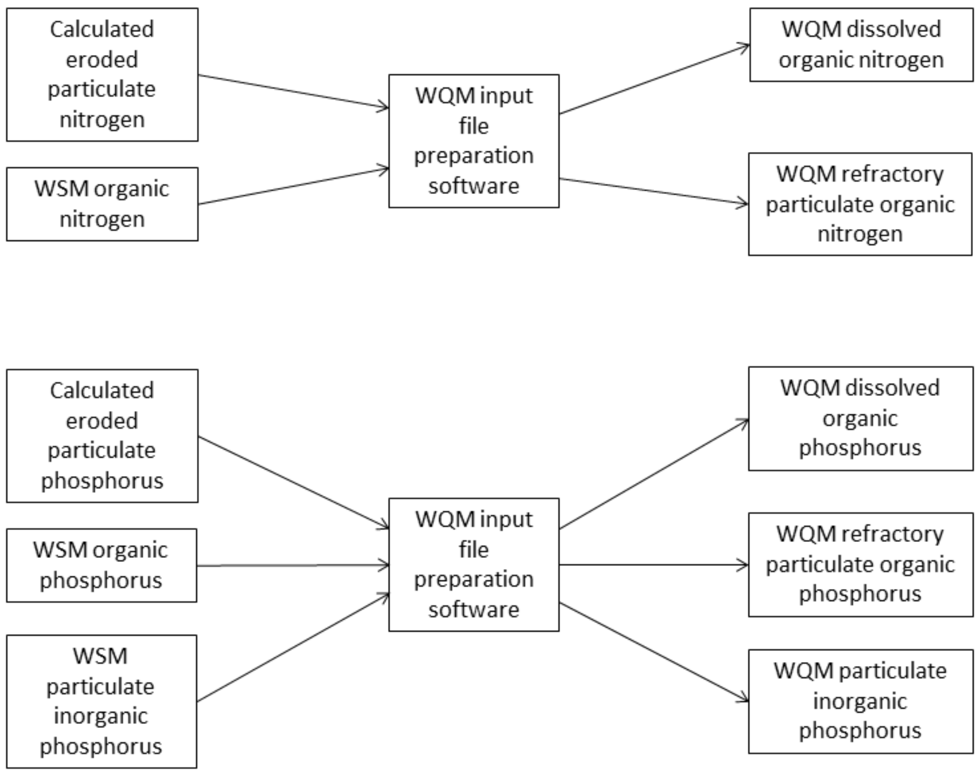


Figure 4-1. Routing of particulate nutrients at Conowingo outfall into WQM state variables.

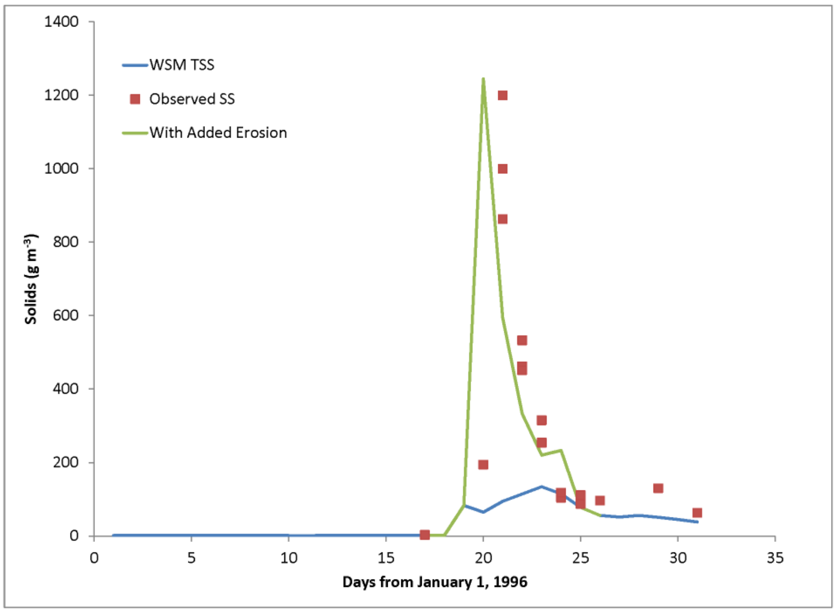


Figure 4-2. Observed and computed suspended solids at the Conowingo outfall, January 1996. Computations are shown for the WSM alone and for the WSM with additional erosion load.

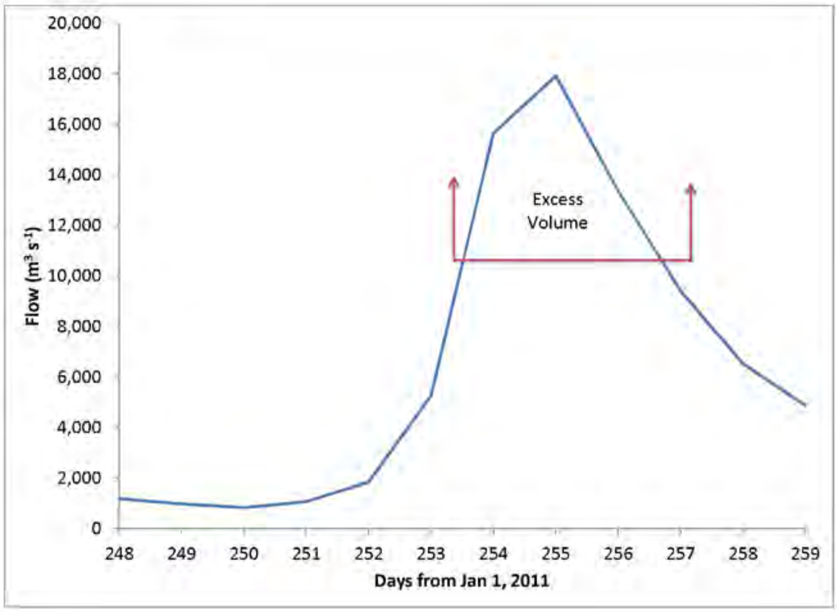


Figure 4-3. Excess volume during Tropical Storm Lee. The excess volume is the volume in excess of the 11,000 $m^3 s^{-1}$ (400,000 $ft^3 s^{-1}$) threshold for bottom scour.

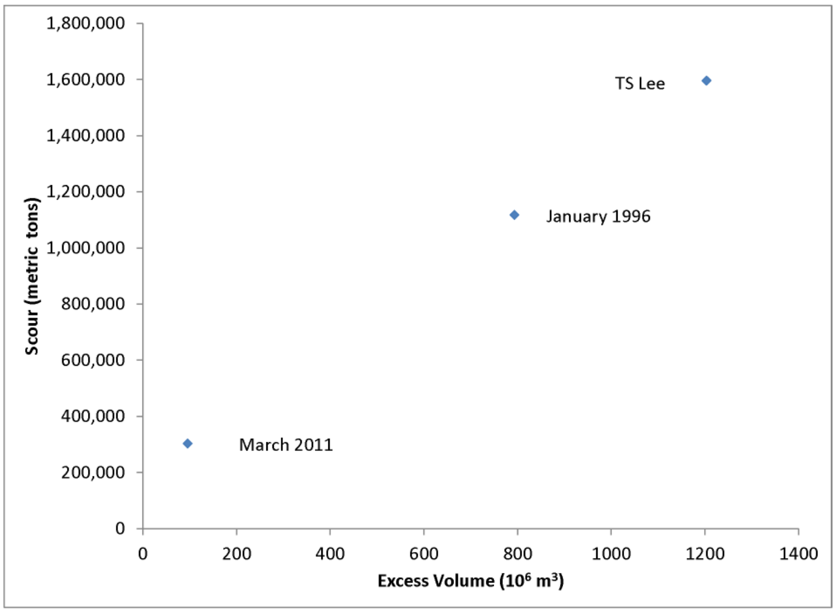


Figure 4-4. Linear interpolation of solids load based on excess volume. This figure shows the determination of silt loading for January 1996.

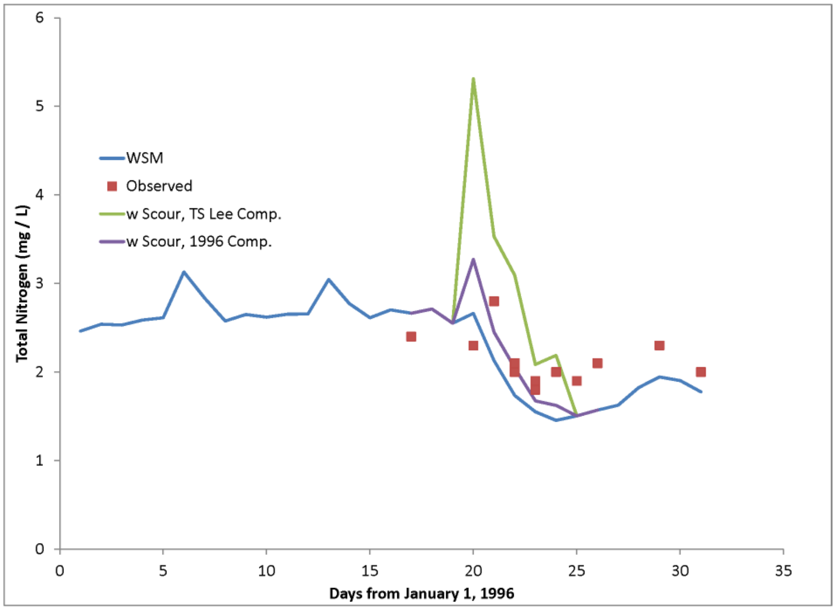


Figure 4-5. Observed and computed total nitrogen concentration at Conowingo Outfall, January 1996. Computations are shown for the WSM alone and for the WSM supplemented with alternate nutrient composition for scoured solids.

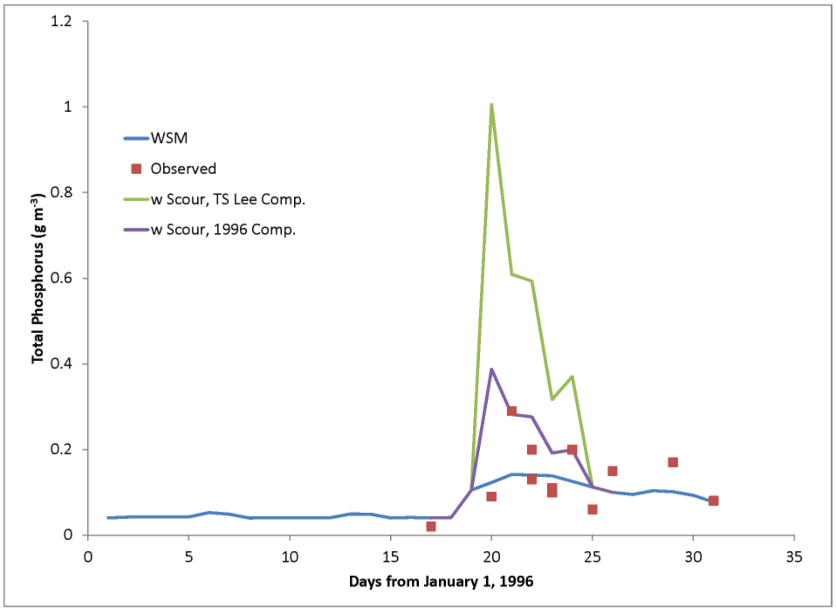


Figure 4-6. Observed and computed total phosphorus concentration at Conowingo Outfall, January 1996. Computations are shown for the WSM alone and for the WSM supplemented with alternate nutrient composition for scoured solids.

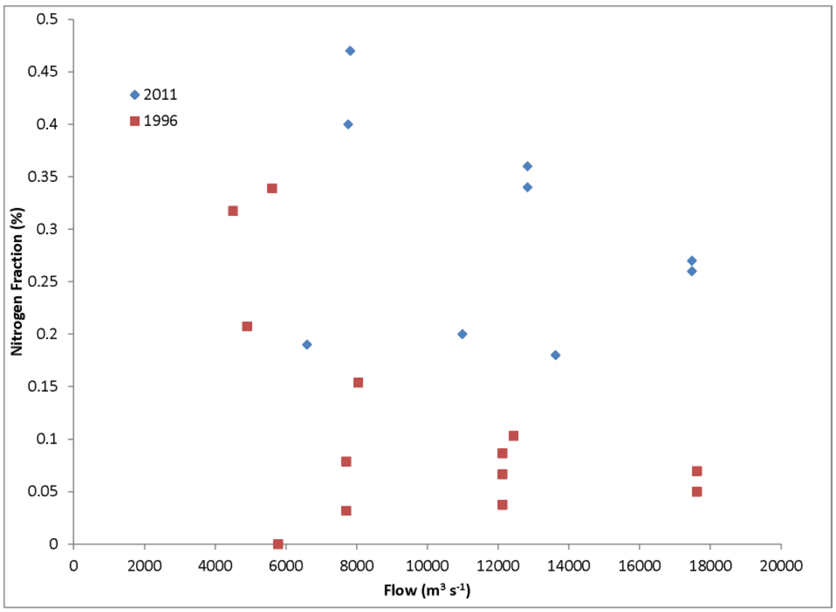


Figure 4-7. Solids nitrogen fraction versus flow at the Conowingo outfall. The 2011 observations are primarily greater than the 1996 observations.

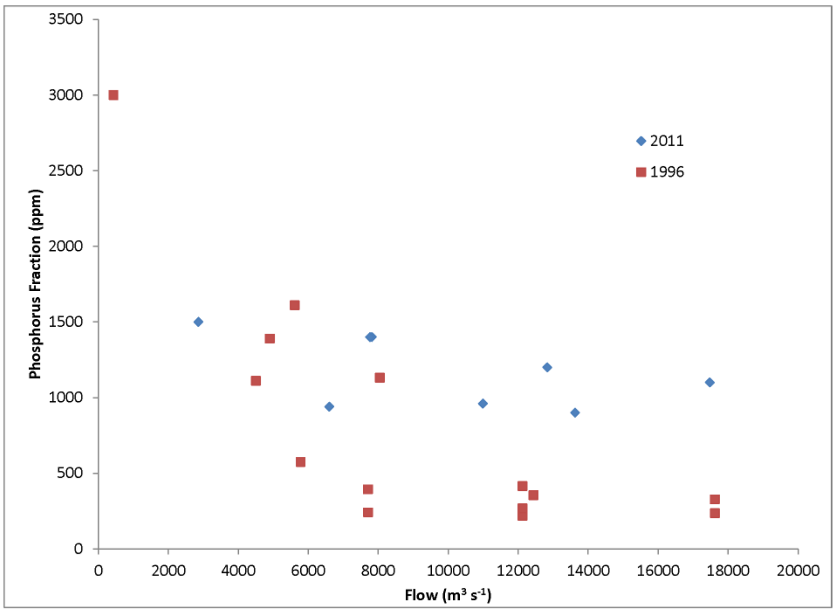


Figure 4-8. Solids phosphorus fraction versus flow at the Conowingo outfall. The 2011 observations are primarily greater than the 1996 observations.

5 Output Formats

The volume of information produced during each ten-year scenario is enormous and requires summarizing and formatting to facilitate assessment. Material presented in this report is limited primarily to results of scenarios conducted for the LSRWA and to runs related to the TMDL. A separate, supplemental, publication is planned to describe results of scenarios conducted for the EPA Chesapeake Bay Program (CBP).

The Total Maximum Daily Loads (USEPA, 2010) are specified to meet criteria in three areas: water clarity, chlorophyll (CHL) concentration, and dissolved oxygen (DO) concentration (Tango and Batiuk, 2013). Water clarity is quantified in the model as the coefficient of diffuse light attenuation (KE) and has units of inverse depth (m^{-1}). DO is quantified in concentration units of g m^{-3} (equivalent to mg/L or ppm). CHL is quantified in concentration units of mg m^{-3} (equivalent to µg/L). Model results are presented for these three criteria, supplemented by total suspended solids (TSS concentration as g m^{-3} or mg/L) which result, in part, from external loading and which contribute to poor water clarity.

Results are presented for the base TMDL conditions, as computed by the CBEMP. Results for the remaining scenarios are presented as difference plots which illustrate the difference between the scenario and base condition. Difference plots are calculated as [Scenario – Base]. Negative differences indicate scenario conditions are less than base conditions. Positive differences indicate scenario conditions are greater than base conditions. Results are presented as time series at five CBP monitoring stations (Figure 5-1) along the axis of the upper bay and as spatial plots for the entire bay. The selected monitoring stations are situated in the portion of the bay expected to show the greatest reaction to scour events and, in several cases, are situated in regions that are critical to meeting DO water quality standards. The time series plots are limited to the last five years of the scenario, 1996 – 2000, to emphasize the effect of the 1996 storm and scour event. Time series are presented for the surface and bottom at all stations and at mid-depth for the deeper stations. Spatial plots are presented for the year 1996, 1997, and 1999. The year 1996 is the storm year. The year 1997 contains the first SAV growing season and summer hypoxic interval following modelled storm events which occur late in 1996. The year 1999 is a drought year emphasized in previous presentations of model results (Cerco et al., 2010). The spatial plots for surface CHL and KE are averaged over the submerged aquatic vegetation growing season, April – October, and correspond to the period specified in the water clarity criteria. The spatial plots for DO show the bottom 1.5 m of the water column and are averaged over the months of June – August. These plots illustrate the occurrence of bottom-water hypoxia during the months when the condition is prevalent. Note, however, that in shallow portions of the bay, the bottom 1.5 m of the water column will be close to or may correspond to the surface.

The colors on the difference plots are configured so that the color red indicates a change towards undesirable conditions. The numeric scales are selected to emphasize differences which are of various magnitudes depending on constituent and scenario. The scales do not refer to specific water quality criteria. The reader may find the following frames of reference useful in judging the magnitude of differences, however. The water quality standard for "deep-channel seasonal refuge use" requires an instantaneous DO minimum > 1 mg/L from June to September; the deep water seasonal fish and shellfish use" requires an instantaneous minimum > 1.7 mg/L (Tango and Batiuk, 2013). The water clarity criteria are a complex combination of observed SAV acreage and percent light through water. A useful guideline is that SAV restoration to the 2m depth in tidal fresh and oligohaline water requires light attenuation < 0.8 m^{-1} (USEPA CBP, 1992). No quantitative chlorophyll criteria apply to upper Bay waters. However, concentrations less than 10 to 15 mg m^{-3} are recommended to avoid DO impairments (Tango and Batiuk, 2013).

Summary tables, as well as graphical presentations, are provided for CHL, KE, and DO. Results are for Chesapeake Bay Program Segments (CBPS) in the upper bay (Table 5-1, Figure 5-2). The CBPS are regions defined by the CBP and distinguished by physical configuration and salinity. Surface CHL and KE are averaged over the growing season. DO is quantified by the anoxic volume days (AVD) statistic. AVD is a spatial and temporal integration of the volume of water with DO concentration less than 1 g m^{-3}:

$$AVD = \sum_{i=1}^{n} \sum_{j=1}^{m} V_i \cdot \Delta t \qquad (5\text{-}1)$$

in which:

AVD = anoxic volume days (m^3 d)
n = number of model computational cells in CBPS
m = number of integration time steps in simulated year (d)
V_i = volume of computational cell with DO < 1 g m^{-3} during time step Δt
Δt = integration time step (d)

Various DO concentrations are employed to define hypoxia, anoxia, and similar terms. The 1 g m^{-3} criteria has been defined as the threshold for "severe hypoxia" and used in multiple analyses of DO trends in Chesapeake Bay (Hagy et al., 2004; Murphy et al., 2011; Cerco and Noel, 2013).

Scenarios Presented

Results for each scenario or difference are included as individual pdf files attached to this report. Significant figures and statistics are pulled into the body of the report in subsequent chapters. The scenarios and differences are as follows:

Concentration plots for LSRWA_3. This is the base TMDL run with no scouring.

Difference plots for LSRWA_21 – LSRWA_3. LSRWA_21 is the TMDL run with scouring adapted from ADH for the January 1996 storm. This run shows the effect of scouring on the TMDL.

Difference plots of LSRWA_21 – LSRWA_23. LSRWA_21 is the TMDL run with scouring adapted from ADH for the January 1996 storm. LSRWA_23 is the TMDL run with the January storm removed. This run shows the effect of a January storm on the TMDL.

Difference plots of LSRWA_24 – LSRWA_23. LSRWA_24 is the TMDL run with the January storm flows, loads, and scour moved to June. LSRWA_23 is the TMDL run with the January storm removed. This run shows the effect of a June storm on the TMDL.

Difference plots of LSRWA_25 – LSRWA_23. LSRWA_25 is the TMDL run with the January storm flows, loads, and scour moved to October. LSRWA_23 is the TMDL run with the January storm removed. This run shows the effect of an October storm on the TMDL.

Difference plots for LSRWA_3 – LSRWA_6. LSRWA_3 is the base TMDL run. LSRWA_6 is the base TMDL run with Conowingo removed. This run shows the effect of processes in the Conowingo Reservoir on the TMDL.

Difference plots of LSRWA_30 – LSRWA_21. LSRWA_30 is the TMDL run with scouring for the January 1996 storm adapted from ADH with the reservoir at equilibrium bathymetry. LSRWA_21 is the TMDL run with scouring for the 1996 storm adapted from ADH storm with 2008 (existing) bathymetry. This run shows the effect of reservoir filling on the TMDL.

Difference plots of LSRWA_28 – LSRWA_21. LSRWA_28 is the TMDL run with scouring adapted from ADH based on the removal of 3 million cubic yards (mcy) by dredging. LSRWA_21 is the TMDL run with scouring based on existing bathymetry. This run shows the effect of dredging 3 mcy on the TMDL.

Difference plots of LSRWA_31 – LSRWA_30. LSRWA_31 is the TMDL run with scouring adapted from ADH based on 1996 bathymetry. LSRWA_30 is the TMDL run with scouring adapted from ADH based on equilibrium bathymetry. LSRWA_31 serves two purposes. Here it is employed as a representation of the bathymetry resulting from dredging back to 1996 conditions. The amount of material removed to restore the 1996 bathymetry depends on the base bathymetry utilized. The amount is 28 mcy based on 2008 bathymetry. Due to subsequent sedimentation, the amount is 31 mcy based on 2011 bathymetry. The amount would be grater still if the equilibrium bathymetry is used as a base.

Difference plots of LSRWA_29 – LSRWA_28. LSRWA_29 is a run with additional sediment and nutrient loads resulting from “sediment bypassing.” Bypassing is the practice of dredging sediment and releasing it downstream, past the dams. The bypassing loads are 3 mcy of dredged sediment spread over the interval December to February of each scenario year. LSRWA_28 is the TMDL run with scouring based on bathymetry with 3 mcy removed by dredging.

Dredging and bypassing for ten years eventually result in the 1996 bathymetry. The January 1996 storm happens at some intermediate, unknown bathymetry. To represent this condition, we used the bathymetry and scour produced by the dredging of 3 mcy. This run shows the effect of bypassing dredged material on the TMDL.

References

Hagy, J., Boynton, W., Keefe, C., and Wood, K. (2004). "Hypoxia in the Chesapeake Bay, 1950-2001: Long-term changes in relation to nutrient loading and river flows," *Estuaries* 27:634-658.

Cerco, C., S-C Kim, and M. Noel, 2010. "The 2010 Chesapeake Bay eutrophication model," A Report to the US Environmental Protection Agency Chesapeake Bay Program and to the U.S. Army Corps of Engineers Baltimore District. http://www.chesapeakebay.net/publication.aspx?publicationid=55318

Cerco, C., and Noel, M. (2013). "Twenty-one-year simulation of Chesapeake Bay water quality using the CE-QUAL-ICM eutrophication model," *Journal of the American Water Resources Association* 49(5), 1119-1133.

Murphy, R., Kemp, W., and Ball, W. (2011). "Long-term trends in Chesapeake Bay seasonal hypoxia, stratification, and nutrient loading," Estuaries and Coasts doi:10.1007/s12237-011-9413-7

USEPA. (2010). "Chesapeake Bay total maximum daily load for nitrogen, phosphorus and sediment," US Environmental Protection Agency Region 3. http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html

USEPA CBP. (1992). "Chesapeake Bay submerged aquatic vegetation habitat requirements and restoration targets: a technical synthesis," CBP/TRS 83/92, U.S. Environmental Protection Agency Chesapeake Bay Program, Annapolis MD.

Tango, P., and Batiuk, R. (2013). "Deriving Chesapeake Bay water quality standards," *Journal of the American Water Resources Association* 49(5), 1007-1024.

Table 5-1
Chesapeake Bay Program Segments Selected for Summation

CBPS	Quantities[1]	CBPS	Quantities
NORTF	CHL, KE	WSTMH	CHL, KE
CB1TF	CHL, KE, AVD	CB4MH, AVD	CHL, KE
BSHOH	CHL, KE	PAXMH, AVD	CHL, KE
GUNOH	CHL, KE	POTMH, AVD	CHL, KE
CB2OH	CHL, KE, AVD	CB5MH, AVD	CHL, KE
MIDOH	CHL, KE	LCHMH, AVD	CHL, KE
BACOH	CHL, KE	CHOMH1, AVD	CHL, KE
PATMH	CHL, KE, AVD	CHOMH2, AVD	CHL, KE
CB3MH	CHL, KE, AVD	EASMH, AVD	CHL, KE
MAGMH	CHL, KE	CHSMH, AVD	CHL, KE
SEVMH	CHL, KE	SASOH	CHL, KE
SOUMH	CHL, KE	BOHOH	CHL, KE
RHDMH	CHL, KE	ELKOH, AVD	CHL, KE

[1]AVD is quantified only for CBPS with substantial volume below the pycnocline.

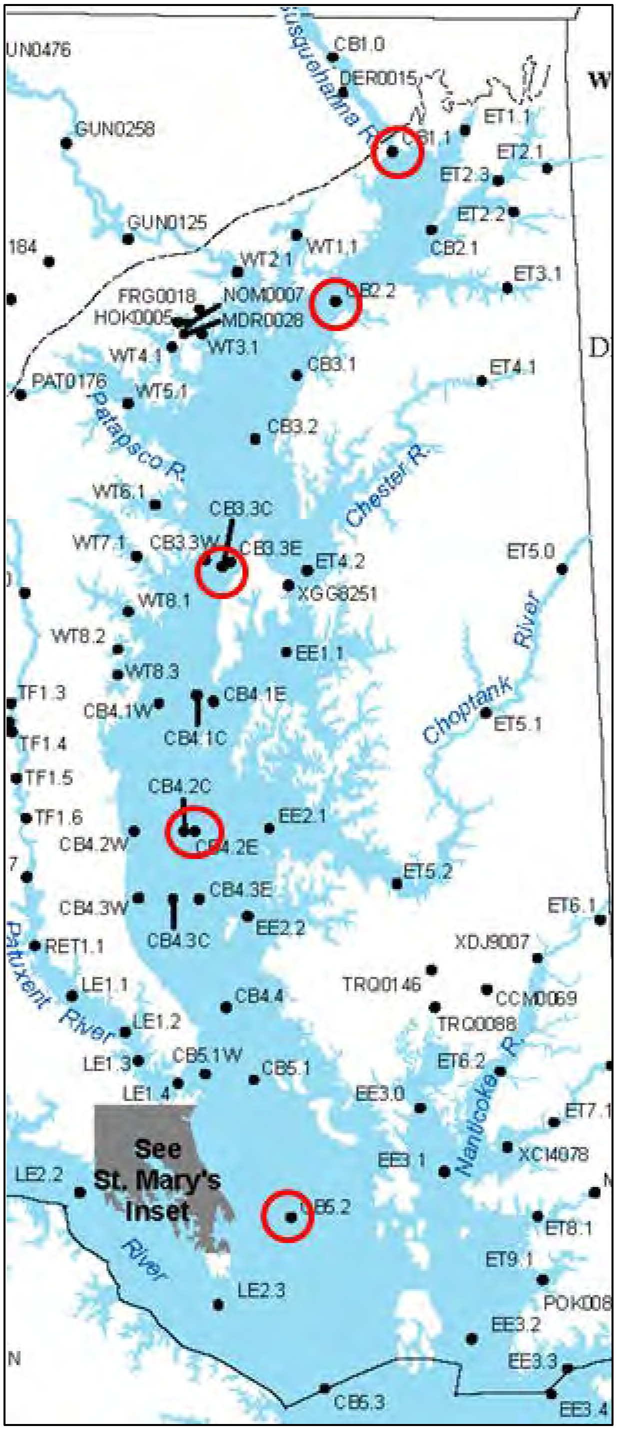


Figure 5-1. CBP monitoring stations (circled in red) selected for time series plots.

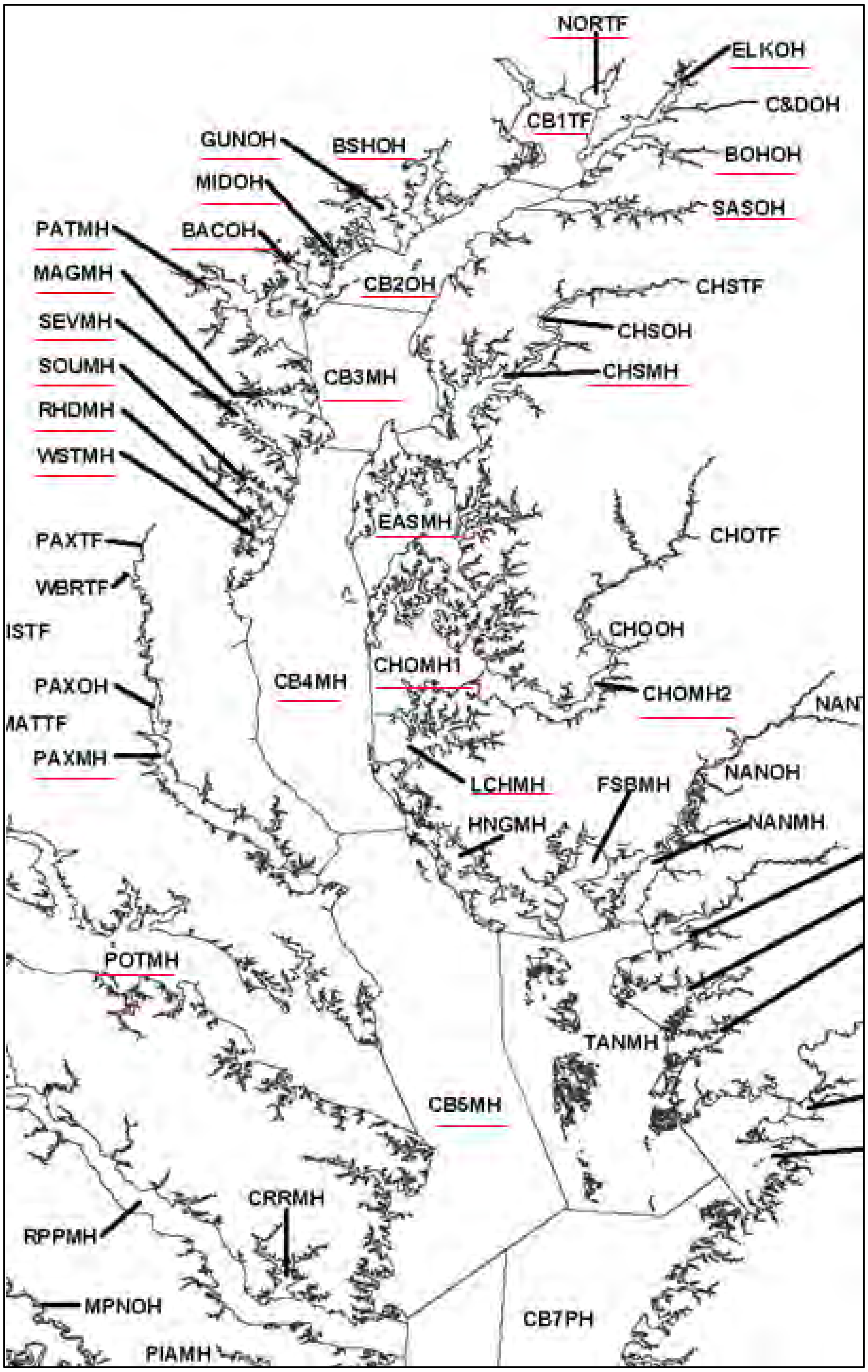


Figure 5-2. Chesapeake Bay Program Segments (underlined in red) selected for summation.

6 Scenario Results

Base Scenario

The Base Scenario consists of a ten-year hydrologic sequence, 1991 – 2000, with watershed solids and nutrient loads from the Chesapeake Bay Program (CBP) Watershed Model (WSM), based on Total Maximum Daily Load (TMDL) conditions. As calibrated and employed here, the WSM provides watershed loads but little or no scour in the Conowingo Reservoir for the January 1996 storm.

The year 1996 is characterized by high flow at the Conowingo outfall, not only in January but throughout the months prior to and during the period of summer hypoxia (Figure 6-1). The year 1996 is followed by 1997 and 1999, respectively, in terms of flow volume during the spring and summer months. The relative ranking of freshwater inflow is reflected in computed stratification (Cerco and Noel, 2013). Summer stratification is strongest in 1996, moderate in 1997, and weakest in 1999. Stratification in the three years influences the magnitude and extent of computed anoxia. (Anoxia is defined here as dissolved oxygen (DO) concentration < 1 g m^{-3}.) DO concentration during the summer months of 1996 is lower, for a longer period, than in 1997 or 1999 (Figures 6-2 to 6-5). Computed anoxic volume days (AVD) also follow the sequence from greatest volume in 1996 to least volume in 1999 (Figure 6-6).

Phytoplankton are quantified in the model as carbonaceous biomass. Their computed concentration is reported both as carbon and as chlorophyll, however, since phytoplankton observations are usually reported as chlorophyll concentration. The saline portions of Chesapeake Bay are subject to no chlorophyll standard. Phytoplankton are a crucial influence, however, on whether bay waters meet DO and water clarity standards. Oxygen consumption associated with the decay of organic carbon fixed by phytoplankton is the primary mechanism for the occurrence of bottom-water hypoxia. Light attenuated by the chlorophyll pigment and by particulate organic matter contributes to poor water clarity.

Phytoplankton in the saline portions of Chesapeake Bay exhibit two recurrent annual phenomena. The first is the spring diatom bloom which occurs roughly from January through May. The bloom is characterized by high chlorophyll concentration but low primary productivity. The second phenomenon is the period of maximum productivity which takes place in summer. Although the warmer months are more productive than spring, the chlorophyll concentration may be lower than during the diatom bloom. The two phytoplankton intervals overlap with the submerged aquatic vegetation (SAV) growing season which is considered to be April – October for the species which occupy the upper bay. This is also the period for application of water clarity standards (Tango and Batiuk, 2013). Due to the variability in chlorophyll through the growing season, time series plots (e.g. Figure 6-7) are difficult to interpret with regard to the role of phytoplankton in light attenuation during the critical period. For this purpose, spatial plots of surface chlorophyll, averaged over the growing season are superior (Figures 6-8 to 6-10).

Light attenuation by colored dissolved organic matter, chlorophyll pigment, fixed (mineral) solids, and volatile (organic) solids all contribute to the total attenuation coefficient in Chesapeake Bay. The relative contribution of individual substances varies with location and season throughout the bay (Cerco et al., 2013). Several useful guidelines can be discerned, however. The first is that fixed solids (FSS) originate primarily in the watershed or from shoreline erosion. The major source of volatile solids (VSS), however, is primary production in the water column rather than external loading. The fraction of fixed solids in the total solids concentration illustrates the role of external loading in light attenuation. As noted, the fraction varies spatially and temporally but it can be less than half of the total solids concentration in portions of the upper bay (Figure 6-11). The period of greatest light attenuation in the upper bay coincides with the period of greatest runoff, usually winter and spring (Figure 6-12). When averaged over the growing season, the region of greatest light extinction extends from nearly the head of the bay down to the Patapsco River (Figures 6-13 to 6-15). This region encompasses the turbidity maximum in which suspended particles are concentrated by estuarine circulation (Schubel, 1968) as well as the region of highest chlorophyll concentration in the mainstem portion of the bay (Figures 6-8 to 6-10).

The Effect of Storm Scour

The Relative Role of Net Scour Loads

Scour in Conowingo Reservoir for the January 1996 storm was computed as described in Chapter 4. Summarizing material presented in that chapter results in the comparison of loads at the Conowingo outfall presented in Table 6-1. The table shows TMDL watershed loads, summed over the interval of peak storm flows, total net scour loads, and total TMDL watershed loads for the winter and spring months. The watershed loads are computed by the WSM and do not include significant scour. The net scour loads are the predominant source of solids and nutrients during the storm interval. For solids and phosphorus, the scour loads are the predominant source over the entire winter-spring period. The relative importance of the scour loads is magnified, in this instance, by comparison to the TMDL watershed loads. These loads are considerably less than estimated 2010 loads (Table 4-1) or loads which occurred in 1996. The relative importance of the nutrient loads is also magnified through use of the 2011 particle composition for this scenario (Table 4-3) rather than 1996 composition (Table 4-4).

The predominant role of net scour loads, reported here, is in contrast to the companion reports to this one (Scott and Sharp, 2013; Langland, 2013) in which scour is assigned a lesser fraction of the total storm loads. Scott and Sharp, for example, report the scoured sediment load is ≈ 20% of the total sediment load computed for Tropical Storm Lee. The relative magnitude of the scour load depends on multiple factors including:

- The nature of the storm event,
- How the scour load is determined,
- Where the watershed loads are specified, and
- How the watershed loads are determined.

We must recognize that the 1996 and 2011 storm events were fundamentally different. Tropical Storm Lee was a tropical storm event which passed over the lower portion of the Susquehanna Watershed. This portion of the entire watershed contains several sub-watersheds which produce notably high sediment loads. The 1996 flood was generated, in part, by snowmelt which is relatively "clean" with regard to sediment content. Therefore, we expect the ratio of watershed load to scour load to differ for these two events.

One method to quantify scour is by comparison of bathymetry measurements obtained before and after the event. This was the method used in one of the earliest studies of scour in Conowingo Reservoir (Langland and Hainly, 1997) and resulted in an estimate in which scour was the predominant source of solids loading during the January 1996 event. An alternate methodology compares loads entering and leaving the system. An excess of loads leaving over loads entering implies the occurrence of net scour. The loads may be obtained from a statistical model based on observations (Hirsch, 2012) or from a mechanistic model such as ADH.

The watershed loads can be specified at the head of the reservoir system, at the entry to Conowingo Reservoir, or at the Conowingo outfall. Conditions at the entry to Conowingo are not monitored. Consequently, calculations which employ observed loads entering the system are based on observations at Marietta, the head of the reservoir system, and the differencing process incorporates all three reservoirs. For the ADH estimates, watershed loads are taken at the Conowingo entrance. The estimates in this report use watershed loads at the Conowingo outfall.

Watershed loads cannot be perfectly observed. They require calculation based on interpolation of observations (Cohn et al., 1989; Hirsch, 2012) or come from a mechanistic model calibrated to observations. For ADH, the watershed loads entering Conowingo are obtained from the HEC-RAS application to the three-reservoir system (Langland, 2013). For the CBEMP application, watershed loads are from the CBP WSM.

Clearly, the relative magnitude of scour loads compared to watershed loads is variable and subject to uncertainity. Estimates will vary depending on characteristics of the storm event and on the methodology employed in deriving the comparison. While the relative magnitude of scour is uncertain, the absolute net scour loads reported here are consistent with the companion reports and with the latest estimates. Scott and Sharp (2013) report net solids scour for Tropical Storm Lee as 3.0×10^6 English tons and Langland (2013) reports net solids scour for the January 1996 event as 4.0×10^6 English tons. Both reports are consistent with the load of 2.37×10^6 tons reported here for January 1996 (Table 6-1).

The Effect of Scour Computed for January 1996

The scour loads produce a tremendous increase in computed light attenuation during the January storm (Figure 6-16). During the 1996 SAV growing season (Figure 6-17) and in later years, however, the change in light attenuation resulting from storm scour is negligible. The median increase in growing-season attenuation in any year is less than 0.01 m^{-1}, compared to median base light attenuation ≈ 0.8 m^{-1}. By the time growing season arrives, most of the solids associated with the storm have settled out. There are a few CBPS, notably NORTF and BACOH, where an increase in TSS of 0.4 to 0.6 g m^{-3} persists into the 1996 growing season (Figure 6-18). For most segments, however, the computed increase in growing-season TSS is less than 0.1 g m^{-3}. The origin of the increase varies. In the upper bay, the increase in TSS is largely in the fixed fraction (Figure 6-18) indicating solids remaining in suspension following the scour event. Further down the bay, the increase in FSS is a small fraction of the increase in TSS indicating an indirect mechanism where scoured nutrients stimulate phytoplankton, which produce organic matter which attenuates light.

Computed surface chlorophyll decreases during the scour event (Figure 6-19), most likely due to increased light attenuation from scoured solids. Computed chlorophyll increases, however, in the first growing season following the event. The extent of the increase is widespread with an average increase of 0.1 to 0.3 mg m^{-3} extending into the lower Potomac River and below the mouth of the Potomac in the mainstem bay (Figure 6-20). The increase in chlorophyll persists into subsequent years although the magnitude of the increase diminishes with time. The pathway for nutrients scoured in winter to stimulate phytoplankton in summer leads through bottom sediments. Particulate nutrients associated with scoured solids settle to the bottom. During the warmer months, diagenesis in the bottom sediments releases the nutrients to the water column (Figure 6-21, 6-22) where they stimulate phytoplankton production. Over time, processes including burial and washout remove the sediment nutrients from the active surface sediment layer and the stimulus provided by additional sediment nutrient release diminishes.

Bottom DO declines by up to 0.2 g m^{-3} as a result of the storm scour (6-23). The mechanism is the classic eutrophication mechanism in Chesapeake Bay. The additional nutrients, made available via sediment diagenesis, stimulate algal production. Organic matter produced by phytoplankton settles to the bottom waters and sediments of the bay and consumes oxygen as it decays. The effect on DO diminishes with time, similar to chlorophyll and sediment nutrient release. The time series and seasonal-average plots (Figures 6-24, 6-25) indicate, however, that the decrease of DO in 1997 exceeds the decrease in 1996. This phenomenon is an artifact of the different base DO concentrations in the two years (e.g. Figure 6-2). The generally higher bottom DO concentrations which prevail in the 1997 base case can fall farther than the bottom DO concentrations in the 1996 base case. In most segments, the anoxic volume in 1996, immediately following the scour event, is greater than in 1997 (Figure 6-26). The anoxic volume indicates an increase in anoxia throughout the water column that is not illustrated in plots of bottom DO.

Storm Seasonal Effects

Runoff events with flows sufficient to scour reservoir sediments occur at various times of the year. Floods occur in the Susquehanna River in late winter and early spring due to precipitation and snowmelt. Tropical storm events are most common during late summer and early fall although the notorious Tropical Storm Agnes occurred in June 1972 (CRC, 1976). The effect of the storm-generated loads, from the watershed and from reservoir scour, will vary depending on the period of storm occurrence. To investigate the effect of storm season, scenarios were completed with the January 1996 Susquehanna storm flows and loads moved to June and October 1996. These were compared to a base scenario with the storm removed. For this base case, the storm was removed completely, both watershed load and storm scour. The scenarios with the storm included both watershed loads and scour. Revised hydrodynamics were completed for the three new scenarios (June Storm, October storm, no storm) to capture the effects of circulation and stratification as well as loading. As with the previous scenarios, results are presented in the form of difference plots which highlight the influence of scenario conditions. Time series plots are presented here for Station CB3.3C. This station is located at the head of the deep trench which forms the natural channel in the upper bay and, consequently, this station is among those with the lowest ambient bottom-water DO concentration. CB3.3C also ranks among the main-channel stations with the greatest summer surface chlorophyll concentration and the highest light attenuation.

Light Attenuation

All three storm events, January, June and October, demonstrate an enormous, immediate response in light attenuation due to solids loads (Figure 6-27). The January response is shortest-lived. In this instance, the high flows which prevail even with the storm removed flush solids downstream and out of the system. The influence of the solids load on attenuation persists for ≈ 90 days for the June and October storms. For both the January and October storms, the fixed solids are virtually gone prior to the subsequent SAV growing season. The increase in light attenuation is primarily due to stimulation of primary production by storm-generated nutrient loads. The June storm occurs during the SAV growing season and the light-attenuating effects of fixed solids loads are incorporated into the seasonal-average light attenuation computation (Figure 6-28). The seasonal-average results indicate the spatial extent of increased attenuation is greater for the June storm than for the January or October storm.

Chlorophyll

Computed surface chlorophyll concentration decreases immediately as the storm flows pass (Figure 6-29). Nutrients introduced by the storm stimulate chlorophyll production in each subsequent SAV growing season. The resulting chlorophyll concentration is highest for the June storm and least for the October storm (Figure 6-29). The region of increased chlorophyll concentration is also most extensive for the June storm (Figure 6-30). This effect is promoted by the introduction of nutrients at the beginning of the season of maximum production. For the January storm, roughly five months pass between the loading and the summer production season. For the October storm, eight months pass, allowing time for the added nutrients to be flushed from the system or buried to deep, inactive bottom sediments.

Dissolved Oxygen

As with chlorophyll, the initial effect of the storm on DO is a decrease as the storm passes (Figure 6-31). For the January and October storms, DO rebounds, then decreases due to oxygen demand associated with additional production and decay of organic matter stimulated by storm-generated nutrient loads. For the June storm, the decrease associated with storm flow nearly connects to the decrease caused by respiration. As a result, the decrease during the summer following the storm is of larger magnitude than for a January or October storm. The spatial plots (Figure 6-32) indicate the effect of the June storm on bottom DO is much more extensive than for the alternate storms. In particular, DO depletion moves up the flanks of the deep trench into water which is usually well aerated. In the shallow shoals, computed DO actually increases due to oxygen production which accompanies the enhanced algal primary production.

Equilibrium Bathymetry

Conowingo bathymetry for most scenarios was based on surveys conducted in 2008. Several scenarios were completed with alternate representations of Conowingo Reservoir. One was the “Reservoir Full” or “Equlibrium Bathymetry” scenario. This scenario employs bathymetry estimated to prevail when the reservoir achieves long-term equilibrium between sediment loads in and sediment loads out. Note that this condition does not imply that loads in and out are always equal. Rather, the reservoir will be in a depositional state punctuated by frequent scour events such that loads in equal loads out when averaged over time scales of a few years or less. The equilibrium bathymetry was based on the estimated configuration after the reservoir achieves long-term equilibrium between solids inflows and outflows.

Figure 6-33 shows the difference between solids loads into Conowingo and solids loads out of Conowingo for 2008 – 2011 with equilibrium bathymetry. The loads are from the ADH model and were provided for use in the CBEMP. The condition when loads in exceed loads out indicates deposition; the condition when loads out exceed loads in indicates erosion. Despite the equilibrium state, deposition is computed up to the March 2011 erosion event and resumes until the Tropical Storm Lee event. Computation of deposition is consistent with the analytical model of Chapter 2 in which deposition is independent of depth, as long as the threshold for erosion is not exceeded. As noted in Table 4-5, the erosion computed for the equilibrium bathymetry is virtually identical to the erosion computed for the existing bathymetry. Effectively, the reservoir had achieved equilibrium by the 2008 – 2011 period.

Owing to the nearly identical loads, the scenario results for the equilibrium bathymetry are virtually identical to the results for the base scenario with scouring (Figures 6-34 – 6-36).

The "No Conowingo" Scenario

A scenario was run with Conowingo Reservoir removed from the system. This was accomplished by routing directly to the bay the calculated WSM loads into Conowingo Reservoir. This routing eliminated settling and other processes computed by the WSM in the reservoir. This run has multiple interpretations. The initial intent was to simulate a reservoir-full condition. In this interpretation, loads to the reservoir would pass directly through in the absence of deposition. This interpretation was superseded by a revised conceptual model in which settling occurs even under reservoir-full conditions. In the revised conceptual model, the reservoir-full or equilibrium condition implies the occurrence of frequent scour events that remove deposited material so that there is no net accumulation of solids in the reservoir. The scenario retains value, however. The difference between the "No Conowingo" scenario and the TMDL scenario shows the effect of computed processes in the reservoir on the calculated TMDL conditions. The difference between the two scenarios may also be interpreted as a quantification of the effect of Conowingo Dam on Chesapeake Bay water quality when the reservoir is in a depositional state.

The difference plots are interpreted so that a difference greater than zero indicates concentrations are higher with the reservoir than without the reservoir. A difference less than zero indicates that concentrations are lower with the reservoir than without the reservoir. This interpretation is readily viewed in a time series plot of TSS at Station CB3.3C (Figure 6-37). Computed solids concentrations in the bay are lower with the reservoir in place than without the reservoir. Lower concentrations of suspended solids result in reduced light attenuation. Benefits of 0.1 to 0.2 m^{-1} are evident at Station CB3.3C (Figure 6-38). The maximum benefit is in winter and spring, however, during periods of peak solids loading. During the SAV growing season, reductions in attenuation due to solids and nutrient retention in the reservoir are lower, $\approx 0.025\ m^{-1}$ (Figure 6-39).

Reservoir processes result in both higher and lower computed chlorophyll concentrations in the bay, depending on season. During winter to spring, higher concentrations are computed (Figure 6-40). Apparently, solids retention leads to lower light attenuation which leads to a larger spring algal bloom. During summer, however, computed chlorophyll concentrations are lower with the reservoir in place. For this season, nutrient retention in the reservoir contributes to nutrient limitation of algal production and biomass. The influence on chlorophyll of nutrient retention in the reservoir can be seen throughout the bay (Figure 6-41).

As a result of nutrient retention and algal limitation, computed bottom DO concentrations are uniformly higher with the reservoir than without (Figure 6-42). Peak benefits of 0.1 to 0.2 $g\ m^{-3}$ are evident at CB3.3C. The benefits are spatially extensive, corresponding to the expansive chlorophyll benefits although the magnitude of the DO benefit, when averaged over the summer months, is less than the peak computations (Figure 6-43).

Sediment Management – Dredging 3 Million Cubic Yards

Several scenarios were conducted to examine sediment management actions. The first was an examination of one-time removal of 3 million cubic yards (mcy, equivalent to 2.3 x 10^6 m^3) of material from Conowingo Reservoir. This scenario was compared to the TMDL scenario with 2008 bathymetry. The sole difference in loading between the two conditions was during the January 1996 scour event. Computed scouring of solids and nutrients was reduced by 32% as a result of the dredging (Table 4-5).

The dredging has little effect on computed conditions in the bay. Computed surface chlorophyll increases immediately following the scour event (Figure 6-44) as a result of reduced solids loading and reduced light attenuation (Figure 6-45). In the first summer following the storm event, surface chlorophyll is reduced a maximum of 0.1 mg m^{-3} (Figure 6-44, 6-46) with the effect diminishing over time. The influence of the dredging on computed light attenuation during the SAV growing season is negligible (Figure 6-47). Changes in CHL and KE were tabulated by CBPS for the first SAV growing season following the storm (Tables 6-2, 6-3). For both variables, the change induced by the dredging is much less than 1%.

Bottom DO improves by 0.01 to 0.04 g m^{-3} (Figure 6-48). The improvement is perhaps better in summer 1997 than summer 1996. Averaged over the summer season, however, the improvement is roughly 0.02 g m^{-3} and of limited spatial extent (Figure 6-49). The improvement was quantified using the AVD statistic (Table 6-4). The reduction in anoxia in the summer following the storm event ranged from effectively zero to 12% in various CBPS. Overall reduction in AVD was 1.7%.

Sediment Management – Dredging Back to 1996 Bathymetry

The ADH run with 1996 bathymetry was originally completed to examine the effects of a major scour event on subsequent scour events. (The 1996 bathymetry survey was completed after the January scour event.) The scour computed with this bathymetry can also be viewed as the scour that would take place if 28 mcy, relative to the 2008 bathymetry, were removed from the reservoir by dredging. This scour load (Table 4-5) can be combined with appropriate watershed loads to produce a scenario with TMDL loading and 28 mcy dredging, relative to 2008 bathymetry. To examine limiting cases, this scenario is compared to the scenario with TMDL loads and equilibrium bathymetry as the base. Computed scouring of solids and nutrients is reduced by 45% by dredging back to 1996 bathymetry compared to the equilibrium bathymetry.

The nature of the response to removal of 28 mcy is similar to the response to the removal of 3 mcy although the magnitude of the effects is greater, especially for CHL and DO. There is, again, an initial increase in computed surface chlorophyll (Figure 6-50), prompted by a reduction in solids load and an improvement in computed water clarity (Figure 6-51). By summer, the improvement in water clarity is nearly indistinguishable (Figure 6-52) as the storm-generated solids settle out of the water column. Surface chlorophyll concentration is reduced by peak values of 0.1 to 0.2 mg m^{-3} during the SAV growing season due to reduction in nutrient loads that accompany scour (Figure 6-50). Averaged over the 1996 growing season, the improvements in CHL are roughly 0.05 mg m^{-3} (Figure 6-53, Table 6-5). Improvements in seasonal-average surface chlorophyll approach 1% in some CBPS while improvements in KE are limited to less than 0.5% (Table 6-6).

During the summer months, the instantaneous improvement in calculated bottom DO is nearly double the improvement from dredging 3 mcy (Figure 6-54). Instantaneous improvements of 0.05 g m^{-3} are calculated for several years following the scour event and extend along the upper bay and into the lower Potomac River (Figure 6-55). Quantified as AVD, anoxia is reduced by up to 15% in some CBPS and by 2.8% overall.

Sediment Management – Sediment Bypassing

Material dredged from the reservoir has to be placed elsewhere. One option is to "bypass" the sediment. That is, pass the material over or around the Conowingo dam and into the bay during a period when biological activity is minimal. The potential for this disposal method was examined in a scenario in which 3 mcy of sediment was bypassed during the months of December – February of each scenario year. This scenario was compared to a base condition of TMDL loads with 3 mcy removed from the reservoir. Although the bypassing was simulated for ten years, the results are shown for five years, 1996 – 2000, for consistency with previous results.

As expected, sediment bypassing results in increased suspended solids computed in the bay during the bypass period. At Station CB3.3C, the increase is usually 1 to 2 g m^{-3} (Figure 6-56). As demonstrated in the scour scenarios, the bypassed solids settle quickly after the source is eliminated. A secondary solids increase occurs during the summer when nutrients that accompany the bypassed sediments stimulate the production of algae and associated organic matter. The net effect on light attenuation during the SAV growing season is small, however. The greatest increase in any CBPS (CB2OH) averages ≈ 0.1 m^{-1} and the typical increase is ≈ 0.025 m^{-1} (Figure 6-57).

As a result of the continuous discharge of nutrients associated with the bypassed sediments, computed increases in surface chlorophyll are extensive (Figure 6-58) and cover most of the bay as well as the lower portions of several tributaries. Averaged over the growing season, increases in surface chlorophyll of 1 mg m^{-3} are computed in multiple CBPS and increases of ≈ 0.5 mg m^{-3} occur in most segments. The enhanced algal production increases computed bottom DO in some shoal areas but the overwhelming effect is diminished DO. The resulting decrease of DO is extensive and of greater magnitude than seen as a result of scour events (Figure 6-59). Decreases of 0.2 to 0.3 g m^{-3} in summer average DO are widespread and an overall increase of 30% is computed for AVD (Table 6-8).

A Caveat

The scenarios reported above use TMDL watershed loads and examine results computed in the bay under TMDL conditions. Conclusions regarding the impact of reservoir scour and of mitigation efforts on Bay water quality standards should not be drawn from this chapter, however. The primary years for development of the TMDL were 1993 – 1995, years not impacted by storm scour and not reported here. In addition, the CBP conducts a detailed procedure to relate computed conditions to observations (Keisman and Shenk, 2013). The CBP has a series of "stop-light" plots which illustrate the effect of various scenarios on standards. The sole authority on the Bay water quality standards is the EPA Chesapeake Bay program.

References

Cerco, C., S-C Kim, and M. Noel, 2010. *The 2010 Chesapeake Bay eutrophication model.* A Report to the US Environmental Protection Agency Chesapeake Bay Program and to the US Army Engineer Baltimore District. http://www.chesapeakebay.net/publication.aspx?publicationid=55318

Cerco, C., Kim, S-C., and Noel, M. (2013). "Management modeling of suspended solids in the Chesapeake Bay, USA," *Estuarine, Coastal and Shelf Science* 116, 87-98.

Chesapeake Research Consortium. (1976). *The effects of Tropical Storm Agnes on the Chesapeake Bay estuarine system.* Jackson Davis, ed., Johns Hopkins University Press, Baltimore MD.

Cohn, T., DeLong, L., Gilroy, E., Hirsch, R., and Wells, D. (1989). "Estimating constituent loads," *Water Resources Research*, 25, 937-942

Hirsch, R. (2012). "Flux of nitrogen, phosphorus, and suspended sediment from the Susquehanna River basin to the Chesapeake Bay during Tropical Storm Lee, September 2011, as an indicator of the effects of reservoir sedimentation on water quality," Scientific Investigations Report 2012-5185, US Geological Survey, Reston VA.

Keisman, J., and Shenk, G. (2013). "Total maximum daily load criteria assessment using monitored and modeled data," *Journal of the American Water Resources Association* 49(5), 1134-1149.

Langland, M., and Hainly, R. (1997). "Changes in bottom-surface elevations in three reservoirs on the lower Susquehanna River, Pennsylvania and Maryland, following the January 1996 flood -Implications for nutrient and sediment loads to Chesapeake Bay," Water-Resources Investigations Report 97-4138, US Geological Survey, Lemoyne PA.

Langland, M. (2013). "Sediment transport simulation of three reservoirs in the lower Susquehanna River basin, Pennsylvania and Maryland," a report to the U.S. Army Corps of Engineers, Baltimore District.

Schubel, J. (1968). "Turbidity maximum in the northern Chesapeake Bay," *Science* 161, 1013-1015.

Scott, S., and Sharp, J. (2013). "Sediment transport characteristics of Conowingo Reservoir," prepared for U.S. Army Corps of Engineers Baltimore District by Engineer Research and Development Center, Vicksburg MS.

Tango, P., and Batiuk, R. (2013). "Deriving Chesapeake Bay water quality standards," *Journal of the American Water Resources Association* 49(5), 1007-1024.

Table 6-1 Computed TMDL Loads at the Conowingo Outfall

	Flow, m^3	Total Nitrogen, kg	Organic Nitrogen, kg	Total Phosphorus, kg	Particulate Phosphorus, kg	Total suspended Solids, kg
Watershed Jan 19 - 25, 1996	64,822	5,899,740	2,483,400	516,081	344,739	404,862,000
January 1996 Scour			7,116,000		2,372,000	2,372,050,000
Watershed Jan - May, 1996	362,934	32,756,318	14,235,853	1,742,474	1,357,043	990,407,321

Table 6-2 Calculated Surface Chlorophyll ($mg\ m^{-3}$) for 1996 SAV Growing Season With and Without Dredging 3 mcy

Region	Dredge 3 mcy	2008 Bathymetry	Change	Percent Change
NORTF	5.68	5.69	-0.007	-0.12
CB1TF	3.56	3.56	-0.002	-0.06
BSHOH	5.06	5.06	-0.003	-0.06
GUNOH	2.54	2.55	-0.003	-0.12
CB2OH	6.28	6.30	-0.018	-0.29
MIDOH	2.72	2.73	-0.005	-0.18
BACOH	6.82	6.82	0.001	0.01
PATMH	11.78	11.82	-0.037	-0.31
CB3MH	9.57	9.61	-0.041	-0.43
MAGMH	5.80	5.84	-0.044	-0.75
SEVMH	4.98	5.01	-0.024	-0.48
SOUMH	6.02	6.06	-0.041	-0.68
RHDMH	6.10	6.14	-0.04	-0.65
WSTMH	2.53	2.55	-0.018	-0.71
CB4MH	8.95	9.00	-0.052	-0.58
PAXMH	6.18	6.20	-0.021	-0.34
POTMH	9.11	9.12	-0.018	-0.20
CB5MH	7.64	7.67	-0.034	-0.44
LCHMH	2.43	2.45	-0.019	-0.78
CHOMH1	3.84	3.86	-0.019	-0.49
CHOMH2	8.41	8.43	-0.018	-0.21
EASMH	3.46	3.49	-0.027	-0.77
CHSMH	7.02	7.05	-0.034	-0.48
SASOH	6.60	6.61	-0.015	-0.23
BOHOH	4.18	4.19	-0.008	-0.19
ELKOH	4.10	4.10	-0.007	-0.17

Table 6-3 Calculated Light Attenuation (m^{-1}) for 1996 SAV Growing Season With and Without Dredging 3 mcy

Region	Dredge 3 mcy	2008 Bathymetry	Change	Percent Change
NORTF	1.94	1.95	-0.006	-0.31
CB1TF	1.46	1.46	0	0.00
BSHOH	1.03	1.03	-0.001	-0.10
GUNOH	0.96	0.96	-0.002	-0.21
CB2OH	1.42	1.42	-0.001	-0.07
MIDOH	1.23	1.23	-0.002	-0.16
BACOH	3.12	3.13	-0.01	-0.32
PATMH	1.60	1.61	-0.004	-0.25
CB3MH	1.02	1.02	-0.003	-0.29
MAGMH	1.41	1.41	-0.002	-0.14
SEVMH	0.99	0.99	0	0.00
SOUMH	0.94	0.94	-0.002	-0.21
RHDMH	0.80	0.80	-0.002	-0.25
WSTMH	0.44	0.44	-0.001	-0.23
CB4MH	0.75	0.76	-0.002	-0.26
PAXMH	0.65	0.65	-0.001	-0.15
POTMH	0.72	0.72	0	0.00
CB5MH	0.55	0.55	-0.001	-0.18
LCHMH	0.58	0.58	0	0.00
CHOMH1	0.58	0.58	-0.001	-0.17
CHOMH2	0.80	0.80	0	0.00
EASMH	0.52	0.52	-0.001	-0.19
CHSMH	0.70	0.70	-0.001	-0.14
SASOH	1.37	1.37	-0.001	-0.07
BOHOH	1.13	1.13	-0.002	-0.18
ELKOH	0.97	0.97	0	0.00

Table 6-4 Calculated Anoxic Volume Days (10^6 m^3 d) for June - August 1996 With and Without Dredging 3 mcy

Region	Depth	Dredge 3 mcy	2008 Bathymetry	Change	Percent Change
PATMH	6.7 < d < 12.8	8724	8788	-64	-0.73
PAXMH	6.7 < d < 12.8	128	135	-8	-5.54
PAXMH	12.8 < d	32	34	-2	-5.06
POTMH	6.7 < d < 12.8	2229	2388	-159	-6.64
POTMH	12.8 < d	1469	1531	-62	-4.03
CB5MH	6.7 < d < 12.8	11627	12117	-490	-4.04
CB5MH	12.8 < d	12352	12691	-339	-2.67
CB4MH	6.7 < d < 12.8	22582	23281	-699	-3.00
CB4MH	12.8 < d	88097	89423	-1326	-1.48
LCHMH	6.7 < d < 12.8	2111	2113	-2	-0.10
CB3MH	6.7 < d < 12.8	12095	12317	-222	-1.80
CB3MH	12.8 < d	10211	10279	-69	-0.67
CB2OH	6.7 < d < 12.8	38	43	-6	-12.67
CHOMH1	6.7 < d < 12.8	936	938	-2	-0.21
CHOMH1	12.8 < d	684	688	-4	-0.60
CHOMH2	6.7 < d < 12.8	3729	3771	-42	-1.10
EASMH	6.7 < d < 12.8	14359	14512	-153	-1.05
EASMH	12.8 < d	8063	8099	-35	-0.44
CHSMH	6.7 < d < 12.8	10129	10211	-82	-0.80
CHSMH	12.8 < d	3382	3384	-2	-0.06
ELKOH	6.7 < d < 12.8	91	93	-2	-2.47
TOTAL	12.8 < d	213068	216836	-3767	-1.74

Table 6-5. Calculated Surface Chlorophyll (mg m-3) for 1996 SAV Growing Season With Dredging Back to 1996 Bathymetry				
Region	**Dredge Back to 1996**	**Equilibrium Bathymetry**	**Change**	**Percent Change**
NORTF	5.67	5.67	0	0.00
CB1TF	3.56	3.56	-0.003	-0.08
BSHOH	5.06	5.06	-0.004	-0.08
GUNOH	2.54	2.55	-0.005	-0.20
CB2OH	6.27	6.30	-0.029	-0.46
MIDOH	2.72	2.73	-0.007	-0.26
BACOH	6.81	6.82	-0.002	-0.03
PATMH	11.76	11.82	-0.061	-0.52
CB3MH	9.54	9.60	-0.067	-0.70
MAGMH	5.77	5.83	-0.069	-1.18
SEVMH	4.97	5.00	-0.038	-0.76
SOUMH	6.00	6.06	-0.063	-1.04
RHDMH	6.08	6.14	-0.064	-1.04
WSTMH	2.52	2.55	-0.029	-1.14
CB4MH	8.91	9.00	-0.084	-0.93
PAXMH	6.16	6.20	-0.032	-0.52
POTMH	9.09	9.12	-0.028	-0.31
CB5MH	7.62	7.67	-0.053	-0.69
LCHMH	2.42	2.45	-0.029	-1.19
CHOMH1	3.82	3.85	-0.03	-0.78
CHOMH2	8.39	8.42	-0.028	-0.33
EASMH	3.44	3.48	-0.044	-1.26
CHSMH	6.99	7.05	-0.056	-0.79
SASOH	6.59	6.61	-0.023	-0.35
BOHOH	4.18	4.19	-0.012	-0.29
ELKOH	4.09	4.11	-0.014	-0.34

Table 6-6 Calculated Light Attenuation (m^{-1}) for 1996 SAV Growing Season With Dredging Back to 1996 Bathymetry

Region	Dredge Back to 1996	Equilibrium Bathymetry	Change	Percent Change
NORTF	1.94	1.94	-0.004	-0.21
CB1TF	1.46	1.46	0	0.00
BSHOH	1.03	1.03	-0.002	-0.19
GUNOH	0.96	0.96	-0.004	-0.42
CB2OH	1.42	1.42	-0.003	-0.21
MIDOH	1.23	1.23	0	0.00
BACOH	3.13	3.13	-0.004	-0.13
PATMH	1.60	1.61	-0.004	-0.25
CB3MH	1.02	1.02	-0.003	-0.29
MAGMH	1.41	1.41	-0.002	-0.14
SEVMH	0.99	0.99	-0.001	-0.10
SOUMH	0.94	0.94	-0.003	-0.32
RHDMH	0.80	0.80	-0.002	-0.25
WSTMH	0.44	0.44	-0.001	-0.23
CB4MH	0.75	0.76	-0.003	-0.40
PAXMH	0.65	0.65	-0.001	-0.15
POTMH	0.72	0.72	0	0.00
CB5MH	0.55	0.55	-0.002	-0.36
LCHMH	0.58	0.58	0	0.00
CHOMH1	0.58	0.58	0	0.00
CHOMH2	0.80	0.80	-0.001	-0.12
EASMH	0.52	0.52	-0.001	-0.19
CHSMH	0.70	0.70	-0.002	-0.28
SASOH	1.37	1.37	-0.002	-0.15
BOHOH	1.13	1.13	-0.002	-0.18
ELKOH	0.98	0.98	-0.001	-0.10

Table 6-7 Calculated Anoxic Volume Days (10^6 m^3 d) for June - August 1996 With Dredging Back to 1996 Bathymetry

Region	Depth	Dredge Back to 1996	Equilibrium Bathymetry	Change	Percent Change
PATMH	6.7 < d < 12.8	8684	8789	-105	-1.20
PAXMH	6.7 < d < 12.8	126	135	-10	-7.09
PAXMH	12.8 < d	29	34	-5	-14.88
POTMH	6.7 < d < 12.8	2142	2386	-244	-10.22
POTMH	12.8 < d	1427	1531	-104	-6.80
CB5MH	6.7 < d < 12.8	11313	12107	-794	-6.56
CB5MH	12.8 < d	12145	12683	-538	-4.24
CB4MH	6.7 < d < 12.8	22216	23270	-1054	-4.53
CB4MH	12.8 < d	87208	89407	-2199	-2.46
LCHMH	6.7 < d < 12.8	2107	2113	-6	-0.30
CB3MH	6.7 < d < 12.8	11956	12314	-358	-2.90
CB3MH	12.8 < d	10172	10279	-107	-1.04
CB2OH	6.7 < d < 12.8	37	43	-6	-14.52
CHOMH1	6.7 < d < 12.8	934	938	-4	-0.43
CHOMH1	12.8 < d	680	688	-8	-1.19
CHOMH2	6.7 < d < 12.8	3703	3767	-64	-1.70
EASMH	6.7 < d < 12.8	14248	14508	-260	-1.79
EASMH	12.8 < d	8028	8099	-71	-0.87
CHSMH	6.7 < d < 12.8	10079	10213	-134	-1.32
CHSMH	12.8 < d	3370	3384	-14	-0.41
ELKOH	6.7 < d < 12.8	90	93	-3	-3.12
TOTAL	12.8 < d	210691	216780	-6089	-2.81

Table 6-8 Calculated Anoxic Volume Days (10^6 m^3 d) for June - August 1996 With and Without Sediment Bypassing					
Region	**Depth**	**With Bypassing**	**Without Bypassing**	**Change**	**Percent Change**
PATMH	6.7 < d < 12.8	10600	8724	1875	21.5
PAXMH	6.7 < d < 12.8	232	128	104	81.1
PAXMH	12.8 < d	78	32	46	143.9
POTMH	6.7 < d < 12.8	5365	2229	3137	140.7
POTMH	12.8 < d	2824	1469	1355	92.2
CB5MH	6.7 < d < 12.8	18941	11627	7314	62.9
CB5MH	12.8 < d	18334	12352	5982	48.4
CB4MH	6.7 < d < 12.8	33690	22582	11108	49.2
CB4MH	12.8 < d	109774	88097	21677	24.6
LCHMH	6.7 < d < 12.8	2288	2111	177	8.4
CB3MH	6.7 < d < 12.8	16021	12095	3926	32.5
CB3MH	12.8 < d	11717	10211	1506	14.7
CB2OH	6.7 < d < 12.8	132	38	94	248.3
CHOMH1	6.7 < d < 12.8	1070	936	133	14.2
CHOMH1	12.8 < d	765	684	81	11.9
CHOMH2	6.7 < d < 12.8	4664	3729	935	25.1
EASMH	6.7 < d < 12.8	16741	14359	2382	16.6
EASMH	12.8 < d	8849	8063	786	9.7
CHSMH	6.7 < d < 12.8	11748	10129	1619	16.0
CHSMH	12.8 < d	3766	3382	384	11.3
ELKOH	6.7 < d < 12.8	212	91	121	133.3
TOTAL	12.8 < d	277810	213068	64741	30.4

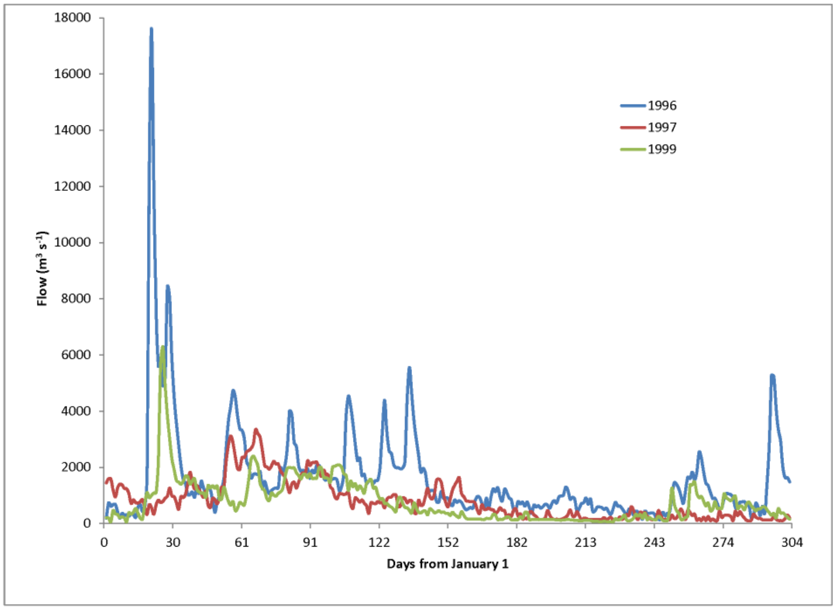


Figure 6-1. Gauged flow at the Conowingo outfall for the months January – October 1996, 1997, 1999.

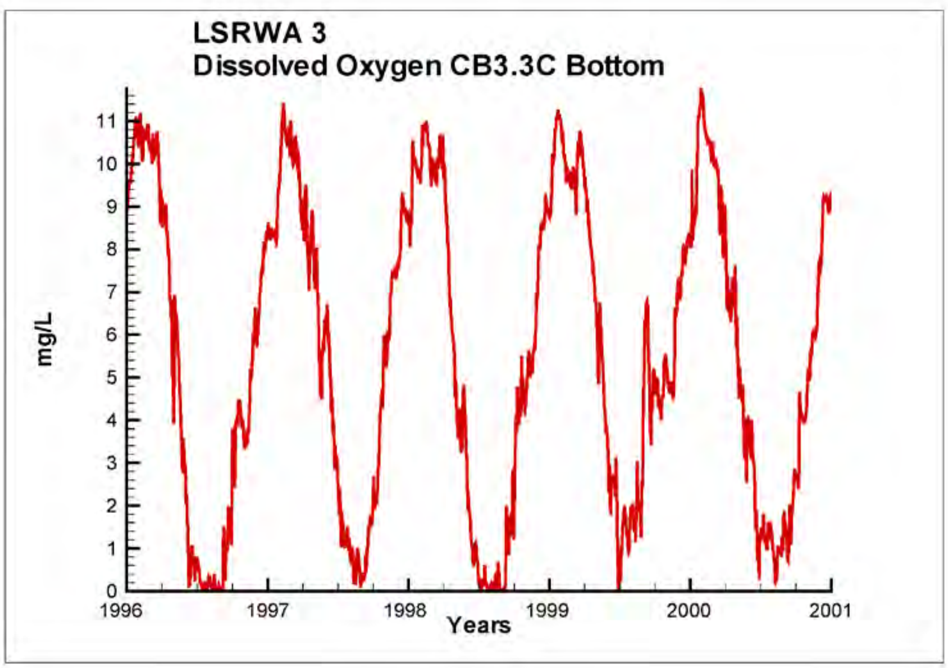


Figure 6-2. Computed DO concentration for the base scenario at the bottom of Station CB3.3C (Figure 5-1), located at the head of the deep trench where hypoxia is most intense.

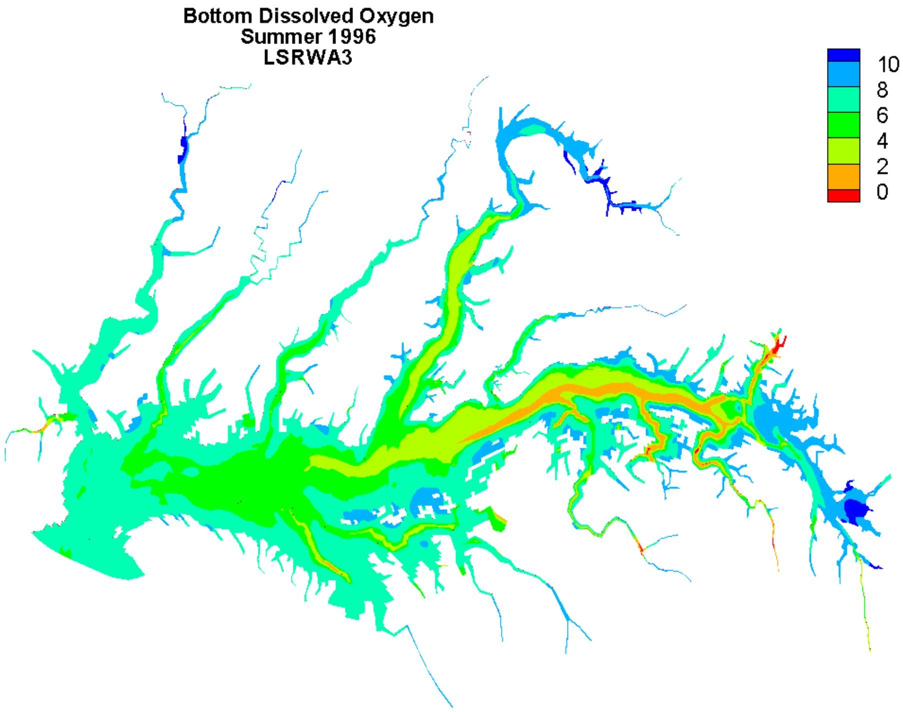


Figure 6-3. Computed bottom DO concentration (g m^{-3} or mg/L) for the base scenario, averaged over June – August 1996.

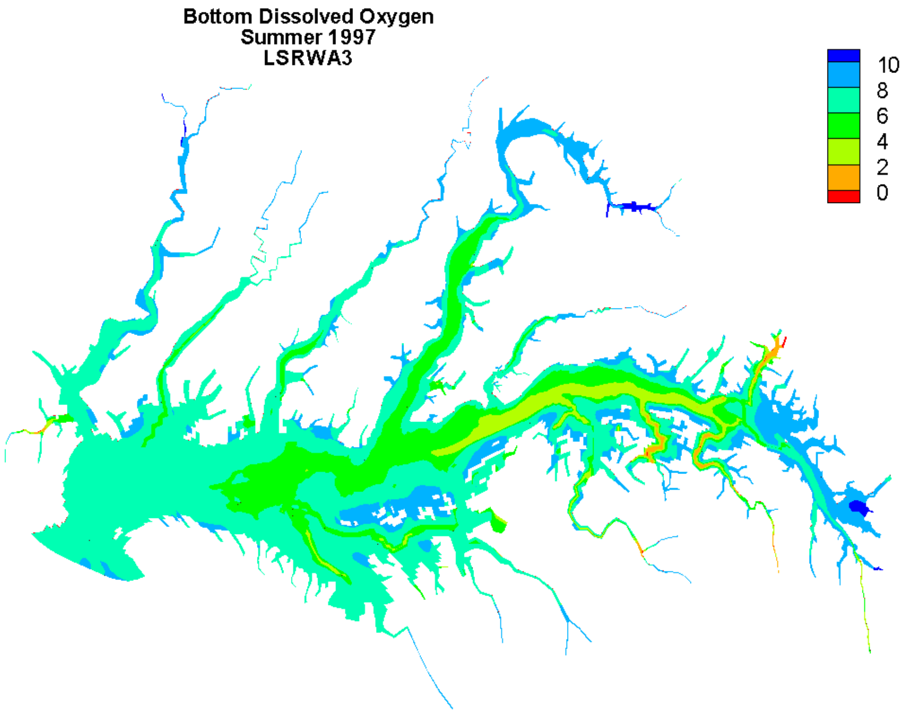


Figure 6-4. Computed bottom DO concentration (g m^{-3} or mg/L) for the base scenario, averaged over June – August 1997.

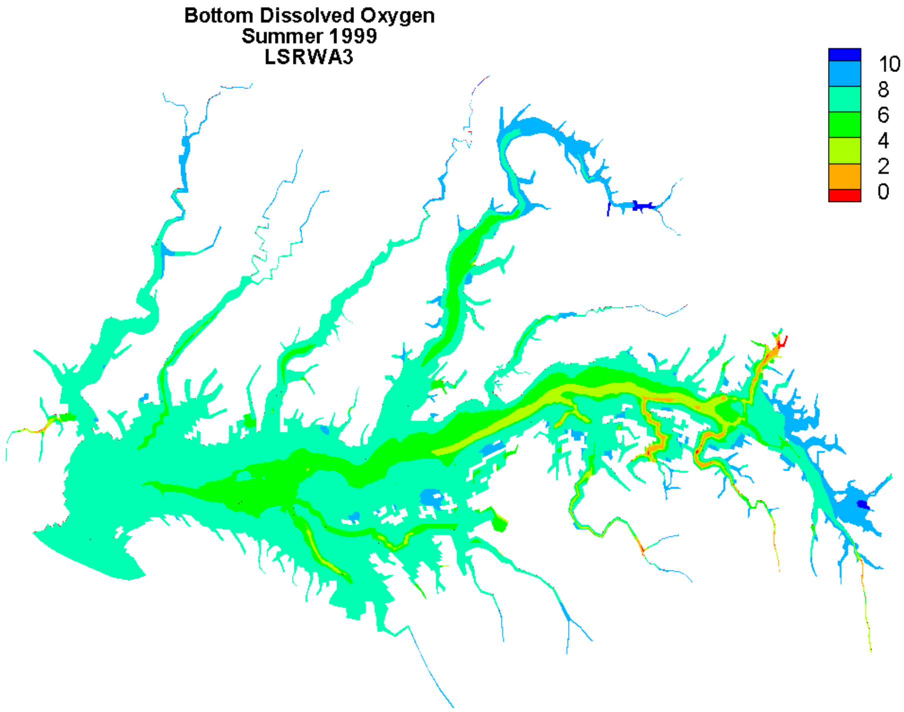


Figure 6-5. Computed bottom DO concentration (g m^{-3} or mg/L) for the base scenario, averaged over June – August 1999.

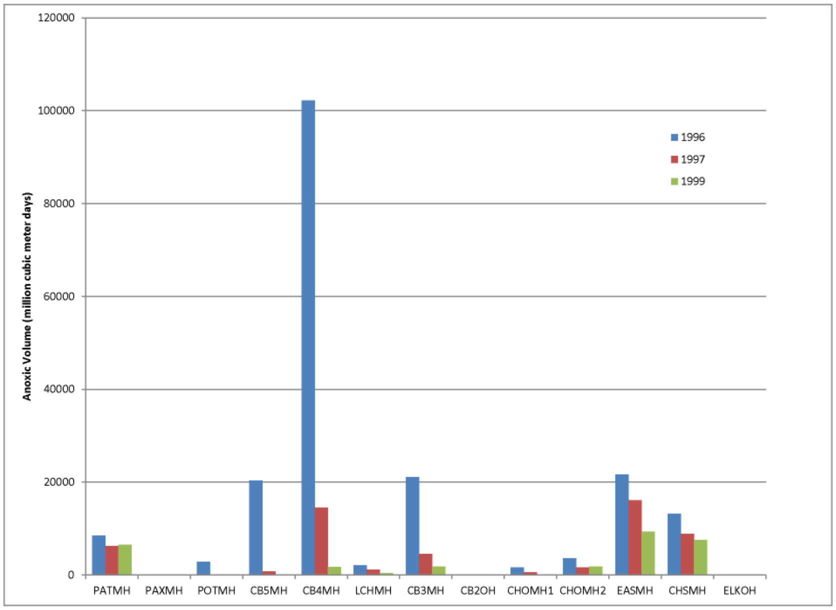


Figure 6-6. Computed anoxic volume days for the base scenario for three years: 1996, 1997, 1999.

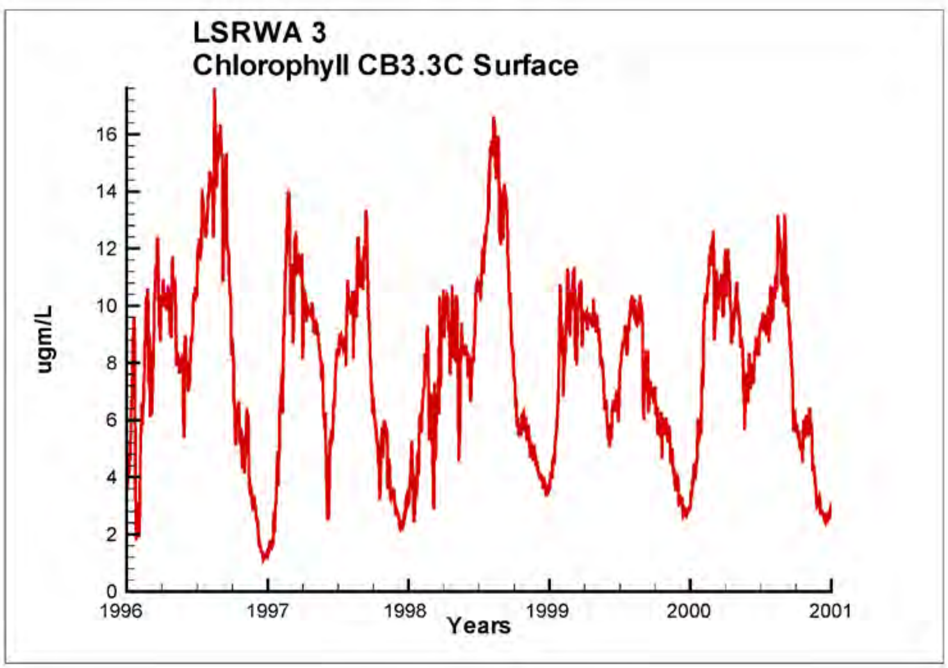


Figure 6-7. Computed chlorophyll concentration for the base scenario at the surface of Station CB3.3C (Figure 5-1).

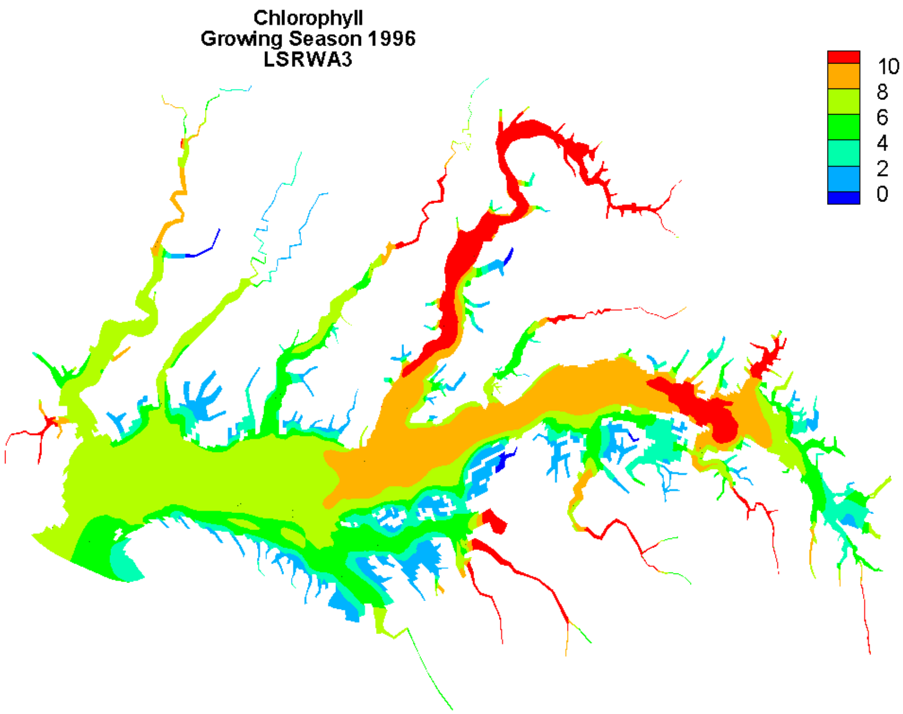


Figure 6-8. Computed surface chlorophyll concentration (mg m^{-3} or µg/L) for the base scenario, averaged over the SAV growing season April – October 1996.

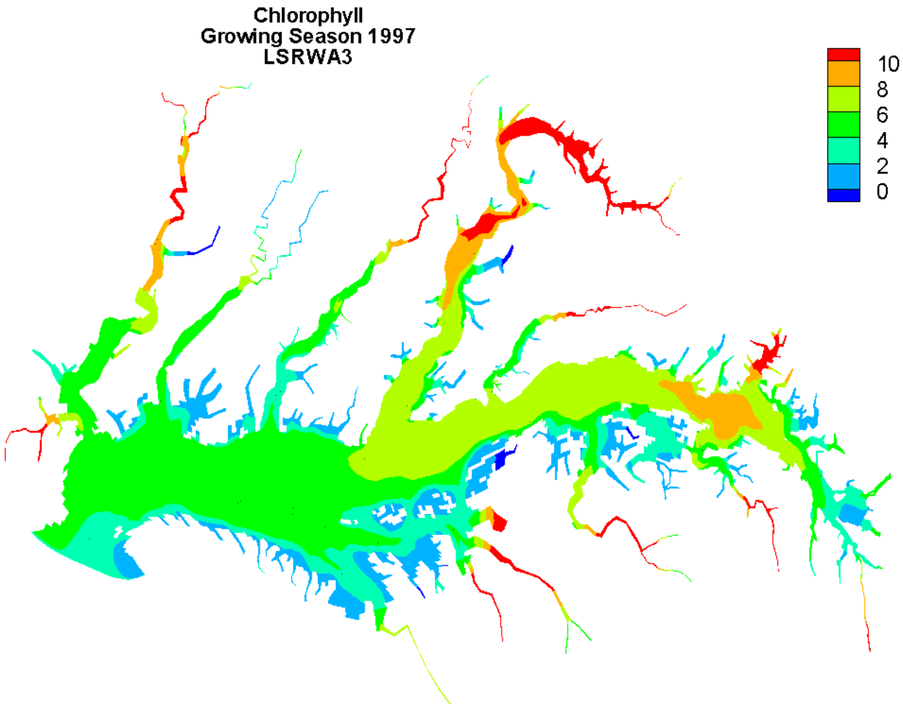


Figure 6-9. Computed surface chlorophyll concentration (mg m^{-3} or µg/L) for the base scenario, averaged over the SAV growing season April – October 1997.

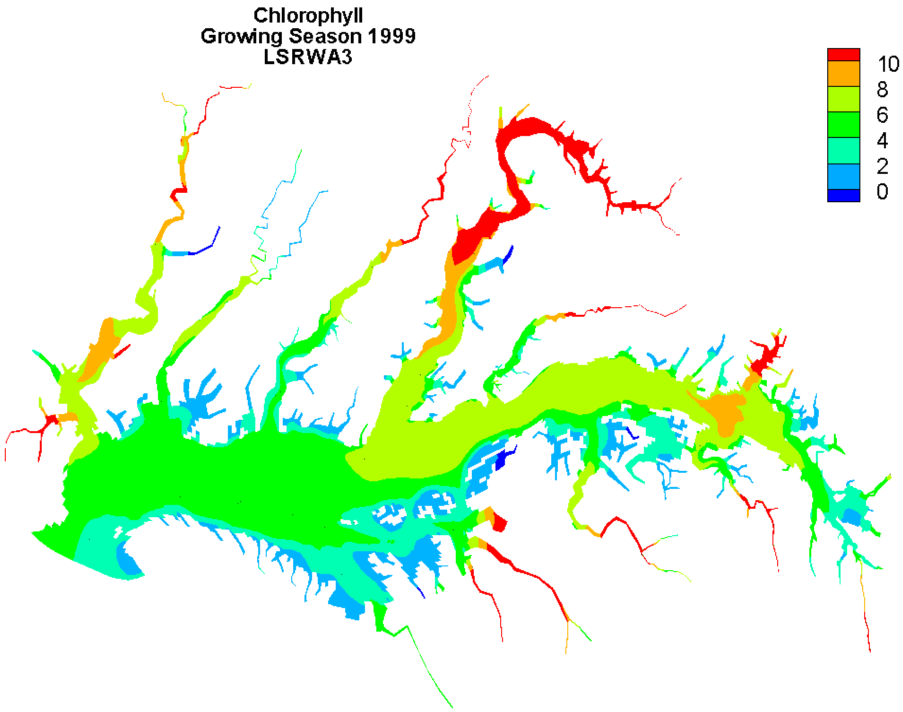


Figure 6-10. Computed surface chlorophyll concentration (mg m^{-3} or µg/L) for the base scenario, averaged over the SAV growing season April – October 1999.

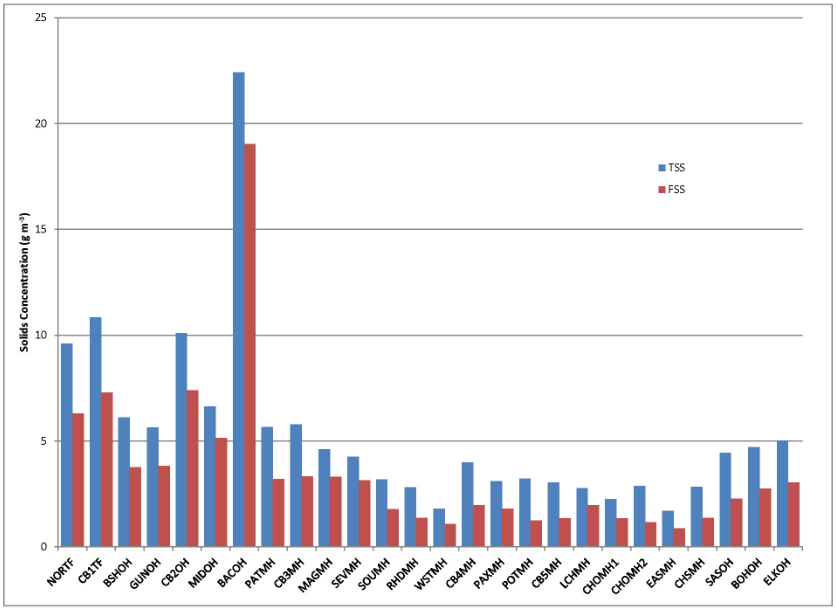


Figure 6-11. Computed total and fixed suspended solids in upper bay CBPS for the base scenario. Results are averaged over the SAV growing season, April – October, 1996.

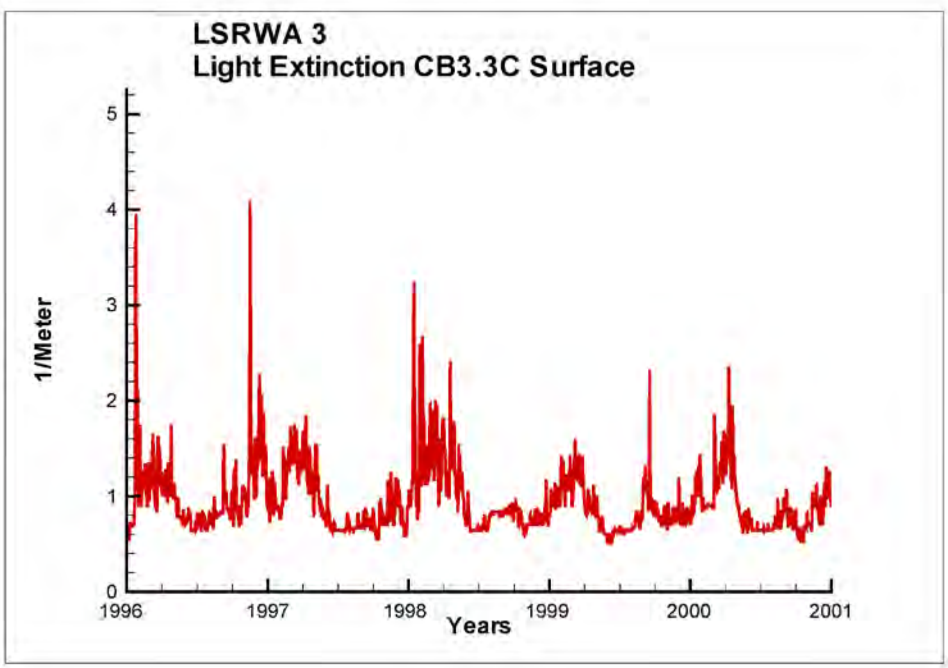


Figure 6-12. Computed light attenuation for the base scenario at the surface of Station CB3.3C (Figure 5-1).

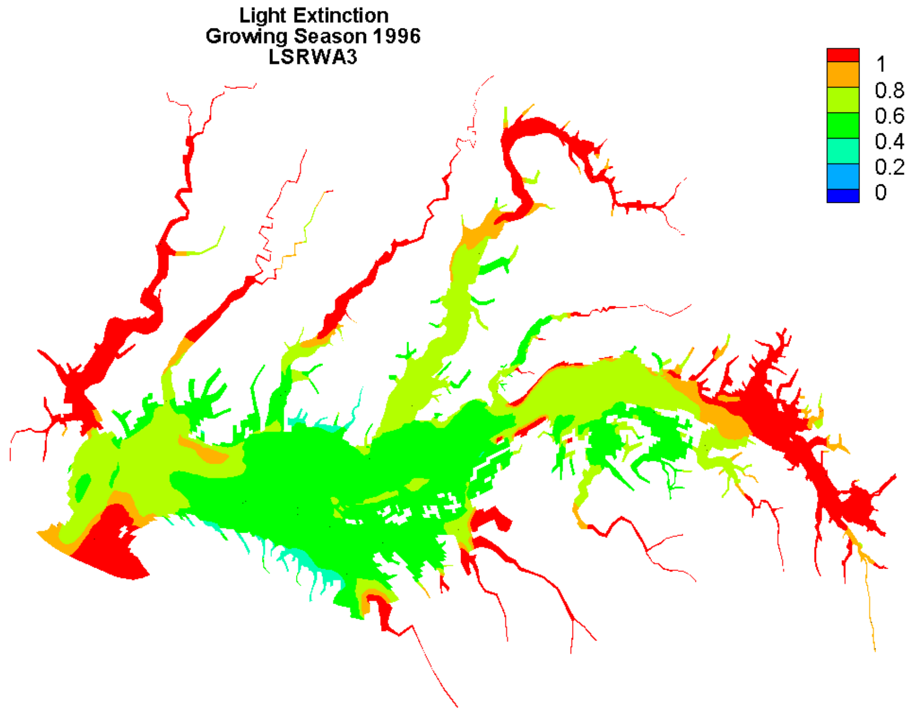


Figure 6-13. Computed light attenuation (m^{-1} or 1/m) for the base scenario, averaged over the SAV growing season April – October 1996.

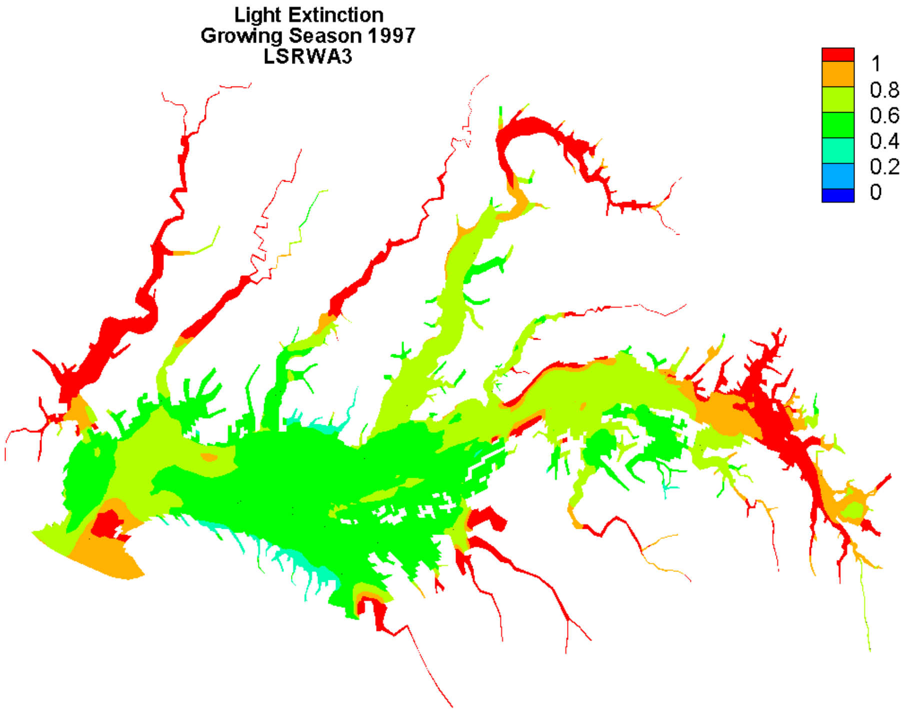


Figure 6-14. Computed light attenuation (m^{-1} or 1/m) for the base scenario, averaged over the SAV growing season April – October 1997.

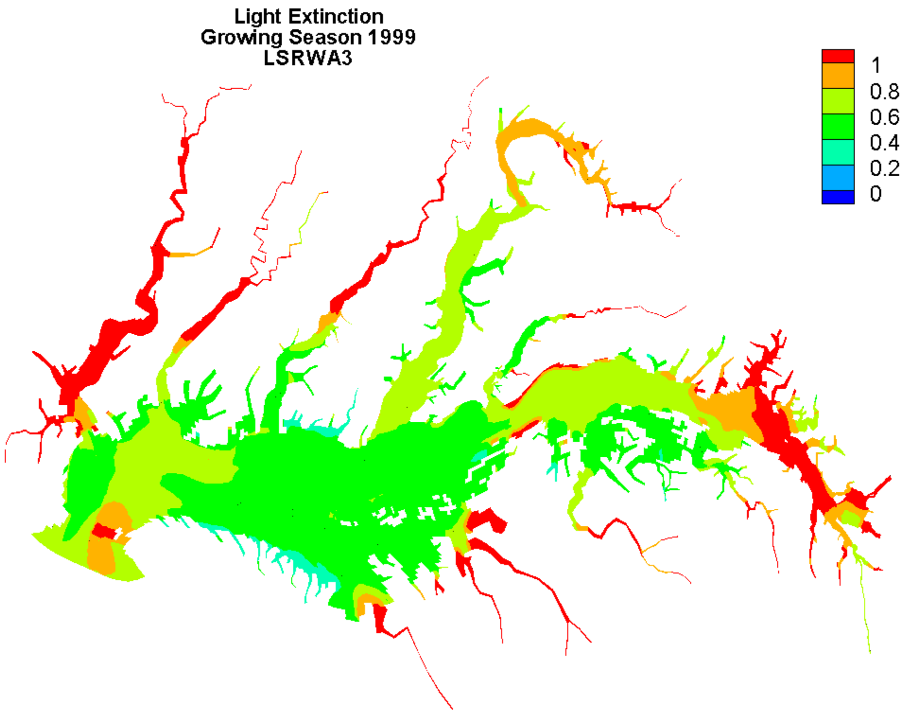


Figure 6-15. Computed light attenuation (m^{-1} or 1/m) for the base scenario, averaged over the SAV growing season April – October 1999.

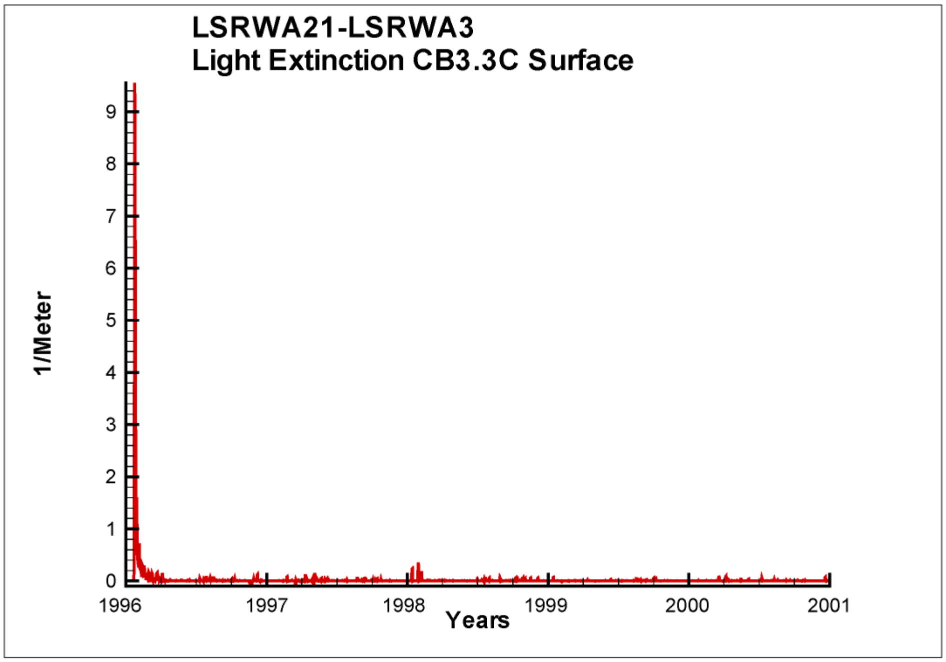


Figure 6-16. Additional light attenuation computed at Station CB3.3C as a result of January 1996 storm scour. Positive values indicate an increase in attenuation relative to the base scenario.

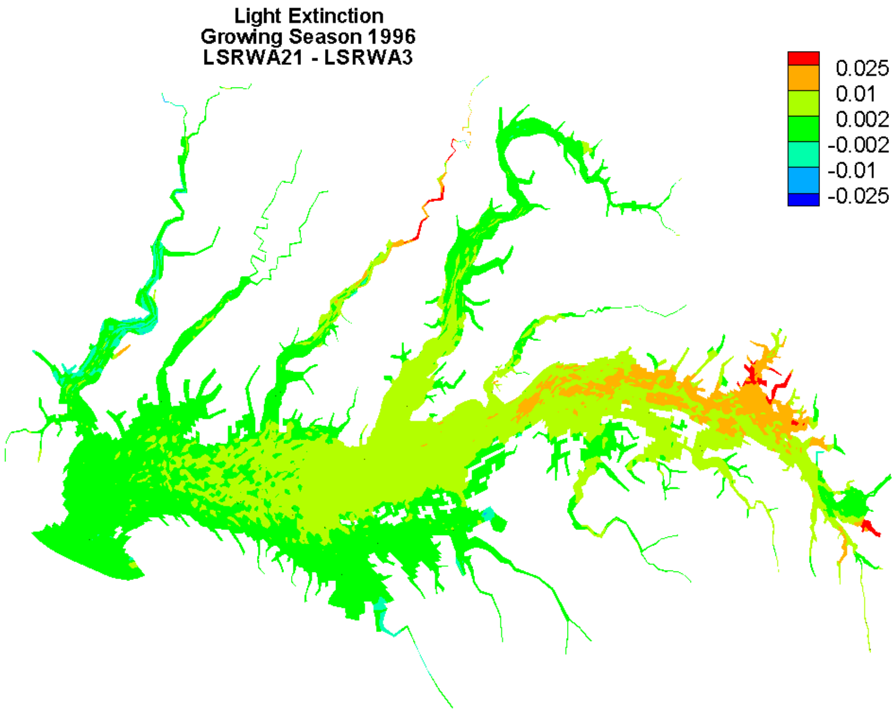


Figure 6-17. Computed additional light attenuation (m^{-1} or 1/m) as a result of January 1996 storm scour, averaged over 1996 SAV growing season. Positive values indicate an increase in attenuation relative to the base scenario.

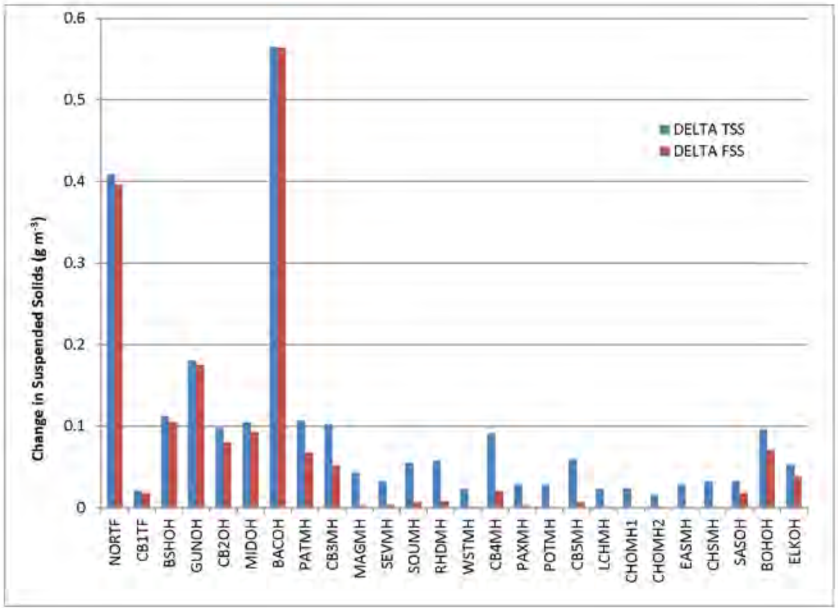


Figure 6-18. Computed additional total and fixed solids resulting from the January 1996 scour event. Results are shown for upper bay CBPS, averaged over the 1996 SAV growing season.

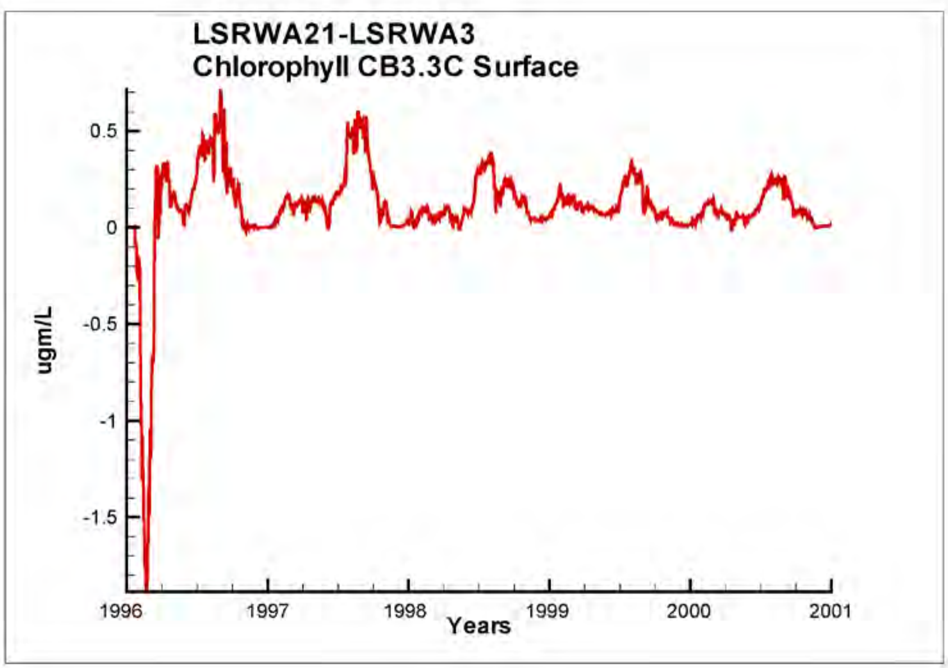


Figure 6-19. Computed change in surface chlorophyll at Station CB3.3C resulting from January 1996 scour event. Positive values indicate an increase relative to the base case; negative values indicate a decrease.

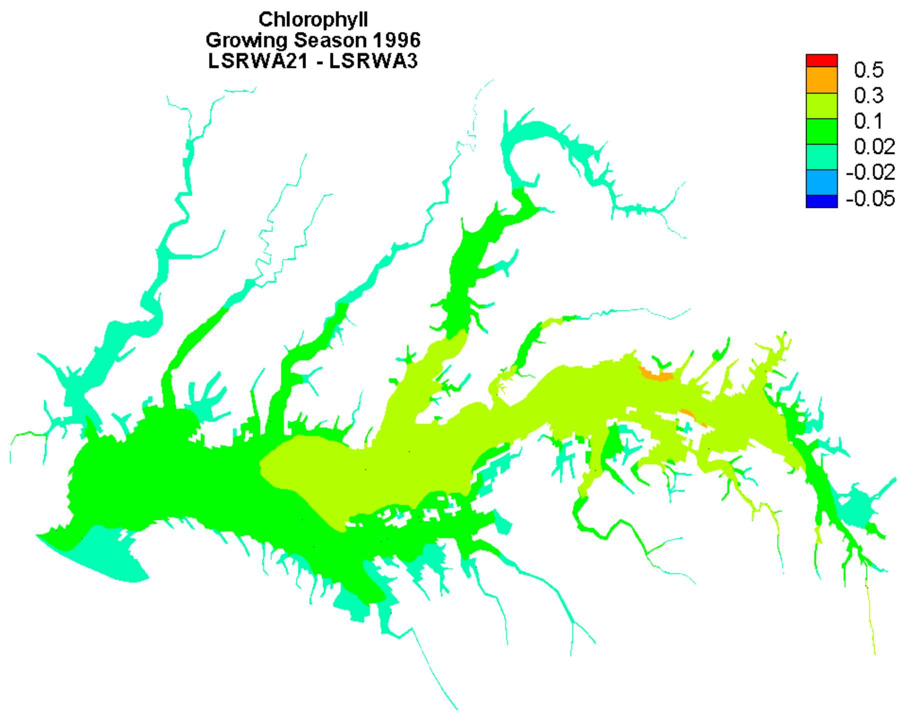


Figure 6-20. Computed additional surface chlorophyll (mg m^{-3} or µg/L) as a result of January 1996 storm scour, averaged over 1996 SAV growing season. Positive values indicate an increase relative to the base scenario.

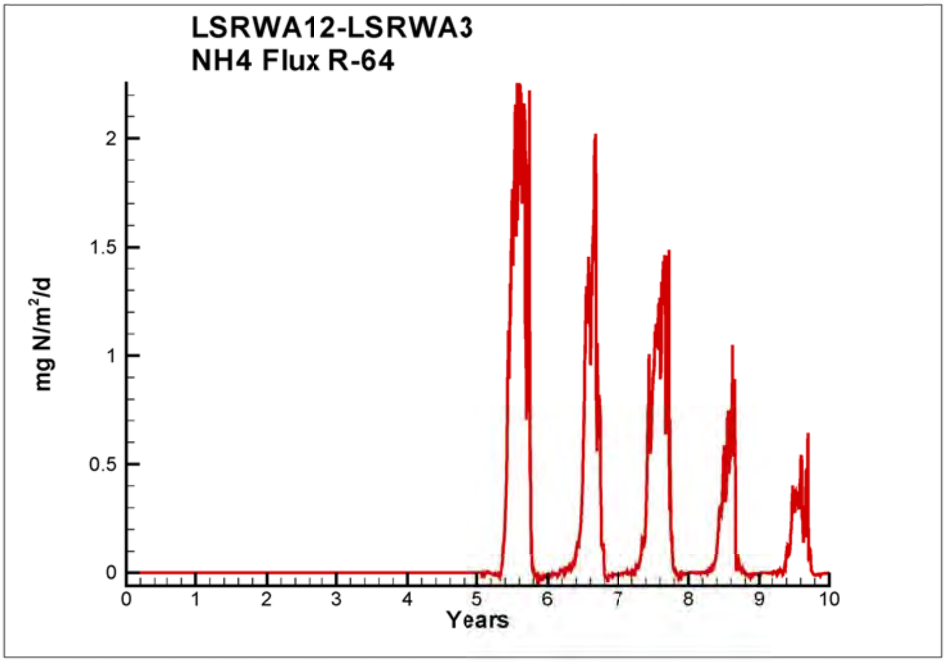


Figure 6-21. Computed additional sediment ammonium release as a result of January 1996 storm scour. Results are shown for SONE station R-64 which is adjacent to CB4.2C (Figure 5-1). The horizontal axis includes the years 1991 – 1995 (Years 0 – 5) and 1996 – 2000 (Years 5 – 10). Positive values indicate an increase in nutrient release relative to the base scenario. The release increases by 16.2% over the base value in the first summer following the storm.

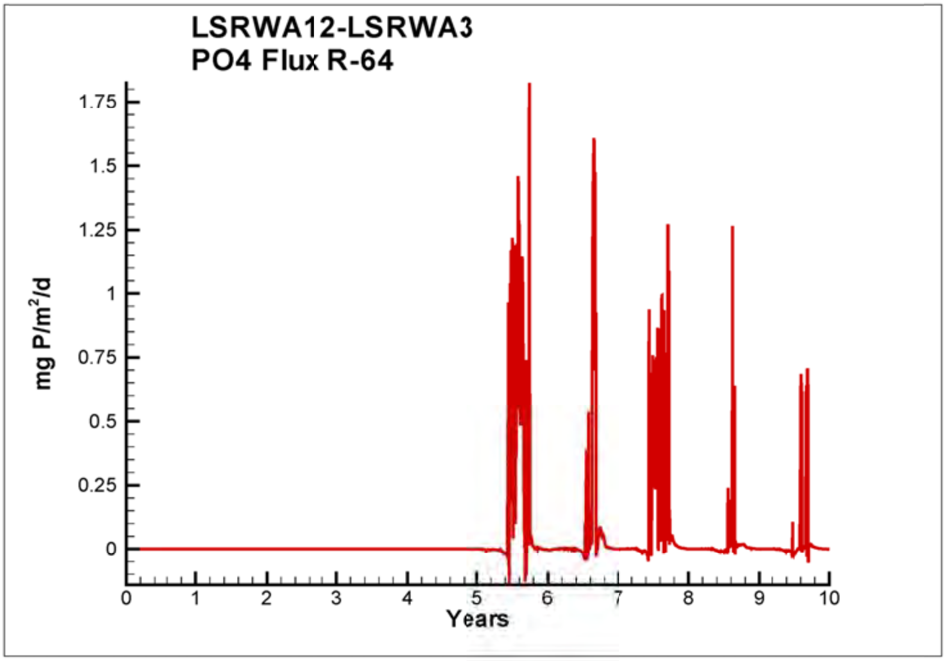


Figure 6-22. Computed additional sediment phosphate release as a result of January 1996 storm scour. Results are shown for SONE station R-64 which is adjacent to CB4.2C (Figure 5-1). The horizontal axis includes the years 1991 – 1995 (Years 0 – 5) and 1996 – 2000 (Years 5 – 10). Positive values indicate an increase in nutrient release relative to the base scenario. The release increases by 7.8% over the base value in the first summer following the storm.

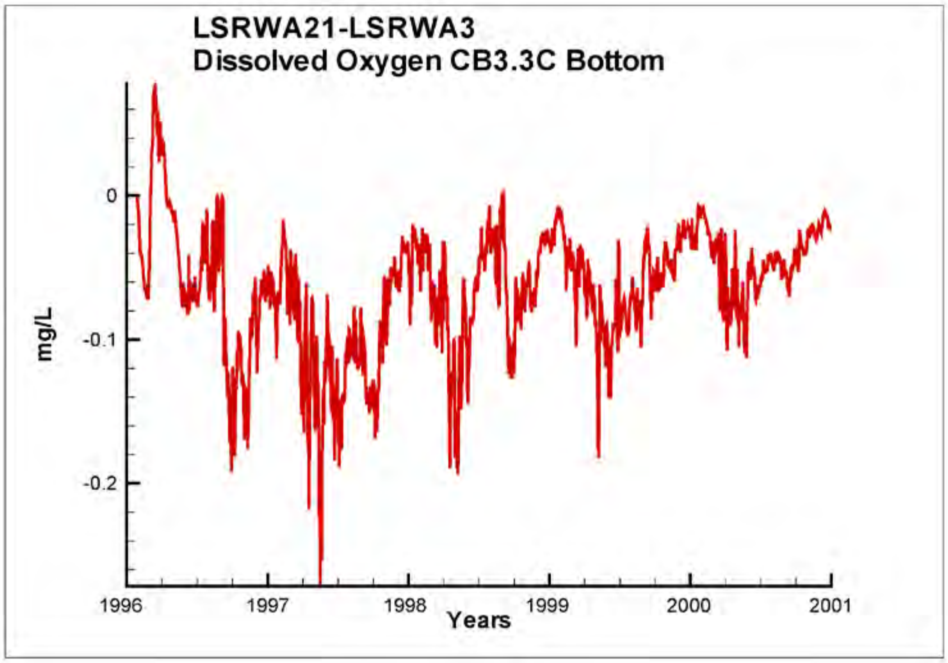


Figure 6-23. Computed change in bottom DO at Station CB3.3C resulting from January 1996 scour event. Positive values indicate an increase relative to the base case; negative values indicate a decrease.

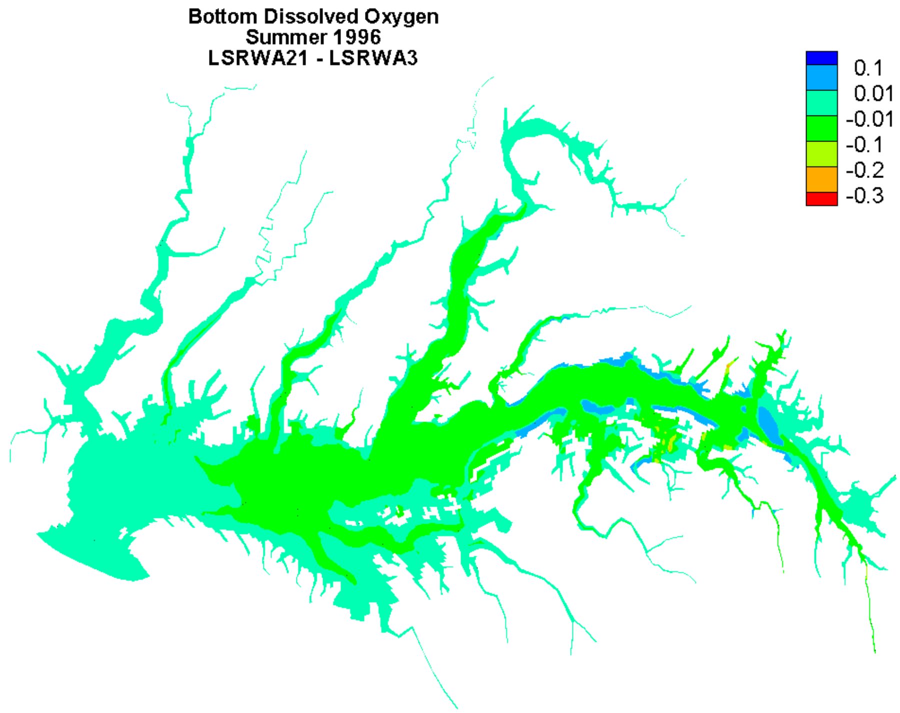


Figure 6-24. Computed change in bottom DO concentration (g m^{-3} or mg/L) as a result of January 1996 storm scour, averaged over June – August 1996. Positive values indicate an increase relative to the base scenario; negative values indicate a decrease.

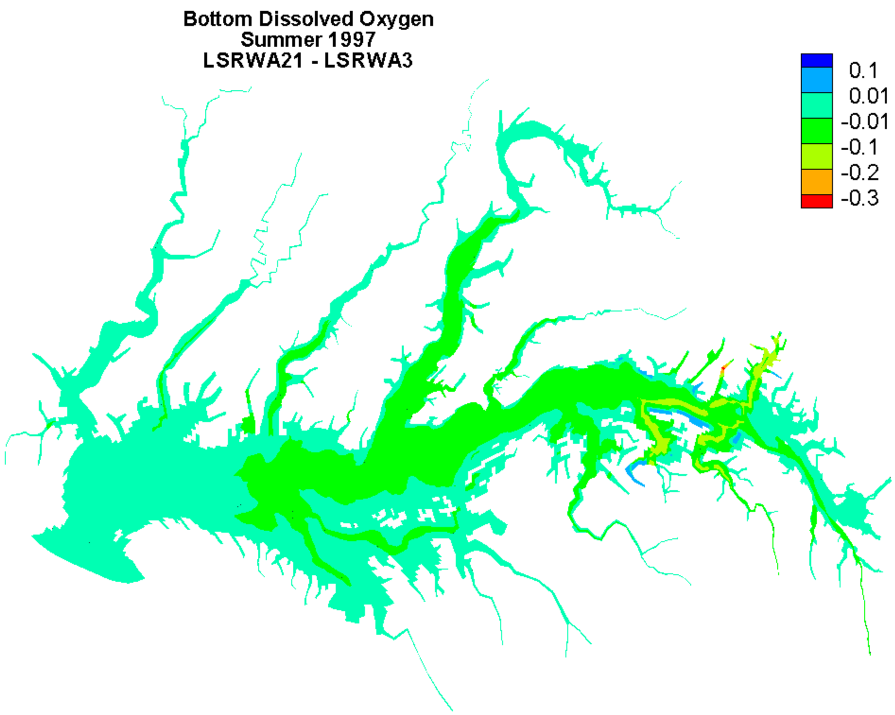


Figure 6-25. Computed change in bottom DO concentration (g m^{-3} or mg/L) as a result of January 1996 storm scour, averaged over June – August 1997. Positive values indicate an increase relative to the base scenario; negative values indicate a decrease.

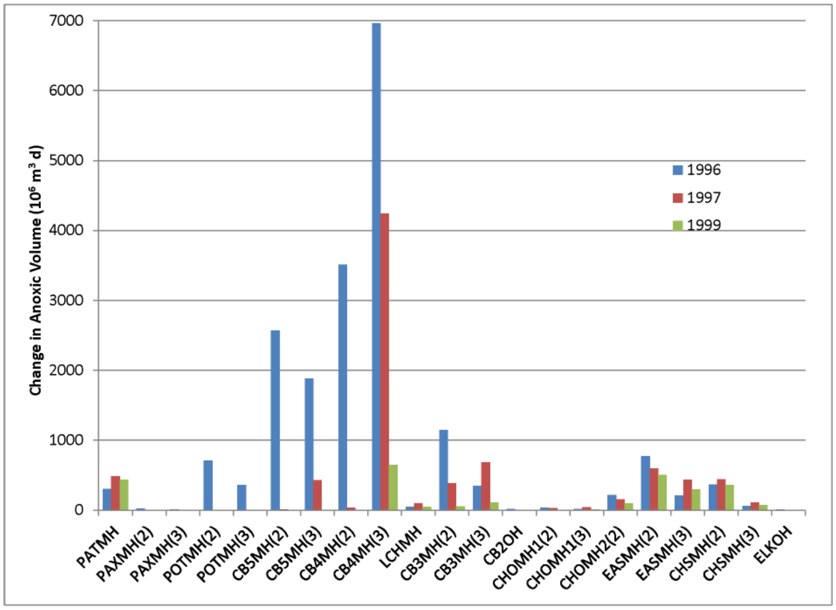


Figure 6-26. Computed additional anoxic volume days as a result of January 1996 storm scour. (2) indicates the pycnocline region between 6.7 and 12.8 m depths. (3) indicates deep water greater than 12.8 m. Note that in 1996, anoxia moves up from deep water into the pycnocline for several CBPS.

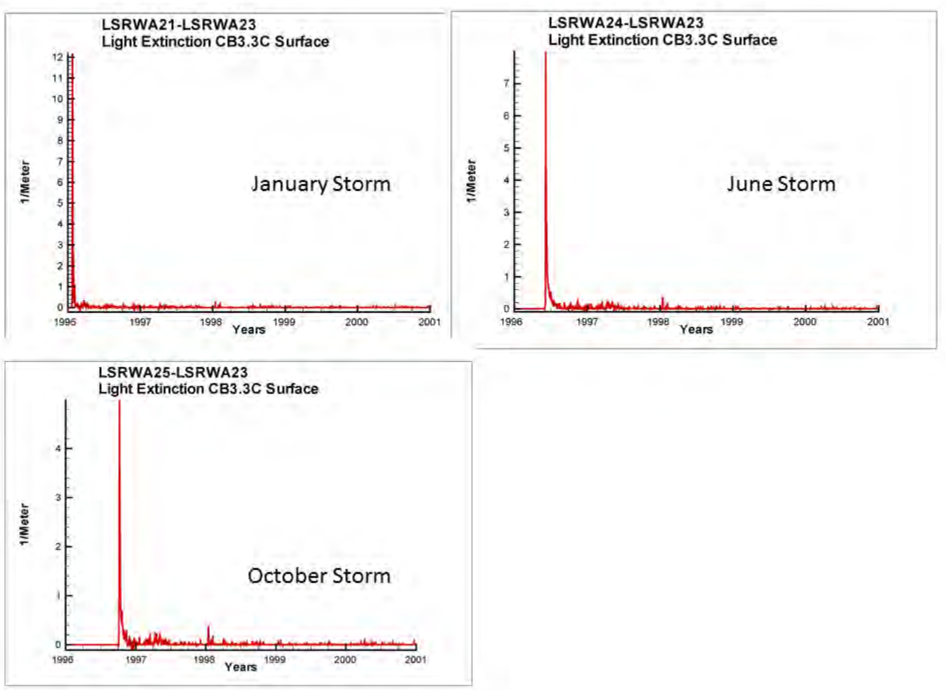


Figure 6-27. Computed increase in light attenuation at Station CB3.3C resulting from storm events in January, June, and October. Results are compared to a base case with no storm.

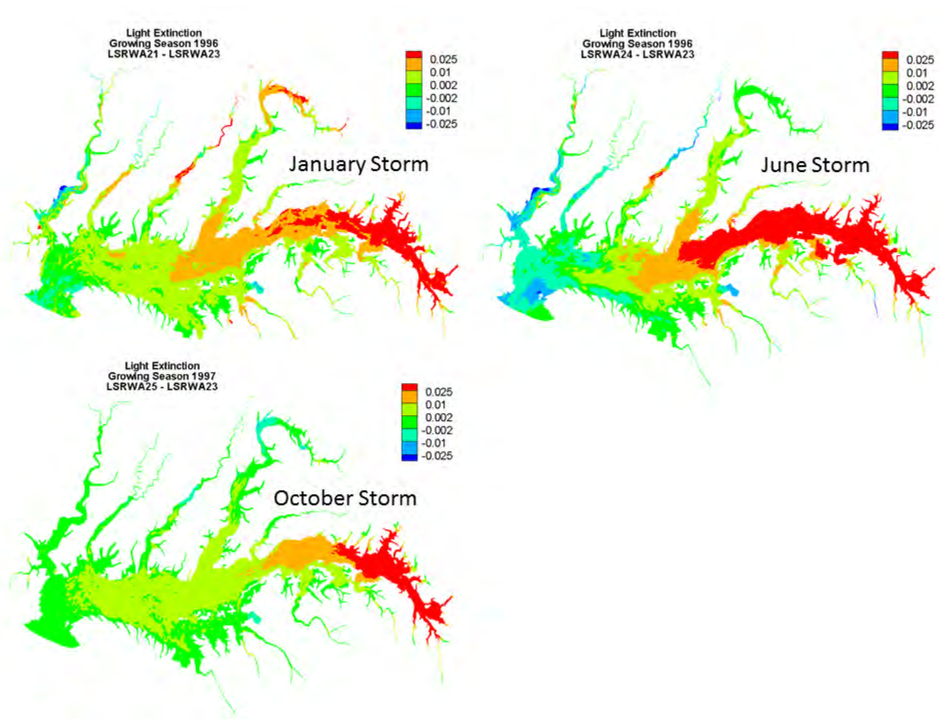


Figure 6-28. Computed change in light attenuation (m^{-1} or 1/m) resulting from storms in January, June, and October, averaged over SAV growing season. Positive values indicate an increase relative to the base scenario; negative values indicate a decrease. Note that the results for the October 1996 storm are shown for 1997 since the storm occurs at the end of the 1996 SAV growing season.

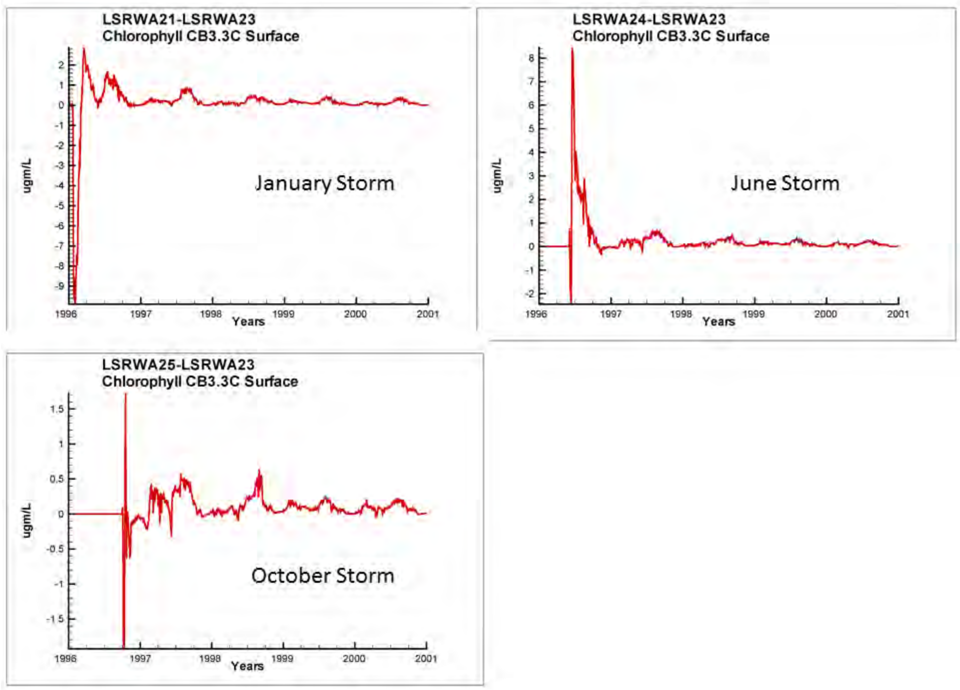


Figure 6-29. Computed change in surface chlorophyll at Station CB3.3C resulting from storm events in January, June, and October. Results are compared to a base case with no storm. Positive values indicate an increase relative to the base scenario; negative values indicate a decrease.

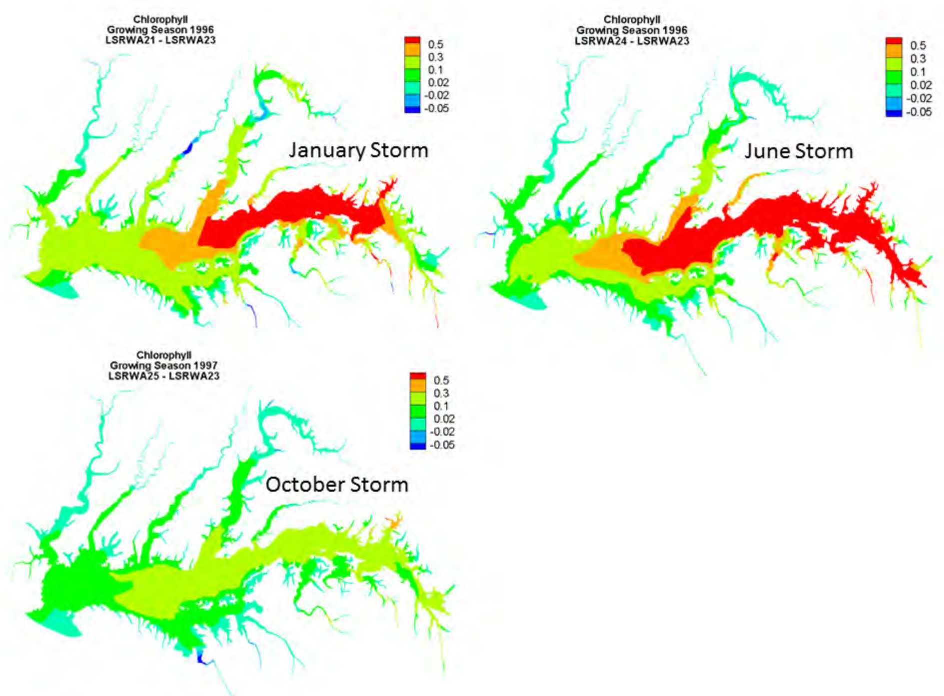


Figure 6-30. Computed change in surface chlorophyll (mg m^{-3} or µg/L) resulting from storms in January, June, and October, averaged over SAV growing season. Positive values indicate an increase relative to the base scenario; negative values indicate a decrease. Note that the results for the October 1996 storm are shown for 1997 since the storm occurs at the end of the 1996 SAV growing season.

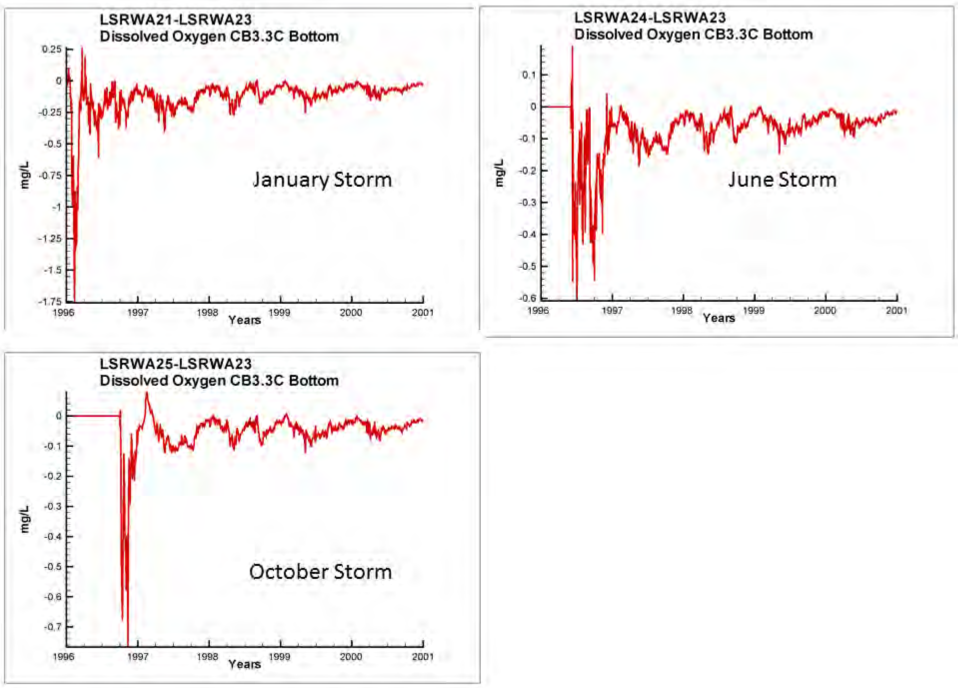


Figure 6-31. Computed change in bottom DO at Station CB3.3C resulting from storm events in January, June, and October. Results are compared to a base case with no storm. Positive values indicate an increase relative to the base scenario; negative values indicate a decrease.

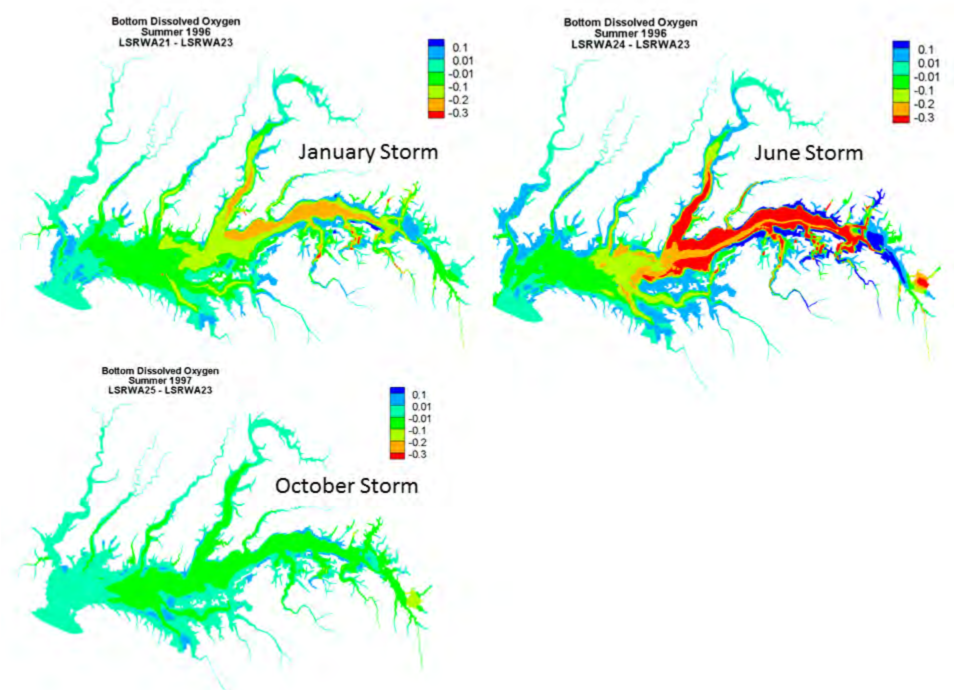


Figure 6-32. Computed change in bottom DO concentration (g m^{-3} or mg/L) resulting from storms in January, June, and October, averaged over June - August. Positive values indicate an increase relative to the base scenario; negative values indicate a decrease. Note that the results for the October 1996 storm are shown for 1997 since the storm occurs at the end of the 1996 SAV growing season.

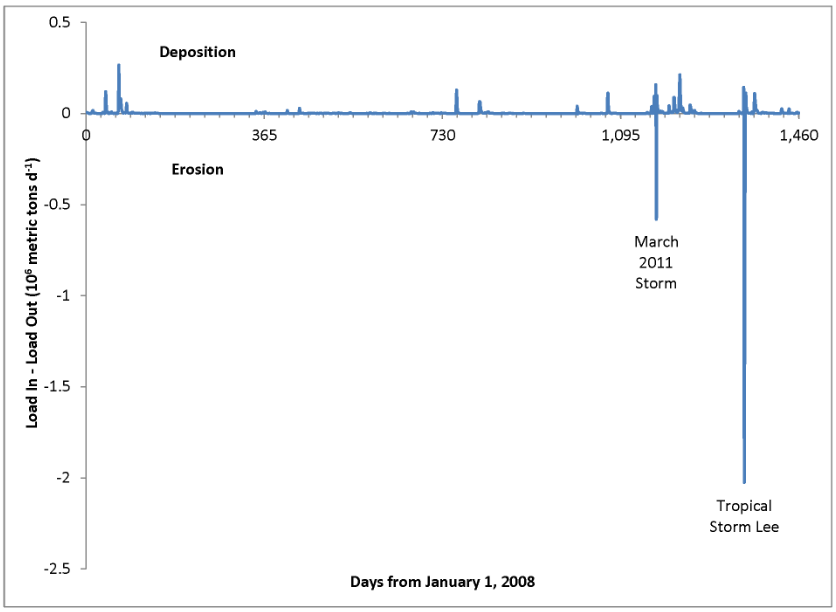


Figure 6-33. Difference between modeled solids loads into Conowingo Reservoir and modeled solids loads out for "Equilibrium Bathymetry." The reservoir is depositional up to the 2011 scour events despite the equilibrium bathymetry.

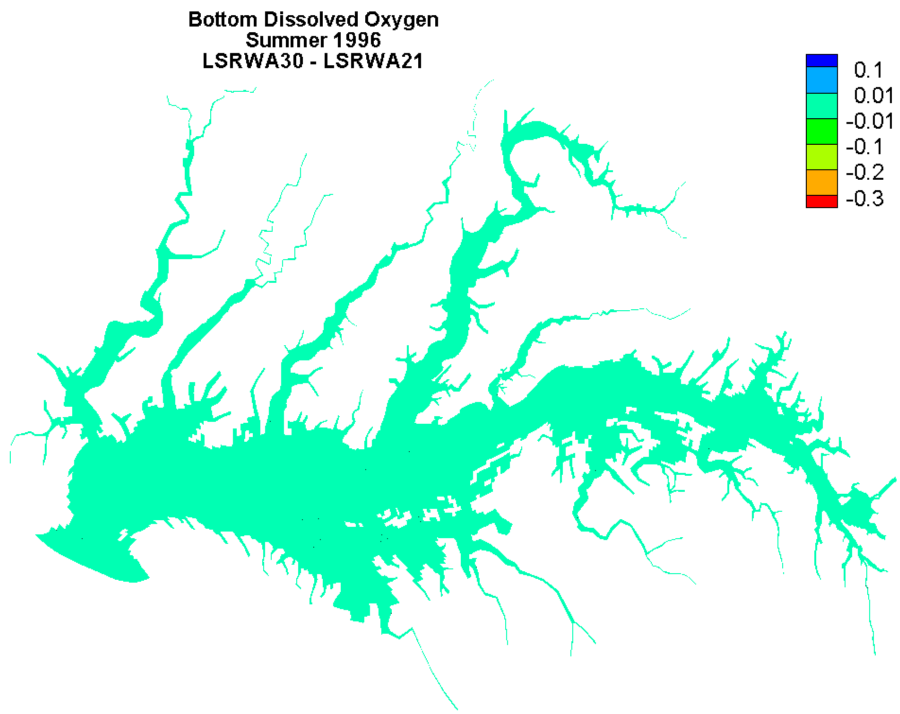


Figure 6-34. Computed change in bottom DO concentration (g m^{-3} or mg/L) when reservoir scour is computed based on equilibrium bathymetry. The base scenario has scour based on 2008 bathymetry. Results are averaged over June – August 1996. Computed differences are negligible.

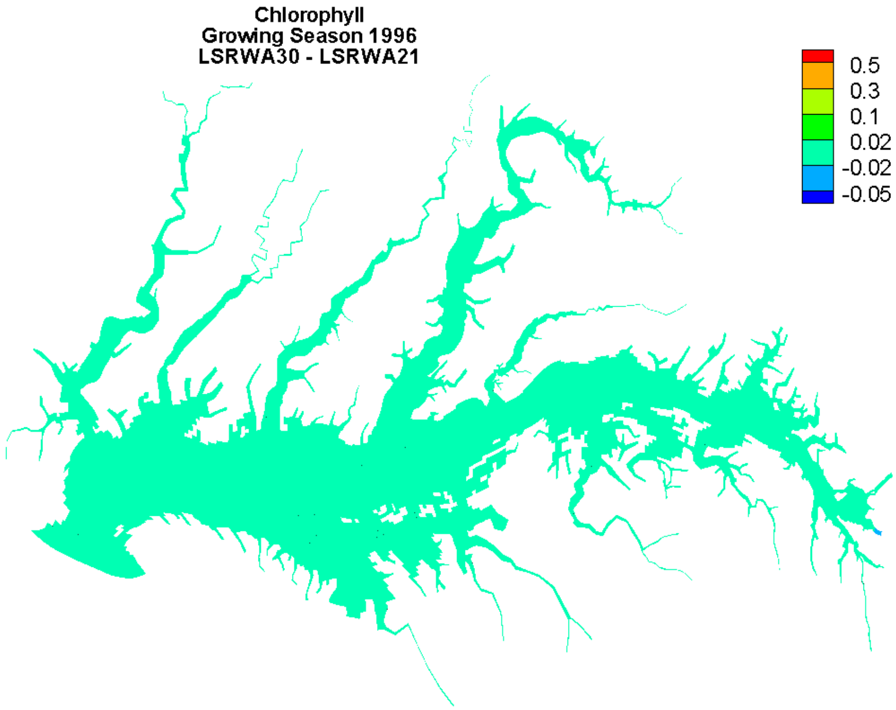


Figure 6-35. Computed change in surface chlorophyll concentration (mg m^{-3} or µg/L) when reservoir scour is computed based on equilibrium bathymetry. The base scenario has scour based on 2008 bathymetry. Results are averaged over the SAV growing season for 1996. Computed differences are negligible.

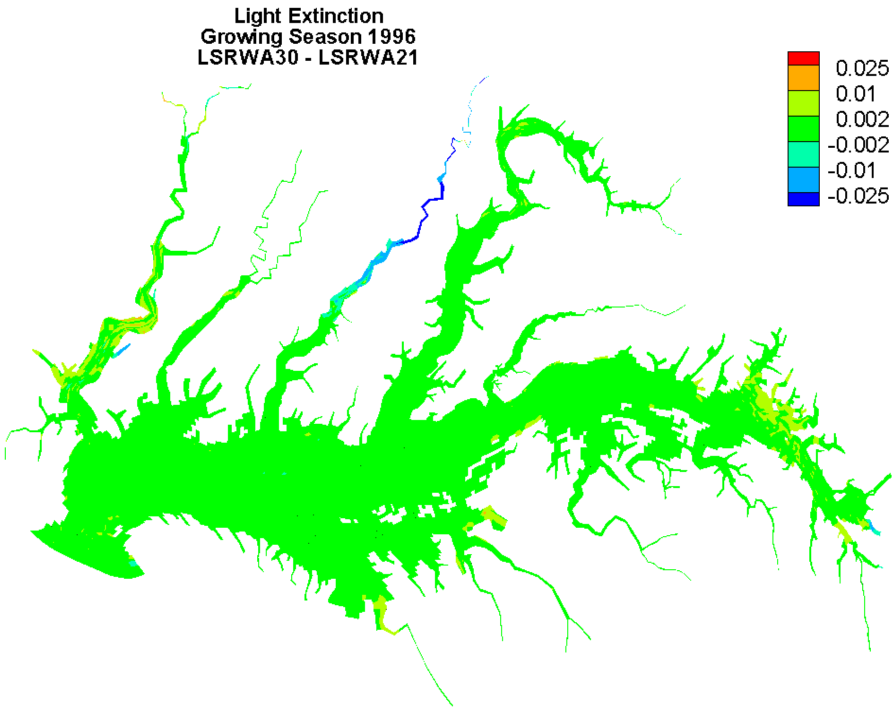


Figure 6-36. Computed change in light attenuation (m^{-1} or 1/m) when reservoir scour is computed based on equilibrium bathymetry. The base scenario has scour based on 2008 bathymetry. Results are averaged over the SAV growing season for 1996. Computed differences are negligible.

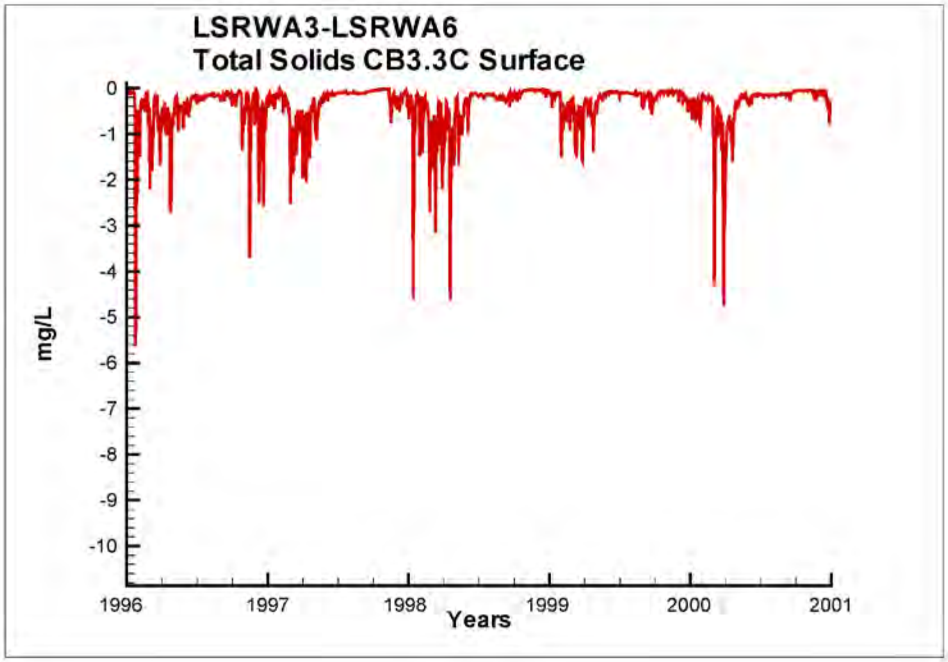


Figure 6-37. Computed effect of processes in Conowingo Reservoir on surface TSS at Station CB3.3C in Chesapeake Bay. Negative values indicate concentrations are lower as a result of reservoir processes.

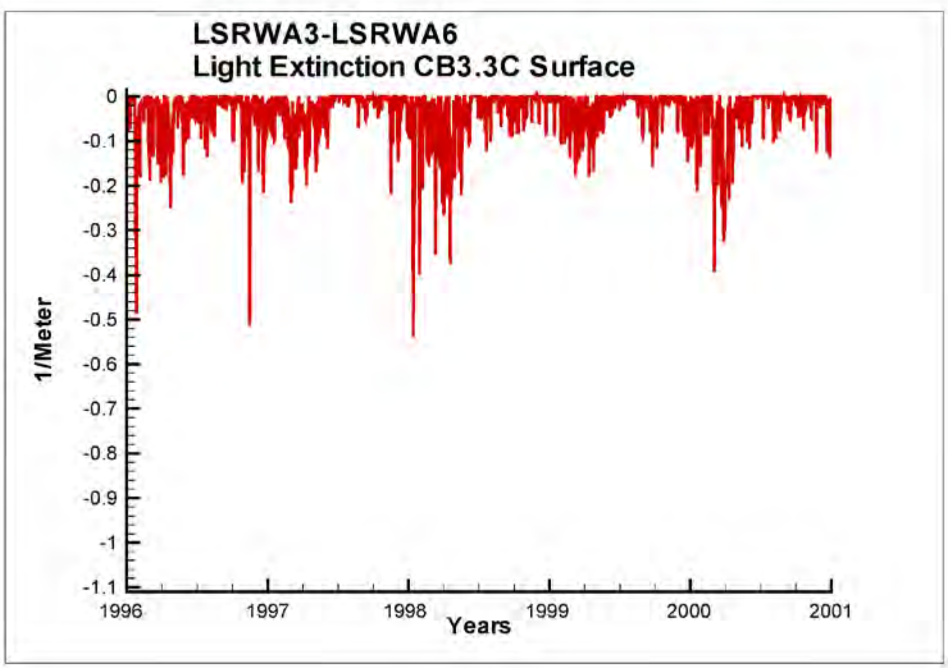


Figure 6-38. Computed effect of processes in Conowingo Reservoir on light attenuation at Station CB3.3C in Chesapeake Bay. Negative values indicate attenuation is lower as a result of reservoir processes.

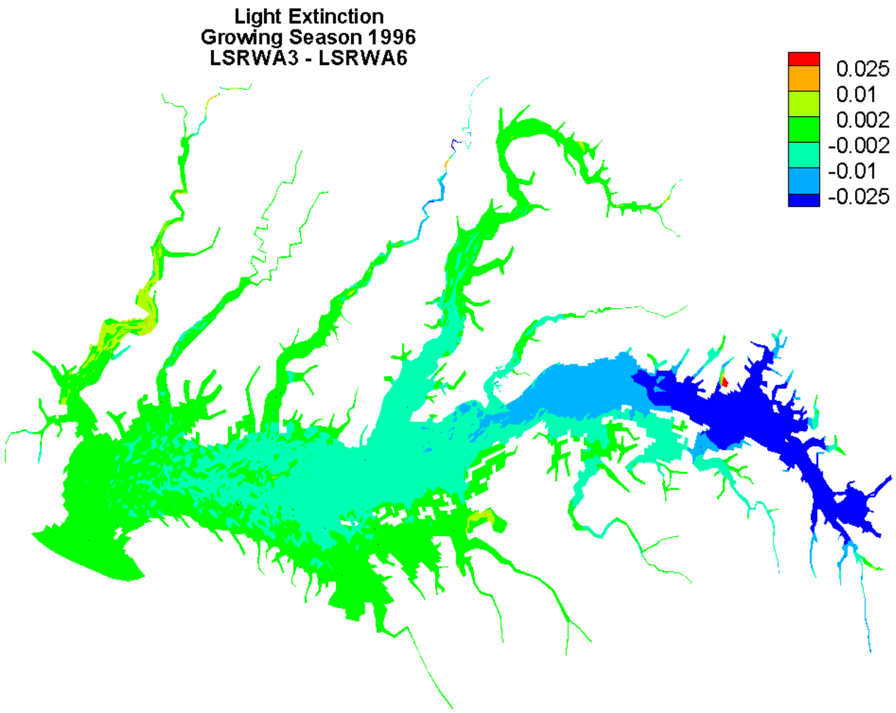


Figure 6-39. Computed effect of processes in Conowingo Reservoir on light attenuation (m^{-1} or 1/m) in Chesapeake Bay, averaged over 1996 SAV growing season. Negative values indicate attenuation is lower as a result of reservoir processes.

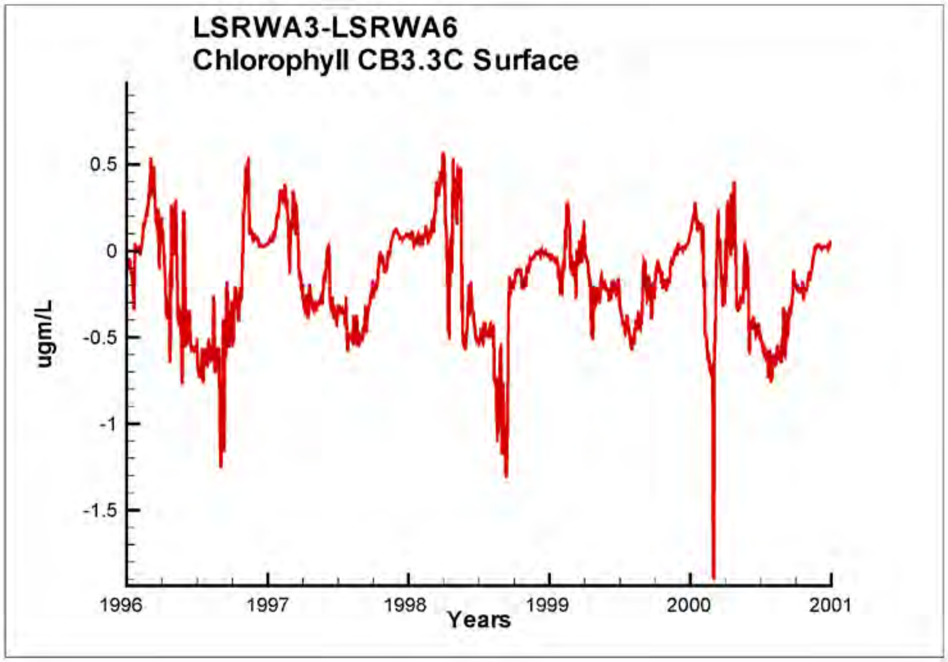


Figure 6-40. Computed effect of processes in Conowingo Reservoir on surface chlorophyll at Station CB3.3C in Chesapeake Bay. Negative values indicate chlorophyll is lower as a result of reservoir processes; positive values indicate chlorophyll is higher as a result of reservoir processes.

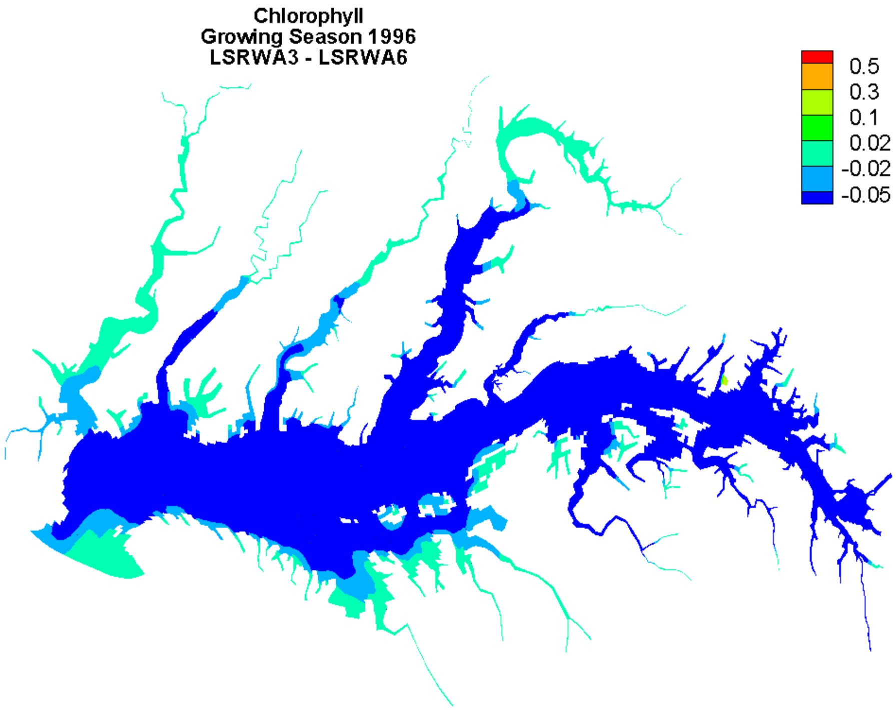


Figure 6-41. Computed effect of processes in Conowingo Reservoir on surface chlorophyll (mg m^{-3} or µg/L) in Chesapeake Bay, averaged over 1996 SAV growing season. Negative values indicate chlorophyll is lower as a result of reservoir processes.

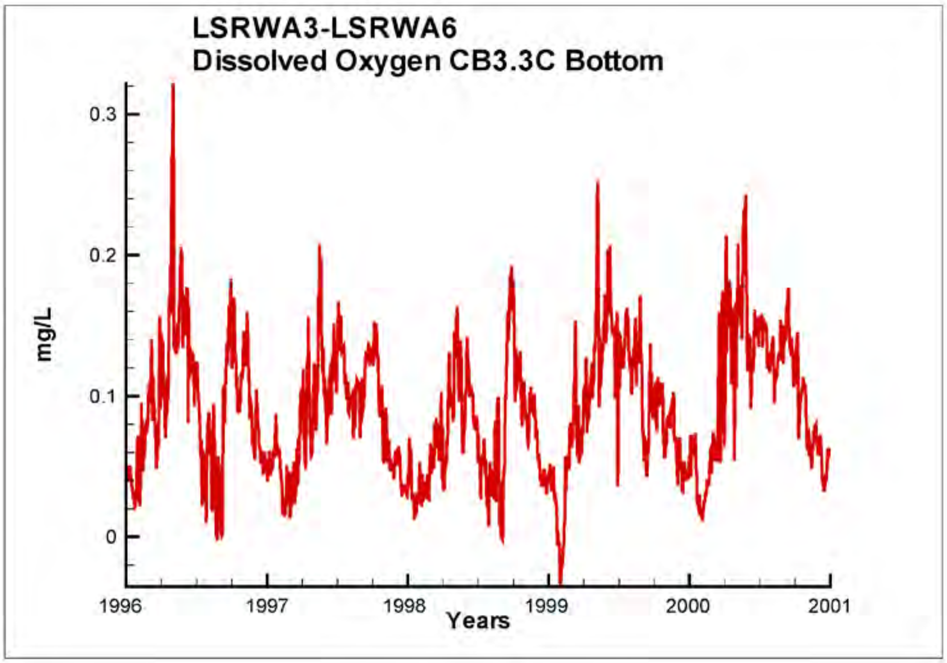


Figure 6-42. Computed effect of processes in Conowingo Reservoir on bottom dissolved oxygen at Station CB3.3C in Chesapeake Bay. Positive values indicate DO is higher as a result of reservoir processes.

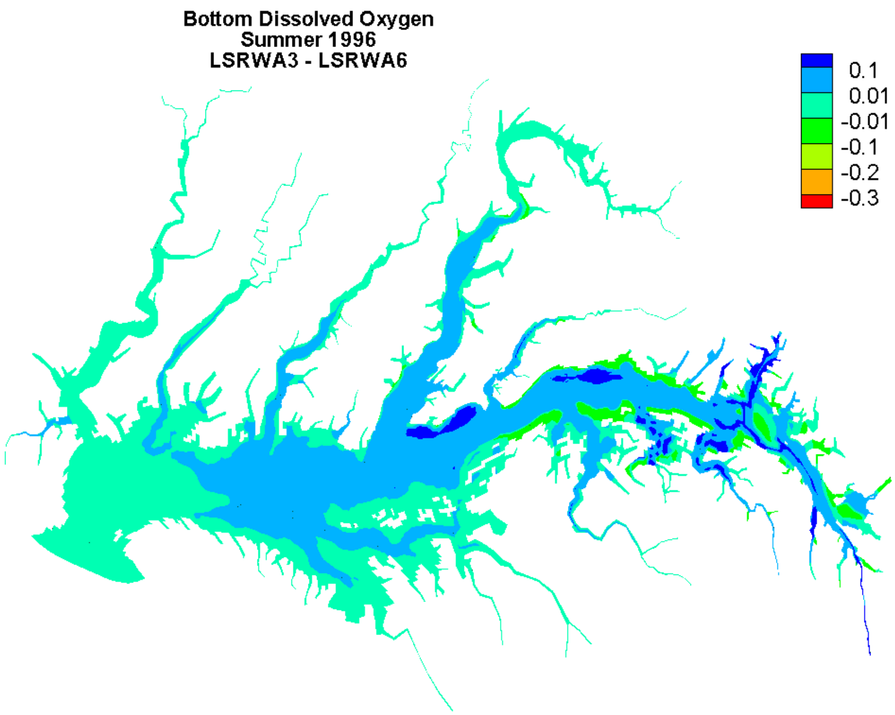


Figure 6-43. Computed effect of processes in Conowingo Reservoir on bottom dissolved oxygen concentration (g m^{-3} or mg/L) in Chesapeake Bay, averaged over June – August 1996. Positive values indicate DO is higher as a result of reservoir processes.

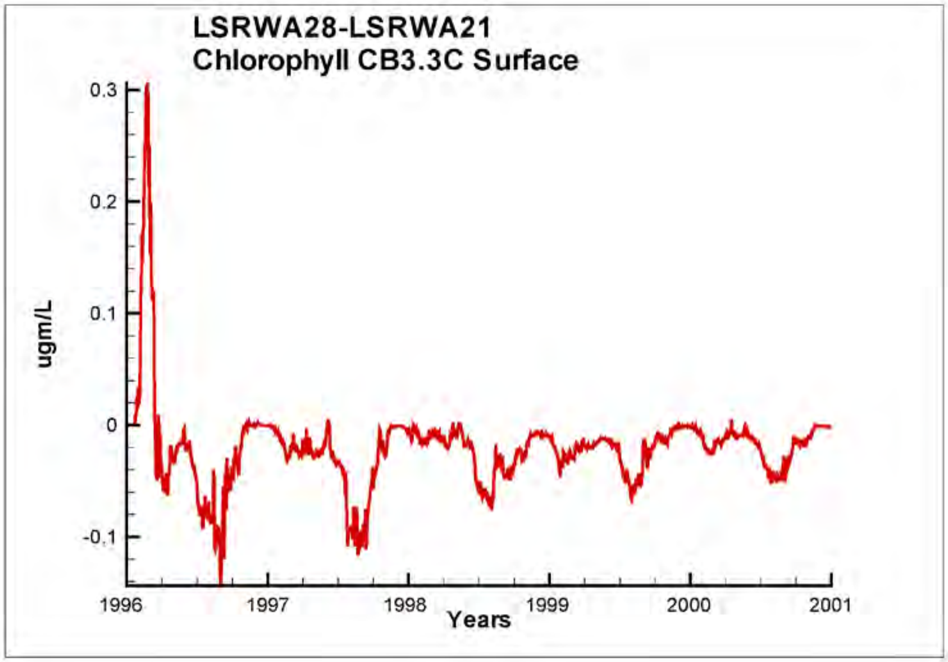


Figure 6-44. Computed effect of dredging 3 mcy from Conowingo Reservoir on surface chlorophyll at Station CB3.3C in Chesapeake Bay. Negative values indicate chlorophyll is lower as a result of dredging.

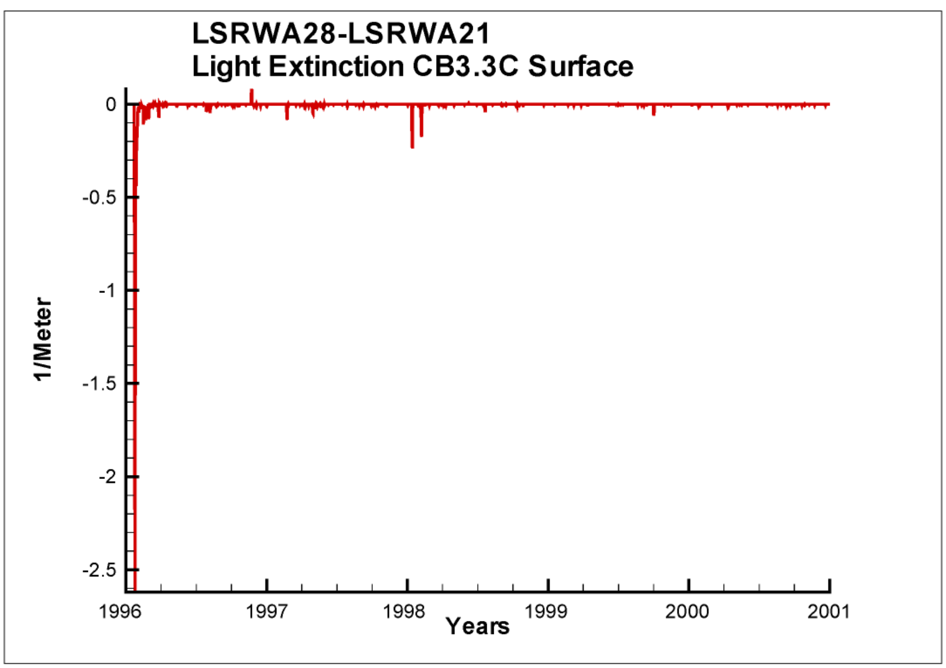


Figure 6-45. Computed effect dredging 3 mcy from Conowingo Reservoir on light attenuation at Station CB3.3C in Chesapeake Bay. Negative values indicate light attenuation is lower as a result of dredging.

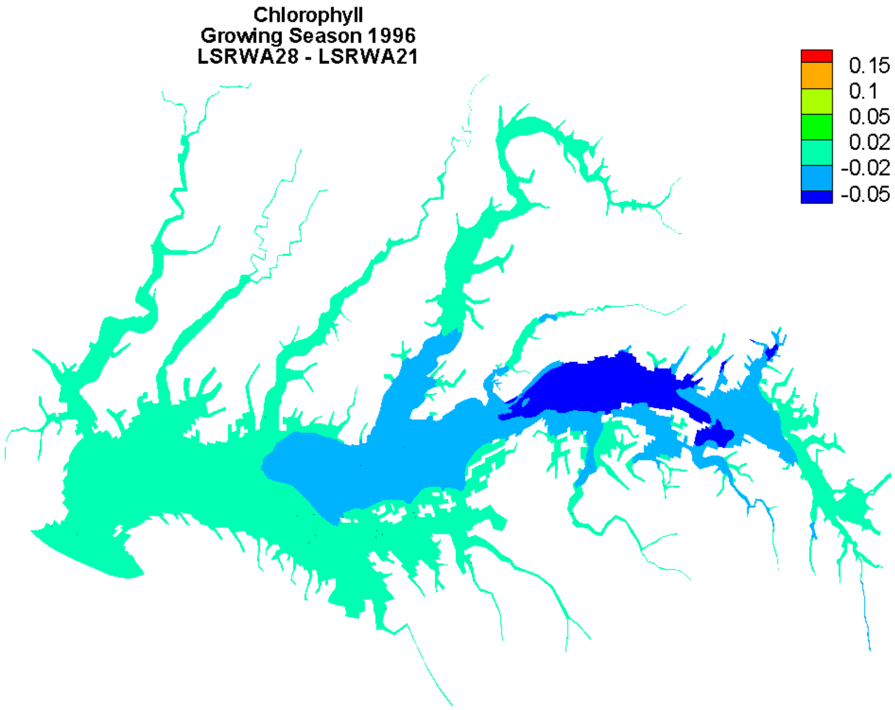


Figure 6-46. Computed effect of dredging 3 mcy from Conowingo Reservoir on surface chlorophyll (mg m^{-3} or µg/L) in Chesapeake Bay, averaged over 1996 SAV growing season. Negative values indicate chlorophyll is lower as a result of dredging.

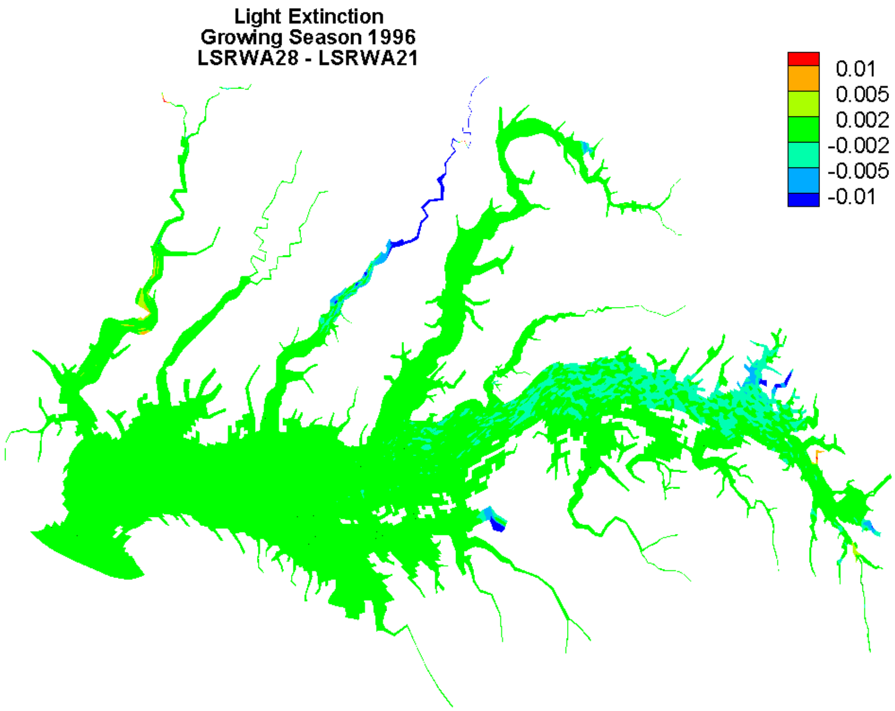


Figure 6-47. Computed effect of dredging 3 mcy from Conowingo Reservoir on light attenuation (m^{-1} or 1/m) in Chesapeake Bay, averaged over 1996 SAV growing season. Negative values indicate attenuation is lower as a result of dredging.

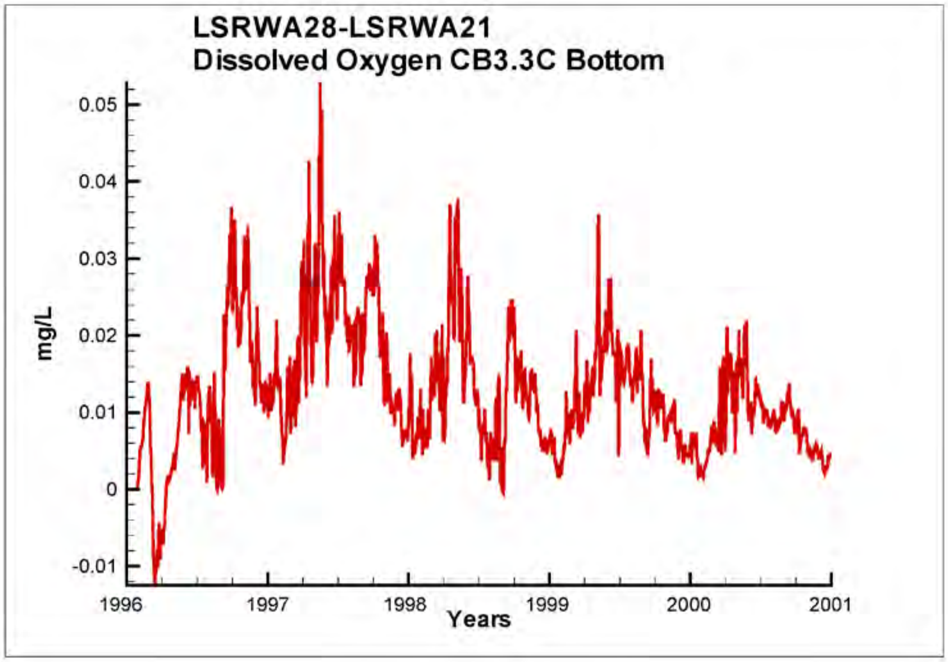


Figure 6-48. Computed effect of dredging 3 mcy from Conowingo Reservoir on bottom dissolved oxygen at Station CB3.3C in Chesapeake Bay. Positive values indicate DO is higher as a result of dredging.

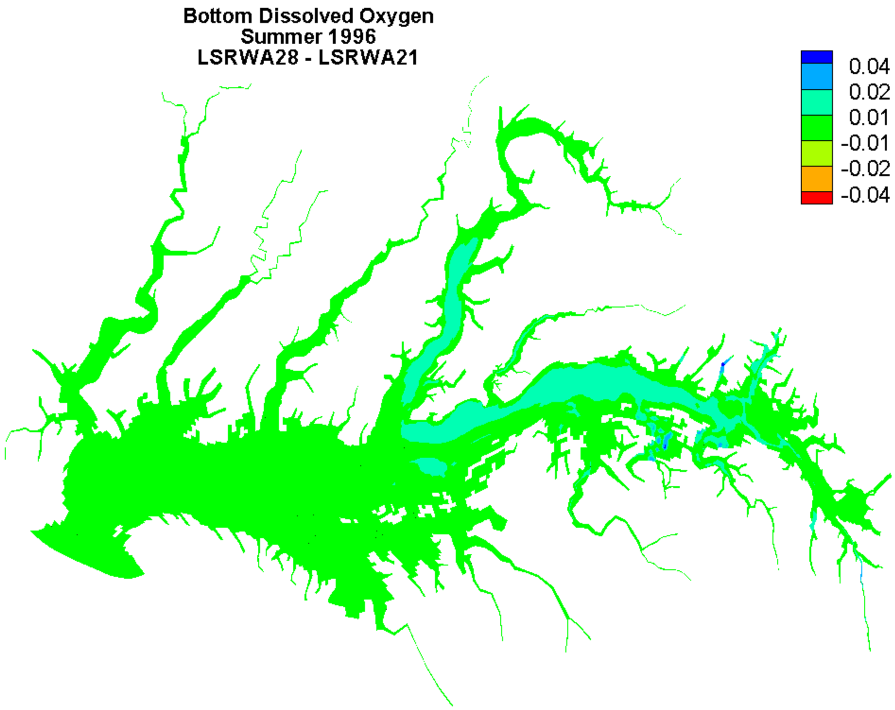


Figure 6-49. Computed effect of dredging 3 mcy from Conowingo Reservoir on bottom dissolved oxygen concentration (g m^{-3} or mg/L) in Chesapeake Bay, averaged over June – August 1996. Positive values indicate DO is higher as a result of dredging.

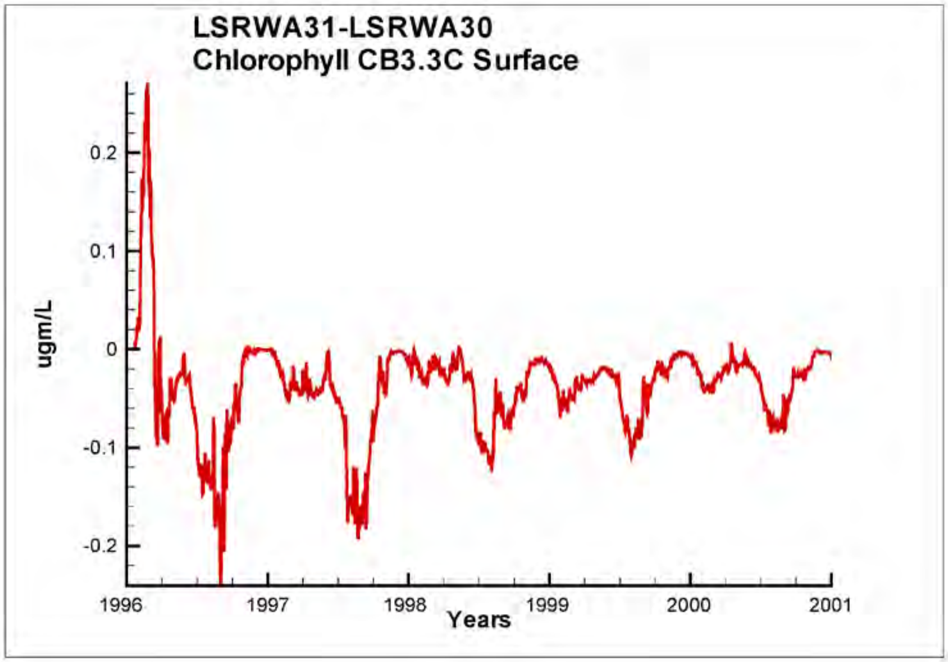


Figure 6-50. Computed effect of dredging back to 1996 bathymetry on surface chlorophyll at Station CB3.3C in Chesapeake Bay. Negative values indicate chlorophyll is lower as a result of dredging.

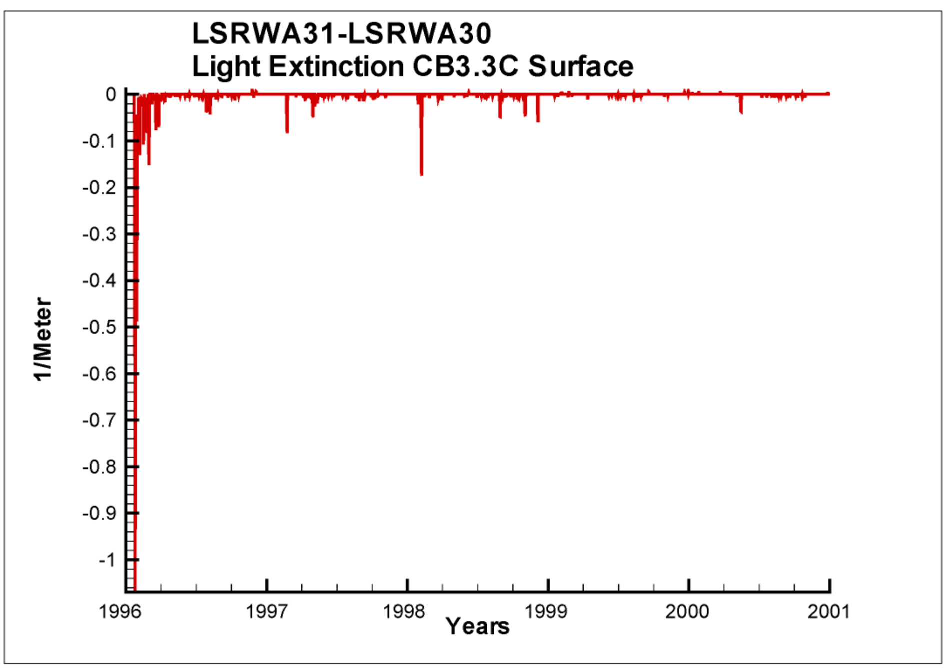


Figure 6-51. Computed effect of dredging back to 1996 bathymetry on light attenuation at Station CB3.3C in Chesapeake Bay. Negative values indicate attenuation is lower as a result of dredging.

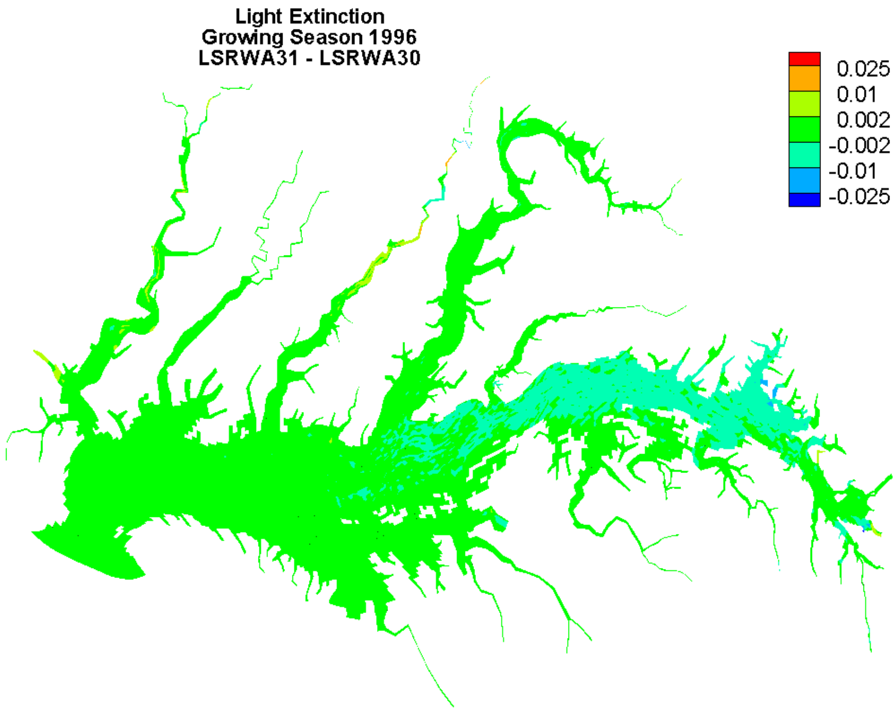


Figure 6-52. Computed effect of dredging back to 1996 bathymetry on light attenuation (m^{-1} or 1/m) in Chesapeake Bay, averaged over 1996 SAV growing season. Negative values indicate attenuation is lower as a result of dredging.

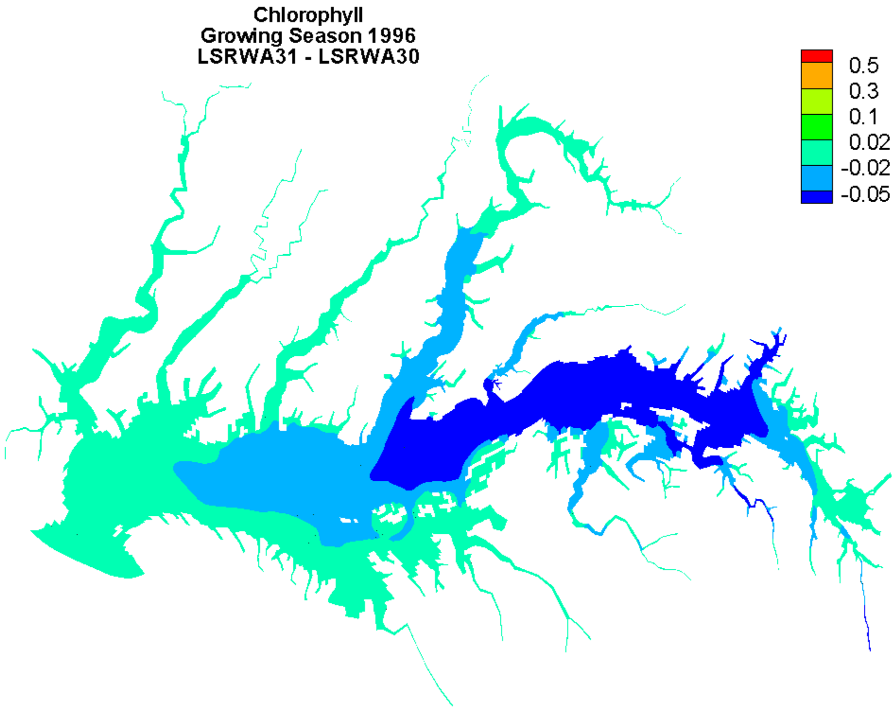


Figure 6-53. Computed effect of dredging back to 1996 bathymetry on surface chlorophyll (mg m^{-3} or µg/L) in Chesapeake Bay, averaged over 1996 SAV growing season. Negative values indicate chlorophyll is lower as a result of dredging.

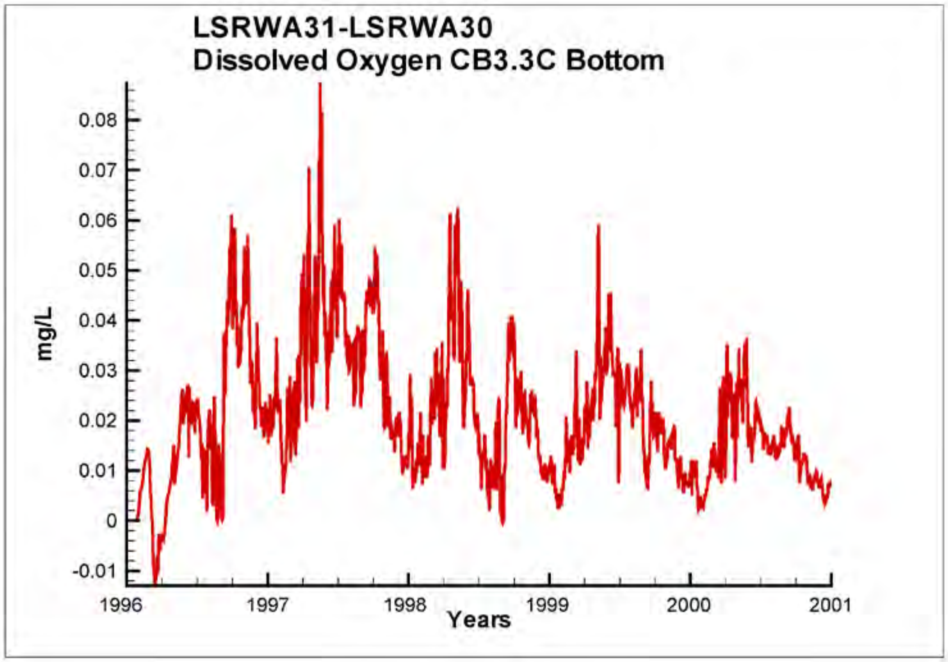


Figure 6-54. Computed effect of dredging back to 1996 bathymetry on bottom dissolved oxygen at Station CB3.3C in Chesapeake Bay. Positive values indicate DO is higher as a result of dredging.

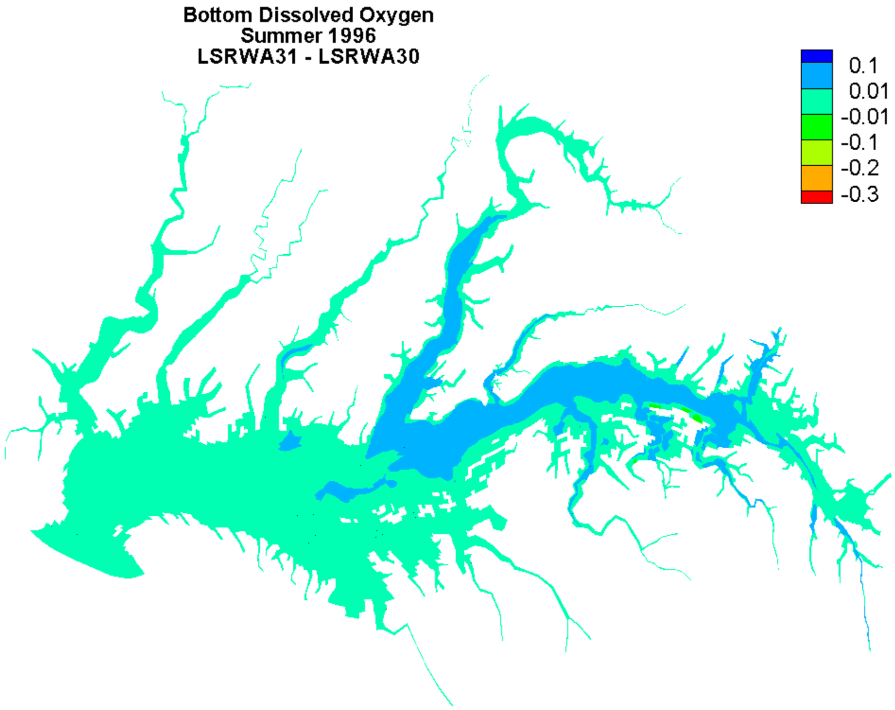


Figure 6-55. Computed effect of dredging back to 1996 bathymetry on bottom dissolved oxygen concentration (g m^{-3} or mg/L) in Chesapeake Bay, averaged over June – August 1996. Positive values indicate DO is higher as a result of dredging.

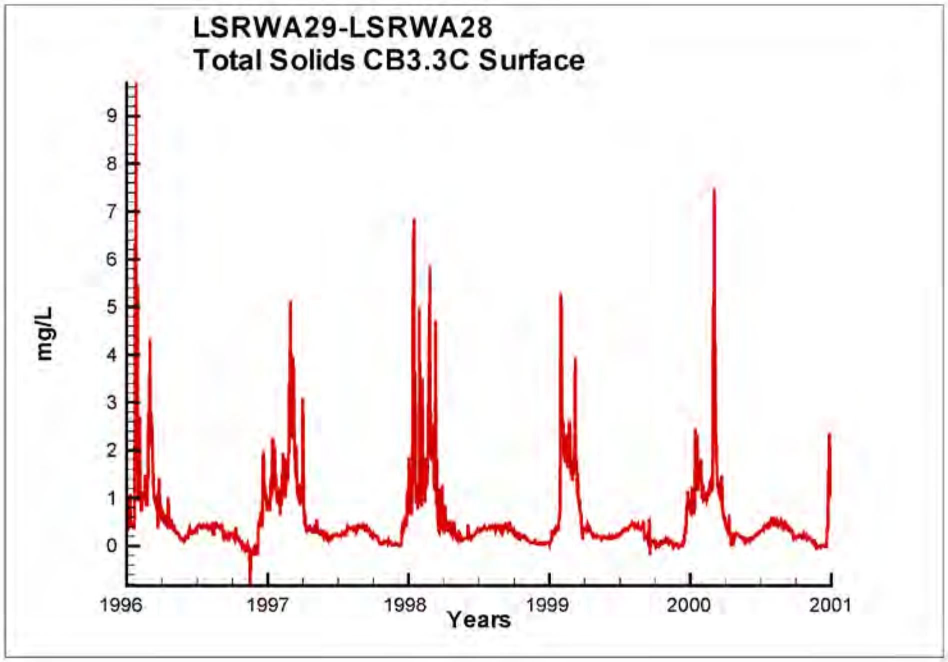


Figure 6-56. Computed increase in surface TSS at Station CB3.3C in Chesapeake Bay resulting from bypassing 3 mcy sediment per annum.

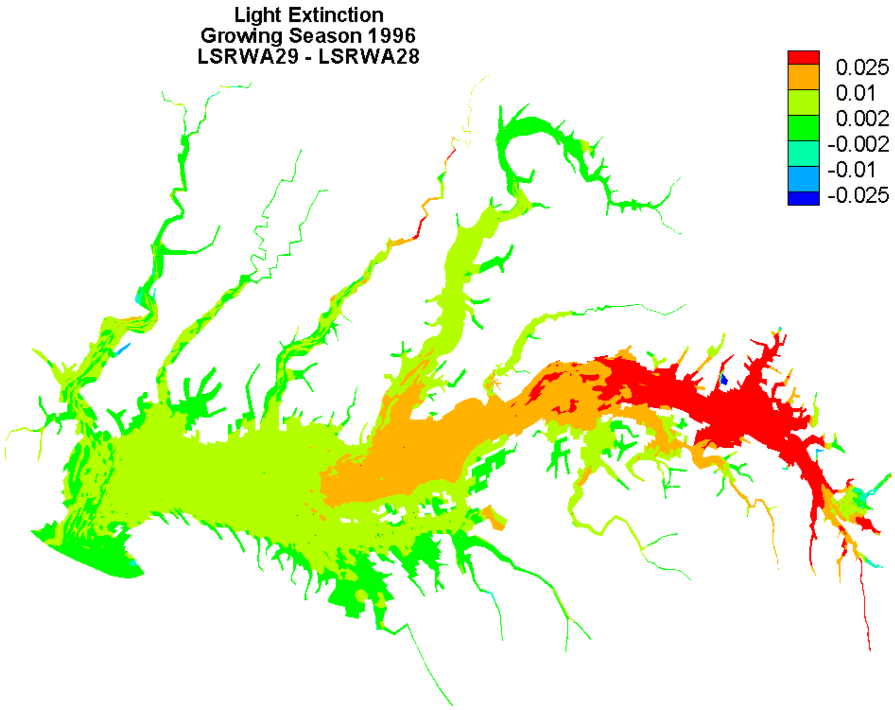


Figure 6-57. Computed increase in light attenuation (m^{-1} or 1/m) in Chesapeake Bay, averaged over 1996 SAV growing season, resulting from bypassing 3 mcy sediment per annum.

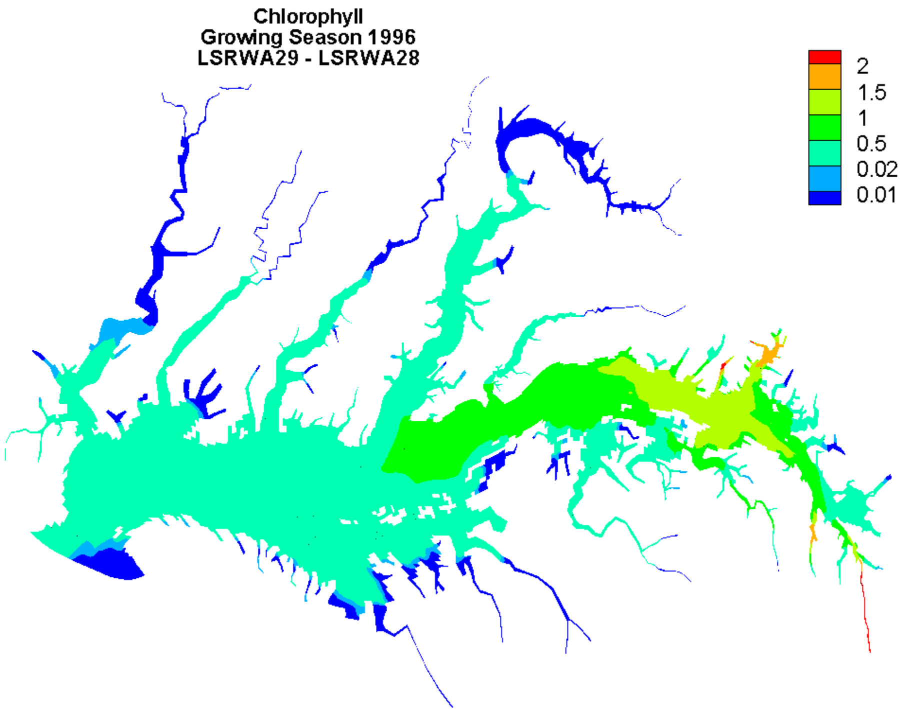


Figure 6-58. Computed increase in surface chlorophyll (mg m^{-3} or µg/L) in Chesapeake Bay, averaged over 1996 SAV growing season, resulting from bypassing 3 mcy sediment per annum.

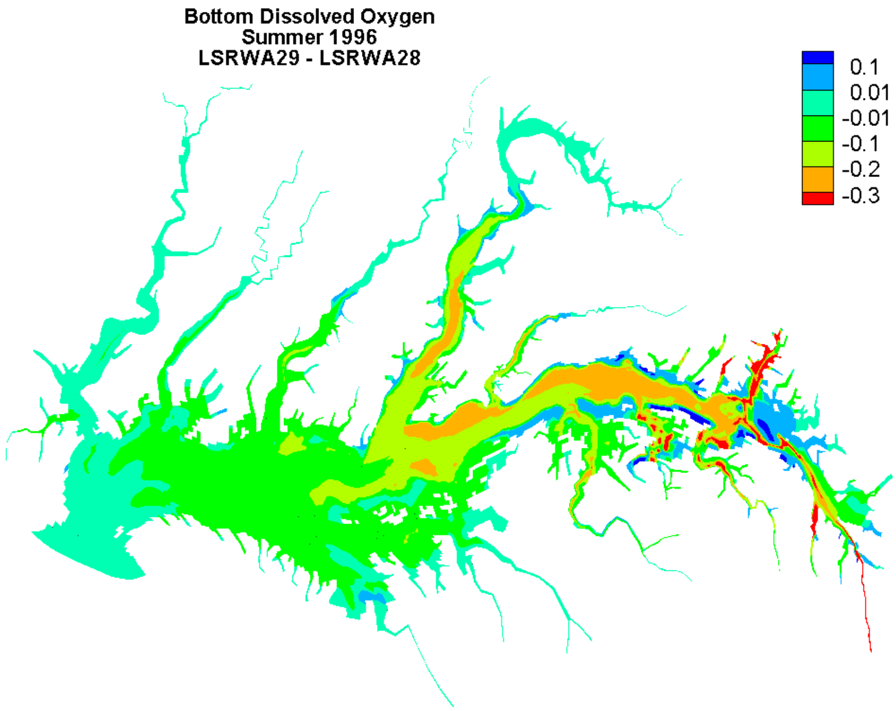


Figure 6-59. Computed effect of bypassing 3 mcy sediment per annum on bottom dissolved oxygen concentration (g m^{-3} or mg/L) in Chesapeake Bay, averaged over June – August 1996. Positive values indicate DO is higher as a result of dredging. Negative values indicate DO is lower.

7 Summary and Conclusions

Introduction

The Susquehanna River empties into the northernmost extent of Chesapeake Bay and provides more than half of the freshwater flow to the estuarine system. A series of dams and reservoirs at the lower terminus of the river regulates flow and influences dissolved and suspended material loads into the bay. Considerable sedimentation has occurred in the reservoirs since the dams were constructed circa 1910 – 1930. Conowingo Reservoir, situated immediately upstream of the bay, was reported to have lost 60% to 70% of its storage capacity by 1997. Recent analysis of loads from the reservoir to the bay associated with the 2011 Tropical Storm Lee event suggest storm-generated loads are now substantially higher than in previous years.

Loss of sediment storage could have environmental consequences for the Chesapeake Bay, especially the portion immediately below the dam. Sediments which pass over the dam and enter the bay, instead of settling to the reservoir bottom, may increase light attenuation, with adverse consequences for submerged aquatic vegetation. Nutrients associated with the sediments may contribute to ongoing eutrophication. Loss of storage may counter or negate load reductions planned under a recently-completed Total Maximum Daily Load (TMDL) program which assumes continued deposition in Conowingo Reservoir at the current rate.

The U.S. Army Corps of Engineers, Baltimore District (USACE), and the state of Maryland (MDE) have entered into a cost-share agreement to conduct Phase I of the Lower Susquehanna River Watershed Assessment (LSRWA). Phase I will:

- Forecast and evaluate sediment loads to the system of hydroelectric dams located on the Susquehanna River,
- Analyze hydrodynamic and sedimentation processes and interactions within the lower Susquehanna River watershed,
- Consider structural and non-structural strategies for sediment management, and
- Assess cumulative impacts of future conditions and sediment management strategies on Chesapeake Bay.

This report emphasizes examination of the impact of reservoir filling on the Chesapeake Bay. Scenarios are presented which examine the impact of scour from a large storm on the bay and which examine benefits from potential remediation efforts. The Chesapeake Bay Environmental Model Package (CBEMP) was the primary tool used to complete these investigations.

The Chesapeake Bay Environmental Model Package

The CBEMP consists of three independent models: a watershed model (WSM), a hydrodynamic model (HM), and a eutrophication model (WQM). The WSM provides daily computations of flow, solids loads, and nutrient loads at the heads of major tributaries and along the shoreline below the tributary inputs. Flows from the WSM are one set of inputs to the Computational Hydrodynamics in Three Dimensions (CH3D) hydrodynamic model. CH3D computes surface level, three-dimensional velocities, and vertical diffusion on a time scale measured in minutes. Loads from the WSM and transport processes from CH3D drive the Corps of Engineers Integrated Compartment Water Quality Model (ICM). ICM computes, in three dimensions, physical properties including suspended solids, algal production, and elements of the aquatic carbon, nitrogen, phosphorus, silica, and oxygen cycles. These are computed on time scales of minutes although computations averaged up to longer time periods, hours to one day, are more representative of observations.

Insights from an Analytical Model

An analytical model was developed of solids transport in Conowingo Reservoir. The model treated the reservoir as a well-mixed system at steady state. Insights from the model included:

1. When volumetric flow is below the erosion threshold, the solids concentration in the reservoir is independent of depth.

2. As reservoir depth decreases, the flow required to initiate erosion, Qe, diminishes.

3. When the erosion threshold is exceeded, the sediment concentration in the outflow is inversely proportional to depth.

The first conclusion is the most significant. This conclusion implies the reservoir is never completely filled. Solids will continue to accumulate until an erosion event occurs. As the reservoir fills, however, the flow threshold to initiate an erosion event diminishes. Erosion events become more frequent and severe.

Scenario Procedure

Chesapeake Bay scenarios are ten years in duration and incorporate the hydrologic record that occurred from 1991 to 2000. This is the record employed in calibration of the CBEMP and incorporates the critical years 1993 – 1995 used in development of the TMDL. The record includes a major scour event in Conowingo Reservoir which occurred in January 1996. Each scenario is preceded by a ten-year spin-up sequence. The spin-up is required to generate initial conditions in the water column and in the sediment bed. Following the spin-up, conditions in the water column and sediments are considered to be in equilibrium with the imposed sediment and nutrient loads.

The scenarios incorporate scour loads from Conowingo Reservoir generated based on alternate bathymetry configurations. Most scenarios employ the “existing” bathymetry, based on a 2008 survey. The “equilibrium” bathymetry is the bathymetry projected to result when sediment loads in and out of the reservoir are in dynamic equilibrium and no net deposition occurs. The “1996” bathymetry is based on a survey completed after the scour event and represents a reservoir with enhanced trapping capacity relative to present conditions. The “dredged” bathymetry is derived from existing bathymetry less 2.3×10^6 m^3 (3×10^6 yd^3) of material removed as a management action.

Roughly thirty scenarios were conducted although all are not reported here. The scenarios described here emphasize examination of the impact of a major storm event. Scenarios were also conducted, under the auspices of the CBP, which examined successive, lesser scour events. These are reported in a document subsequent to this one.

Load Computation

Loads for Chesapeake Bay scenario runs are influenced by hydrology, by land use and management practices in the watershed, by the presence of Conowingo dam, and by the storage capacity of Conowingo Reservoir. Loads from the watershed are calculated by the CBP WSM. The WSM routes watershed loads through Conowingo Reservoir, in which processes including settling, erosion, and transformation are calculated.

The WSM incorporates algorithms to calculate particle settling and erosion in Conowingo Reservoir. The algorithms are parameterized empirically to optimize agreement between computed and observed sediment and nutrient concentrations flowing over Conowingo Dam. During the course of this study, we determined that little or no scouring of bottom material was calculated during the January 1996 flood event. As a consequence, computed solids concentrations and, potentially, particulate nutrient concentrations were less than observed. For the scenarios, solids loads from erosion were calculated independently, based on computations from the ADH model for Conowingo Reservoir, and added to the WSM loads for this event. Nutrient loads associated with bottom erosion were calculated by assigning a fractional nitrogen and phosphorus composition to the eroded solids.

Solids and nutrient loads from bottom scour were computed for a range of bathymetric conditions and solids nutrient composition. Considering TMDL loads calculated for the watershed, solids scour calculated for January 1996, and observed 2011 sediment composition, scour loads comprise the majority of the total storm-generated solids and nutrient loads calculated at the Conowingo Dam. In fact, for solids and phosphorus, the scour loads are the predominant source over the entire winter-spring period. These proportions represent our best estimates for the 1996 flood event under described loading conditions. The proportions of watershed and scour for alternate events, notably Tropical Storm Lee, and alternate loading conditions may be substantially different. One significant finding from the computed loads is that scoured solids contain three times the concentration of nitrogen as phosphorus. Since dissolved nitrogen is a large fraction of the watershed load, however, particulate nitrogen is a smaller fraction of the total, compared to the fraction of particulate phosphorus in the total.

Uncertainty Analysis

Model results can be reported with extensive precision, consistent with the precision of the computers on which the models are executed. Despite the precision, model results are inherently uncertain for a host of reasons including uncertain inputs, variance in model parameters, and approximations in model representations of prototype processes. The uncertainty in model results can be described in quantitative and qualitative fashions. Quantitative measures are usually generated through multiple model runs with alternate sets of inputs and/or parameters. The number of model runs quickly multiplies so that this type of quantitative uncertainty analysis is impractical for complex models with numerous parameters and extensive computational demands. A qualitative, descriptive uncertainty analysis is the practical alternative in these instances.

One source of uncertainty is the use of the WSM to provide solids and nutrient loads at the Conowingo outfall. In fact, the WSM is the sole means for projecting watershed loads once the watershed implementation plans (WIPS) are in place. The WSM also presents the sole means for estimating loads under various hydrologic sequences given existing land uses and management practices (2010 Progress Runs). Still, two sources of uncertainty are inherent in the loading record employed in this study. The first is due to the uncertainties in the WSM itself. The second arises from the unknown hydrologic sequence which will actually occur in the future. The WSM loads, as well as the WQM hydrodynamics, are based on a design hydrologic record that occurred from 1991 to 2000. This exact sequence will not repeat itself in the future.

A second source of uncertainty is in the nutrient loads carried over Conowingo as a result of sediment scour from the reservoir bottom. Two alternative sets of observations were presented here, one based on observations at the outfall in January 1996 (Table 4-4) and one based on observations collected at Conowingo during Tropical Storm Lee in September 2011 (Table 4-3). The nutrients associated with suspended solids differ in the two events with 1996 being lower. In fact, both data sets represent a mixture of solids from the watershed and solids scoured from the bottom so that neither exactly represents the composition of scoured material alone. The 2011 observations are consistent with samples collected in the reservoir bed (see the data summaries presented by Cerco, 2012), are more recent, and represent a typical tropical storm event rather than the anomalous circumstances of January 1996. For this reason, nutrient composition observed at Conowingo in 2011 is preferred to characterize the future and is emphasized in this report. Several key scenarios were repeated with 1996 composition, however, to quantify the uncertainty inherent in the composition of solids scoured from the reservoir bottom.

This study reports that the nitrogen loads associated with the scoured solids exceed the phosphorus loads. While the magnitude of the loads is uncertain, the excess of nitrogen over phosphorus is not. The excess of nitrogen over phosphorus in Conowingo bottom sediments can be seen in in the results of multiple surveys, independent of any model calculations (see the data summaries presented by Cerco, 2012). The ratio of nitrogen to phosphorus in the sediments indicates nitrogen load will exceed phosphorus load any time bottom material is scoured, regardless of the quantity of bottom material.

A third source of uncertainty lies in the reactivity and biological availability of the nutrients scoured from the reservoir bottom. The majority of particle analyses at the Conowingo outfall and in the reservoir bottom sediments quantify simply particulate nitrogen and particulate phosphorus without further defining the nature of the nitrogen or phosphorus. Long experience with the WQM provides guidelines to partition particulate nitrogen and phosphorus into model state variables. Subsets of the available data (e.g. Durlin and Schaffstall, 1997) provide additional analyses including splits between organic and inorganic phosphorus and plant-available phosphorus. In view of the sporadic nature of the additional analyses and the passage of time since the data collection, we opted to maintain the accepted, consistent particle composition we have employed throughout the WQM application. Still, we must acknowledge the uncertainty in the particle composition and, consequently, the processes by which particulate nutrients are transformed into biologically available forms.

One remaining source of uncertainty lies in the nature of scour events at this time and into the future. This report is oriented towards the analysis of a single large event. Recent reports suggest that the trend of recent scour events is for smaller, more frequent events (Hirsch, 2012). This result is not without controversy. For example, direct physical observations of scour at flows less than the commonly accepted threshold of 11,300 $m^3 s^{-1}$ are absent. The amount of material available to be scoured will also decrease into the future as watershed implementation plans come into effect. Still, the potential for the future alternative of smaller, more frequent scour events cannot be ignored. Scenarios based on this assumption were conducted for the EPA CBP and are the subject of an upcoming report.

Scenario Results

Reporting concentrated on scenarios involving TMDL loads in combination with bottom scour. Scenarios examined the impact of scour under alternate reservoir bathymetries, the potential ecosystem benefits of the dam, the potential for remediation of scour impacts, and the potential impact of sediment bypassing. One over-arching conclusion from the scenarios is that the solids loads are not the major threat to bay water quality. For most conditions examined, solids from bottom scour settle out before the period of the year during which light attenuation is critical. The nutrients associated with the solids are more detrimental. The particulate nutrients settle to the bottom and are mineralized in bottom sediments. The mineralized nutrients are recycled to the water column in dissolved form and stimulate algal production. Algal organic matter decays and consumes oxygen in the classic eutrophication cycle. As a consequence, dissolved oxygen is diminished by reservoir scour events.

Effect on TMDL Conditions

The TMDL for Chesapeake Bay is aimed at attaining and maintaining desirable conditions of chlorophyll concentration, water clarity, and dissolved oxygen concentration. The computed impact of storm scour associated with the January 1996 flood event on TMDL conditions is small in magnitude relative to projected ambient conditions. Averaged over the SAV growing season, the median increase in growing-season light attenuation in any year is less than 0.01 m^{-1}. Computed chlorophyll increases by 0.1 to 0.3 mg m^{-3} over a widespread area extending into the lower Potomac River and below the mouth of the Potomac in the mainstem bay. Bottom-water dissolved oxygen declines up to 0.2 g m^{-3} although the decline is 0.1 g m^{-3} or less when averaged over the summer season. Although this decline is small in magnitude, the implications could be significant for the TMDL in regions where the projected DO concentration, in the absence of scour, just meets the standards. Determination of the significance of the decline depends on analyses from the CBP which are part of this project.

Scour events can occur at various times of the year, depending on the mechanism behind the flood event. Model computations indicate that an autumn event has the least detrimental impact on Bay water quality. A late spring storm has the greatest impact.

One-time dredging of 3 mcy (2.3 x 10^6 m^3) of material from Conowingo Reservoir reduces scour of solids and nutrients by 32% relative to conditions computed for the January 1996 event and 2011 bathymetry. The impact of this reduction on computed chlorophyll and light attenuation, averaged over the SAV growing season, is less than 1%. Computed bottom DO improves by 0.01 to 0.04 g m^{-3}. Averaged over the summer season, however, the improvement is roughly 0.02 g m^{-3} and of limited spatial extent. Overall reduction in anoxia (DO < 1 g m^3) is 1.7%.

The nature of the response to removal of 28 mcy is similar to the response to the removal of 3 mcy although the magnitude of the effects is greater, especially for CHL and DO. Surface chlorophyll concentration is reduced by peak values of 0.1 to 0.2 mg m^{-3} during the SAV growing season. Averaged over the 1996 growing season, the improvements in CHL are roughly 0.05 mg m^{-3}. During the summer months, the instantaneous improvement in calculated bottom DO is nearly double the improvement from dredging 3 mcy. Instantaneous improvements of 0.05 g m^{-3} are calculated for several years following the scour event and extend along the upper bay and into the lower Potomac River. Anoxia is reduced by up to 15% in some segments of the system and by 2.8% overall.

References

Cerco, C. (2012). “Data assembly for application of the CBEMP in the lower Susquehanna River watershed assessment,” A report to the U.S. Army Corps of Engineers Baltimore District, Baltimore MD. (Available from the author carl.f.cerco@usace.army.mil)

Durlin, R., and Schaffstall, W. (1997). "Water Resources Data Pennsylvania Water Year 1996," Vol. 2 Susquehanna and Potomac River Basins. US Geological Survey, Lemoyne PA.

Hirsch, R. (2012). “Flux of nitrogen, phosphorus, and suspended sediment from the Susquehanna River basin to the Chesapeake Bay during Tropical Storm Lee, September 2011, as an indicator of the effects of reservoir sedimentation on water quality,” Scientific Investigations Report 2012-5185, US Geological Survey, Reston VA.

Scott, S., and Sharp, J. (2013). “Sediment transport characteristics of Conowingo Reservoir,” prepared for U.S. Army Corps of Engineers Baltimore District by Engineer Research and Development Center, Vicksburg MS.

Attachment C-1:
Data Assembly for Application of the CBEMP in the Lower Susquehanna River Watershed Assessment

Data Assembly for Application of the CBEMP in the Lower Susquehanna River Watershed Assessment

A Report to the US Army Engineers Baltimore District

May 2012 Final Report

Carl F. Cerco

US Army Engineer Research and Development Center, Vicksburg MS

Abstract

The US Army Corps of Engineers Baltimore District and the Maryland Department of the Environment have partnered to conduct Phase I of the Lower Susquehanna River Watershed Assessment. As part of the assessment, the Chesapeake Bay Environmental Model Package (CBEMP) will be used to assess impacts of future conditions and sediment management strategies in the Susquehanna River on the environment of Chesapeake Bay. Use of the CBEMP to fulfill goals of the Phase I Assessment requires information on the physical properties and composition of solids flowing over the Conowingo Dam, which is situated immediately upstream of the bay. The present publication reports results of a search and compilation of relevant data. The search included publications, personal communication, and inventory of data residing at US Army Engineer Research and Development Center. Data was assembled for material flowing over the dam and for characteristics of the sediment bed in Conowingo Reservoir. Information on bed sediments was compiled based on the assumption that this material would be mobilized and flow over the dam during erosion events. Multiple data sets were located and subsequently reduced to observations relevant to the study goals and useful in the CBEMP. These were observations in Conowingo Reservoir of: solids size distribution; associated carbon, nitrogen and phosphorus species and concentration; and concentration of metals which affect nutrient diagenesis in bed sediments. The report includes a listing of data bases, a data summary, and a data listing. The data compiled is sufficient for use in the CBEMP in the Phase I Assessment.

Point of Contact

Carl F. Cerco, PhD, PE
Research Hydrologist
Mail Stop EP-W
US Army ERDC
3909 Halls Ferry Road
Vicksburg MS 39180 USA
601-634-4207 (voice)
601-634-3129 (fax)
Carl.F.Cerco@usace.army.mil

1 Introduction

The Susquehanna River empties into the northernmost extent of Chesapeake Bay and provides more than half of the freshwater flow to the estuarine system. A series of dams and reservoirs (Figure 1) at the lower terminus of the river regulates flow and dissolved and suspended material loads into the bay. The most upstream reservoir, Lake Clarke, forms behind Safe Harbor Dam. Holtwood Dam forms Lake Aldred which sits below Lake Clarke. Conowingo Reservoir, the largest of the three, forms behind Conowingo Dam which is situated roughly six kilometers above the Chesapeake Bay head of tide.

Considerable sedimentation has occurred in the reservoirs since the dams were constructed circa 1910 – 1930. Lakes Clarke and Aldred have filled to the extent that they are in equilibrium with sediment loads coming down the river. Gravitational particle settling is balanced by erosion in these shallow systems. Although Conowingo Reservoir has lost 60% to 70% of its storage capacity (Langland and Hainly, 1997), the reservoir continues to accumulate sediment particles and associated nutrients and organic matter. Estimated time for the remaining sediment storage capacity of the reservoir to fill varies, depending on assumed loads and probability of erosion events, but estimates center around two decades remaining.

Loss of sediment storage could have environmental consequences for the Chesapeake Bay, especially the portion immediately below the dam. Sediments which pass over the dam and enter the bay, instead of settling to the reservoir bottom, may increase light attenuation, with adverse consequences for submerged aquatic vegetation. Nutrients associated with the sediments may contribute to ongoing eutrophication. Loss of storage may counter or negate load reductions planned under a recently completed Total Maximum Daily Load program (USEPA, 2010) which assumes continued deposition in Conowingo Reservoir at the current rate.

The US Army Corps of Engineers Baltimore District (USACE) and the Maryland Department of the Environment (MDE) have partnered to conduct Phase I of the Lower Susquehanna River Watershed Assessment (LSRWA). Phase I will:

- Forecast and evaluate sediment loads to the system of hydroelectric dams located on the Susquehanna River,
- Analyze hydrodynamic and sedimentation processes and interactions within the lower Susquehanna River watershed,

- Consider structural and non-structural strategies for sediment management, and
- Assess cumulative impacts of future conditions and sediment management strategies on Chesapeake Bay.

Critical components of the Phase I Watershed Assessment (USACE, 2011) include:

- Identification of watershed-wide sediment management strategies,
- Use of engineering models to link incoming sediment and associated nutrient projections to in-reservoir processes at the hydroelectric dams and forecast impacts to living resources in the upper Chesapeake Bay,
- Use of the Chesapeake Bay Environmental Model Package (CBEMP), a cooperative effort of the US Environmental Protection Agency Chesapeake Bay Program and the US Army Engineer Research and Development Center, to assess cumulative impacts of the various sediment management strategies to the upper Chesapeake Bay, and
- Integration of the Maryland and Pennsylvania Watershed Implementation Plans for nitrogen, phosphorus, and sediment reduction, as required to meet Chesapeake Bay TMDL's.

Use of the CBEMP to fulfill goals of the Phase I Assessment requires information on the physical properties and composition of solids flowing over the Conowingo Dam. The present publication reports results of a search and compilation of relevant data. The search included publications, personal communication, and inventory of data residing at ERDC. Data was assembled for material flowing over the dam and for characteristics of the sediment bed in Conowingo Reservoir. Information on bed sediments was compiled based on the assumption that this material would be mobilized and flow over the dam during erosion events. Multiple data sets were located and subsequently reduced to observations relevant to the study goals and useful in the CBEMP. These were observations in Conowingo Reservoir of: solids size distribution; associated carbon, nitrogen and phosphorus species and concentration; and concentration of metals which affect nutrient diagenesis in bed sediments. The report includes a listing of data bases, a data summary, and a data listing. The data compiled is sufficient for use in the CBEMP in the Phase I Assessment.

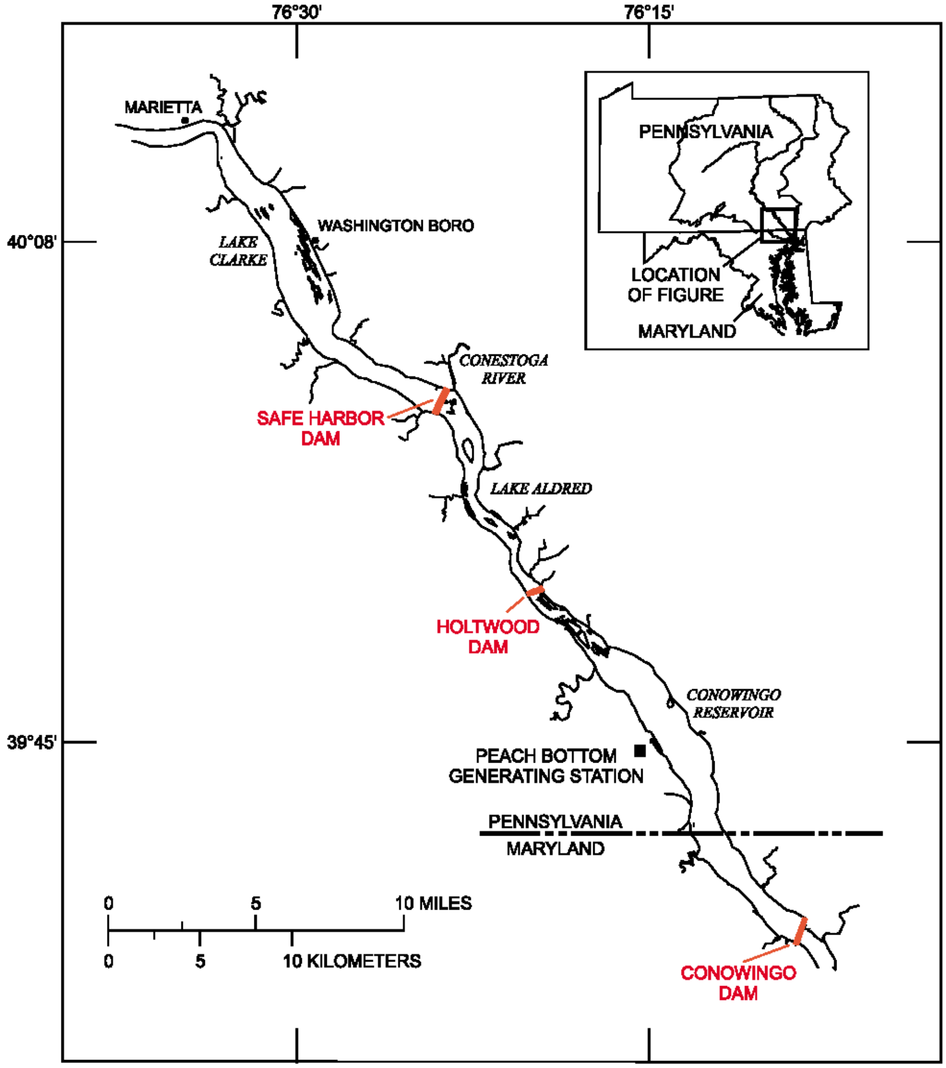


Figure 1. Lower Susquehanna River reservoir and dam system (extracted from USGS, 2003).

2 Summary of Data Sources

Table 1, below, describes the sources of data compiled for this report. A letter code in ( ) after the source citation indicates correspondence to data subsequently summarized in Table 2.

Table 1. Data Sources

Data Description	Collected	Source
Summary of 23 sediment cores from Conowingo Reservoir. Includes particle size, nitrogen (N), phosphorus (P), iron (Fe), and manganese (Mn).	Oct. 1990 - April 1991	Hainly, R., Reed, L., Flippo, H., and Barton, G. (1995). "Deposition and simulation of sediment transport in the lower Susquehanna River reservoir system," Water-Resources Investigations Report 95-4122, US Geological Survey, Denver CO. (A)
Individual observations from 22 sediment cores from Conowingo Reservoir. Analyses include size fractionation, moisture content, ammonium (NH4), nitrate (NO3), organic N, total N, total P, Fe, calcium (Ca), and Mn. This is the data base summarized by Hainly et al. (1995).	1990	Langland, Michael. (2012). Personal communication. US Geological Survey, New Cumberland PA. (B)
Summary of 29 sediment cores from Conowingo Reservoir. Includes total N, total P, and plant-available P.	Summer and fall 1996	Langland, M., and Hainly, R. (1997). "Changes in bottom-surface elevations in three reservoirs on the lower Susquehanna River, Pennsylvania and Maryland, following the January 1996 flood - Implications for nutrient and sediment loads to Chesapeake Bay," Water-Resources Investigations Report 97-4138, US Geological Survey, Lemoyne PA. (C)

Individual observations from 29 sediment cores from Conowingo Reservoir. Analyses include size fractionation, moisture content, NH4, NO3, organic N, total N, inorganic P, organic P, plant-available P, total P, Fe, Ca, and Mn. This is the data base summarized by Langland and Hainly (1997).	August of 1996	Durlin, R., and Schaffstall, W. (1997). "Water Resources Data Pennsylvania Water Year 1996," Vol. 2 Susquehanna and Potomac River Basins. US Geological Survey, Lemoyne PA. (D)
Particle size distribution from 20 analyses of water flowing over Conowingo Dam. Instantaneous discharge concurrent with multiple samples exceeds the threshold for erosion in Conowingo Reservoir.	1979 - 1984	Recovered from USGS on-line data base (http://nwis.waterdata.usgs.gov/md/nwis/qwdata/?site_no=01578310&agency_cd=USGS) for USGS 01578310 SUSQUEHANNA RIVER AT CONOWINGO, MD. (E)
Analyses of particulate phosphorus (PP) and particulate inorganic phosphorus (PIP) from 52 samples of water flowing over Conowingo Dam.	2004 - 2005	Chesapeake Biological Laboratory, Solomons MD. Personal Communication. (F)
Particulate C, N, P, and TSS at Conowingo outfall. More than 100 samples, including replicates, collected at approximately monthly intervals.	2005 - 2011	Station 1.0 in the Chesapeake Bay Program Water Quality Data Base (http://www.chesapeakebay.net/data/downloads/cbp_water_quality_database_1984_present) (G)
Particle analyses at Conowingo outfall. Ten samples collected especially for this study. These include samples collected during Tropical Storm Lee. Samples were analyzed for PC, PN, PP, Fe, Mn, suspended sediment, and particle size	2010 - 2011	Jeffrey Chanat, USGS MD-DE-DC Water Science Center. Personal Communication. (H)
Analyses from 23 sediment cores from Conowingo Reservoir (21) and Susquehanna Flats (2). Analyses include bulk density, size fractions, and particulate Fe, Mn, C, N, P. The cores were analyzed at multiple depth intervals. Data selected for this study is from the top-most section, typically 25 cm deep.	2000	Edwards, R. (2006). "Comprehensive analysis of the sediments retained behind hydroelectric dams of the lower Susquehanna River," Publication 239, Susquehanna River Basin Commission, Harrisburg PA. (I)

Sequential phosphorus extractions of surficial sediments from three cores collected in Conowingo Reservoir and 1 core collected at the mouth of the Susquehanna River. Analyses indicate total phosphorus phases are 2% to 4% exchangeable phosphate, 2% to 20% calcium-bound phosphate, 30% to 60% phosphate sorbed to iron oxides, and 30% to 70% organic phosphorus.	2000	Edwards, R. (2006). "Comprehensive analysis of the sediments retained behind hydroelectric dams of the lower Susquehanna River," Publication 239, Susquehanna River Basin Commission, Harrisburg PA.(J)

3 Characteristics of Materials Flowing Over the Dam

Data from the sources listed in Chapter 2 is summarized in Table 2 below. Letters in ( ) after the citation indicate correspondence to data sources in Table 1. The original data were revised, where necessary, for consistent units. Some data sources report sediment size classes e.g. mm while others report composition e.g. clay. For conversion purposes, we assume clay represents particles less than 0.004 mm in diameter and silt represents particles greater than 0.004 mm but less than 0.063 mm. Particles greater than 0.063 mm are considered sand. This convention appears to be consistent with the scheme used by the original investigators.

Three of the four sources which report size classes for the Conowingo bed sediments indicate the majority of the bed, ≈ 75%, is silt and clay with the remainder being sand and sporadic patches of coal. The samples reported by Durlin and Schaffstall (1997) are exceptional in that they are more than half sand. The material flowing over the spillway is virtually 100% silt and clay, however, (Figure 2) even at flow rates > 11,000 $m^3\ s^{-1}$, sufficient to erode the bottom (Lang, 1982; Reed and Hoffman, 1997). The data suggest a slight decline in the silt and clay fraction at the highest flows, with the remainder consisting of sand, but the trend is not statistically significant ($R^2 = 0.08$, $0.5 < p < 0.2$). Although the data are widely scattered, there is a clear and significant decline in clay fraction as flow increases ($R^2 = 0.38$, $p < 0.002$). Nevertheless, particles in the clay size class represent more than half of the solids in all but a few samples.

The concentrations of suspended solids, particulate carbon (PC), particulate nitrogen (PN), and particulate phosphorus (PP) increase, in an approximately exponential relationship, as a function of flow (Figures 3 - 6). Evidence is difficult to perceive of a change in the relationship of concentration to flow when flow exceeds the threshold for bottom erosion. Based on the composition of the bed, the PN is virtually all organic in nature. In contrast, inorganic forms can represent more than half the PP in both the bed and outflow.

Analyses of particle fraction of PC, PN, PP, as function of flow yield interesting results (Figures 7 – 9). The fractions decline, apparently exponentially, as flow increases. The PN and PP fractions asymptotically approach the composition of bed sediment (≈ 0.3% N, ≈ 1,000 ppm P). The C fraction of the particles in the outfall approaches a limit less that the composition of the bed sediments (≈ 10% C). We can’t judge whether this disparity is genuine or an artifact of limited data in the bed sediments. In all cases, the asymptotic fraction is approached at flows insufficient to erode bottom sediments. We suggest the particle fractions at low flows, less than 4,000 $m^3 s^{-1}$, represent particles formed by primary production within the reservoir. At higher flows, the residence time of the reservoir is short and particle composition at the spillway represents particles entering the reservoir from upstream.

The particle fractions of Fe and Mn in the outflow show no relation to flow. Fe fraction is ≈ 5% and Mn fraction is ≈ 2,200 ppm.

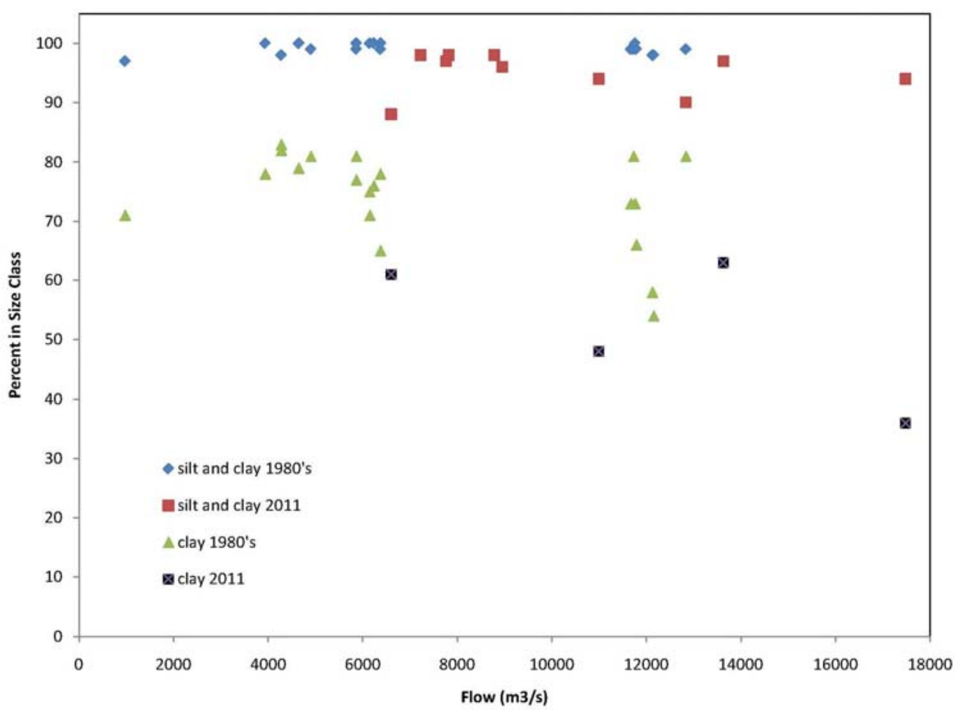


Figure 2. Fractions of clay and of clay and silt in Conowingo overflow. The data designated 1980's is from the USGS on-line data base. The data designated 2011 was collected for this study.

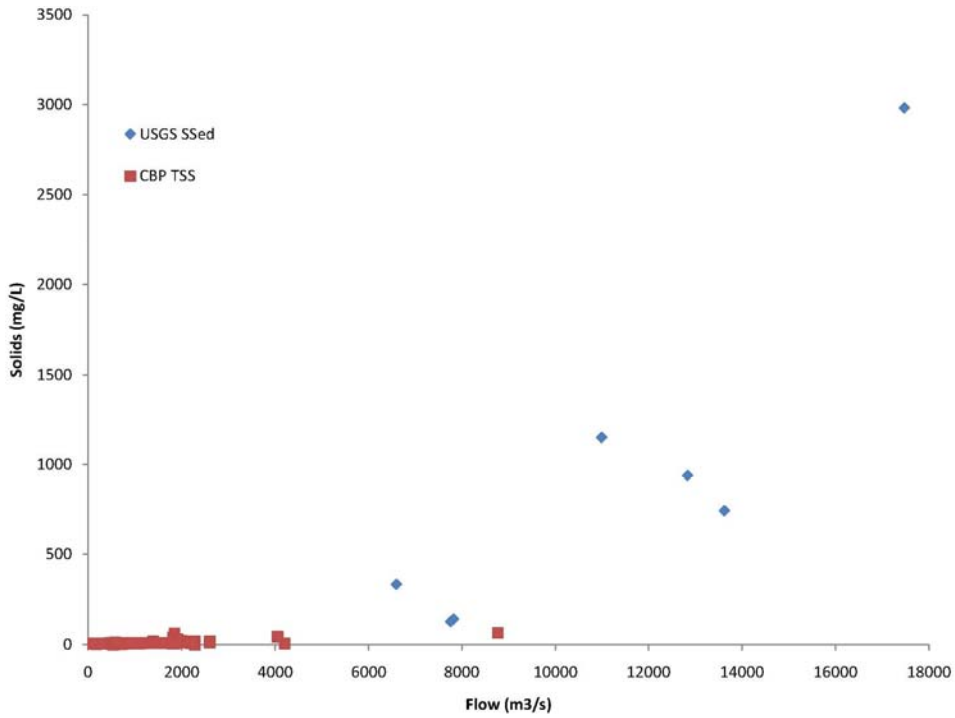


Figure 3. Suspended solids concentration in Conowingo outfall vs. flow. Data designated USGS was collected for this study and reported as suspended sediment. Data designated CBP is from the Chesapeake Bay Program data base and reported as TSS.

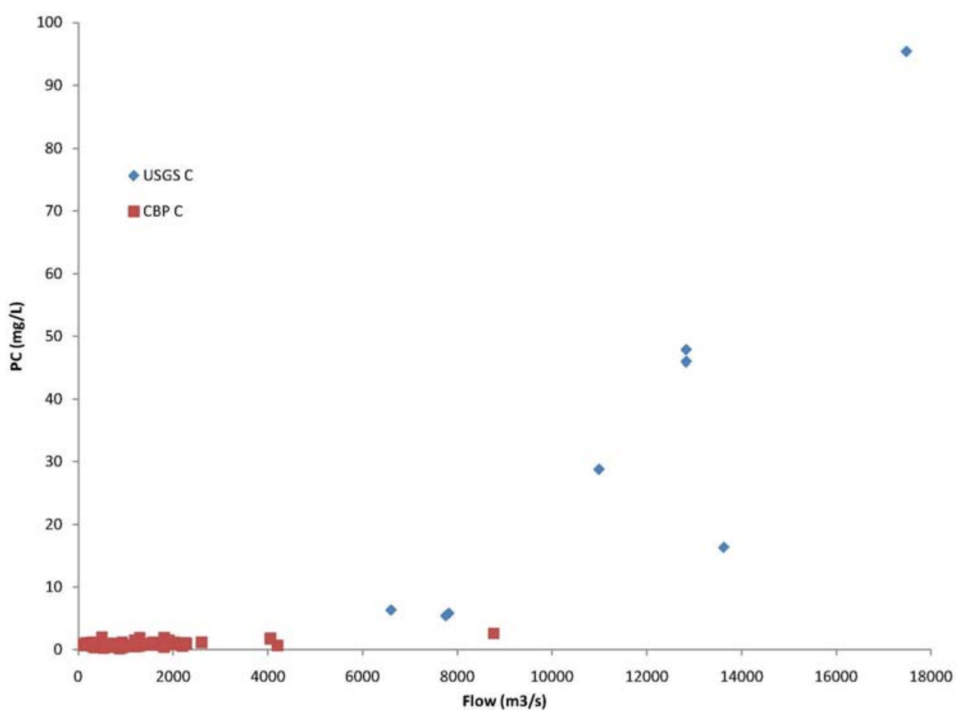


Figure 4. Particulate carbon concentration in Conowingo outfall vs. flow. Data designated USGS was collected for this study. Data designated CBP is from the Chesapeake Bay Program data base.

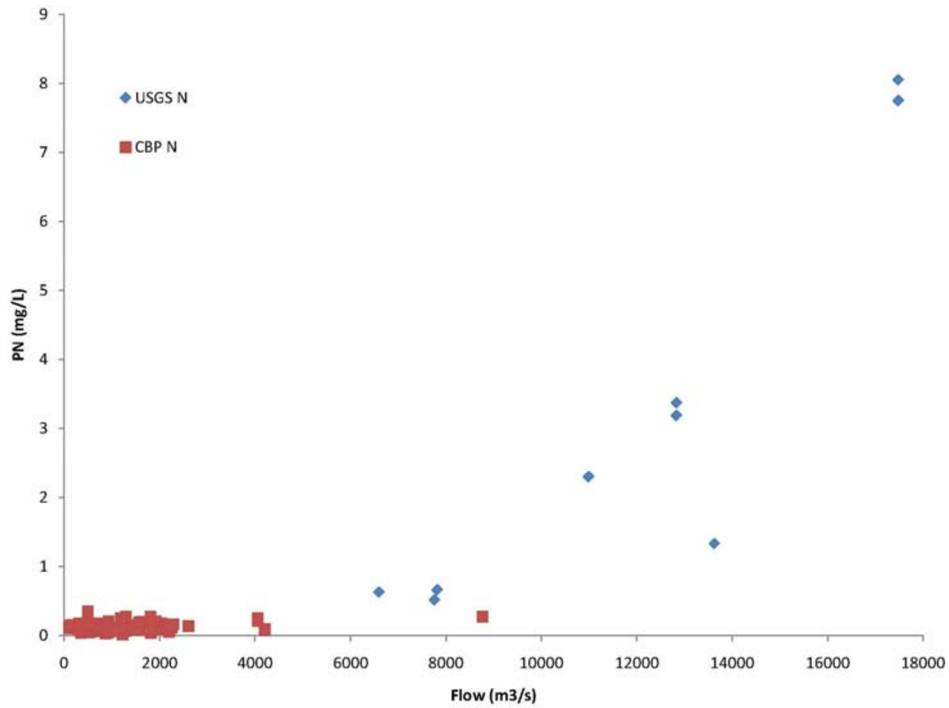


Figure 5. Particulate nitrogen concentration in Conowingo outfall vs. flow. Data designated USGS was collected for this study. Data designated CBP is from the Chesapeake Bay Program data base.

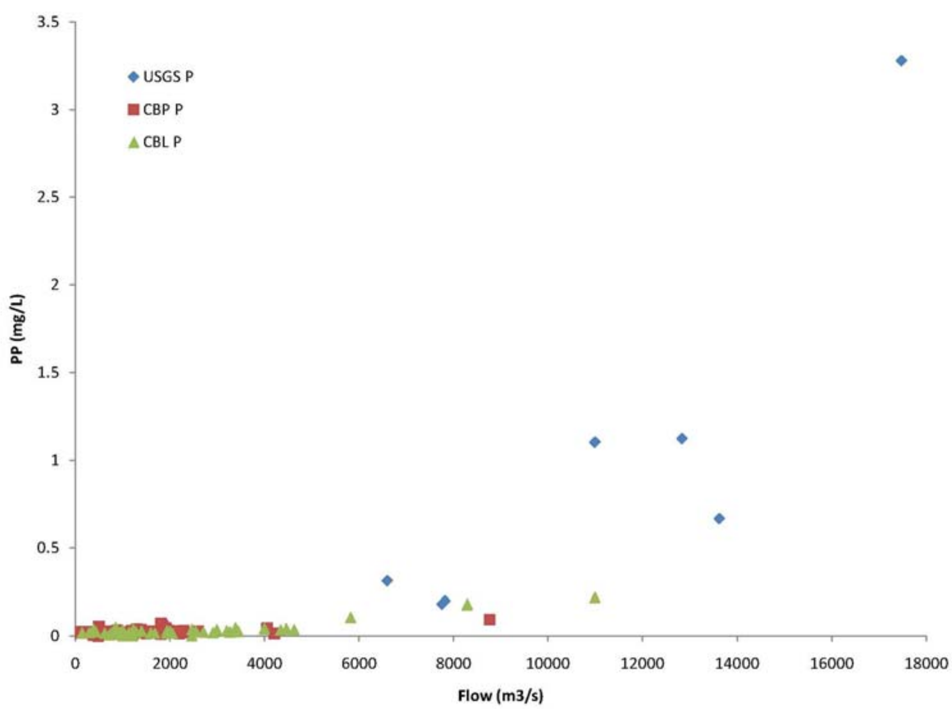


Figure 6. Particulate phosphorus concentration in Conowingo outfall vs. flow. Data designated USGS was collected for this study. Data designated CBP is from the Chesapeake Bay Program data base. Data designated CBL is from Chesapeake Biological Laboratory.

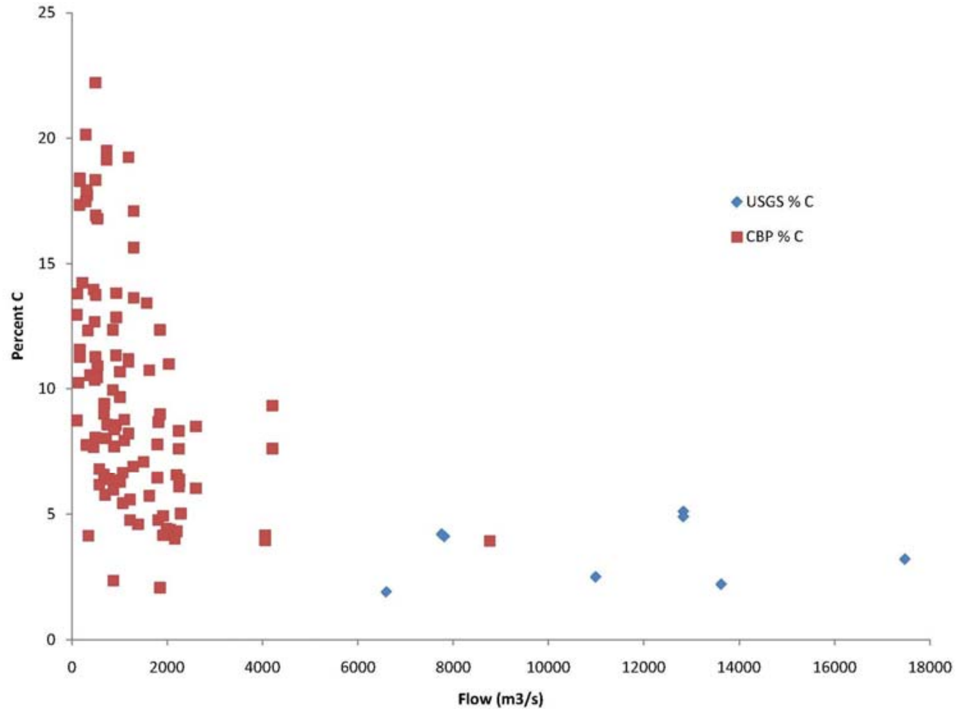


Figure 7. Carbon fraction of particles in Conowingo outfall vs. flow. Data designated USGS was collected for this study. Data designated CBP is from the Chesapeake Bay Program data base.

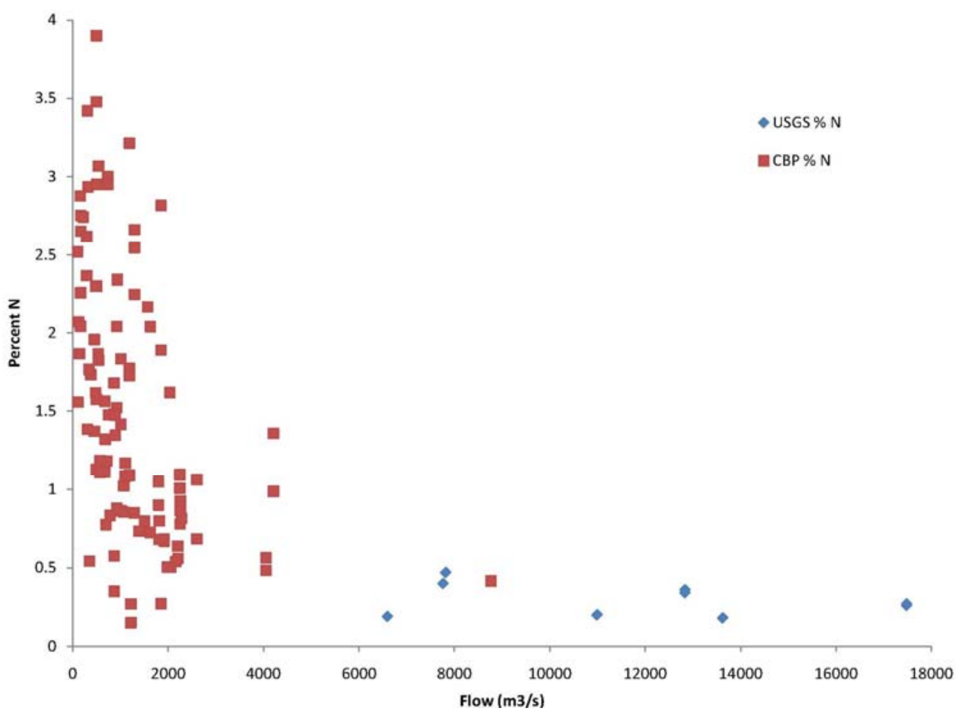


Figure 8. Nitrogen fraction of particles in Conowingo outfall vs. flow. Data designated USGS was collected for this study. Data designated CBP is from the Chesapeake Bay Program data base.

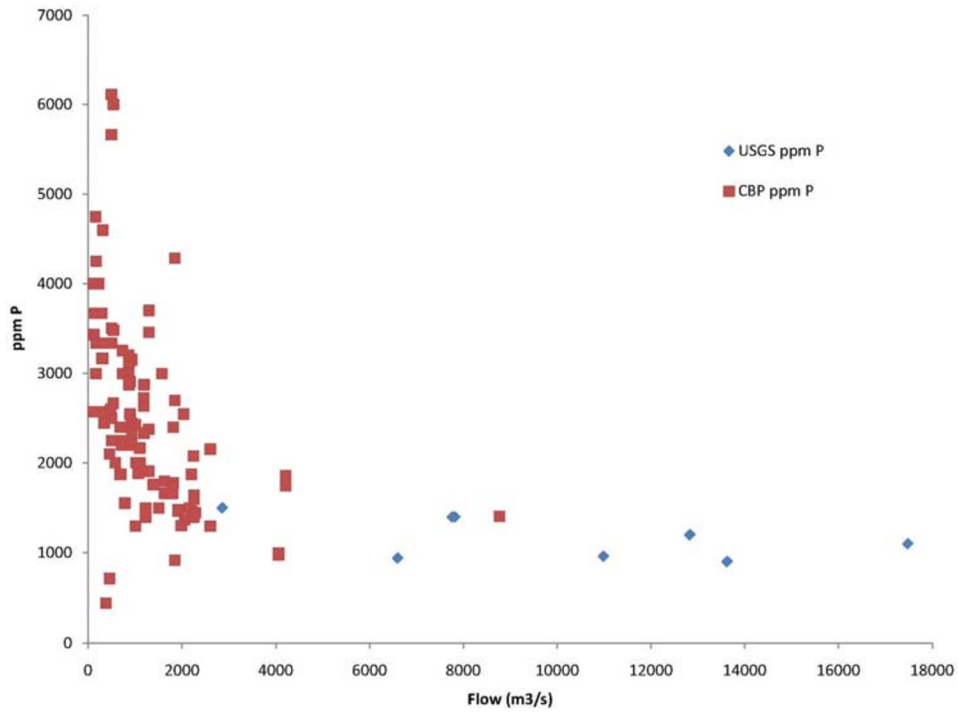


Figure 9. Phosphorus fraction of particles in Conowingo outfall vs. flow. Data designated USGS was collected for this study. Data designated CBP is from the Chesapeake Bay Program data base.

Table 2. Summary of Data in the Bed Sediments and Dam Outflow

	Hainly et al. 1995 (A)	Langland and Hainly 1997 (C)	Publication 239 (I)	Durlin and Schaffstall 1997 (D)	USGS Fall Line Monitoring 1979 – 1984 (E)	CBP Monitoring CB1.0 (G)	USGS Fall Line Sampling 2010 – 2011 (H)	Langland Personal Comm. 2012 (B)	CBL Sample Analyses (F)
Bed Sediment % Sand	22 (1)		20.4 (avg), 70.7 (max), 0.2 (min) (3)	53.7 (4)				24.7 (4)	
Bed Sediment % Silt	46 (1)		48.2 (avg), 61 (max), 22.9 (min) (3)	35.6 (4)				45.2 (4)	
Bed Sediment % Clay	26 (1)		31.4 (avg), 50.7 (max), 5.8 (min) (3)	10.4 (4)				25.4 (4)	
Bed Sediment % Coal	6 (1)		11.7 (avg), 46 (max), 0.7 (min) (3)						
Bed Sediment NH4, mg/kg	404 (1)			122 (avg), 400 (max), 24 (min) (3)				386 (avg), 730 (max), 13 (min) (5)	
Bed Sediment NO3, mg/kg				1.0 (avg), 2.4 (max), 0.3 (min) (3)				6 (avg), 18 (max), 2 (min) (5)	
Bed Sediment Org N, mg/kg	3,020 (1)			3,672 (avg), 6,900 (max), 1,500 (min) (3)				3,109 (avg), 4,266 (max), 2,127 (min) (5)	
Bed Sediment Total N, mg/kg		3,780 (avg), 6,900 (max), 1,500 (min) (2)	3040 (avg), 4190 (max), 2080 (min) (3)	3,783 (avg), 6,900 (max), 1,500 (min) (3)				3,501 (avg), 4,303 (max), 2,218 (min) (5)	

Bed Sediment Inorganic P, mg/kg				624 (avg), 1,310 (max), 286 (min) [3]					
Bed Sediment Organic P, mg/kg				97 (avg), 272 (max), 15 (min) [3]					
Bed Sediment Total P, mg/kg	920 [1]	720 (avg), 1,390 (max), 286 (min) [2]	1,147 (avg), 1,644 (max), 571 (min) [3]	722 (avg), 1,390 (max), 286 (min) [3]				961 (avg), 1,400 (max), 370 (min) [5]	
Bed Sediment % Organic C			9.7 (avg), 23.6 (max), 4.0 (min) [3]						
Plant Available P		1.25 (avg), 3.5 (max), 0.6 (min) % of total [2]		9.1 (avg), 13.1 (max), 6.2 (min) mg/kg [3]					
Sequential P Extraction			x						
Bed Sediment Fe, mg/kg	24,400 [1]		36,000 (avg), 52,000 (max), 22,000 (min) [3]					22,727 (avg), 37,000 (max), 2,200 (min) [5]	
Bed Sediment Al, mg/kg	10,400 [1]								
Bed Sediment Mn, mg/kg	1,650 [1]							1,568 (avg), 2,400 (max), 990 (min) [5]	

Bed Sediment Ca, mg/kg								1,986 (avg), 2,600 (max), 1,500 (min) (5)	
Moisture Content, %				50 (avg), 92 (max), 32 (min) (3)				46 (avg), 65 (max), 24 (min) (5)	
Bed Sediment Size Distribution				x				x	
Fall Line Flow, m3/s							11,028 (avg), 17,479 (max), 2,861 (min) (5)		
Fall Line Solids Size Distribution					x				
Fall Line Solids % Clay					74 (avg), 83 (max), 54 (min) (5)				
Fall Line Solids % Silt and Clay					99 (avg), 100 (max), 97 (min) (5)				
Fall Line TSS, mg/L					157 (avg), 359 (max), 17 (min) (5)	11 (avg), 66 (max), 1.5 (min) (5)			
Fall Line PC, mg/L						0.880 (avg), 2.595 (max), 0.188 (min) (5)			

Fall Line PN, mg/L						0.134 (avg), 0.351 (max), 0.015 (min) [5]			
Fall Line PP, mg/L						0.023 (avg), 0.093 (max), 0.004 (min) [5]			0.036 (avg), 0.218 (max), 0.002 (min) [5]
Fall Line PIP, mg/L									0.020 (avg), 0.134 (max), 0.002 (min) [5]
P Fraction in Suspended Solids, mg/kg							1,170 (avg), 1,500 (max), 900 (min) [5]		
Fe Fraction in Suspended Solids, %							4.6 (avg), 5.4 (max), 3.6 (min) [5]		
Mn Fraction in Suspended Solids, mg/kg							2,260 (avg), 3,400 (max), 1,800 (min) [5]		
C Fraction in Suspended Solids, %							3.5 (avg), 5.1 (max), 1.9 (min) [5]		
N Fraction in Suspended Solids, mg/kg							2,967 (avg), 4,700 (max), 1,800 (min) [5]		

[1] reported mean values for Conowingo Reservoir
[2] summary values reported by authors for Conowingo Reservoir
[3] calculated from reported values for Conowingo Reservoir
[4] based on mean fractions of reported size distributions
[5] calculated from reported values

References

Lang, D. (1982). "Water quality of the three major tributaries to the Chesapeake Bay, the Susquehanna, Potomac, and James Rivers, January 1979 – April 1981," Water-Resources Investigations Report 82-32, US Geological Survey, Towson MD.

Langland, M., and Hainly, R. (1997). "Changes in bottom-surface elevations in three reservoirs on the lower Susquehanna River, Pennsylvania and Maryland, following the January 1996 flood - Implications for nutrient and sediment loads to Chesapeake Bay," Water-Resources Investigations Report 97-4138, US Geological Survey, Lemoyne PA.

Reed, L., and Hoffman, S. (1997). "Sediment deposition in Lake Clarke, Lake Aldred, and Conowingo Reservoir, Pennsylvania and Maryland, 1910-93," Water-Resources Investigations Report 96-4048, US Geological Survey.

USACE. (2011). "Lower Susquehanna River watershed assessment," Draft Project Management Plan, US Army Corps of Engineers Baltimore District, Baltimore MD.

USEPA. (2010). "Chesapeake Bay total maximum daily load for nitrogen, phosphorus and sediment," US Environmental Protection Agency Region 3. (http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html)

Appendix Data Listing

Individual observations from 22 sediment cores from Conowingo Reservoir.
Langland, Michael. (2012). Personal communication. US Geological Survey, New Cumberland PA.

Latitude (degrees, minutes, secs north)	Longitude (degrees, minutes, secs west)	Begin date	Moisture content, fraction of dry weight, percent	Ammonia, bed sediment, total, dry weight, mg/kg as nitrogen	Ammonia plus organic nitrogen, bed sediment, total, dry weight, mg/kg as nitrogen	organic N	total N	Nitrate plus nitrite, bed sediment, total, dry weight, mg/kg as nitrogen	Phosphorus, bed sediment, total, dry weight, mg/kg as phosphorus
393939	761109	12/17/1990	62	710	3900	3190	3902	2	1300
393955	761058	12/17/1990	50	380	3300	2920	3302	2	1200
394007	761124	12/6/1990	47	420	3400	2980	3402	2	1100
394010	761049	12/17/1990	61	620	3600	2980	3602	2	1300
394017	761200	12/17/1990	65	730	4000	3270	4002	2	1200
394025	761152	12/13/1990	61	600	3600	3000	3616	16	1400
394039	761150	12/13/1990	46	510	2800	2290	2802	2	1200
394104	761255	11/30/1990	54	710	3500	2790	3502	2	1300
394107	761223	12/6/1990	50	470	3000	2530	3014	14	1100
394126	761258	11/30/1990	47	590	4300	3710	4302	2	850
394148	761318	11/30/1990	48	560	3900	3340	3902	2	1100
394208	761402	11/27/1990	44	250	3500	3250	3508	8	990
394212	761335	11/27/1990	46	260	3200	2940	3218	18	930
394254	761407	11/27/1990	46	310	3600	3290	3603	3	950
394339	761407	11/27/1990	26	73	2200	2127	2218	18	370
394453	761441	11/7/1990	49	250	3400	3150	3402	2	790
394524	761545	11/20/1990	39	210	3800	3590	3802	2	730
394530	761430	11/20/1990	42	270	3700	3430	3702	2	720
394544	761523	11/7/1990	26	13	3400	3387	3405	5	520
394608	761508	11/7/1990	60	490	3200	2710	3202	2	1200
394655	761622	11/8/1990	24	40	3300	3260	3310	10	380
394704	761605	11/8/1990	25	34	4300	4266	4303	3	510

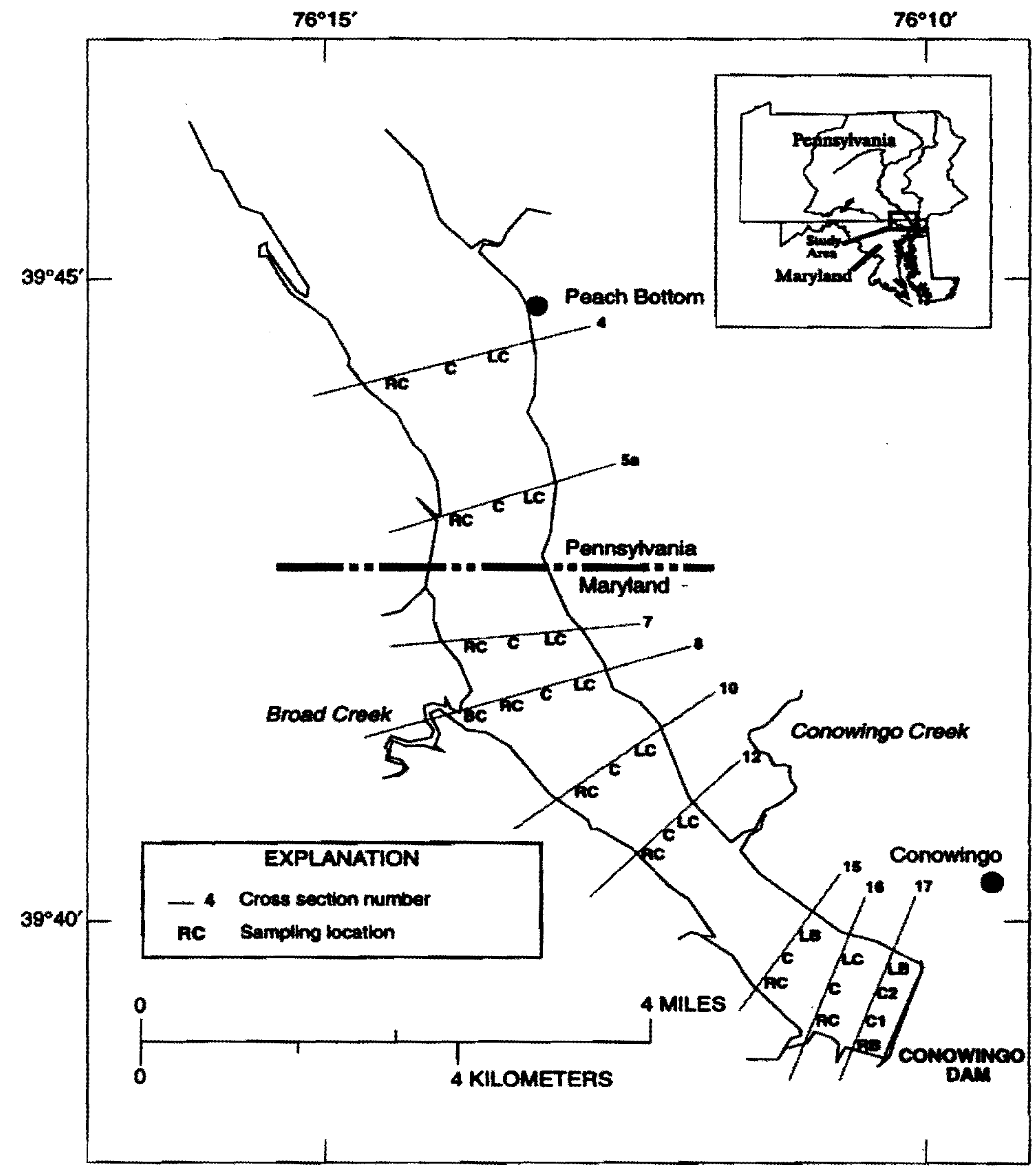
Latitude (degrees, minutes, secs north)	Longitude (degrees, minutes, secs west)	Begin date	Calcium, bed sediment, recoverable, dry weight, mg/kg	Manganese, bed sediment, recoverable, dry weight, mg/kg	Iron, bed sediment, total digestion, dry weight, mg/kg	Bed sediment, fall diameter (deionized water), percent < 0.004 millimeters	Bed sediment, dry sieved, sieve diameter, percent < 0.0625 millimeters
393939	761109	12/17/1990	1800	1500	19000	41	98
393955	761058	12/17/1990	2000	1500	24000	39	98
394007	761124	12/6/1990	2400	2000	24000	28	90
394010	761049	12/17/1990	1600	1400	21000	38	98
394017	761200	12/17/1990	1500	1300	16000	37	97
394025	761152	12/13/1990	1700	1700	18000	37	96
394039	761150	12/13/1990	2400	2000	9600	34	98
394104	761255	11/30/1990	1900	1700	25000	39	96
394107	761223	12/6/1990	2100	2000	21000	35	96
394126	761258	11/30/1990	2500	2100	23000	32	85
394148	761318	11/30/1990	2600	2400	24000	32	90
394208	761402	11/27/1990	2400	1900	32000	27	81
394212	761335	11/27/1990	2000	1700	2200	27	81
394254	761407	11/27/1990	2000	1600	28000	1	4
394339	761407	11/27/1990	2000	1200	33000	23	67
394453	761441	11/7/1990	1700	1400	24000	21	66
394524	761545	11/20/1990	1900	1100	34000	19	54
394530	761430	11/20/1990	2000	1300	28000	15	50
394544	761523	11/7/1990	1600	1100	27000	2	6
394608	761508	11/7/1990	1600	1200	4200	27	89
394655	761622	11/8/1990	2300	1400	37000	3	9
394704	761605	11/8/1990	1700	990	26000	2	4

Individual observations from 29 sediment cores from Conowingo Reservoir.
Durlin, R., and Schaffstall, W. (1997). "Water Resources Data Pennsylvania Water year 1996,"
Vol. 2 Susquehanna and Potomac River Basins. US Geological Survey, Lemoyne PA.
Data collected August 1996, following the flood event of January 1996.

Station	Latitude (degrees, minutes, secs north)	Longitude (degrees, minutes, secs west)	Moisture Content (%)	Total Nitrogen (mg N/kg)	Nitrate (mg N/kg)	NH4 (mg N/kg)	Organic Nitrogen (mg N/kg)	Total Phosphorus (mg P/kg)	Inorganic P (mg P/kg)	Organic P (mg P/kg)	Plant-Available P mg P/kg)
XC-4 RC	394436	0761355	39	3600	0.7	25	3600	401	375	26	9.9
XC-4 C	394426	0761413	34	1500	0.5	32	1500	386	369	17	8.7
XC-4 LC	394418	0761428	52	3200	0.4	180	3000	961	877	84	6.2
XC-5A RC	394330	0761341	43	2000	0.5	40	2000	572	473	99	12.4
XC-5A C	394329	0761357	47	2700	0.6	43	2700	428	323	105	10.6
XC-5A LC	394328	0761414	69	3300	0.9	130	3200	667	646	21	8.7
XC-7 RC	394240	0761335	48	3600	0.5	250	3400	866	789	77	8.7
XC-7 C	394238	0761351	39	4300	0.4	100	4200	559	502	57	8.1
XC-7 LC	394236	0761409	55	2900	0.6	190	2700	933	661	272	6.8
XC-8 RC	394219	0761321	50	4200	0.8	45	4200	496	391	105	9.9
XC-8 C	394214	0761340	44	4400	0.5	130	4300	603	588	15	12.4
XC-8 LC	394207	0761358	33	2900	0.3	70	2800	517	430	87	12.4
XC-8 Broad Ck	394158	0761416	56	3800	1	170	3600	1010	986	21	13.1
XC-10 RC	394144	0761241	35	4300	0.8	39	4300	336	239	97	11.8
XC-10 C	394136	0761258	47	5200	1.2	190	5000	617	515	102	11.2
XC-10 LC	394121	0761316	54	4600	2.4	160	4400	916	759	157	6.8
XC-12 RC	394070	0761211	63	3700	1.1	400	3300	1390	1310	77	13.1
XC-12 C	394107	0761220	32	6300	0.5	38	6300	286	202	84	6.2
XC-12 LC	394055	0761229	92	6900	1.8	24	6900	442	297	145	6.8
XC-15 RC	394001	0761134		3600	1.3	230	3400	960	884	76	7.4
XC-15 C	394010	0761125	50	4400	1.3	170	4200	782	563	219	11.2
XC-15 LC	394018	0761117	52	3700	0.9	95	3600	694	560	134	7.4

Station	Latitude (degrees, minutes, secs north)	Longitude (degrees, minutes, secs west)	Moisture Content (%)	Total Nitrogen (mg N/kg)	Nitrate (mg N/kg)	NH4 (mg N/kg)	Organic Nitrogen (mg N/kg)	Total Phosphorus (mg P/kg)	Inorganic P (mg P/kg)	Organic P (mg P/kg)	Plant-Available P mg P/kg)
XC-16 RC	394007	0761052	55	3000	2	120	2900	961	822	139	8.1
XC-16 C	393957	0761058	55	3900	1.3	100	3800	784	658	126	8.7
XC-16 Lt Bank	393947	0761106	49	3200	1.9	71	3100	793	683	110	6.8
XC-17 Rt Bank	394002	0761035	52	4000	1	130	3900	770	754	16	8.1
XC-17 RC	393955	0761039		3200	0.9	110	3100	832	805	27	8.1
XC-17 LC	393470	0761044	53	3700	1.2	130	3600	901	803	98	7.4
XC-17 Lt Bank	393940	0761049	57	3600	1.8	130	3500	1070	844	228	6.8

Station	Latitude (degrees, minutes, secs north)	Longitude (degrees, minutes, secs west)	Bed Mat Fall Diameter (% finer than 0.004 mm)	Bed Mat Sieve Dia (% finer than 0.062 mm)	Bed Mat Sieve Dia (% finer than 1.0 mm)
XC-4 C	394426	0761413	3	12	100
XC-5A C	394329	0761357	2	7	100
XC-7 C	394238	0761351	21	60	100
XC-8 C	394214	0761340	3	29	97
XC-10 C	394136	0761258	7	32	100
XC-12 C	394107	0761220	13	38	100
XC-15 C	394010	0761125	16	64	100
XC-16 C	393957	0761058	19	68	100
XC-17 RC	393955	0761039	14	70	100
XC-17 LC	393470	0761044	6	80	100



76°15′
76°10′
39°45′
39°40′
Pennsylvania
Study Area
Maryland
Peach Bottom
Pennsylvania
Maryland
Broad Creek
Conowingo Creek
Conowingo
CONOWINGO DAM
4
5a
7
8
10
12
15
16
17
RC
C
LC
LB
RB
C1
C2
EXPLANATION
4 Cross section number
RC Sampling location
0
4 MILES
0
4 KILOMETERS

agency_cd   - Agency Code
site_no   - USGS site number
sample_dt   - Date of sample
sample_tm   - Time of sample
p00061   - Discharge, instantaneous, cubic feet per second
p70331   - Suspended sediment, sieve diameter, percent smaller than 0.063 millimeters
p70338   - Suspended sediment, fall diameter (deionized water), percent smaller than 0.004 millimeters
p70339   - Suspended sediment, fall diameter (deionized water), percent smaller than 0.008 millimeters
p70340   - Suspended sediment, fall diameter (deionized water), percent smaller than 0.016 millimeters
p70341   - Suspended sediment, fall diameter (deionized water), percent smaller than 0.031 millimeters
p80154   - Suspended sediment concentration, milligrams per liter
#
Data for the following sites are included:
USGS 01578310 SUSQUEHANNA RIVER AT CONOWINGO, MD
#

agency_cd	site_no	sample_dt	sample_tm	p00061	p70331	p70338	p70339	p70340	p70341	p80154
5s	15s	10d	4d	12s	12s	12s	12s	12s	12s	12s
USGS	1578310	3/31/1980	10:31	151000	98	83	95	97	97	35
USGS	1578310	3/31/1980	10:30	151000	98	82	88	89	95	43
USGS	1578310	3/22/1980	10:30	173000	99	81	95	97	98	49
USGS	1578310	3/23/1980	18:30	207000	99	81	95	96	98	132
USGS	1578310	2/17/1984	11:30	453000	99	81	82	91	96	359
USGS	1578310	2/17/1984	13:10	414000	99	81	81	94	98	282
USGS	1578310	2/13/1981	15:00	164000	100	79	94	97	98	183
USGS	1578310	2/13/1981	17:00	139000	100	78	92	97	99	194
USGS	1578310	4/2/1980	11:31	225000	99	78	92	98	99	31
USGS	1578310	3/23/1980	18:31	207000	100	77	94	98	99	107
USGS	1578310	3/23/1980	14:15	220000	100	76	91	98	99	113
USGS	1578310	3/23/1980	20:30	217000	100	75	91	94	96	138
USGS	1578310	2/17/1984	13:05	415000	100	73	88	95	98	235
USGS	1578310	2/17/1984	13:11	412000	99	73	86	95	98	265
USGS	1578310	3/23/1980	14:30	217000	100	71	86	94	94	123
USGS	1578310	8/8/1979	12:00	34300	97	71	83	88	94	17
USGS	1578310	2/17/1984	13:00	416000	99	66	80	94	97	276
USGS	1578310	4/2/1980	11:30	225000	100	65	83	93	98	40
USGS	1578310	2/17/1984	12:40	428000	98	58	80	94	96	230
USGS	1578310	2/17/1984	12:30	429000	98	54	75	84	88	295

Analyses of particulate phosphorus (PP) and particulate inorganic phosphorus (PIP)
Chesapeake Biological Laboratory, Solomons MD.

Sample Date	PP (mg P/l) pcode 667		PIP (mg P/l) pcode ?	% PIP
1/3/2003	0.0234		0.0124	53.0%
1/9/2003	0.0179		0.0088	49.2%
2/4/2003	0.0071		0.0052	73.2%
2/4/2003	0.0079		0.0052	65.8%
3/5/2003	0.0222		0.0106	47.7%
4/2/2003	0.0217		0.0119	54.8%
5/7/2003	0.0024	L	0.0024	
5/7/2003	0.0230		0.0114	49.6%
6/4/2003	0.0404		0.0230	56.9%
6/4/2003	0.0419		0.0240	57.3%
6/4/2003	0.0408		0.0237	58.1%
6/4/2003	0.0416		0.0231	55.5%
6/20/2003	0.0382		0.0241	63.1%
7/1/2003	0.0024	L	0.0024	
7/1/2003	0.0283		0.0168	59.4%
8/6/2003	0.0158		0.0289	182.9%
9/4/2003	0.0283		0.0154	54.4%
9/10/2003	0.0256		0.0149	58.2%
10/14/2003	0.0198		0.0097	49.0%
11/13/2003	0.0149		0.0083	55.7%
12/17/2003	0.0356		0.0205	57.6%
1/22/2004	0.0142		0.0054	38.0%
2/10/2004	0.0489		0.0210	42.9%
3/5/2004	0.0185		0.0096	51.9%
3/15/2004	0.0150		0.0105	70.0%
4/6/2004	0.0238		0.0124	52.1%
4/6/2004	0.0281		0.0136	48.4%
4/15/2004	0.0288		0.0173	60.1%
5/5/2004	0.0024		0.0024	100.0%
5/5/2004	0.0377		0.0191	50.7%
6/16/2004	0.0349		0.0180	51.6%

Sample Date	PP (mg P/l) pcode 667	PIP (mg P/l) pcode ?	% PIP
7/6/2004	0.0192	0.0110	57.3%
8/5/2004	0.0268	0.0152	56.7%
9/13/2004	0.0464	0.0260	56.0%
9/22/2004	0.1052	0.0618	58.7%
10/13/2004	0.0219	0.0102	46.6%
11/16/2004	0.0081	0.0042	51.9%
11/29/2004	0.0261	0.0118	45.2%
12/14/2004	0.0356	0.0241	67.7%
1/10/2005	0.0415	0.0210	50.6%
1/10/2005	0.0406	0.0221	54.4%
1/27/2005	0.0154	0.0103	66.9%
2/16/2005	0.0300	0.0184	61.3%
3/7/2005	0.0095	0.0044	46.3%
3/29/2005	0.0342	0.0172	50.3%
3/31/2005	0.1800	0.1040	57.8%
3/31/2005	0.1777	0.1028	57.9%
4/4/2005	0.2175	0.1335	61.4%
4/21/2005	0.0205	0.0100	48.8%
5/12/2005	0.0155	0.0027	17.4%
6/2/2005	0.0265	0.0099	37.4%
7/20/2005	0.0373	0.0172	46.1%
8/16/2005	0.0170	0.0073	42.9%

L = "Less than"

Particulate C, N, P, and TSS at Conowingo outfall.
Station 1.0 in the Chesapeake Bay Program Water Quality Data Base

PC (mg/L)	PN (mg/L)	PP (mg/L)	TSS (mg/L)	Flow (m3/s)	CHLa (ug/L)
0.732	0.11	0.017	4	169	
0.949	0.156	0.004	9	380	7
0.966	0.145	0.024	7	121	6.73
0.688	0.087	0.02	12	1,628	0.9
0.834	0.096	0.026	19	2,057	0.9
0.525	0.051	0.015	8	2,200	1.28
0.434	0.04	0.012	5	1,815	0.75
0.47	0.066	0.012	5	682	1.5
1.209	0.178	0.028	11	2,036	10.47
1.882	0.28	0.021	11	1,296	29.9
1.205	0.137	0.026	20	2,602	4.78
1.105	0.138	0.028	13	2,602	4.19
1.285	0.168	0.057	62	1,849	
1.029	0.177	0.027	12	748	4.49
1.016	0.116	0.03	23	1,985	0.9
0.461	0.062	0.015	8	696	1.2
0.915	0.117	0.021	15	2,249	0.85
0.709	0.08	0.015	10	1,507	0.3
0.552	0.068	0.019	8	1,290	1.92
0.401	0.059	0.011	5	716	
0.966	0.154	0.037	21	1,389	3.36
0.648	0.084	0.022	15	2,206	1.5
1.075	0.204	0.018	10	1,627	23.03
0.768	0.137	0.021	10	456	3.29
1.104	0.159	0.02	6	166	2.09
0.712	0.137	0.02	5	224	5.13
0.615	0.112	0.022	6	142	2.54
0.612	0.109	0.018	7	106	3.89
0.29	0.038	0.018	7	350	3.2
0.69	0.095	0.022	11	1,016	1.79
0.318	0.044	0.011	5	926	
1.954	0.279	0.073	41	1,812	2.99
2.595	0.275	0.093	66	8,767	4.98
0.724	0.097	0.027	18	2,159	
1.208	0.195	0.027	9	1,574	14.05
0.941	0.168	0.024	9	536	5.98
1.064	0.176	0.02	6	320	6.28
1.11	0.159	0.022	9	339	5.68
0.694	0.115	0.019	4	160	4.49
0.648	0.126	0.02	5	105	5.15
0.978	0.137	0.005	7	456	3.99
0.575	0.075	0.014	9	783	3.24
0.558	0.027	0.014	10	1,223	
0.476	0.015	0.015	10	1,223	
0.322	0.045	0.009	4	497	1.39
0.451	0.063	0.01	4	497	0.85
0.526	0.07	0.013	6	1,100	2.03
0.476	0.065	0.012	6	1,100	2.03
0.899	0.189	0.027	10	1,850	17.73
0.865	0.197	0.03	7	1,850	17.94
1.231	0.195	0.03	11	1,188	11.75

1.218	0.19	0.029	11	1,188	10.68
1.5	0.247	0.038	11	1,296	12.82
1.564	0.266	0.037	10	1,296	11.96
1.106	0.187	0.018	8	933	7.48
1.157	0.211	0.021	9	933	7.26
0.77	0.137	0.022	9	924	6.41
0.828	0.149	0.023	7.3	924	6.41
0.477	0.046	0.025	8	872	9.61
0.188	0.028	0.023	8	872	9.83
0.825	0.138	0.021	6	502	7.32
1.016	0.177	0.02	6	502	5.65
0.893	0.121	0.023	14	2,255	1.34
0.942	0.139	0.024	15	2,255	1.5
0.677	0.099	0.017	7	1,008	4.7
0.641	0.11	0.0078	6	1,008	4.91
1.247	0.201	0.044	30	1,915	2.56
1.53	0.212	0.046	31	1,915	2.99
0.618	0.084	0.015	5	864	4.7
0.498	0.074	0.016	5	864	4.7
1.005	0.163	0.029	20	2,285	2.56
0.981	0.163	0.03		2,285	2.78
0.74	0.098	0.021	9	1,189	31.58
1.539	0.257	0.023	8	1,189	31.58
1.65	0.313	0.055	9	496	4.91
1.999	0.351	0.051	9	496	4.91
1.209	0.157	0.022	6	290	4.49
1.049	0.142	0.019	6	290	4.27
0.621	0.097		6	480	2.35
0.634	0.115	0.013	5	480	2.78
0.789	0.143	0.021	7	165	5.65
0.81	0.158	0.021	7	165	
0.598	0.092	0.018	9	1,070	1.71
0.49	0.077	0.017	9	1,070	1.71
0.526	0.089	0.015	8	676	3.63
0.72	0.125	0.015	8	676	3.63
0.653	0.095	0.013	7	4,206	2.85
0.609	0.079	0.014	8	4,206	2.73
0.251	0.042	0.008	2.3	538	
0.252	0.046	0.009	1.5	538	
0.78	0.12	0.012	4	732	2.42
0.766	0.118	0.013	4	732	2.35
0.989	0.131	0.027	13	2,245	7.48
1.082	0.142	0.027	13	2,245	7.9
0.623	0.084	0.014	8	1,797	3.6
0.581	0.081	0.015	9	1,797	3.47
1.871	0.254	0.044	45	4,056	1.6
1.738	0.213	0.044	44	4,056	
0.921	0.162	0.032	11	890	4.73
0.847	0.148	0.028	11	890	4.58
0.815	0.142	0.024	12	575	4.7
0.864	0.155	0.028	14	575	4.7
0.466	0.083	0.019	6	310	10.41
0.896	0.171	0.023	5	310	10.28

Particle analyses at Conowingo outfall.
Jeffrey Chanat, USGS MD-DE-DC Water Science Center.

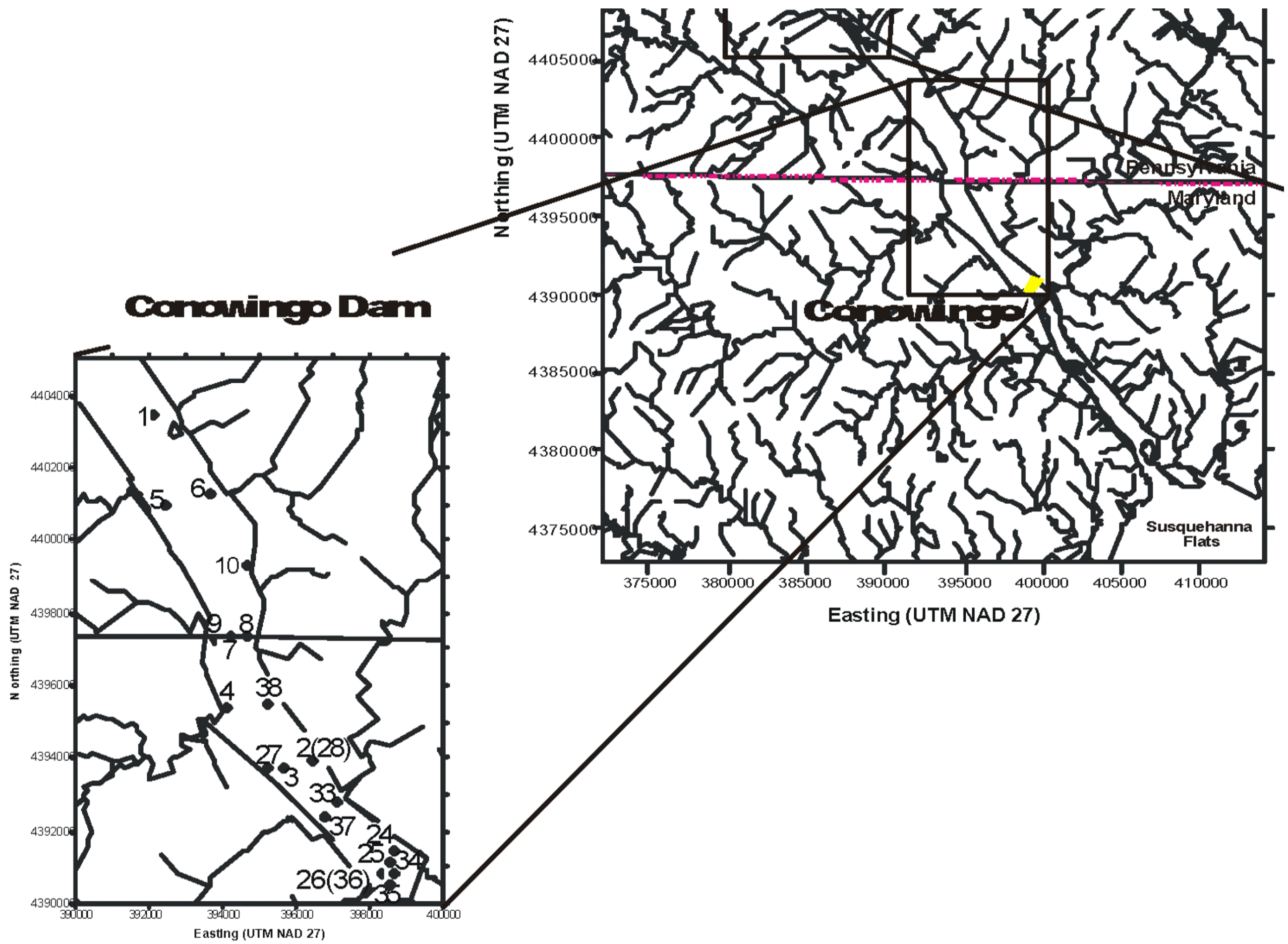
Date	Flow, m3/s	Phosphorus, ppm	Fe, %	Mn, ppm	TOC,%	TN, %	Susp. Sediment, mg/L		TOC (mg/L)	TN (mg/L)	TP (mg/L)
10/3/2010	2,861	1500	3.6	2500							
12/3/2010	7,819	1400	4.7	3000	4.1	0.47	141		5.8	0.66	0.197
3/8/2011	7,762	1400	5	3400	4.2	0.4	129		5.4	0.52	0.181
3/12/2011	12,833	1200	4.2	2100	5.1	0.36	937		47.8	3.37	1.124
3/12/2011	12,833	1200	4.4	2200	4.9	0.34	937		45.9	3.19	1.124
9/8/2011	17,479	1100	4.4	1900	3.2	0.26	2980		95.4	7.75	3.278
9/8/2011	17,479	1100	4.3	2000	3.2	0.27	2980		95.4	8.05	3.278
9/10/2011	13,626	900	5.3	1900	2.2	0.18	741		16.3	1.33	0.667
9/11/2011	10,992	960	4.9	1800	2.5	0.2	1150		28.8	2.30	1.104
9/12/2011	6,600	940	5.4	1800	1.9	0.19	332		6.3	0.63	0.312

Date	Flow, m3/s	Susp. Sediment, mg/L	Percent smaller than 0.063 mm (silt and clay)	Percent smaller than 0.004 mm (clay)
12/3/2010	7,819	141	98	
3/8/2011	7,762	129	97	
3/12/2011	12,833	937	90	
4/18/2011	7,219	206	98	
4/30/2011	8,946	184	96	
9/8/2011	17,479	2980	94	36
9/10/2011	13,626	741	97	63
9/11/2011	10,992	1150	94	48
9/12/2011	6,600	332	88	61

Analyses from 23 sediment cores from Conowingo Reservoir (21) and Susquehanna Flats (2).
Edwards, R. (2006). "Comprehensive analysis of the sediments retained behind hydroelectric dams of the lower Susquehanna River,"
Publication 239, Susquehanna River Basin Commission, Harrisburg PA.

ID	Latitude	Longitude	Intervals	%H20	Bulk Densi	%Coal	%SAND	%SILT	%CLAY	Fe (%)	Mn
1	39.78278	76.26417	10-20 in	40.75	1.6	21.74	40.84	45.23	13.93	3.3	1295.62
3	39.69333	76.21611	8-18 in	52.57	1.43	6.47	15.36	61.99	22.65	2.93	2374.78
4	39.70583	76.23611	9-19 in	38.37	1.64	10.98	52.91	37.29	9.8	3.85	2179.65
5	39.75611	76.2575	5-15 in	38.51	1.64	28.48	24.09	50.64	25.27	3.7	1123.39
6	39.76222	76.245	7-17 in	28.3	1.83	45.97	70.72	23.52	5.76	2.17	1052.46
7	39.725	76.23389	11-21 in	32.3	1.75	18.44	57.58	31.94	10.48	2.43	801.54
8	39.72472	76.22778	6-16 in	28.43	1.83	13.86	66.74	22.89	10.37	2.15	691.66
9	39.72389	76.23944	10-20 in	43.02	1.56	11.65	36.04	43.07	20.89	2.98	1659.55
10	39.74361	76.23111	3-13 in	45.48	1.53	25.36	8.93	59.35	31.72	3.91	1775.08
24	39.66917	76.18111	0-10	59.78	1.34	9.52	0.2	54.05	45.76	5.15	2328.49
25	39.66583	76.1825	23-33	52.98	1.42	5.35	5.83	60.63	33.54	3.49	2102.83
26	39.66306	76.18528	10-20 in	60.88	1.33	9.32	7.01	53.53	39.45	3.64	1800.59
27	39.68917	76.22083	7-17 in	63.43	1.3	4.82	6.21	56.11	37.68	3.53	2036.52
28	39.695	76.21083	10-20 in	60.74	1.33	1.01	0.85	61.81	37.35	3.78	2217.49
29	39.54694	76.02194	10-20 in	47.73	1.49	1.29	38.77	33.84	27.39	3.05	1117.41
30	39.54722	76.02222	10 20 in	48.65	1.48	0.46	34.38	34	31.61	2.95	973.55
33	39.68306	76.19944	10 20 in	62.91	1.31	4.24	0.36	55.05	44.59	4.14	1819.37
34	39.66611	76.17333	10-20 in	55.56	1.39	1.47	0.74	48.78	50.48	3.89	1512.63
35	39.6625	76.17444	10-20 in	68.41	1.25	2.31	0.31	49.04	50.65	4.28	3623.41
36	39.66167	76.18556	10-20 in	61.8	1.32	0.72	1.39	51.16	47.45	4.08	2304.78
37	39.67861	76.20389	10-20 in	63.61	1.3	1.84	0.36	52.99	46.65	4.1	2168.32
38	39.7075	76.22139	10-20 in	62.75	1.31	1.49	1.48	55.03	43.49	3.76	2854.29
2A	39.69556	76.2111	4-14 in	53.18	1.42	2.89	2.87	60.97	36.16	3.47	2412.41

ID	Latitude	Longitude	Intervals	P(ug/g)	%N	%C	
1	39.78278	76.26417	10-20 in	857.9	0.256	13.775	
3	39.69333	76.21611	8-18 in	1188.52	0.275	6.097	
4	39.70583	76.23611	9-19 in	1128.8	0.266	7.502	
5	39.75611	76.2575	5-15 in	696.03	0.276	17.536	
6	39.76222	76.245	7-17 in	571.43	0.224	23.634	
7	39.725	76.23389	11-21 in	701.38	0.21	14.369	
8	39.72472	76.22778	6-16 in	571.35	0.208	22.509	
9	39.72389	76.23944	10-20 in	1050.36	0.284	14.038	
10	39.74361	76.23111	3-13 in	1315.4	0.301	10.215	
24	39.66917	76.18111	0-10	1643.98	0.419	9.622	
25	39.66583	76.1825	23-33	1158.05	0.324	7.018	
26	39.66306	76.18528	10-20 in	1435.36	0.349	6.193	
27	39.68917	76.22083	7-17 in	1371.87	0.34	4.808	
28	39.695	76.21083	10-20 in	1162.49	0.326	4.815	
29	39.54694	76.02194	10-20 in	771.08	0.198	7.69	Susq Flats
30	39.54722	76.02222	10 20 in	699.98	0.188	7.364	Susq Flats
33	39.68306	76.19944	10 20 in	1466.74	0.357	4.493	
34	39.66611	76.17333	10-20 in	1131.83	0.264	4.332	
35	39.6625	76.17444	10-20 in	1714.93	0.445	4.809	
36	39.66167	76.18556	10-20 in	1402.89	0.352	4.395	
37	39.67861	76.20389	10-20 in	1401.73	0.35	4.041	
38	39.7075	76.22139	10-20 in	1375.63	0.346	4.957	
2A	39.69556	76.2111	4-14 in	1250.81	0.363	4.684	



Conowingo Dam
Northing (UTM NAD 27)
Easting (UTM NAD 27)
Pennsylvania
Maryland
Conowingo
Susquehanna Flats
Northing (UTM NAD 27)
Easting (UTM NAD 27)

Attachment C-2:
Individual Results for Each Chesapeake Bay Environmental Model Package in the LSRWA

(Not Included – Contact USACE-Baltimore District)

Appendix D:
Estimated Influence of Conowingo Infill on the Chesapeake Bay Water Quality

Estimated Influence of Conowingo Reservoir Infill on Chesapeake Bay Water Quality

Lewis C. Linker[1] Carl Cerco[2], Ping Wang[3], Richard Tian[4], Guido Yactayo[4], Gary Shenk[5], and Lee Currey[6]

1. CBP Modeling Coordinator, U.S. Environmental Protection Agency Chesapeake Bay Program Office, 410 Severn Avenue, Suite 109, Annapolis, Maryland 21403 linker.lewis@epa.gov,
2. U.S. Corps of Engineers, ERDC
3. Virginia Institute of Marine Science
4. University of Maryland Center for Environmental Studies
5. U.S. EPA Chesapeake Bay Program Office
6. Maryland Department of the Environment

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INTRODUCTION

As part of the Lower Susquehanna River Watershed Assessment (LSRWA), the influence of the Conowingo Reservoir infill on Chesapeake water quality was assessed using Delaware, District of Columbia, Maryland, and Virginia's water quality standards that were developed and adopted into state water quality regulations to protect Chesapeake Bay living resources. The Susquehanna River basin, sitting at the headwaters of Chesapeake Bay, is the Bay's largest watershed and drains an area of 27,500 square miles, 43 percent of the Chesapeake Bay's total watershed, covering half of Pennsylvania, and portions of New York and Maryland. The Susquehanna River delivers about 41 percent of the nitrogen loads, 25 percent of the phosphorus loads, and 27 percent of the suspended solids loads on an annual average basis (CBPO, 2012 Phase 5.3.2 Watershed Model 1991-2000 simulation period). The infill condition of the three lower Susquehanna River reservoirs contributes a portion of the nutrient and sediment loads delivered to Chesapeake Bay (Hirsch, 2012; Zhang et al., 2013).

The Chesapeake Bay Program (CBP) Partnership, a state-federal partnership, is an ongoing effort in restoring the national treasure which is the United States' largest estuary. Chesapeake Bay restoration work has now been underway for three decades, and in 2010 a new tool was added to the restoration effort when the nation's most extensive Total Maximum Daily Load (TMDL) program was established for the Chesapeake Bay watershed (USEPA, 2010a). The Chesapeake Bay TMDL was required under the federal Clean Water Act and responded to consent decrees in Virginia and the District of Columbia from the late 1990s. By 2007, an assessment of nutrient loads found that estimated nutrient and sediment load reductions by 2010 would be insufficient to avoid a Chesapeake Bay TMDL, and work began in 2008 to ensure completion of the TMDL allocations by 2010 (USEPA, 2008a).

The Clean Water Act sets an overarching environmental goal that all waters of the United States be “fishable” and “swimmable.” Specifically, it requires the Chesapeake Bay states and the District of Columbia to establish appropriate uses for their waters, adopt water quality standards that are protective of those uses, and list waterways that are impaired by pollutants causing them to fail to meet water quality standards. For waterways on the impaired list, a TMDL must be developed which identifies the maximum amount of pollutants the waterway can receive and still meet water quality standards. Most of Chesapeake Bay and its tidal tributary and embayment waters are impaired because of excess nitrogen, phosphorus, and sediment (USEPA, 2010a). These pollutants enter the water from agricultural operations, urban and suburban stormwater runoff, wastewater facilities, air pollution, septic systems, and other sources.

More than 49,000 TMDLs have been completed across the United States, but the Chesapeake Bay TMDL is the most extensive and complex thus far (Linker et al., 2013a) . It is designed to achieve significant reductions in nitrogen, phosphorus, and sediment pollutant loads throughout a 64,000-square-mile watershed. The Chesapeake watershed has a population of over 17 million people and includes portions of Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia, and all of the District of Columbia (USEPA, 2010a). The Chesapeake Bay TMDL is a combination of 276 individual TMDLs—separate nitrogen, phosphorus, and sediment TMDLs for each of the 92 Chesapeake Bay tidal segments shown in Figure 1.

The Chesapeake Bay TMDL incorporates several key elements. Water quality standards that are scientifically-based and publically understandable are among the most important. The Chesapeake Bay water quality standards are based on requirements for the Bay’s living resources to thrive, including adequate dissolved oxygen (DO) in deep-water habitats, appropriate levels of chlorophyll as a source of food at the base of the estuarine food web, and good water clarity in the shallow waters necessary for growth of underwater grasses which provide habitat for juvenile fish and crabs (USEPA, 2010c). Other elements include a time and space accounting of estimated water quality impairments (Keisman and Shenk, 2013) and a quantifiable TMDL 2010 Chesapeake allocation process for the Chesapeake that ensures achievement of all tidal water quality standards while assessing equitable levels-of-effort in reducing nutrients and sediments across all seven watershed jurisdictions (Linker et al., 2013a).

Developing the 2010 Chesapeake Bay TMDL and associated allocations involved the selection of a 10-year average hydrologic period that had an equitable distribution of high and low flow periods across the major basins (USEPA, 2010a; 2010b). This hydrologic period was then used to set the average long-term watershed allocation loads. Within the 10-year average period, a particular 3-year critical period was chosen that would serve as the assessment period of the tidal water quality standards. The 3-year period was selected as representative of a 10-year return frequency of high flows and loads (USEPA, 2010b). The 10-year average hydrologic period chosen was 1991-2000 and the key 3-year critical period for DO was 1993-1995 (USEPA, 2010a; 2010b). A time and space approach was used to assess the water quality standards, which allowed the comparison of observed and model simulated water quality conditions to criteria and reference conditions in healthy living resource sites, to determine if Delaware, District of Columbia, Maryland, and Virginia's Chesapeake Bay water quality standards were achieved (USEPA, 2003, 2010a, 2010b; Keisman and Shenk, 2013).

The 2010 Chesapeake Bay TMDL sets watershed-wide limits of 186 million pounds (84.3 million kilograms) of nitrogen, 12.5 million pounds (5.67 million kilograms) of phosphorus, and 6.46 billion pounds (2.93 billion kilograms) of sediment per year (USEPA, 2010a). Implementation of the nutrient and sediment limits is through the seven watershed jurisdictions' Watershed Implementation Plans (WIPs), which detail how and when the six Chesapeake Bay watershed states and the District of Columbia will complete implementation of management actions sufficient to meet their assigned pollution allocations.

The infill of the Conowingo Reservoir with the increased sediment and associated nutrient loads delivered to Chesapeake Bay creates a potential challenge in meeting the jurisdictions' Chesapeake Bay water quality standards with the nutrient and sediment reduction goals already set in the 2010 Chesapeake Bay TMDL allocations. A major Midpoint Assessment of the Chesapeake Bay TMDL and its progress to date is planned for 2017 (CBP Partnership, 2012). During the 2017 Midpoint Assessment, decisions will be made by the CBP Partnership regarding any necessary adjustments to the Chesapeake Bay TMDL and the jurisdictions' WIPs in order to account for Conowingo Reservoir infill and offset any additional sediment and associated nutrient pollutant loads to Chesapeake Bay and their impact on the jurisdictions' Chesapeake Bay water quality standards attainment.

THE CBP PARTNERSHIP'S MODELING SYSTEM

The collaborative work and decision making of hundreds of representatives from state, federal, and local agencies, universities, and non-governmental organizations was required for the development of the Chesapeake Bay TMDL (USEPA, 2010a). Decisions were supported by decades of scientific discovery as well as the application of a suite of integrated environmental models. Models of the Chesapeake Bay airshed (Community Multi-scale Air Quality Model – CMAQ, watershed (Watershed Model (WSM) Phase 5.3.2), and tidal Bay water quality (Water Quality and Sediment Transport Model – WQSTM) were applied to develop the 2010 Chesapeake Bay TMDL allocations (Cerco, 2000; Cerco et al., 2002; Cerco and Noel, 2004; Linker et al., 2000; Linker et al., 2008; Cerco et al., 2010; Shenk and Linker, 2013; Linker et al., 2013; Cerco and Noel, 2013).

The CBP Partnership's airshed, watershed, and Bay tidal water quality models that were used to develop the Chesapeake Bay TMDL were used in the LSRWA study to predict water quality conditions for the more than 30 Conowingo Reservoir infill loading scenarios. The Chesapeake Bay Watershed Model provided the estimated Susquehanna River watershed loads in the LSRWA study (Shenk and Linker, 2013) and the Chesapeake Bay WQSTM model was a key element to the assessment of Chesapeake Bay water quality responses (Cerco et al. 2013). Interposed between the Watershed Model of the Susquehanna River watershed and the WQSTM model of the Chesapeake Bay were the HEC-RAS and ADH models of the Lower Susquehanna reservoirs described in Appendices A and B. The Chesapeake Bay airshed model provided atmospheric nitrogen deposition loads to the Chesapeake watershed and tidal waters. Atmospheric deposition is one of the largest nitrogen sources to the Chesapeake Bay (Linker et al., 2013).

It was necessary to compare the Chesapeake Bay WQSTM model results with the applicable jurisdictions' Chesapeake Bay water quality standards regulations to determine estimated compliance with the standards. In general, to determine the degree of water quality standard achievement, model scenarios were run representing different Conowingo Reservoir infill management conditions using the CBP Partnership's suite of models (Linker et al., 2013; Shenk and Linker, 2013 Cerco et al., 2013). The resultant combined model simulated nitrogen, phosphorus, and sediment loadings were used as input into the Bay WQSTM to evaluate the response of critical water quality parameters, specifically DO, submerged aquatic vegetation (SAV), and water clarity.

To quantify the degree to which the different Conowingo Reservoir infill analysis scenarios' estimated Bay water quality conditions were projected to meet the jurisdictions' Chesapeake Bay DO and SAV-clarity water quality standards, the Bay WQSTM's simulated tidal water quality responses for DO, SAV, and water clarity were compared to the corresponding observed monitoring values collected during the same 1991-2000 hydrological period as described in Keisman and Shenk (2013). In other words, the Chesapeake Bay WQSTM was primarily used to estimate the *change* in water quality that would result from various modeled loading scenarios. Figure 2 provides an overall representation of the CBP Partnership's Modeling System.

The full simulation period of the key Chesapeake Bay airshed, watershed, and estuary water quality models used in the Chesapeake Bay TMDL allocation analysis were from 1985 to 2005, but the hydrologic period chosen to represent the long-term hydrologic conditions for the Chesapeake Bay watershed in the Chesapeake TMDL was for the ten years of 1991-2000 (USEPA, 2010b). The ten year period provided average long-term simulation conditions for each state jurisdiction of the Chesapeake Bay watershed and the Bay's tidal waters so that all Bay watershed states had a representative mix of point and nonpoint loads under a wide range of high to low river flows. The selection of a representative hydrologic averaging period was determined by examining the statistics of long-term flow relative to each 10-year period at nine key USGS gauging stations, which measure the discharge of the major rivers flowing to the Bay (USEPA, 2010b). The 10-year average period was used to set 10-year average loads in the 2010 Chesapeake Bay TMDL allocations.

KEY HYDROLOGIC PERIODS

Within the 10-year hydrologic period a 3-year critical period was chosen, which was used as the assessment period of the water quality standards in the tidal Bay. The critical period was based

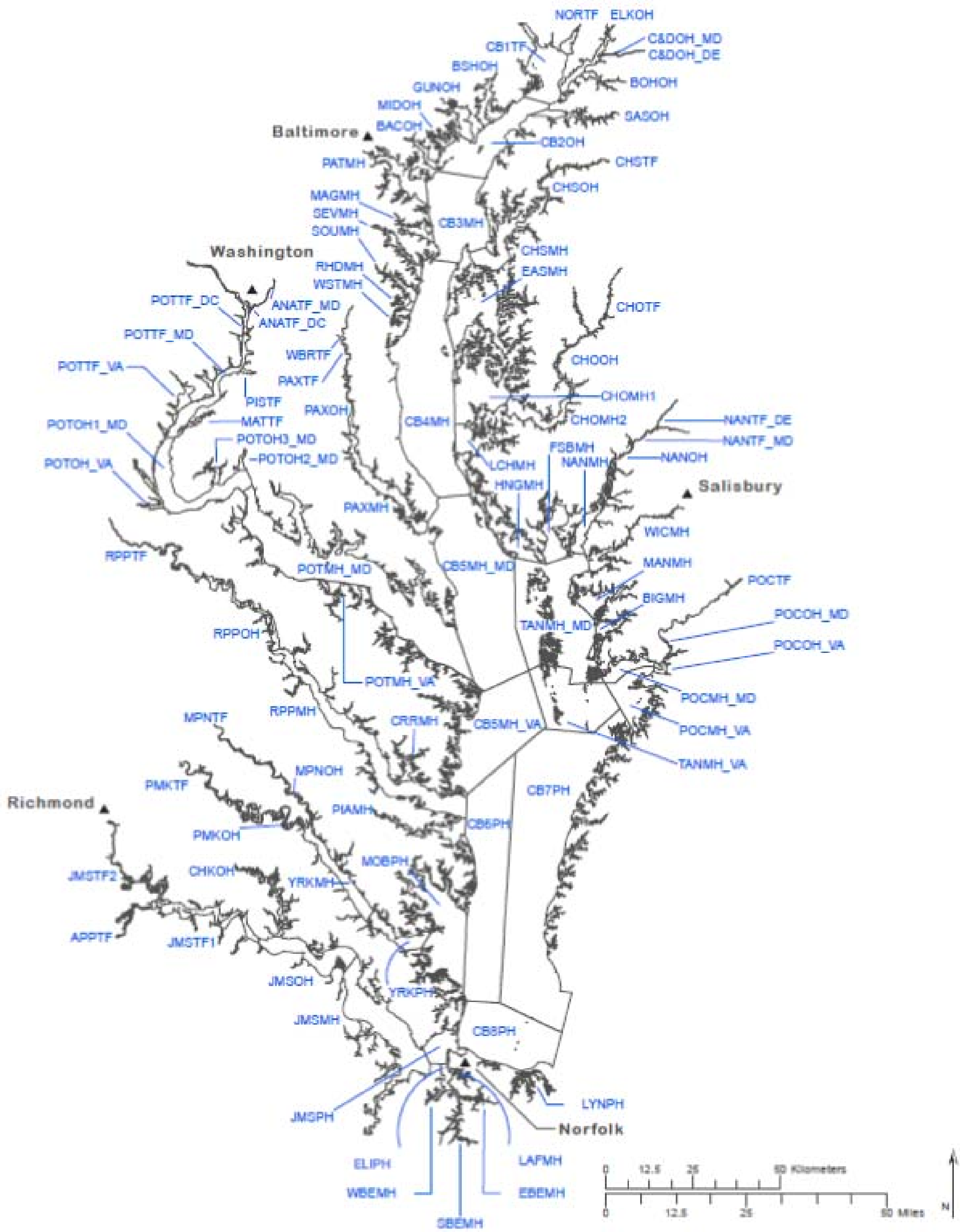

Figure 1. The 92 Chesapeake Bay TMDL segments.

Source: USEPA 2004a, 2005, 2008b

on key environmental factors, principally rainfall and streamflow, which influenced the DO water quality standard in the deep-water and deep-channel habitats of the Chesapeake Bay. The critical period and conditions determined major design conditions of the Chesapeake Bay TMDL [40 CFR 130.7(c)(1)] (CFR, 2011), in particular the period of loads, flows, and other environmental conditions during which the water quality standards were assessed in the tidal waters. The 3-year period selected as the critical period was 1993-1995, which was the second highest flow period of all the eight 3-year contiguous periods contained in the 1991-2000 record. In Chesapeake Bay, high flows bring high levels of nutrient and sediment loads, resulting in more DO and SAV-clarity impairments. The 1993–1995 critical period was chosen because it experienced stream flows that historically occurred about once every 10 years, which is typical of the return frequency for hydrological conditions employed in developing TMDLs in the Chesapeake Bay region (USEPA, 2010b). While the modeling for the Chesapeake Bay TMDL consisted of an assessment of the entire hydrologic period of 1991–2000 for many aspects of the allocation, including the 10 year average loads of the basin-jurisdictions, the water quality conditions during the 1993–1995 critical period was specifically used to assess attainment of the four jurisdictions' Chesapeake water quality standards.

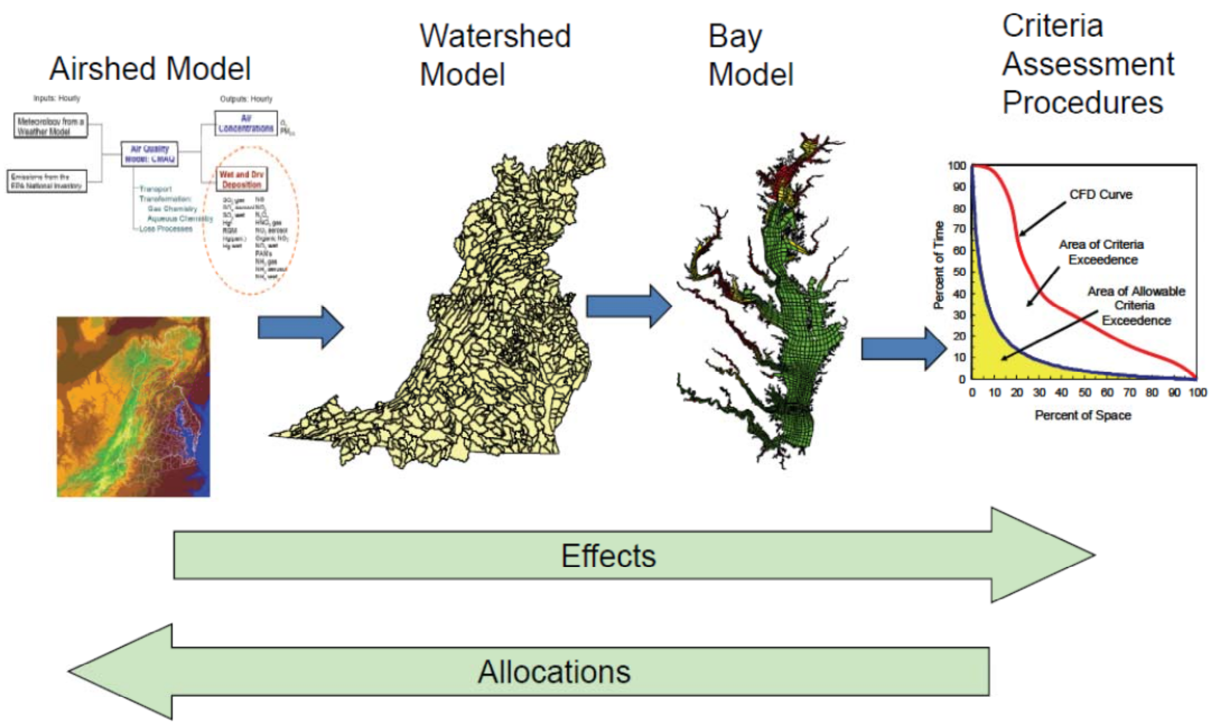

Figure 2. CBP Partnership decision-support simulation system including the Chesapeake Bay airshed, watershed and estuary models along with the criteria assessment procedures for water quality standard assessment.

Source: USEPA 2010a.

The highest 3 year flow and load period contained the January 1996 Susquehanna extreme flow event of the *Big Melt*, an event that was brought about by a rain event during a warming trend on existing snow pack in the lower Susquehanna. The Big Melt occurred in January 1996, which led to extreme flows and flooding because of a period of warmer weather and extensive rain on snowpack, as well as the formation and subsequent breaching of an ice dam (SRBC, 2006). For January 1996, precipitation over the entire Susquehanna River basin was above average, with the upper portion of the basin receiving more than 75 percent above normal. Snowpack over the upper portion of the basin through January 12 averaged 8 to 10 inches. Mild temperatures, combined with a precipitation event of 0.75 to 1.50 inches, caused the January 1996 flood event (SRBC, 2006). The January 1996 event was used extensively in the LSRWA scenarios described in this report because it is the highest observed and simulated flow within the 10 year simulation period of the CBP Partnership's models used in the LSRWA assessment. The January 1996 event was outside the 1993-1995 Chesapeake Bay TMDL critical period, so adjustments to the criteria assessment procedures of the Chesapeake Bay water quality standards were applied as described below to compare water quality results in the 1996-1998 three-year period.

CHESAPEAKE BAY WATER QUALITY STANDARDS

A good TMDL is based on scientifically sound and publically understandable water quality standards (Tango and Batiuk, 2013). In 2003, the Chesapeake Bay Program partners worked with the U.S. Environmental Protection Agency to develop and publish ambient water quality criteria protective of five specific Chesapeake Bay tidal water designated uses along with assessment procedures for dissolved oxygen, SAV, water clarity, and chlorophyll *a* criteria (USEPA, 2003a; b). The adoption of these criteria, designated uses, and assessment procedures into Delaware, District of Columbia, Maryland, and Virginia's water quality standards regulations ultimately provided the basis for developing the 2010 Chesapeake Bay TMDL (USEPA, 2010a). Table 1 lists the Chesapeake Bay DO criteria. The SAV-clarity criteria can be found in USEPA (2010c). The chlorophyll *a* water quality standard has little bearing on the analysis of Conowingo Reservoir infill because the only numeric chlorophyll standards are in the tidal fresh waters of the District of Columbia and in the tidal James River in Virginia (USEPA, 2010a). Both are tidal bodies of water that are too far removed from the Conowingo Reservoir to be influenced by it.

Water quality criteria are usually numerical, although sometimes narrative, values of environmental parameters (chemical, biological, and physical) which reflect concentrations, levels, or conditions protective of desired aquatic life species and communities. Water quality standards, on the other hand, are the combination of criteria, designated uses (defining the desired human and/or aquatic life uses of the subject water body), and antidegradation statements (commitments not to degrade the current water quality conditions) promulgated and adopted into states' water quality standard regulations through a public process and final approval by U.S.

EPA. In the case of the four Chesapeake Bay jurisdictions with tidal waters of the Chesapeake Bay within their respective jurisdiction, i.e., Delaware, the District of Columbia, Maryland, and Virginia, their water quality standards regulations also include descriptions of, and references to, more detailed criteria attainment assessment procedures (USEPA, 2010c).

The DO criteria were designed to be protective of living resources in all major habitat regions of the Chesapeake including regions of open surface waters, migratory fish spawning areas, deep-water habitats, and deep-channel areas (Batiuk et al., 2009; USEPA, 2003a; 2003d; Tango and Batiuk, 2013). The SAV-clarity criteria were protective of the shallow water regions of the Chesapeake (USEPA, 2003a, 2003b, 2004, 2007a; Kemp et al., 2004; Tango et al., 2013).
The DO, chlorophyll-*a*, and SAV-clarity criteria were adopted into water quality standard regulations by all of the tidewater Chesapeake Bay Program jurisdictions of Virginia, Maryland, Delaware, and the District of Columbia (USEPA, 2003a, 2003b, 2003c, 2007a, 2007b, 2010a).

Under simulated conditions of the estimated 1985 nutrient and sediment loads the water quality standard violations of surface Open-Water, Deep-Water, and Deep-Channel DO criteria, and chlorophyll *a* spring and summer criteria were estimated by the WQSTM to be widespread, particularly in the Deep-Water and Deep-Channel of the mainstem, with 110 violations (USEPA, 2010a). Under the 2009 model estimated load conditions, in which nutrient loads were reduced about half way toward the Chesapeake TMDL load levels, the number of total DO water quality criteria violations decreased to 34. By the time the estimated nutrient and sediment loads of the 2010 Chesapeake Bay TMDL were achieved, the model simulation the number of water quality criteria violations was estimated by the WQSTM to be zero (USEPA, 2010a).

TIME AND SPACE ASSESSMENT OF STANDARDS ATTAINMENT

The degree of achievement of the Chesapeake Bay water quality standards was assessed through quantitative analyses of the WQSTM scenario results for each Chesapeake Bay segment (see Figure 1). The same methods used for the 2010 Chesapeake Bay TMDL were used for the analysis of the Conowingo Reservoir LSRWA scenarios and consisted of an assessment of the percent of time and space that the modeled water quality results exceeded the allowable criterion concentration as described in USEPA, 2003a, 2004a, 2007a, 2008b, 2010c; and Keisman and Shenk, (2013).

Designated Use	Criteria Concentration/Duration	Protection Provided	Temporal Application
Migratory fish spawning and nursery use	Seven-day mean ≥6mg/l (tidal habitats with 0-0.5 ppt salinity	Survival and growth of larval/juvenile tidal-fresh resident fish; protective of threatened/endangered species	February 1-May 31
	Instantaneous minimum ≥ 5 mg/l	Survival and growth of larval/juvenile migratory fish; protective of threatened/endangered species	
	Open-water fish and shellfish designated use criteria apply		June 1-January 31
Shallow-water Bay grass use	Open-water fish and shellfish designated use criteria apply		Year-round
Open-water fish and shellfish use	30-day mean ≥5.5 mg/l (tidal habitats with 0-0.5 ppt salinity)	Growth of tidal-fresh juvenile and adult fish; protective of threatened/endangered species	Year-round
	30-day mean ≥5 mg/l (tidal habitats with >0.5 ppt salinity)	Growth of larval, juvenile, and adult fish and shellfish; protective threatened/ endangered species	
	Seven-day mean ≥ 4 mg/l	Survival of open-water fish larvae	
	Instantaneous minimum ≥ 3.2 mg/l	Survival of threatened/ endangered sturgeon species	
Deep-water seasonal fish and shellfish use	30-day mean ≥ 3 mg/l	Survival and recruitment of Bay anchovy eggs and larvae	June 1-September 30
	One-day mean ≥ 2.3 mg/l	Survival of open-water juvenile and adult fish	
	Instantaneous minimum ≥ 1.7 mg/l	Survival of Bay anchovy eggs and larvae	
	Open-water fish and shell designated use criteria apply		October 1-May 31
Deep-channel seasonal refuge use	Instantaneous minimum ≥ 1 mg/l	Survival of bottom-dwelling worms and clams	June 1-September 30
	Open-water fish and shellfish designated use criteria apply		October 1-May 31

Table 1. Chesapeake Bay dissolved oxygen criteria (mg/L = milligrams per liter; ppt = parts per thousand salinity)
Source: USEPA 2003a

Figure 3 is a graphical representation of the water quality standards assessment in a Chesapeake Bay segment. The green reference curve represents the maximum allowable exceedance of the criterion concentration in space and time. The reference curve is based on observations of healthy ecosystem habitats for the assessed criterion where those observations exist with a default reference curve used in other areas. If any part of the blue assessment curve is above the reference curve, the segment is considered to be violation of the standard. The yellow area represents the fraction of space and time that are allowable exceedances of the criterion concentration. The red area represents unallowable exceedances and the unshaded area represents non-exceedances.

The same approach of considering the time and space of the critical hydrologic conditions is applied in the assessment of the water quality standards achievement with observed monitoring data. Ultimately, the time and space of water quality criteria exceedances are assessed against a reference curve derived from healthy living resource communities to determine the degree of water quality standard attainment (USEPA, 2007; Tango and Batiuk, 2013). Other more detailed aspects of the 2010 Chesapeake Bay TMDL, including consideration of daily loads and margins of safety, are described in the extensive Chesapeake Bay TMDL documentation and supporting appendices (USEPA, 2010a; b).

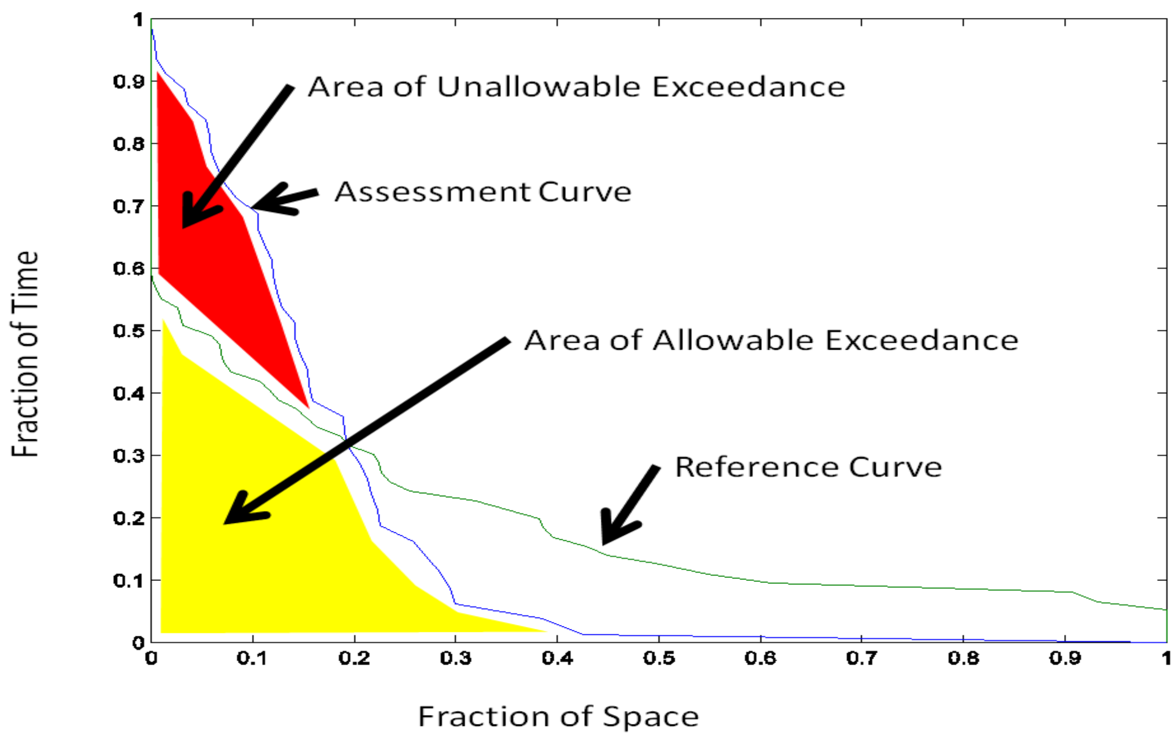

Figure 3. The analysis applied for each TMDL CB segment to determine the percent time and space that the simulated Chesapeake Bay water quality results exceeded the allowable concentration.

Source: USEPA 2003a.

RESULTS

Scenarios Employed In the LSRWA Study

A series of scenarios were employed in the LSRWA study. The scenarios applied different loading conditions in the Susquehanna River watershed, different bathymetries of the Conowingo Reservoir, different management actions to mitigate Conowingo infill conditions, and used different simulation tools. A list of the LSRWA scenarios described in the section below is adapted from Appendix C.

LSRWA-3 This is the base TMDL Watershed Implementation Plan (WIP) Scenario which represents the future conditions when all of the point source, nonpoint source, and atmospheric emission controls are in place in order to achieve the 2010 Chesapeake Bay TMDL in 2025. The LSRWA-3 Scenario uses only the HSPF simulation of scouring in the Conowingo and was developed solely with the Chesapeake Bay Watershed Model Phase 5.3.2. See Figure 4-2 of Cerco and Cole, Appendix D (this report) to see the observed and computed suspended solids at the Conowingo outfall during January 1996 for the WSM alone and for the WSM with additional erosion load.

LSRWA-4 This is the estimated existing current condition scenario which applies the simulation conditions of the estimated 2010 Chesapeake Bay watershed land use, management actions, populations, point source loads and atmospheric deposition loads. The LSRWA-4 Scenario uses only the HSPF simulation of scouring in the Conowingo and was developed solely with the Chesapeake Bay Watershed Model Phase 5.3.2. See Figure 4-2 of Cerco and Cole, Appendix D (this report) to see the observed and computed suspended solids at the Conowingo outfall during January 1996 for the WSM alone and for the WSM with additional erosion load.

LSRWA-21 This is the WIP Scenario (LSRWA-3) with scouring adapted from ADH for the January 1996 storm. This run shows the effect of scouring on the Chesapeake Bay TMDL allocations. The scenario was developed with the Chesapeake Bay Watershed Model Phase 5.3.2 and ADH models. The ADH model employed the Conowingo Reservoir bathymetry based on surveys conducted in 2011. The nutrients associated with the solids scoured from the Conowingo Reservoir were based on observations collected during Tropical Storm Lee in 2011.

LSRWA-22 This is the WIP Scenario (LSRWA-3) with scouring adapted from ADH for the January 1996 storm. This scenario is the same as LSRWA-21 except that the nutrients associated with the solids scoured from the Conowingo Reservoir were based on observations collected during the January 1996 scour event.

LSRWA-23 This is the WIP Scenario (LSRWA-3) with the January storm removed. The scenario was developed solely with the Chesapeake Bay Watershed Model Phase 5.3.2 model.

LSRWA-24 This is the LSRWA-21 Scenario with the January 1996 storm flows, loads, and scour moved to the June timeframe. The scenario was developed with the Chesapeake Bay Watershed Model Phase 5.3.2 and ADH models. The ADH model employed the Conowingo

Reservoir bathymetry based on surveys conducted in 2011. The nutrients associated with the solids were based on observations collected during Tropical Storm Lee in 2011.

LSRWA-25 This is the LSRWA-21 Scenario with the January 1996 storm flows, loads, and scour moved to the October timeframe. The scenario was developed with the Chesapeake Bay Watershed Model Phase 5.3.2 and ADH models. The ADH model employed the Conowingo Reservoir bathymetry based on surveys conducted in 2011. The nutrients associated with the solids were based on observations collected during Tropical Storm Lee in 2011.

LSRWA-26 This is the LSRWA-21 Scenario with the January 1996 storm flows, loads, and scour moved to the June timeframe. The scenario was developed with the Chesapeake Bay Watershed Model Phase 5.3.2 and ADH models. The ADH model employed the Conowingo Reservoir bathymetry based on surveys conducted in 2011. The nutrients associated with the solids scoured from the Conowingo Reservoir were based on observations collected during the January 1996 scour event.

LSRWA-27 This is the LSRWA-21 Scenario with the January 1996 storm flows, loads, and scour moved to the October timeframe. The scenario was developed with the Chesapeake Bay Watershed Model Phase 5.3.2 and ADH models. The ADH model employed the Conowingo Reservoir bathymetry based on surveys conducted in 2011. The nutrients associated with the solids scoured from the Conowingo Reservoir were based on observations collected during the January 1996 scour event.

LSRWA-28 This is the LSRWA-21 Scenario with scouring adapted from the ADH model based on the removal of 3 million cubic yards (mcy) by dredging. The scenario was developed with the Chesapeake Bay Watershed Model Phase 5.3.2 and ADH models. The ADH model employed the Conowingo bathymetry based on surveys conducted in 2011 combined with the removal of the removal of 3 million cubic yards (mcy) from high depositional regions in the Conowingo Reservoir.

LSRWA-29 This is the LSRWA-21 Scenario representing sediment and associated nutrient loads delivered to the tidal Chesapeake Bay equivalent to bypassing 3 mcy of dredged sediment during December – February of each year. Dredging and bypassing eventually result in the 1996 bathymetry at some period between one and two decades because of ongoing infill (followed presumably by continuous dredging operations to maintain 1996 bathymetry). Because the high flow event is assumed to happen at some intermediate, unknown bathymetry, the January 1996 high flow condition is represented by the bathymetry and scour produced by the dredging of 3 mcy scenario (LSRWA-28). The LSRWA-29 Scenario shows the effect of bypassing dredged material on sediment and associated nutrient loads to the tidal Chesapeake and resultant estimated Chesapeake Bay water quality conditions. The scenario was developed with the Chesapeake Bay Watershed Model Phase 5.3.2 and ADH models.

LSRWA-30 This is the LSRWA-21 Scenario with scouring for the January 1996 storm adapted from the ADH model with the Conowingo Reservoir at equilibrium bathymetry. Equilibrium bathymetry is the representation when the Conowingo Reservoir is full. The scenario employs bathymetry estimated to prevail when the reservoir achieves long-term equilibrium between sediment and associated nutrient loads in and sediment and associated nutrient loads out. Equilibrium bathymetry is equivalent to the 2011 bathymetry in the scour and discharge behavior of sediment and associated nutrients from the Conowingo Reservoir. The scenario was developed with the Chesapeake Bay Watershed Model Phase 5.3.2 and ADH models.

LSRWA-31 This is the LSRWA-21 Scenario with scouring adapted from the ADH model based on 1996 Conowingo Reservoir bathymetry. The LSRWA-31 scenario is a representation of the bathymetry resulting from dredging 27 mcy from the current (2011) reservoir bathymetry conditions back to the 1996 bathymetry conditions. This run shows the effect of removing 27 mcy of sediment and associated nutrient loads from the Conowingo Reservoir and the resultant estimated Chesapeake Bay water quality conditions. The scenario was developed with the Chesapeake Bay Watershed Model Phase 5.3.2 and ADH models.

DO Water Quality Standard Results

The process used for determining the influence of Conowingo Reservoir infill on the achievement of the jurisdictions' DO water quality standards in the Bay's Deep-Channel, Deep-Water, and Open-Water habitats was to apply the system of Chesapeake Bay simulation models, which are the Watershed Model (Phase 5.3.2) and the WQSTM of the tidal Bay (Figure 2). The ADH and HEC-RAS models of the lower Susquehanna River were also applied in specific scenarios as described above and in Appendices B and C.

The scenario representing current conditions was the 2010 Scenario (LSRWA-4). This scenario was run with a simulation period of 1991 to 2000 and is representative of the state of Conowingo Reservoir infill of the mid-1990s. The 2010 Scenario used estimated 2010 Chesapeake Bay land uses, animal numbers, manure and fertilizer loads, atmospheric deposition, point source and septic loads, and nonpoint source management actions. This was the base scenario of current conditions that all other model scenarios representing the Conowingo Reservoir infill condition could be compared to with respect to attainment of the jurisdictions' Chesapeake Bay water quality standards. The 2010 Scenario (LSRWA-4) is the fourth scenario listed in Tables 2a and 2b.

Similarly, the Watershed Implementation Plan (WIP) Scenario (LSRWA-3) represents the future conditions when all of the point source, nonpoint source, and atmospheric emission controls are in place in order to achieve the Chesapeake Bay TMDL in 2025 (but not including watershed and estuary lag times that could delay the ultimate achievement of the Chesapeake Bay water quality standards). The WIP Scenario represents the estimated Chesapeake Bay water quality conditions when all management actions called for in the seven watershed jurisdictions' WIPs—New York, Pennsylvania, West Virginia, Maryland, Delaware, the District of Columbia, and Virginia—are fully implemented (USEPA, 2010a). The WIP Scenario (LSRWA-3) is the fifth scenario listed in Tables 2a and 2b.

The assessment of Chesapeake Bay water quality standard attainment estimated in Tables 2a and 2b required consideration of restoration variances and application of the 2010 Chesapeake Bay TMDL Allocation decision rules. A restoration variance is the percentage of an allowable exceedance of an established water quality standard based on water quality modeling which incorporates the best available data and assumptions on achievable water quality conditions. The restoration variances, adopted into a state's water quality standards regulations, are temporary, and are reviewed, at a minimum every three years, as required by the Clean Water Act and EPA regulations. Currently, EPA has approved restoration variances in Maryland's water quality standards regulations of 7 percent in CB4MH and PATMH Deep-Water. This means that time and space occurrences of DO failing to meet Deep-Water criterion must be greater than 7 percent of the allowable exceedance before measures of nonattainment are actually reached. The CB4MH and EASMH Deep-Channel designated uses each have a restoration variance of 2 percent, and the CHSMH Deep-Channel has a variance of 16 percent[1], all approved by EPA. In addition, the 2010 Chesapeake Bay TMDL allocation decision rules allowed rounding to the nearest whole number of nonattainment and allowed a one-time 1 percent nonattainment for uncertainties in the overall allocation analysis procedure (USEPA, 2010a).

To illustrate how Chesapeake Bay water quality responds to changes in nutrient and sediment loads, several key scenarios and loads used in the development of the 2010 Chesapeake TMDL are tabulated in Table 2a illustrating percent non-attainment of the Deep-Channel DO water quality standard USEPA, 2010a). The scenarios in Table 2a are ordered from the highest to the lowest nutrient and sediment loads and were all run on the Chesapeake Bay Watershed Model Phase 5.3.2. The Deep-Channel DO has a criterion of at least 1 mg/l DO concentration which is required to be met at all times (except for the time and space area of allowable exceedances as shown in Figure 3). All of the Chesapeake Bay segments that have a Deep-Channel designated use are listed in Table 2a, and the location of the Chesapeake Bay segments can be seen in Figure 1. The greatest estimated loads are in the No Action Scenario, which is a "what if" scenario representing the 2010 conditions of land use and population with no management actions in place anywhere in the Chesapeake Bay watershed. In order of decreasing nutrient and sediment loads from the No Action Scenarios are the scenarios of 1985, 2007, and 2010, all of which estimate the loads under the land use, population, and estimated management actions extant in the Chesapeake Bay watershed in those years. As described previously, the 2010 Scenario and the WIP Scenario in Tables 2a and 2b are the same scenarios applied in the LSRWA analysis and are also described as LSRWA-4 and LSRWA-3, respectively.

Among the final three lowest loading scenarios in Table 2a is the WIP Scenario representing the loads under full implementation of the Chesapeake Bay TMDL as represented by the seven Chesapeake Bay watershed jurisdictions' Phase II Watershed Implementation Plans. Even lower load scenarios include the E3 Scenario, which is a full implementation of all management actions

[1] Maryland COMAR 26.08.02.03-3

by “everyone, everywhere, doing everything”, and the All Forest Scenario, in which the estimated load conditions represent the forest land use as the sole land use across the entire Chesapeake Bay watershed.

As nutrient and sediment loads decrease, the level of estimated nonattainment of the Chesapeake Bay water quality standards, quantified in red font, decreases. Attainment of the Deep-Channel DO standard of 1.0 mg/l is displayed in green font. Deep-Channel DO is estimated to reach full attainment under the WIP Scenario conditions (Table 2a). Table 2b describes the estimate of water quality nonattainment for Deep-Water, a region of the water column within the pycnocline and above the Deep-Channel designated use. The Deep-Water DO criterion is a 30-day mean of 3 mg/l (USEPA, 2003a). All of the Deep-Water DO segments are estimated to achieve full attainment under the WIP Scenario conditions (Table 2b). Table 2b lists all of the Deep-Water Chesapeake Bay segments.

In Tables 2a and 2b attainment is estimated to further increase as loads are reduced beyond the WIP Scenario. This can be seen by the estimated response under the E3 and All Forest Scenarios in the cases of Deep-Channel DO in the CB segments of CB4MH, EASMH, and CHSMH where restoration variances are currently in place within Maryland’s water quality standards regulations (Table 2a).

The scenarios in Tables 2a and 2b assume the Conowingo Reservoir conditions of relative net deposition (Hirsch, 2012) during the 1991-2000 period. This is because the calibration period of the Phase 5.3.2 Watershed Model used to simulate the Tables 2a and 2b scenarios was 1985 to 2005, and the calibration centered on the 1991-2000 TMDL application period (Shenk and Linker, 2013). These periods had relative net deposition of sediment and particulate nutrients in the Conowingo Reservoir.

All of the scenarios of Tables 2a and 2b were run for the 10 years of the 1991-200 hydrology period and the 10 year annual average loads are listed with each scenario in millions of pounds total nitrogen (TN), total phosphorus (TP), and total suspended solids (TSS). The DO water quality standard percent non-attainment levels for the Chesapeake Bay TMDL critical period of 1993-1995 are shown in Tables 2a and 2b (USEPA, 2010a).

CB Segment	Scenario→ Year → State	No Action (N-Based) Scenario 371 TN, 37.6 TP, 10630TSS '93-'95 DO Deep Channel	1985 Scenario 353 TN, 24.6 TP, 10100 TSS '93-'95 DO Deep Channel	2007 Scenario 269 TN, 19.5 TP, 8770 TSS '93-'95 DO Deep Channel	2010 (LSRWA-4) Scenario 263 TN 19.4 TP 8360 TSS '93-'95 DO Deep Channel	WIP (LSRWA-3) Scenario 191 TN 15 TP 6675 TSS '93-'95 DO Deep Channel	E3 (2010 N-Based) Scenario 135 TN, 10.4 TP, 4850 TSS '93-'95 DO Deep Channel	All Forest Scenario 54 TN, 2.6 TP, 1340 TSS '93-'95 DO Deep Channel
CB3MH	MD	22%	17%	12%	5%	0%	0%	0%
CB4MH	MD	54%	49%	40%	23%	1.49%	0%	0%
CB5MH	both	22%	17%	10%	0%	0%	0%	0%
CHSMH	MD	45%	39%	36%	28%	15.01%	5%	0%
EASMH	MD	38%	29%	24%	14%	1.09%	0%	0%
PATMH	MD	46%	42%	25%	18%	0%	0%	0%
POTMH	both	27%	20%	13%	0%	0%	0%	0%
RPPMH	VA	29%	23%	6%	0%	0%	0%	0%

Table 2a. Assessment of Chesapeake Bay DO Deep-Channel water quality standard nonattainment for key scenarios.

The Open-Water DO standard has a designated use of all tidal waters of the Chesapeake above the pycnocline (USEPA, 2010a). The Open-Water DO criterion is a 30-day mean of 5.0 mg/l (USEPA, 2003a). Generally, the Open-Water DO standard was relatively easily achieved in the 2010 Chesapeake Bay TMDL because the Open-Water designated use is in contact with the atmosphere and reaeration is rapid. Under all LSRWA Conowingo scenario conditions the Open-Water DO standard was achieved for all Chesapeake Bay segments.

The findings of the 2010 Chesapeake Bay TMDL were that Deep-Channel and Deep-Water DO water quality standards were difficult to achieve, and the CBP Partnership found that achievement of these two water quality standards largely drove the magnitude of nutrient pollutant load reductions in setting the 2010 Chesapeake Bay TMDL allocations (USEPA, 2010a). This was also the case with the LSRWA scenarios of Conowingo Reservoir infill. Deep-Channel DO and Deep-Water DO were the most sensitive water quality standards to estimated Conowingo Reservoir infill conditions, i.e., were the water quality standards most likely to go into nonattainment with increases in sediment and the associated nutrient loads.

The jurisdictions' Chesapeake Bay SAV-clarity water quality standards of were largely attained through sediment reductions associated with required nutrient reductions brought about by farm plans, conservation tillage, and other management actions in the Chesapeake Bay watershed (USEPA, 2010a). In addition, the 2010 Chesapeake TMDL also applies a water quality standard for chlorophyll-*a* in the tidal James River in Virginia and in the tidal waters of the District of Columbia (USEPA, 2007b), but the chlorophyll standards applied in the tidal James River and tidal fresh waters of the District are too far removed from the Susquehanna River and are uninfluenced by Conowingo Reservoir infill conditions.

CB Segment	Scenario → Year → State	No Action (N-Based) Scenario 371 TN, 37.6 TP, 10630TSS '93-'95 DO Deep Water	1985 Scenario 353 TN, 24.6 TP, 10100 TSS '93-'95 DO Deep Water	2007 Scenario 269 TN, 19.5 TP, 8770 TSS '93-'95 DO Deep Water	2010 (LSRWA-4) Scenario 263 TN, 19.4 TP, 8360 TSS '93-'95 DO Deep Water	WIP (LSRWA-3) Scenario 191 TN, 15 TP, 6675 TSS '93-'95 DO Deep Water	E3 (2010-N Based) Scenario 135 TN, 10.4 TP, 4850 TSS '93-'95 DO Deep Water	All Forest Scenario 54 TN, 2.6 TP, 1340 TSS '93-'95 DO Deep Water
CB3MH	MD	4%	2%	2%	1%	0%	0%	0%
CB4MH	MD	28%	22%	17%	11%	4.7%	3%	0%
CB5MH	both	7%	5%	3%	2%	0%	0%	0%
CB6PH	VA	1%	1%	0%	0%	0%	0%	0%
CHSMH	MD	39%	32%	21%	11%	0%	1%	0%
EASMH	MD	34%	14%	4%	2%	0.90%	0%	0%
PATMH	MD	31%	21%	11%	6%	0%	0%	0%
PAXMH	MD	23%	12%	2%	0%	0%	0%	0%
POTMH	both	9%	5%	2%	0%	0%	0%	0%
RPPMH	VA	13%	8%	3%	0%	0%	0%	0%
SBEMH	VA	5%	3%	0%	0%	0%	0%	0%
YRKPH	VA	0%	0%	0%	0%	0%	0%	0%

Table 2b. Assessment of Chesapeake Bay DO Deep-Water water quality standard nonattainment for key scenarios.

The assessments of Chesapeake Bay DO water quality standard attainment in Table 2a and Table 2b provide background and context for the Conowingo Reservoir infill scenarios presented in Table 3. In Table 3, the 2010 Scenario is in column 1 (also designated as Scenario LSRWA-4). The scenario when the Watershed Implementation Plans (WIPS) are in full effect, Scenario LSRWA-3 corresponding to the WIP Scenario in Tables 2a and 2b, is in column 2. As described previously in Table 2a, the level of Deep-Channel DO attainment is relatively low in the 2010 Scenario. Tables 2a and 2b quantify the degree of nonattainment in all Deep-Channel and Deep-Water segments for the 2010 Scenario (LSRWA-4) and the WIP Scenario (LSRWA-3).
As a graphical representation of Deep-Channel DO nonattainment, Figure 4 shows the extent of nonattainment under estimated 2010 Scenario conditions (LSRWA-4). The segments of CH3MH, CB4MH, EASMH, and CHSMH are in a region of contiguous Deep-Water and Deep-

Channel waters. These CB segments have similar depths so that advection from gravitational circulation as well as tidal dispersion plays a role in the continuous area of hypoxia among these Chesapeake Bay segments. Under WIP Scenario conditions (LSRWA-3), full attainment (with restoration variances in place) of the Deep Channel DO standard is estimated.

LSRWA Results: Non-Management Scenarios

The LSRWA-21 Scenario represents the Conowingo Reservoir infill condition represented by the ADH Model simulation of the 2011 Conowingo Reservoir bathymetry (see Appendix B and C, this report) and with the seven watershed jurisdictions' WIPs are fully implemented.

In the LSRWA-21 Scenario, the high flow event occurs in January 1996 making the 1993-1995 critical period of the TMDL impractical for comparison purposes because the January 1996 event is outside the 1993-1995 simulation period. Therefore, the 1996-1998 period of the LSRWA-3 Scenario was used for comparison. The key difference between LSRWA-21 and LSRWA-3 scenarios is that the January 1996 high flow event was simulated in the LSRWA-21 Scenario using the ADH Model scour of sediment resulting in an improved estimate of storm scoured sediment and associated particulate nutrients. The estimates of particulate nutrients scoured by the storm were determined by observations made during Tropical Storm Lee in 2011 (Appendix C, this report). The nutrient and sediment loads estimated by Cerco (2014) using the ADH model replaced the nutrient and sediment loads estimated by the Chesapeake Bay Watershed Model Phase 5.3.2 for this event. The estimated response in the Deep-Channel DO standards under the LSRWA-21 Scenario was an increase of 1 percent nonattainment over the Base WIP Scenario (LSRWA-3) for CB4MH, EASMH, and CHSMH as shown in Figure 5. For the LSRWA-22 Scenario with estimated particulate nutrients scoured by the storm determined by observations made during the 1996 January Big Melt (Appendix C, this report), attainment of water quality standards was higher due to less scoured particulate nutrients estimated for the January 1996 event and only CB4MH was in 1% Deep-Channel nonattainment.

Scenario LSRWA-18 represents the current (2010) condition, with Conowingo Reservoir infilled and a winter scour event. As in the LSRWA-21 Scenario, the event occurs in January 1996 making the 1993-1995 critical period of the Chesapeake Bay TMDL impractical for comparison purposes. Therefore, the 1996-1998 period of LSRWA-4 Scenario was used for comparison. The difference between LSRWA-18 and LSRWA-4 is inclusion of a January 1996 high flow event simulated with an ADH Model estimate of sediment scour and by an estimate of associated nutrient loads as determined by observations made during Tropical Storm Lee (see Appendix B, this report for details of nutrient scour associated with the 1996 Big Melt event). The estimated response in the Deep-Channel DO standards under the LSRWA-18 Scenario was an increase of 1 percent nonattainment for CB4MH, and PATMH compared to the LSWRA-4 Scenario.

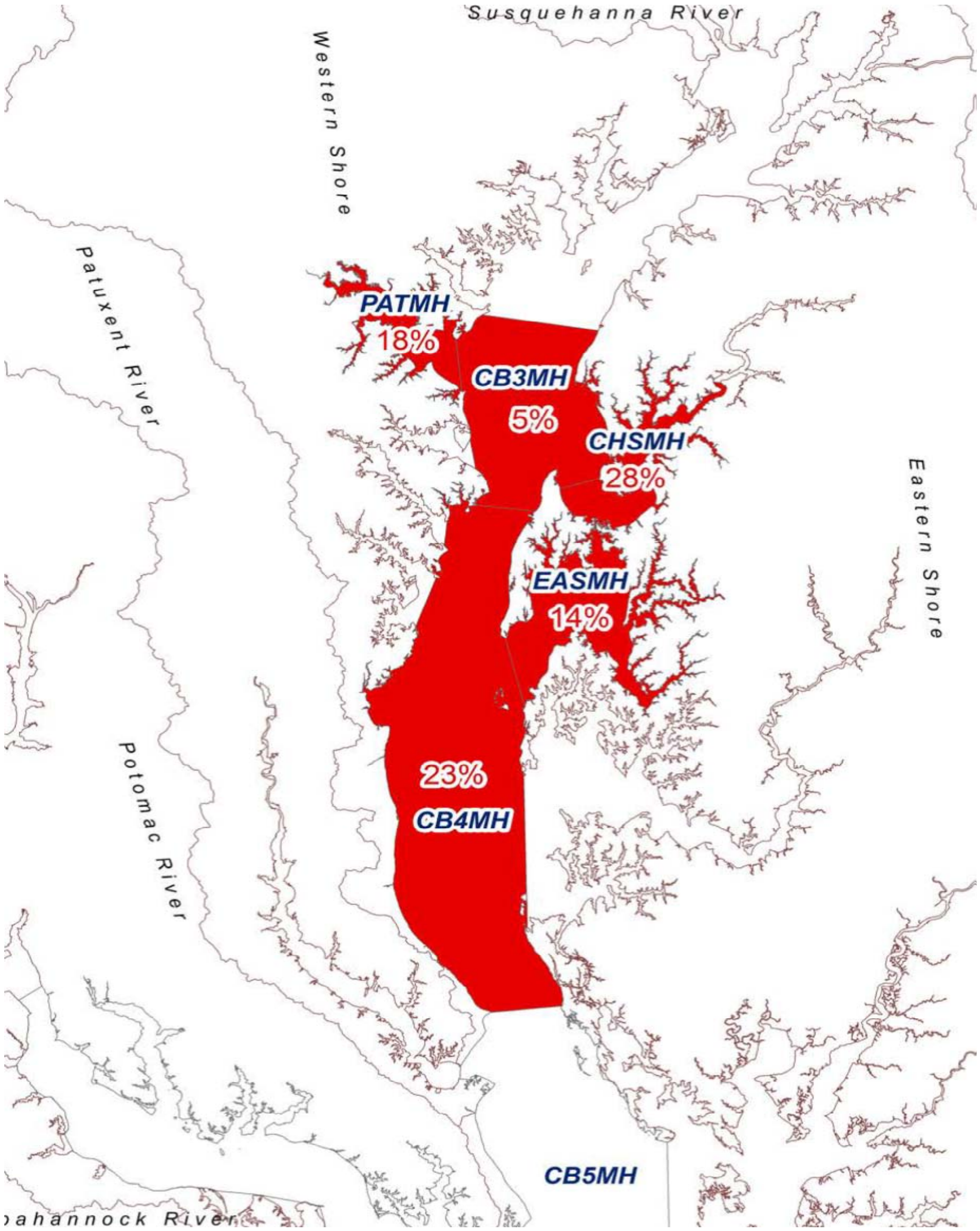

Figure 4. Estimated nonattainment of the Deep-Channel DO standard in Chesapeake Bay segments CB3MH, CB4MH, EASMH, PATMH, and CHSMH under the 2010 Scenario (LSRWA-4).

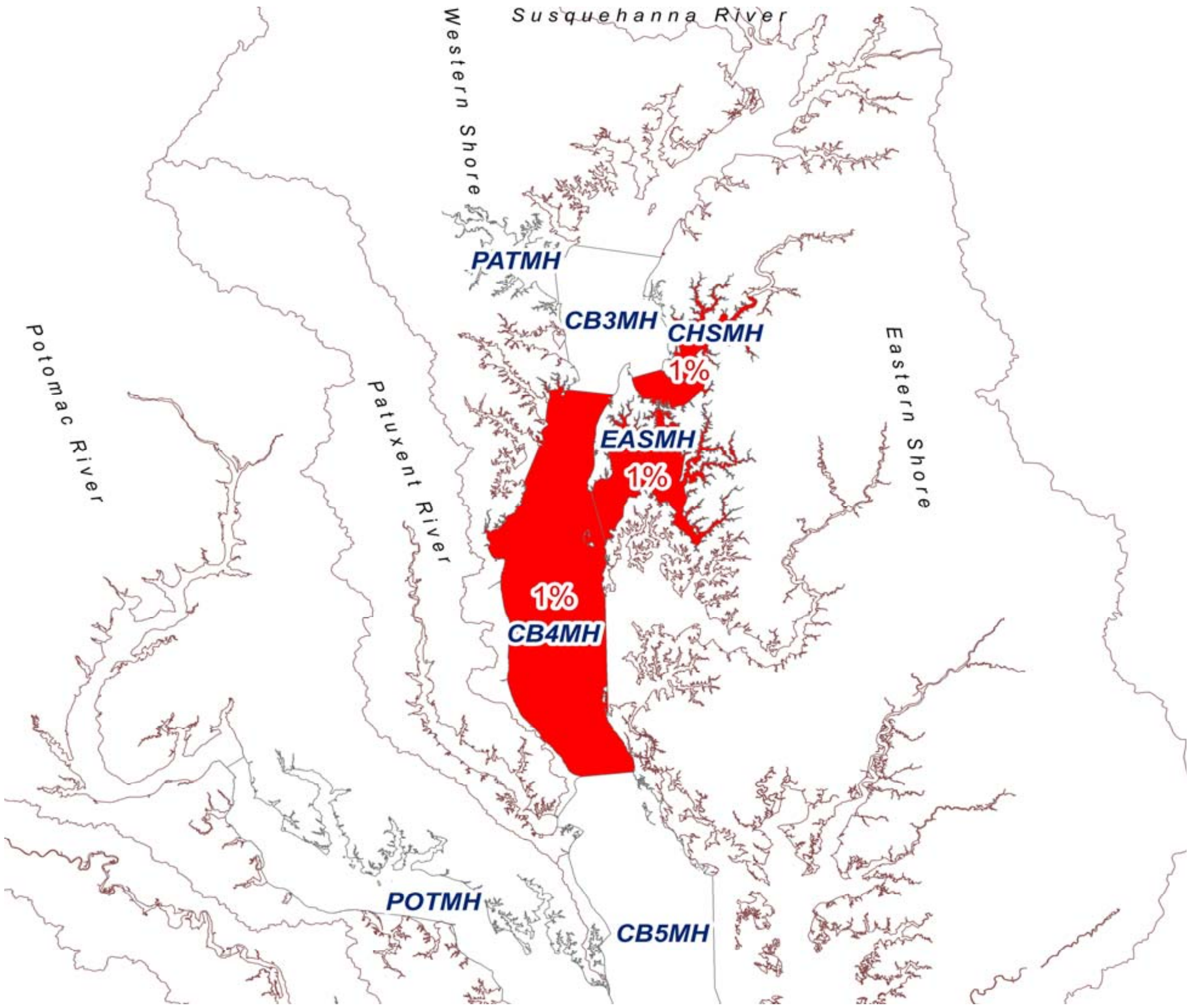

Figure 5. An estimated 1 percent increase of nonattainment of the Deep-Channel DO standard in Chesapeake Bay segments CB4MH, EASMH, and CHSMH under the LSRWA-21 Scenario compared to the LSRWA-3 Scenario using the 1996-1998 hydrology period.

The LSRWA-30 Scenario represents the Chesapeake Bay system's water quality condition when seven jurisdictions' WIPs are in full effect, the Conowingo Reservoir is in-filled at an equilibrium bathymetry, and there is a January 1996 scour event. As in the LSRWA-21 and LSRWA-18 scenarios, the event occurs in January 1996 and therefore, 1996-1998 hydrologic period of the LSRWA-3 Scenario was used for comparison. Again, the difference between LSRWA-30 and LSRWA-3 scenarios is the January 1996 high flow event was simulated with ADH model scour of sediment and by an improved estimate of associated scoured nutrients as determined by observations made during Tropical Storm Lee (see Appendix C for details of nutrient scour associated with the 1996 Big Melt). The estimated response in the Chesapeake

Bay Deep-Channel DO water quality standards was an increase of 1 percent nonattainment over the Base WIP Scenario (LSRWA-3) for Chesapeake Bay segments CB4MH, and CHSMH respectively (Table 3). There is little difference in Chesapeake Bay low dissolved oxygen response between the LSRWA-21 and LSRWA-30 scenarios because the sole difference between the two is that LSRWA-21 applies a 2011 Conowingo Reservoir bathymetry and LSRWA-30 applies an estimated equilibrium bathymetry and there is little difference between the two's scoured sediment and nutrient loads, i.e., the 2011 bathymetry is essentially the equilibrium bathymetry.

Finally, to examine the influence of a high flow scour event in different seasons of the year, the January 1996 Big Melt estimated flows and loads, along with the Chesapeake Bay hydrodynamics as modified through the CH3D Hydrodynamic Model, were moved to the June 1996 (LSRWA-24 Scenario) and October 1996 (LSRWA-25 Scenario) time periods. The LSRWA-24 and LSRWA-25 scenarios were run with the seven watershed jurisdictions' WIPs in full effect and Conowingo Reservoir trapping sediment at a level consistent with the LSRWA-21 Scenario (2011 bathymetry). Consistent with the published findings of Wang and Linker (2005), a June high flow storm event has the most detrimental influence on Deep-Channel DO water quality standard attainment followed by a storm of the same magnitude in January and then October time periods. The "no large storm" condition (LSRWA-23 Scenario) was used as a point of comparison with the seasonal January (LSRWA-21), June (LSRWA-24), and October (LSRWA-25) scenarios. The LSRWA-23 Scenario had the January storm removed and was developed solely with the Chesapeake Bay Watershed Model Phase 5.3.2 model. A counterpoint to the LSRWA-24 and LSRWA-25 scenarios were the LSRWA-26 and LSRWA-27 Scenarios which were like the previous two scenarios in every way except that the nutrients associated with the solids scoured from the Conowingo Reservoir were based on observations collected during the January 1996 scour event.

June Event

The June high flow event scenario (LSRWA-24 Scenario) had an estimated increase in Chesapeake Bay Deep-Channel DO water quality standard nonattainment of 1 percent, 4 percent, 8 percent, and 3 percent in segments CB3MH, CB4MH, CHSMH, and EASMH, respectively when compared to the LSRWA-23 Scenario in the 1996-1998 hydrology period. Likewise, the LSRWA-24 Scenario had an estimated increase in Deep-Water DO water quality standard nonattainment of 1 percent in segments CB4MH and SEVMH, when compared to the LSRWA-23 Scenario in the 1996-1998 hydrology period resulting in relatively higher estimated levels of both Deep-Water and Deep-Channel DO nonattainment than for other LSRWA scenarios. For the LSRWA-26 Scenario, the degree of Deep-Channel nonattainment was only 2 percent for segment CB4MH but was otherwise unchanged for Deep-Channel and Deep-Water DO nonattainment compared to LSRWA-24.

October Event

The estimated Deep-Channel DO water quality conditions from the October high flow event (LSRWA-25 Scenario) compared to the LSRWA-23 Scenario (which represents the no storm condition), using the 1996-1998 hydrology period, was increased nonattainment of 2 percent and 1 percent in the lower Chester River (CHSMH) and Severn River segments (SEVMH), respectively. The estimated Chesapeake Bay Deep-Water DO water quality standard achievement for the October high flow event (LSRWA-25) was increased nonattainment of 1 percent in the Severn River segment (SEVMH), compared to the LSRWA-23 Scenario. The Deep-Water segment of CB4MH showed a negligible impact from an October event. For the LSRWA-27 Scenario the degree of Deep-Channel nonattainment was only 1 percent for segment CHSMH but was otherwise unchanged for Deep-Channel and Deep-Water DO nonattainment compared to the LSRWA-24 Scenario.

January Event

The January condition (LSRWA-21 Scenario) had had an estimated increase in Chesapeake Bay Deep-Channel DO water quality standard nonattainment of 1 percent, 1 percent, 2 percent, and 2 percent in segments CB3MH, CB4MH, CHSMH, and EASMH, respectively when compared to the LSRWA-23 Scenario in the 1996-1998 hydrology period. The Deep-Water DO water quality standard attainment levels of LSRWA-21 Scenario were estimated to be 1 percent in segments CB4MH and SEVMH, when compared to the LSRWA-23 Scenario in the 1996-1998 hydrology period.

Summary of Seasonal Impact of a Major Event

The severity of the DO hypoxia response estimated by the degree of nonattainment of the Deep-Channel and Deep-Water DO standards was greatest in the June storm scenario followed by the January and October storm scenarios. The seasonal differences in water quality response, despite the same magnitude of nutrient and sediment loads in the LSRWA-24 (June storm), LSRWA-25 (October storm), and LSRWA-21 (January storm) scenarios, is thought to be because of the fate and transport of nutrients in the different seasons. In June, the pulse of delivered nutrient loads contribute directly to ongoing primary production as they are taken up to produce more algae. As a consequence, these loads contribute to Deep-Channel and Deep-Water DO nonattainment when the increased production of June algal biomass sinks to the bottom and generate sediment and water column oxygen demand. The water quality effects in the October and January periods are diminished because of colder temperatures and decreased primary productivity, resulting in less interception of nutrient loads by algae. In the fall and winter, a greater portion of the storm pulsed nutrient load is transported down the Bay to be discharged at the ocean boundary or is lost though denitrification or deep burial in sediments. The long-term impacts of the October Storm on DO were estimated to be less than the January storm (see Main Report Figure 6-31). This is because the simulated January storm load of particulate nutrients scoured from the Conowingo Reservoir was processed during that summer and cycled through the system, while much of the simulated October 1996 storm load was buried or discharged out of the Chesapeake over the simulated 1996-97 winter before the particulate nutrient load was ultimately expressed as a depression of DO in the simulated 1997 summer.

Table 4 provides an evaluation of Deep-Water DO and Open-Water DO water quality standards attainment results consistent with the Table 3 results. The Deep-Water DO findings are similar to the Deep-Channel DO findings. However, the Open-Water DO standard is relatively insensitive to the load changes estimated under the Conowingo Reservoir infill conditions. The Open-Water DO standard was estimated to be in full attainment under the WIP Scenario (LSRWA-3) and remained unchanged from this condition of full attainment under all estimated scenario loads of Conowingo Reservoir infill. The Open-Water designated use is relatively easier to achieve than the Deep-Channel or Deep-Water designated uses because it is in contact with the atmosphere, reaeration is rapid, and there is no pycnocline barrier to reaeration as there is in the other DO designated use habitats.

LSRWA Results: Management Scenarios

Table 5 contains the estimated Chesapeake Bay dissolved oxygen water quality standards attainment under a series of three management scenarios aimed at removing sediment from the Conowingo Reservoir by different means. Three management scenarios were examined with the full simulation of the WQSTM and were, as a result, available for water quality standard assessment.

	1. What is the system's current (existing) condition? **Scenario LSRWA-4**	2. What is the system's condition if the WIPs are in full effect and reservoirs are still trapping? Scenario **LSRWA-3**	3. What is the system's condition when WIPS are in full effect, reservoirs are still trapping sediments and a scour event occurs during winter? **Scenario LSRWA-21**	4. What is the system's condition when WIPS are not in effect, reservoirs are full and there is a winter scour event? Scenario **LSRWA-18**	5. What is the system's condition when WIPs are in full effect, the reservoirs are full and there is a winter scour event? **LSRWA-30**	6. What is the system's condition if WIPs are in full effect, reservoirs are full and a large scour event occurs during summer (**LSRWA-24**), fall (**LSRWA-25**) or winter (**LSRWA-21**)?
Deep Channel DO Water Quality Standard Achievement for Total Maximum Daily Load (TMDL)	Widespread nonattainment of TMDL of Deep Channel DO. Nonattainment of 23% in the CB4 mainstem, 14% in Eastern Bay, and 28% in the Lower Chester River was estimated. This and other areas of nonattainment in the Deep Channel amounted to more than half of the Deep Channel habitat.	Complete attainment of the Deep Channel DO standard was estimated.	Using the 1996-1998 period to capture the January 1996 "Big Melt" event, an increase of 1% nonattainment over the Base TMDL Scenario (LSRWA-3) was estimated for CB4MH, EASMH, and CHSMH.	Using for comparison, the scenario of the systems current condition (LSRWA-4), an increase of 1% nonattainment for CB4MH, and PATMH was estimated.	Using the 1996-1998 period to capture the January 1996 "Big Melt" event, an increase of 1% nonattainment over the Base TMDL Scenario (LSRWA-3) was estimated for CB4MH, EASMH, and CHSMH.	Generally, a June high flow storm event has the most detrimental influence on Deep Channel DO followed by a storm of the same magnitude in January and then October.

Table 3. Assessment of the Chesapeake Bay Deep-Channel DO water quality standards attainment for key scenarios in the Conowingo Reservoir infill analysis.

Strategic Dredging

The LSRWA-28 Scenario examines the application of strategic dredging which simulated the removal of 3 million cubic yards of material from regions in the Conowingo Reservoir most susceptible to scour. Using the 1996-1988 period to capture the January 1996 "Big Melt" event, an improvement in water quality characterized by a decrease of 0.2 percent nonattainment in the Deep-Channel DO water quality standard over the LSRWA-21 Scenario for segments CB3MH and CB4MH, and a decrease of 0.1 percent nonattainment in segment EASMH was estimated (Table 5). The LSRWA-21 Scenario is the Chesapeake Bay system's condition when seven watershed jurisdictions WIPs are in full effect, the Conowingo Reservoir 2011 bathymetry is simulated, and a major scour event occurs during winter. The LSRWA-21 Scenario was used to provide a consistent point of comparison for all three of the management scenarios listed in Table 5 which were all based on additional reservoir sediment removal under LSRWA-21 simulated conditions. A water quality improvement of 0.1 percent over LSRWA-21 conditions was also found for Deep-Water DO water quality standard in CB4MH (Table 5).

	1. What is the system's current (existing) condition? **Scenario LSRWA-4**	2. What is the system's condition if the WIPs are in full effect and reservoirs are still trapping? Scenario **LSRWA-3**	3. What is the system's condition when WIPS are in full effect, reservoirs are still trapping sediments and a scour event occurs during winter? **Scenario LSRWA-21**	4. What is the system's condition when WIPS are not in effect, reservoirs are full and there is a winter scour event? Scenario **LSRWA-18**	5. What is the system's condition when WIPs are in full effect, the reservoirs are full and there is a winter scour event? **LSRWA-30**	6. What is the system's condition if WIPs are in full effect, reservoirs are full and a large scour event occurs during summer **(LSRWA-24),** fall **(LSRWA-25)** or winter **(LSRWA-21)?**
Deep Water DO Water Quality Standard Achievement for TMDL	Widespread nonattainment of TMDL of Deep Water DO. Estimated nonattainment of 11% in the CB4 mainstem, 2% in Eastern Bay, and 11% in the Lower Chester River.	Complete attainment of the Deep Water DO standard was estimated to be attained.	Using the 1996-1998 period to capture the January 1996 "Big Melt" event, an increase of 1% nonattainment over the Base TMDL Scenario (LSRWA-3) was estimated for CB4MH and CB5MH.	Using for comparison, the scenario of the systems current condition (LSRWA-4), an increase of 1% nonattainment for CB3MH and PAXMH was estimated.	Using the 1996-1998 period to capture the January 1996 "Big Melt" event, an increase of 1% nonattainment over the Base TMDL Scenario (LSRWA-3) was estimated for CB4MH and CB5MH.	Generally, a June high flow storm event has the most detrimental influence on Deep Channel DO followed by a storm of the same magnitude in January and then October.
Open Water DO Water Quality Standard Achievement for TMDL	Widespread, but not complete attainment of the Open Water DO standard was estimated to be attained.	Complete attainment of the Open Water DO standard was estimated.	Complete attainment of the Open Water DO standard was estimated.	Complete attainment of the Open Water DO standard was estimated.	Complete attainment of the Open Water DO standard was estimated.	Complete attainment of the Open Water DO standard was estimated.

Table 4. Assessment of the Chesapeake Bay Deep-Water and Open-Water DO water quality standards attainment for key scenarios in the Conowingo Reservoir infill analysis.

Sediment By-Pass

The scenario examining the effects of passing sediment downstream for three winter months, over-time for a period of 10 years, was the LSRWA-29 Scenario. The LSRWA-29 Scenario released sediment from the bottom of the Conowingo Reservoir during a time of the year (December-February) when there was no adverse influence by sediment on achievement of the SAV-clarity water quality standard in Chesapeake Bay. Unfortunately this approach had the effect of increasing nutrient loads delivered to Chesapeake Bay by 6,545 metric tons/year of total nitrogen and 2,182 metric tons/year of total phosphorus because of the nutrients associated with the released sediment. This scenario was estimated to increase Chesapeake Bay Deep-Channel DO water quality standards nonattainment by an estimated 4 percent, 5 percent, 3 percent, 4 percent, and 2 percent over the comparative LSRWA-21 Scenario for segments CB3MH, CB4MH, CHSMH, EASMH, and PATMH, respectively.

	What are the effects of strategic dredging? **LSRW-28**	What are the effects of passing sediment downstream for 3 winter months, over-time for a period of 10 years? **LSRWA-29**	What are the effects of extreme long-term removal out of system) restoring to 1996 bathymetry? **LSRWA-31**
Deep-Channel DO Water Quality Standard Achievement for Total Maximum Daily Load (TMDL)	Using the 1996-1988 period to capture the January 1996 “Big Melt” event, water quality was estimated to be improved by a decrease of 0.2% nonattainment over the Base WIP (**LSRWA-21**) Scenario for CB3MH and CB4MH and a 0.1% decrease in attainment in EASMH.	Using the 1996-1988 period to capture the January 1996 “Big Melt” event, water quality was estimated to increase nonattainment by an estimated 4%, 5%, 3%, 4%, and 2% over the comparative LSRWA-21 Scenario for CB3MH, CB4MH, CHSMH, EASMH, and PATMH, respectively.	Using the 1996-1988 period to capture the January 1996 “Big Melt” event, water quality was estimated to be improved by a decrease of 0.3%, 0.5%, and 0.2% nonattainment over the Base WIP (**LSRWA-21**) Scenario for CB3MH, CB4MH and EASMH, respectively.
Deep-Water DO Water Quality Standard Achievement for TMDL	Using the 1996-1998 period to capture the January 1996 “Big Melt” event, nonattainment in CB4MH was estimated to decrease by 0.1% over the Base WIP Scenario (**LSRWA-21**)	Using the 1996-1998 period to capture the January 1996 “Big Melt” event, nonattainment in CB4MH was estimated to decrease by 0.2% over the Base WIP Scenario (**LSRWA-21**)	Using the 1996-1998 period to capture the January 1996 “Big Melt” event, nonattainment in CB4MH was estimated to decrease by 0.2% over the Base TMDL Scenario (**LSRWA-21**)
Open-Water DO Water Quality Standard Achievement for TMDL	Complete attainment of the Open Water DO standard was estimated.	Complete attainment of the Open Water DO standard was estimated.	Complete attainment of the Open Water DO standard was estimated.

Table 5. Assessment of the Deep-Channel DO, Deep-Water DO, and Open-Water DO water quality standard for key management scenarios in the Conowingo infill analysis.

Long-Term Sediment Removal

The scenario examining the effects of long-term sediment removal (out of system) and restoring the Conowingo Reservoir to its 1996 bathymetry is LSRWA-31. This scenario further extended the estimated water quality benefits of LSRWA-21. The Chesapeake Bay Deep-Channel DO water quality standards nonattainment was estimated to be improved by a decrease of 0.3 percent, 0.5 percent, and 0.2 percent in nonattainment over the comparative LSRWA-21 Scenario for segments CB3MH, CB4MH, and EASMH, respectively (Table 5). The Chesapeake Bay Deep-Water DO water quality standard attainment is also estimated to be improved by a decrease in nonattainment of 0.2 percent in segment CB4MH.

SAV-Clarity Water Quality Standard Results

During the 2010 Chesapeake Bay TMDL allocation development widespread attainment of the jurisdictions' Chesapeake Bay SAV-clarity water quality standards was found at the Chesapeake Bay TMDL allocation levels of nutrient and sediment loads sufficient to achieve the respective DO standards. In this sense, the SAV-clarity water quality standards were not the drivers behind the established 2010 Chesapeake Bay TMDL allocations that the DO water quality standards were. The nutrient reductions needed to achieve the DO water quality standards were often accompanied by reductions in sediment loads given implementation of management practices such as farm plans and conservation tillage. Together, the nutrient and sediment load reductions were sufficient to achieve the jurisdictions' Chesapeake Bay SAV-clarity water quality standards (USEPA, 2010a).

Across all the LSRWA scenarios referenced in this report and described in this appendix, model simulated sediment and associated nutrient loads above the full application of the seven watershed jurisdictions' Phase II WIPs resulted in estimates of full attainment of the SAV-clarity water quality standards in the upper Chesapeake Bay. There were estimated detrimental impacts of sediment. For example, light attenuation during the Big Melt event storm moved to the June time period was estimated to be greater than 2 1/m for 12 days, a level of light attenuation insufficient for long-term SAV growth and survival (Figure 6). These results are consistent with relatively high coverage and density of SAV observed on the Susquehanna Flats just downstream of the Conowingo Dam and Reservoir.

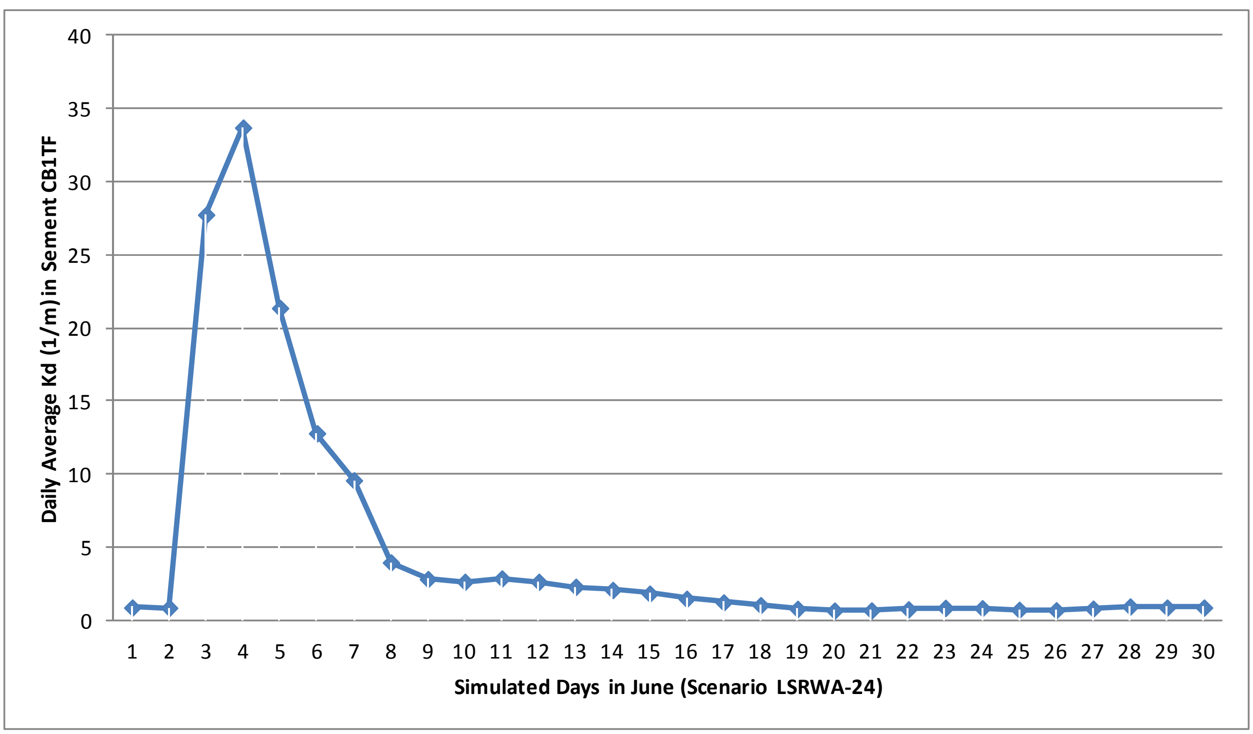

Figure 6. Estimated average daily light attenuation (1/m) in the Susquehanna Flats (CB1TF) for the June high flow event scenario (LSRWA-24).

CONCLUSIONS

The 2010 Chesapeake Bay TMDL sets watershed-wide loads limits of 186 million pounds (84.3 million kilograms) of total nitrogen, 12.5 million pounds (5.67 million kilograms) of total phosphorus, and 6.46 billion pounds (2.93 billion kilograms) of total suspended solids per year (USEPA, 2010a) – a 25 percent reduction in nitrogen, 24 percent reduction in phosphorus, and 20 percent reduction in sediment from 2010 estimated loads, and a 46 percent reduction in nitrogen, 48 percent reduction in phosphorus, and 33 percent reduction in sediment from estimated 1985 loads. These pollution limits were further divided by basin-jurisdictions on the basis of the CBP Partnership's model scenario analysis findings, extensive monitoring data, peer-reviewed science, and close interaction with the jurisdictional partners (USEPA, 2010a). In the 2010 Chesapeake Bay TMDL assessment by the CBP partners, the Conowingo Reservoir sediment and associated nutrient delivery was simulated over the 1991-2000 period, which was a condition prior to the current dynamic equilibrium state of sediment infill of the Conowingo Reservoir (USEPA 2010a).

The Deep-Water and Deep-Channel DO water quality standards are on a knife-edge of attainment with full implementation of the seven watershed jurisdictions' Watershed Implementation Plans (WIPS). Achieving the Deep-Water and Deep-Channel DO standards in the 2010 Chesapeake Bay TMDL was difficult and required management actions that went far beyond what was needed for estimated attainment of the jurisdictions' SAV-clarity and chlorophyll (except in the case of the tidal James River) water quality standards. The annual difference in DO generally ranges from about 12 mg/l in the winter to near hypoxia/anoxia conditions in the summer in the Deep-Water and Deep-Channel regions of the Chesapeake largely due to DO solubility differences with temperature and also due to the summertime presence of the pycnocline. But it is the summer hypoxic period that is of concern and small difference in DO during this period make big differences to living resources as reflected in the development of the DO water quality standards (USEPA 2003a; Batiuk et al. 2009).

Appendix T of the Chesapeake Bay TMDL report projected that there would be future increased nutrient and sediment loads under the conditions of the current dynamic equilibrium state of the Conowingo Reservoir (USEPA, 2010d). In a TMDL, any increase in pollutant loads that result in a failure to achieve of water quality standards must be addressed and offset so as to ensure full attainment of the applicable water quality standards.

The LSRWA study has found that as the Conowingo Reservoir has filled, the minimum discharge required for sediment and associated nutrient scour decreases as the reservoir becomes shallower. The Conowingo Reservoir was evaluated under the estimated 1996 and 2011 bathymetries with the ADH model to determine the minimum discharge for erosion to commence. For the 1996 reservoir bathymetry, the minimum discharge for erosion to commence was estimated to be 427,000 cfs. For the 2011 reservoir bathymetry, the minimum discharge for erosion to commence was estimated to be 333,000 cfs. The scour threshold has been reduced by 22 percent between 1996 and 2011 (Scott, S. - personal communication 11-20-13 email). As a consequence, more of bottom sediment and associated nutrient loads from the Conowingo Reservoir are estimated to be available for transport to the tidal Chesapeake Bay due to the higher frequency of river flows reaching the lower scour thresholds.

Of these increased pollutant loads, nutrients are most important from a Chesapeake Bay water quality perspective. Sediment loads from a Conowingo Reservoir in dynamic equilibrium infill condition are estimated to have relatively little influence on achievement of the jurisdictions' Chesapeake Bay SAV-water clarity water quality standards attainment. Additional evidence for the relative insensitivity of Chesapeake water quality conditions to episodic high flow sediment load events is the existence of the large SAV bed in the Chesapeake Segment CB1TF (the Susquehanna Flats) which has often exceeded Maryland's SAV-clarity standard for segment CB1TF in recent years.

Nutrient loads are another matter. Consistent with the 2010 Chesapeake Bay TMDL findings, water quality impairments estimated to be caused by the Conowingo Reservoir infill condition are the increased nutrient loads associated with increased sediment scour. The Chesapeake Bay water quality standards most sensitive to increased nutrient loads generally, including the increased nutrient loads estimated under Conowingo infill conditions, are the Deep-Channel and Deep-Water DO water quality standards (USEPA, 2010a). Nutrient loads are estimated to be decreased somewhat under conditions of strategic dredging of 3 million cubic yards (LSRWA-28 Scenario) and as a consequence the Deep-Channel and Deep-Water DO standard were estimated to be slightly improved under this condition. Further slight improvements were estimated when the Conowingo Reservoir was simulated at its 1996 bathymetry condition in the LSRWA-31 Scenario. Conversely, Deep-Channel DO and Deep-Water DO water quality were estimated to be seriously degraded by passing sediment downstream for three winter months over-time for a period of 10 years because of the release of nutrients from the bed of the Conowingo Reservoir associated with sediment by-pass.

From the perspective of the 2010 Chesapeake Bay TMDL, a key finding of the LSRWA is that concurrent with the problem of Conowingo infill is the estimated increase in nutrient releases from the Conowingo Reservoir sediments under the current infill condition of equilibrium bathymetry. At equilibrium bathymetry, the Conowingo Reservoir is full, and there is long-term equilibrium between sediment and associated nutrient loads in, and sediment and associated nutrient loads out. During episodic high flow scouring events, large nutrient loads are delivered to Chesapeake Bay, while at the same time storage capacity in the reservoir is increased which allows for more deposition sediment and the associated nutrient which, in turn, can fuel another episodic high flow, high nutrient and sediment load release. The relative importance of nutrient loads impacts due to Conowingo Reservoir infill is a finding that provides nutrient management and mitigation options that could be more cost effective and provide more management flexibility than solely relying on reservoir dredging as a management option.

To provide a first order estimate of the degree of Susquehanna River watershed nutrient pollutant load reduction needed to avoid estimated increases in DO nonattainment due to Conowingo Reservoir infill, Table 2a can be used to assess the degree of attainment under different scenario loads of nutrients. Using the loads in Table 2a for the scenarios that produce some non-attainment, the Deep-Channel DO percent attainment for CB4MH was found to be related to the estimated nitrogen and phosphorus loads for the entire Bay. Using the slope of the lines relating TN and TP to percent non-attainment of CB4MH Deep-Channel, a rough estimate of the load reduction needed Bay-wide to offset 1 percent nonattainment is about 4.4 million pounds of total nitrogen and 0.41 million lbs of total phosphorus. Scoping scenarios provide an estimate of the nitrogen and phosphorus pollutant load reductions from the Susquehanna River watershed needed to offset the increase in DO nonattainment. In this case, a nutrient reduction solely from the Susquehanna River watershed to offset a 1 percent increase in Deep-Channel DO nonattainment from Conowingo Reservoir infill would be about 2.4 million pounds of nitrogen, or alternately, a reduction of 0.27 million pounds of phosphorus.

The 2010 Chesapeake Bay TMDL report's Appendix T points out that in developing the Chesapeake Bay TMDL, an array of factors that affected the loadings to the Chesapeake Bay were accounted for and the Chesapeake Partnership worked to appropriately assign load allocations to each state (USEPA, 2010d). A large influencing factor in sediment and nutrient loads to the Chesapeake Bay are the major dams of the lower Susquehanna River (Safe Harbor, Holtwood, and Conowingo) which retain large quantities of sediment and nutrients in their reservoirs. Appendix T describes the case where "future monitoring shows that the trapping capacity of the reservoir has been reduced" and suggests that then the Chesapeake Bay Program Partners will need to consider adjusting the Pennsylvania, Maryland, and New York 2-year milestone loads based on the new delivered loads to ensure that all are meeting their target load obligations.

Future Research Needs

Going forward, further research and analysis is needed to provide a refined assessment of the influence of Conowingo Reservoir infill on Chesapeake Bay water quality, including an improved understanding of the fate and transport of particulate organic and inorganic nutrients associated with scoured sediment from the Conowingo Reservoir. Refinements in monitoring, research, and model simulation of the particulate organic and inorganic nutrients associated with Conowingo Reservoir sediment, their fate when scoured with sediment from the Conowingo

Reservoir, and their subsequent transport to the Chesapeake Bay along with their diagenesis and utilization in tidal waters would advance considerably the understanding of the influence Conowingo Reservoir infill has on Chesapeake water quality.

REFERENCES

Batiuk, R.A., D.L. Breitburg, R.J. Diaz, T.M. Cronin, D.H. Secor, and G. Thursby. 2009. Derivation of habitat-specific dissolved oxygen criteria for Chesapeake Bay and its tidal tributaries. *Journal of Experimental Marine Biology and Ecology* 381:S204–S215.

CBP (Chesapeake Bay Program) Partnership. 2012. *Guiding Principles: The 2017 Chesapeake Bay TMDL Midpoint Assessment*. Adopted by the Chesapeake Bay Program Partnership's Principals' Staff Committee December 5, 2012.

Cerco, C.F., 2000. Phytoplankton kinetics in the Chesapeake Bay model. *Water Quality and Ecosystem Modeling* 1:5-49.

Cerco, C.F, B. Johnson, and H. Wang. 2002. *Tributary Refinements to the Chesapeake Bay Model*. ERDC TR-02-4. U.S. Army Engineer Corps of Engineers Research and Development Center, Vicksburg, MS.

Cerco, C.F. and M.R. Noel. 2004. *The 2002 Chesapeake Bay Eutrophication Model*. EPA 903-R-04-004. U.S. Environmental Protection Agency, Chesapeake Bay Program Office, Annapolis, MD.

Cerco, C.F., S.C. Kim, and M.R. Noel. 2010. *The 2010 Chesapeake Bay Eutrophication Model*. A Report to the US Environmental Protection Agency and to the US Army Corps of Engineer Baltimore District. US Army Engineer Research and Development Center, Vicksburg, MS. <http://www.chesapeakebay.net/publications/title/the_2010_chesapeake_bay_eutrophication_model1> Accessed March 3, 2012.

Cerco, C.F. and M.R. Noel, 2013. Twenty-One-Year Simulation of Chesapeake Bay Water Quality Using the CE-QUAL-ICM Eutrophication Model. *Journal of the American Water Resources Association*, doi: 10.1111/jawr.12107. EPA-903-R-13-011, CBP/TRS-317-13-10.

Cerco, C.F., M.R. Noel, and P. Wang, 2013. The Shallow-Water Component of the Chesapeake Bay Environmental Model Package. *Journal of the American Water Resources Association*, doi:10.1111/jawr.12106. EPA-903-R-13-009, CBP/TRS-315-13-8.

CFR (Code of Federal Regulations), 2011. 40 CFR 130.7-Total Maximum Daily Loads (TMDL) and Individual Water Quality-Based Effluent Limitations. Code of Federal Regulations (annual edition). 50 FR (Federal Register) 1779, Jan. 11, 1985, as amended at 57 FR 33049, July 24, 1992; 65 FR 17170, Mar. 31, 2000; 66 FR 53048, Oct. 18, 2001.

Hirsch, R.M., 2012. *Flux of Nitrogen, Phosphorus, and Suspended Sediment From the Susquehanna River Basin to the Chesapeake Bay During Tropical Storm Lee, September 2011, As An Indicator of the Effects of Reservoir Sedimentation On Water Quality*. U.S. Geological Survey Scientific Investigations Report 1012-5185, 17p.

Keisman, J. and G. Shenk, 2013. Total Maximum Daily Load Criteria Assessment Using Monitoring and Modeling Data. *Journal of the American Water Resources Association*, doi: 10. 1111/jawr.12111. EPA-903-R-13-012, CBP/TRS-318-13-11.

Linker, L.C., G.W. Shenk, R.L. Dennis, and J.S. Sweeney, 2000. Cross-Media Models of the Chesapeake Bay Watershed and Airshed. *Water Quality and Ecosystem Modeling* 1(1–4):91–122.

Linker, L.C., G.W. Shenk, P. Wang, R. Batiuk, 2008. *Chapter 3: Integration of Modeling, Research, and Monitoring in the Chesapeake Bay Program* in Management of Water Quality and Irrigation Techniques, Editors: Jose Albiac and Ariel Dinar, Earthscan. London, UK.

Linker, L.C., R.A. Batiuk, G.W. Shenk, and C.F. Cerco, 2013a. Development of the Chesapeake TMDL Allocation. *Journal of the American Water Resources Association*. EPA-903-R-13-003, CBP/TRS-309-13-2.

Linker, L.C., R. Dennis, G.W. Shenk, R.A. Batiuk, J. Grimm, and P. Wang, 2013b. Computing Atmospheric Nutrient Loads to the Chesapeake Bay Watershed and Tidal Waters. *Journal of the American Water Resources Association*, doi: 10.1111/jawr. 12112. EPA-903-R-13-008, CBP/TRS-314-13-7.

Shenk, G.W. and L.C. Linker, 2013. Development and Application of the 2010 Chesapeake Watershed Total Maximum Daily Load Model. *Journal of the American Water Resources Association*, doi: 10.1111/jawr.12109. EPA-903-R-13-004, CBP/TRS-310-13-3.

SRBC (Susquehanna River Basin Commission). 2006. *January 1996 Flash Flood in the Susquehanna River*. <http://www.srbc.net/flood96.htm>. Accessed August 7, 2007.

Tango, P.J. and R.A. Batiuk, 2013. Deriving Chesapeake Bay Water Quality Standards. *Journal of the American Water Resources Association.* EPA-903-R-13-005, CBP/TRS-311-13-4.

USEPA (U.S. Environmental Protection Agency), 2003a. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries*. EPA 903-R-03-002. U.S. Environmental Protection Agency, Region 3, Chesapeake Bay Program Office, Annapolis, MD.

USEPA (U.S. Environmental Protection Agency). 2003b. *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability*. EPA 903-R-03-004. U.S. Environmental Protection Agency, Region 3, Chesapeake Bay Program Office, Annapolis, MD.

USEPA (U.S. Environmental Protection Agency). 2004a. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries. 2004 Addendum*. EPA 903-R-03-002. U.S. Environmental Protection Agency, Region 3, Chesapeake Bay Program Office, Annapolis, MD.

USEPA (U.S. Environmental Protection Agency). 2004b. *Chesapeake Bay Program Analytical Segmentation Scheme: Revisions, Decisions and Rationales 1983–2003*. EPA 903-R-04-008. CBP/TRS 268/04. U.S. Environmental Protection Agency, Region 3, Chesapeake Bay Program Office, Annapolis, MD.

USEPA (U.S. Environmental Protection Agency), 2004c. *Technical Support Document for Identification of Chesapeake Bay Designated Uses and Attainability–2004 Addendum.* EPA 903-R-04-006. U.S. Environmental Protection Agency, Region 3 Chesapeake Bay Program Office, Annapolis, MD.

USEPA (U.S. Environmental Protection Agency). 2005. *Chesapeake Bay Program Analytical Segmentation Scheme: Revisions, Decisions and Rationales 1983-2003. 2005 Addendum*. EPA 903-R-05-004. CBP/TRS 278-06. U.S. Environmental Protection Agency, Region 3 Chesapeake Bay Program Office, Annapolis, MD.

USEPA (U.S. Environmental Protection Agency), 2007a. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries—2007 Addendum*. EPA 903-R-07-003. CBP/TRS 285-07. U.S. Environmental Protection Agency, Region 3, Chesapeake Bay Program Office, Annapolis, MD.

USEPA (U.S. Environmental Protection Agency). 2007b. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries. 2007 Chlorophyll Criteria Addendum*. EPA 903-R-07-005 CBP/TRS 288/07. U.S. Environmental Protection Agency, Region 3 Chesapeake Bay Program Office, Annapolis, MD.

USEPA (U.S. Environmental Protection Agency). 2008a. September 11, 2008, Letter from Region 3 Administrator Donald Welsh to Secretary John Griffin, Maryland Department of the Environment. <http://www.epa.gov/reg3wapd/pdf/pdf_chesbay/EPARegionIIIlettertoPSC091108.pdf> Accessed August 10, 2011.

USEPA (U.S. Environmental Protection Agency), 2008b. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries–2008 Technical Support for Criteria Assessment Protocols Addendum*. EPA 903-R-08-001. CBP/TRS 290-08. U.S. Environmental Protection Agency, Region 3, Chesapeake Bay Program Office, Annapolis, MD.

USEPA (U.S. Environmental Protection Agency), 2010a. *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment.* U.S. Environmental Protection Agency Chesapeake Bay Program Office, Annapolis MD.

USEPA (U.S. Environmental Protection Agency), 2010b. *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment Appendix F. Determination of the Hydrologic Period for Model Application.* U.S. Environmental Protection Agency Chesapeake Bay Program Office, Annapolis MD. < http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html> Accessed February 2, 2012.

USEPA (U.S. Environmental Protection Agency), 2010c. *Ambient Water Quality Criteria for Dissolved Oxygen, Water Clarity and Chlorophyll a for the Chesapeake Bay and Its Tidal Tributaries: 2010 Technical Support for Criteria Assessment Protocols Addendum*. May 2010. EPA 903-R-10-002. CBP/TRS 301-10. U.S. Environmental Protection Agency, Region 3 Chesapeake Bay Program Office, Annapolis, MD.

USEPA (U.S. Environmental Protection Agency), 2010d. *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment Appendix T. Sediments behind the Susquehanna Dams Technical Documentation: Assessment of the Susquehanna River Reservoir Trapping Capacity and the Potential Effect on the Chesapeake Bay.* U.S. Environmental Protection Agency Chesapeake Bay Program Office, Annapolis MD. < http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html> Accessed February 2, 2012.

Wang, P. and L.C. Linker, 2005. *Effect of Timing of Extreme Storms on Chesapeake Bay Submerged Aquatic Vegetation*. In: Hurricane Isabel in Perspective, K.G. Sellner (Editor). Chesapeake Research Consortium, CRC Publication 05-160, Edgewater, Maryland, pp. 177-185. <http://www.chesapeake.org/pubs/Isabel/Wang%20and%20Linker.pdf>, accessed August 2012.

Zhang, Q., D.C. Brady, W.P. Ball, 2013. Long-term seasonal trends of nitrogen, phosphorus, and suspended sediment load from the non-tidal Susquehanna River Basin to Chesapeake Bay. *Science of the Total Environment* 252-253 (2013) 208-221.

Appendix E:
Coastal and Environmental Geosciences File Report No. 14-05: Susquehanna River Flat Surficial Sediment Survey, Harford and Cecil Counties, Maryland

Department of Natural Resources
MARYLAND GEOLOGICAL SURVEY
Jeffrey P. Halka, Director

COASTAL AND ENVIROMENTAL GEOSCIENCES
FILE REPORT NO. 14-05

SUSQUEHANNA RIVER FLATS SURFICIAL SEDIMENT SURVEY HARFORD AND CECIL COUNTIES, MARYLAND

by
Elizabeth Sylvia, Richard Ortt, and Darlene Wells

May 2012

INTRODUCTION

The Susquehanna River is the largest tributary to the Chesapeake Bay delivering one-half of all freshwater to the bay with a drainage basin incorporating six states. The mouth of this river is impounded by several dams with the last being Conowingo Dam. Historically, these dams functioned as sediment traps, reducing the amount of sediments and associated nutrients reaching the Chesapeake Bay. Over time, the trapping efficiency of these dams has diminished as the volume of sediment trapped behind the dams approached storage capacity. As a result, increasingly more sediments bypass the dams and enter into the Chesapeake Bay. There is growing concern that, if not properly managed, the increase in sediment delivery to the Chesapeake Bay will have deleterious effects on the ecosystem.

Sediment transport and storage is greatly controlled by the amount of energy within the water column, the extent which that energy exerts on the bottom sediments, and the character of the bottom sediments. As part of the Lower Susquehanna River Watershed Assessment, the Army Corps of Engineers, in cooperation with the Maryland Department of the Environment, has conducted a modeling effort to assess sediment transport under various flow conditions. Knowledge of the grain size characteristics of the bottom sediments is a requirement for accurate modeling both in the portion of the river below the dam and the Susquehanna Flats area of the Upper Chesapeake Bay.

In support of this need, the Resource Assessment Service, Maryland Geological Survey (MGS) collected a series of surficial grab samples in the Susquehanna Flats area of the Upper Chesapeake Bay (Figure 1) and analyzed the sediment samples for textural properties.

METHODS

Field Methods

On May 2, 2012, MGS staff collected 16 sediment grab samples in the Susquehanna Flats area of the Upper Chesapeake Bay (Figure 1). A 17-ft Boston Whaler was used to collect the samples. The sample locations were determined through consultation with the Army Corps of Engineers based on existing sediment sample data that was available and the appropriate locations for model input and verification. Two proposed sample locations (#1 and #2) were located in the Susquehanna River. However, preliminary flow modeling indicated that bedrock would be exposed at these locations (Email from Steve Scott to Jeff Halka, dated 3/23/2012). Therefore, these locations were not sampled.

Locations of the sediment samples were documented in the field using a Thales Navigation Promark 3 GPS receiver. Location coordinates were recorded in UTM, NAD83, meters.

Sediment samples were collected with a hand-operated LaMotte stainless-steel dredge which sampled a bottom surface area of 19 cm x 14 cm and a mean sediment depth of 5 cm. Upon collection, the samples were placed in Whirl-Pak™ bags and kept cool until delivery to the MGS laboratory where they were refrigerated at 4˚ C until analyses.

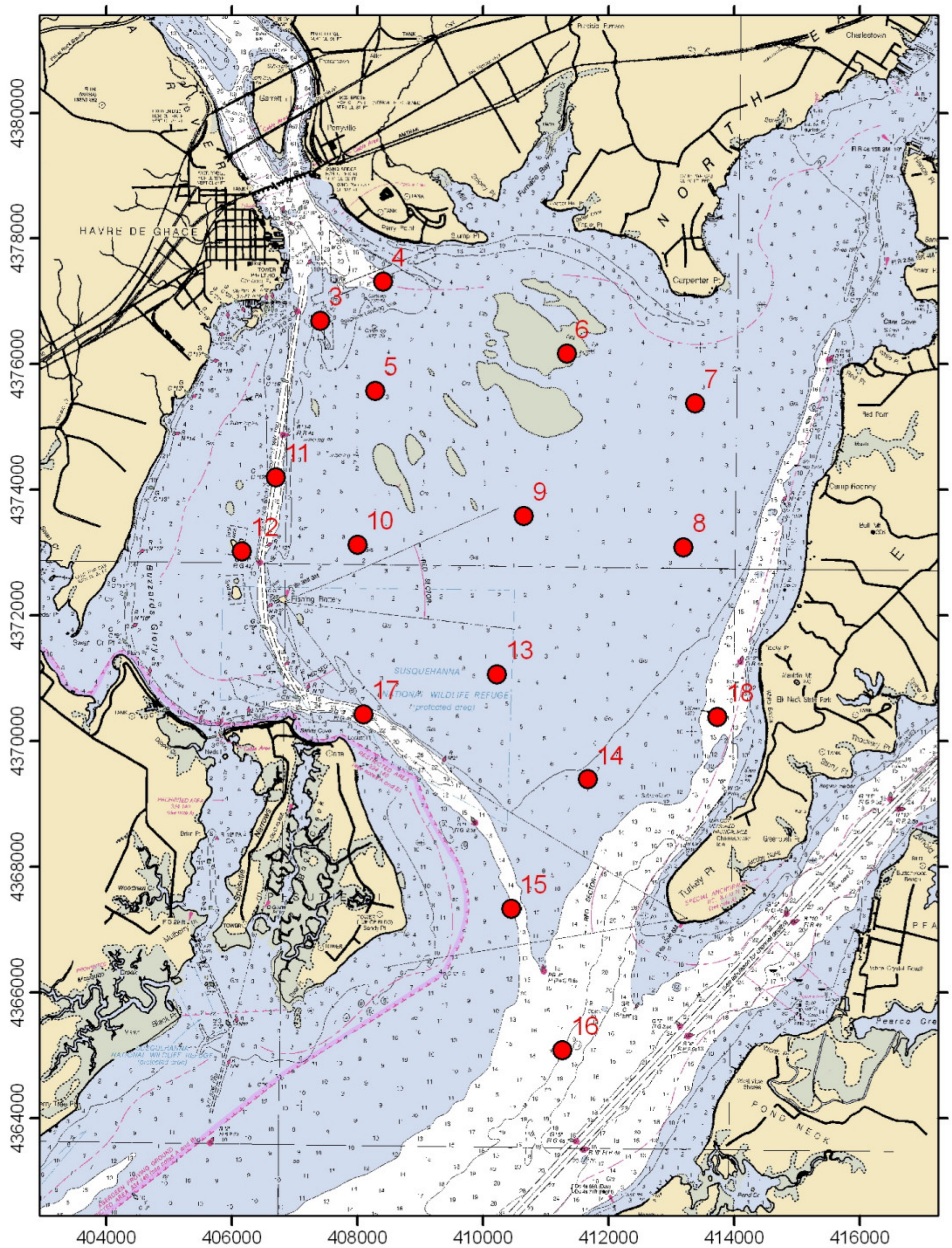

Figure 1. Locations of sediment samples collected in Susquehanna River Flats. Samples 1 and 2 were originally planned for upstream of the location map; however, the lack of sediment in the proposed locations created conditions that made sediment collection at those locations not possible with the methodology used in this study.

Laboratory Methods

Sediment grab samples were analyzed for water content, bulk density, and grain size (sand, silt, clay contents, as well as gravel, when present). Two homogeneous splits of each sample were processed, one for bulk property analyses and the other for grain-size characterization. Analyses were performed as soon as possible after sample collection, and all samples were refrigerated in sealed Whirl-Pak™ plastic bags prior to analysis.

Water content was determined by weighing 20-30 g of sediment; the sediment was dried at 65°C, and then re-weighing the dried sediment. Water content was calculated as the percentage of water weight to the weight of the wet sediment using Equation 1.

$$\%Water = \frac{W_w}{W_t} * 100 \qquad \text{Equation 1}$$

where: $\boldsymbol{W_w}$ is the weight of water;

and

$\boldsymbol{W_t}$ is the weight of wet sediment.

Wet bulk density (ρ_B) is calculated from water content utilizing Equation 2 by assuming an average grain density (ρ_s) of 2.72 g/cm^3 and saturation of voids with water of density ρ_w = 1.0 g/cm³. This method was adopted from the work of Bennett and Lambert (1971):

$$\rho_B = \frac{W_t}{W_d \ / \ 2.72 + W_w} \qquad \text{Equation 2}$$

where $\boldsymbol{W_d}$ is the weight of dry sediment.

Gravel, sand, silt and clay contents were determined using the textural analysis detailed in Kerhin and others (1988). Grain size, in this report (Table 1), is given in phi units, a scale devised by Krumbein (1936) where phi is define as negative log (to the base 2) of the particle diameter (mm). For example, 4 phi corresponds to a particle with a diameter of 1 /2^4 mm (=1/16 mm, or 0.0625 mm or 62.5 microns).

Grain size analysis consisted of cleaning the sediment samples in solutions of 10 percent hydrochloric acid and 6 or 15 percent hydrogen peroxide (determined by water content) with subsequent rinsing with deionized water. This process removed soluble salts, carbonates, and organic matter that could interfere with the dis-aggregation of the individual grains. The samples were then treated with a 0.26 percent solution of the dispersant sodium hexametaphosphate ($(NaPO_3)_6$) to ensure that individual grains did not re-aggregate (flocculate) during pipette analysis.

The separation of sand and silt-clay (mud) portions of the sample was accomplished by wet-sieving through a 4-phi mesh sieve (0.0625 mm, U.S. Standard Sieve #230). The gravel-sand fraction (*i.e.* that portion of the sample not passing thought the sieve) was dried and weighed, and saved for further analysis. The finer silt and clay-sized particles (*i. e.*, passing the through the sieve) were suspended in a 1000 ml cylinder in a solution of 0.26 percent sodium hexametaphosphate. The suspension was agitated and, at specified times thereafter; 20 ml pipette withdrawals are made (Carver, 1971; Folk, 1974). The rationale behind this process is that larger particles settle faster than smaller ones (Stoke's law). By calculating the settling velocities for different sized particles, times for withdrawal can be determined at which all particles of a specified size will have settled past the point of withdrawal. Sampling times were calculated to permit the determination of the amount of particles corresponding to 4 phi, 5 phi, 6 phi, 7 phi (silt subclasses) and clay sized (8 phi) particles in the suspension. Withdrawn samples are dried at 65°C and weighed. From these data the percentages by dry weight of sand, silt, and clay were calculated for each sample and classified according to Shepard (1954) and Folk (1954) nomenclatures (Figures 2 and 3). Sample weight loss due to cleaning was determined; the weight loss approximates the amount of non-clastic component in the sediment.

The sand/gravel fractions of the samples were passed through a series of 3-inch sieves, at whole phi intervals. The largest sieve used corresponds to -2 phi (4 mm mesh). The resulting whole phi size fractions were converted to cumulative weight percentages and incorporated the silt and clay components of the sediment sample, extrapolating the fine-grained end to 14 phi (6×10^{-5} mm)).

Table 1. Sediment grain size definitions used in this study are based on the Wentworth (1922) scale. The term Mud is used to describe all particles smaller than sand (less than 0.0625 millimeters). The term Gravel is used to describe all rock fragment particles that are 2 millimeters or larger.

Descriptor	Grain Size (millimeters)	Class Sizes (phi)
Mud	< 0.0625	> 4
Clay	< 0.004	> 8
Silt	0.004 to 0.0625	> 4 to 8
Sand	0.0625 to 2	4 to -1
Very Fine Sand	0.0625 to 0.125	4 to 3
Fine Sand	0.125 to 0.25	3 to 2
Medium Sand	0.25 to 0.5	2 to 1
Coarse Sand	0.5 to 1	1 to 0
Very Coarse Sand	1 to 2	0 to -1
Gravel	2 to 4,096	-1 to -12
Granule	2 to 4	-1 to -2
Pebble	4 to 64	-1 to -6
Cobble	64 to 256	-6 to -8
Boulder	256 to 4,096	-8 to -12

Based on the cumulative weight distributions of the size fractions, the following Folk (1974) graphic statistical parameters were calculated for each sample.

The graphic mean (M_G) is defined by equation 3.

$$M_G = \frac{phi16 + phi50 + phi84}{3} \qquad \textbf{Equation 3}$$

where *phi16* (or *50, 84..*) is the phi class corresponding to 16th percentile (or 50%, 84%...) on the cumulative weight curve.

This graphic mean corresponds very closely to the mean as computed by the method of moments, yet is much easier to find. Inclusive Graphic Standard Deviation (SD_{IG}), defined by equation 4, gives the best overall measure of sorting (Table 2).

$$SD_{IG} = \frac{phi84 - phi16}{4} + \frac{phi95 - phi5}{6.6} \qquad \textbf{Equation 4}$$

Table 2. Folk definitions of sorting.

SD_{IG} Range	Verbal Description
< 0.35 phi	very well sorted
0.35 - 0.50 phi	well sorted
0.50 - 0.71 phi	moderately well sorted
0.71 - 1.00 phi	moderately sorted
1.00 - 2.00 phi	poorly sorted
2.00 - 4.00 phi	very poorly sorted
> 4.00 phi	extremely poorly sorted

Inclusive Graphic Skewness (Sk_{IG}), define by equation 5, measures the asymmetry of the distribution as well as the direction of the skewness (*i.e.,* excessive coarse tail (-) or excessive fine tail (+)).

$$Sk_{IG} = \frac{phi16 + phi84 - 2*phi50}{2*(phi84 - phi16)} + \frac{phi5 + phi95 - 2*phi50}{2*(phi95 - phi5)} \qquad \textbf{Equation 5}$$

Graphic Kurtosis (K_G) is defined by equation 6. This statistic defines the degree of peakedness or departure from the "normal" frequency or cumulative curve.

$$K_G = \frac{phi95 - phi5}{2.44*(phi75 - phi25)} \qquad \textbf{Equation 6}$$

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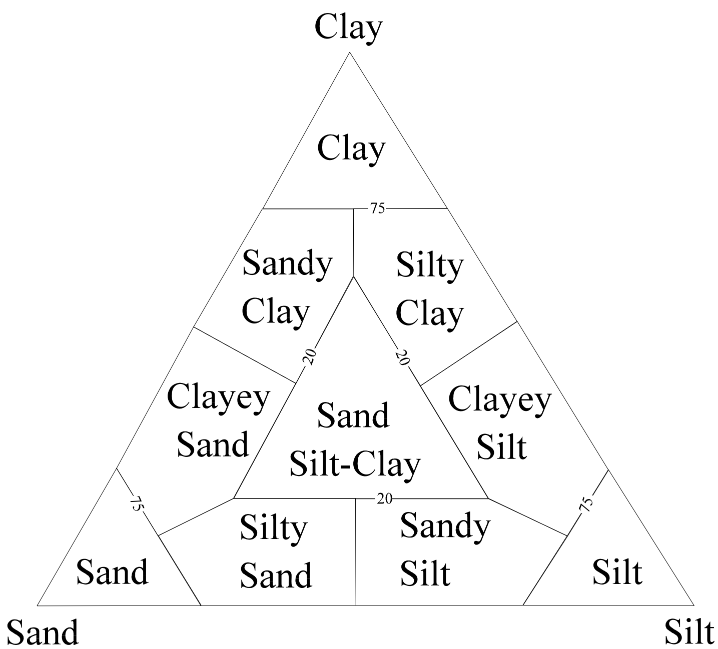
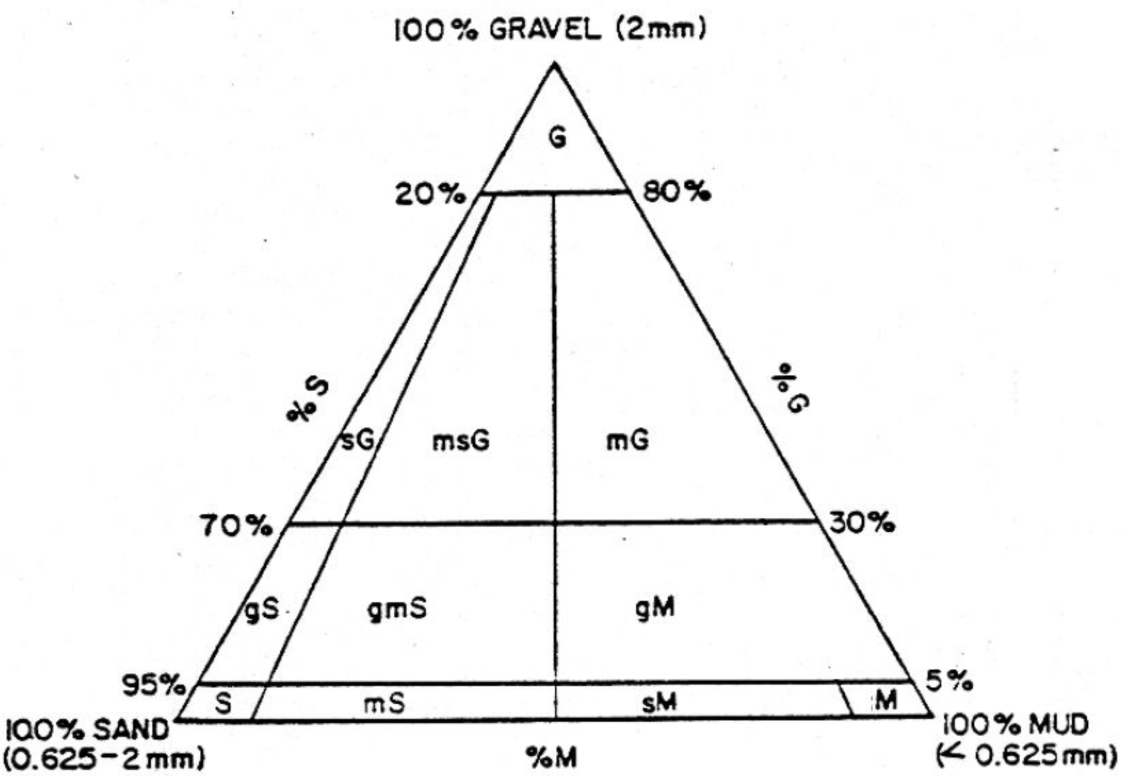


Figure 2. Shepard (1954) classification of sediment types. Sediment type classification is based on relative percentages of each size component (sand, silt and clay).

Figure 3. Folk (1974) classification of sediment types. Sediment type classification is



based on relative percentages of each size component (gravel, sand, and mud [i.e., silt plus clay]).

RESULTS

Field data and results of grain size analyses are presented in Tables 3 through 7. Cumulative grain size curves for each sample are plotted in Figure 4.

Table 3. Location coordinates for sediment grab samples collected on May 2, 2012 in the Susquehanna River Flats, with a count of shells in each sample at each sample site.

Sample ID	Easting (UTM, NAD88, m)	Northing (UTM, NAD88, m)	Depth (ft)	# of alive clams	# of dead clams	MacroAlgae
3	407400	4376697	5	0	0	0
4	408399	4377321	18	0	0	0
5	408276	4375580	2	0	0	0
6 *	411331	4376171	0.5	0	0	0
7	413380	4375384	4	10 (Asian??)	5 to 6	Yes
8	413187	4373089	3.5	0	0	0
9	410648	4373585	2	0	0	0
10	407994	4373124	3	0	0	0
11	406692	4374202	25	tiny?	0	0
12**	406156	4373022	1	0	0	0
13	410220	4371060	5	0	0	0
14	411666	4369390	7.5	0	5 Rangia	0
15	410443	4367334	13	0	4 to 5 Rangia	0
16	411261	4365082	20	5 Rangia	4	0
17	408087	4370427	25	0	0	0
18	413734	4370390	15	1 Rangia	0	0

*Sample #6: Originally planned site was too shallow (<0.5 foot depth) for navigation and collection. Sample was taken as close as possible to location approximately 400 meters from original location. Coordinates are of the actual location of the collected sample.

**Sample #12: Originally planned site was located on or behind an exposed shoal. Sample was taken as close to planned site as possible. Coordinates are of the actual location of the collected sample.

***Sample #17: Sample was very difficult to collect due to sediment type. Sediment was not homogenous as it contained clay balls in a fine well-packed sand matrix.

Table 4. Field descriptions of the sediment samples collected on the Susquehanna River Flats. Colors and color codes (e.g. 5 YR 3/4) from the Rock-Color Chart (Rock-Color Chart Committee, 1984).

Sample ID	Time collected*	Description^	Other
1		Did not sample	River bottom mostly in bedrock outcrop; site eliminated
2		Did not sample	River bottom mostly in bedrock outcrop; site eliminated
3	12:14	Medium brown (5 YR 3/4) m to c sand, several shells (clams), dead, disarticulated	dropped sampler many times; collected small sample
4	12:00	Medium brown (5 YR 3/4) slightly muddy, poorly sorted (f to c) sand, some gravel	very difficult to get sample; dropped sampler 10+ times; collected samples from multiple grabs, hard bottom?
5	9:30	Dark brown (10YR 2/2) to black (N2), vf to f sand; several rooted SAV	
6	11:04	Grey brown (5YR 3/2) f to m sand, with some black (N2) heavy minerals; several SAV roots/rhizomes	
7	10:44	Dark brown (5YR 3/2) slightly muddy vf to f sand with black (N2) heavy minerals and fecal strands; clams, dead, disarticulated	macroalgae and 4-5 clam shells (Asian clam), bagged
8	10:26	Dark brown (10YR 2/2) silty vf sand with black (N2) heavy minerals and fecal strands	
9	10:00	Dark brown (10YR 2/2) with black (N2) heavy minerals and coal particles, muddy, vf sand; rooted SAV; ~0.5 cm floc layer, medium brown (5YR 4/4)	
10	13:00	Medium brown (10YR 4/2) f to m sand, trace coarse sand, coal, trace silt	

Sample ID	Time collected*	Description^	Other
11	12:20	Medium brown (5 YR 3/4) m to c sand; lots of coal particles; juvenile clams, live	
12	12:45	Medium brown (5 YR 3/4) f to m sand with trace silt	
13	13:26	Grey brown (5YR 3/2), very slightly gritty mud, cohesive	
14	13:40	Grey brown (5YR 3/2) muddy, vf sand, few clams, both adult and juvenile, dead, disarticulated	
15	14:25	Medium brown (5 YR 3/4) silty vf to f sand; couple of clams, dead, disarticulated	
16	14:12	Medium brown (10YR 4/2) gritty mud, soft watery; abundant clams, both live and dead	when bagging samples, included some clams
17	15:00	Dark brown (5YR 3/2) slightly silty, very firm, f to m sand with few mud clasts	very difficult to get sample; dropped sampler 10+ times before getting a bottom sample, hard bottom?
18	13:53	Medium brown (10YR 4/2) slightly gritty mud, adult clam, live	
*All samples collected May 2, 2012			
^Size descriptors: vf= very fine; f= fine; m=medium; c= coarse			

Table 5. Cumulative weight percentages corresponding to phi class (whole phi intervals). These values are plotted in Figure 4.

Sample ID	Cumulative % Coarser than Phi Class										
	(-1) Φ	**0 Φ**	**1 Φ**	**2 Φ**	**3 Φ**	**4 Φ**	**5 Φ**	**6 Φ**	**7 Φ**	**8 Φ**	**14 Φ**
3	0.21	0.66	8.13	78.66	93.52	94.89	95.86	96.93	97.95	98.28	100.00
4	1.15	2.14	28.25	80.96	83.70	84.79	87.02	89.97	93.25	95.09	100.00
5	0.00	0.00	0.20	51.81	86.20	93.24	96.35	97.49	98.20	98.58	100.00
6	0.00	0.34	2.68	10.26	82.54	89.93	93.30	95.40	96.84	97.60	100.00
7	0.00	0.28	3.27	12.19	57.84	78.41	86.14	90.78	93.50	95.06	100.00
8	0.00	0.05	0.91	7.63	27.98	66.67	72.66	81.30	86.78	90.61	100.00
9	0.00	0.46	1.82	11.99	71.54	78.40	83.75	89.23	92.46	95.08	100.00
10	0.00	0.45	3.16	62.44	88.96	91.43	93.98	95.79	96.85	98.18	100.00
11	0.00	1.55	11.23	90.73	97.15	98.07	98.68	98.98	99.13	99.49	100.00
12	0.00	0.02	1.00	53.03	62.62	74.35	83.87	88.86	91.71	94.63	100.00
13	0.00	0.00	0.04	0.16	0.45	2.29	13.36	38.72	55.97	66.97	100.00
14	0.00	0.06	0.32	4.10	13.91	43.05	58.96	76.28	84.41	87.68	100.00
15	0.00	0.46	1.50	12.95	55.19	80.65	86.04	90.59	92.88	94.74	100.00
16	0.00	0.22	1.46	11.24	20.03	44.46	54.69	68.55	76.73	82.42	100.00
17	0.00	0.18	0.71	60.73	93.96	95.76	96.70	98.03	98.35	98.71	100.00
18	0.00	0.00	-0.01	0.16	1.40	10.07	17.75	46.13	62.09	72.44	100.00

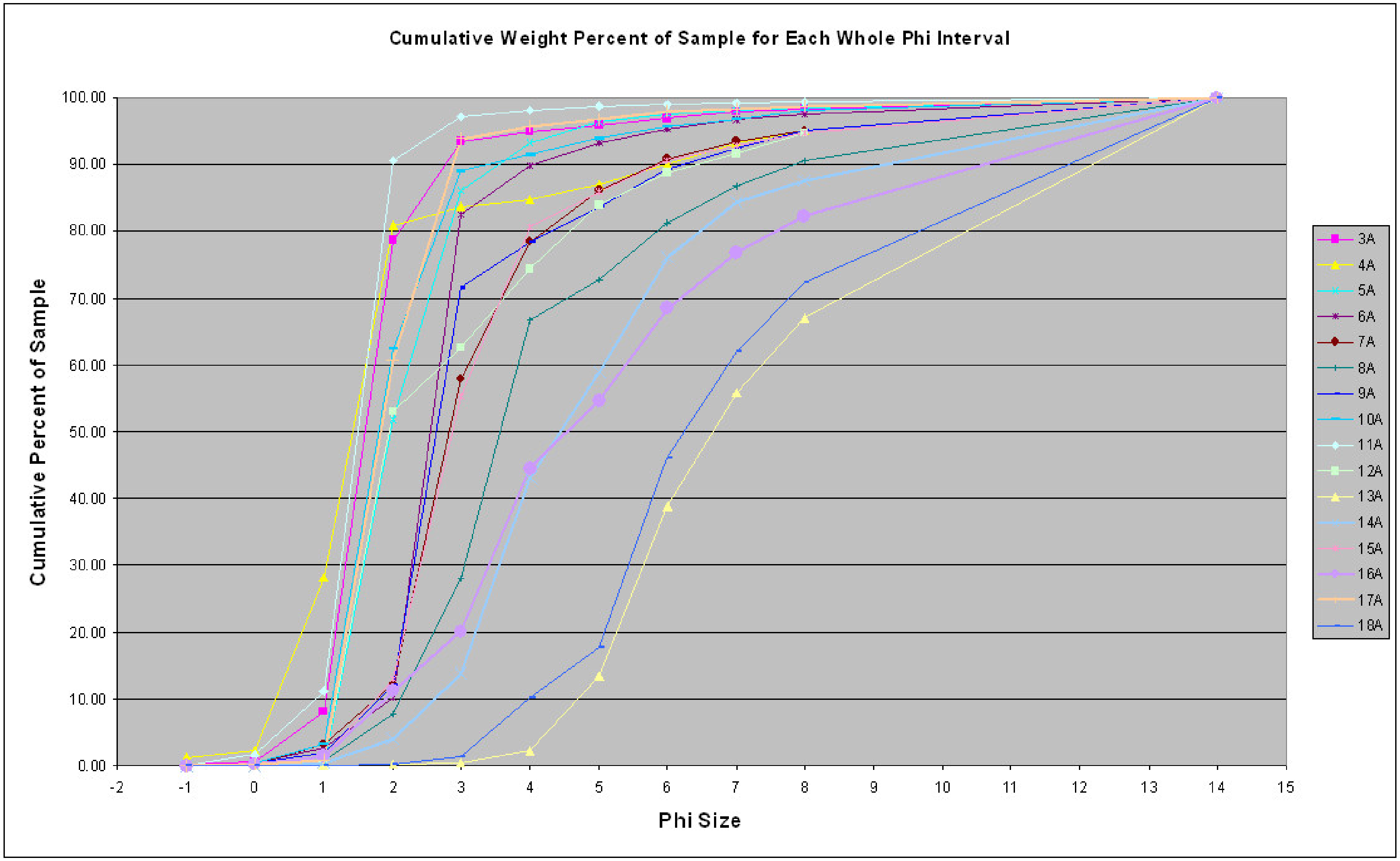


Figure 4. Plots of the cumulative weight percents for whole phi intervals for each sample. Median (by weight) grain size is identified where the data line crossed the 50% mark on the y-axis (Cumulative Percent of sample). The slope of the data line is indicative of the sorting or homogeneity of the sediment. The more vertical the data line is, the more uniform the sediment sample is. For example, Sample 11 is almost entirely composed of sediments in the 1-2 phi size range where sample 13 is composed of the much wider range of grain sizes between 4 and >8 phi..

Table 6. Phi size corresponding to various cumulative percentiles listed. These phi sizes were used to calculate the Folk graphic statistical parameters defined in equations 3 through 6). The graphic statistics for each sample are listed in Table 7.

Sample ID	Phi corresponding to cumulative percentile						
	5 %tile	16 %tile	25 %tile	50 %tile	75 %tile	84 %tile	95 %tile
3	0.58	1.11	1.24	1.59	1.95	2.36	5.06
4	0.11	0.53	0.88	1.41	1.89	3.3	9.91
5	1.09	1.31	1.48	1.96	2.67	2.94	5.56
6	1.31	2.08	2.2	2.55	2.9	3.23	6.81
7	1.19	2.08	2.28	2.83	3.84	5.72	9.93
8	1.61	2.41	2.85	3.57	6.27	7.49	11.87
9	1.31	2.07	2.22	2.64	3.51	6.05	9.94
10	1.03	1.22	1.37	1.79	2.47	2.81	6.56
11	0.36	1.06	1.17	1.49	1.8	1.92	2.67
12	1.08	1.29	1.46	1.94	5.06	6.03	10.28
13	5.24	6.1	6.46	7.65	10.97	12.06	13.39
14	2.09	3.07	3.38	5.43	6.93	7.95	12.38
15	1.31	2.07	2.29	2.88	3.78	5.61	10.2
16	1.36	2.54	3.2	5.54	7.79	10.36	12.86
17	1.07	1.25	1.4	1.82	2.43	2.7	3.61
18	3.42	5.77	6.26	7.24	10.37	11.68	13.27

Table 7. Summary of bulk properties and textural statistics for sediment samples.

Sample	%H20	Wet Bulk Density g/cm^3	WGHT LOSS %	Broad Textural Component				Sediment Classification		Folk (1974) Graphic Statistics			
				%GRAVEL	%SAND	%SILT	%CLAY	Shepard (1954)	Folk (1974)	Mean	Sorting	Skewness	Kurtosis
3	27.96	1.84	-0.74	0.21	94.74	3.33	1.72	Sand	Sand	1.69	0.99	0.39	2.59
4	33.50	1.73	3.03	1.15	83.74	10.20	4.91	Sand	muddy-Sand	1.75	2.18	0.55	3.97
5	19.85	2.03	3.67	0.00	93.32	5.26	1.42	Sand	Sand	2.07	1.08	0.4	1.53
6	23.11	1.95	3.25	0.00	90.85	6.75	2.40	Sand	Sand	2.62	1.12	0.36	3.26
7	26.02	1.88	3.95	0.00	78.51	16.54	4.94	Sand	muddy-Sand	3.54	2.23	0.61	2.3
8	39.73	1.62	7.20	0.00	66.75	23.86	9.39	Silty-Sand	muddy-Sand	4.49	2.82	0.58	1.23
9	33.22	1.73	4.54	0.00	78.48	16.59	4.92	Sand	muddy-Sand	3.58	2.3	0.7	2.74
10	21.70	1.98	1.89	0.00	91.45	6.73	1.82	Sand	Sand	1.94	1.24	0.5	2.05
11	22.94	1.95	1.64	0.00	98.09	1.39	0.51	Sand	Sand	1.49	0.56	0.01	1.5
12	35.58	1.69	5.14	0.00	74.44	20.19	5.37	Silty-Sand	muddy-Sand	3.09	2.58	0.77	1.05
13	62.04	1.32	13.46	0.00	2.39	64.59	33.03	Clayey-Silt	Mud	8.61	2.73	0.44	0.74
14	49.11	1.47	4.58	0.00	43.12	44.56	12.32	Sandy-Silt	sandy-Mud	5.49	2.78	0.19	1.19
15	34.80	1.70	3.56	0.00	80.80	13.94	5.26	Sand	muddy-Sand	3.52	2.23	0.6	2.43
16	56.22	1.38	3.65	0.00	44.51	37.91	17.58	Silty-Sand	sandy-Mud	6.15	3.7	0.25	1.03
17	26.42	1.87	1.17	0.00	95.86	2.86	1.29	Sand	Sand	1.93	0.75	0.31	1.02
18	54.37	1.41	15.63	0.00	10.15	62.29	27.56	Clayey-Silt	sandy-Mud	8.23	2.97	0.36	0.98

REFERENCES

Bennett, R.H., and Lambert, D.V., 1971, Rapid and reliable technique for determining unit weight and porosity of deep-sea sediments: Marine Geology, v. 11, p. 201-207.

Carver, R.E., 1971, *Procedures in Sedimentary Petrology*, Wiley-Interscience, New York, 653 pp.

Folk, R.L., 1974, Petrology of Sedimentary Rocks: Austin, TX, Hemphill Publishing Co., 182 p.

Gibbs, R.J., 1974, A settling tube system for sand-size analysis: Jour. Sed. Petrol., v. 41, pp. 7-18.

Kerhin, R.T., Halka, J.P., Wells, D.V., Hennessee, E.L., Blakeslee, P.J., Zoltan, N., and Cuthbertson, R.H., 1988. The surficial sediments of Chesapeake Bay, Maryland: physical characteristics and sediment budget. Maryland Geological Survey RI 48, 82 p., 8 plates.

Krumbein, W.C., 1938, Size frequency distributions of sediments and the normal phi curve: Jour. Sed. Petrol., v.8, pp. 84-90.

Rock-Color Chart Committee, 1984, Rock Color Chart, Geological Society of America: Boulder, Colorado.

Shepard, F.P., 1954, Nomenclature based on sand-silt-clay ratios: Jour. Sed. Petrology, vol. 24, p. 151-158.

Wentworth, C.K., 1922, A scale of grade and class terms for clastic sediments, Jour. Geology, vol. 30, p. 377-392.

Appendix F:
U.S. Geological Survey Conowingo Outflow Suspended Sediment Data Report

APPENDIX F: Introduction

This Assessment was computer-model intense and the models required data to estimate physical processes accurately. Data gaps were identified by the experts involved in this scoping of this effort. One of the data gaps identified was a need for updated chemical and physical measures of suspended sediment flowing through Conowingo Dam. U.S. Geological Survey (USGS) supplemented their current sample collection at Susquehanna River at Conowingo, MD (USGS station ID 01578310) that is supported by the USGS-DNR Maryland River-Input Monitoring Program (RIM) and the USGS National Stream-Quality Accounting Network (NASQAN). During four storm-flow events in Water-Year 2010 (October 1, 2010 - September 30, 2011) large-volume samples were collected to support analysis of detailed suspended-sediment size fractions and physical and chemical measures of sediment. The results of this monitoring are presented in this appendix.

United States Department of the Interior

U.S. GEOLOGICAL SURVEY

MD-DE-DC Water Science Center
5522 Research Park Drive
Baltimore, MD 21228
(443) 498-5500

February 10, 2012

From: Jeffrey Chanat, MD-DE-DC Water Science Center, Baltimore, MD

To: Bruce Michael, Director, Resource Assessment Service, Maryland Department of Natural Resources, Annapolis, MD

SUBJECT: Suspended-sediment chemistry, concentration, and particle-size analysis data, Susquehanna River at Conowingo, Maryland (USGS 01578310)

Mr. Michael,

I'm pleased to transmit tables of suspended-sediment chemistry, concentration, and particle size analysis data for 10 samples collected during 4 high-flow events during water year 2011, including the near-record events of September, 2011. I trust that these data will prove valuable to the team working on stored sediments in the Susquehanna reservoir system. All data tabulated herein are stored in the National Water Information System (NWIS; http://waterdata.usgs.gov/nwis), and are accessible to you through that medium as well.

The USGS anticipates publication of these data in an Open-File Report, which will include a complete discussion of methods. Briefly, samples were collected along a representative cross-section from the catwalk on Conowingo Dam and composited in a large carboy. Sample-collection methods were identical to those used for the River-Input Monitoring program (RIM), and a separate sample was collected for water chemistry at the same time the sediment samples were collected. Separate subsamples were drawn for chemical analysis, and for determination of suspended-sediment concentration and particle-size distribution. Chemical analyses of the suspended sediment were performed at the USGS Georgia Water Science Center's Sediment Partitioning Laboratory under the direction of Art Horowitz. These results are tabulated in separate tables based on analysis method. Suspended-sediment concentration and particle-size analyses were determined at the USGS Kentucky Water Science Center's Sediment Laboratory. Data reported herein represent all available concentration and distribution results corresponding to the tabulated sediment chemistry samples, as well as a few historic high-flux events for which comparable data were available.

Please feel free to contact either myself (517-485-0418) or Joel Blomquist (443-498-5560) with any questions you may have.

Table 1. Elements in suspended-sediment samples collected at the Susquehanna River at Conowingo, Maryland (USGS 01578310), determined by inductively coupled plasma-atomic emission spectrometry, Georgia WSC Sediment-Partitioning Research Lab (method PLA21; Horowitz and others, 2001).

[-, not available; <, less than; ppm, parts per million; QA, quality assurance]

Date	Time	QA Type	Copper (ppm)	Zinc (ppm)	Chromium (ppm)	Cobalt (ppm)	Nickel (ppm)	Barium (ppm)	Vanadium (ppm)	Lithium (ppm)
10/3/2010	0915		43	250	67	34	62	530	88	62
12/3/2010	1030		42	270	81	47	73	650	120	74
3/8/2011	1000		-	-	-	-	-	-	-	-
3/12/2011	1215		-	-	-	-	-	-	-	-
3/12/2011	1215	Replicate	-	-	-	-	-	-	-	-
9/8/2011	1100		42	260	83	43	64	530	110	67
9/8/2011	1100	Replicate	41	250	85	42	62	510	100	66
9/10/2011	0930		42	220	100	34	53	640	130	81
9/11/2011	0930		42	230	95	40	60	590	120	74
9/12/2011	0900		38	210	110	38	61	650	140	83

Table 1- continued. Elements in suspended-sediment samples collected at the Susquehanna River at Conowingo, Maryland (USGS 01578310), determined by inductively coupled plasma-atomic emission spectrometry, Georgia WSC Sediment-Partitioning Research Lab (method PLA21; Horowitz and others, 2001).

[-, not available; <, less than; ppm, parts per million; QA, quality assurance]

Date	Time	QA Type	Beryllium (ppm)	Molybdenum (ppm)	Phosphorus (ppm)	Strontium (ppm)	Tin (ppm)	Thallium (ppm)	Uranium (ppm)	Iron (percent)
10/3/2010	0915		2.5	<5	1,500	390	<5	<250	<250	3.6
12/3/2010	1030		3.5	<2	1,400	150	5	<100	<100	4.7
3/8/2011	1000		-	-	1,400	-	-	-	-	5.0
3/12/2011	1215		-	-	1,200	-	-	-	-	4.2
3/12/2011	1215	Replicate	-	-	1,200	-	-	-	-	4.4
9/8/2011	1100		3.0	<1	1,100	90	4	<50	<50	4.4
9/8/2011	1100	Replicate	2.9	<1	1,100	88	5	<50	<50	4.3
9/10/2011	0930		3.4	<1	900	110	4	<50	<50	5.3
9/11/2011	0930		3.1	<1	960	110	6	<50	<50	4.9
9/12/2011	0900		3.2	<1	940	130	5	<50	<50	5.4

Table 1-continued. Elements in suspended-sediment samples collected at the Susquehanna River at Conowingo, Maryland (USGS 01578310), determined by inductively coupled plasma-atomic emission spectrometry, Georgia WSC Sediment-Partitioning Research Lab (method PLA21; Horowitz and others, 2001).

[-, not available; <, less than; ppm, parts per million; QA, quality assurance]

Date	Time	QA Type	Manganese (ppm)	Aluminum (percent)	Titanium (percent)	Calcium (percent)	Potassium (percent)	Magnesium (percent)	Sodium (percent)	Total Sulfur (percent)
10/3/2010	0915		2,500	6.1	0.34	5.6	2.2	2.2	3.2	2.2
12/3/2010	1030		3,000	8.2	0.50	1.3	2.5	1.1	0.5	0.35
3/8/2011	1000		3,400	8.5	-	-	-	-	-	-
3/12/2011	1215		2,100	7.0	-	-	-	-	-	-
3/12/2011	1215	Replicate	2,200	7.3	-	-	-	-	-	-
9/8/2011	1100		1,900	8.4	0.57	-	-	-	-	-
9/8/2011	1100	Replicate	2,000	8.6	0.57	-	-	-	-	-
9/10/2011	0930		1,900	9.3	0.58	-	-	-	-	-
9/11/2011	0930		1,800	8.5	0.56	-	-	-	-	-
9/12/2011	0900		1,800	9.3	0.60	-	-	-	-	-

Table 2. Elements in suspended-sediment samples collected at the Susquehanna River at Conowingo, Maryland (USGS 01578310), determined by atomic absorption spectrophotometry, Georgia WSC Sediment-Partitioning Research Lab (method AA096; Horowitz and others, 2001).

[-, not available; <, less than; ppm, parts per million; QA, quality assurance]

Date	Time	QA Type	Silver (ppm)	Lead (ppm)	Cadmium (ppm)
10/3/2010	0915		<2.5	50	0.5
12/3/2010	1030		<1.0	43	0.7
3/8/2011	1000		-	-	-
3/12/2011	1215		-	-	-
3/12/2011	1215	Replicate	-	-	-
9/8/2011	1100		1.2	46	0.9
9/8/2011	1100	Replicate	0.7	45	0.7
9/10/2011	0930		0.5	45	0.6
9/11/2011	0930		1.3	45	0.8
9/12/2011	0900		1.1	40	0.5

Table 3. Elements in suspended-sediment samples collected at the Susquehanna River at Conowingo, Maryland (USGS 01578310), determined by hydride generation inductively coupled plasma-atomic emission spectrometry, Georgia WSC Sediment-Partitioning Research Lab (method HY018; Horowitz and others, 2001).

[-, not available; <, less than; ppm, parts per million; QA, quality assurance]

Date	Time	QA Type	Arsenic (ppm)	Antimony (ppm)	Selenium (ppm)
10/3/2010	0915		11	2.1	0.9
12/3/2010	1030		14	1.3	0.8
3/8/2011	1000		-	-	-
3/12/2011	1215		-	-	-
3/12/2011	1215	Replicate	-	-	-
9/8/2011	1100		13	1.5	1.1
9/8/2011	1100	Replicate	10	1.6	0.9
9/10/2011	0930		20	1.4	1.5
9/11/2011	0930		17	1.1	1.2
9/12/2011	0900		19	1.1	1.2

Table 4. Elements in suspended-sediment samples collected at the Susquehanna River at Conowingo, Maryland (USGS 01578310), determined by cold vapor atomic absorption spectrophotometry, Georgia WSC Sediment-Partitioning Research Lab (method CV026; Horowitz and others, 2001).

[-, not available; <, less than; ppm, parts per million; QA, quality assurance]

Date	Time	QA Type	Mercury (ppm)
10/3/2010	0915		-
12/3/2010	1030		0.16
3/8/2011	1000		-
3/12/2011	1215		-
3/12/2011	1215	Replicate	-
9/8/2011	1100		0.18
9/8/2011	1100	Replicate	0.21
9/10/2011	0930		0.10
9/11/2011	0930		0.10
9/12/2011	0900		0.07

Table 5. Elements in suspended-sediment samples collected at the Susquehanna River at Conowingo, Maryland (USGS 01578310), determined by combustion, Georgia WSC Sediment-Partitioning Research Lab (method CMB02; Horowitz and others, 2001).

[-, not available; <, less than; ppm, parts per million; QA, quality assurance]

Date	Time	QA Type	Total organic carbon (percent)	Total carbon (percent)	Total nitrogen (percent)
10/3/2010	0915		-	-	-
12/3/2010	1030		3.8	4.1	0.47
3/8/2011	1000		3.8	4.2	0.40
3/12/2011	1215		4.7	5.1	0.36
3/12/2011	1215	Replicate	4.7	4.9	0.34
9/8/2011	1100		3.5	3.2	0.26
9/8/2011	1100	Replicate	3.4	3.2	0.27
9/10/2011	0930		2.4	2.2	0.18
9/11/2011	0930		2.7	2.5	0.20
9/12/2011	0900		1.8	1.9	0.19

Reference:

Horowitz, A.J., Elrick, K.A., and J.J. Smith, 2001, Estimating suspended sediment and trace element fluxes in large river basins: methodological considerations as applied to the NASQAN programme, Hydrological Processes, v. 15, p 1107-1132.

Table 6. Particle-size distribution, suspended-sediment concentration, and instantaneous discharge for observations made during selected periods of high suspended-sediment flux, Susquehanna River at Conowingo, Maryland (USGS 01578310).

[Progressively darker shading from left to right indicates transitions between semi-quantitative categories “sand”, “silt”, and “clay”, respectively; cfs, cubic feet per second; mg, milligrams; L, liter]

Date	Time	Percent of sample with sieve diameter less than indicated value in millimeters										Suspended-sediment concentration, in mg/L	Instantaneous discharge, in cfs
		1	0.5	0.25	0.125	0.0625	0.031	0.016	0.008	0.004	0.002		
8/8/1979	1200		100	99	98	97	94	88	83	71	67	17	34,300
3/22/1980	1030			100	99	99	98	97	95	81		49	173,000
3/23/1980	1415					100	99	98	91	76		113	220,000
3/23/1980	1430					100	94	94	86	71		123	217,000
3/23/1980	1830				100	99	98	96	95	81		132	207,000
3/23/1980	1831					100	99	98	94	77		107	207,000
3/23/1980	2030					100	96	94	91	75		138	217,000
3/31/1980	1030	100	99	99	99	98	95	89	88	82		43	151,000
3/31/1980	1031		100	99	98	98	97	97	95	83		35	151,000
4/2/1980	1130					100	98	93	83	65		40	225,000
4/2/1980	1131			100	99	99	99	98	92	78		31	225,000
2/13/1981	1200								100	83		173	185,000
2/13/1981	1500					100	98	97	94	79		183	164,000
2/13/1981	1700					100	99	97	92	78		194	139,000
2/14/1981	1100							100	97	79		144	146,000
2/17/1984	1305					100	98	95	88	73	57	235	415,000
1/27/2010	1545					98						263	310,000
12/3/2010	1030					98						141	276,000
3/8/2011	1000					97						129	274,000
3/12/2011	1215					90						937	453,000
4/18/2011	0945					98						206	255,000
4/30/2011	1145					96						184	316,000
9/8/2011	1100			100	99	94	83	65	47	36	27	2,980	617,000
9/10/2011	0930			100	99	97	91	84	71	63	51	741	481,000
9/11/2011	0930			100	99	94	84	72	59	48	30	1,150	388,000
9/12/2011	0900	100	99	97	94	88	81	76	68	61	52	332	233,000

Appendix G:
2011 Exelon Conowingo Pond Bathymetric Survey Analysis

APPENDIX G: Introduction

This Assessment was computer-model intense and the models required data to estimate physical processes accurately. In October 2011, Exelon conducted bathymetric surveys of Conowingo Reservoir. This is the most recent bathymetric survey taken of Conowingo Reservoir; thus, representing the most current condition of the reservoir. Bathymetric surveys in Conowingo Reservoir have been conducted by U.S. Geological Survey (USGS) in the past. Exelon 2011 survey data and methods were evaluated by U.S. Geological Survey (USGS) who determined that the methods and collected data from this survey were appropriate and usable for this effort. The results of this survey are presented in this appendix.

Memo

To: Conowingo Relicensing Stakeholders

From: Gomez and Sullivan

Date: 8/3/2012

Re: Conowingo Pond Bathymetric Survey Analysis

Introduction

In September 2011, the Susquehanna River basin received heavy precipitation from Tropical Storm Lee[1]. Following the storm, the USGS estimated that Conowingo Dam's daily average flow peaked at 708,000 cfs with an instantaneous peak of 767,000 cfs (Personal Communication, Mike Langland [USGS], February 2012) – the Conowingo USGS gage's third highest recorded flow since it was established in October 1967. Given the opportunity to investigate how Conowingo Pond's sediment levels may have been affected by a major flood, Exelon decided to conduct a bathymetric survey of Conowingo Pond, with the following objectives:

1) Compare the 2011 results to the 2008 USGS bathymetry survey to determine whether Conowingo Pond experienced net deposition or scour.
2) Establish a physical "baseline" benchmark.
3) Provide the results for use as an input data set for the Lower Susquehanna River Watershed Assessment's Conowingo Pond modeling efforts.

This memo describes the background and analysis related to the bathymetric survey that Gomez and Sullivan conducted during the week of October 24, 2011.

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[1] Tropical Storm Irene preceded Tropical Storm Lee, and was responsible for the Susquehanna River's high base flow immediately prior to Tropical Storm Lee's arrival. This memo refers to the cumulative event as Tropical Storm Lee.

Methodology

Gomez and Sullivan collected bathymetric data at previously surveyed USGS transect locations, as well as at several additional transect locations in Conowingo Pond during the week of October 24, 2011 (Figure 1 and Figure 2). Data were collected from a 19-foot-long pontoon boat with a front-mounted echo-sounder and a real time kinematic global positioning system (RTK-GPS) placed directly above the echo-sounder.

The RTK-GPS utilized was a Sokkia GRX1 base and rover. A 35 W Pacific Crest repeater radio was used to extend the base-rover link distance to approximately 5 miles. When the GPS unit is in RTK mode, it has a horizontal accuracy of approximately ± 0.033 ft + 0.005 ft per mile from the base station. When in differential GPS (DGPS) mode, the unit has a horizontal accuracy of approximately ± 1.6 ft. GSE cross-sections 1 through 52 and all longitudinal profiles were collected in RTK mode. GSE cross-sections 53 through 59 were collected in DGPS mode. All position data were streamed to the bathymetric unit at a 10 Hz frequency (10 samples per second), where the position and timestamp were stored.

The bathymetric unit used was a Sontek RiverSurveyor M9. The RiverSurveyor M9 uses a vertical hydroacoustic beam to measure water depths between approximately 0.65 ft and 260 ft, with an approximately 0.003 ft resolution. The unit specifications state a depth accuracy of ±1% (e.g., ±0.5 ft at a 50-ft water depth), which was verified in the field during the survey through the use of a flat metal surface attached to a pre-measured rope length lowered into the water (Table 1). The RiverSurveyor also recorded water column velocities and a second water depth measurement through the use of eight angled hydroacoustic beams, only four of which are used at one time. The average water depth recorded by the velocity beams served as a secondary depth measurement to verify the primary (vertical beam) depth measurement. Water velocity and water depth measurements were continuously recorded in one-second intervals[2] throughout the entire study. The RiverSurveyor M9 recorded all data internally and also outputted to a USB-linked tablet computer for real-time data monitoring. Real-time data streamed to the tablet computer were redundantly saved on the tablet to prevent data loss.

Measured depth data were combined with water surface elevations (WSE) to calculate bed elevations, such that Bed Elevation = Water Surface Elevation – Water Depth[3]. WSEs were recorded at three locations along Conowingo Pond: Conowingo Dam, Peach Bottom Atomic Power Station (Peach Bottom), and Muddy Run. Though the surveyed portion of Conowingo Pond is primarily a backwater-type area from Conowingo Dam, a small but perceptible WSE gradient, typically less than

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[2] The unit measured bottom depths several times per second, and then recorded the average of all valid measurements made during the one-second interval.

[3] The bathymetry unit was placed approximately 8 inches (0.67 ft) deep in the water. The exact distance was measured and input into the RiverSurveyor's software every day prior to surveying. The RiverSurveyor's software automatically accounts for this in recorded depths.

0.25 ft, is measurable between Conowingo and Peach Bottom. To account for this WSE difference, the WSE gradient between Conowingo Dam and Peach Bottom was used to determine the WSE throughout Conowingo Pond. Muddy Run WSEs were not used because that area of Conowingo Pond is heavily influenced by Holtwood and Muddy Run operations. Thus, we determined that extrapolating the WSE gradient between Conowingo Dam and Peach Bottom to the most upstream cross-section (just downstream of Hennery Island) was the most appropriate WSE estimation method.

Several steps were taken to get Conowingo Pond's WSE gradient. First, WSEs at Conowingo (30-min interval) and Peach Bottom (~2.5-min interval) were interpolated over time to create a 1-min time series for both stations. Next, a WSE gradient (WSE change per river mile) was calculated between the two stations, for each 1-min interval. Then, for each depth measurement point, the linear distance upstream of Conowingo Dam was calculated, and the measurement point's time stamp (rounded to the nearest minute) was matched with a corresponding Conowingo Pond WSE gradient by matching 1-minute time stamps. The WSE at each measurement point was then calculated by multiplying the point's distance upstream of Conowingo Dam by the timestamp-matched WSE gradient. WSEs were then subtracted by the water depths to calculate bed elevations.

The Quality Assurance/Quality Control (QAQC) version of the 2008 Conowingo Pond bathymetry data set was provided by the USGS to Exelon. Data collection and analysis methodology for the 2008 data set are described in Langland (2009). The data set consists of spatially-georeferenced (latitude/longitude) depths from Conowingo Pond's normal water surface elevation of 109.2 ft NGVD 1929[4]. These data were used to compute bed elevation changes relative to historic bed elevations from fall 2008.

Our analysis followed the methodology described in Langland (2009), except that an additional method for calculating transects' average water depths from Normal Pool (109.2 ft NGVD 1929) was used. Langland (2009) calculated water volumes using the mid-point method, such that water volume equaled cross-sectional effective length multiplied by width between adjacent cross-sections multiplied by the cross-sectional average depth. The cross-section *width* was determined by calculating the distance between the first and last point of each cross-section. The cross-section *effective length* was calculated as half the distance to the next upstream cross-section plus half the distance to the next downstream cross-section. Langland (2009) calculated transects' *average depths* by taking the average of all points collected in each cross-section, normalized to Conowingo Pond's normal pool elevation, such that $D_{avg} = \frac{\sum_{i=1}^{n} d_i}{n}$, where D_{avg} is a transects' average depth, n is the number of points in a transect, and d_i is the depth from Normal Pool at point i. Our alternative method

[4] The Langland (2009) data set was collected with reference to Conowingo Datum water surface elevations. All water depth data provided to Exelon were converted to bed elevation data in NGVD 1929. Conowingo Datum elevations are 0.7 ft below NGVD 1929 elevations, such that elevation 108.5 ft in Conowingo Datum equals elevation 109.2 ft in NGVD 1929.

was similar, except that it weighted depths by the distance, such that $D_{avg} = \frac{\sum_{i=1}^{n} d_i * w_i}{\sum_{i=1}^{n} w_i}$, where D_{avg} is a transects' average depth, n is the number of points in a transect, d_i is the depth from Normal Pool at point i, and w_i is the space between adjacent points in the same transect. Then, the total water volume was calculated for each cross-section as: $V_{water} = L_{eff} * W * D_{avg}$, where V_{water} is the cross-section's water volume, L_{eff} is the cross-section's effective length, W is the cross-section's width and D_{avg} is the cross-section's average depth.

Since the raw QAQC data available for the USGS 2008 survey had been adjusted for QAQC reasons during the initial steps of this analysis, cross-sectional average depths were re-calculated for this analysis, rather than using the volumes reported in Langland (2009). The cross-sectional widths and lengths were not changed from the Langland (2009) values, since those parameters have not appreciably changed since 2008. The Langland (2009) and recalculated total water volumes matched closely. When compared, Langland (2009) reported a total water volume of 162,398 acre-ft (the report had rounded to the nearest 1,000 acre-ft), while we computed a total 2008 water volume of 162,604 acre-ft using our recalculated unweighted average depths. Thus, the two calculations matched within 206 acre-ft.

As was done in Langland (2009), net sediment deposition was calculated as the change in water volumes between 2008 and 2011, such that any decrease in water volume was attributed to an equal increase in sediment volume (net deposition) and any increase in water volume was attributed to an equal decrease in sediment volume (net scour[5]). A normalized dry density of 67.8 lb/ft^3 was used to calculate sediment weight from sediment volumes. Sediment weights were reported in tons, where 1 ton equals 2,000 pounds. Once the individual cross-section sediment changes were computed, an aggregated Conowingo Pond water volume and sediment change was calculated as the sum of all cross-sections' net volume and sediment volume/weight change.

Results

The data were compiled and combined with other near-shore elevation data to create an updated Conowingo Pond bed elevation map (Figure 3). Bed elevations from the 2008 and 2011 surveys were compared at all 26 historic USGS cross-sections (Appendix A: Historic Cross-Section Comparison). All 59 transects collected in 2011 are shown in Appendix B: 2011 Cross-Section Plots.

The results showed that there were three distinguishable sections within Conowingo Pond. The upper Pond (USGS XC 1 – USGS XC 10) was shallow, with average channel depths of 17 feet or less[6]. The

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[5] In the context of a particular cross-section, "scour" refers to a net sediment removal between 2008 and 2011, only implying that the sediment has moved out of that particular cross-section. In the context of the entire Conowingo Pond, "net scour" refers to the Pond's overall sediment flux across all cross-sections, meaning that the total amount of sediment in Conowingo Pond has changed.

[6] The depths and changes in depths cited in this section refer to the weighted average depth calculations.

upper Pond generally had small amounts of net scour (< 1 ft avg.) between the 2008 and 2011 survey, such as in USGS XC 6 (Figure 4). The middle of the Pond (USGS XC 11 – USGS XC 18) was moderately shallow, with average channel depths between 14 and 22 feet. The middle Pond experienced small to negligible amounts of net deposition, with average bed elevations rising between 0.0 and 0.6 ft. Though the middle Pond experienced little net change, there were local areas of scour and deposition that were roughly balanced, such as in USGS XC 16 (Figure 5). The lower end of the Pond (USGS XC 19 – USGS XC 26) had increasingly deeper cross-sections, with average depths ranging from just over 21 feet to nearly 50 feet. The lower Pond transects had relatively large amounts of net deposition, with between 1 and 3.5 feet of average bed elevation increase between the 2008 and 2011 surveys. The only exception to this in the Lower Pond was at USGS XC 21, which only experienced a 0.38 ft average bed elevation increase between the 2008 and 2011 survey[7].

Deposition and scour occurred in predicable locations. Deposition was generally most noticeable along the river's edges or shallower areas. Conversely, there was typically little to no deposition (or occasionally scour) near the river's thalweg (the deepest point in the transect, or area where the majority of the flow travels through). This pattern emerged in the middle pond, and became more apparent in farther downstream transects (Figure 6).

Aggregated cross-section data were plotted in longitudinal profiles to compare 2008 and 2011 average bed elevations (Figure 7 and Figure 8) and changes in average bed elevation (Figure 9 and Figure 10), using both average depth methodologies. The profiles support the hypothesis that the upper and middle pond are in dynamic equilibrium. It also confirms that the lower pond is still experiencing substantial deposition, with the amount of deposition increasing closer to Conowingo Dam.

The sediment volume change for each cross-section was calculated using the weighted and unweighted water volume methodologies. Water volume and sediment results for each cross-section are shown for the unweighted methodology in Table 2 and for the weighted methodology in Table 3. Between 2008 and 2011, the net Conowingo Pond water volume decrease was between 2,940 acre-ft (using the unweighted methodology) and 3,434 acre-ft (using the weighted methodology). This corresponds to a sediment volume [weight] increase between 2,940 acre-ft [4.34 million tons] and 3,434 acre-ft [5.07 million tons] from fall 2008 to October 2011. Averaged over the approximately 3 years between the 2008 and 2011 survey, the data show a Conowingo Pond sediment deposition rate of approximately 980 acre-ft per year to 1,145 acre-ft per year, or 1.45 million tons per year to 1.69 million tons per year for the 2008-2011 period.

Using data from Langland (2009), an analysis was done comparing the pond's estimated remaining sediment capacity over time. Conowingo Pond's remaining sediment capacity calculated by subtracting the Pond's total water volume by Langland (2009)'s Conowingo Pond steady state water

[7] The cross-section plot of USGS XC 21 shows several "spikes" in the 2008 data set that were not picked up in the 2011 survey. These spikes raised the 2008 average cross-section depth, explaining why USGS XC 21 appeared to experience less deposition than the surrounding cross-sections. These spikes may be due to logs, debris, or localized bedrock features.

volume estimation of 142,000 acre-ft. Figure 11a and Figure 11b show the plot of remaining sediment capacity over time next to a similar plot originally shown in Academy of Natural Sciences (1994). An exponential trendline was fitted to Figure 11b to show a similar line as the Academy of Natural Sciences (1994) figure. A sensitivity analysis for several steady-state water volumes showed that the trendline's general shape was maintained for a wide range of steady state volumes. A second sensitivity analysis showed that the trendline's general shape was insensitive to removing any of the individual points from the best-fit plot, including the 2011 results.

Discussion

A comparison of the 2008 and 2011 data sets provide great insight into the sediment transport processes occurring in Conowingo Pond. But, while these two surveys were taken within a relatively short period of time, these comparisons are not the same as a before and after comparison isolating a single event. Historic data have shown there is a considerable amount of deposition that occurs in Conowingo Pond on an annual basis, as the average Conowingo Pond sediment inflow between 1996 and 2008 was approximately 1.5 million tons/year, with a long-term (1959–2008) average deposition of approximately 2 million tons per year (Langland 2009). These historic deposition rates are comparable to the 2008-2011 deposition rates calculated in this study 1.45 to 1.69 million tons per year).

When viewing the individual cross-section plots, it is apparent that the magnitude and location of riverbed changes varied longitudinally along the Pond. In the upper and middle Pond (USGS XC 1 to USGS XC 18) there is little net change between 2008 and 2011, though some cross-sections experienced channel "shifting" or redistribution, such that the deposition and scour areas were roughly equal. This indicates that a large portion of the Pond is likely in "dynamic equilibrium". This is consistent with other USGS findings, which had concluded that the Pond has been in equilibrium at or above USGS XC 16 since 1959. It also shows that the proportion of the Pond in equilibrium is increasing. Beginning around USGS XC 19, three phenomena are apparent:

1) Within each cross-section, the amount of deposition begins to clearly outweigh the amount of scour, resulting in net deposition. The longitudinal profile comparison (Figure 7) further supports the first observation, generally showing between 1 and 3.5 feet of deposition averaged across the cross-section at USGS XC 19 and farther downstream.

2) The cross-sections generally experienced some scour along the river's thalweg or main channel, accompanied by larger amounts of deposition along the banks. Deposition was only observed along one bank when the thalweg was located adjacent to one of the river banks (e.g., USGS XC 20-23). The disparity was most obvious in the farthest downstream cross-sections (Figure 6). It is logical that local scour would occur at a cross-section's thalweg, as one would expect re-suspension to occur where the highest flows, and thus velocities, are found. It is not clear from this data set where the scoured sediment was transported to (e.g., downstream cross-sections, out of the Pond). It would be reasonable to assume that at least

some of the sediment scoured from the farthest downstream comparable cross-section (USGS XC 26) passed over the Conowingo Dam spillway.

3) Between 2008 and 2011, the river thalweg appeared to shift towards the center of the dam, where the spillway is located. This was likely a result of flows following Tropical Storm Lee, during which the Conowingo powerhouse was shut down to protect the turbines. As a result, all flow was passed through the Conowingo spillway, which had a large number of its crest gates (42 of 50) opened at one point.

While 2011 cross-section data were collected closer to the dam than at USGS XC 2008, no previous data sets exist in these areas. Thus, no scour/deposition comparison could be completed for Conowingo Pond downstream of USGS XC 26 at this time. These cross-sections may serve as a reference point for future surveys.

The Academy of Natural Sciences (1994) figure shows equilibrium as a condition where net deposition never permanently stops, though it does occur at reduced rates, and stored sediment never permanently remains at the non-flood steady-state level. It shows that storm events mobilize and remove previously deposited sediment, pushing the system back below a non-flood steady state condition, starting the net deposition cycle again.

The comparison in Figure 11 between the Academy of Natural Sciences (1994) figure and Conowingo Pond's estimated remaining sediment capacity shows a clear trend of Conowingo Pond filling over time in a manner consistent with the Academy of Natural Sciences (1994) figure. It shows that Conowingo Pond, on the whole, is on the rising limb of the curve, but is at a point where the rate of net deposition is reduced and net scour may begin to influence the reservoir's position above or below the long-term mean. The trendline's insensitivity to steady state water volume estimates and removal of individual data points further support this statement. It is unclear at this point whether Conowingo Pond has reached its long-term mean sediment storage level.

In summary, the Academy of Natural Sciences (1994) figure shows that 1) a reservoir's long-term equilibrium sediment volume is less than its true steady-state volume, due to periodic scouring events; and 2) as a reservoir approaches its steady state capacity, it fills increasingly slower, such that a true steady-state volume is rarely, if ever, reached. The Conowingo Pond data show that Conowingo Pond has experienced diminishing sedimentation over time, as the Pond approaches a non-flood steady state capacity. It also shows a scour event (1996), though no immediate pre-storm bathymetric sample was available to show the actual pre and post-storm sediment volumes. The similarity between the Conowingo Pond data and the Academy of Natural Sciences (1994) figure show that Academy of Natural Sciences's (1994) figure likely serves as a good template for predicting Conowingo Pond's future behavior.

Conclusions

Several important points were addressed through analysis of the 2011 bathymetric survey.

First, the survey results support the previous USGS hypothesis that the upper and middle portions of Conowingo Pond have reached dynamic equilibrium, where long term sediment inflow approximately equals long term sediment outflow. It also appears that the zone of dynamic equilibrium has expanded farther downstream than in previous surveys, perhaps extending to USGS XC 18, which is approximately 3.7 miles upstream of Conowingo Dam.

Secondly, 2008-2011 cross-section comparisons indicate that there was local scour (re-suspension) in portions of the Pond's lower cross-sections. The amount of deposition, however, generally exceeded the amount of scour. It was not clear where the re-suspended sediment was transported to.

Thirdly, given that the deposition prior to Tropical Storm Lee is unknown, the flood's sediment profile impacts cannot be directly assessed. Using two different methods, we calculated that the Conowingo Pond water volume decreased (due to a sediment volume increase) between 2,940 acre-ft and 3,434 acre-ft from 2008 to 2011, or between 980 acre-ft per year and 1,145 acre-ft per year. This corresponds to a total sediment deposition of 4.34 million tons to 5.07 million tons, or a rate of 1.45 million tons per year to 1.69 million tons per year, which matches historic deposition rates well.

Finally, the Conowingo Pond data compare well to a typical reservoir sedimentation profile over time. This was true in sensitivity analyses testing various steady state water volumes and excluding individual data points throughout the fitted curve. Thus, it appears the Academy of Natural Sciences (1994) curve likely serves as a reasonable template for how Conowingo Pond will continue to accumulate and scour over time. It is unclear at this point whether Conowingo Pond has reached its long-term mean sediment storage levels as shown in the Academy of Natural Sciences (1994) figure.

References

Langland, M.J., 2009. Bathymetry and Sediment-storage Capacity Change in Three Reservoirs on the Lower Susquehanna River, 1996-2008. United States Geological Survey Scientific Investigations Report 2009-5110. 21p.

Langland, M.J. and R.A. Hainly, 1997. Changes in Bottom-Surface Elevations in Three Reservoir on the Lower Susquehanna River, Pennsylvania and Maryland, Following the January 1996 Flood – Implications for Nutrient and Sediment Loads to Chesapeake Bay. United States Geological Survey Water-Resources Investigations Report 97-4138. 34p with plates.

Academy of Natural Sciences. Issues Regarding Estimated Impacts of the Lower Susquehanna River Reservoir System on Sediment and Nutrient Discharge to Chesapeake Bay. The Academy of Natural Sciences of Philadelphia, Division of Environmental Research. Report No. 94-20. 6 September, 1994.

Table 1: Observed versus measured water depths, from the bathymetric unit verification.

Observed Depth (ft)	Bathymetric Unit Measured Depth (ft)	Difference (ft)	Difference (%)
7.0	6.99	-0.01	-0.14
12.0	11.91	-0.09	-0.75
17.0	17.03	0.03	0.17
22.0	22.09	0.09	0.41
27.0	26.89	-0.11	-0.41

Table 2: Conowingo Pond cross-section sediment calculations, using unweighted average depths. Red numbers in parentheses are negative.

USGS Cross-Section Number	Distance US of Dam (ft)	Effective Length (ft)	Cross-Section Width (ft)	Unweighted Average Depth at Normal Pool [109.2 ft NGVD 1929] (ft)			Water Volume at Normal Pool (acre-ft)			Sediment Accumulation (acre-ft)	Sediment Accumulation (tons)
				2008	2011	Difference	2008	2011	2008-2011		
1	60,000	2,200	4,880	12.20	12.51	0.31	3,084	3,006	77	77	114,340
2	57,700	2,250	6,400	14.37	14.15	(0.22)	4,678	4,751	(72)	(72)	(106,770)
3	56,600	2,350	6,200	15.21	15.53	0.32	5,194	5,088	106	106	156,012
4	54,800	2,150	6,310	16.42	16.19	(0.24)	5,041	5,115	(74)	(74)	(108,849)
5	52,900	1,800	5,900	15.64	15.49	(0.15)	3,777	3,813	(36)	(36)	(52,948)
6	49,800	2,600	6,810	14.87	14.95	0.07	6,075	6,046	30	30	44,137
7	47,010	2,775	6,350	14.96	17.04	2.08	6,895	6,053	842	842	1,243,557
8	44,250	2,430	6,900	15.09	14.14	(0.95)	5,442	5,808	(365)	(365)	(539,555)
9	42,150	2,130	6,540	16.20	15.88	(0.32)	5,080	5,182	(102)	(102)	(150,747)
10	39,990	1,400	7,000	15.26	15.09	(0.17)	3,394	3,432	(38)	(38)	(55,922)
11	37,500	1,900	7,710	12.93	14.53	1.60	4,885	4,347	538	538	794,504
12	35,800	3,420	6,510	15.94	16.17	0.23	8,263	8,146	116	116	171,981
13	33,150	3,175	4,700	20.13	20.32	0.19	6,961	6,896	65	65	96,682
14	29,450	3,150	4,710	20.68	21.09	0.41	7,183	7,043	140	140	206,816
15	26,850	2,530	5,050	20.92	20.70	(0.21)	6,073	6,135	(62)	(62)	(92,147)
16	24,400	2,570	5,300	19.24	19.49	0.26	6,095	6,015	81	81	118,977
17	21,700	2,550	6,180	20.45	20.74	0.29	7,503	7,399	104	104	153,158
18	19,300	2,525	5,000	21.74	21.73	(0.01)	6,299	6,302	(4)	(4)	(5,276)
19	16,650	2,625	5,240	21.64	21.93	0.29	6,926	6,833	93	93	137,103
20	14,050	2,187	3,560	28.66	29.28	0.62	5,233	5,122	111	111	163,832
21	12,275	2,085	3,350	30.28	28.62	(1.66)	4,589	4,856	(267)	(267)	(394,202)
22	9,880	2,162	3,380	30.50	31.15	0.65	5,226	5,116	110	110	161,778
23	7,950	2,175	3,520	32.96	34.06	1.09	5,986	5,793	192	192	284,131
24	5,530	2,400	4,450	37.78	40.50	2.71	9,929	9,263	665	665	982,556
25	3,150	1,915	4,610	45.28	47.23	1.96	9,572	9,176	396	396	585,159
26	1,700	2,425	4,750	48.89	50.00	1.11	13,222	12,929	293	293	432,539
Total	-	-	-	-	-	-	**162,604**	**159,664**	**2,940**	**2,476**	**4,340,848**

Table 3: Conowingo Pond cross-section sediment calculations, using weighted average depths. Red numbers in parentheses are negative.

USGS Cross-Section Number	Distance US of Dam (ft)	Effective Length (ft)	Cross-Section Width (ft)	Weighted Average Depth at Normal Pool [109.2 ft NGVD 1929] (ft)			Water Volume at Normal Pool (acre-ft)			Sediment Accumulation (acre-ft)	Sediment Accumulation (tons)
				2008	2011	Difference	2008	2011	2008-2011		
1	60,000	2,200	4,880	12.60	12.54	0.06	3,106	3,090	16	16	23,337
2	57,700	2,250	6,400	14.26	14.42	(0.16)	4,715	4,769	(53)	(53)	(78,452)
3	56,600	2,350	6,200	15.96	15.98	(0.02)	5,339	5,345	(5)	(5)	(7,591)
4	54,800	2,150	6,310	16.66	16.96	(0.31)	5,188	5,284	(95)	(95)	(140,737)
5	52,900	1,800	5,900	15.65	15.66	(0.01)	3,817	3,819	(2)	(2)	(3,007)
6	49,800	2,600	6,810	15.09	15.40	(0.30)	6,135	6,259	(124)	(124)	(183,005)
7	47,010	2,775	6,350	16.49	16.80	(0.30)	6,671	6,794	(123)	(123)	(181,706)
8	44,250	2,430	6,900	14.82	15.78	(0.96)	5,704	6,074	(370)	(370)	(545,906)
9	42,150	2,130	6,540	16.37	16.61	(0.25)	5,234	5,313	(79)	(79)	(116,491)
10	39,990	1,400	7,000	15.31	16.05	(0.74)	3,444	3,611	(167)	(167)	(246,907)
11	37,500	1,900	7,710	15.01	14.48	0.52	5,047	4,871	176	176	259,516
12	35,800	3,420	6,510	16.43	16.24	0.19	8,398	8,303	96	96	141,080
13	33,150	3,175	4,700	20.87	20.57	0.30	7,150	7,047	102	102	151,068
14	29,450	3,150	4,710	20.86	20.86	0.00	7,106	7,104	2	2	2,347
15	26,850	2,530	5,050	21.64	21.36	0.28	6,347	6,264	83	83	123,021
16	24,400	2,570	5,300	20.27	19.72	0.55	6,338	6,166	172	172	253,873
17	21,700	2,550	6,180	20.87	20.62	0.25	7,550	7,460	90	90	133,167
18	19,300	2,525	5,000	22.04	21.77	0.28	6,388	6,308	80	80	117,718
19	16,650	2,625	5,240	22.62	21.63	0.99	7,143	6,829	314	314	463,741
20	14,050	2,187	3,560	30.16	28.60	1.56	5,391	5,112	279	279	411,278
21	12,275	2,085	3,350	31.13	30.73	0.40	4,992	4,927	64	64	94,812
22	9,880	2,162	3,380	33.43	31.79	1.64	5,608	5,333	274	274	405,053
23	7,950	2,175	3,520	35.94	33.58	2.36	6,317	5,903	414	414	611,712
24	5,530	2,400	4,450	41.64	38.61	3.04	10,210	9,465	745	745	1,100,243
25	3,150	1,915	4,610	49.07	45.61	3.46	9,946	9,244	702	702	1,036,292
26	1,700	2,425	4,750	52.75	49.56	3.19	13,949	13,105	844	844	1,246,207
Total	-	-	-	-	-	-	**167,234**	**163,800**	**3,434**	**3,434**	**5,070,661**

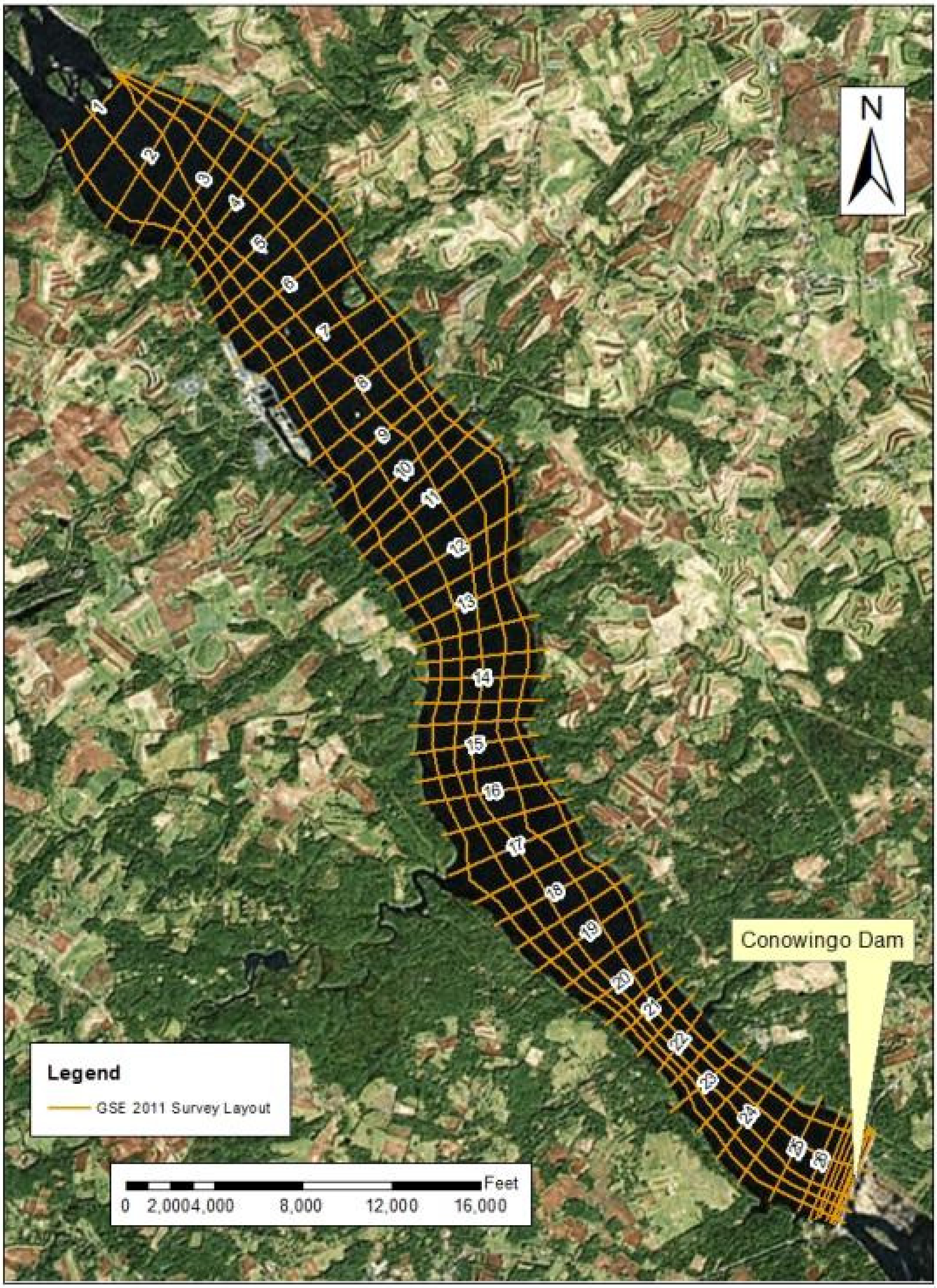


Figure 1: GSE 2011 data collection transects. Numbers shown are USGS 2008 XC numbers.

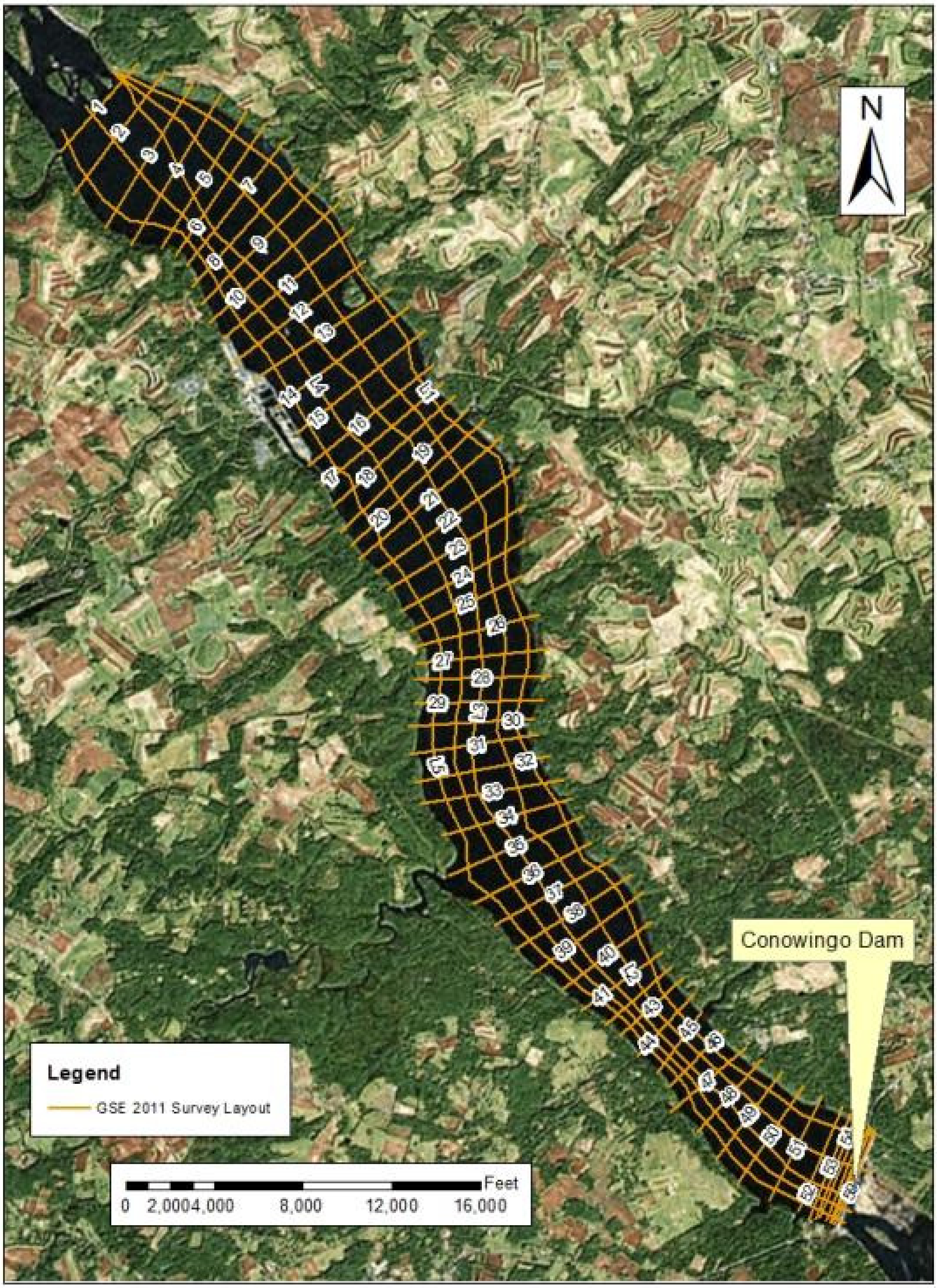


Figure 2: GSE 2011 data collection transects, with GSE 2011 transect numbers.

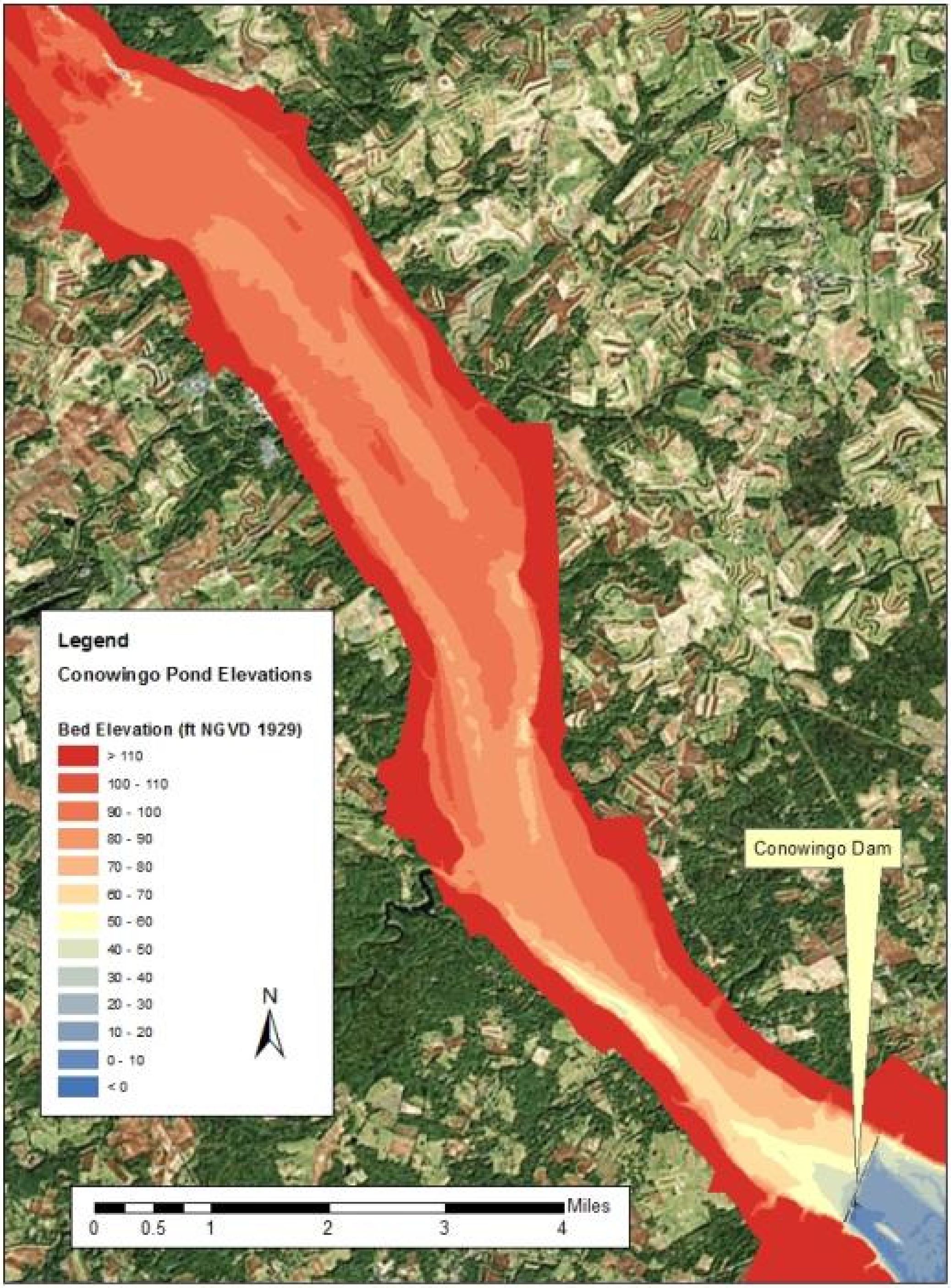


Figure 3: Composite elevation data set including 2011 Conowingo Pond data.

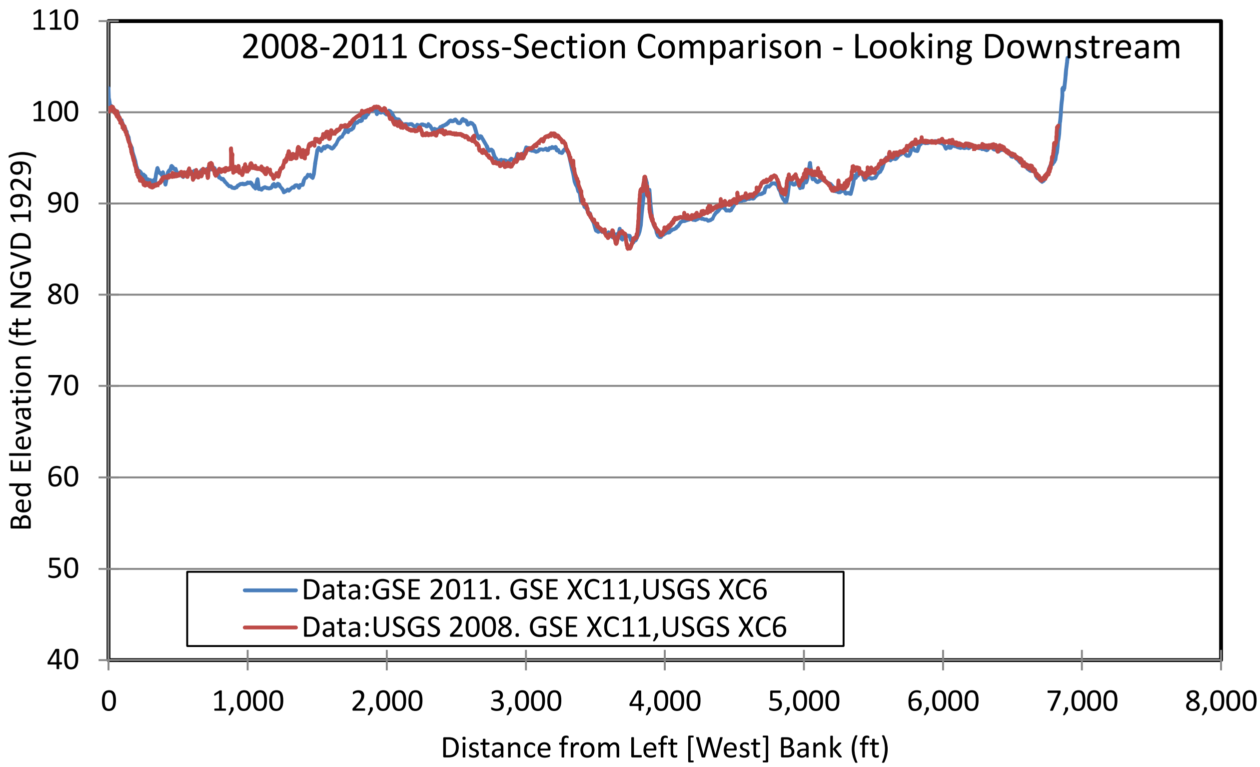


Figure 4: Plot comparing USGS 2008 and GSE 2011 cross-sections at USGS XC 2, located approximately 11.3 miles upstream of Conowingo Dam.

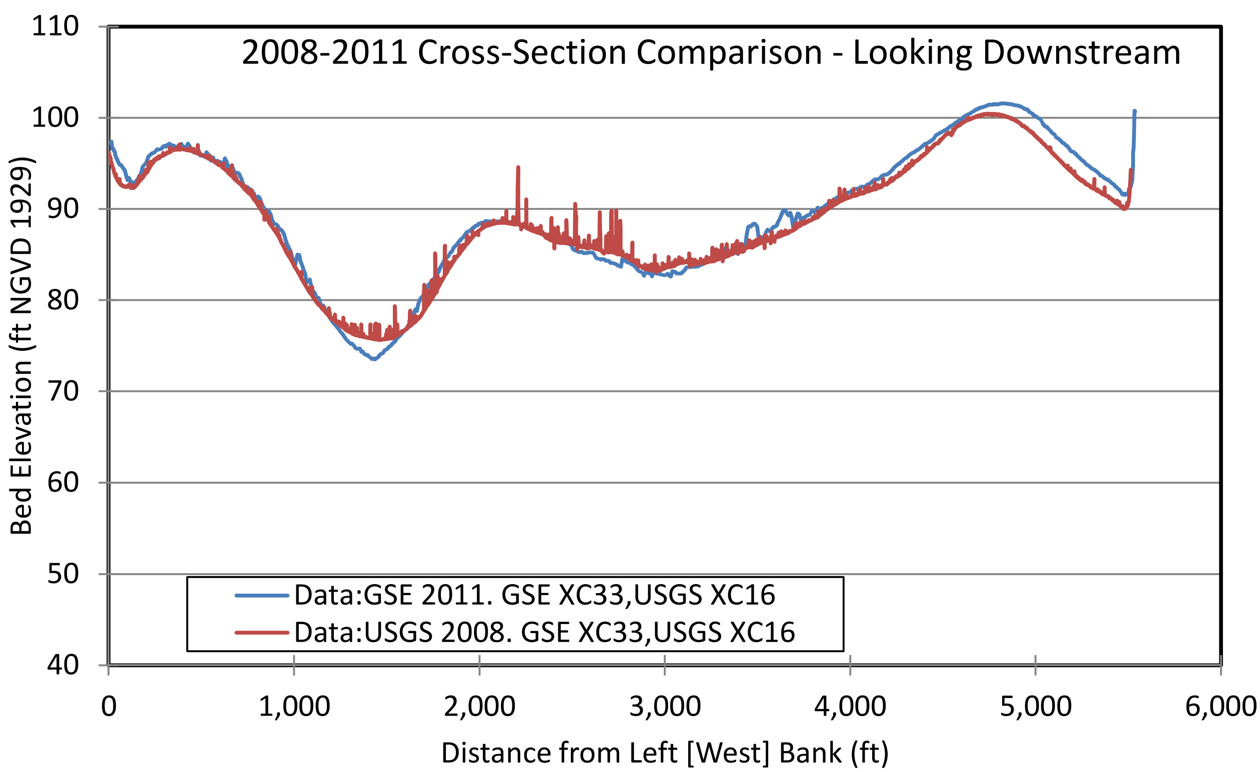
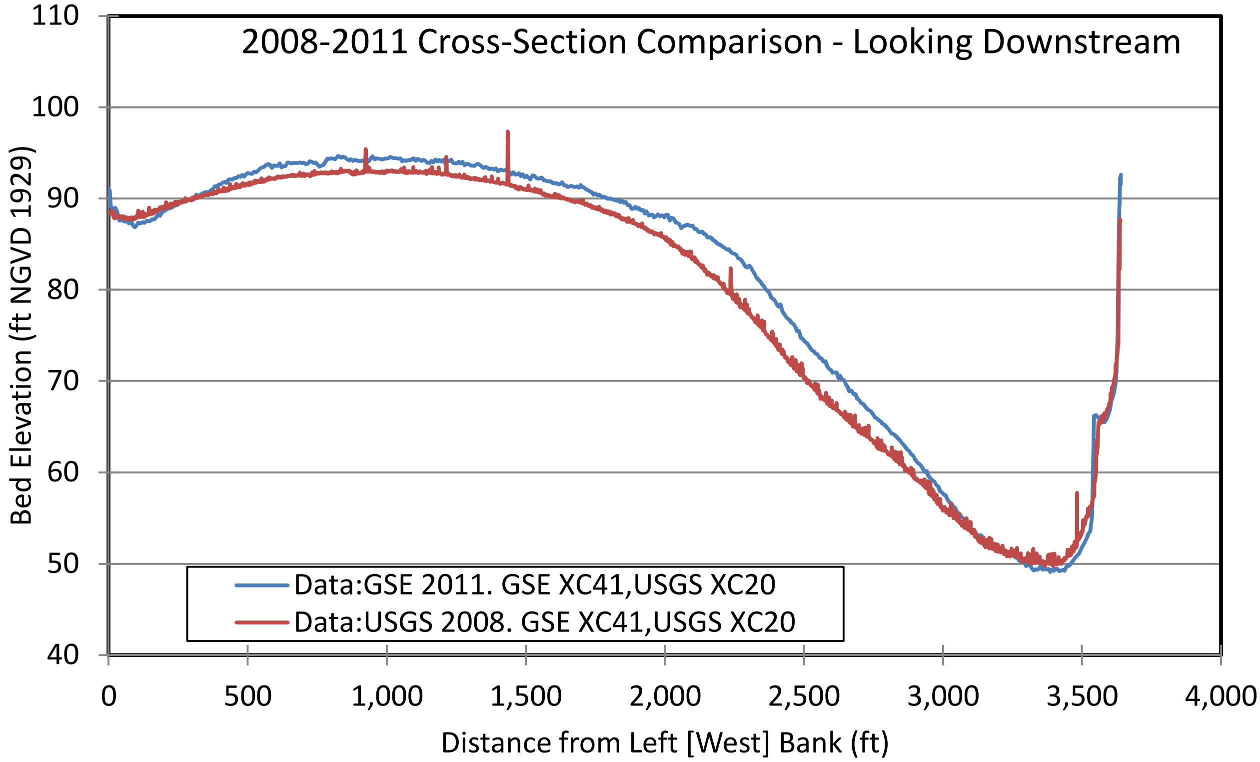


Figure 5: Plot comparing USGS 2008 and GSE 2011 cross-sections at USGS XC 16, located approximately 4.7 miles upstream of Conowingo Dam.



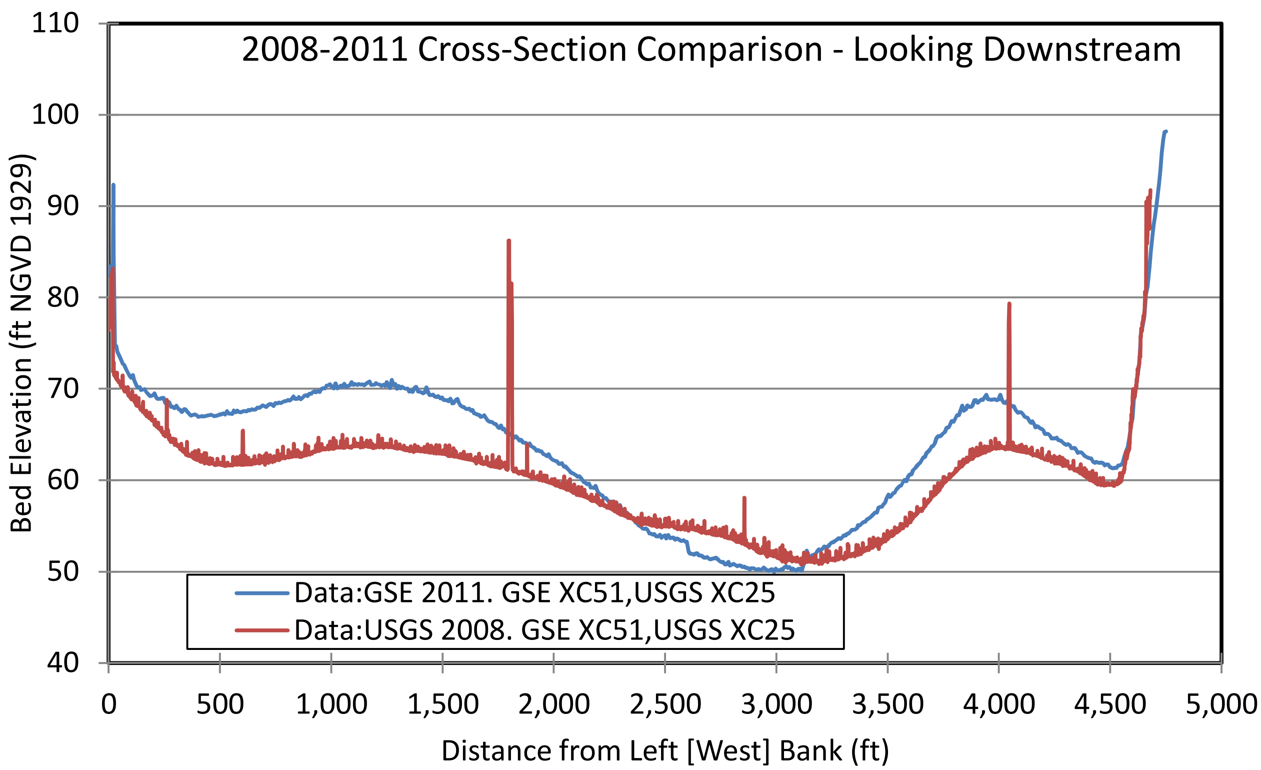


Figure 6: Comparison of two lower Pond transects. USGS XC 20 and 25 located 2.7 and 0.6 miles upstream of Conowingo Dam, respectively.

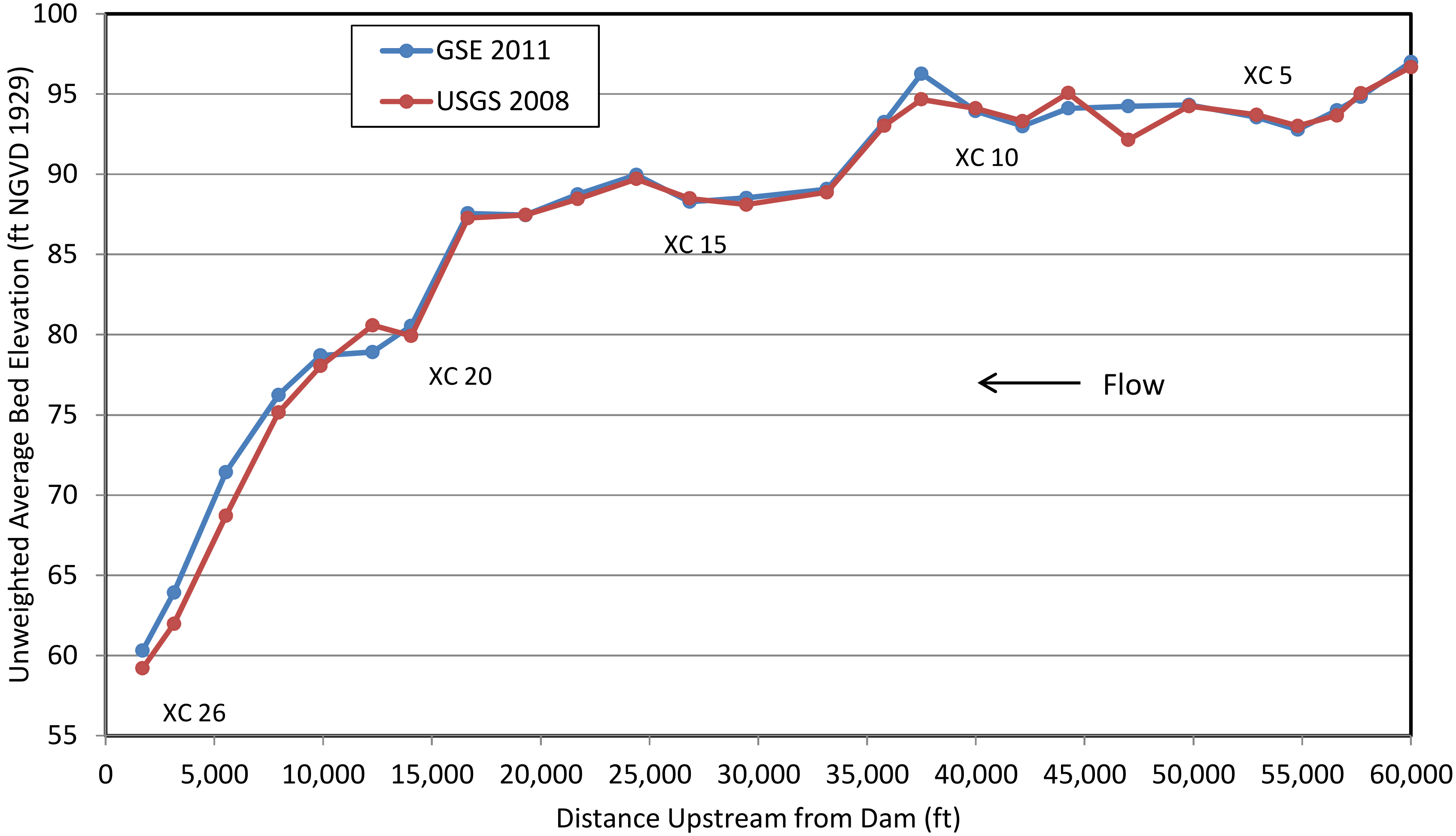


Figure 7: Unweighted average transect bed elevation versus distance upstream from Conowingo Dam.

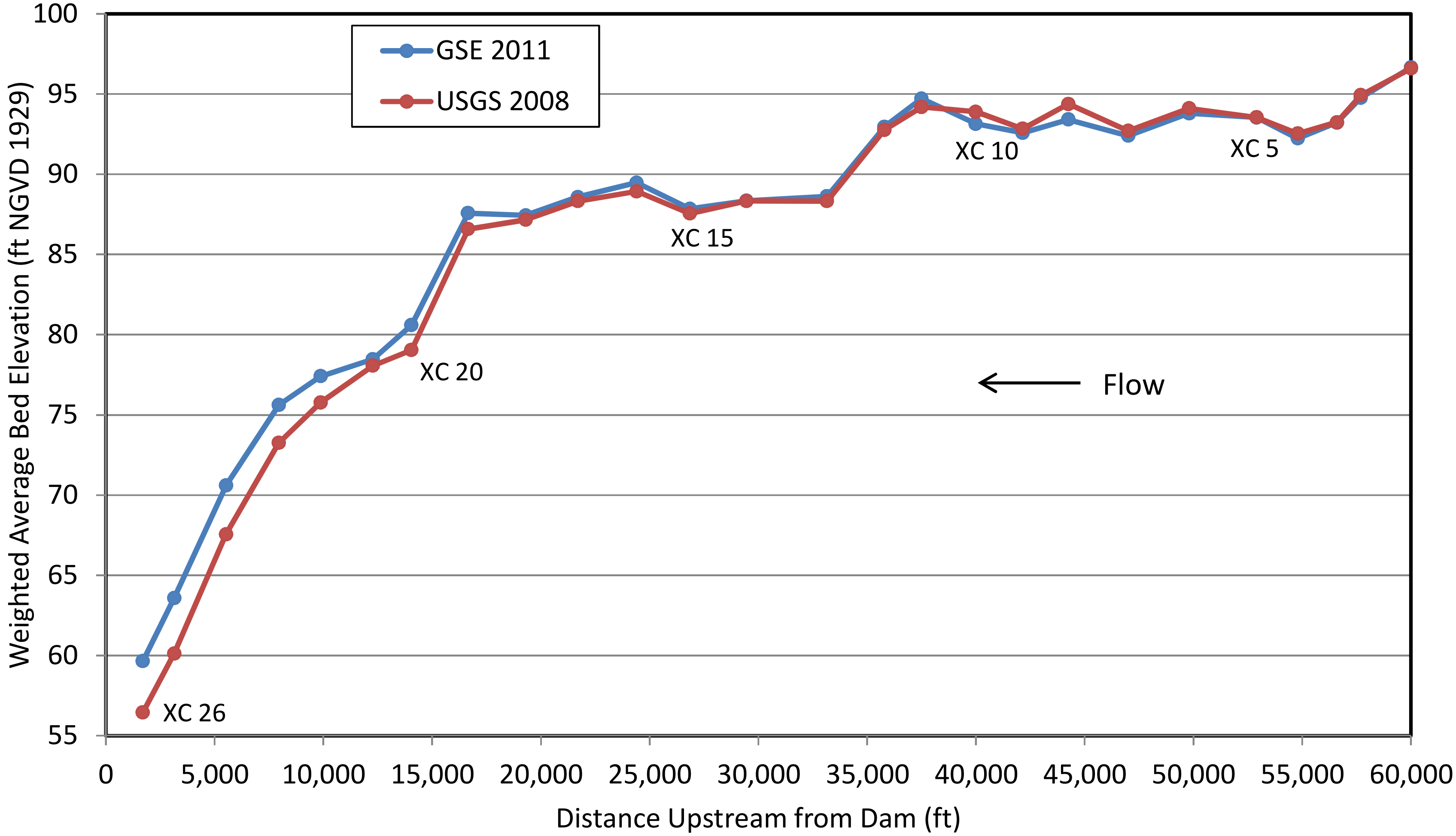


Figure 8: Weighted average transect bed elevation versus distance upstream from Conowingo Dam.

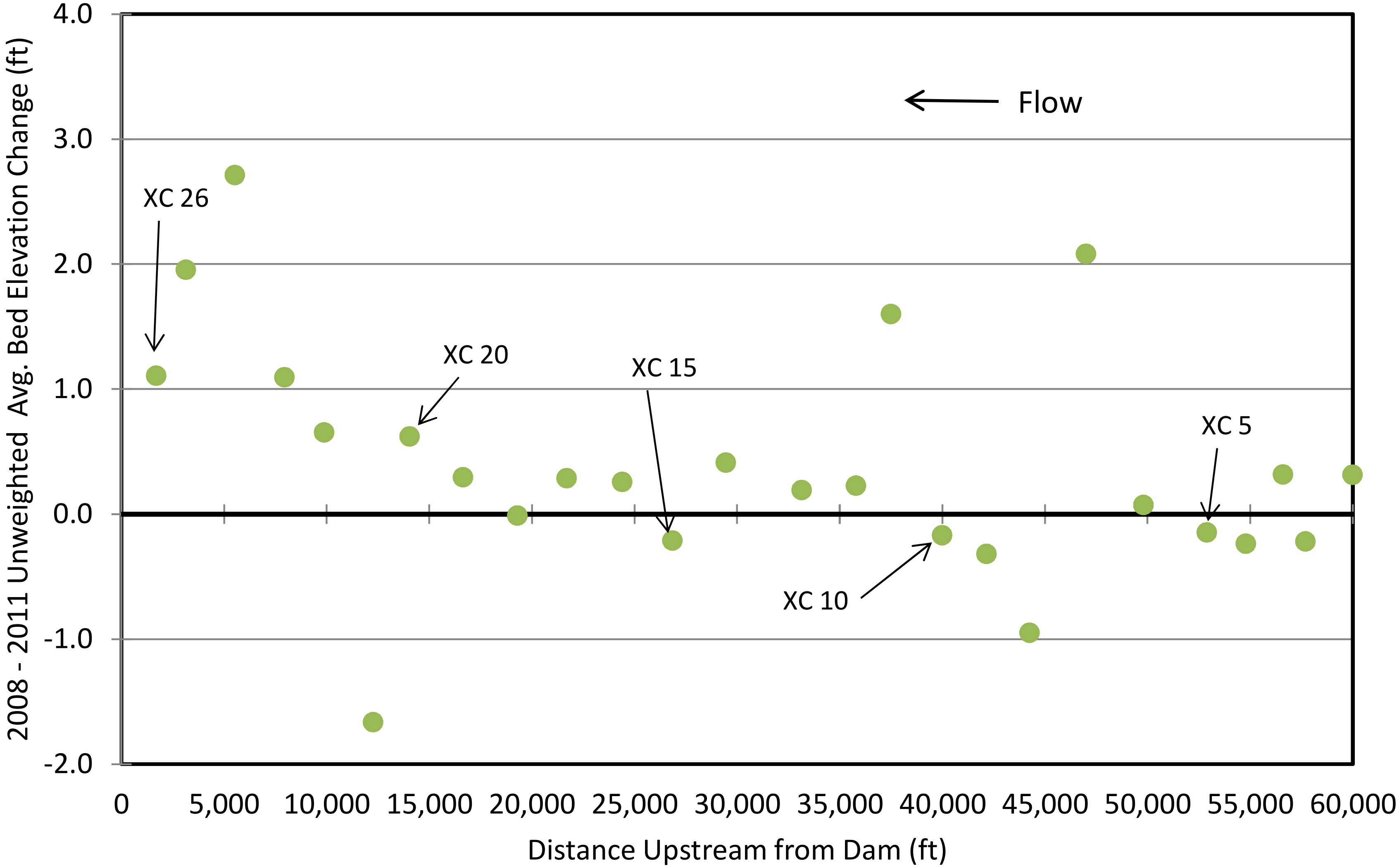


Figure 9: Unweighted average bed elevation change longitudinal profile, showing net deposition (positive values) and net scour (negative values).

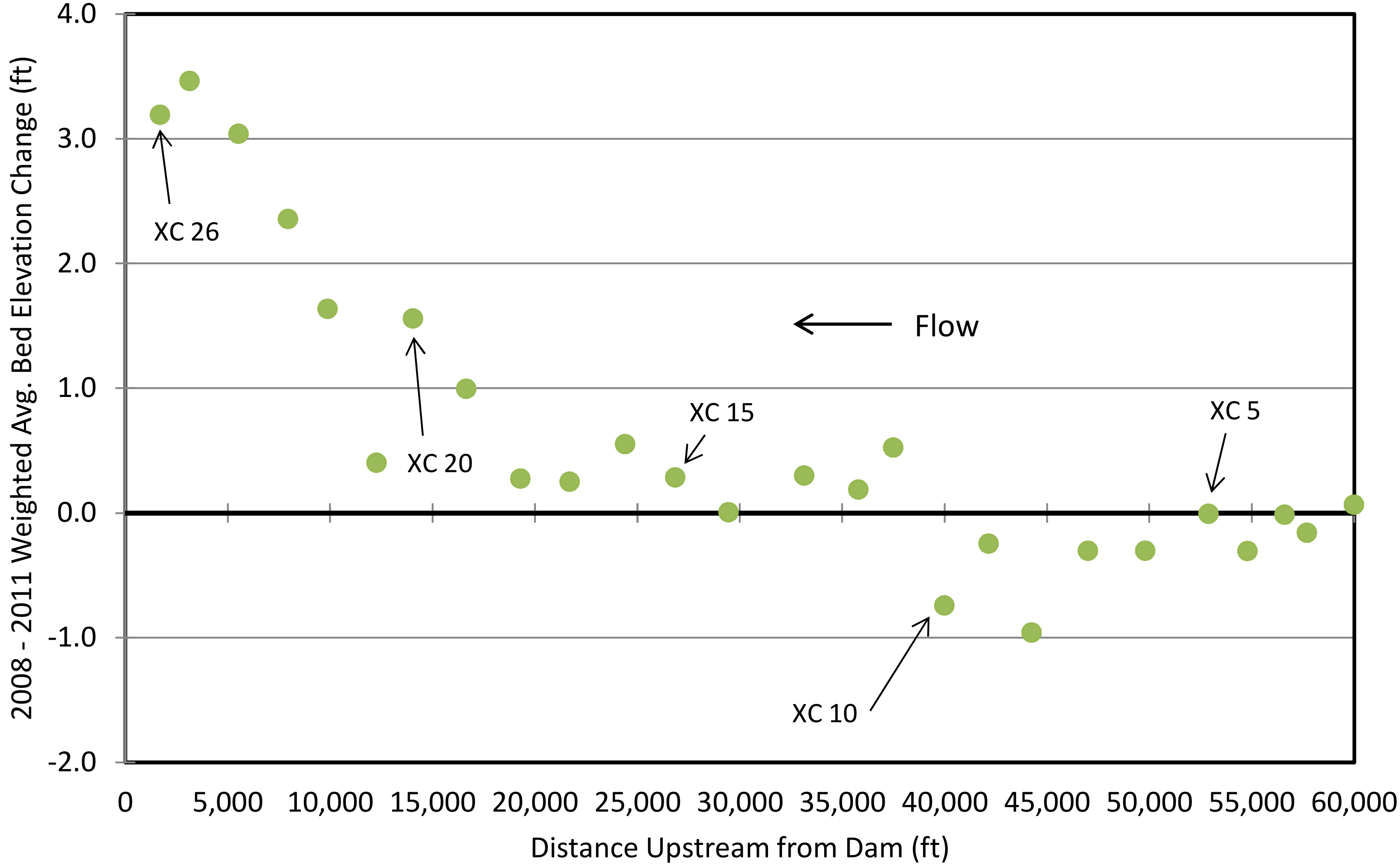


Figure 10: Weighted average bed elevation change longitudinal profile, showing net deposition (positive values) and net scour (negative values).

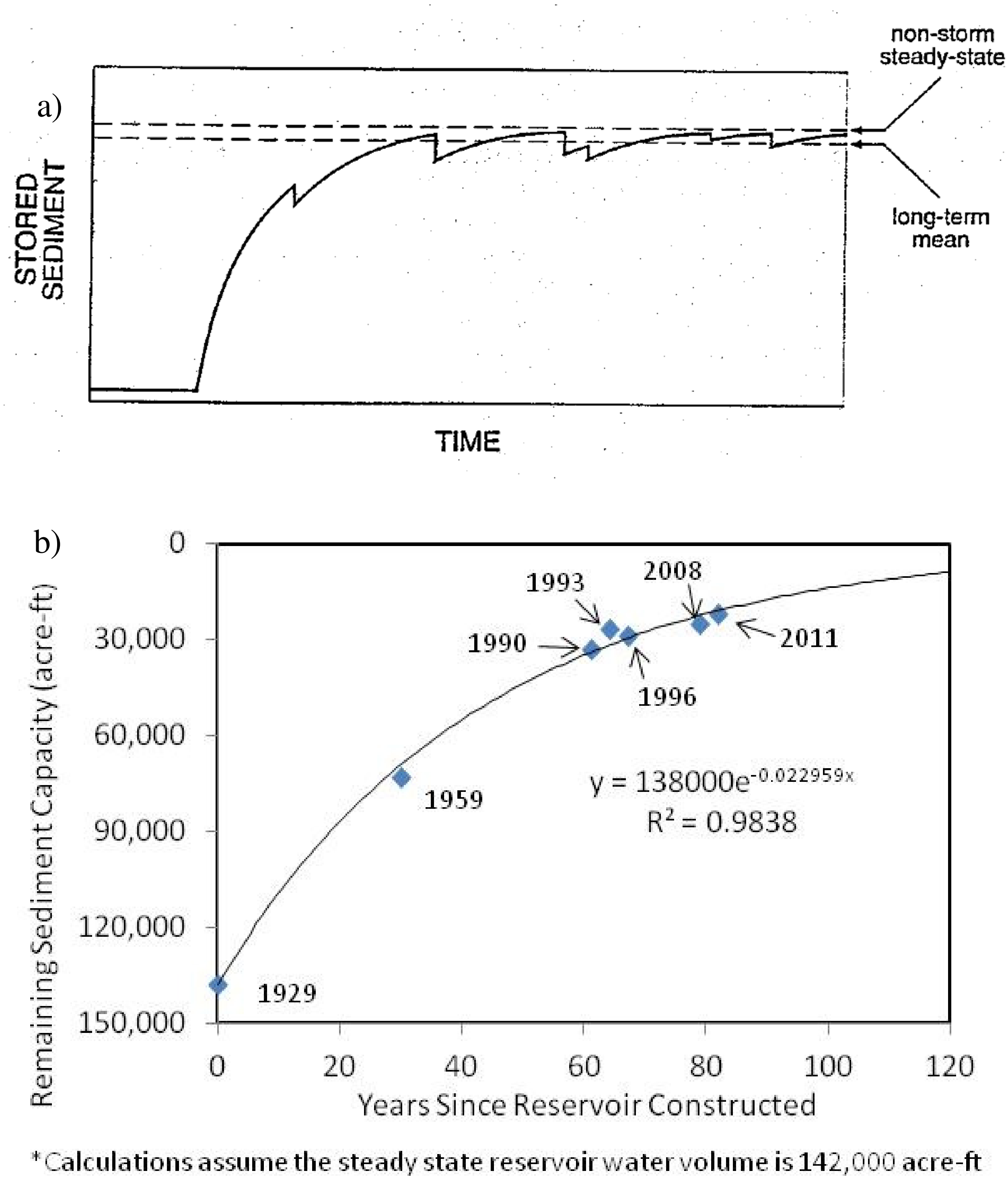
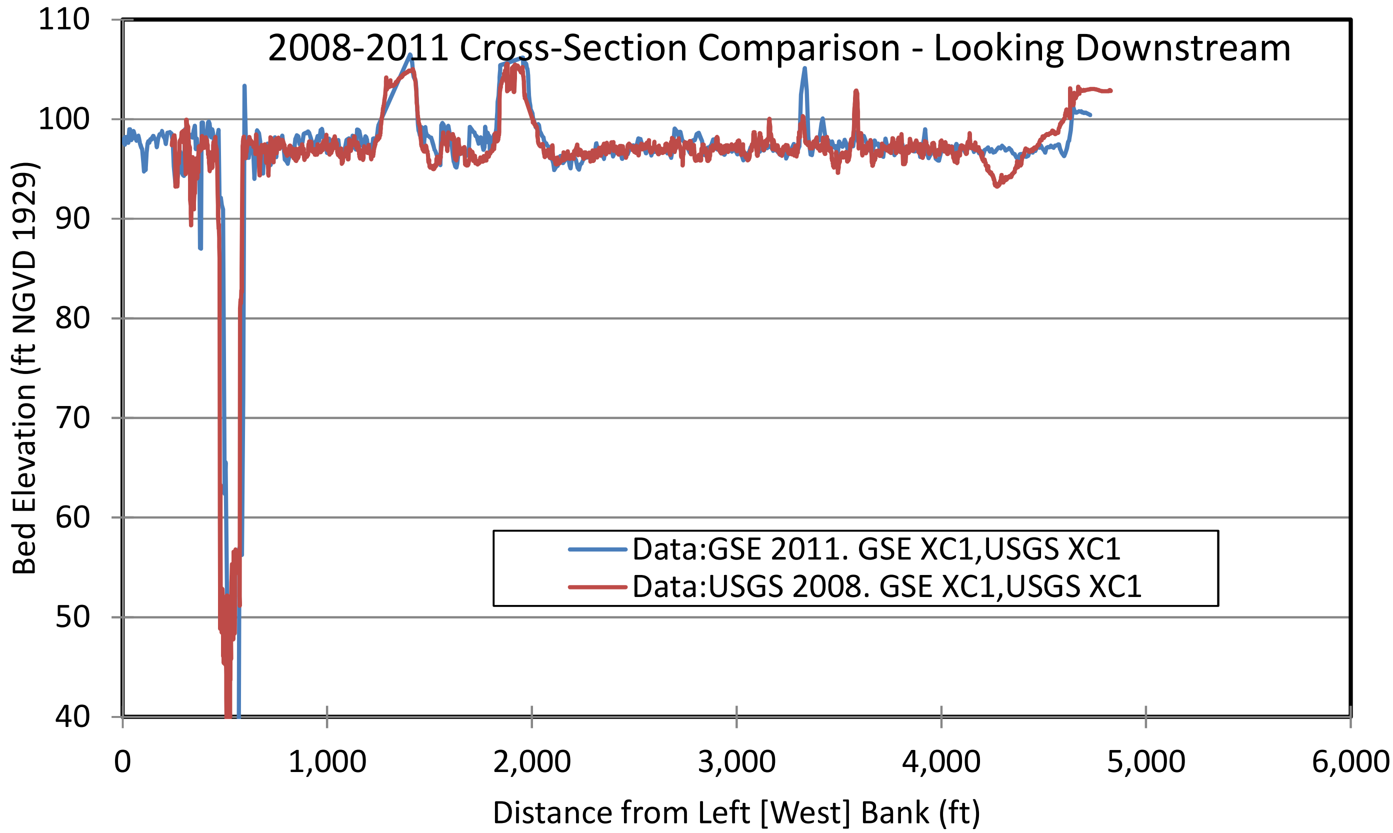
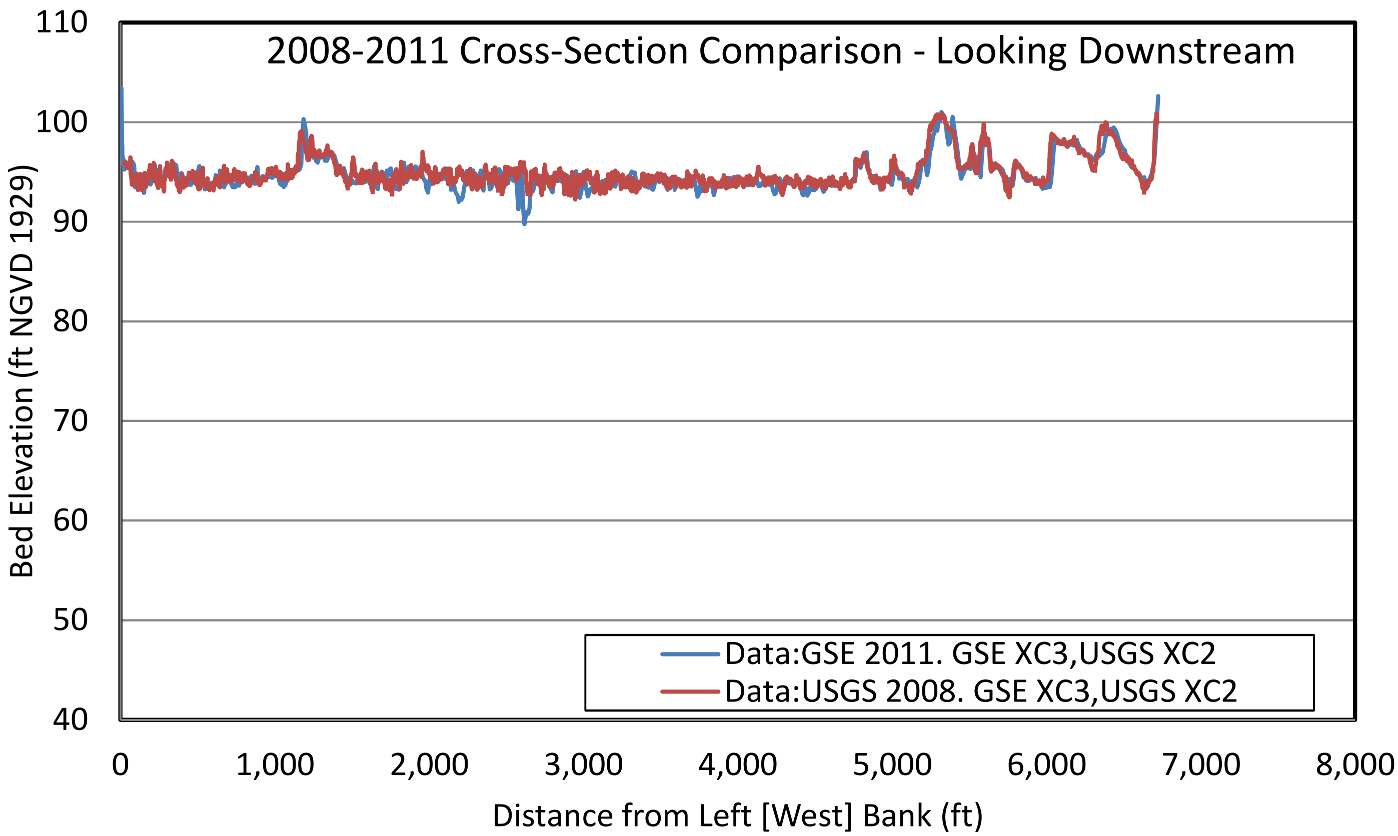
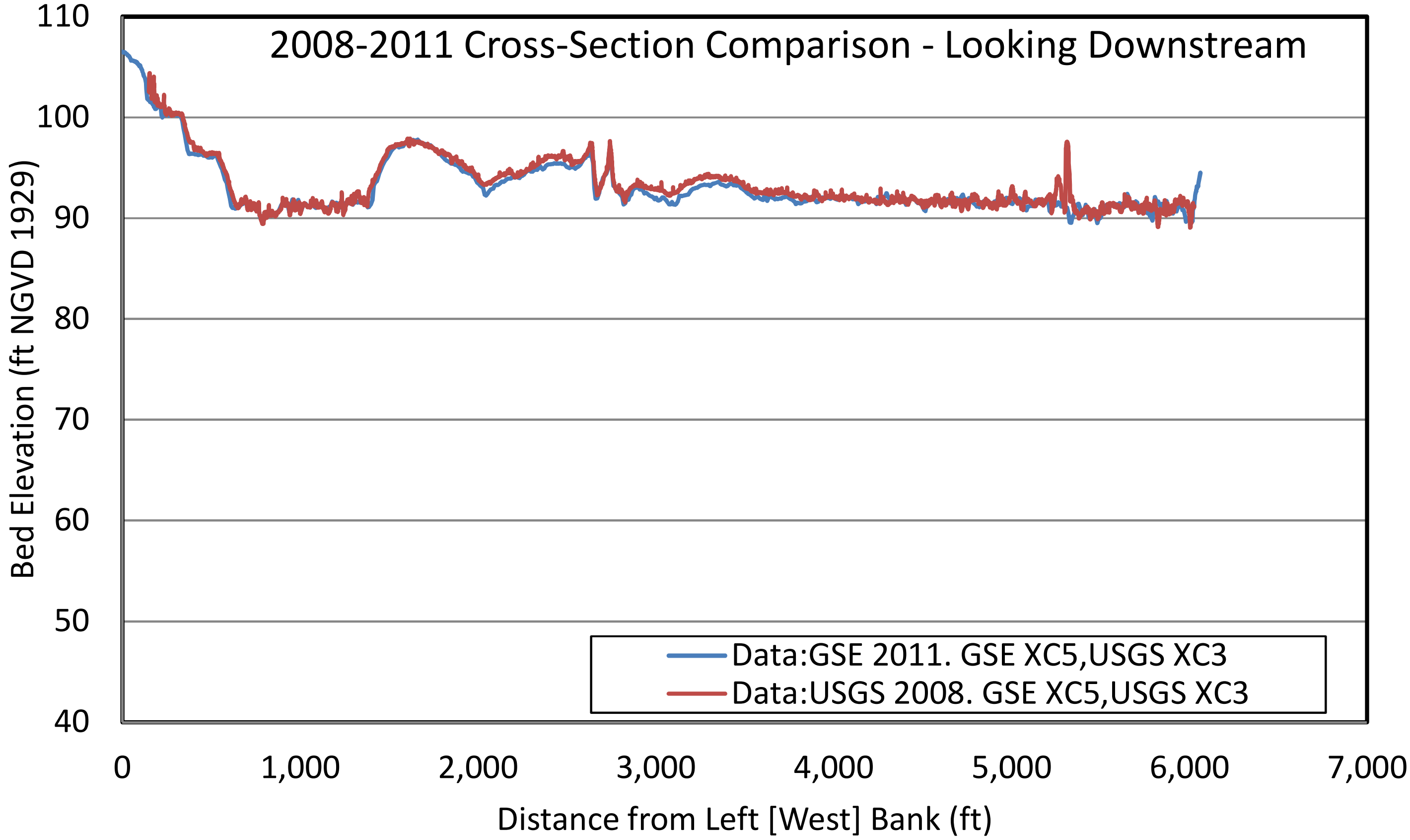


Figure 11: Comparison of a) sediment stored versus time for a general reservoir, taken from Academy of Natural Sciences (1994); and b) Conowingo Pond's estimated remaining sediment capacity versus time since the reservoir was constructed.

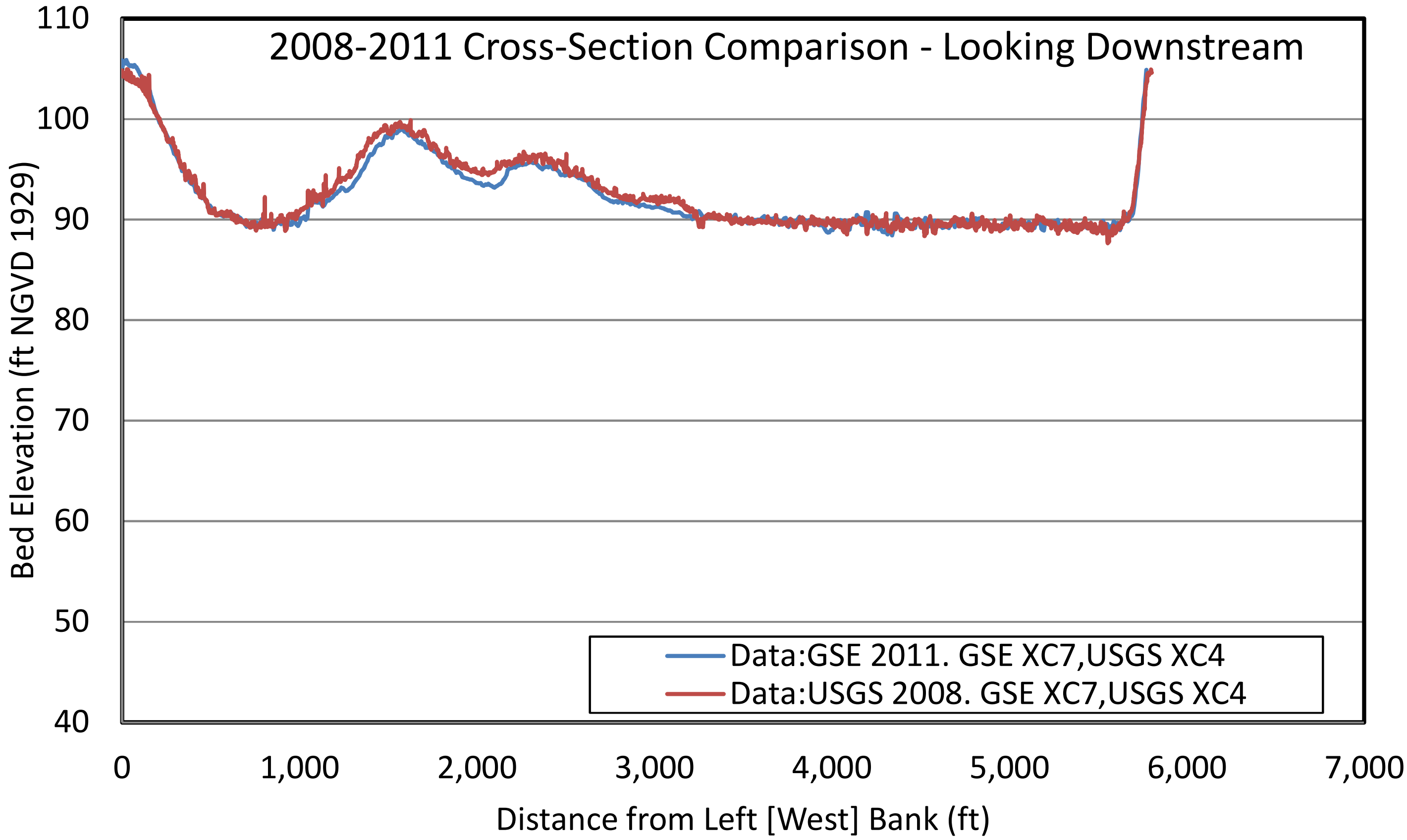
Appendix A: Historic Cross-Section Comparison



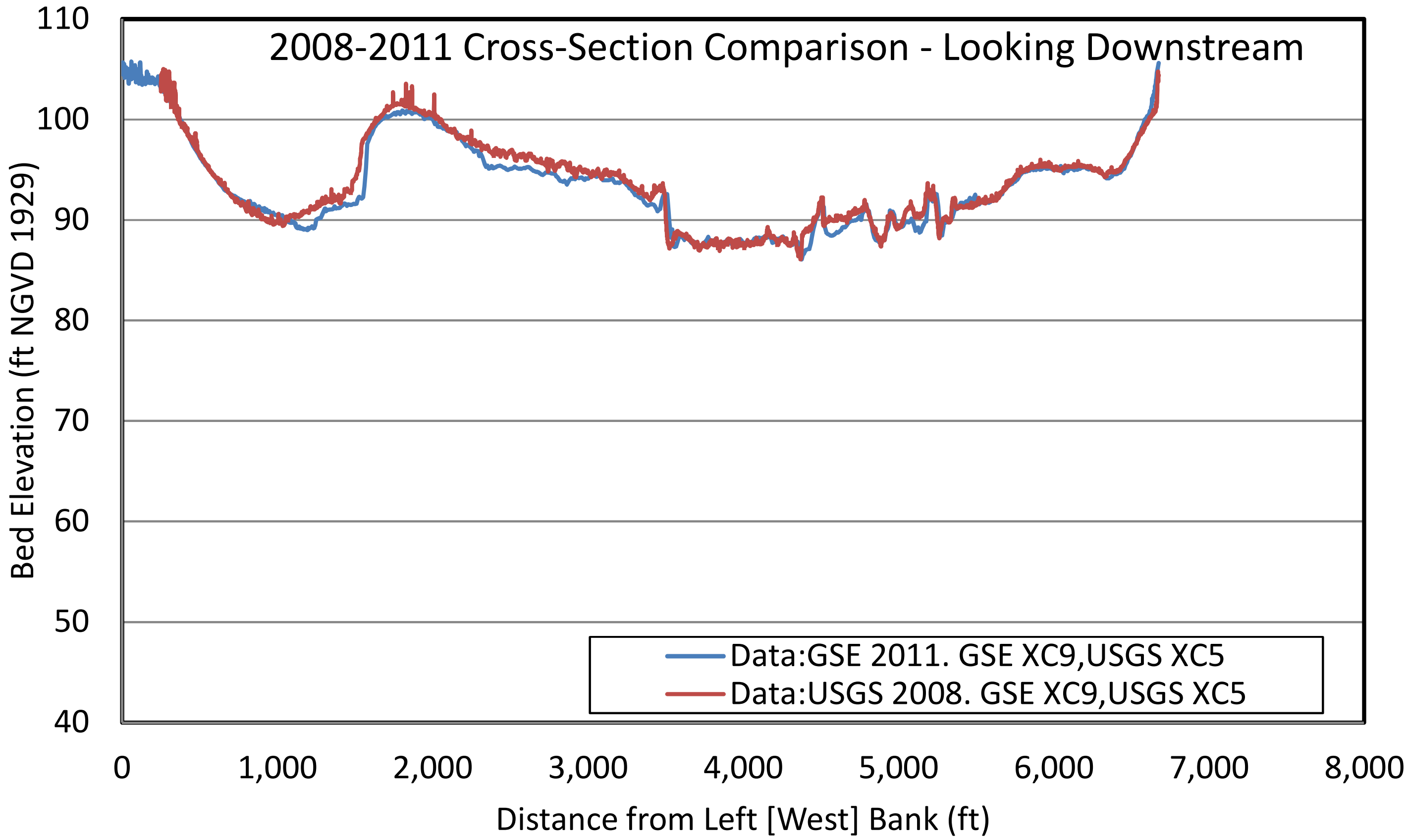


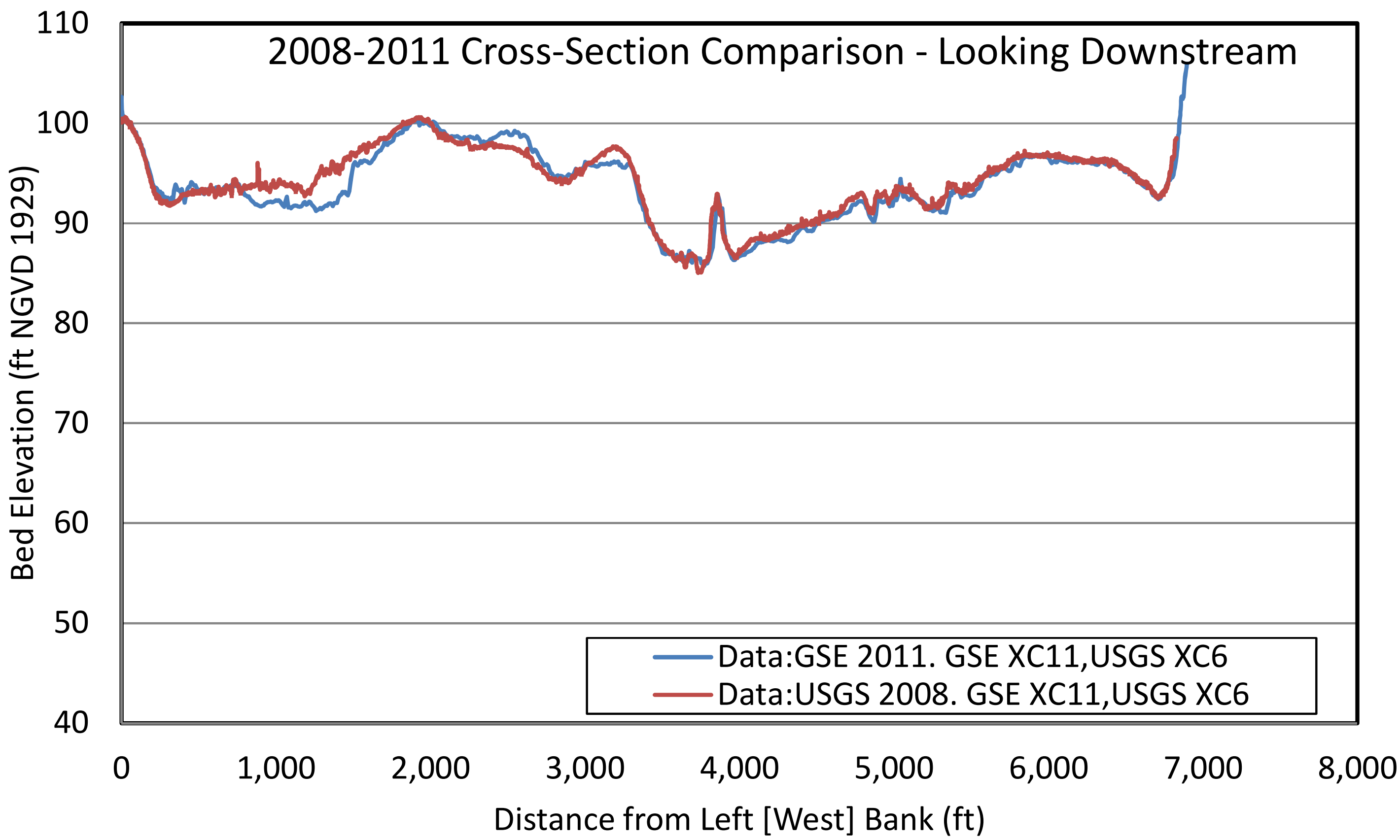


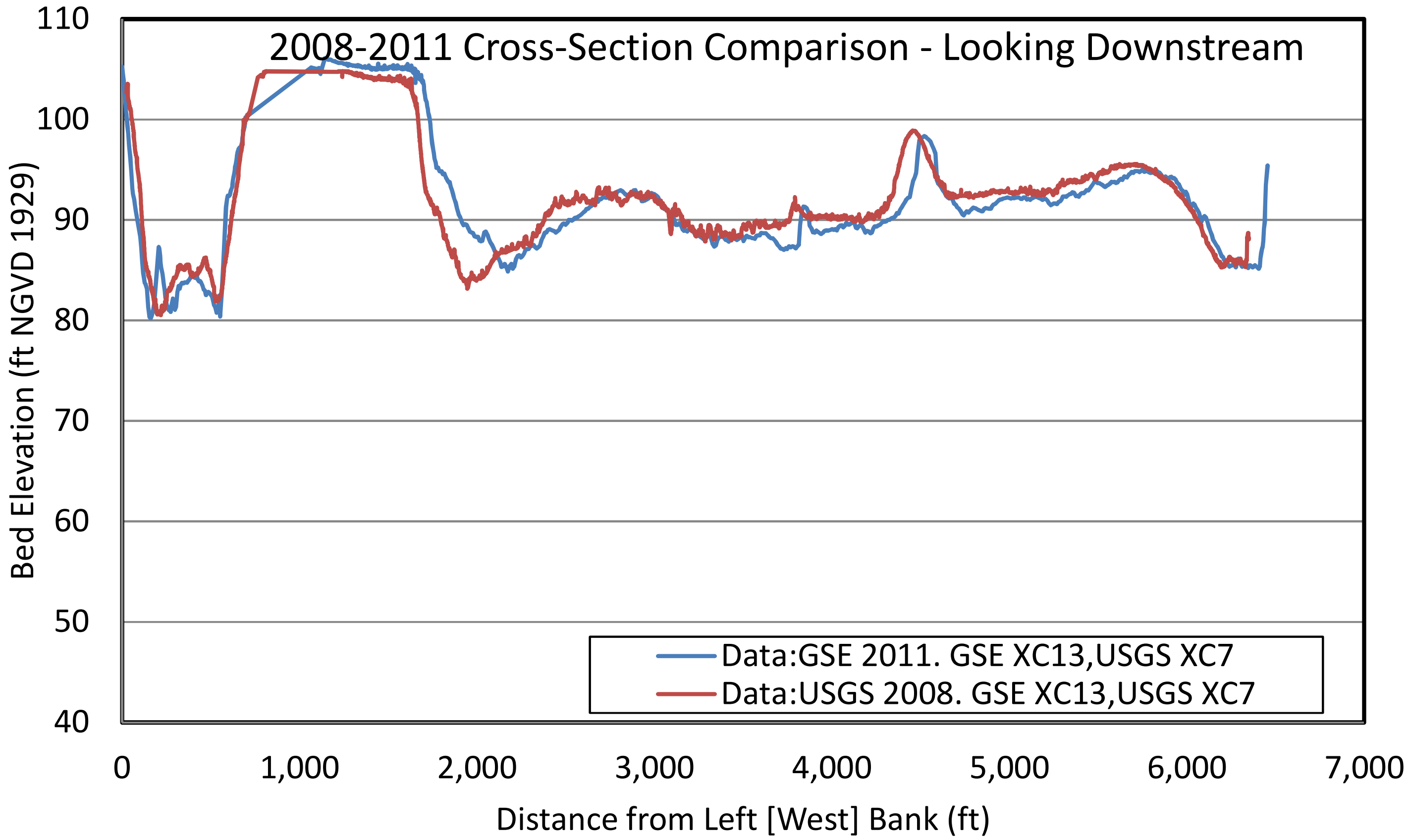
2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC5,USGS XC3
Data:USGS 2008. GSE XC5,USGS XC3

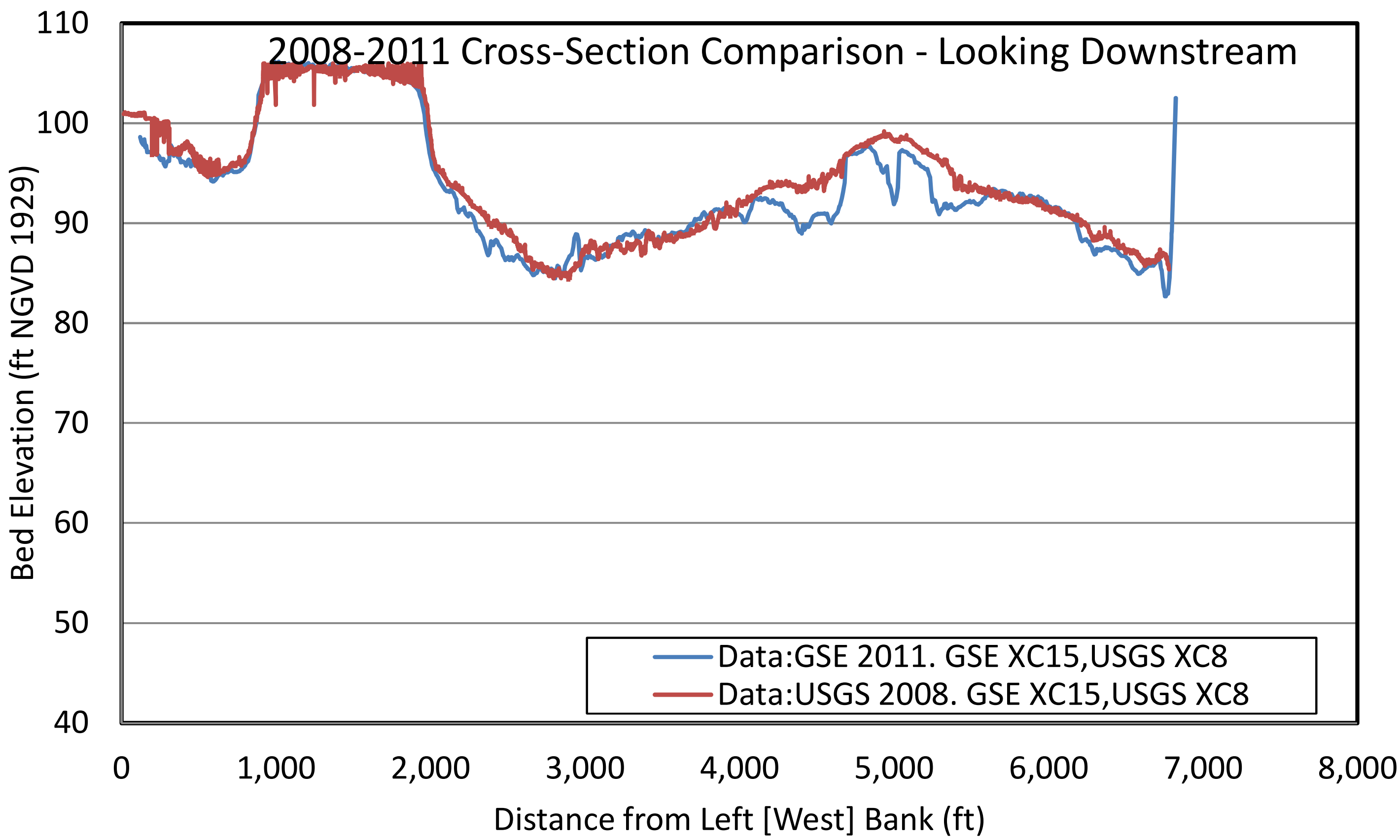


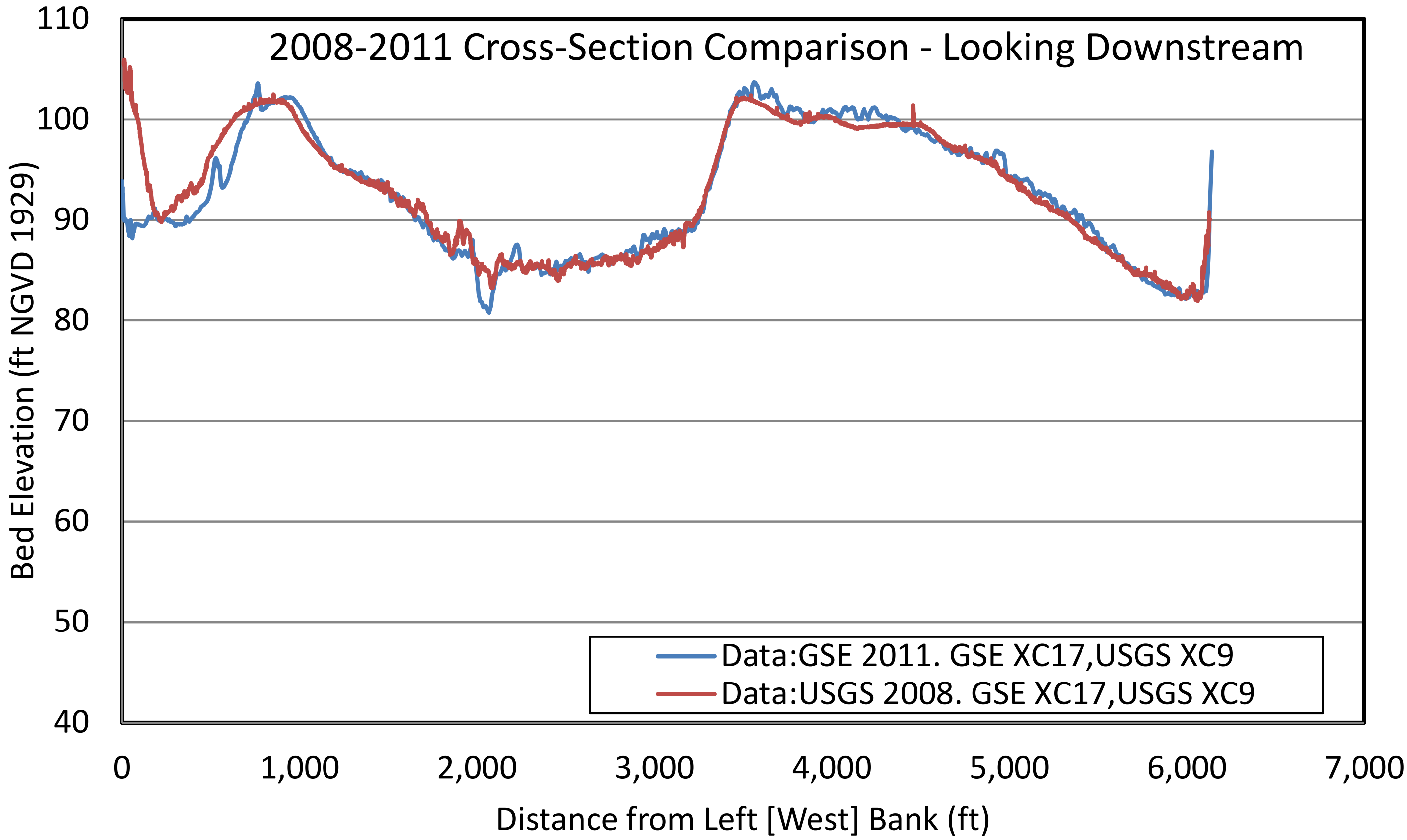
2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC7,USGS XC4
Data:USGS 2008. GSE XC7,USGS XC4

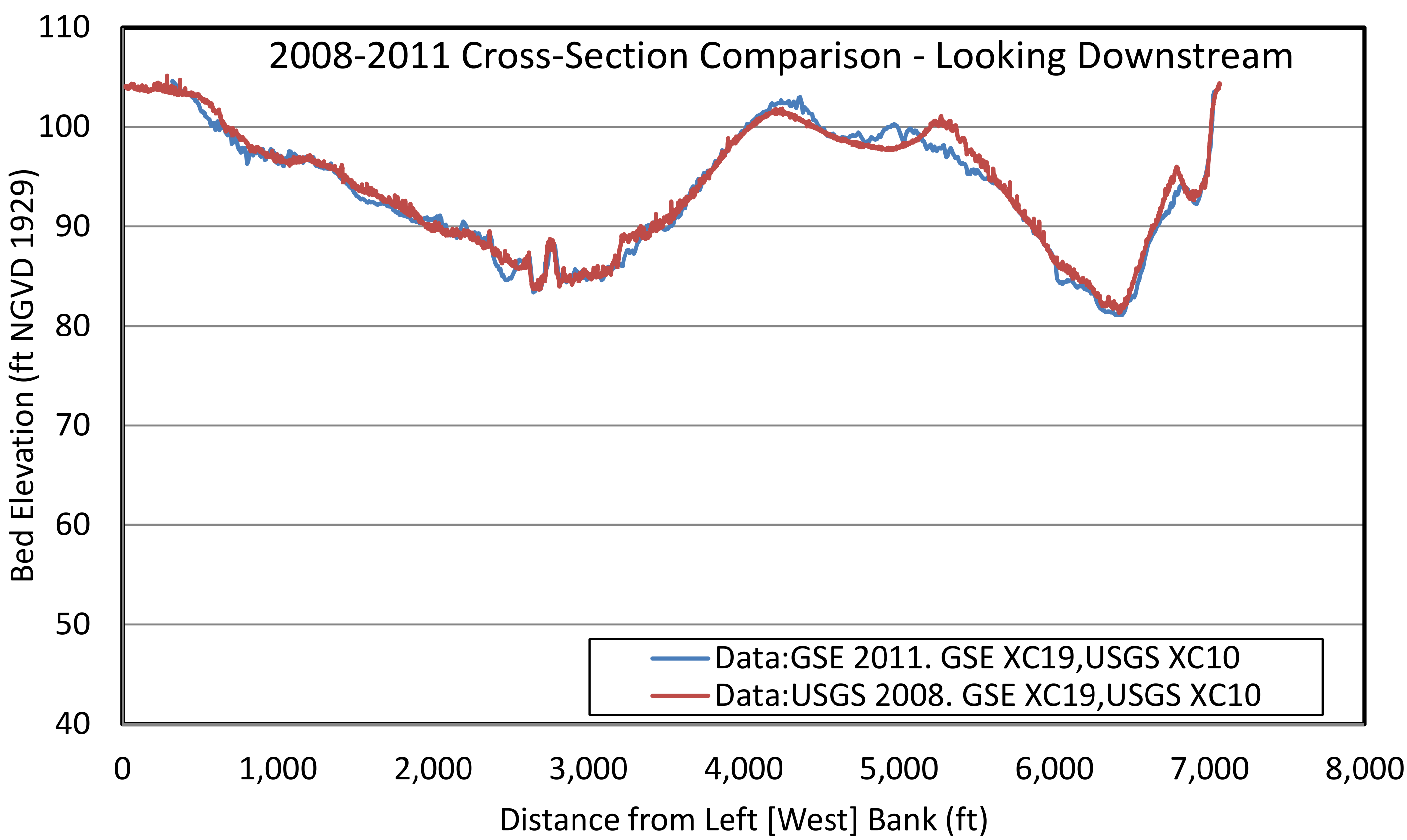

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC9,USGS XC5
Data:USGS 2008. GSE XC9,USGS XC5

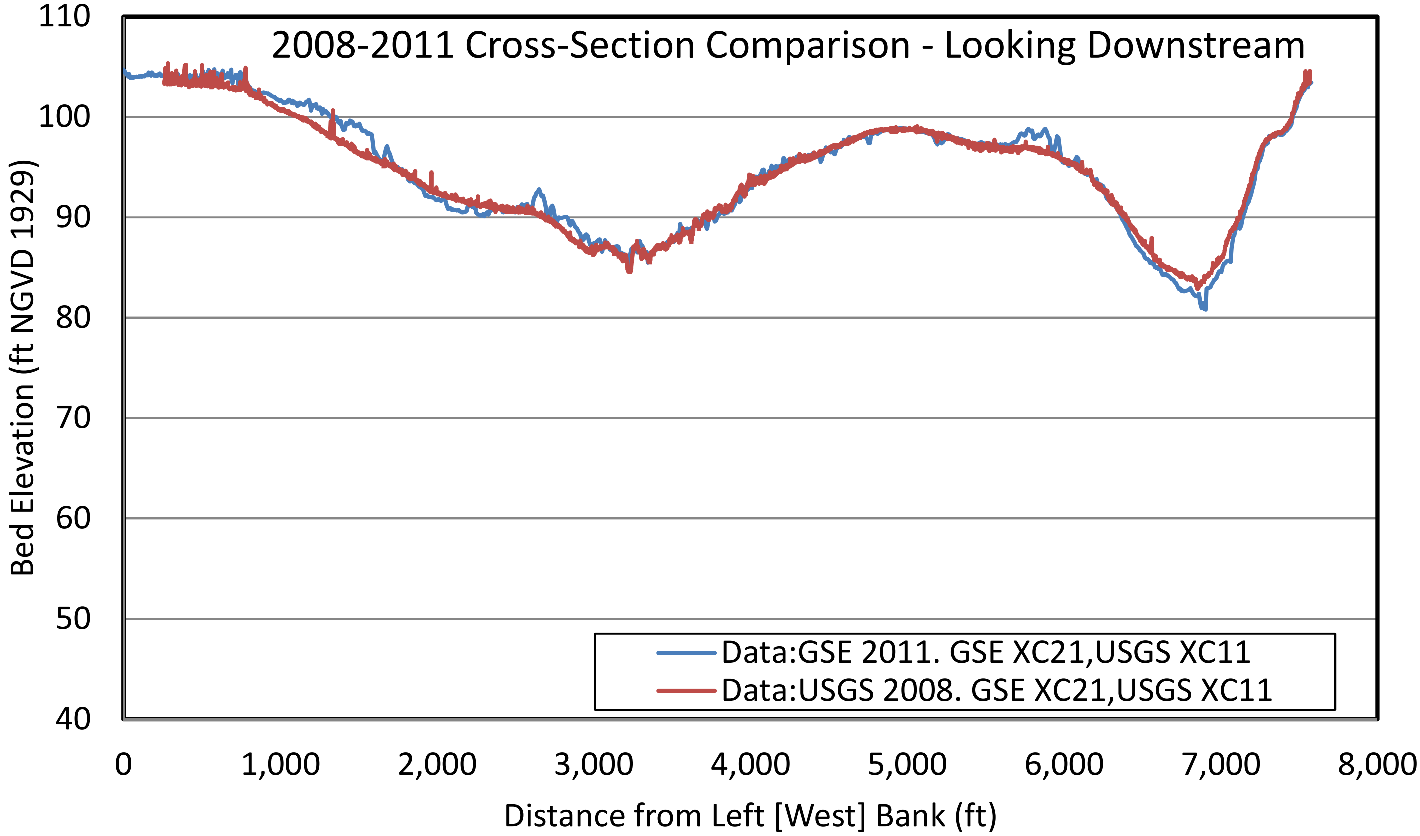

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC11,USGS XC6
Data:USGS 2008. GSE XC11,USGS XC6

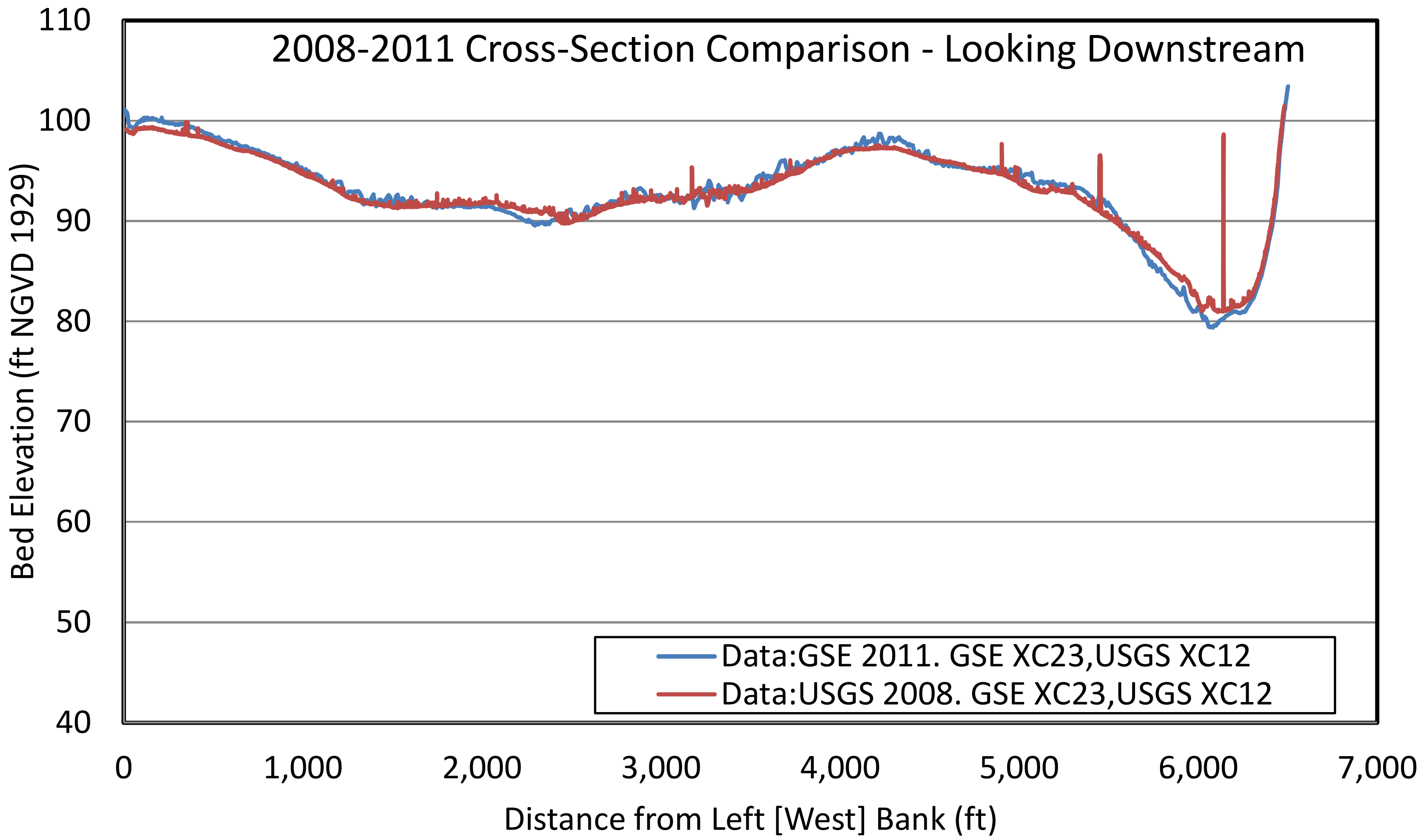

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC13,USGS XC7
Data:USGS 2008. GSE XC13,USGS XC7

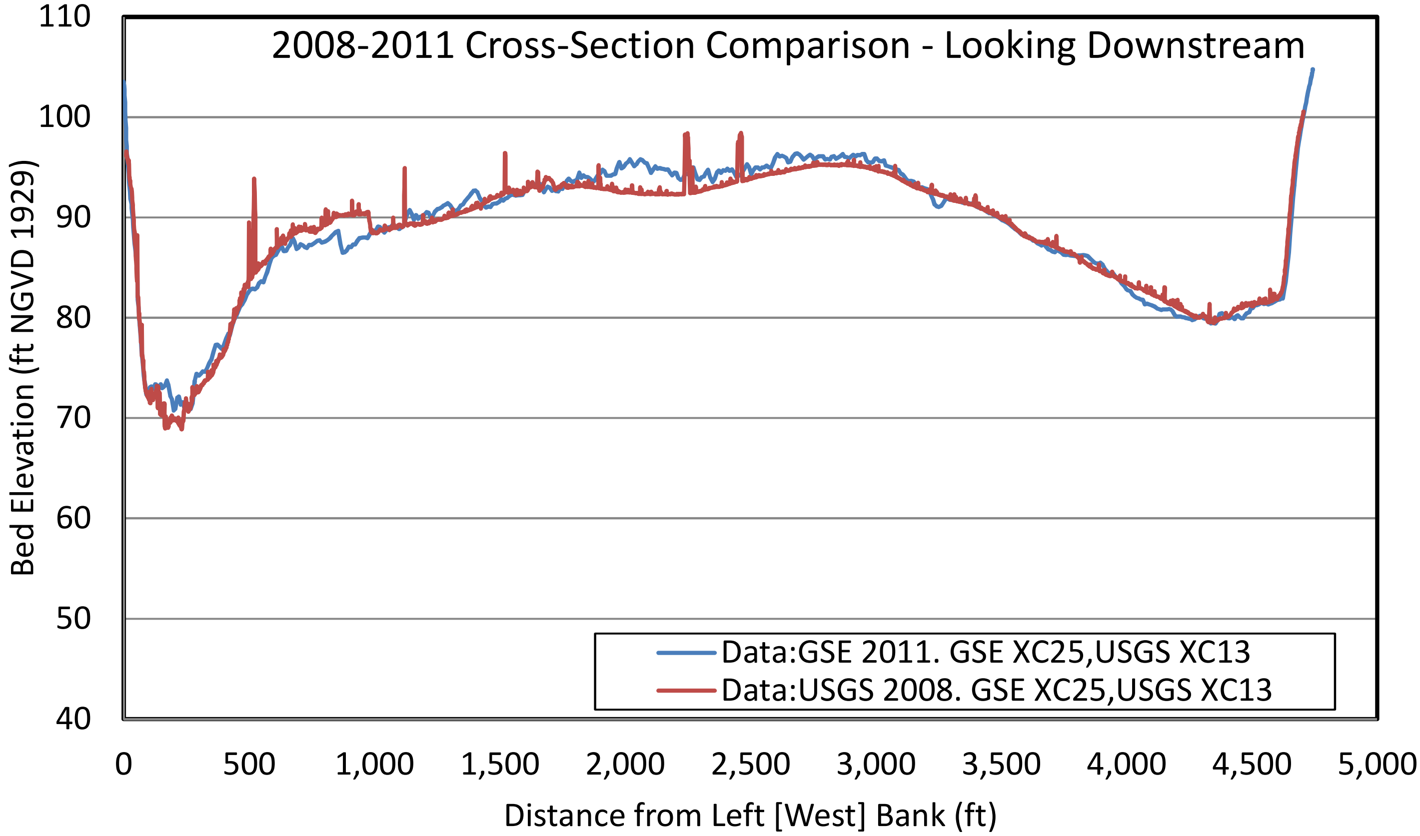

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC15,USGS XC8
Data:USGS 2008. GSE XC15,USGS XC8


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC17,USGS XC9
Data:USGS 2008. GSE XC17,USGS XC9

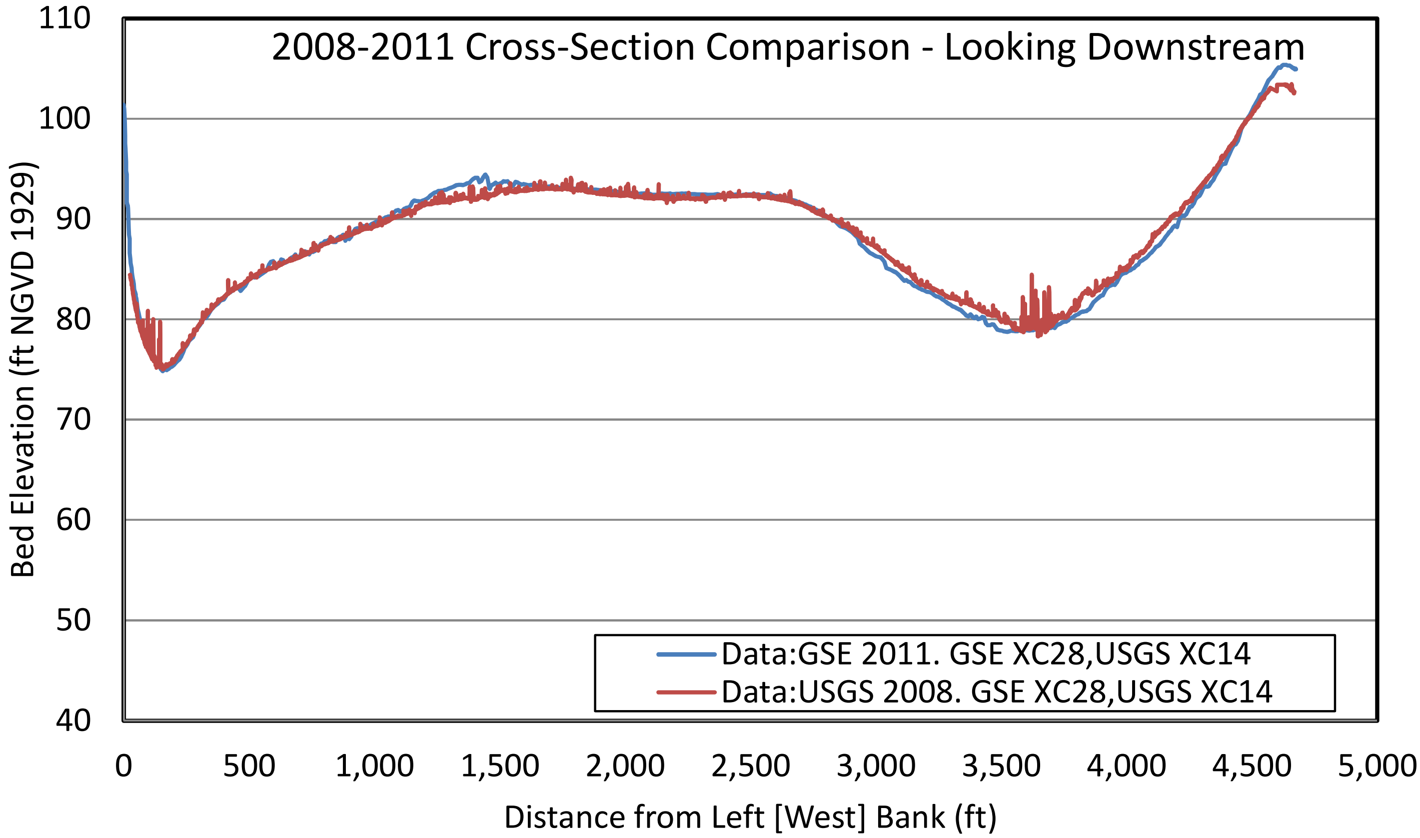

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC19,USGS XC10
Data:USGS 2008. GSE XC19,USGS XC10


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC21,USGS XC11
Data:USGS 2008. GSE XC21,USGS XC11
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)

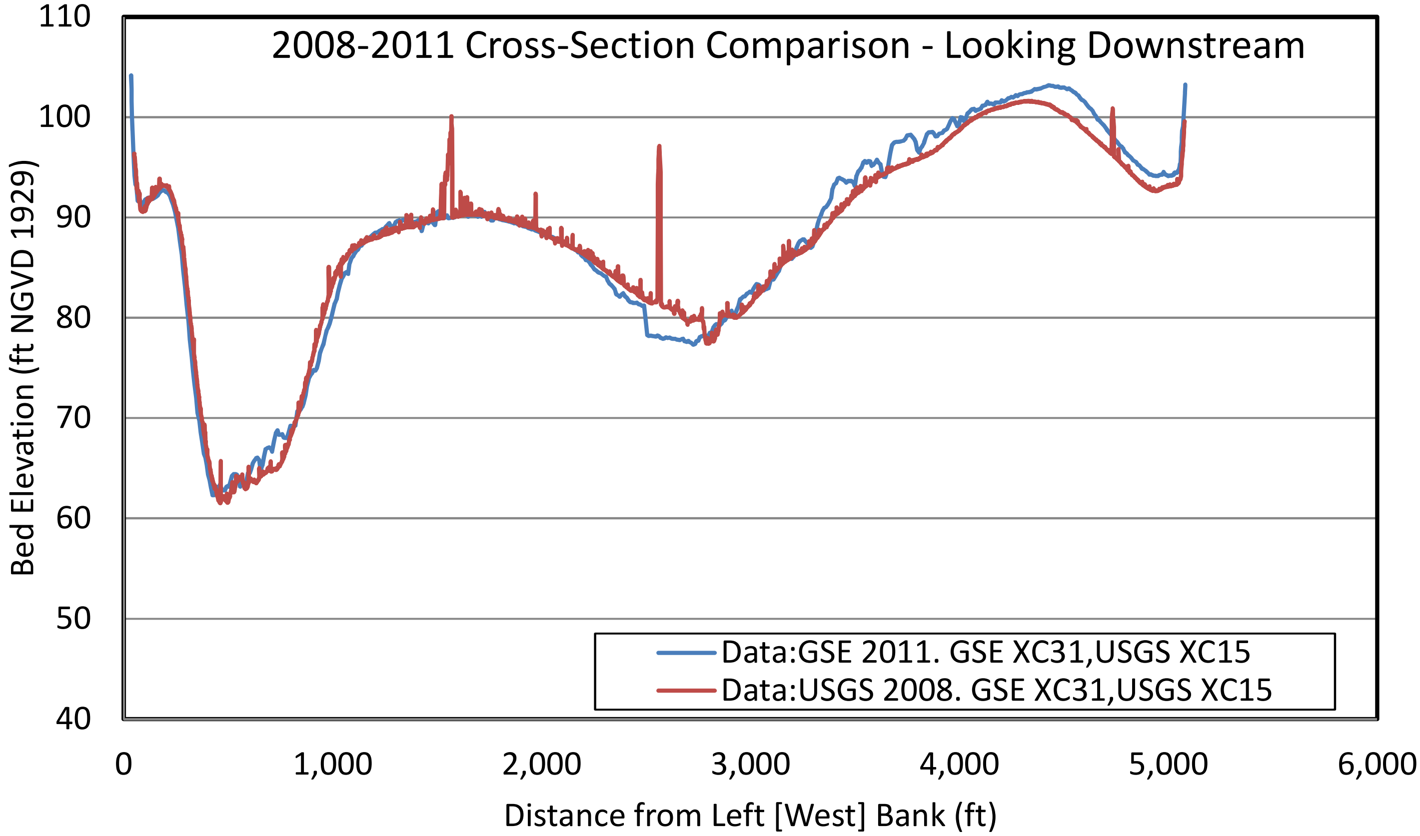

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC23,USGS XC12
Data:USGS 2008. GSE XC23,USGS XC12
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)

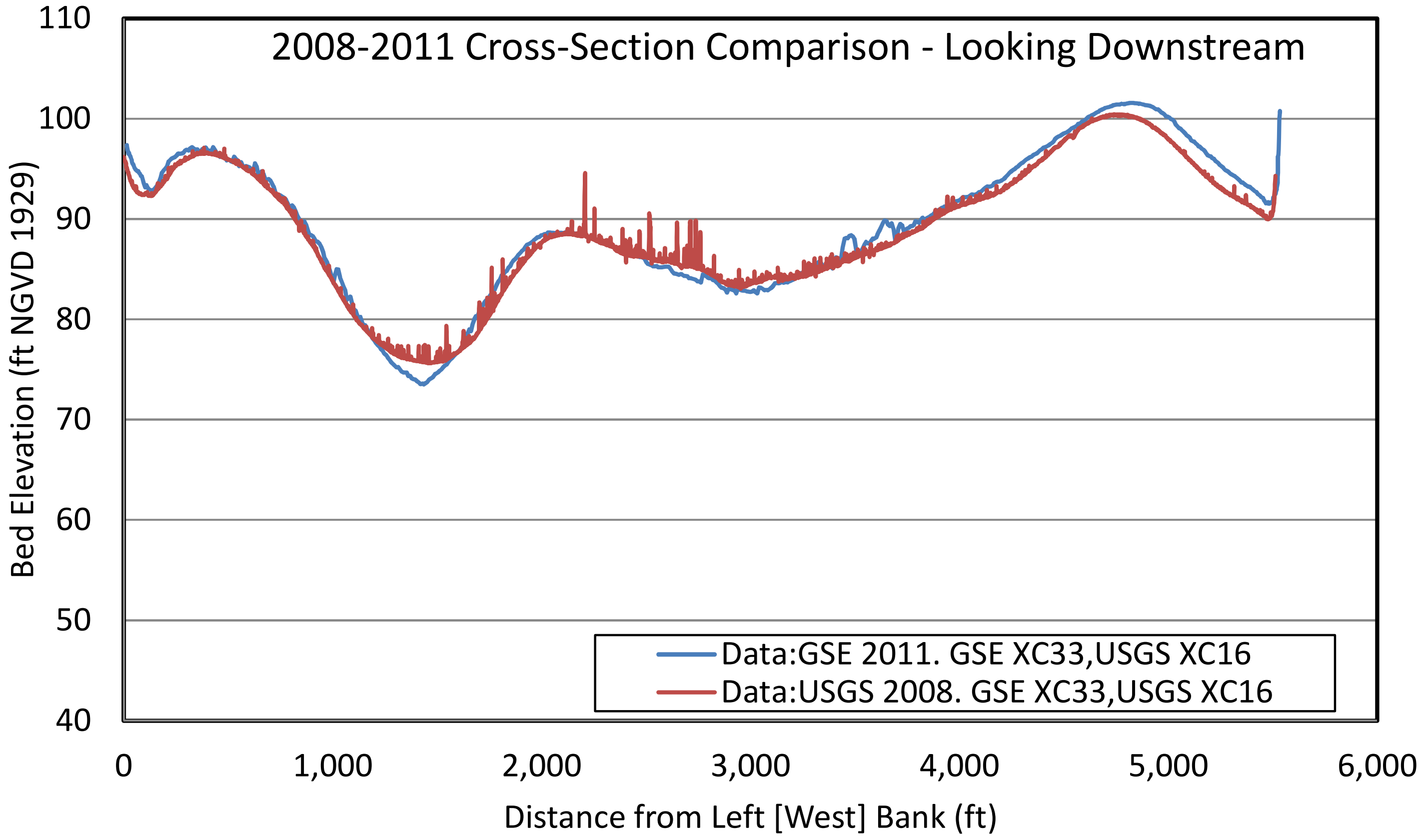


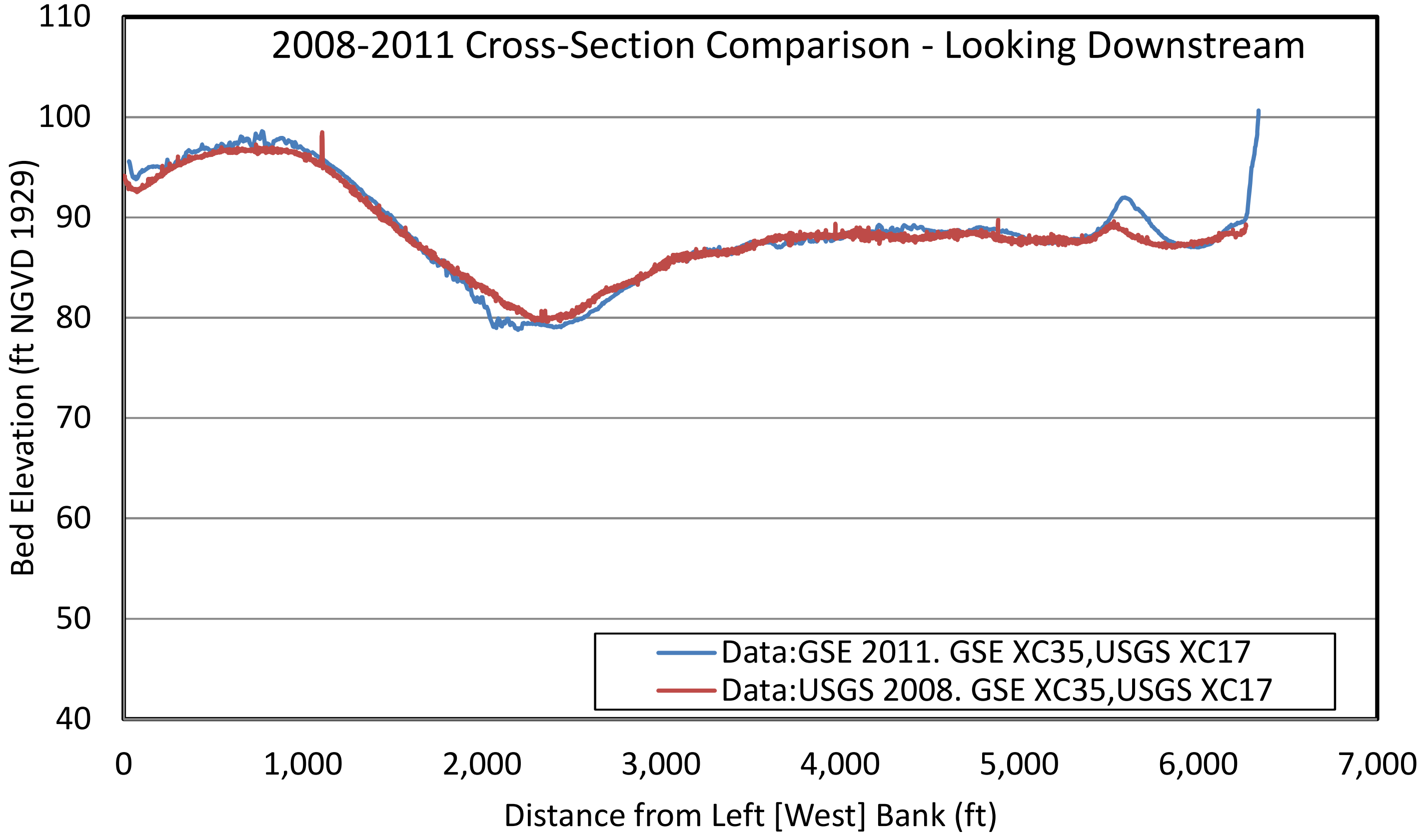
2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC25,USGS XC13
Data:USGS 2008. GSE XC25,USGS XC13

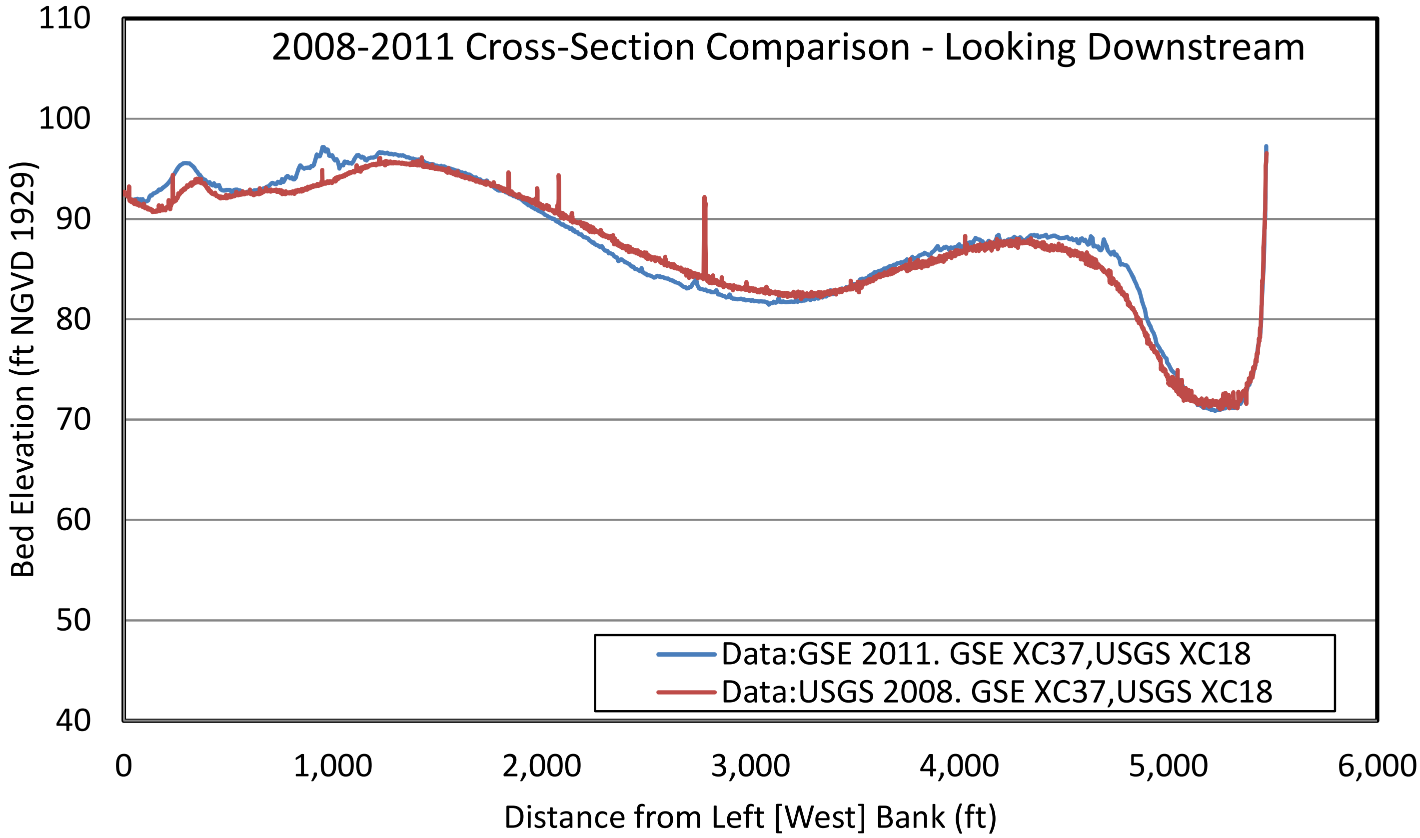


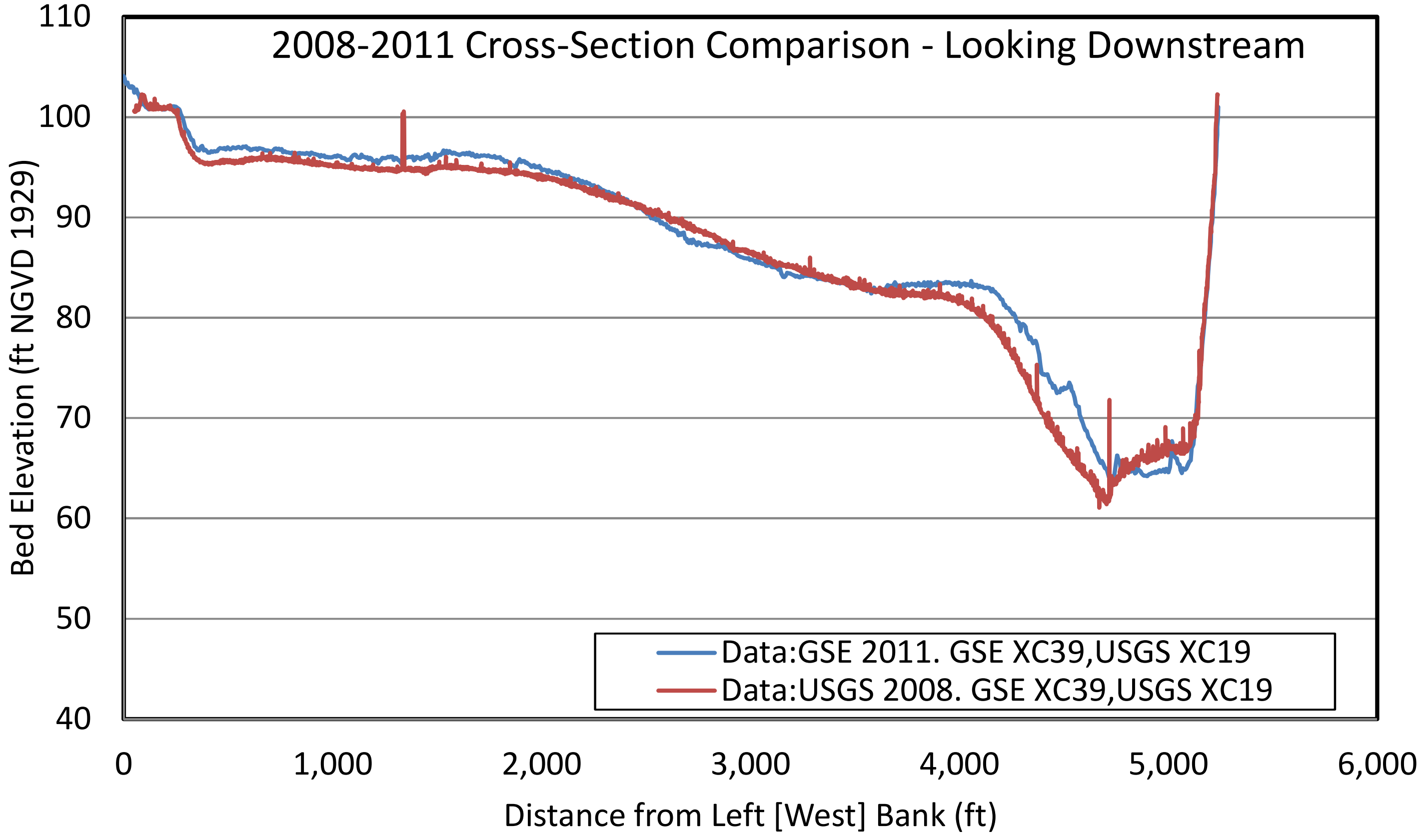
2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC28,USGS XC14
Data:USGS 2008. GSE XC28,USGS XC14


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC31,USGS XC15
Data:USGS 2008. GSE XC31,USGS XC15
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000

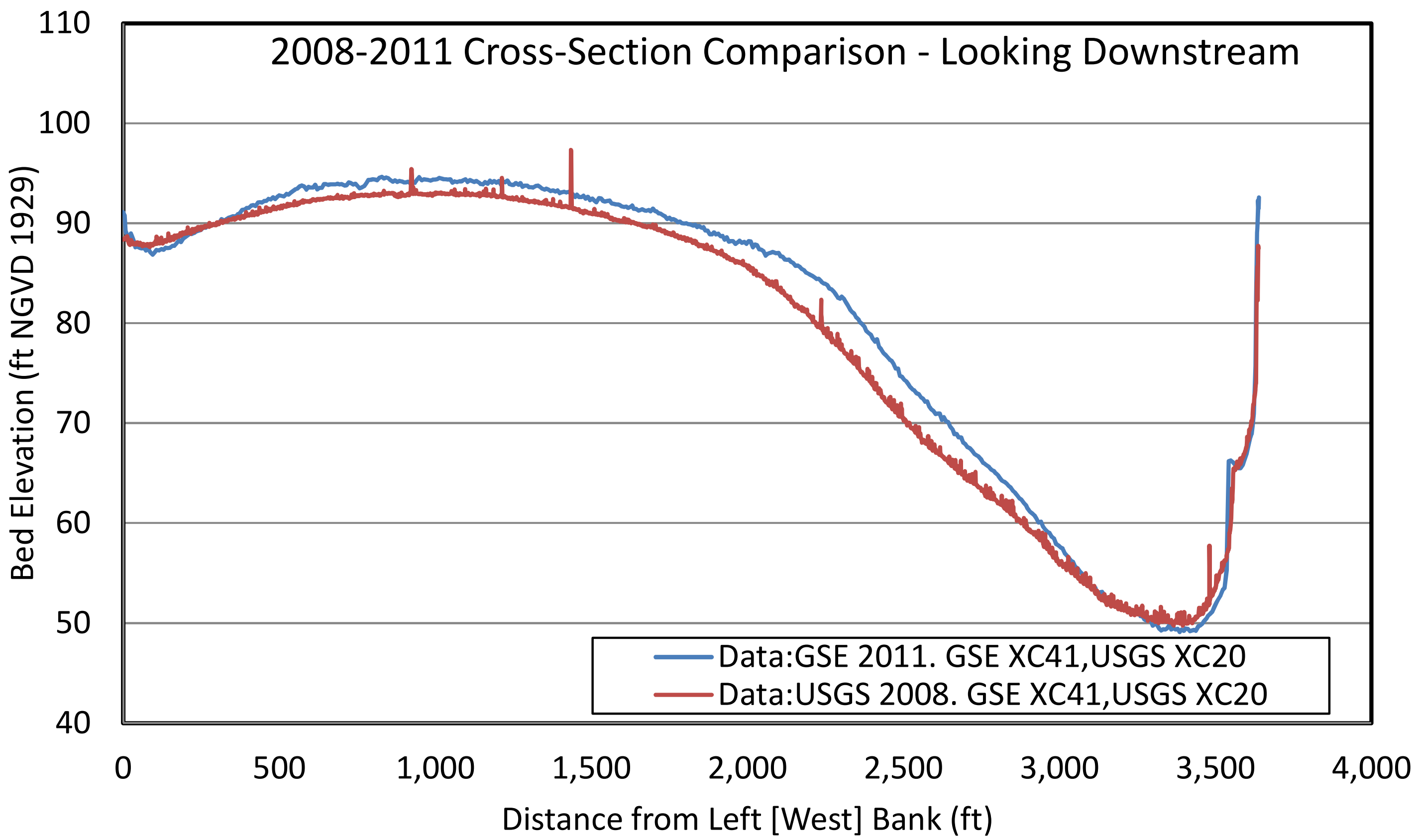

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC33,USGS XC16
Data:USGS 2008. GSE XC33,USGS XC16
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC35,USGS XC17
Data:USGS 2008. GSE XC35,USGS XC17

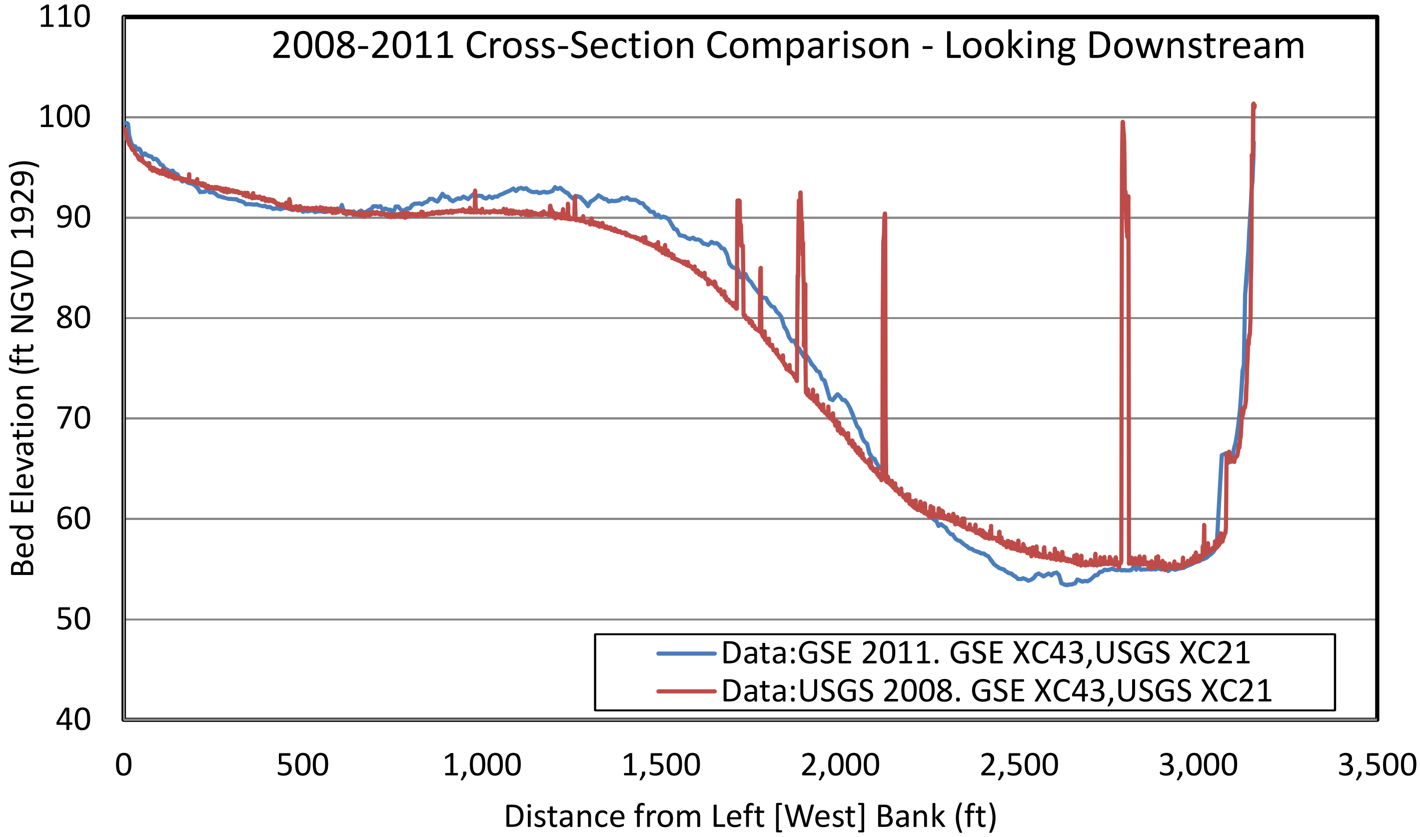

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC37,USGS XC18
Data:USGS 2008. GSE XC37,USGS XC18

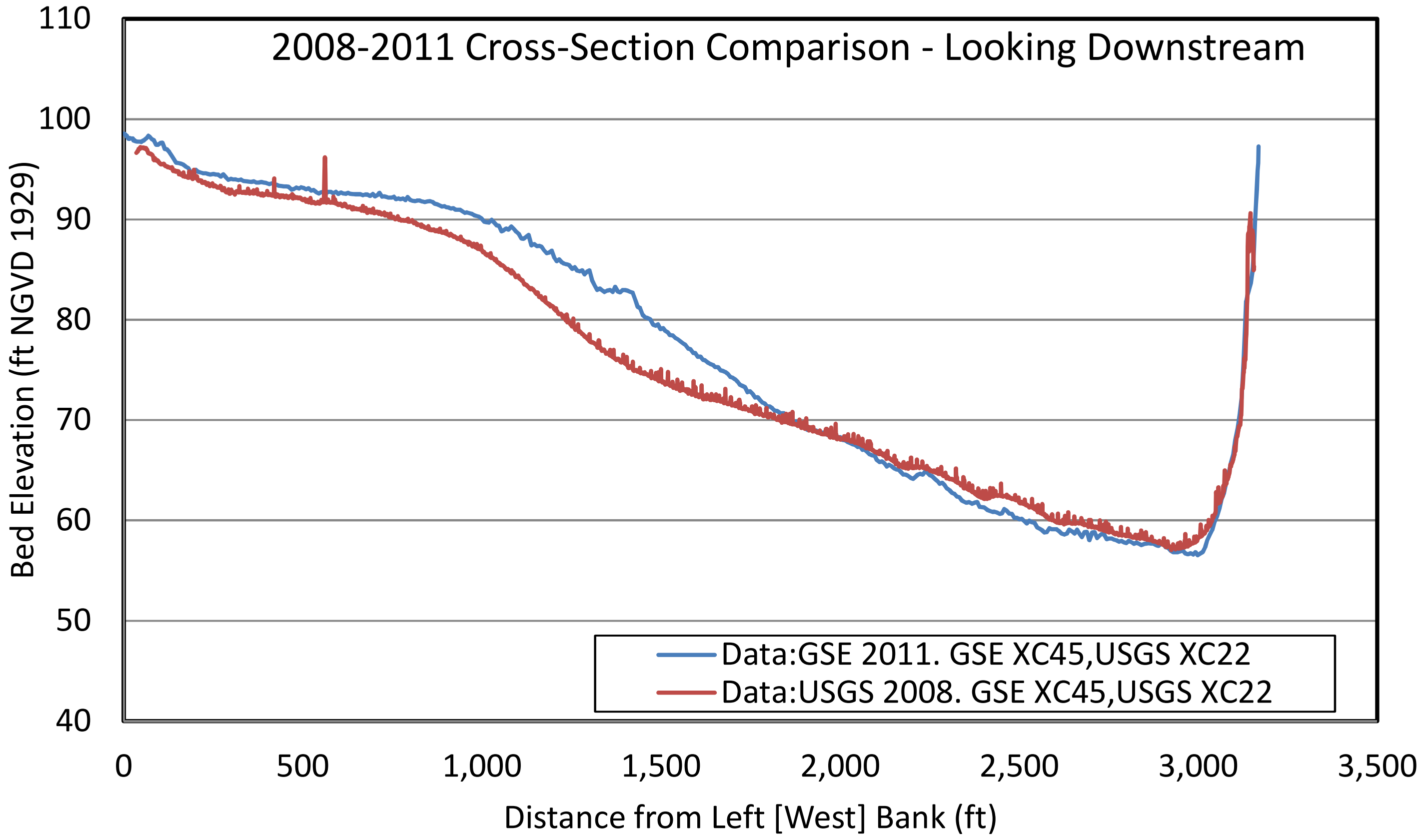


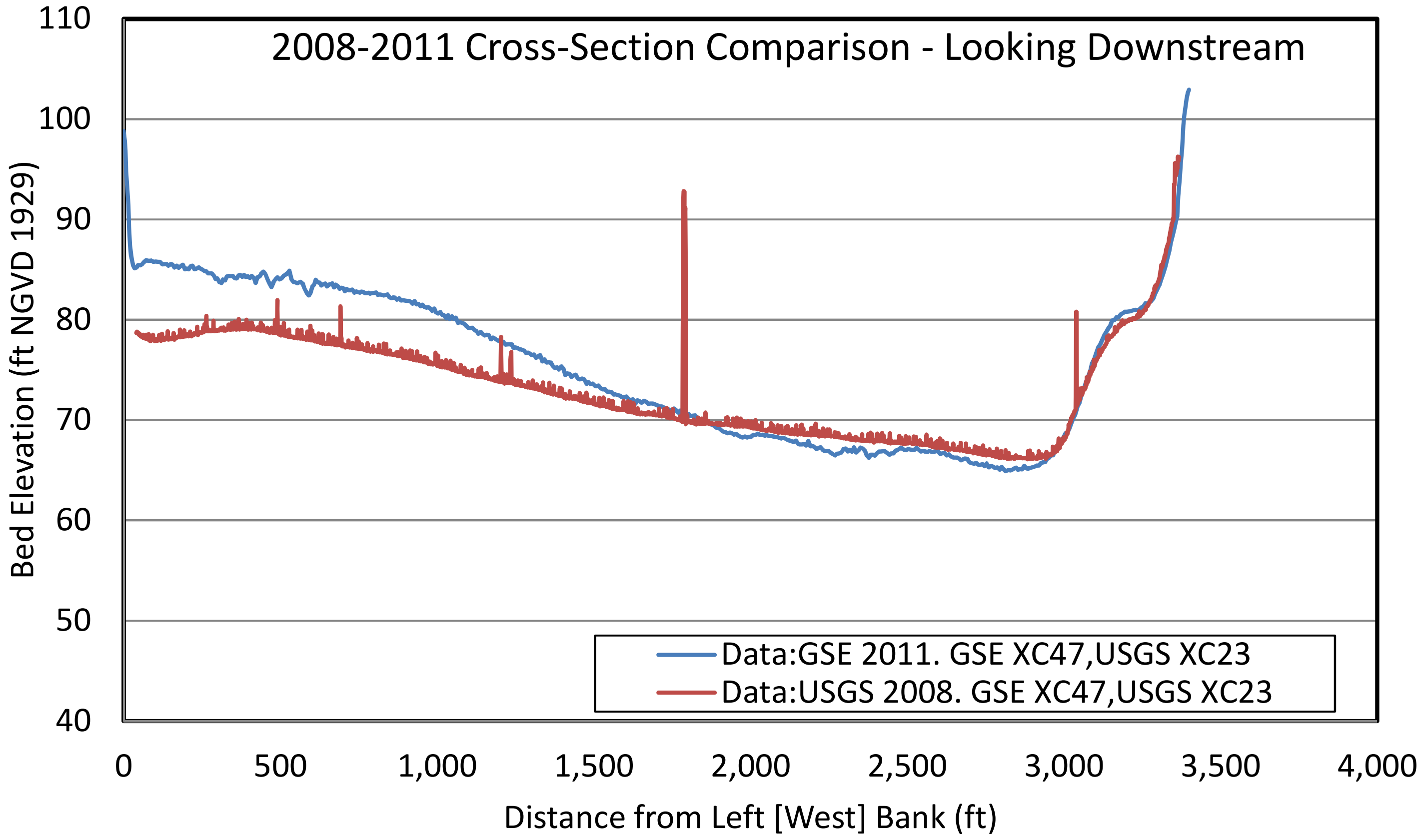
2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC39,USGS XC19
Data:USGS 2008. GSE XC39,USGS XC19

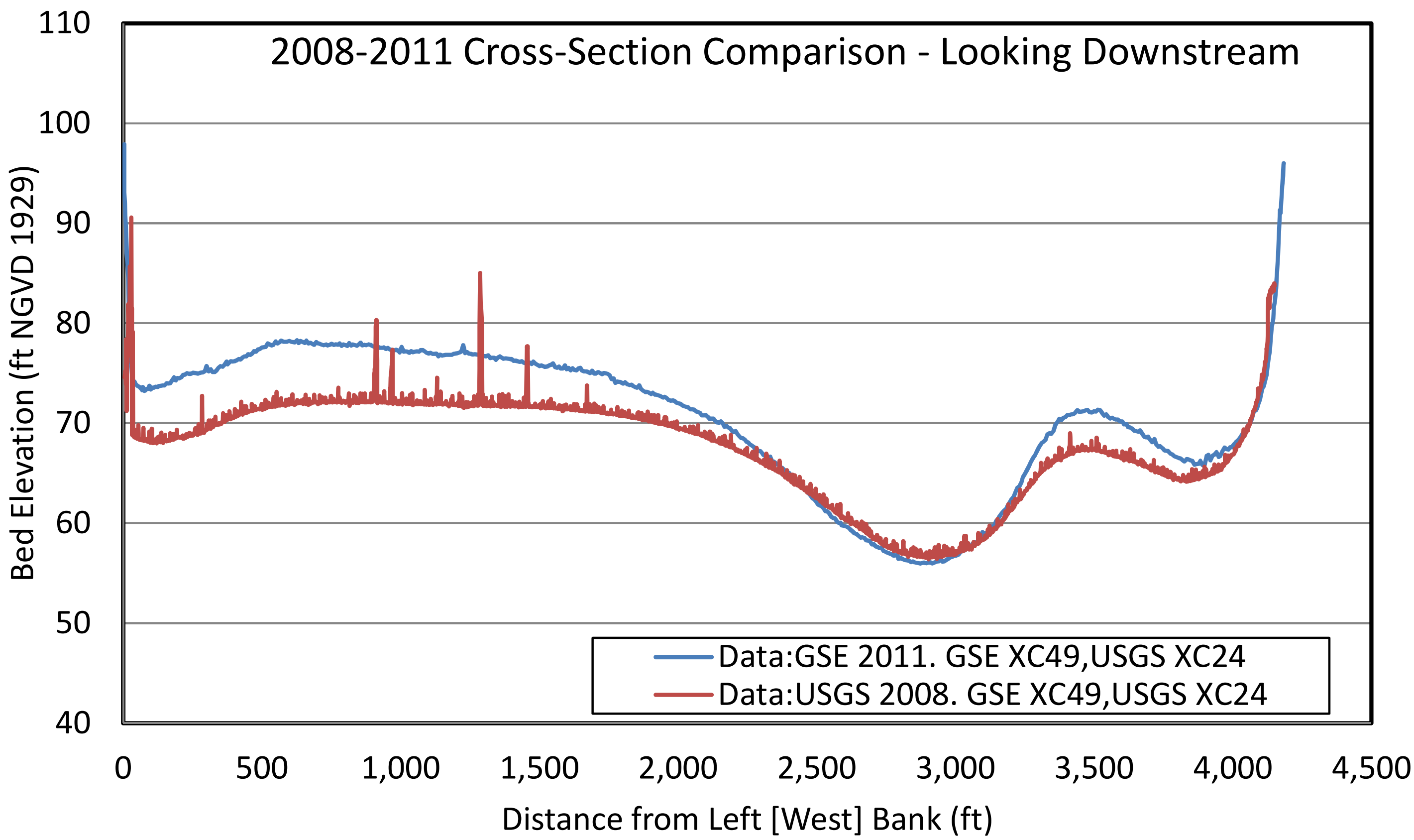


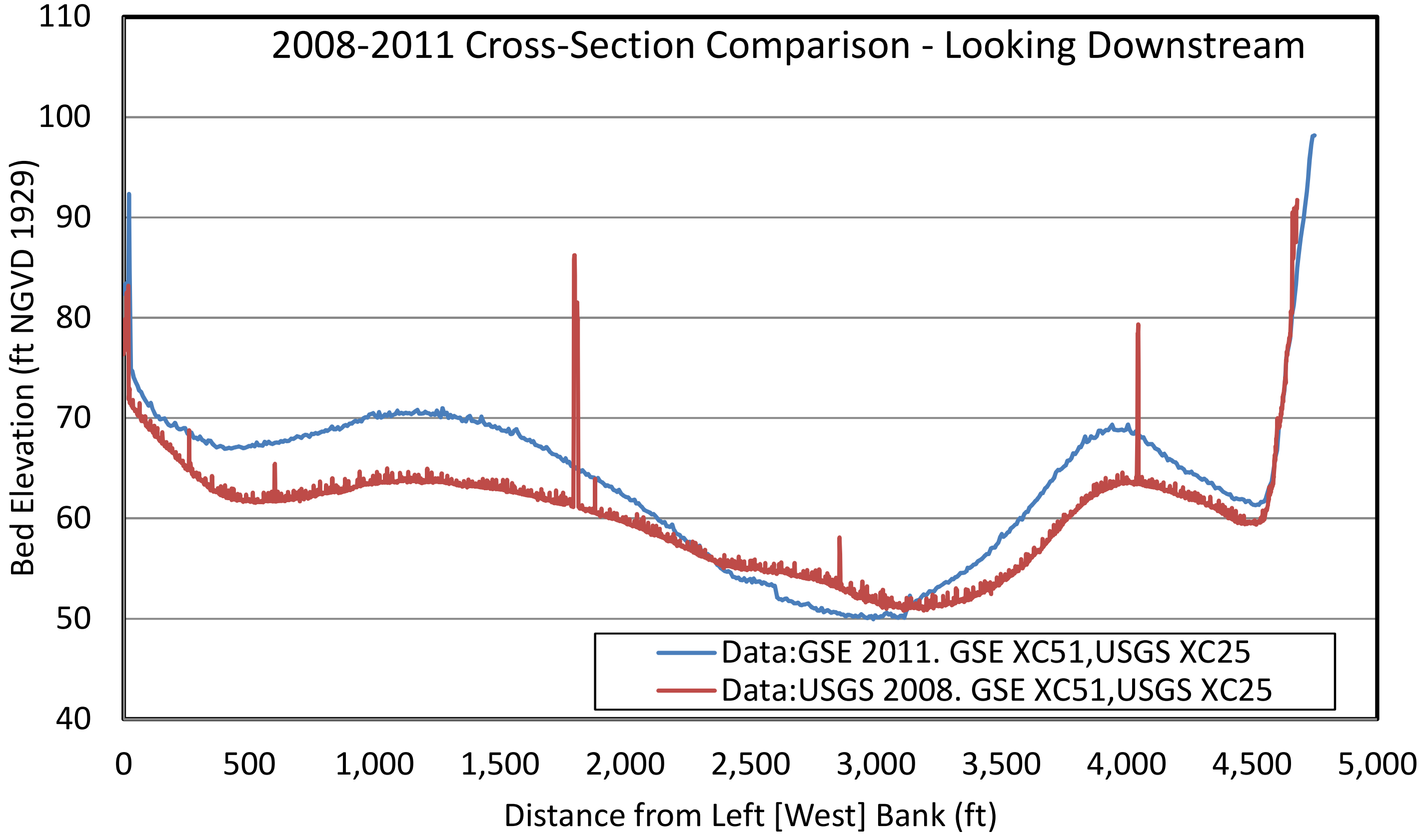
2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC41,USGS XC20
Data:USGS 2008. GSE XC41,USGS XC20


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC43,USGS XC21
Data:USGS 2008. GSE XC43,USGS XC21

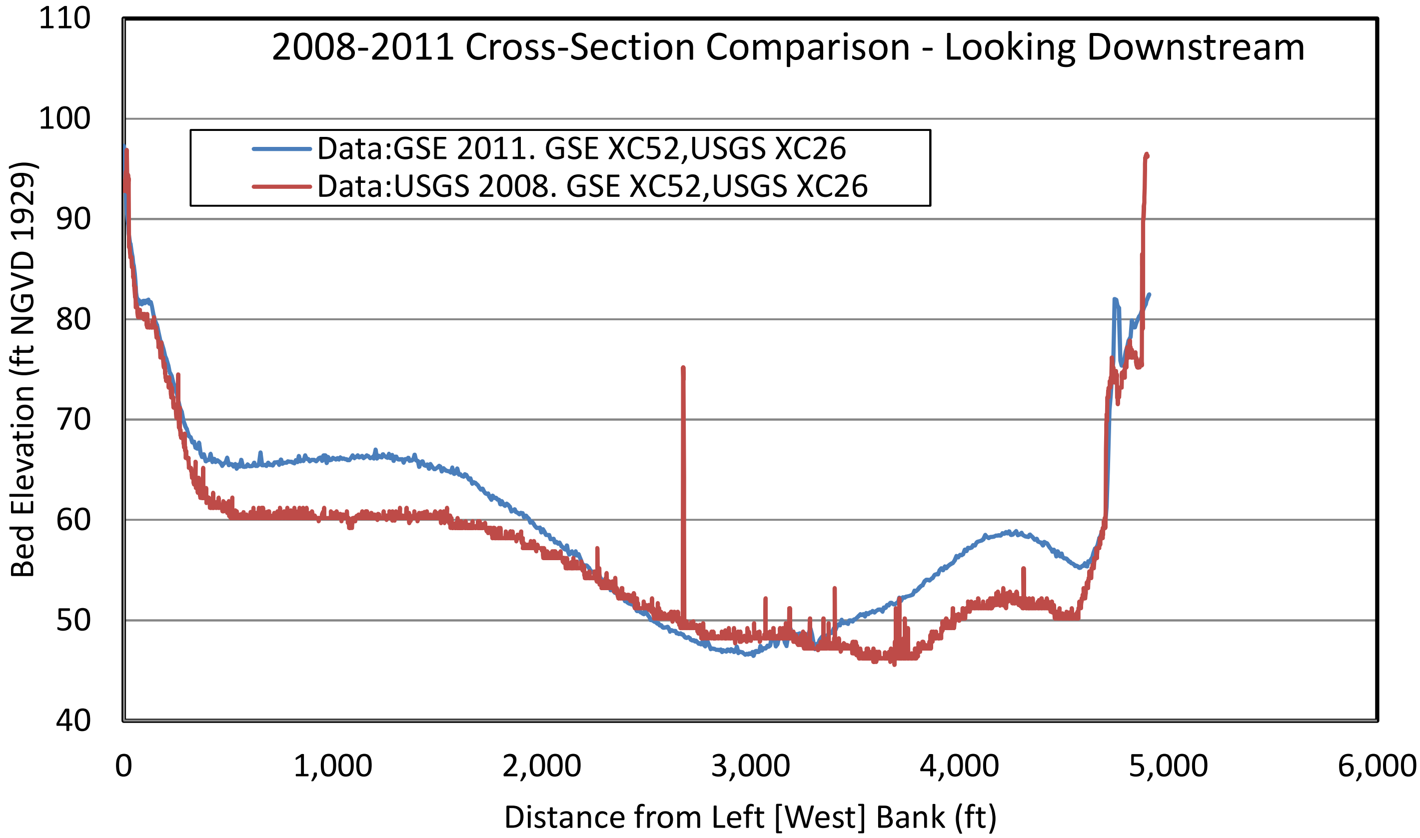

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC45,USGS XC22
Data:USGS 2008. GSE XC45,USGS XC22


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC47,USGS XC23
Data:USGS 2008. GSE XC47,USGS XC23


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC49,USGS XC24
Data:USGS 2008. GSE XC49,USGS XC24

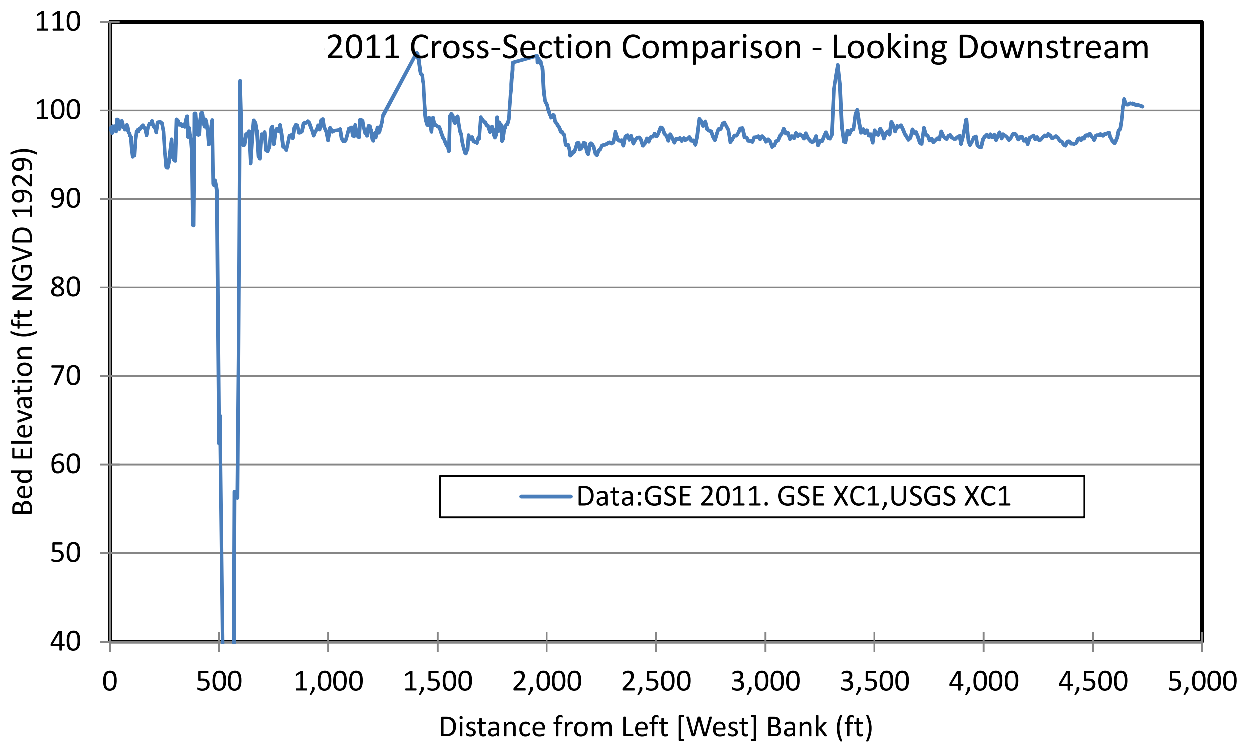


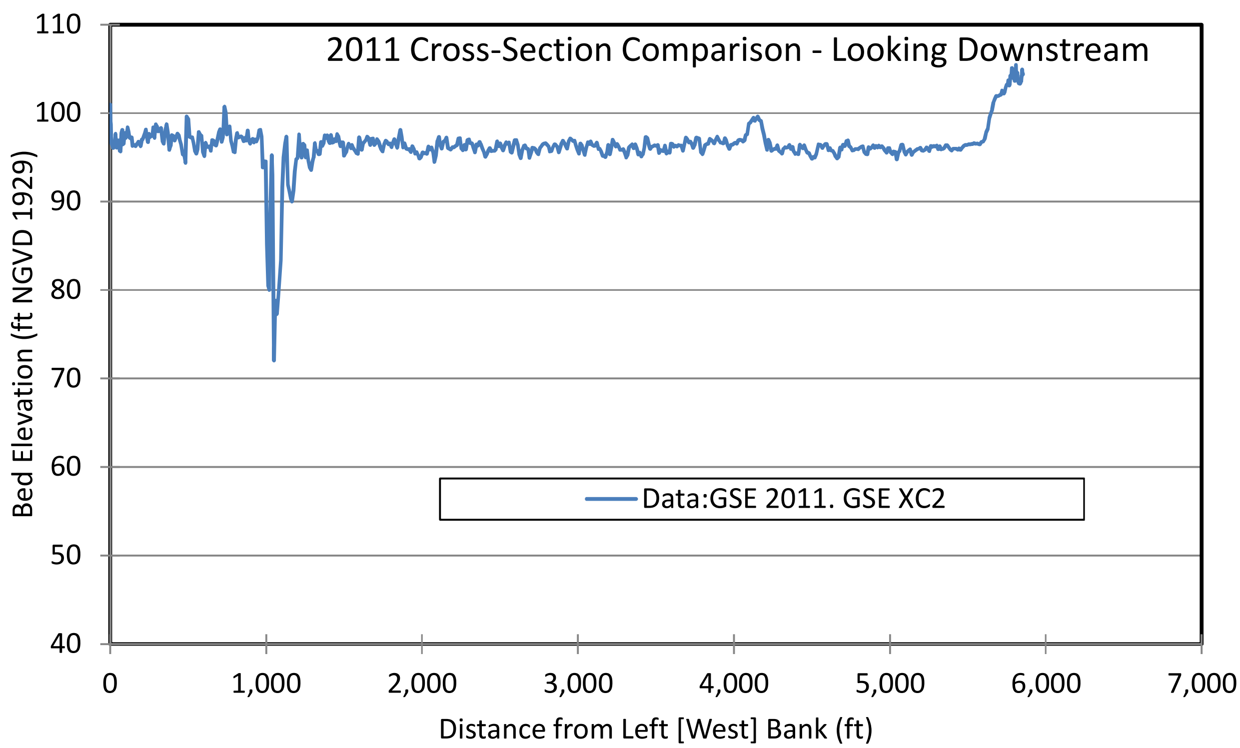
2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC51,USGS XC25
Data:USGS 2008. GSE XC51,USGS XC25
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)



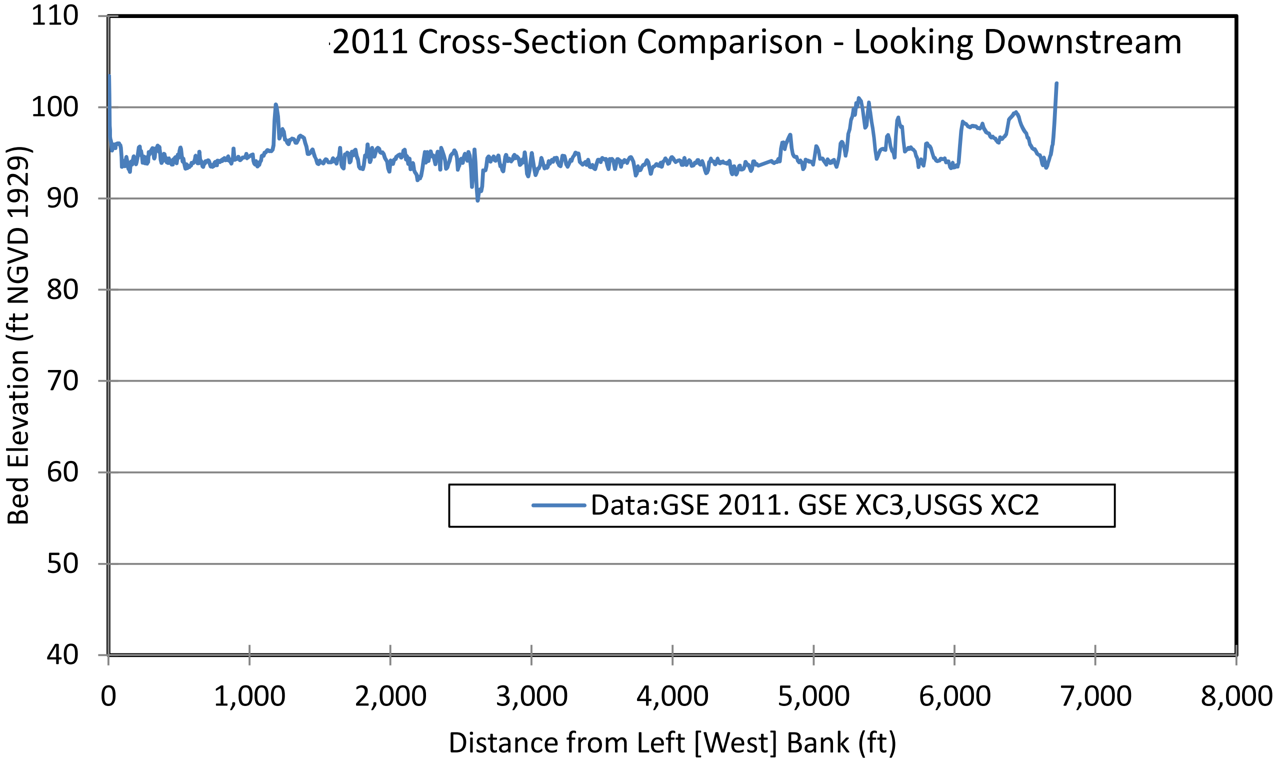
2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC52,USGS XC26
Data:USGS 2008. GSE XC52,USGS XC26
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)

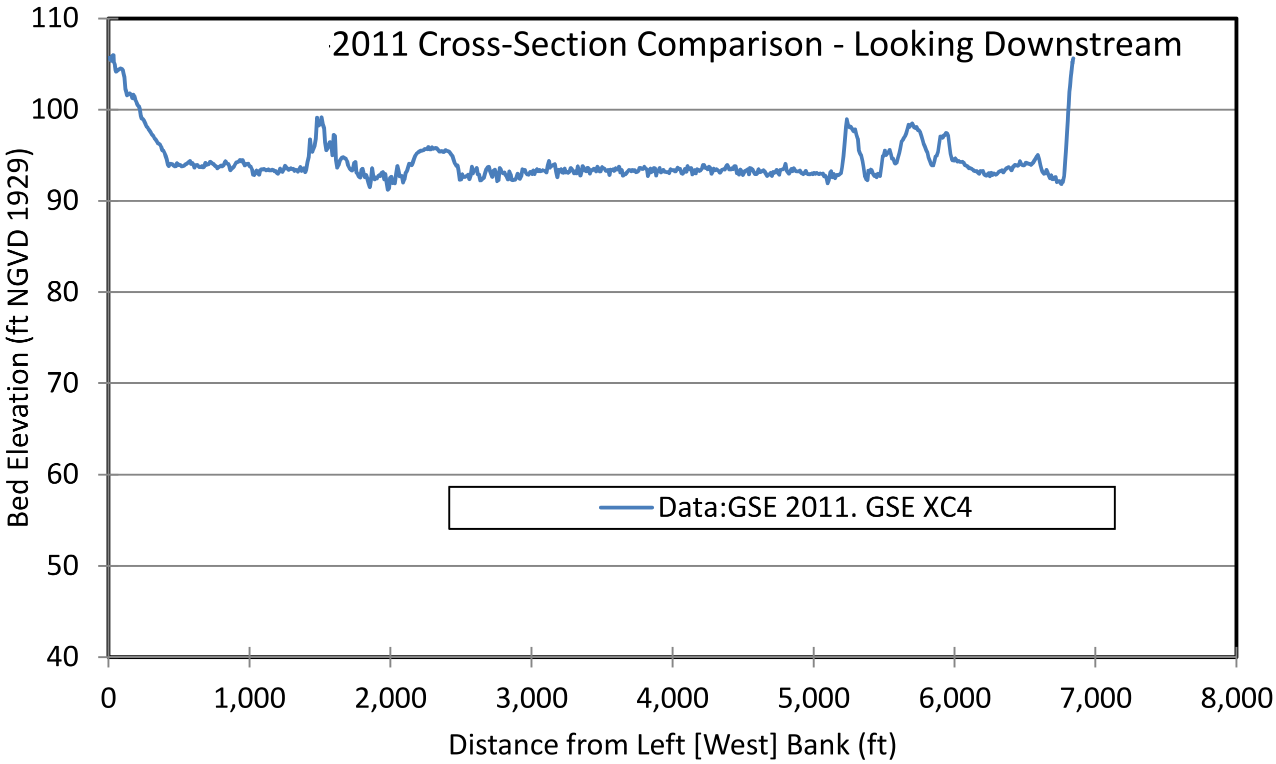
Appendix B: 2011 Cross-Section Plots[8]

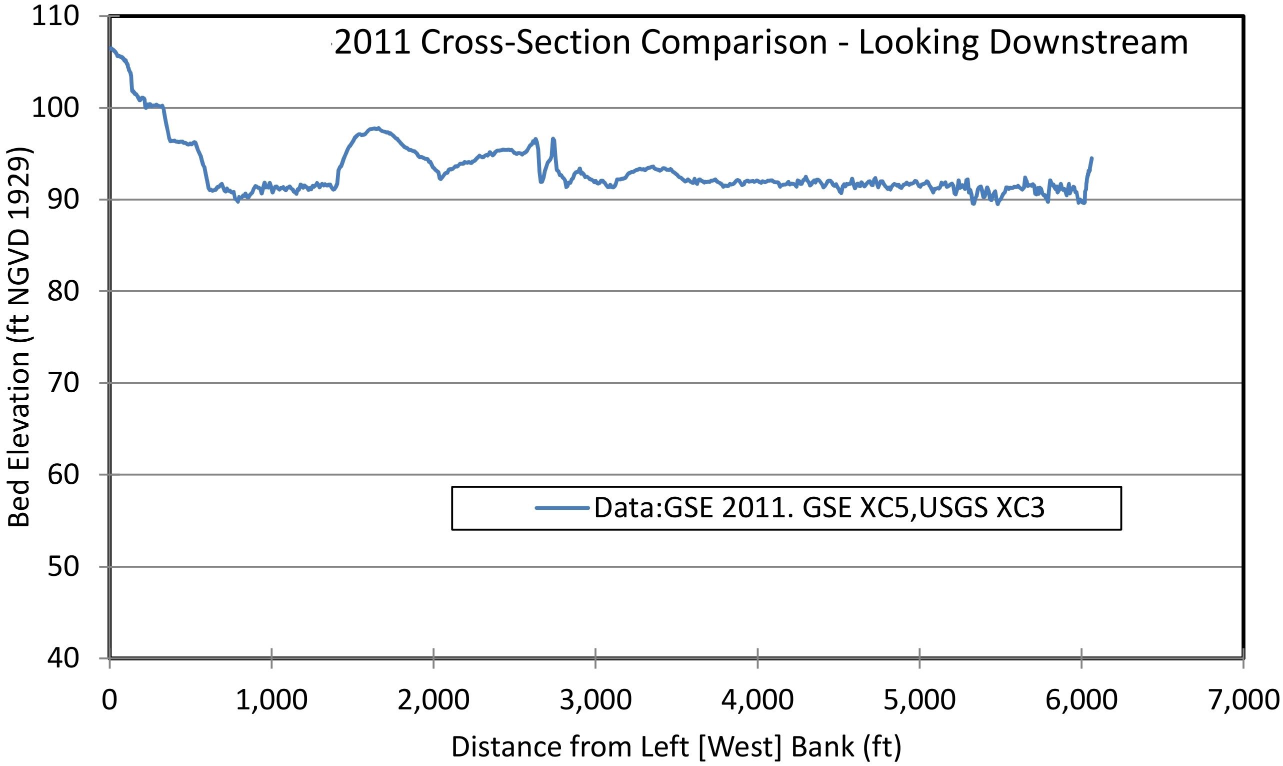


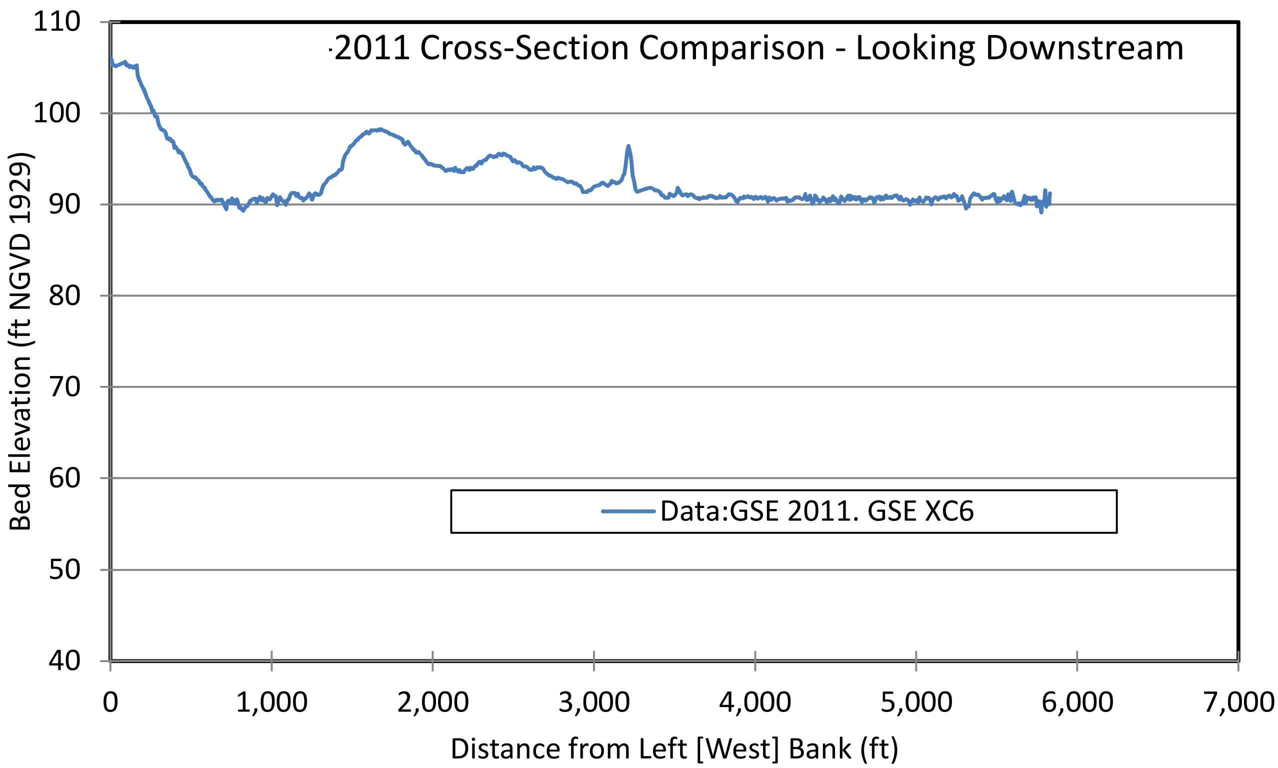


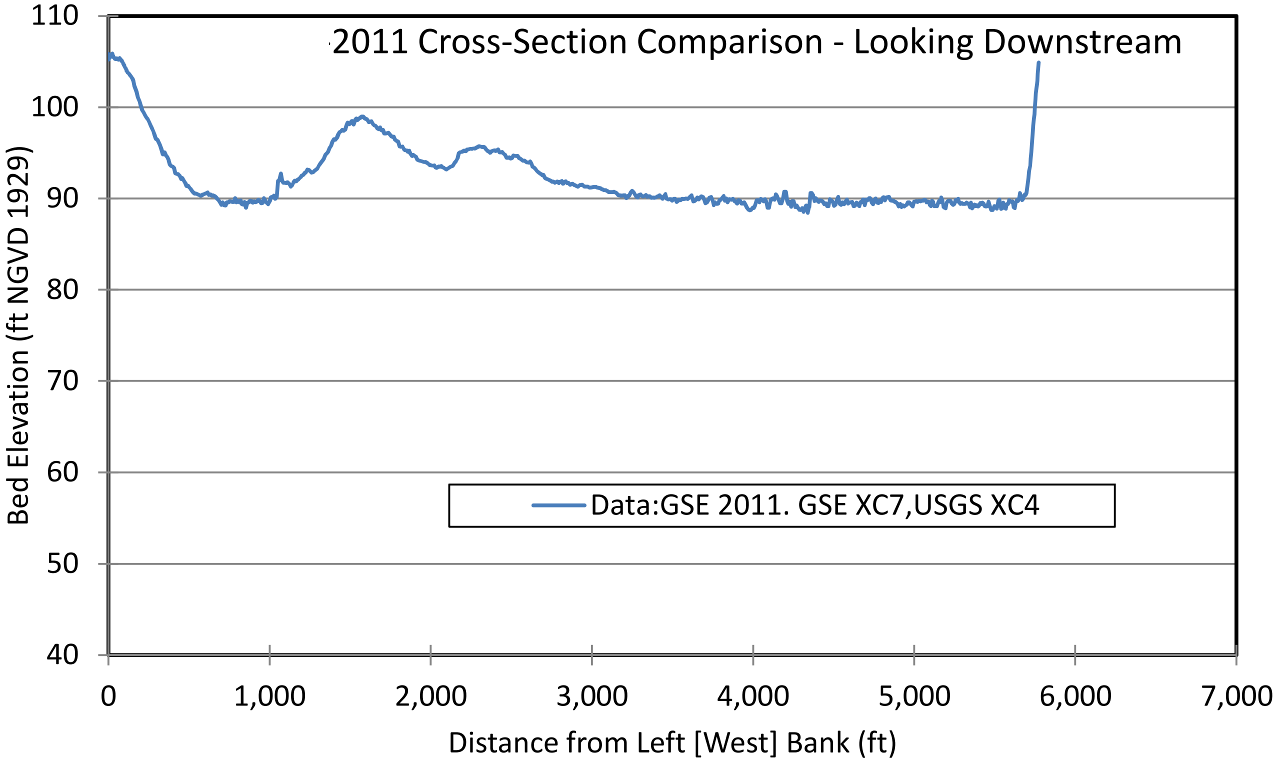
[8] Only 2011 cross-sections are shown in this appendix, but XC numbering for both surveys (2008 and 2011) are shown. Where GSE cross-sections overlapped with USGS cross-sections, both cross-section numbers are included. Appendix A compares overlapping cross-sections.

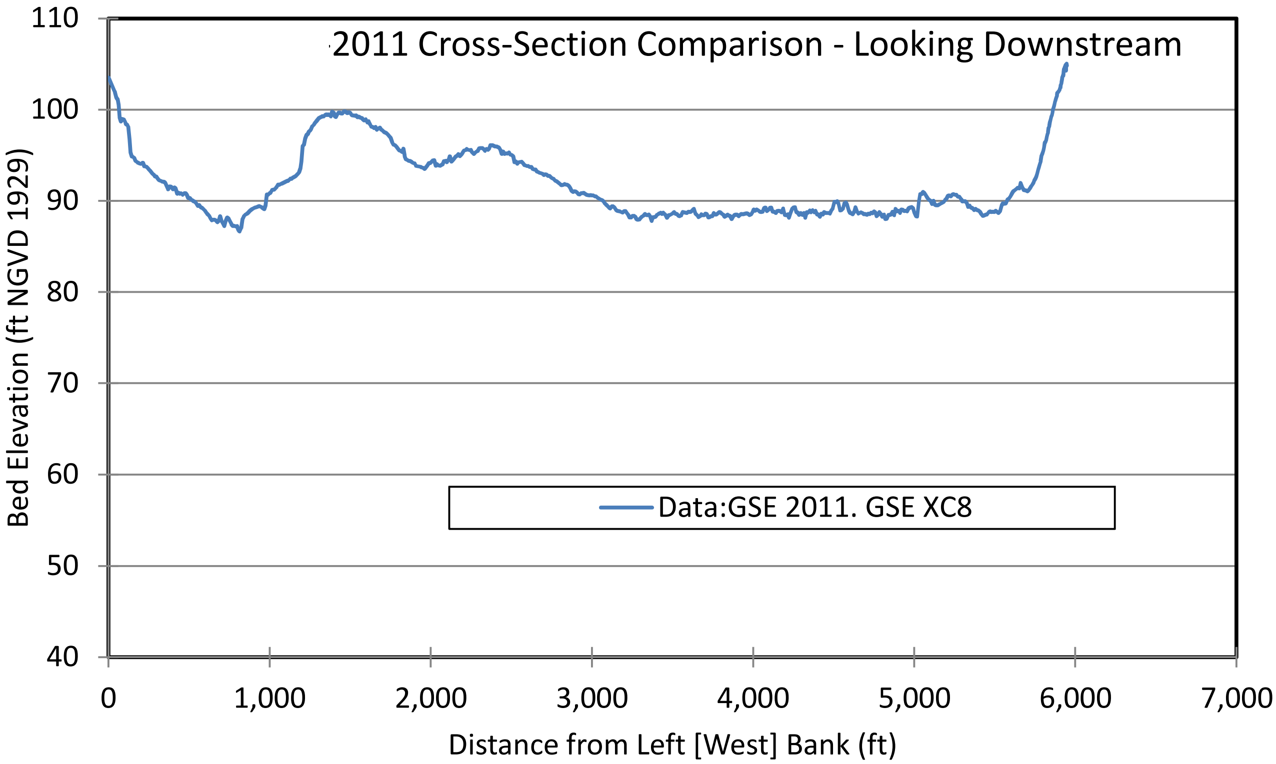

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC3,USGS XC2
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)

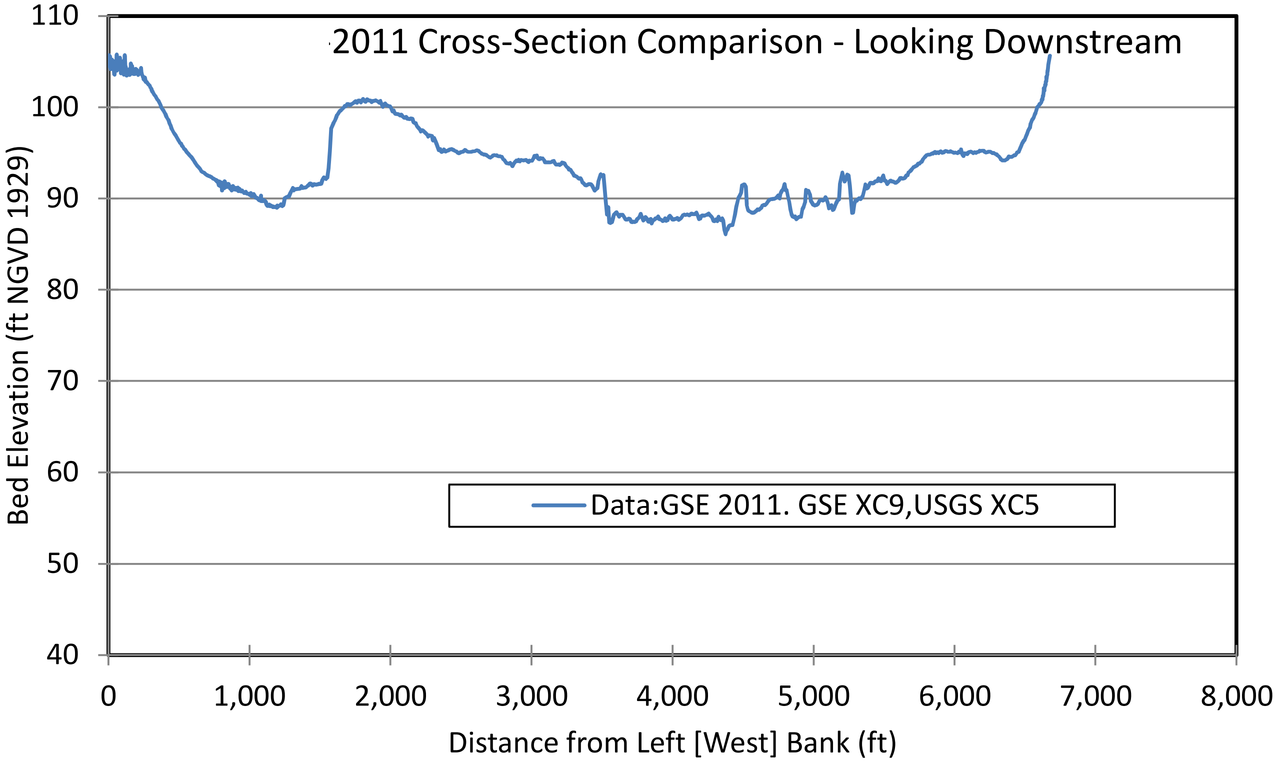

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC4
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC5,USGS XC3

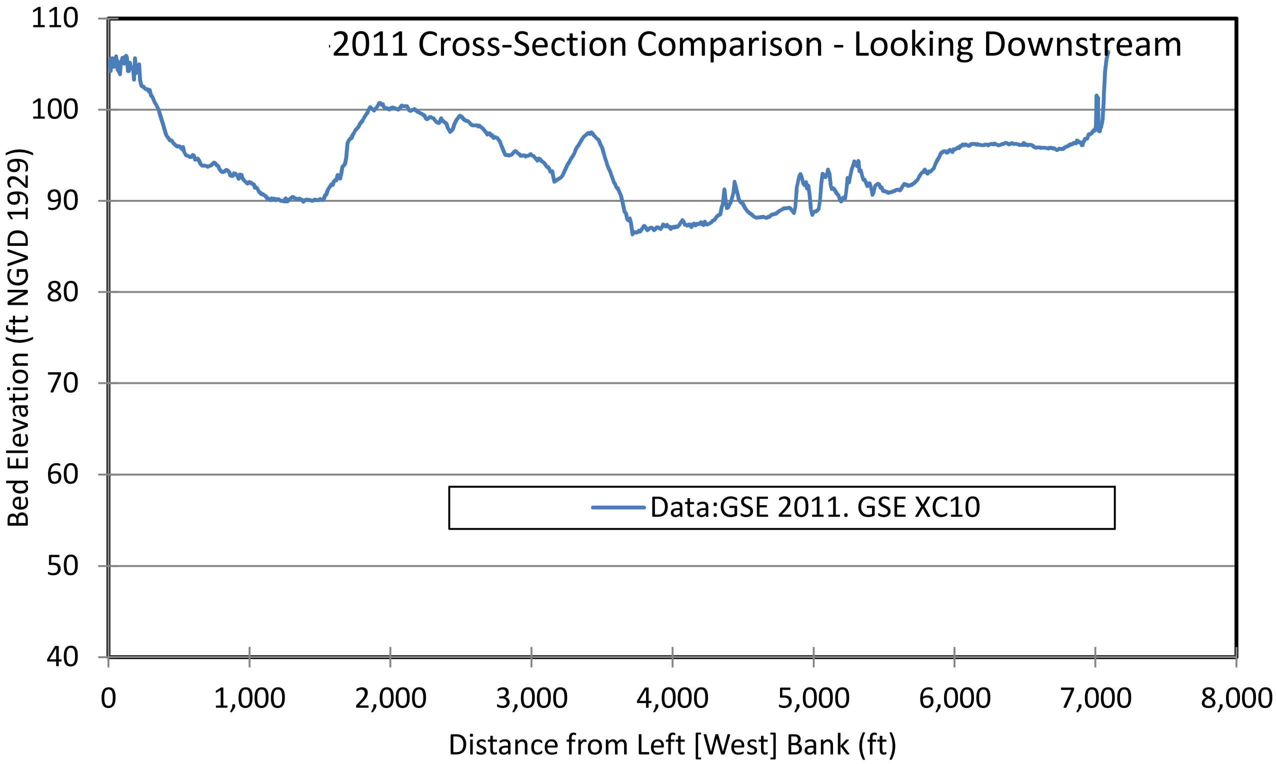

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC6


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC7,USGS XC4

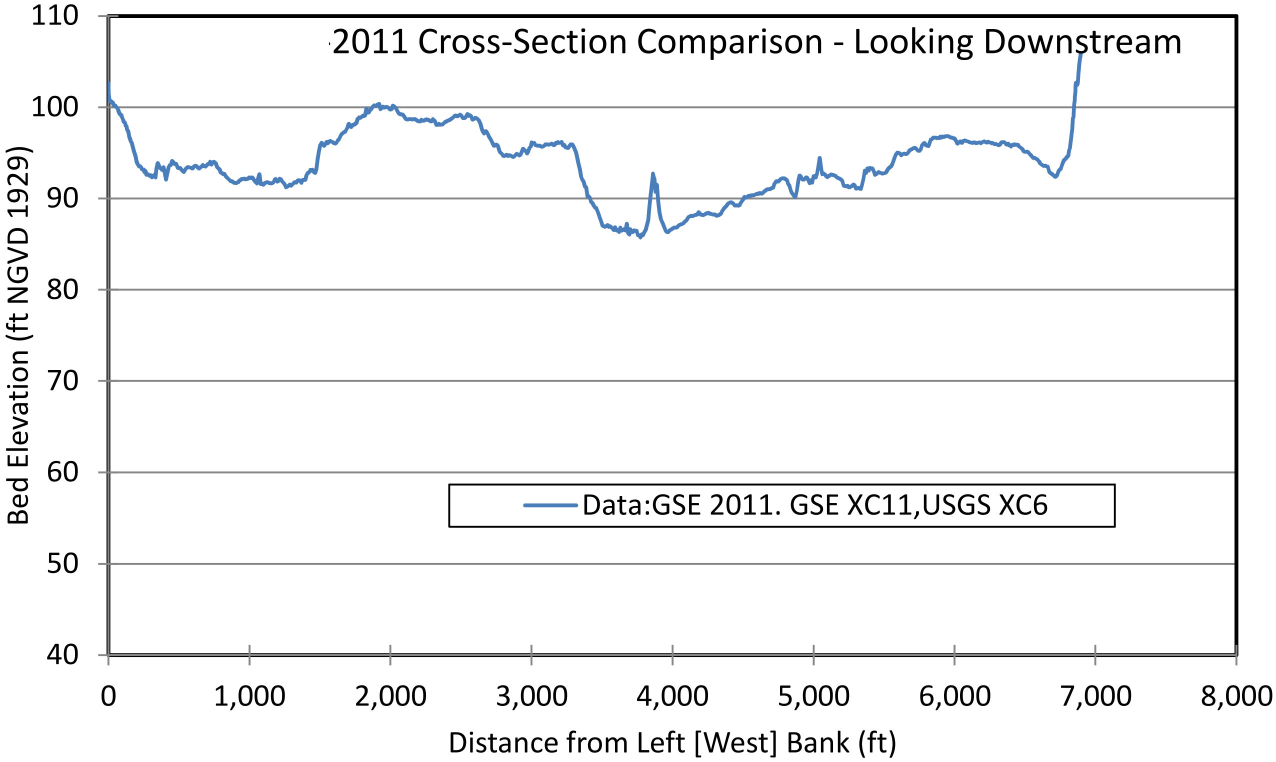

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC8



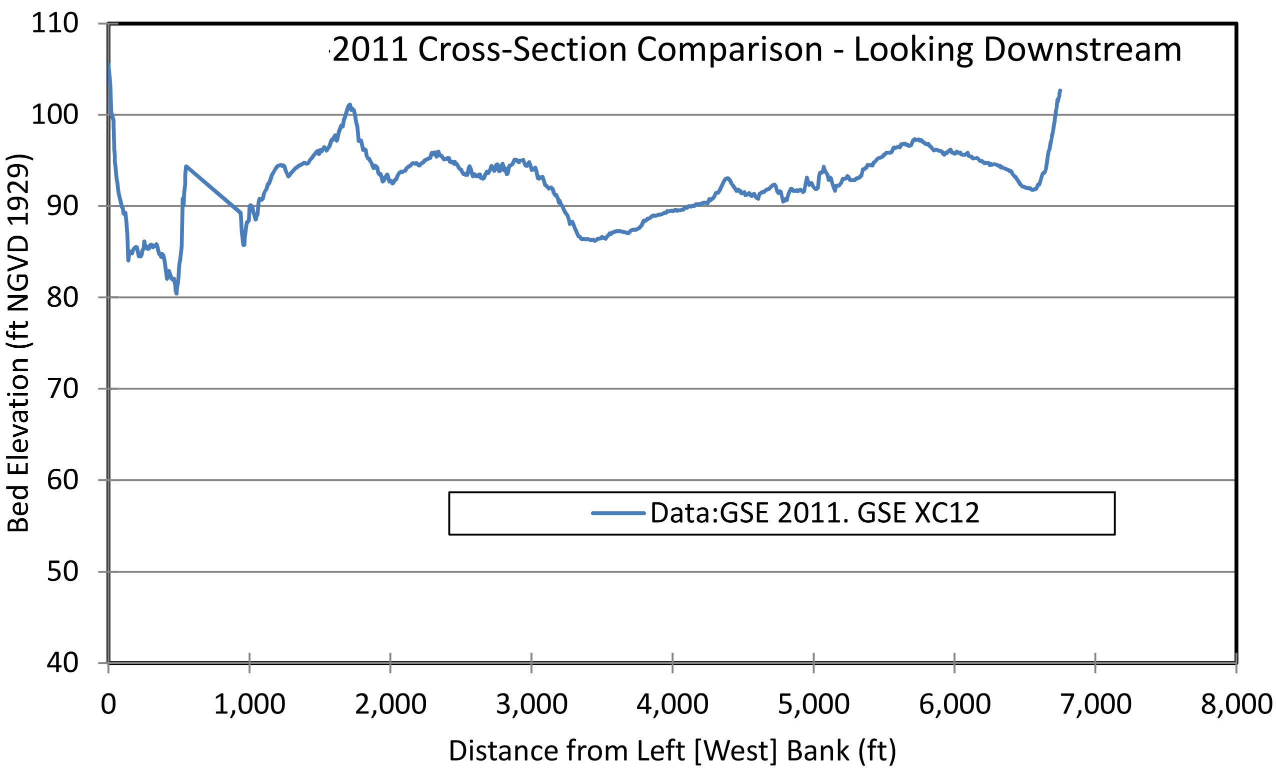
2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC9,USGS XC5
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000



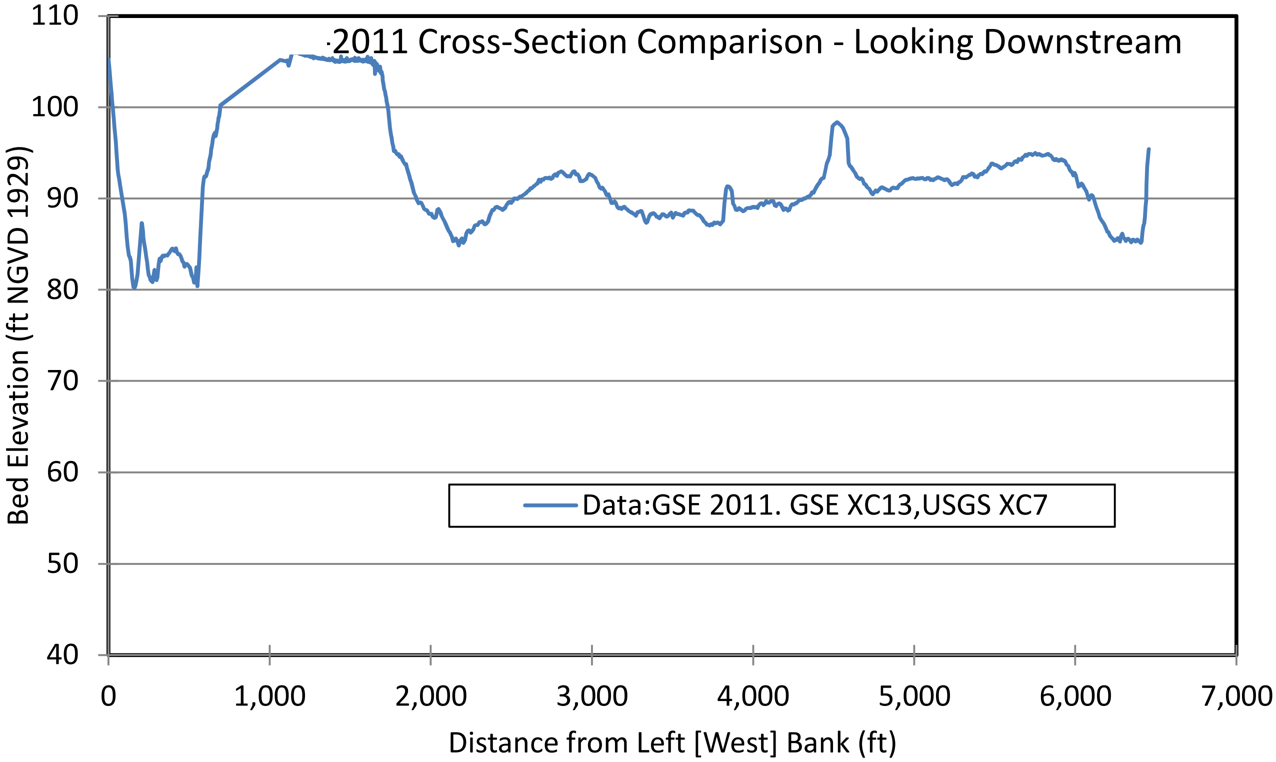
2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC10
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000

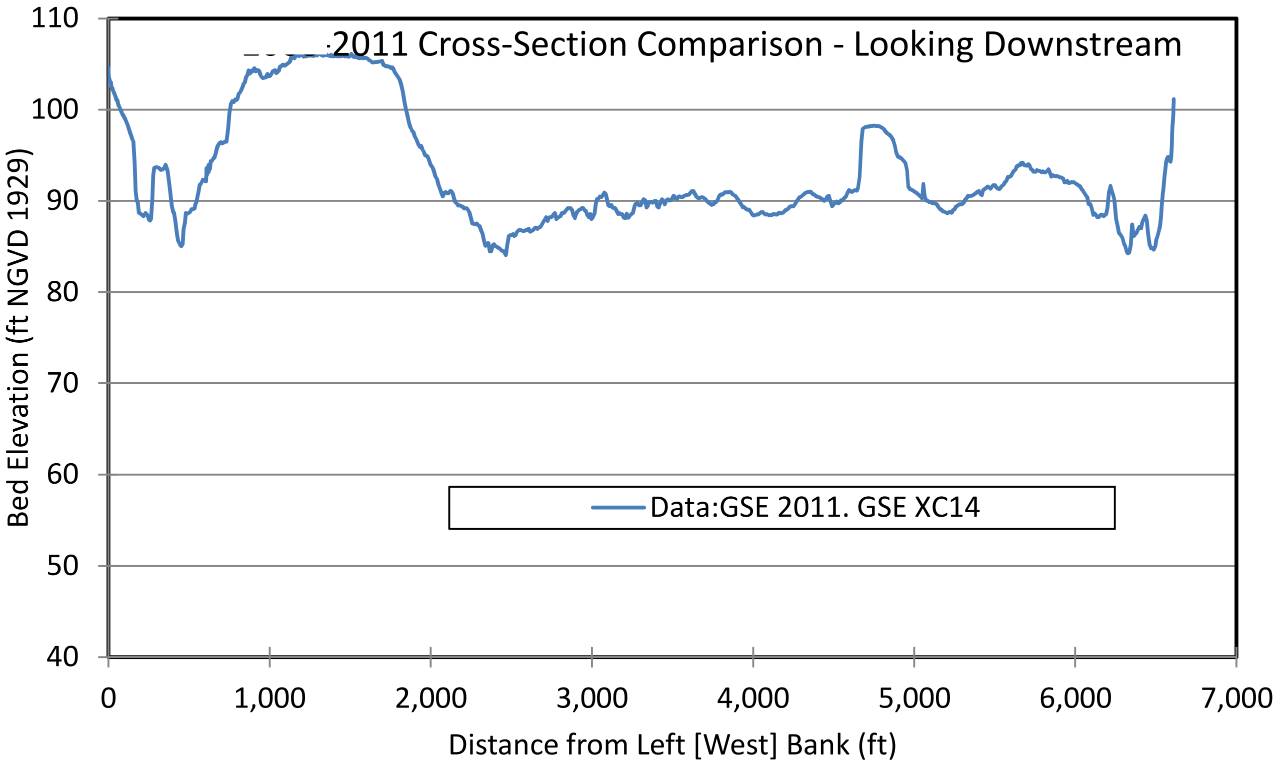


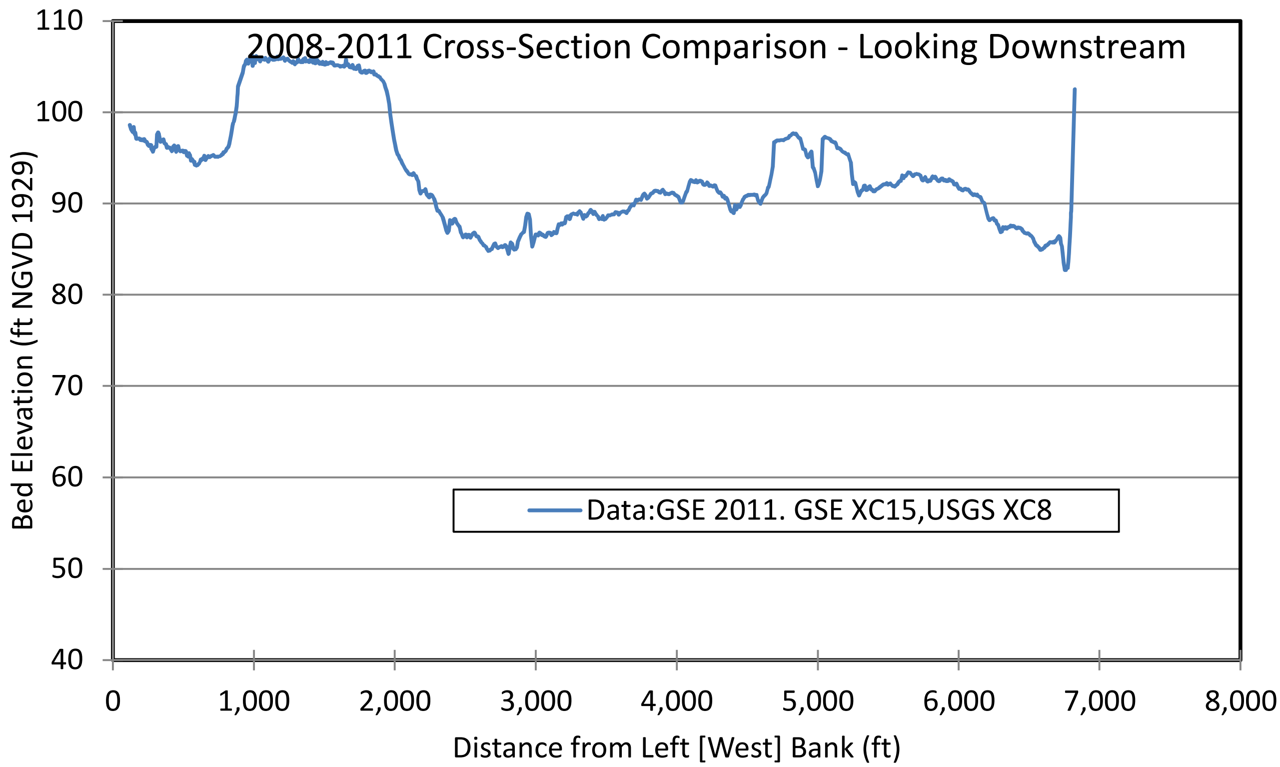
2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC11,USGS XC6

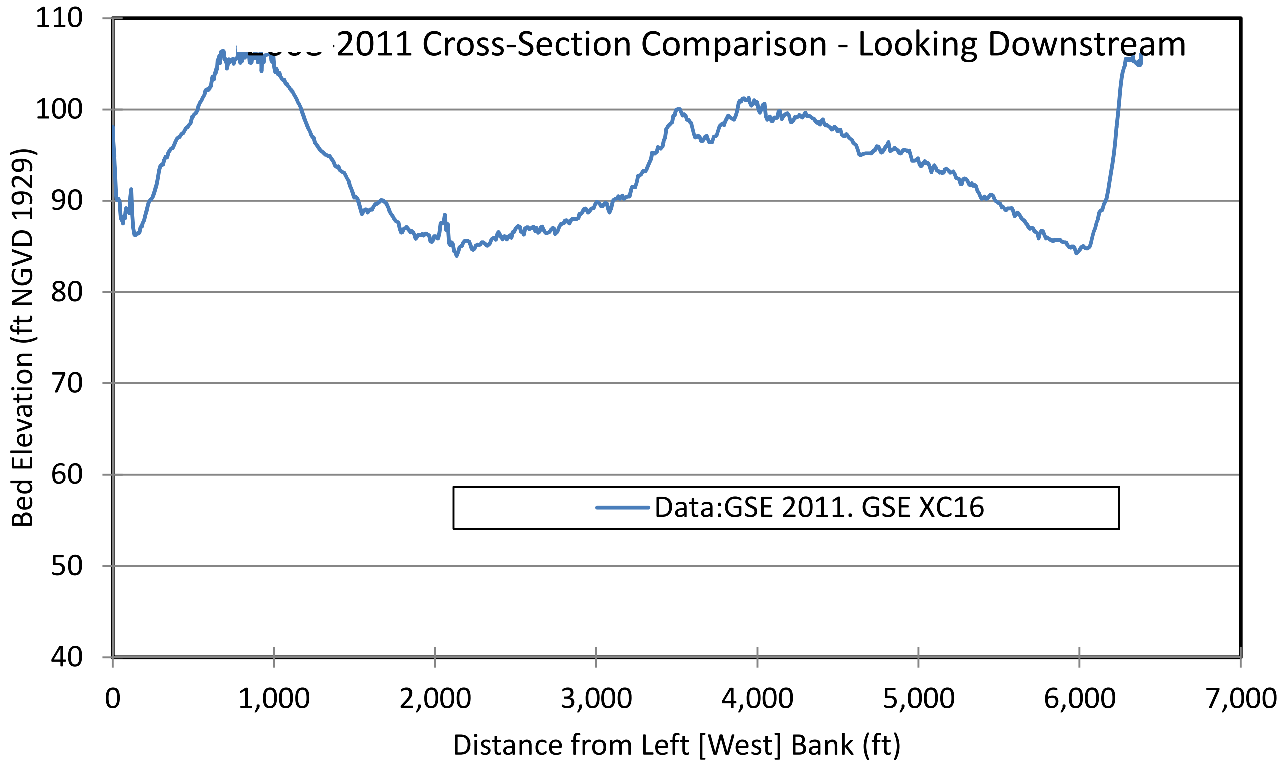


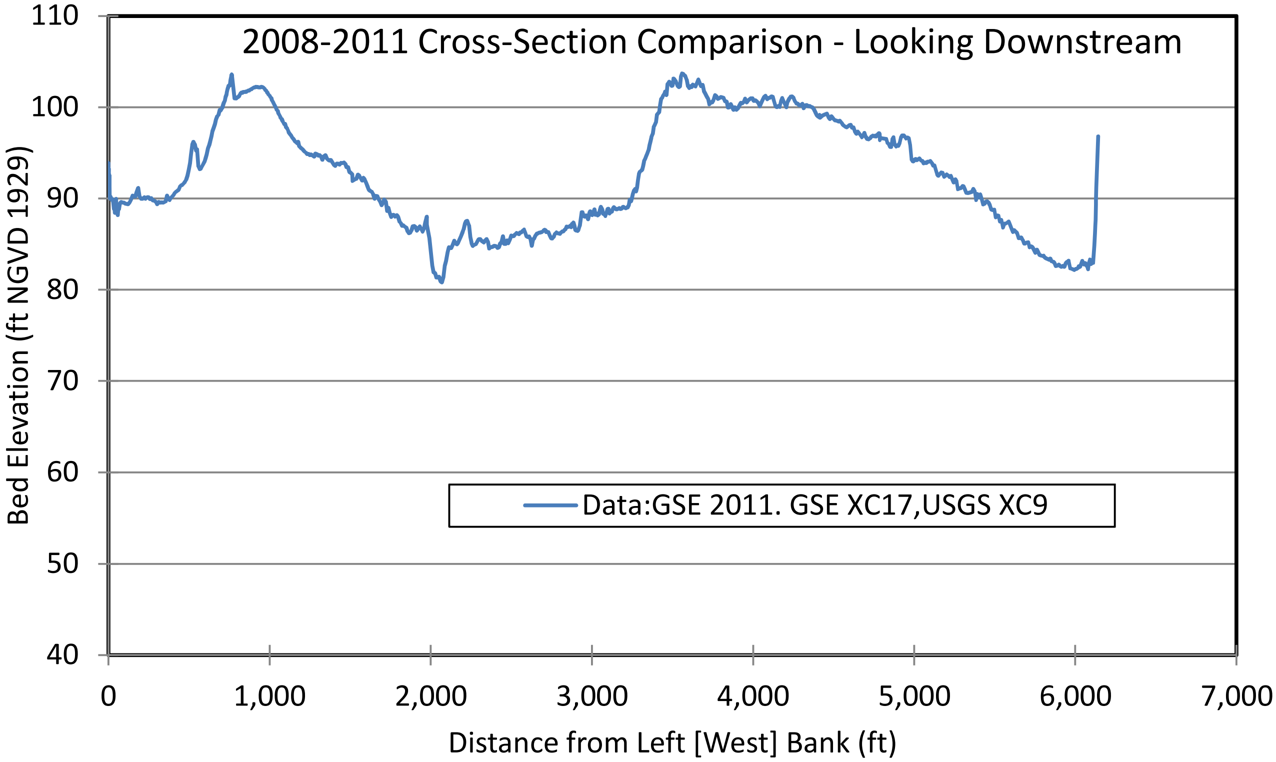
2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC12

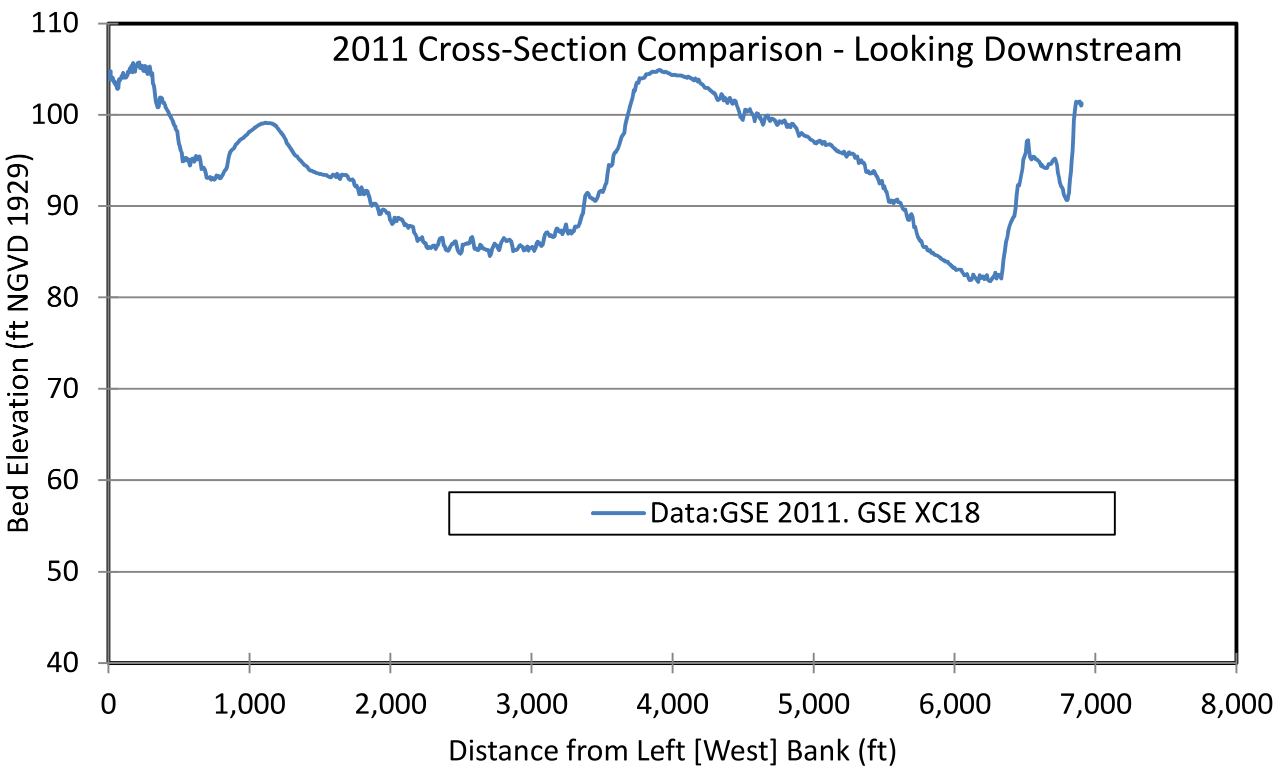

2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC13,USGS XC7
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)

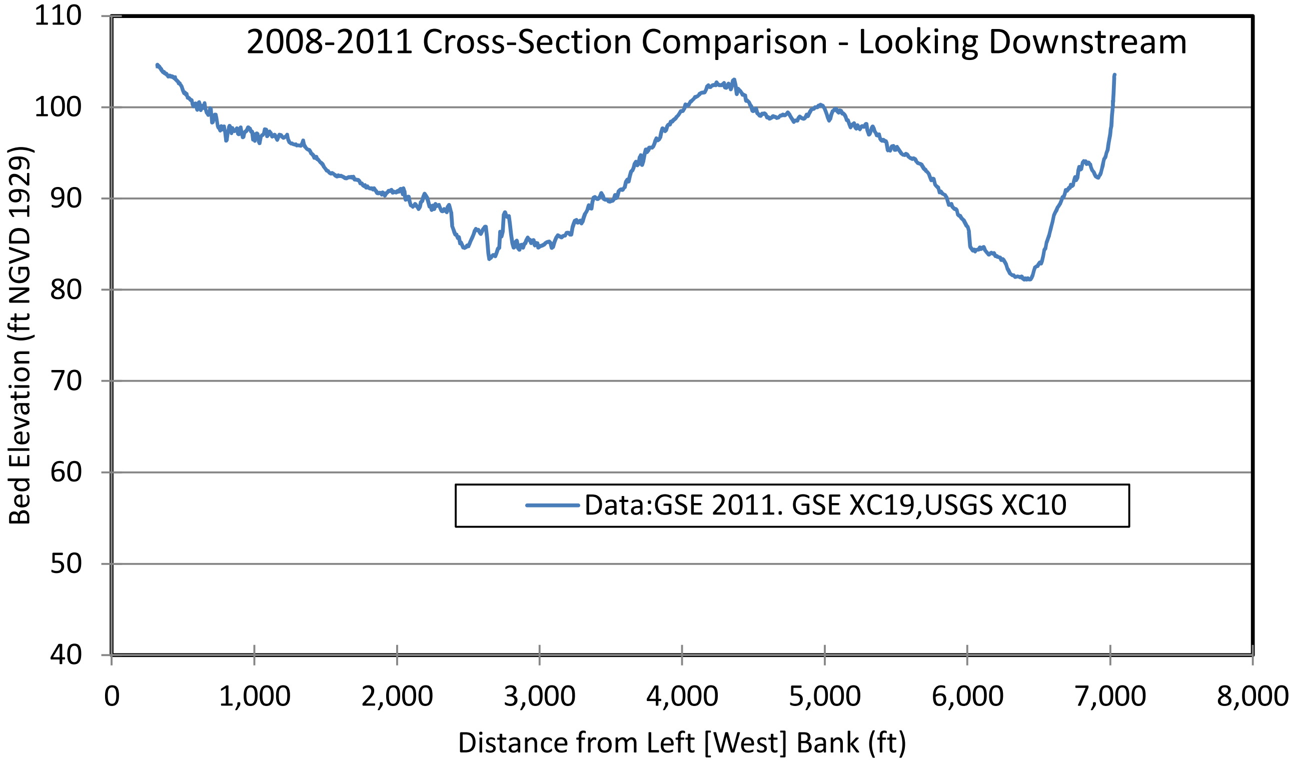

2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC14
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)

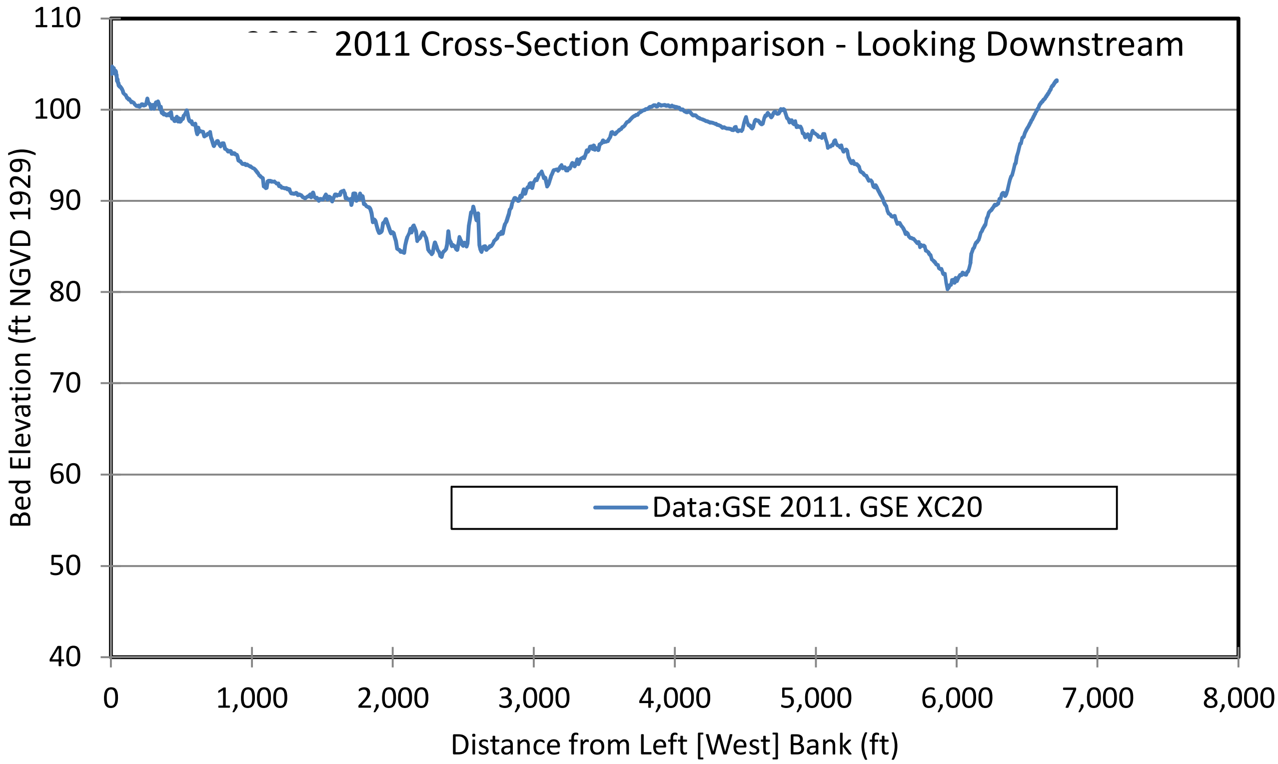

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC15,USGS XC8
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000

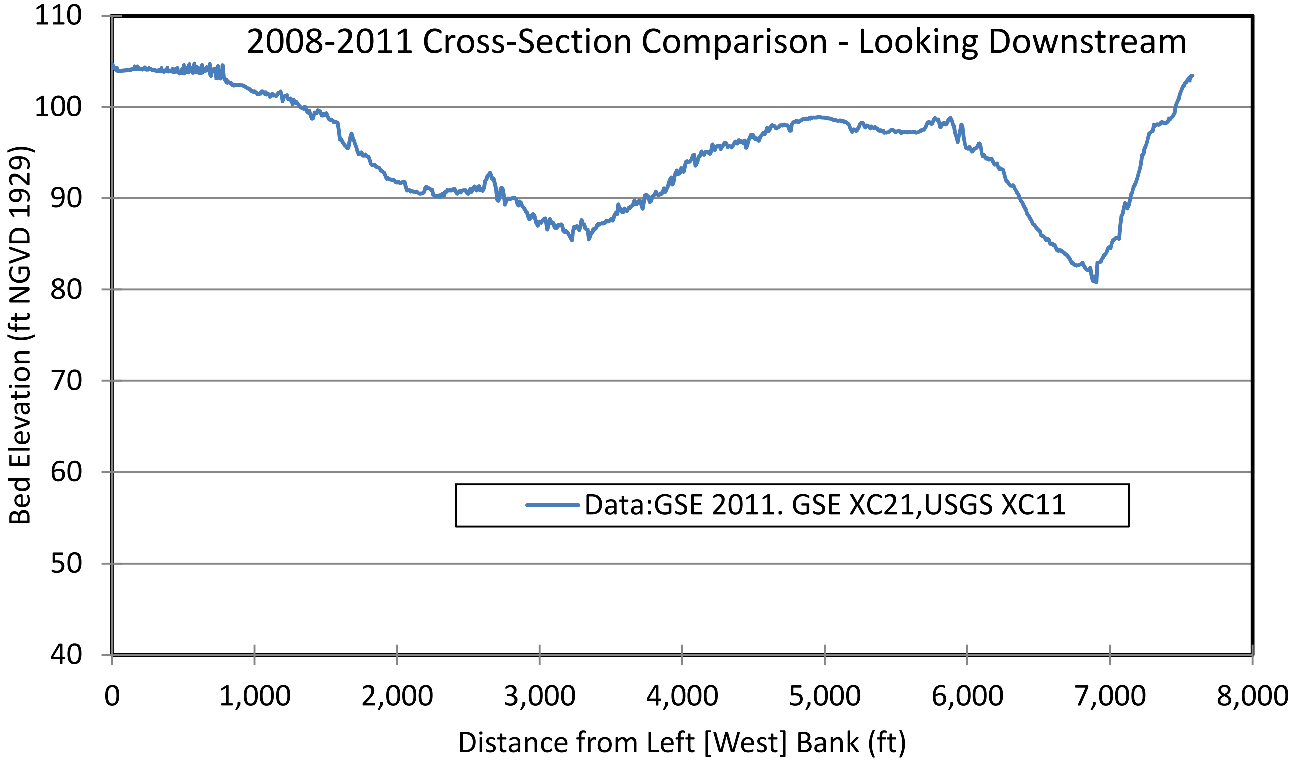

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC16
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000

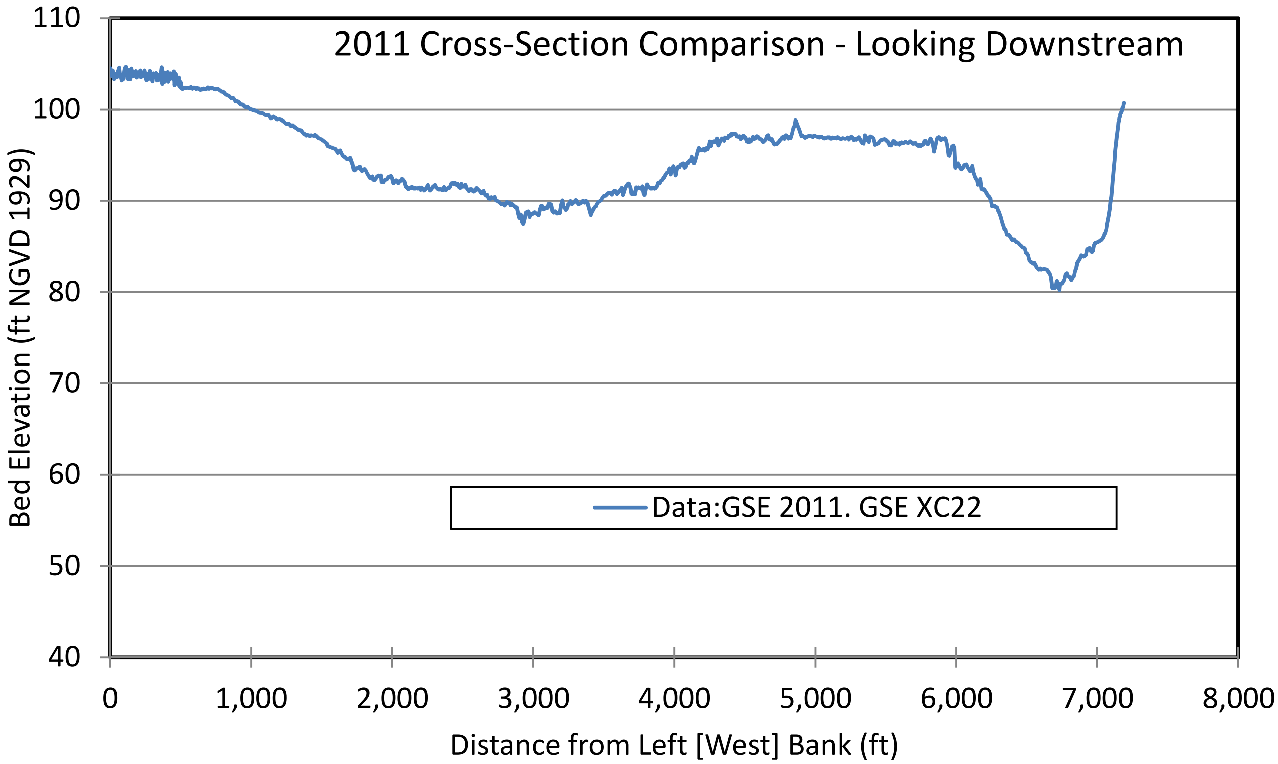

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC17,USGS XC9
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000

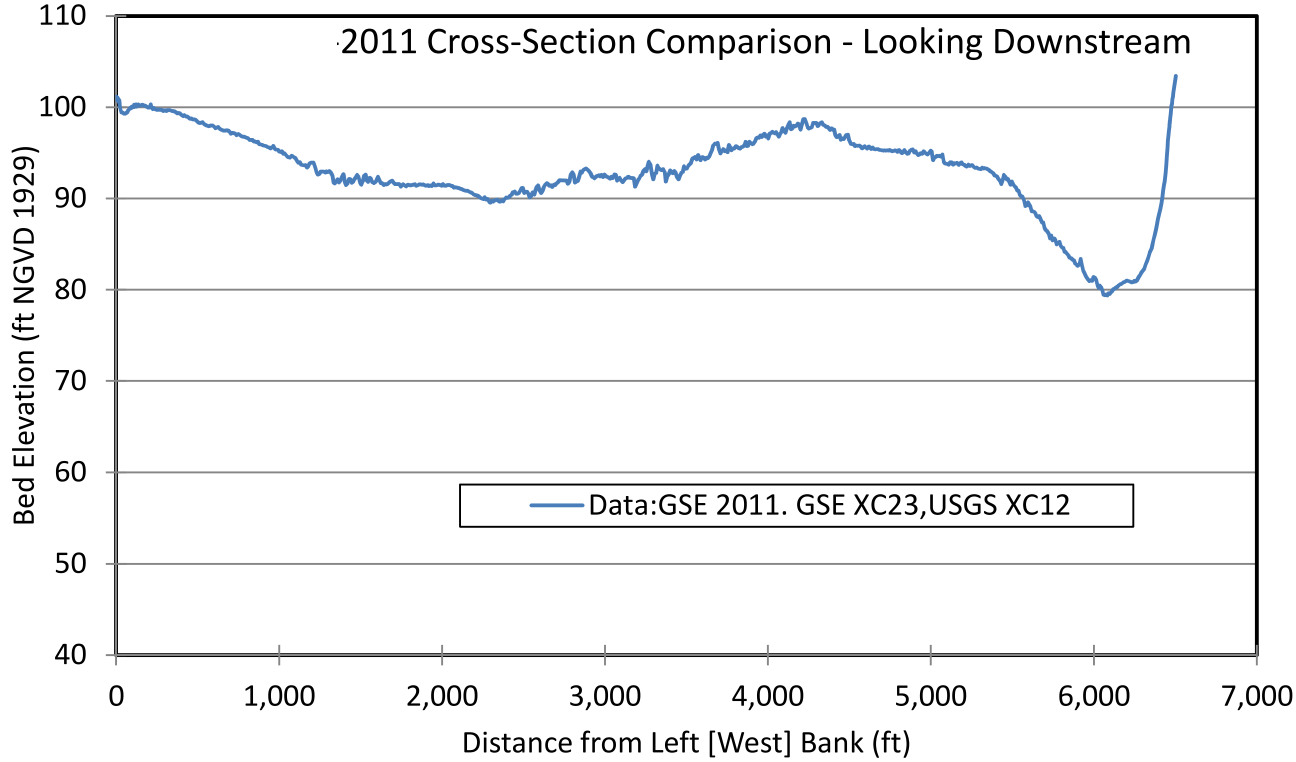

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC18
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000

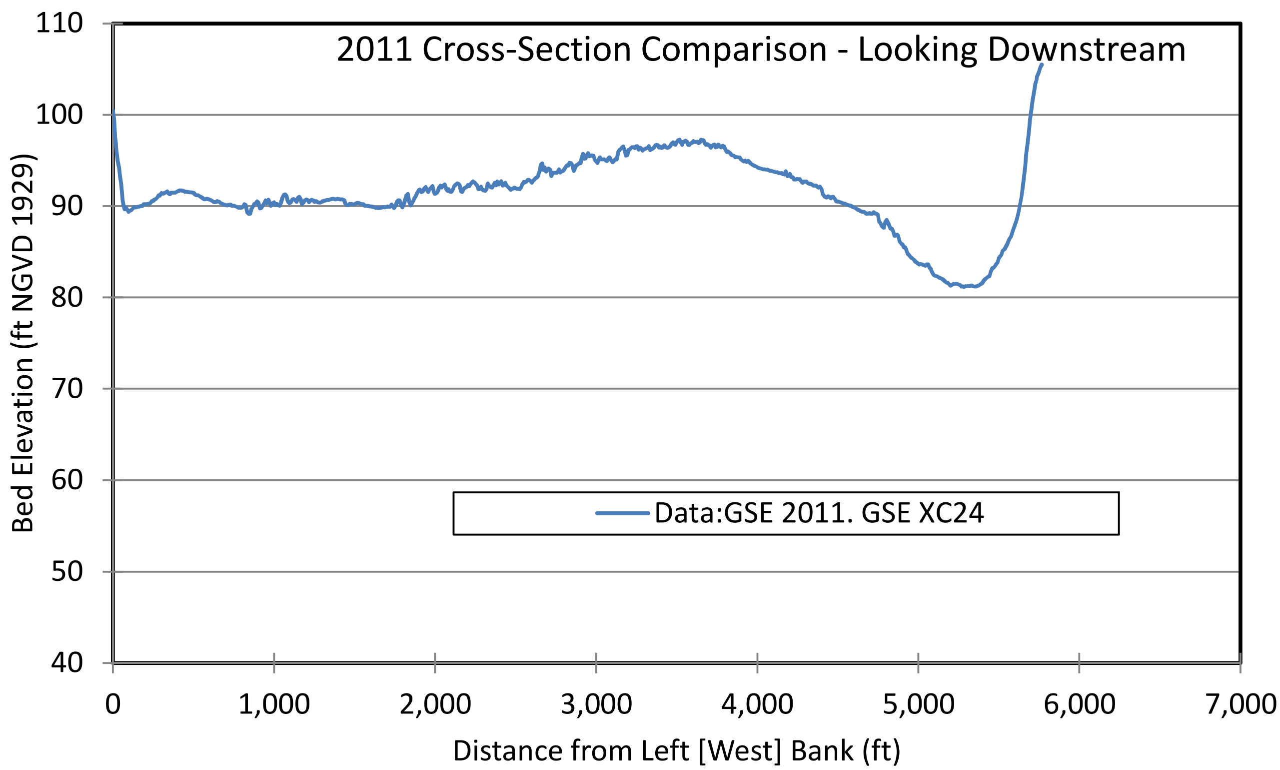

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC19,USGS XC10
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000

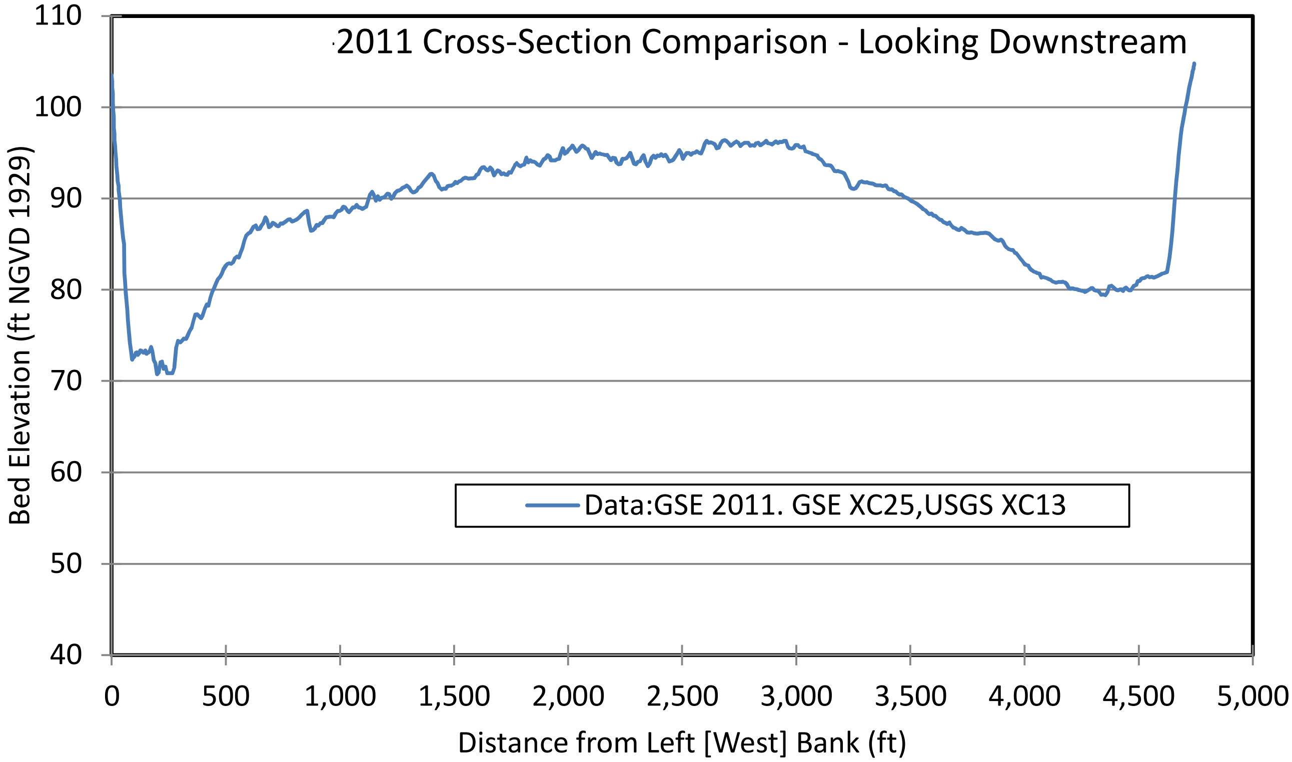

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC20
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC21,USGS XC11

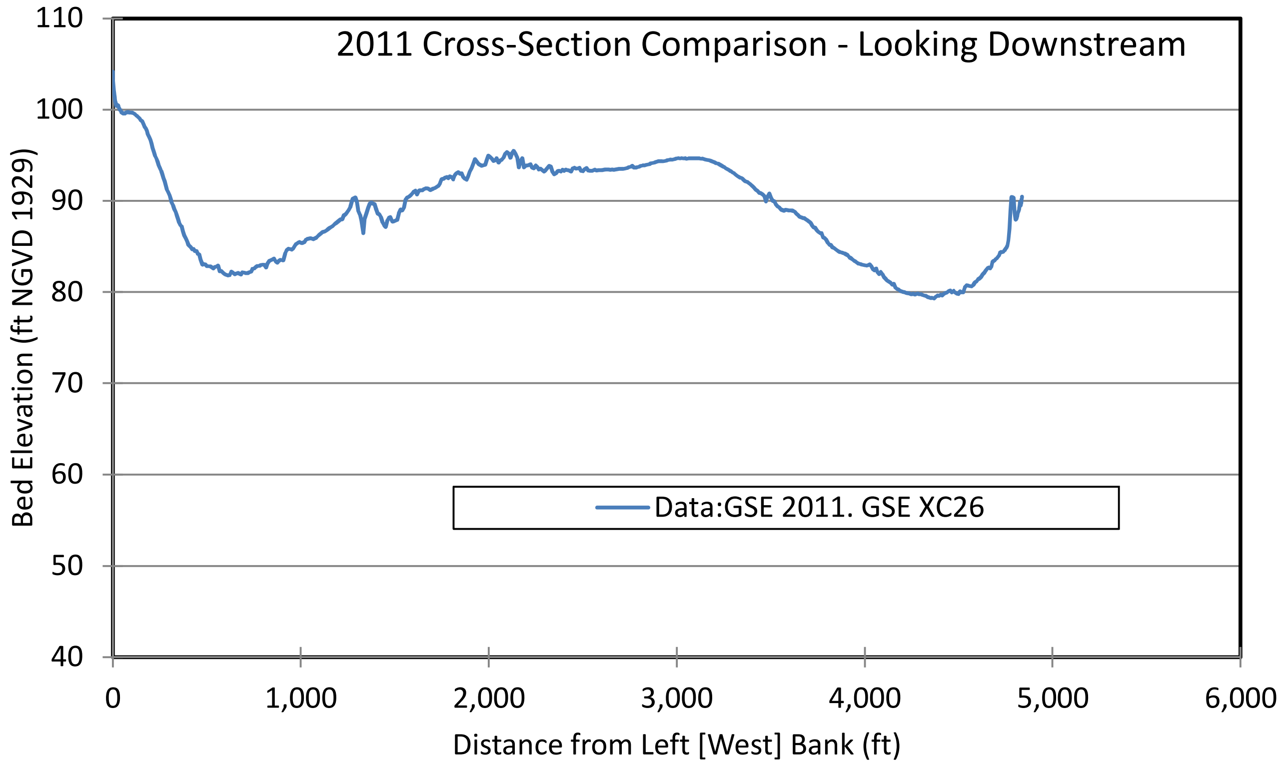

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
8,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC22


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC23,USGS XC12

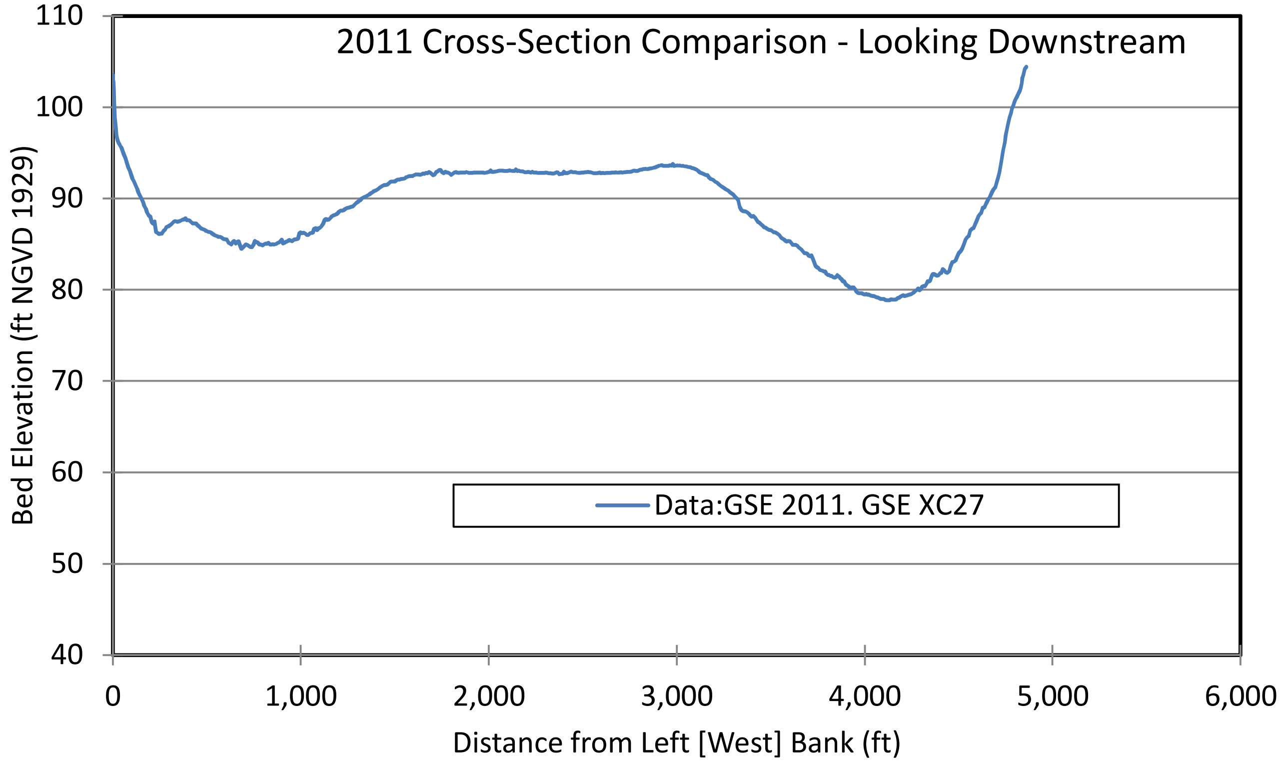

2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC24

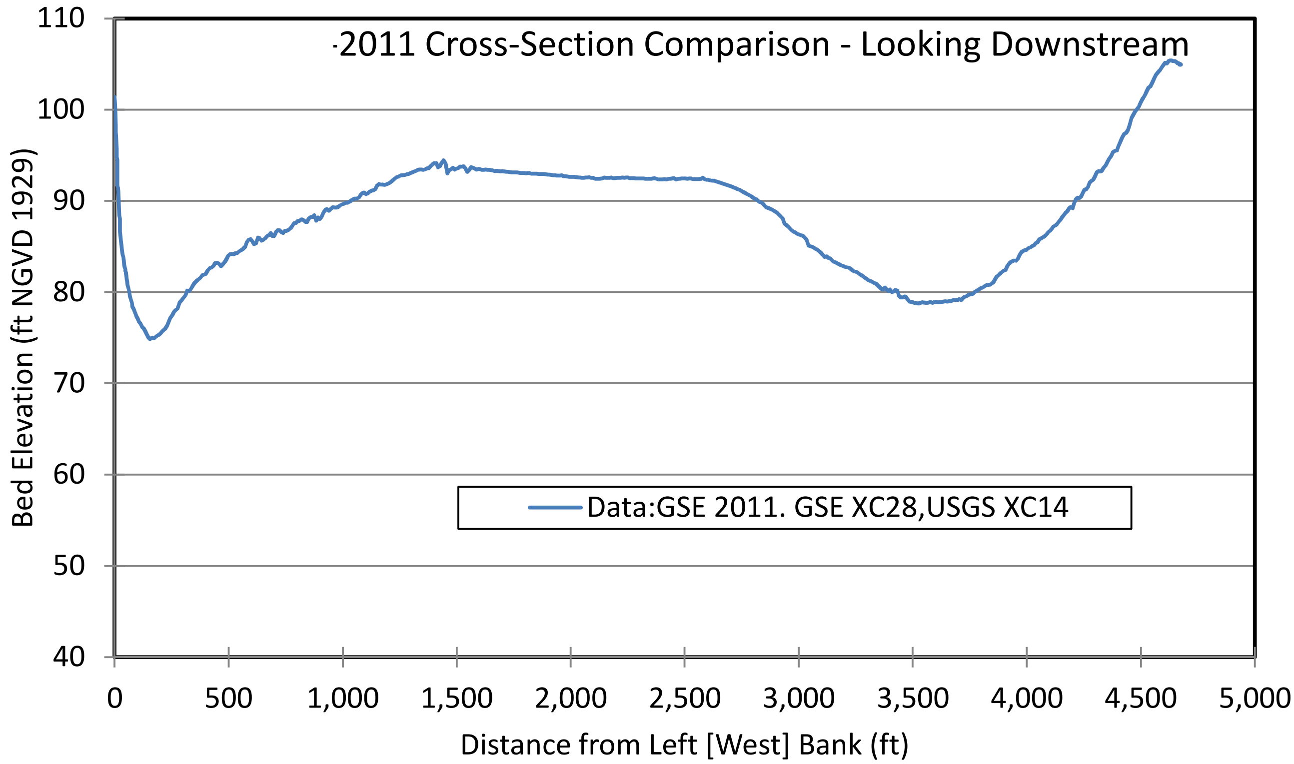


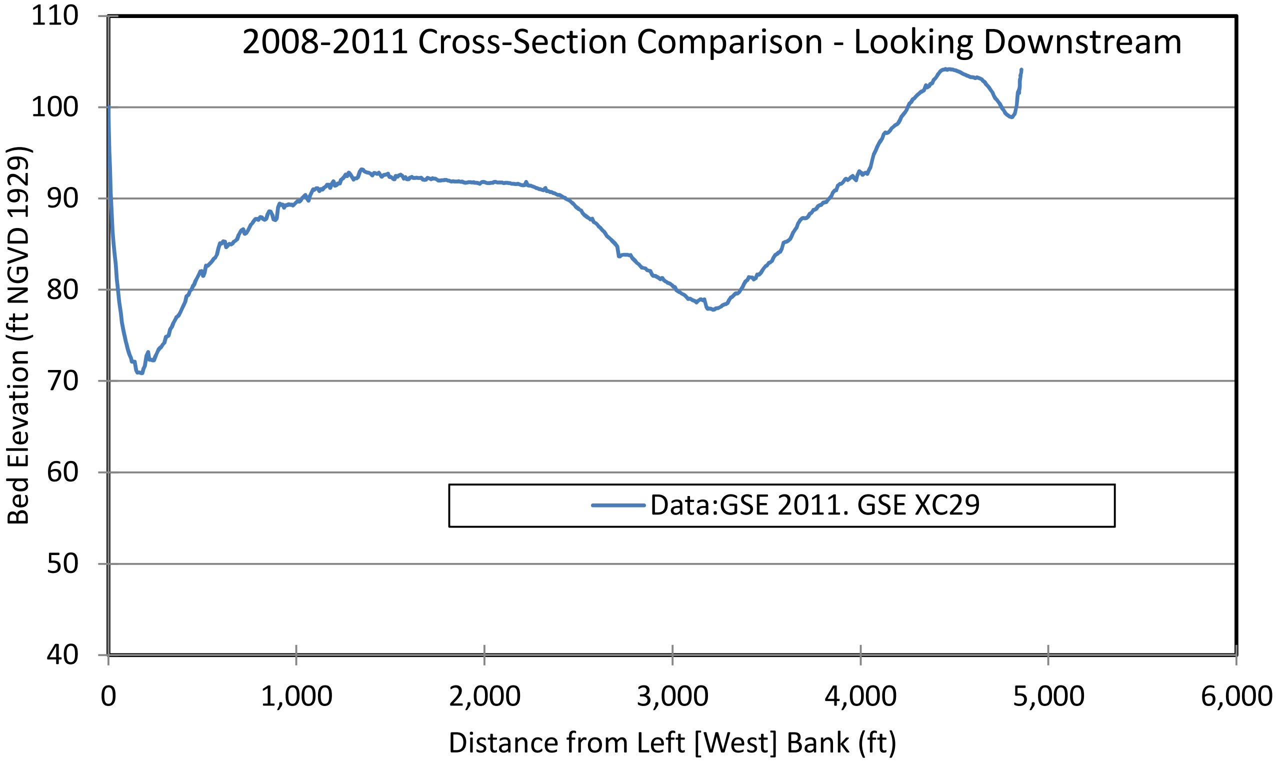
2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC25,USGS XC13
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000



2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC26
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC27
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC28,USGS XC14
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
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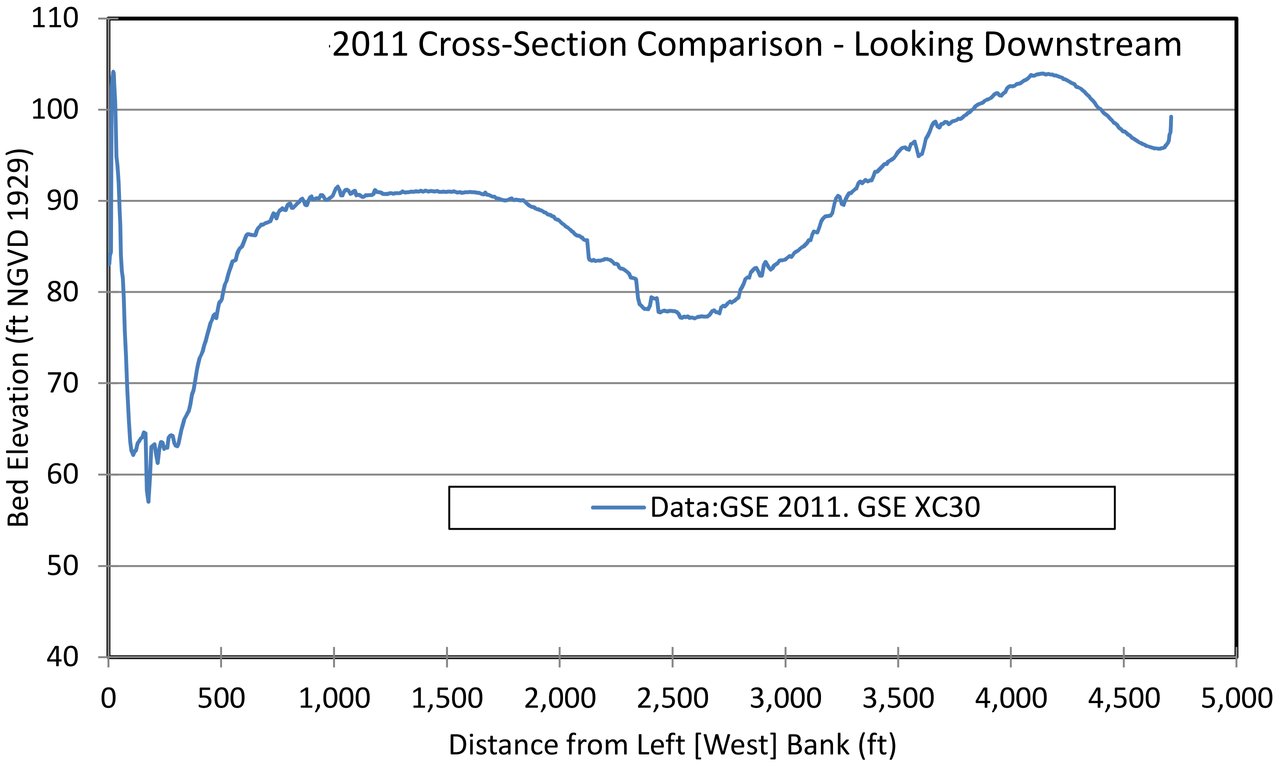
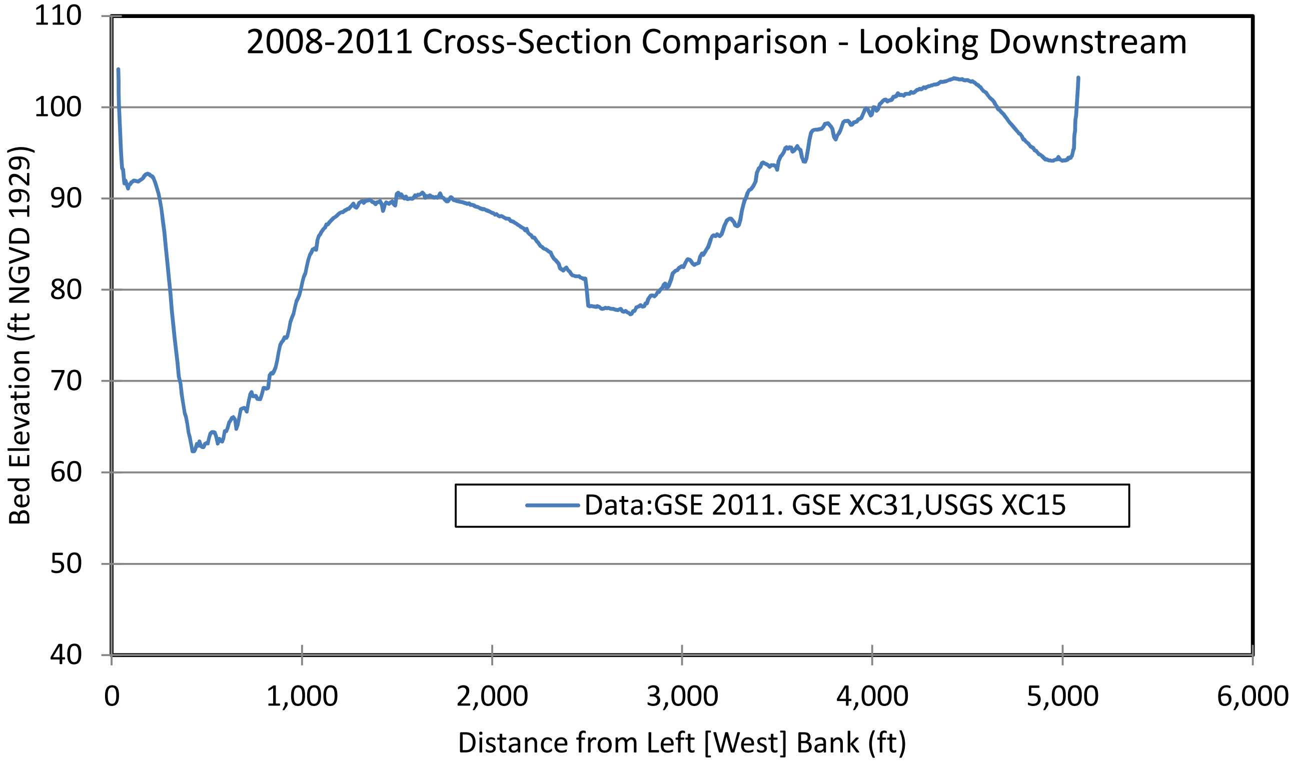
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC29


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC30


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC31,USGS XC15
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90
80
70
60
50
40
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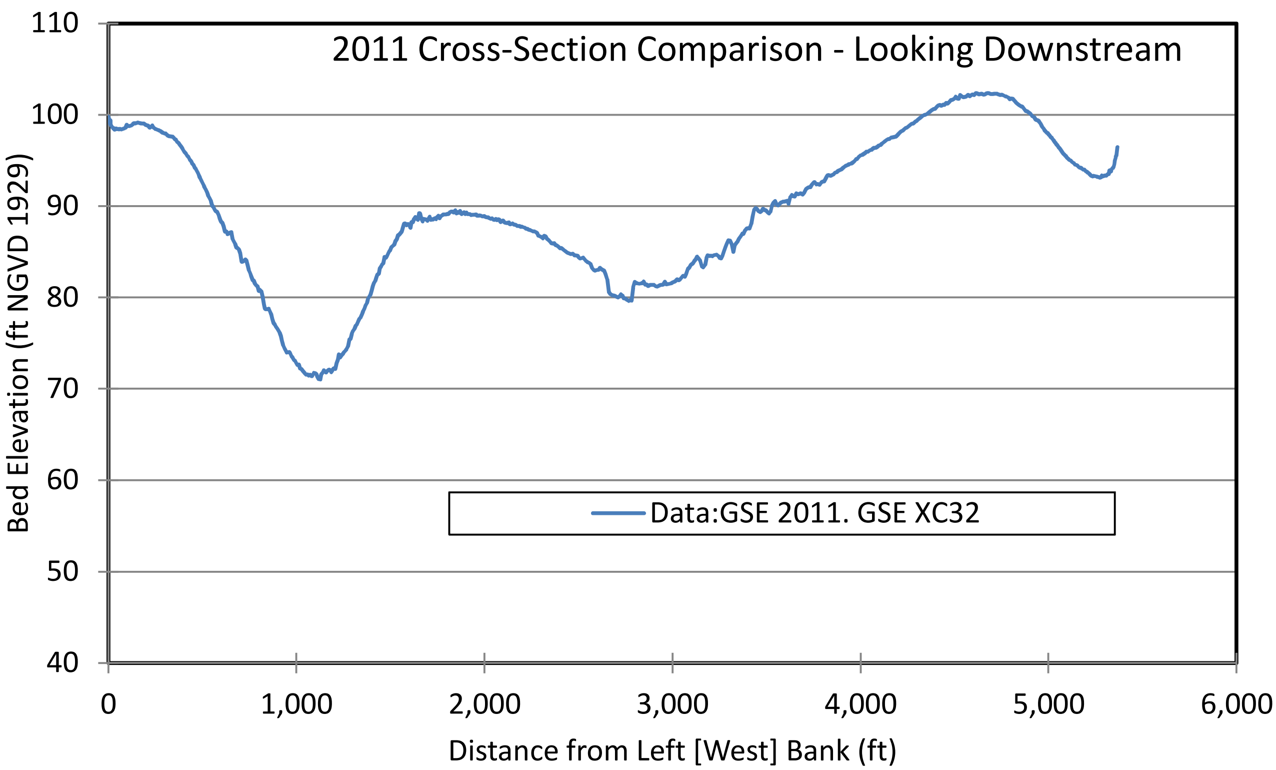
2,000
3,000
4,000
5,000
6,000


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC32
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90
80
70
60
50
40
0
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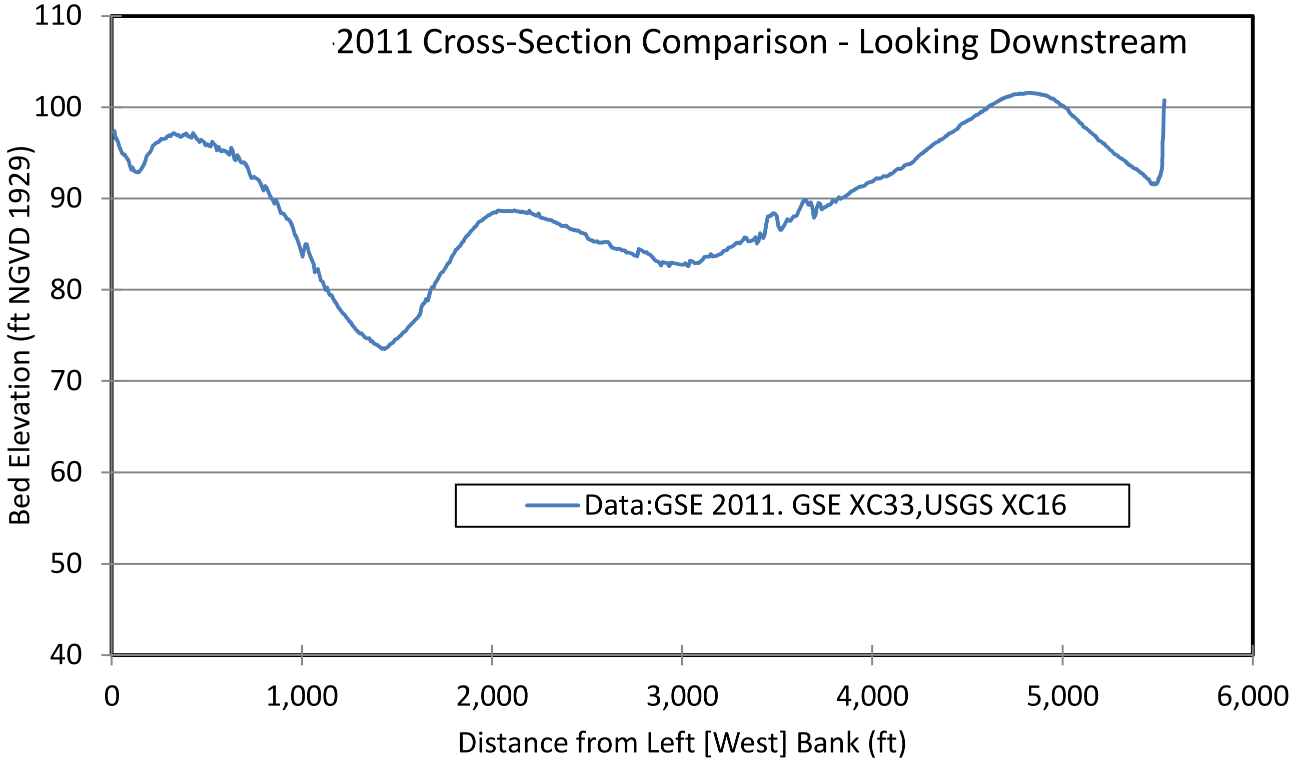
2,000
3,000
4,000
5,000
6,000



2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC33,USGS XC16
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
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100
90
80
70
60
50
40
0
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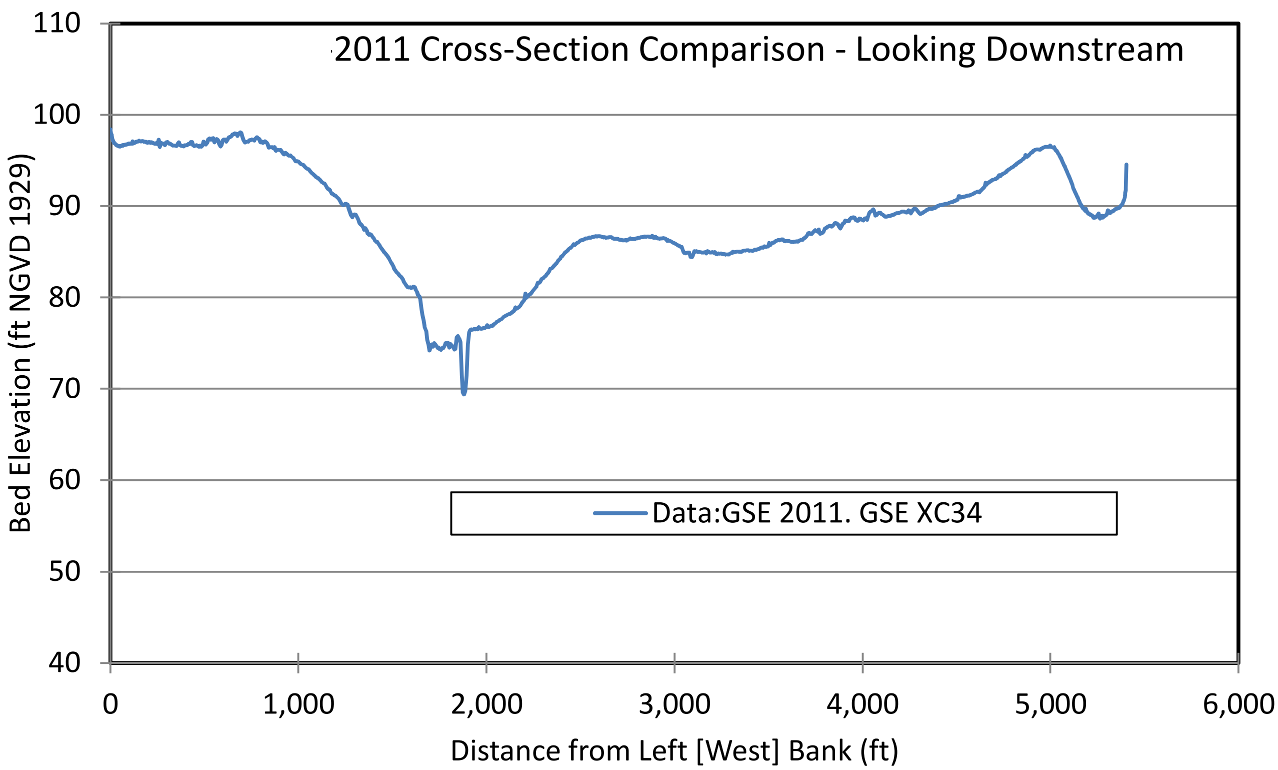
2,000
3,000
4,000
5,000
6,000



2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC34
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
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90
80
70
60
50
40
0
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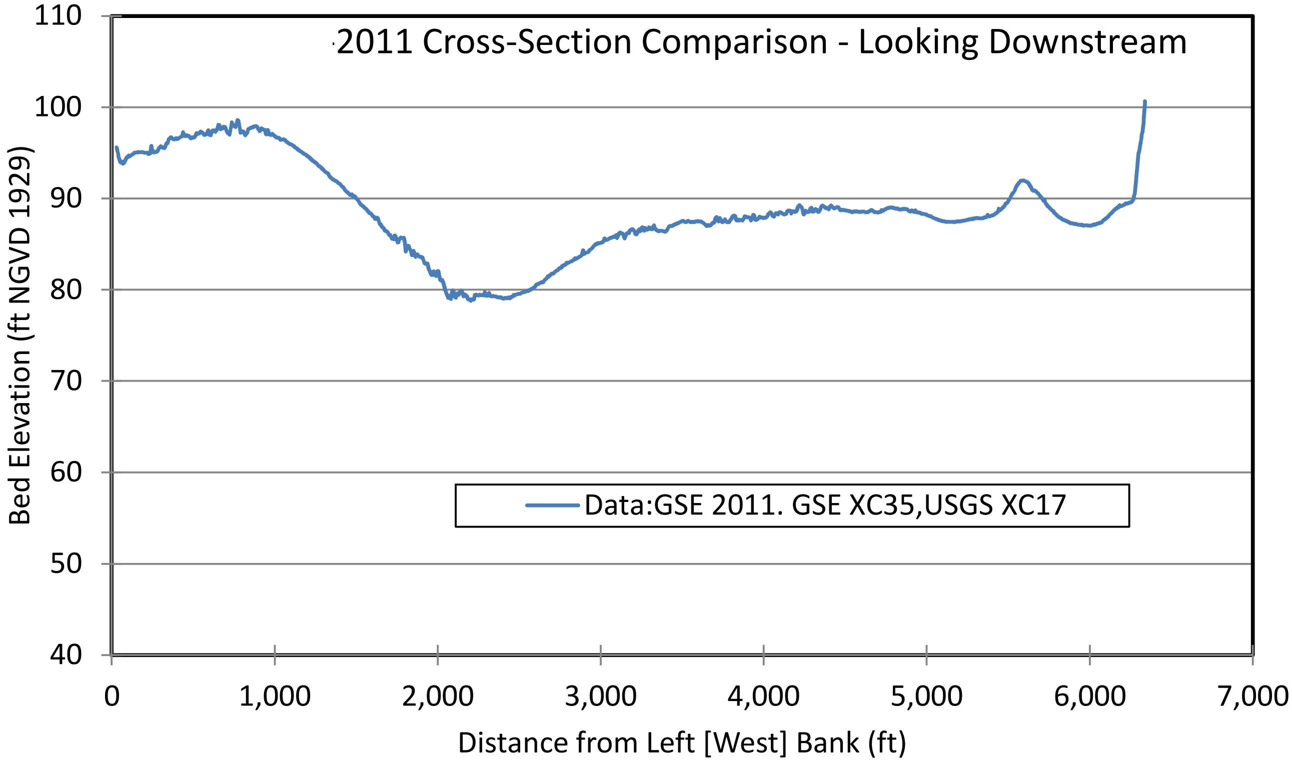
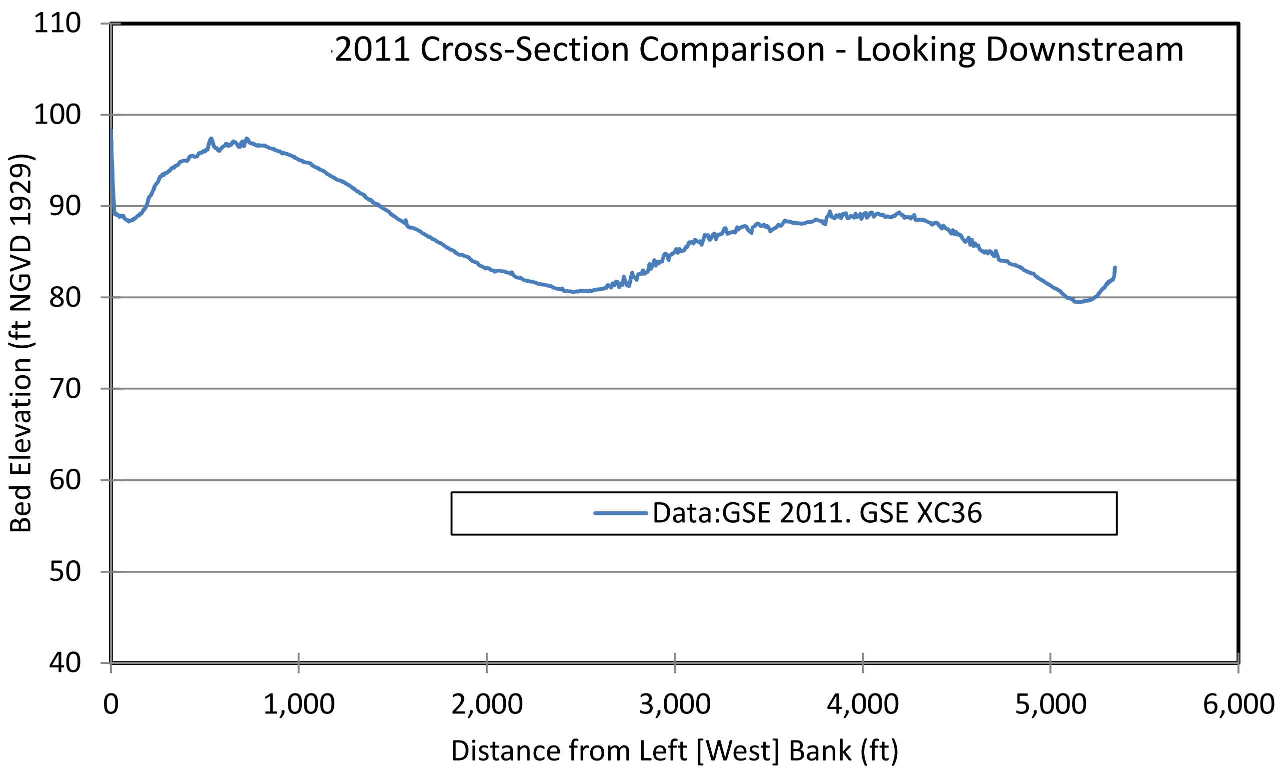
2,000
3,000
4,000
5,000
6,000


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC35,USGS XC17
0
1,000
2,000
3,000
4,000
5,000
6,000
7,000
Distance from Left [West] Bank (ft)


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC36
0
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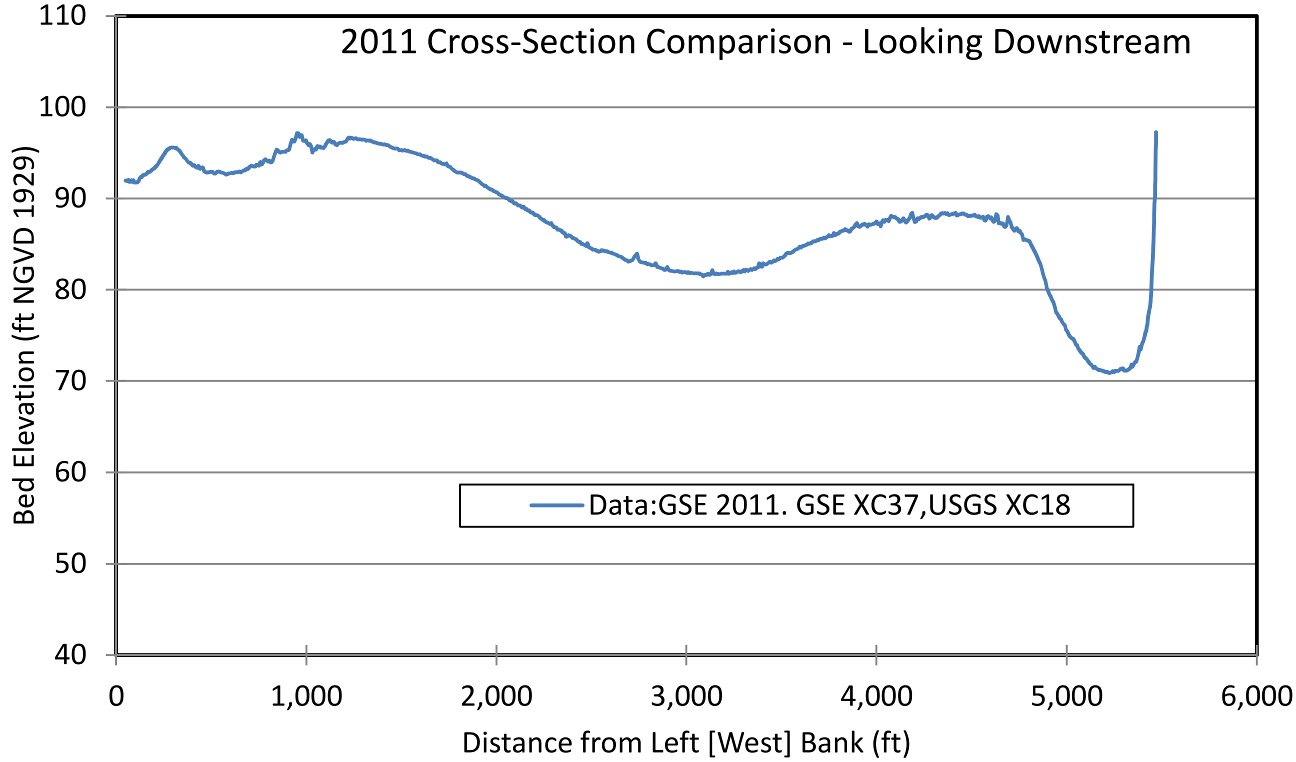
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
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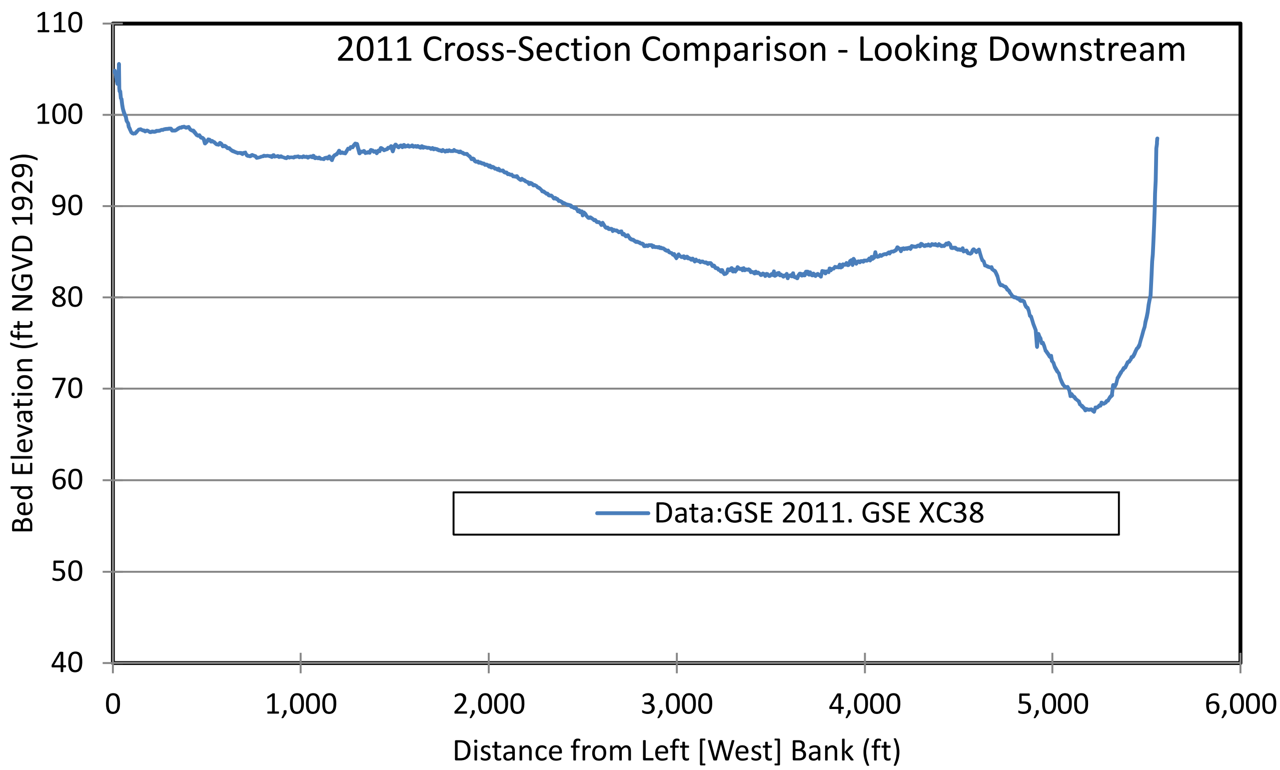
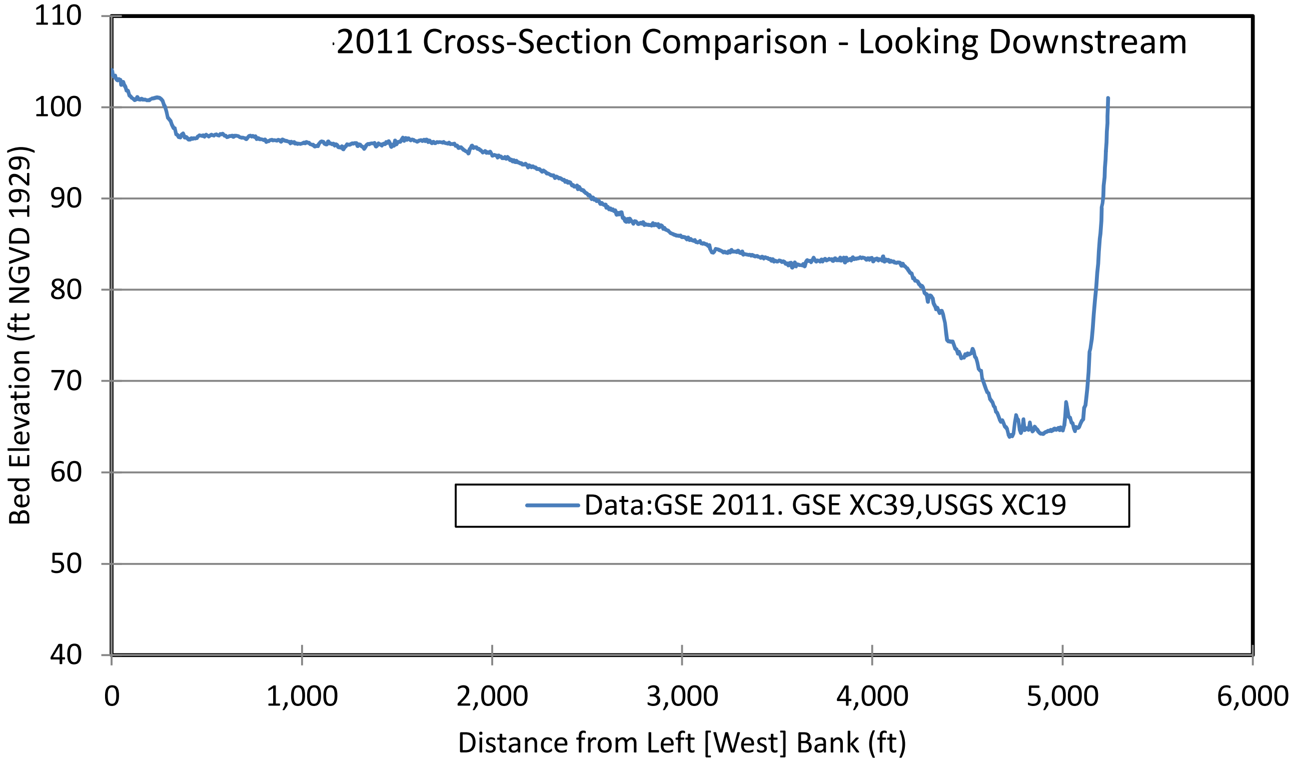
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC37,USGS XC18


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
0
1,000
2,000
3,000
4,000
5,000
6,000
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC38


2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC39,USGS XC19
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
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100
90
80
70
60
50
40
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2,000
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4,000
5,000
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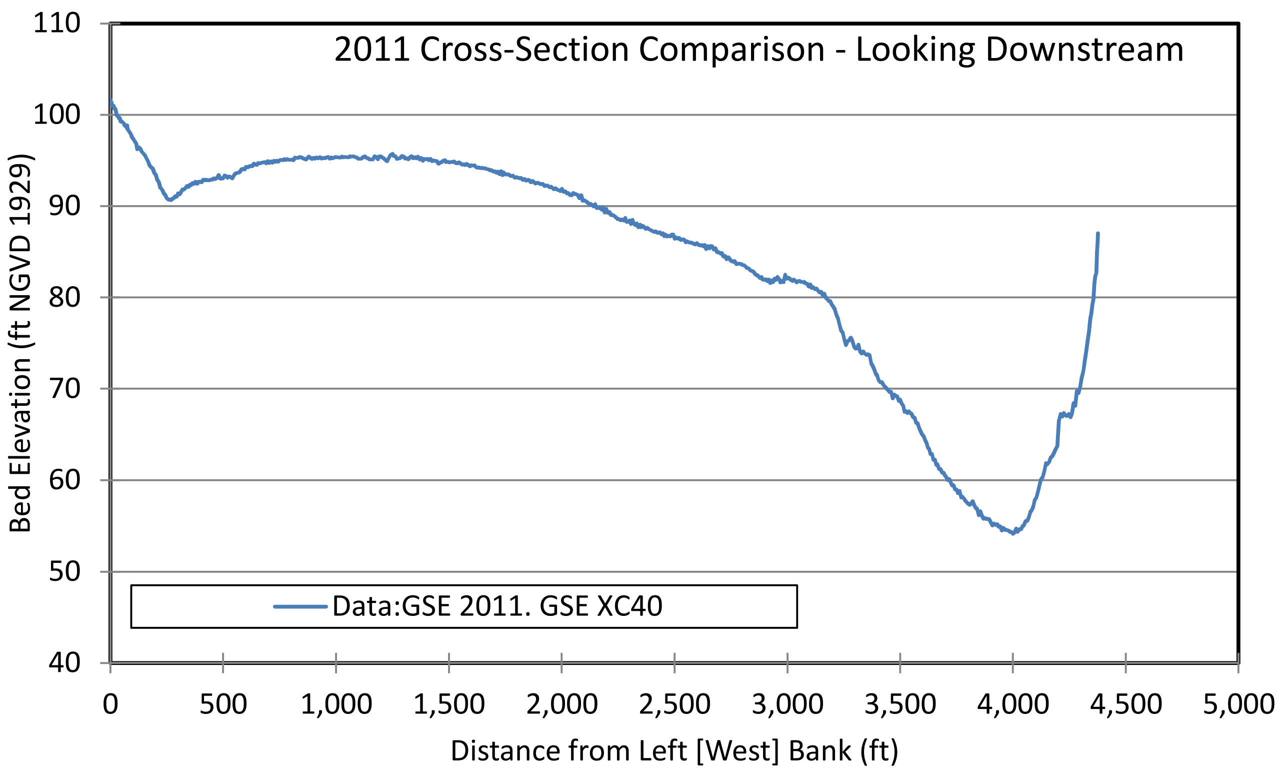
2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC40
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
110
100
90
80
70
60
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40
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4,000
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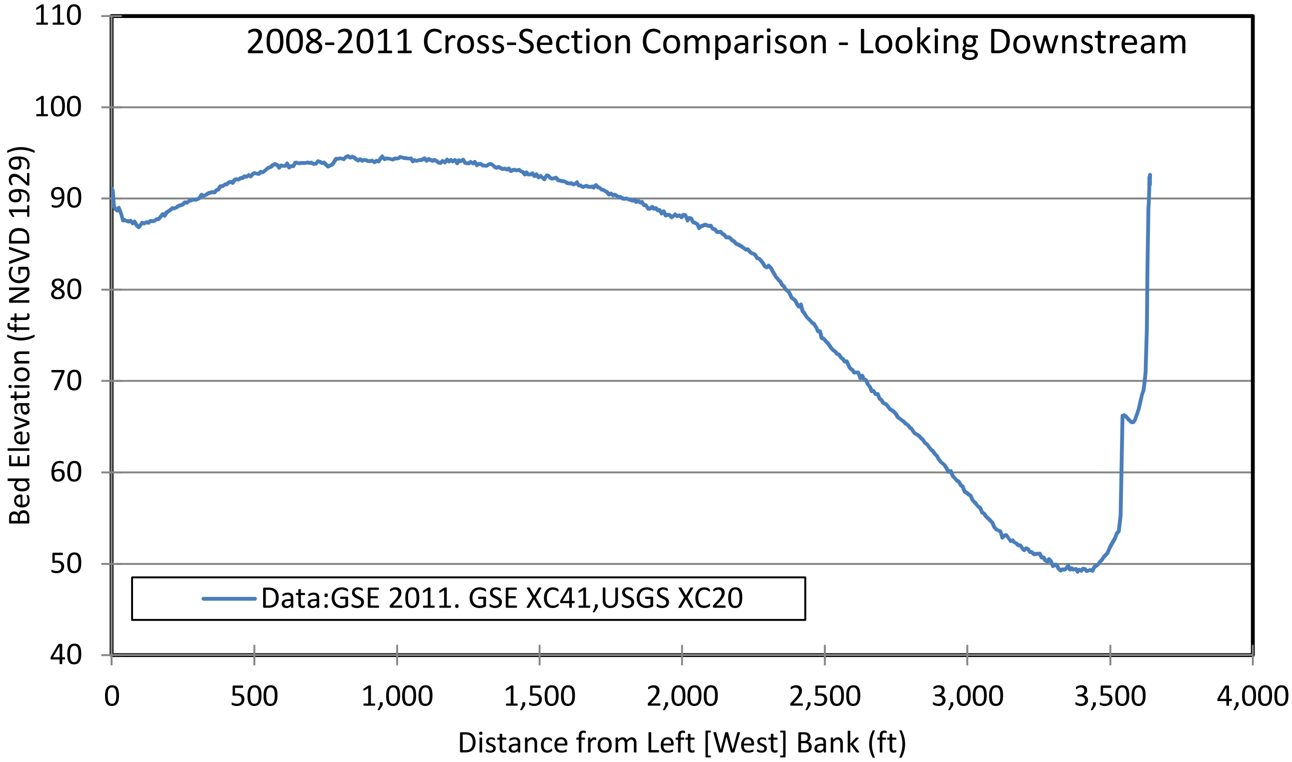
5,000



2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC41,USGS XC20
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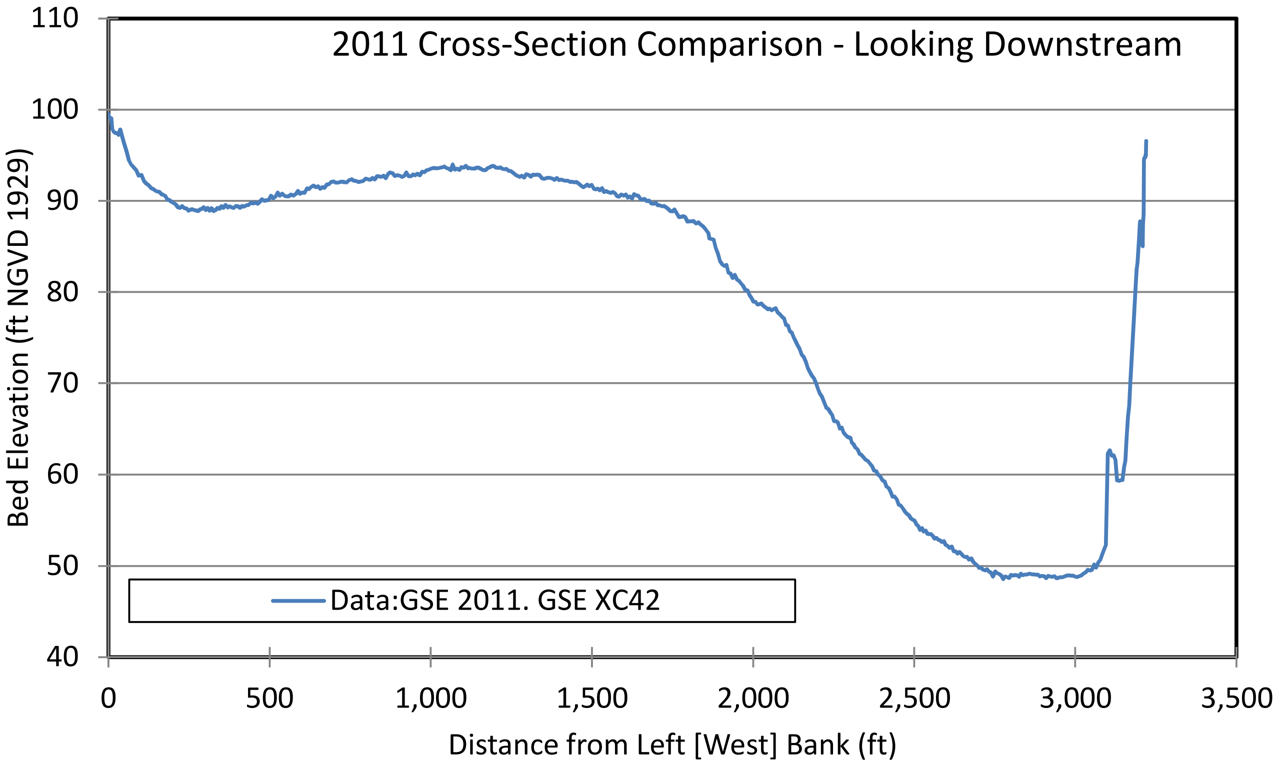
Distance from Left [West] Bank (ft)



2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC42
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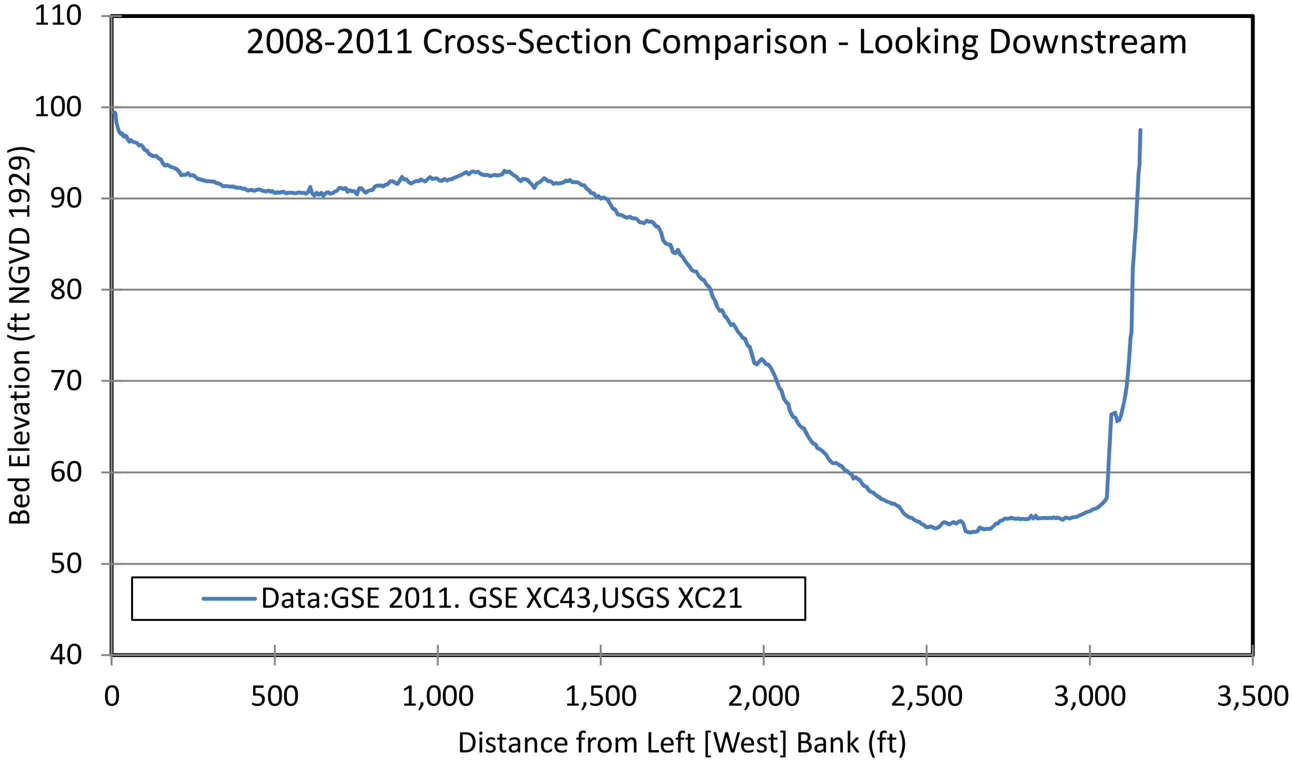
Distance from Left [West] Bank (ft)


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC43,USGS XC21
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80
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60
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40
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1,500
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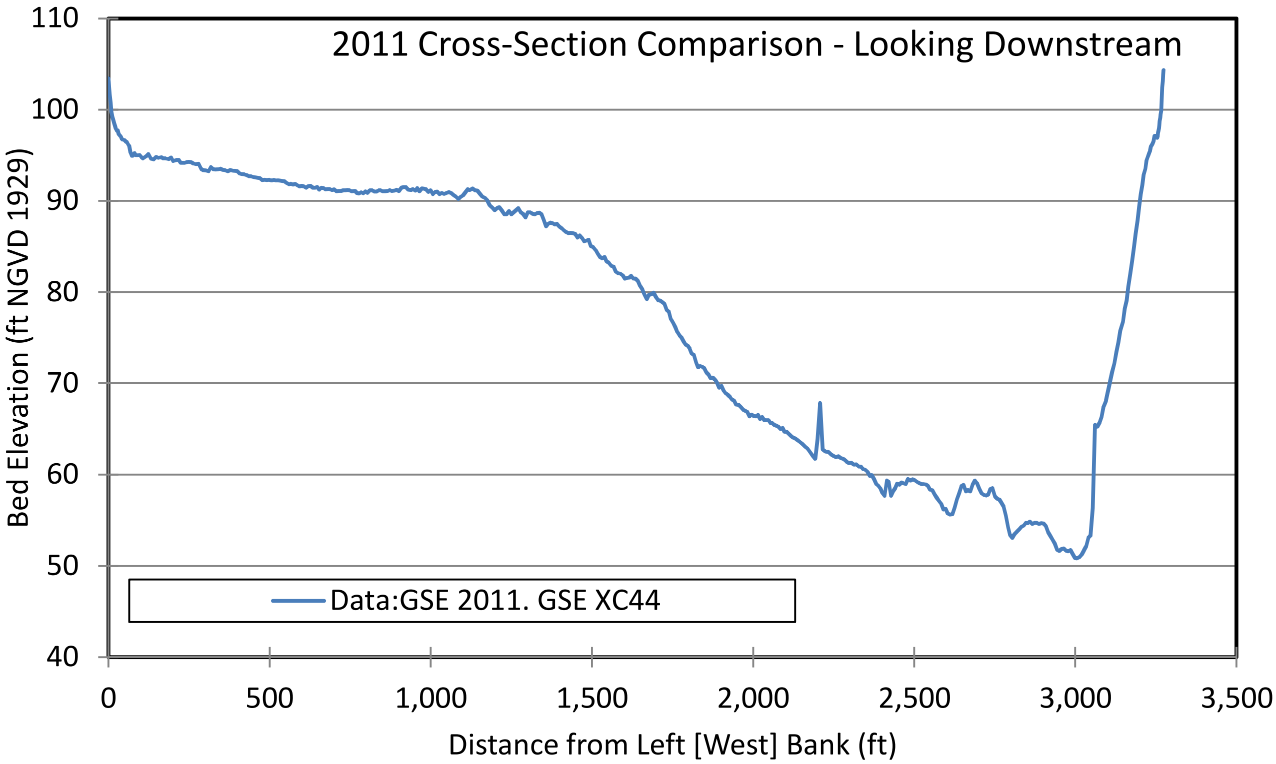
3,500


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC44
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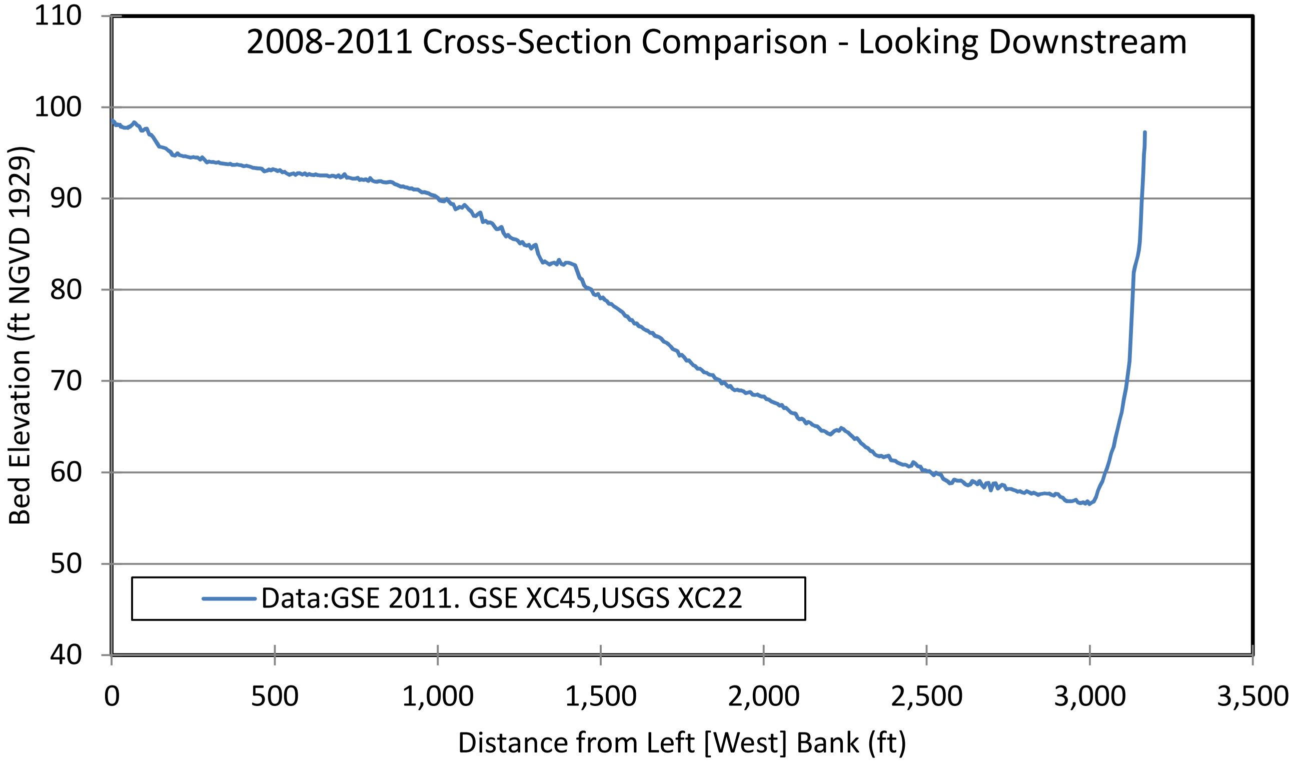

2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC45,USGS XC22
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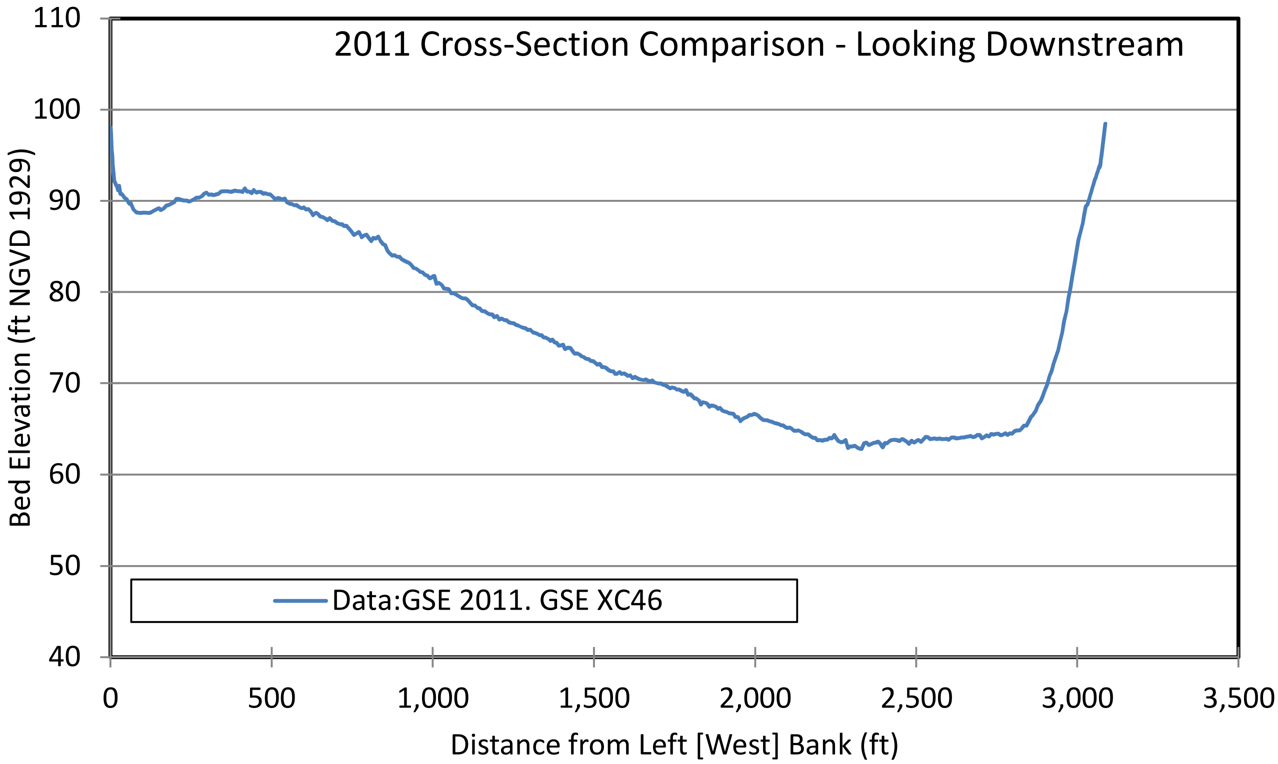
3,500
Distance from Left [West] Bank (ft)



2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC46
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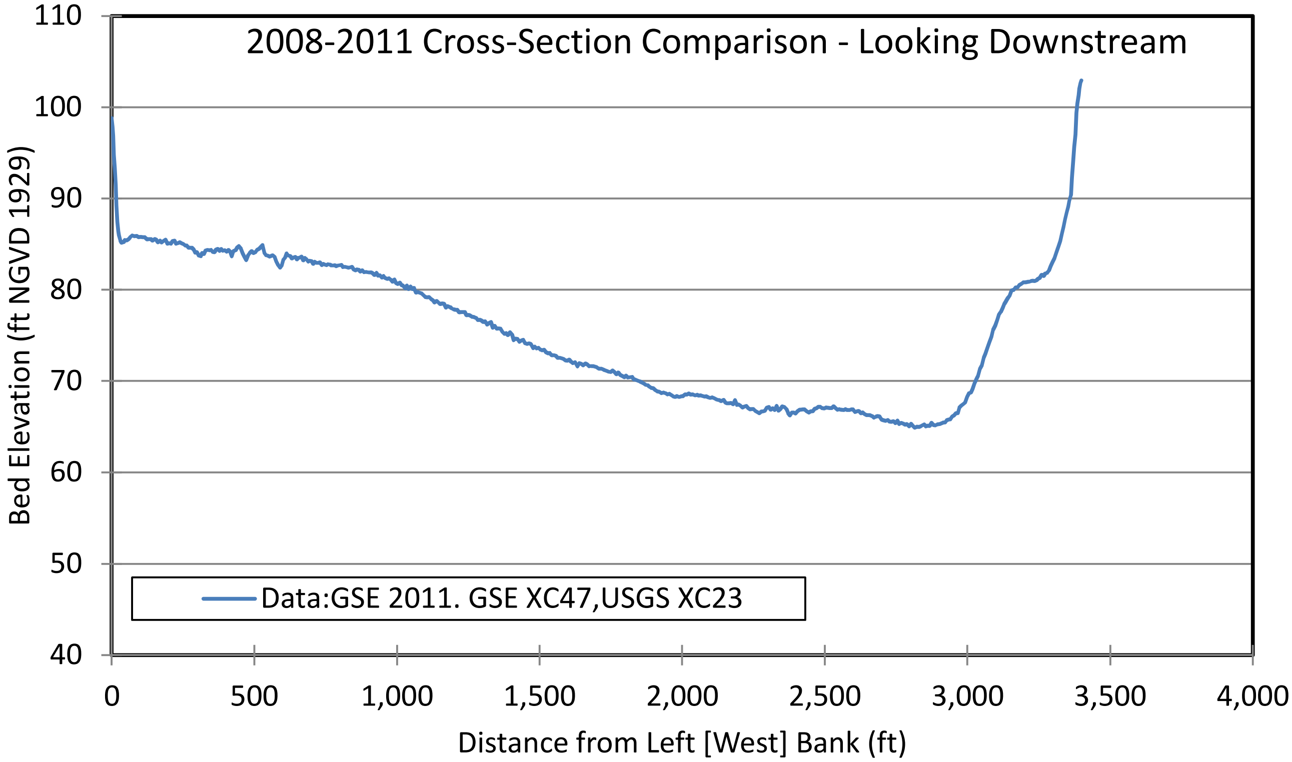
2,500
3,000
3,500
Distance from Left [West] Bank (ft)


2008-2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
Data:GSE 2011. GSE XC47,USGS XC23
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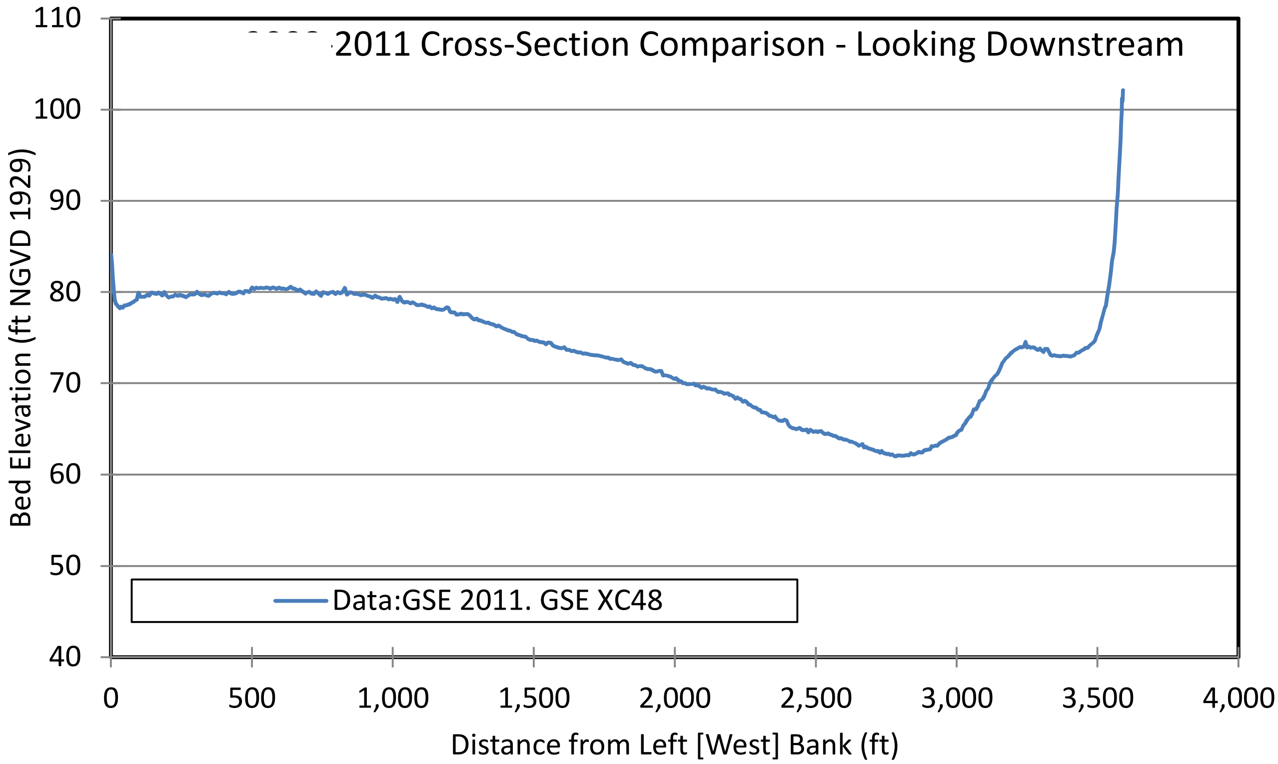
1,000
1,500
2,000
2,500
3,000
3,500
4,000
Distance from Left [West] Bank (ft)


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
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100
90
80
70
60
50
40
Data:GSE 2011. GSE XC48
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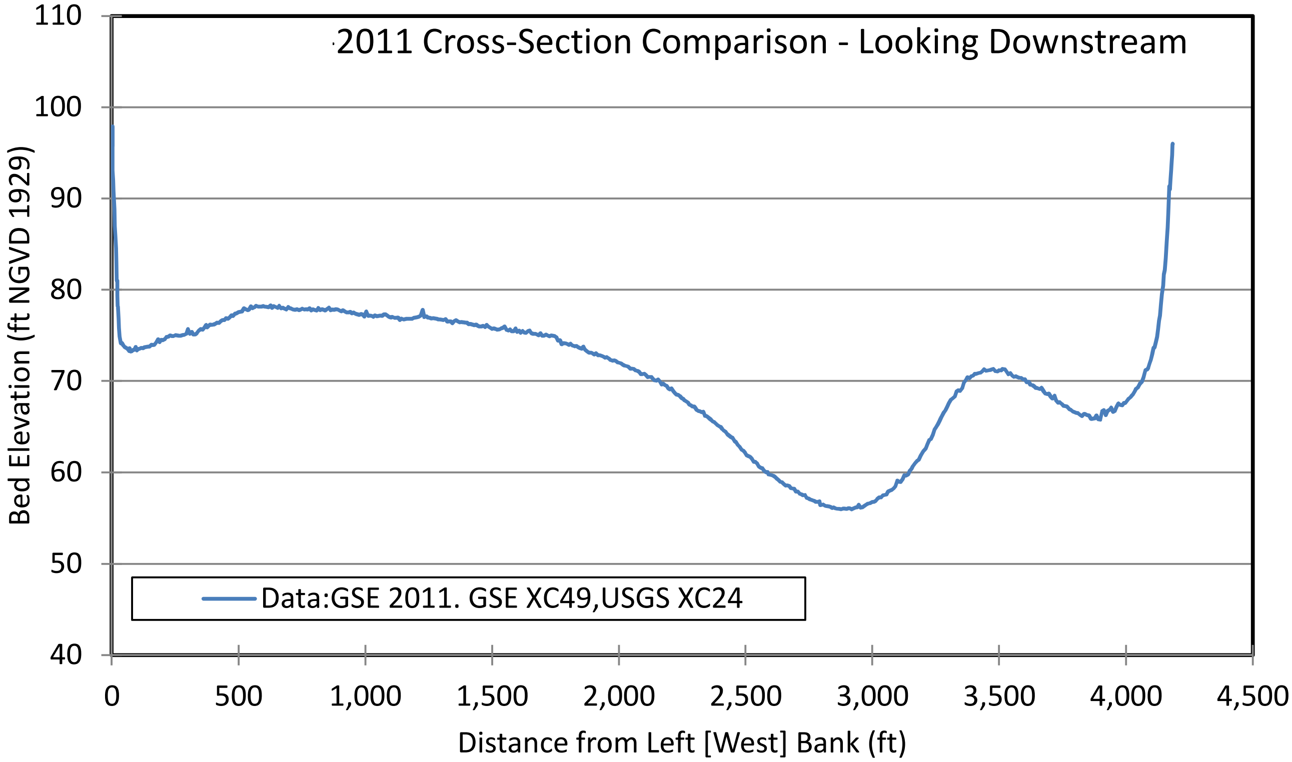
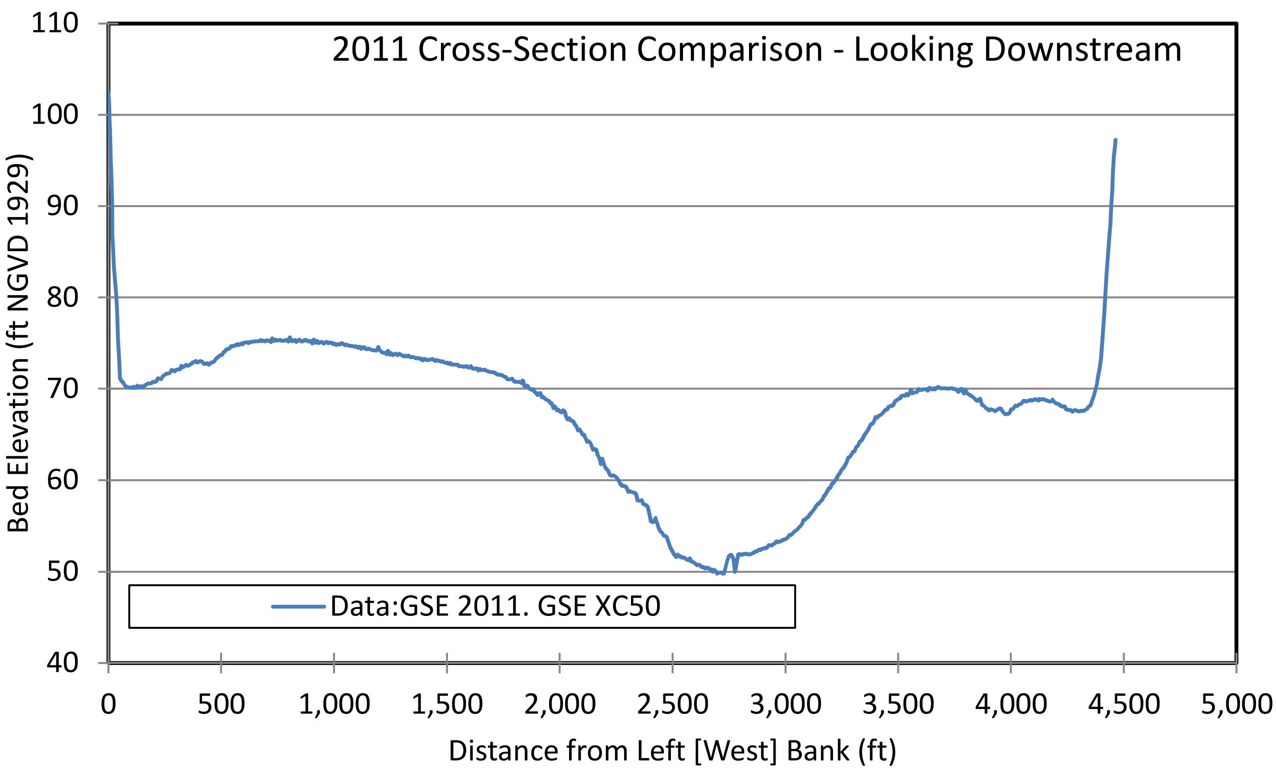
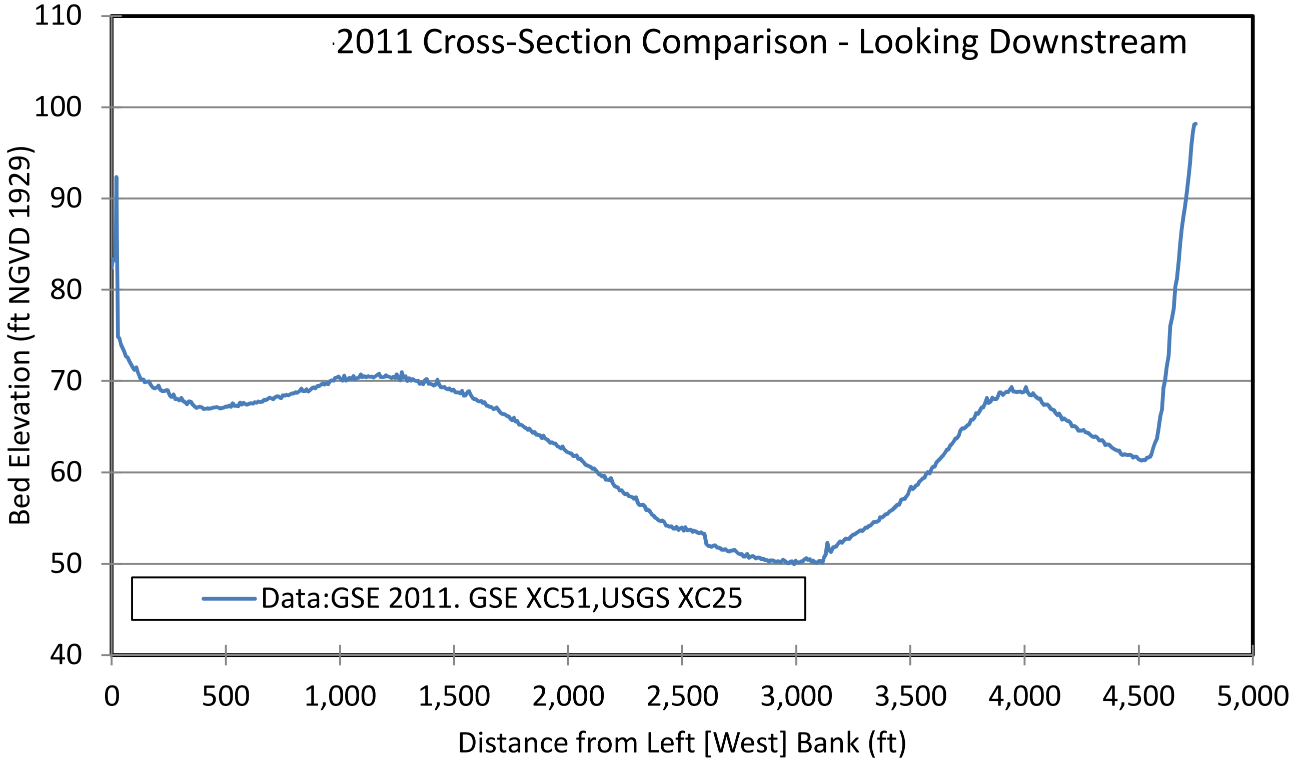
3,500
4,000
Distance from Left [West] Bank (ft)


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC49,USGS XC24


2011 Cross-Section Comparison - Looking Downstream
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
Data:GSE 2011. GSE XC50



2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC51,USGS XC25
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
110
100
90
80
70
60
50
40
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500
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2,000
2,500
3,000
3,500
4,000
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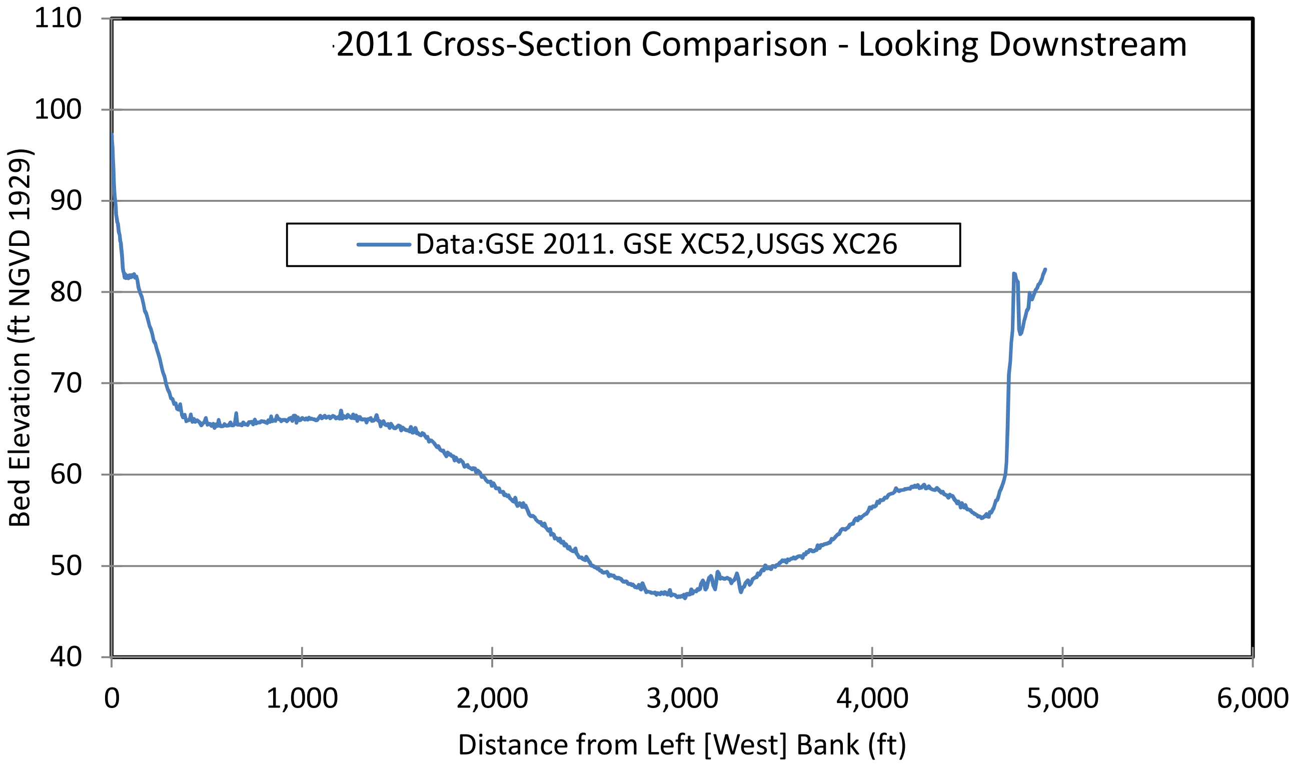
5,000



2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC52,USGS XC26
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
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100
90
80
70
60
50
40
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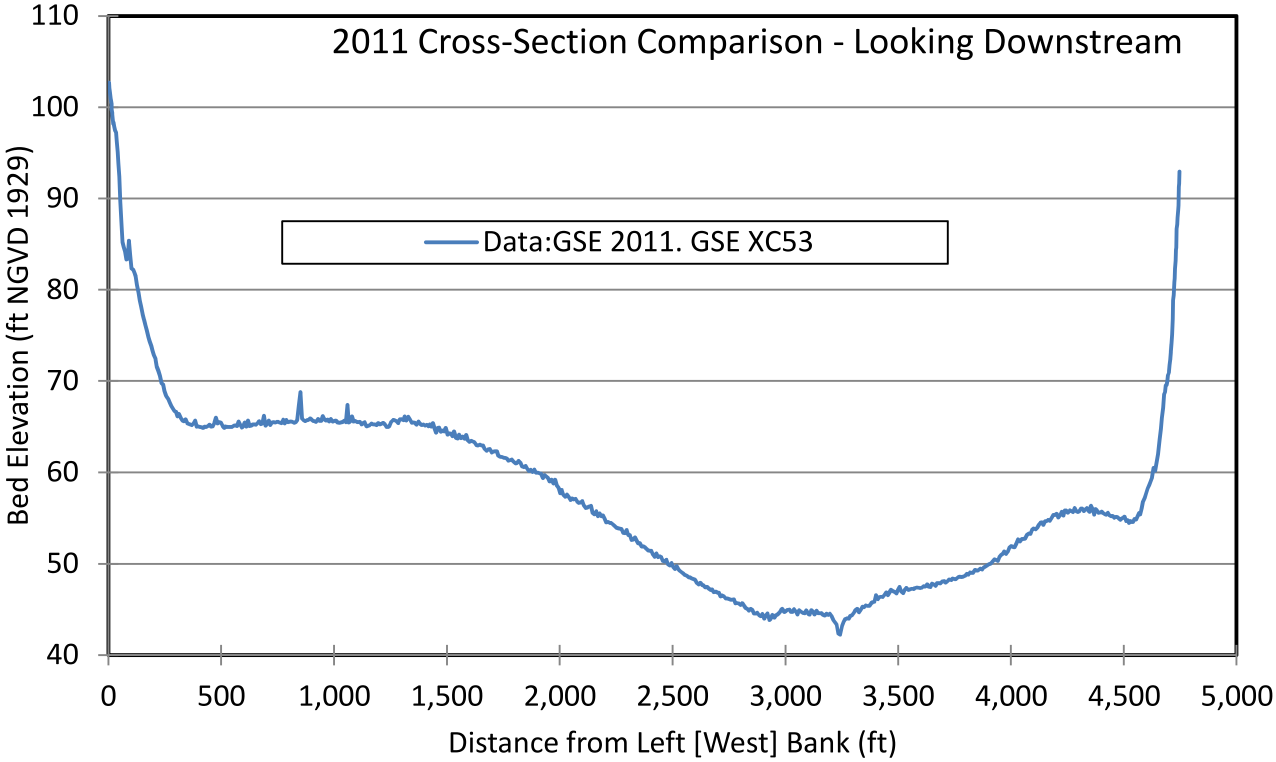
1,000
2,000
3,000
4,000
5,000
6,000


2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC53
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
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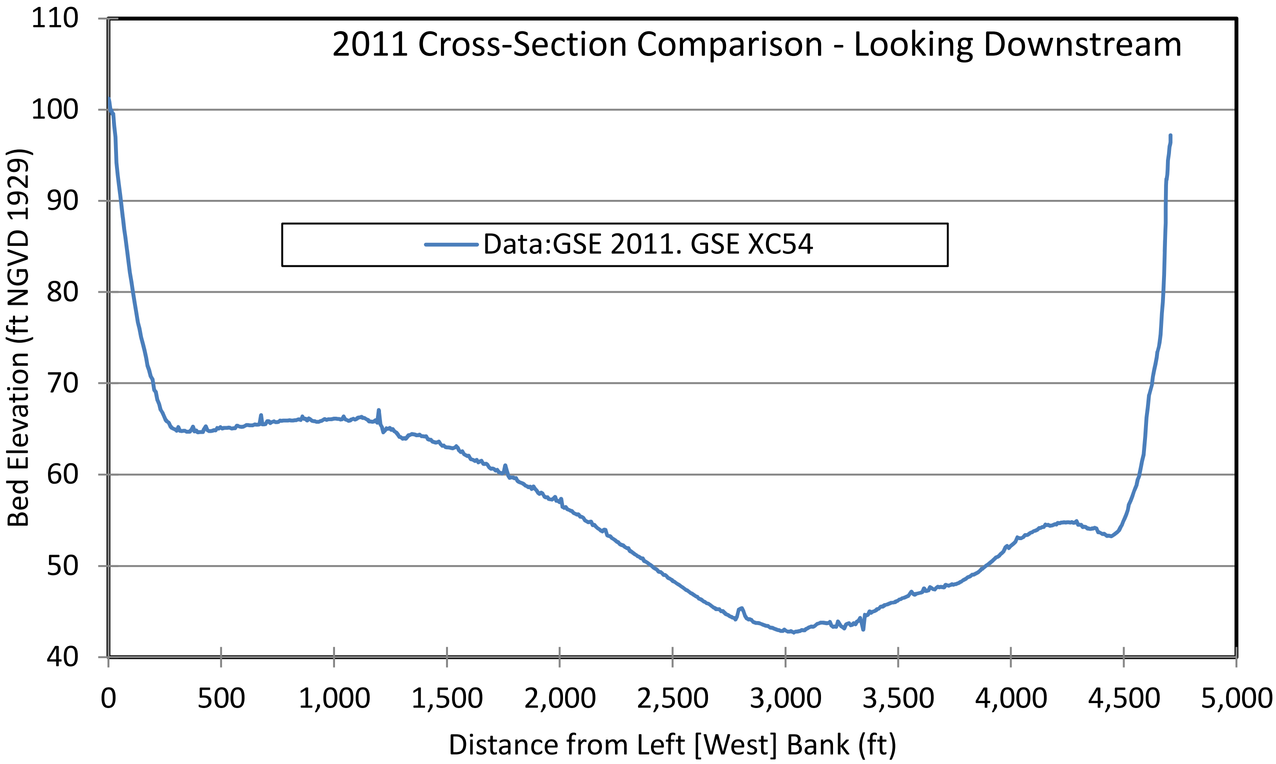
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)


2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC54
Bed Elevation (ft NGVD 1929)
110
100
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80
70
60
50
40
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3,500
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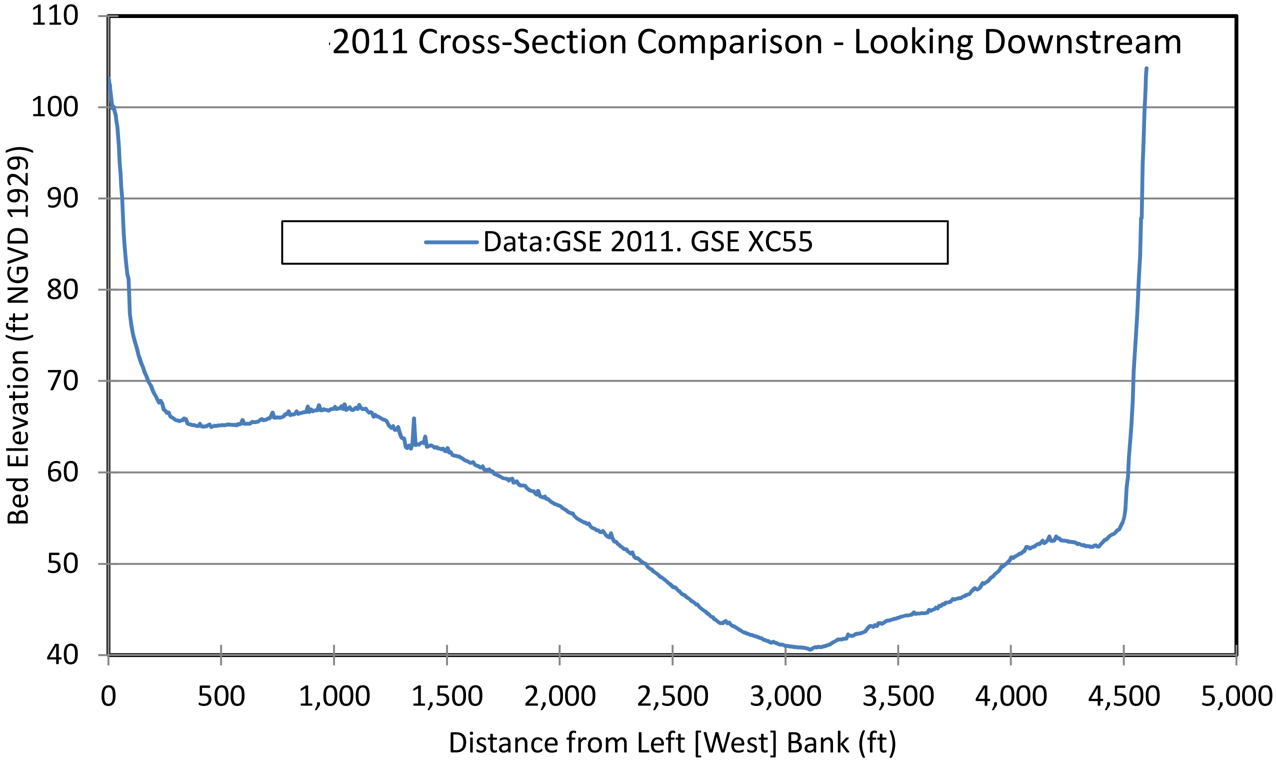
4,500
5,000
Distance from Left [West] Bank (ft)



2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC55
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
110
100
90
80
70
60
50
40
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500
1,000
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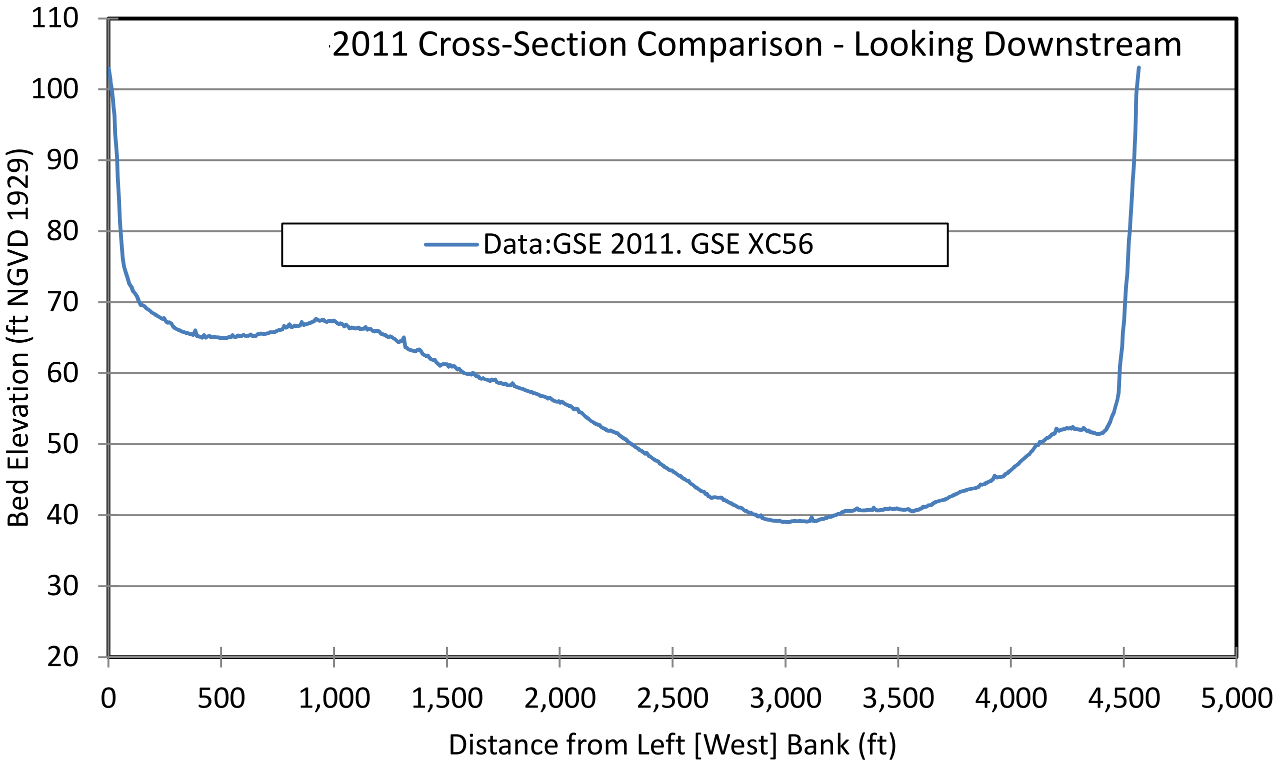
2,000
2,500
3,000
3,500
4,000
4,500
5,000



2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC56
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
110
100
90
80
70
60
50
40
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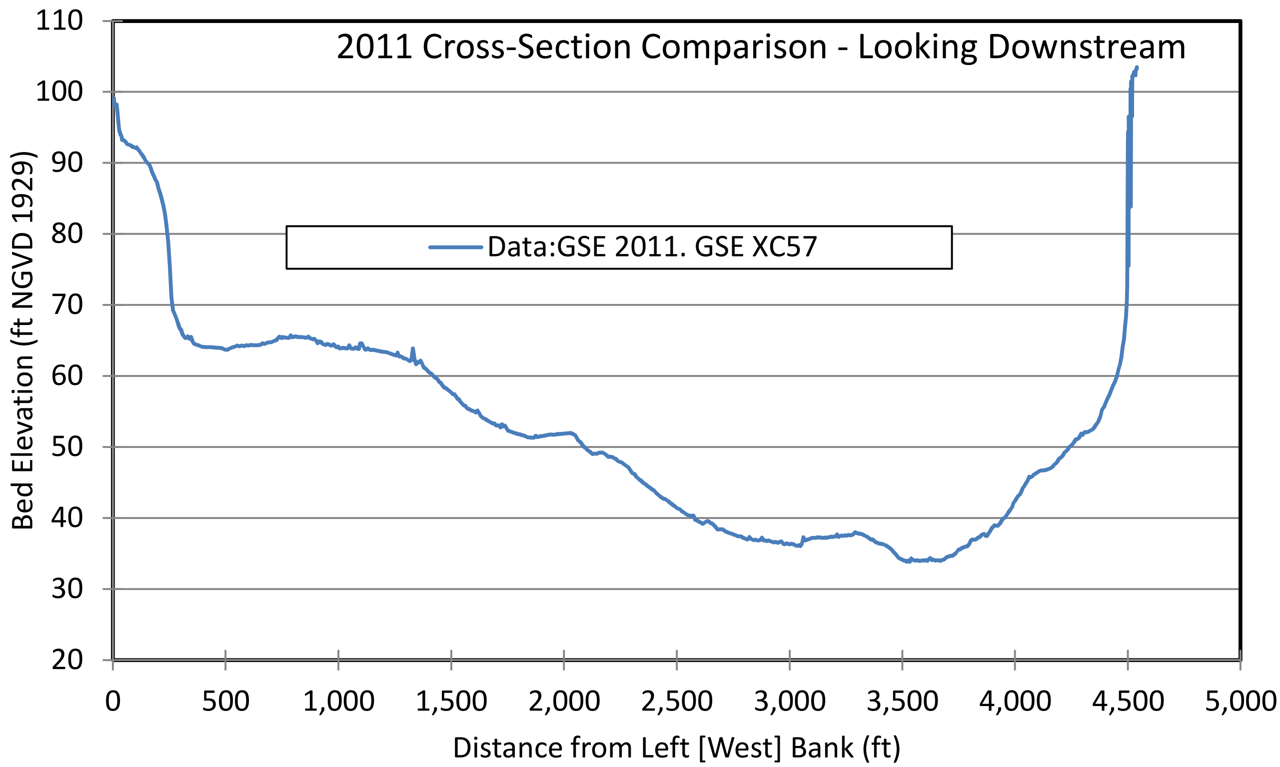
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000



2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC57
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
110
100
90
80
70
60
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40
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20
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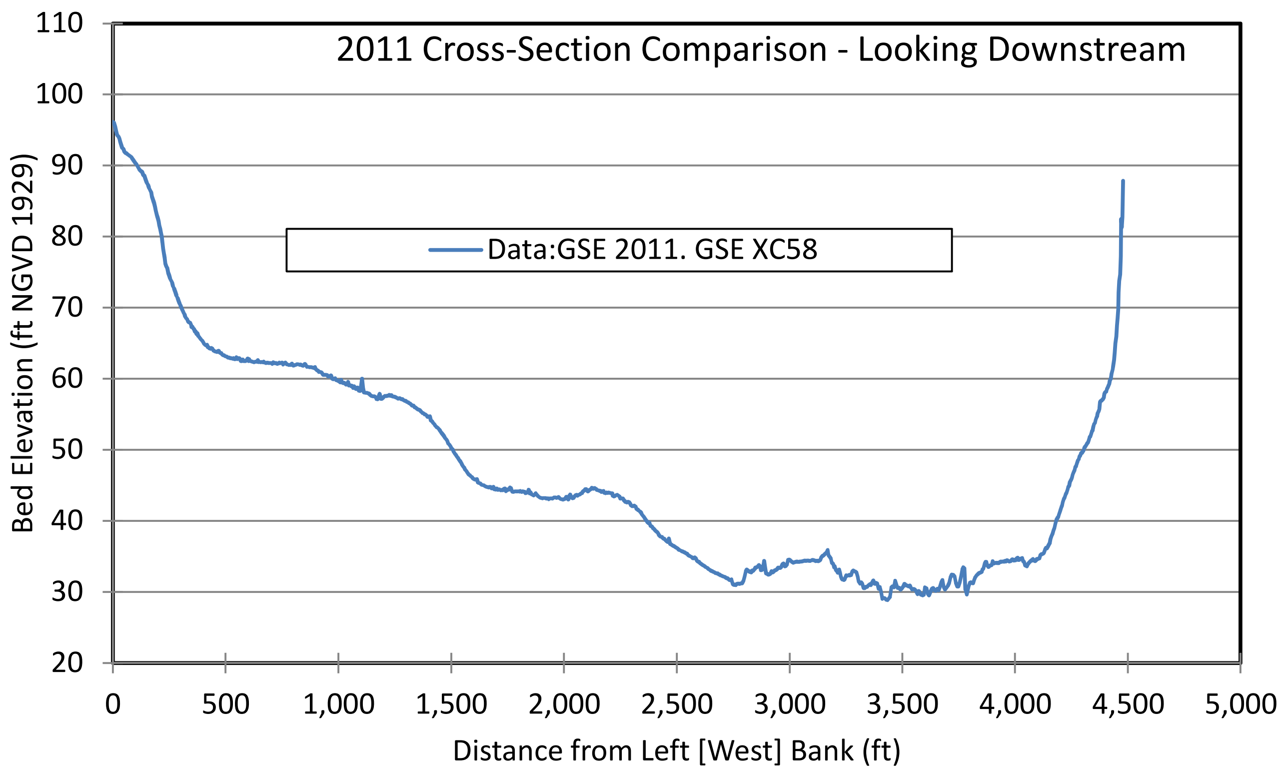
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000



2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC58
Bed Elevation (ft NGVD 1929)
Distance from Left [West] Bank (ft)
110
100
90
80
70
60
50
40
30
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500
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1,500
2,000
2,500
3,000
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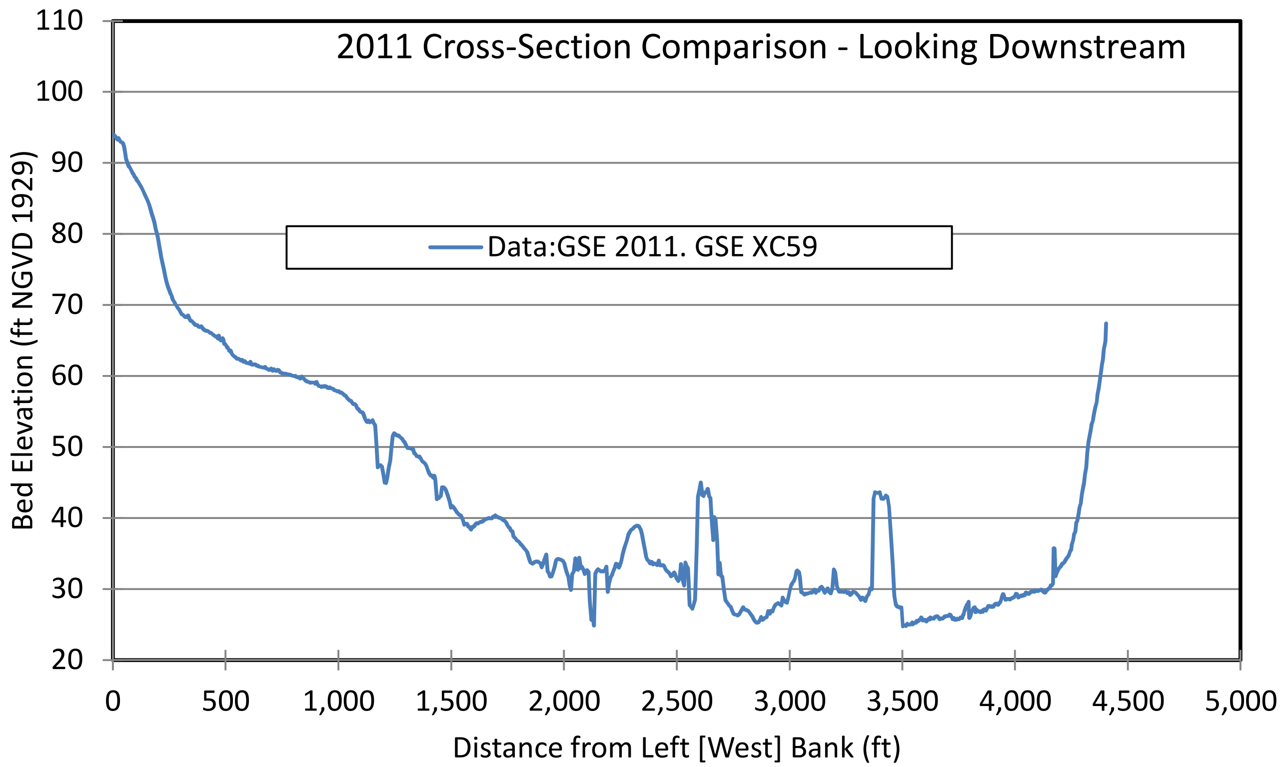
4,500
5,000



2011 Cross-Section Comparison - Looking Downstream
Data:GSE 2011. GSE XC59
Bed Elevation (ft NGVD 1929)
110
100
90
80
70
60
50
40
30
20
0
500
1,000
1,500
2,000
2,500
3,000
3,500
4,000
4,500
5,000
Distance from Left [West] Bank (ft)

Appendix H:
Literature Search Findings Report

Attachment H-1:
Evaluation of Reservoir Sediment Management Implementation

Attachment H-2:
Literature Search Overview Presentation

APPENDIX H: Introduction

A literature search was conducted on managing watershed/reservoir sedimentation. Findings and lessons learned from the literature search were incorporated into refining sediment management strategies for this Assessment. Results of this literature search are presented in this appendix.

Literature Search

Lower Susquehanna River Watershed Assessment

USACE

September 2012

Table of Contents

INTRODUCTION

This literature search was undertaken to review, analyze, and synthesize literature on managing watershed/reservoir sedimentation around the nation and the world. Findings and lessons learned will be incorporated into refining sediment/nutrient management strategies for the Lower Susquehanna River Watershed Assessment (LSRWA). A summary of findings, trends and conclusions are discussed herein and literature is organized into “Domestic” and “Overseas” literature. Attachment 1 to this literature search is a spreadsheet of literature evaluating whether a sediment management measure was implemented. Attachment 2 is a presentation providing an overview and findings of this literature search.

DOMESTIC

1. *Capitol Lake Adaptive Management Plan Final Report*

Location: State of Washington, United States
Waterbody/Dam: Deschutes Watershed/Deschutes River (252 miles)
Parties involved: Capitol Lake Adaptive Management Plan (CLAMP) Steering Committee, City of Olympia, City of Tumwater, Washington Department of Ecology, Washington Department of Fish and Wildlife (WDFW), Washington Department of General Administration (GA), Washington Department of Natural Resources (WDNR), Squaxin Island Tribe, Thurston County, Port of Olympia
Methods Used/Proposed: Dredging
Citation:
Capitol Lake Alternatives Analysis - Final Report. Rep. Seattle: Herrera Environmental Consultants, 2009. Print.

Summary

Capitol Lake is located in Olympia, Washington. A group called the Capitol Lake Adaptive Management Plan (CLAMP) Steering Committee is working on ways to improve the area. Sediment is carried downstream from the Deschutes River and is trapped by the dam that forms Capitol Lake. The Steering Committee finds this to be a problem for several reasons, including water quality, recreation and wildlife, and public safety because the sedimentation creates a higher risk of flooding the city. The reports suggest two possible solutions (managed lake or removing of the dam) and feasibility of each method in each issue paper. Both methods require some dredging. Any dredged material could be taken to open water dump sites or used as construction fill. The main concern is that the sediments at the inlet are known to be contaminated. Dredging needs were described in two categories: initial dredging and maintenance dredging. Disposal options considered were open-water disposal, beneficial reuse for mine reclamation, beneficial reuse for shoreline or nearshore restoration.

If the lake is managed, regular dredging of the entire area down to 13 feet is necessary. Sediment traps (holes) would need to be re-excavated every four to five years and the whole lake needs would need to be dredged to the 13 foot level every nine years.

Removing the dam is one possible solution which would restore the estuary. Regular dredging of the inlet would still be necessary. The water would be a mix of salt and freshwater. The Steering Committee produced their final report on alternatives for the lake in July of 2009 and is awaiting a decision from the state of Washington which has the final say on the future of Capitol Lake.

Costs/Funding:
Infrastructure Costs-$2-$4 million
Maintenance Costs-$39.8-$134.7 million

Amount of Sediment: 1.7 million cubic yards has accumulated in the lake, 875,000 cubic yards needs to be removed. Annual Rate is about 35,000 cubic yards

2. Condition of Sixmile Creek and Watershed

Location: City of Ithaca, Tompkins County, New York, United States
Waterbody Size: Six Mile Creek Watershed
Waterbody/Dam Size: extends about 20 miles and covers an area of approximately 46.5 square miles
Parties Involved: N/A
Methods Used/Proposed: Hard engineering structure, remove the dam
Citation:
http://www.egovlink.com/public_documents300/ithaca/published_documents/Public_Works/Water_and_Sewer/Watershed/SMC%20Management%20Overview.PDF

Milone and MacBroon, Inc., 2003, Flood Mitigation Needs Assessment; Six Miles Creek, Tomkins County, New York
Sixmile Creek: A Status Report, 2007. 35p, http://ecommons.library.cornell.edu/handle/1813/8354
Leopold, Luna, 1994, A View of the River, Harvard University Press
Keller, E. A. 2001. Environmental Geology, Upper Saddle River, New Jersey, Prentice Hall
Rosgen, Dave, 1996, Applied River Morphology, Wildland Hydrology, Pagosa Springs, Colorado, http://www.communityscience.org/SixMile/SixMileCreel.html
Langen, et. Al., 2006. Environmental Impacts of Winter Road Management at the Cascade Lakes and Chapel Pond. Clarkson Center for the Environmental, Report #1.

Summary

Largest problem in Sixmile Creek (Ithica New York) is the high load of suspended sediment as a result of erosion along the main channel and tributaries, predominantly from Brooktondale downstream to the dams. Several priorities for future research were identified. These include: 1) Quantifying the amount and source of bedload sediment moving through the watershed; 2) Describing how channel sinuosity and channel cross-sectional shape has evolved during the 20th century; 3) Quantifying the amount and source of the sediment input to Sixmile Creek from its tributaries, and 4) Determining the effects of road drainage ditches on storm-water runoff and channel erosion. Another factor with largely unknown effects on the Sixmile system is climate change.

Continued incision of and slumping along these channels will follow the equilibrium trend now occurring in the main channel and will lead naturally to a reduction in sediment supply, although the time frame is uncertain. The most reasonable solution to erosional problems in these reaches is the use of hard engineering structures to control the channel location. Alternative is to remove the dam. This alternative would result in the transport of several hundred thousand cubic yards of sediment stored behind the dams downstream into the Cayuga Inlet, where efforts are underway to dredge sediment already accumulated there. If abandoned for water supply and not removed, the dams must still be maintained, although they could be allowed to fill. Once the dam is filled with sediment, the sediment load transported by Sixmile Creek will pass through the dam and ultimately be deposited into Cayuga Inlet. If the Inlet is to remain navigable, a decision will have to be made whether to remove sediment from behind the dams or from the Inlet.

Channel erosion control projects such as Natural Channel Design (NCD) projects, in particular those following the Rosgen protocol have been implemented (Barrile project), and are being planned for other reaches of Sixmile Creek.

Cost/Funding: Not Provided

Amount of Sediment: Several hundred thousand cubic yards

3. Dredging Slated for Russell Plant Dam

Location: Russell, Massachusetts, United States
Waterbody/Dam: Westfield River Watershed (78.1 miles)
Parties Involved: Swift River Hydro Operations and W. Davis Hobbs
Methods Used/Proposed: Dredging
Citation:
LaBorde, Ted. "Dredging slated for Russell plant dam." *The Republican* 15 Nov. 2009: n. pag. *The Republican* . Web. 16 July 2012.

Summary

Swift River Hydro Operations Company has plans in place to dredge the dam they own that is located on the Westfield River in Russell, Massachusetts. Dredging is set to start in 2009 by lowering the dam over 24 hours, then dredging the material. The lowering of the dam is temporary, and "There will be very little, if any, disruption of the Westfield River during the operation," according to the president of the company. Lowering will occur at the forebay (immediately upstream from the powerhouse) and tailrace (channel that carries water away from the dam) so that a silt fence can be installed before dredging. This keeps disturbance from dredging within the fenced area. The hydro plant has not been used since 1994 when it stopped supplying power to the local paper mill (Westfield River Paper Company closed at the same time), but Swift River bought the hydro plant in 2001. The company is spending $3.5 million to rehabilitate the plant. The goal after dredging is complete is to produce approximately 4.5 million kilowatts of energy but it will also include the installation of a fish ladder other wildlife protection structures.

Cost/Funding: estimated $3.5 million rehabilitation project

Amount of Sediment: 1,200 cubic yards

4. *Ecological-Economic Assessment of a Sediment-Producing Stream Behind Lower Granite Dam on the Lower Snake River*

Location: Pacific Northwest Region, Wyoming, Idaho, Oregon and Washington, United States
Waterbody/Dam: Snake River (1,078 miles)
Parties Involved: N/A
Methods Used/Proposed: Dredging
Citation:
Brusven, Walker, Painter, Biggam, 1995, Regulated Rivers: Research and Management, Vol. 10, 373-387

Summary

The Lower Snake River flows through Idaho and Washington. Lower Granite Dam is one of eight dams on the Lower Snake River and is the primary receiving pool that receives sediments that are leaving Idaho from the Colorado and Lower Snake River. The main applications of this river are fisheries, navigation, recreation, hydropower generation, and irrigation. With approximately 611,680 cubic meters (~800,050 cubic yards) of sedimentation collecting annually, it has interfered with navigation and flood control operations. Dredging has taken place intermittently in the 12 years since the report was published but the process is costly. The authors of the paper admit that dredging is inevitable, but the amount of dredging can be reduced by using several best management alternatives after finding the critical sediment producing watersheds from upstream.

Cost/Funding: Not Provided

Amount of Sediment: 611,680 cubic meters (~800,050 cubic yards) of sedimentation collecting annually

5. Grove Lake Sediment Bypass

Location: Northeastern Nebraska, United States
Waterbody/Dam: Grove Lake
Parties Involved: The Nebraska Game and Parks Fisheries' Department
Methods Used/Proposed: Dredging
Citation:

Hotchkiss, R.H. and Hauang, X. 1995. Hydrosuction Sediment Removal Systems (HSRS): Principles and Field Test. ASCE Journal of Hydraulic Engineering, 121 (6) 479-489, June

Ingersoll-Rand Corporation. 1988. Cameron Hydraulic Data, Woodcliff Lake, NJ 07675

Maidment, David, R. 1993. Handbook of Hydrology, McGraw-Hill, Inc. New York

Summary

Grove Lake, formed by an impoundment structure (dam) on Verdigre Creek, is located in northeastern Nebraska and traps approximately 2,466 cubic meters (~3,225 cubic yards) of sediment every year. Large amounts of sediments have created a delta in the inlet of the lake due to large amounts of agricultural grazing in the Verdigre Creek Watershed above the lake. The sediment is composed of very fine sand to medium gravel. Verdigre Creek is a naturally reproducing trout stream and a trout rearing station stocks trout both above and below Grove Lake. There were a few options that were abandoned due to infeasibility or logistics issues. The first option was to create a sediment trap by building a concrete basin that extended across the creek. Another method explored was dredging the channel with a small pump and stockpiling the material but there was a lack of storage area and scheduling problems. A hydrosuction system was also investigated but as some particles were larger than average and suction needed would be greater, this concept was abandoned. The option chosen for the project was to install a siphon in the lake that would transport sediment and discharge it below the dam. Under current operating conditions, the siphon bypasses approximately 50 percent of the sediment entering the lake. If remaining material is dredged in addition to being siphoned, it is predicted that the life of the lake will be 100+ years.

About the Siphon:

- Made of PVC pipe
- Height of siphon above discharge point = 32 ft.
- Cost to install = $42,000 (labor provided by Nebraska Game and Parks employees)
- Water Surface is at 32
- Total length 1000 meter (3200')
- Total change in elevation 10 meter (32')
- Flow is from left to right
- Entrance is in Verdigre Creek
- Discharge is below dam forming Grove Lake

Cost/Funding: $42,000

Amount of Sediment: 2,466 cubic meters (~3,225 cubic yards) of sediment every year

6. Louisiana Coastal Restoration

Location: Lousiana, United States
Waterbody/Dam: N/A
Parties Involved: U.S. Army Corps of Engineers and Research and Development Center
Methods Used/Proposed: Hydraulic Transport of Sediment
Citation:
U.S. Army Corps of Engineers and Research and Development Center Website

Summary

Application of Long Distance Conveyance (LDC) of Dredged Sediments to Louisiana Coastal Restoration. LDC projects are defined as those Louisiana coastal restoration projects that involve hydraulic transport of slurry (mixture of sediment and water) through pipelines for distances of 16 km (10 miles) or greater. Long distance transport is a mature technology that has been used efficiently for applications like coal and iron ore transport.

Cost/Funding: N/A

Amount of Sediment: N/A

7. Hydro-suction Sediment Removal Systems for Woodside I and Woodside II Dams, Final Report.

Location: Twelvemile Creek, South Carolina, United States
Waterbody/Dam: N/A
Parties Involved: Department of Civil and Environmental Engineering, Washington State University/South Carolina District of U.S. Geological Survey
Methods Used/Proposed: Hydro-suction Sediment Removal System
Citation:
Appendix F: HEC-6 Sediment Transport Model. 1993. Remedial Investigation Report.
Atkinson, Edmund. 1994. Vortex-Tibe Sediment Extractors. I. Trapping Efficiency

Summary

The purpose of this report is to describe Hydrosuction Sediment Removal System (HSRS) alternatives for Woodside I and Woodside II dams (WSI and WSII, Respectively). An HSRS is a pipeline system capable of transporting a water/sediment mixture past a dam using the natural energy represented by the difference in water surface elevations between the upstream and downstream sides of the dam.

The bypass alternatives assume the pipeline entrance is located upstream from the dam at a point near where the reservoir begins. Thus, sediment would be intercepted before depositing in the reservoir, and would be passed downstream. Bypass pipeline systems are longer than dredge systems. A dredge system collects sediments near the face of the dam after the sediments have been deposited and moved slowly through the reservoir along the bed towards the dam.
It was found to be technically feasible to employ HSRS bypassing or dredging systems to move the annual sediment load past Woodside I and Woodside II dams with no external source of energy other than a winch and pulley system in the case of HSRS dredging.

Costs for pipeline and installation vary from about $160,000 for short dredging systems to about $865,000 for the longer bypassing systems. Annual losses to hydropower vary from a low of $3,500 for short dredging systems at both dams to a high value of $11,200 for the longer bypassing systems.

The required pipe size for HSRS systems depends upon pipeline length, sediment load and size of grains, and available energy to drive the water/sediment mixture through the pipe. Available energy is represented by the difference between the water surface elevations above the pipe inlet and outlet. Six alternatives were analyzed for the two dams; two for WSI and four for WSII. The range for available head is 38.2-42.05 feet and total pipeline range from 850 -3700 feet. The pipe +installation cost range by the size. The ranges are between $15.90/ft+$17.75ft to $43.50/ft+$30.00/ft. This study use 24 inches and 36 inches diameter pipes.

Clogged pipe entrances and pipelines represent the major maintenance issues for HSRS installations. The dredging alternative collection pipeline may also be easily back flushed using a similar pump system mounted on the dam. This research shows that HSRS is a feasible method for maintaining sediment balance both Woodside I and II.

The bypassing alternative requires no power sources and will likely intercept 75% of the sediment load. This will cause a decreasing the need for maintenance dredging for flushing near the dam. The dredging systems are very inexpensive and would maintain a 50 foot radius sediment free zone.

Cost/Funding: N/A

Amount of Sediment: N/A

8. Hydro-Suction Sediment-Removal Systems (HSRS) – Principles and Field Test

Location: Elkhorn River, Nebraska, United States
Waterbody/Dam: Lake Atkinson, on the Elkhorn River
Parties involved: City of Atkinson, the Upper Elkhorn Natural Resources District, the Nebraska Game and Parks Department, the Nebraska Department of Environmental Quality, and the U.S. Army Corps of Engineers
Methods Used/Proposed: Hydro-suction Sediment Removal System
Citation:
Hotchkiss H., Huang X., 1995, Hydro-suction Sediment-Removal Systems (HSRS): Principles and Field Test, Journal of Hydraulic Engineering

Summary

Hydrosuction sediment-removal systems (HSRS) remove deposited or incoming sediments from reservoirs using the energy represented by the difference between water levels upstream and downstream from a dam. Field tests were carried out at Lake Atkinson, on the Elkhorn River, in Nebraska. The field study demonstrated that several different inlet shapes are capable of removing deposited sediment at the rate that it enters the reservoir on an annual basis. The relatively low-cost, low-power requirement system may be designed to either dredge or bypass sediments to downstream receiving waters. Potential benefits include partially restoring pre-dam conditions downstream and extending the life of the project. Increased turbidity levels downstream, similar to those found upstream from the reservoir, may or may not be a negative impact.

There are two types of hydrosuction sediment removal. Hydrosuction dredging, in which deposited sediment is dredged and transported to either a downstream receiving stream or to a holding or treatment basin. Hydrosuction bypassing, in which incoming sediment is transported without deposition past the dam to the downstream receiving stream.

Conventional methods of hydraulic dredging use a mechanical pump to supply the driving power to remove deposited sediment from a reservoir. Hydrosuction dredging removes sediment from reservoirs using the hydraulic head represented by the difference between the water levels upstream and downstream from the dam. The water-sediment mixture is transported through the pipeline until it is discharged into the relatively clear water that passes the dam through outlets or hydropower turbines. Sediments need not be stored in a spoil area. Two variations of hydrosuction dredging have been used: bottom discharge and siphon dredging. In siphon dredging, the discharge pipe is passed over the top of the dam, and in bottom dredging the pipe passes through low-level outlets at the dam. Both methods may employ a floating barge, which moves the pipeline inlet around the reservoir to access a larger area. Hydrosuction bypassing would employ the same principle to transport sediment, but would feature a permanent inlet station upstream from the reservoir deposition zone to collect the sediment into a pipe or pipelines. The sediment/water mixture is transported through the pipeline and past the dam, where it is returned to downstream receiving waters.

In the dredging mode, sediments can be evacuated in order to selectively introduce desirable grain size distributions downstream (assuming contaminants do not preclude introducing the sediments into the receiving waters). The releases are more continuous over longer durations to more closely match clear water release transport capacity, thus reducing the shock associated with flushing techniques. Less water is used, thus conserving reservoir water storage. In the bypassing mode. Any method that reintroduces sediment into downstream waters will increase turbidity. The objective with HSRS techniques is to return the downstream system to its more natural, predam conditions by releasing sediment in accordance with the downstream transport capacity. If the downstream habitats have adjusted to a clearer water regime, HSRS activity will change the system. Whether or not this change is desirable or acceptable must be evaluated on a case-by-case basis.

Ancillary facilities for hydrosuction dredging may include a raft or barge to move the pipeline inlet in the reservoir, and externally powered water jet or cutter head at the inlet to break up consolidated sediments (if required), and instrumentation to monitor the operation. For reservoirs larger than a few acres a barge is used for efficient movement of the inlet portion of the pipeline.

China to date has the most experience with hydrosuction dredging. The Chinese have used either the siphon or bottom withdrawal modes in 10 reservoirs, beginning in 1975. In all cases, the fertile sediment-laden water was passed into irrigation canals downstream and spread on cropland to replenish the topsoil and recharge the nitrogen content. Often the outlet is attached to downstream irrigation works and spread the sediment-laden water on fields to replenish topsoil and nitrogen content.

Objectives can be dredging for restoration of lost storage or hydrosuction bypassing for maintaining storage. Important factors include: sediment location (reservoir sediment surveys should be conducted to determine where sediment deposits are relative to the dam; sediment size characterization: the systems are most effective for transporting fine, non-cohesive materials head and pipeline diameter depend on this, the presence of consolidated sediment and debris will require an externally powered cutter head or jet at the pipeline entrance; contaminants: contaminated sediments may be present in the reservoir, a thorough sampling program should be conducted to determine the extent and toxicity of any contaminants and a land-use history of the watershed can provide important clues as to potential contamination problems; placement of transported sediment, sediment may be passed to downstream receiving waters only if there are no objectionable levels of contaminants present, if there is sufficient clear-water flow to transport the pipeline sediment delivery without significant deposition downstream, and if all permitting activities have been successful; reservoir operation, the HSRS depends on clear-water discharge downstream, if flow only occurs during wet seasons or after heavy rain, the HSRS should be controlled to release sediment only during these times; pipeline diameter selection, pipeline will need to be at least slightly larger than one designed to pass clear-water flow; environmental impacts must be considered such as the effects of increased turbidity levels downstream, changes in water chemistry, and impacts of sediment-removal upstream; all possible regulatory Parties should be contacted early in the proposal phase to fully inform them of plans and possible impacts.

Cost/Funding: N/A

Amount of Sediment: N/A

9. Lessons Learned from a Dam Failure

Location: Village of Chagrin Falls, Ohio, United States
Waterbody/Dam: Lower Lake Dam
Parties involved: Federal Emergency Management Agency (FEMA), Ohio Department of Natural Resources (ODNR)
Methods Used/Proposed: Rebuilding the dam
Citation:

Evans, James E., Scudder D. Mackey, Johan F. Gottgens, and Wilfred M. Gill. "Ohio Journal of Science." *Lessons from a Dam Failure* 100 (n.d.): n. pag. Web.

Summary

The IVEX Dam in northeastern Ohio failed on August 13, 1994 after a 70-year rainfall event. The dam was originally built in 1842 and has failed either partially or completely at least five times in 152 years. Before the most recent failure, the dam was 7.4 m (24.5 ft) tall, 33 m (109 ft) wide and attached to bedrock on one side and an earth filled dam on the other. Failure of the dam occurred because of a combination of the following factors: inadequate spillway design, lack of emergency spillway, large loss of capacity from a large amount of sedimentation (86% over 152 years), and poor dam maintenance. The dam failure caused rapid incision of the stream bank and this changed the course of the river westward along the bedrock.

Cost/Funding: The cost of rebuilding the IVEX dam was estimated at $1-2.5 million.

Amount of Sediment: Accordingly, the total mass of sediment in the reservoir was found to be 246,000 metric tons, or an annual loading of 1,770 metric tons yr

10.Nebraska Valentine Mill Pond

Location: Valentine, Nebraska, United States
Waterbody/Dam: Valentine Mill Pond (15 acres)
Parties Involved: Middle Neobrara Natural Resources District (NRD), Nebraska Department of Environmental Quality, Nebraska Public Power District, Cherry County, Nebraska Game and Parks Commission, Nebraska Environmental Trust, City of Valentine
Methods Used/Proposed: Hydro-suction Sediment Removal System
Citation:
"Nebraska: Valentine Mill Pond." *Home*. N.p., n.d. Web. 12 Feb. 2014. <http://water.epa.gov/polwaste/nps/success319/state_ne.cfm#partners>.

Summary

Valentine Mill Pond was originally created to power a gristmill. Over the years the capacity of this pond has decreased from 30 acres to 15 acres. The pond has also been added to the Nebraska Department of Environmental Quality section 303(d) list for impairment for aquatic life. Some mechanical excavation of sediment was necessary, but the state needed to control the ongoing accumulation of sediments. The other method used is one designed by Rollin Hotchkiss, PhD. called the "hydrosuction sediment removal system." The system is a pipeline that catches the sediment as it enters the pond and travels around the dam and is discharged further down the creek. The system is unique because it also does not use any external energy. As a result of sediment removal system, the pond was taken off the 303(d) list in 2003 and serves agricultural needs and supports aquatic life.

Cost/Funding: Total Project Cost of $1.6 million

Amount of Sediment: Minnechaduza Creek, the pond's water source, was depositing as much as 60 tons of sediment into the lake daily

11.Potential for Increasing Storage Capacity in Los Padres Reservoir

Location: Carmel River, Monterey County, California, United States
Waterbody/Dam: Carmel River (36 miles)
Parties involved: The Monterey Peninsula Water Management District (MPWMD) Board of Directors
Methods Used/Proposed: Dredging
Citation:
Bell, Andrew M. "Potential for Increasing Storage Capacity in Los Padres Reservoir." Letter to David Gutierrez. 8 Apr. 2009. MS. California Department of Water Resources, Sacramento, California.

Summary

This letter outlines possible solutions to increase dam capacity. The Los Padres Dam was built in the 1940s and its capacity has decreased from 3,030 acre-feet to 1,760 acre-feet due to sedimentation. The letter outlines 3 different concept possibilities to increase the storage capacity of the reservoir. The first concept is to dredge the sediment that has built up behind the dam. The owner of the dam has asked for a feasibility study for dredging, but the author would like input from the Division of Safety of Dams on this. The second concept is to seasonally raise the reservoir level. This would change the level of the reservoir to make sure that during seasonal periods where precipitation levels or run-off is high, then the reservoir can accommodate these fluctuations. The third option offered to increase the capacity of the dam is to add on to the existing dam or remove and build a new dam.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

12.Regional Sediment Management

Location: N/A
Waterbody: N/A
Size of Waterbody: N/A
Parties Involved: U.S. Army Corps of Engineers, Institute for Water Resources (IWR)
Methods Used/Proposed: Regional Approaches to Sediment Management
Citation:
USACE, IWR Regional Sediment Management 2010

Summary

Implementation of the Regional Sediment Management Approach (RSM) to examine, apply and evaluate opportunities, practices, tools, benefits and impediments to applying regional approaches to sediment management. Lessons from these experiences are used to assist the field in applying the approach and to assist HQUSACE in developing policy and guidance.

Progress: Maintaining the navigability of ports and water Stakeholders met to hear their range of perspectives, and identify next steps for dredged material, sediment, and watershed managers to work together more in the future. Themes were protecting the environment; Conservation and restoration of estuaries and associated resources; Protecting water quality; Maintaining reservoir capacity ; Reducing flood and coastal storm damage; Managing watersheds; Managing coasts.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

13.Reservoir Conservation RESCON Volume I

Location: Algeria, China, Japan, Sudan, Switzerland, United States
Waterbody/Dam: Various Reservoirs
Parties Involved: N/A
Methods Used/Proposed: Research study
Citation:
Palmieri, Alessandro, Farhed Shah, George W. Annandale, and Ariel Dinar. "The RESCON Approach." *Reservoir Conservation* 1 (2003): 1-102.

Summary

This book outlines the principal methods and provides references for further information on alternatives for managing reservoir sedimentation. Each reservoir site has its own constraints and not all alternatives will be suitable. This book provides some guidance as to the applicability of the various alternatives. This research develops a computer model called RESCON. The model helps to evaluate at the pre-feasibility-level the technical and economic feasibility of implementing the life cycle management approach. The results from the economic optimization routine identify the preferred sediment management technique for sustainable use of the water resource infrastructure. Before the RESCON model is used to assess the options available for a dam or a suite of dams, it is advisable to undertake a preliminary screening to include: watershed management potential; environmental and social considerations; potential for mechanical removal; and reservoir operation.

There are numerous ways of managing and mitigating reservoir sedimentation problems. These include measures to: reduce sediment inflows into the reservoir; manage sediments within the reservoir; evacuate sediments from the reservoir; replace lost storage. Each measure can be further sub-divided and each has technical, environmental and economic benefits and consequences. Each has been used for managing sedimentation problems around the globe and sufficient expertise and tools are available for their technical appraisal at the feasibility level and beyond.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

14.Reservoir Conservation RESCON Volume II

Location: Various countries
Waterbody/Dam: Various Reservoirs
Parties Involved: N/A
Methods Used/Proposed: Flushing, Hydro-suction Sediment Removal System, Dredging & Trucking
Citation:
Shigekazu Kawashima, Tamara Butler, Farhed Shah, and George W. Annandale. "The RESCON Approach." *Reservoir Conservation* 2 (2003): 1-102

Summary

Volume I of the book outlines the RESCON approach to reservoir sedimentation management. Volume II details the mathematical model that has been developed as part of the RESCON research. The following sediment removal techniques can be considered: Flushing; Hydrosuction (HSRS); Traditional Dredging; Trucking; In addition, net economic benefits of the scenario involving “No sediment removal” are also computed as the benchmark case. RESCON approach is to select a sediment management strategy that is technically feasible and also maximizes net economic benefits. The solution may be 1. SUSTAINABLE, where reservoir capacity is maintained in perpetuity, or 2. NON-SUSTAINABLE, where the reservoir fills with sediments in finite time. 2a. the dam is decommissioned at an optimally determined time allowing the salvage value (=cost of decommissioning minus any benefits due to decommissioning) to be collected at this time; or 2b.the dam is maintained as a “run-of-river” project even after the reservoir is silted.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

15.Robles Diversion Dam HFB Study Report

Location: Ventura, California, United States
Waterbody/Dam: Ventura River (16.5 miles)
Parties Involved: U.S. Department of the Interior Bureau of Reclamation
Methods Used/Proposed: High Flow Bypass
Citation:
Mefford, Brent, Hillary Stowell, and Chuck Heinje. "Hydraulic Laboratory Report ." *Robles Diversion Dam High Flow and Sediment Bypass Structure* Physical Model Study (2008): 1-72

Summary

This report presents the results of a Bureau of Reclamation hydraulic model study of the proposed high flow bypass (HFB) spillway for Robles Diversion Dam. Robles Diversion Dam is located on the Ventura River approximately 14 river miles from the ocean. A 1:20 Froude-scale model of the proposed facility was tested to determine the interaction of flows and bed load sediments near the facility following decommissioning and removal of Matilija Dam located about two river miles upstream. The HFB spillway was proposed to enhance sediment movement through the diversion pool thereby reducing the impacts of elevated bed load levels resulting from the upstream dam removal. A new auxiliary fishway and 1.5 ft dam raise associated with the HFB is also proposed to improve upstream fish passage at the diversion dam during HFB operation.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

16.San Clemente Dam to Come Down

Location: Carmel River, Monterey County, California, United States
Waterbody/Dam: Carmel River (36 miles)
Parties Involved: Department of Water Resources Division of Dam Safety, Coastal Conservancy, Public Utilities Commission
Methods Used/Proposed: Removing the dam
Citation:
Lopez, Daniel. "San Clemente Dam to Come down." *MontereyCountyTheHerald.com*. N.p., 14 Nov. 2009. Web. 16 July 2012.

Summary

California American Water says it will tear down San Clemente Dam on the Carmel River. The purpose of the dam is to provide a diversion point for water withdrawal in the area. The dam is 106 feet tall concrete arch and the reservoir it creates originally held 1,425 acre-feet of water but has now been reduced to 125 acre-feet due to sedimentation. This has created a dam safety issue because the dam could now fail from a seismic episode because of pressure against the dam or flooding because of the low capacity of the reservoir. Other options included rerouting the river via a bypass to avoid the accumulated sediment and reinforcing the current dam by "buttressing" (reinforcing the dam by adding supports with rock or concrete structures) Environmentalists favor the dam removal because it is the greatest benefit to the river ecosystem. Dam removal is set to begin January 2013 and finish in three years.

Cost/Funding: $84 million

Amount of Sediment: Not Provided

17.Savage Rapids Dam Sediment Evaluation Study

Location: Savage Rapids Dam, Rogue River, Oregon, United States
Waterbody/Dam: Rogue River (215 miles)
Parties Involved: The Bureau of Reclamation
Methods Used/Proposed: Removing the dam, construction of two pumping plants
Citation:
Department of the Interior Bureau of Reclamation. "Josephine County Water Management Improvement Study, Oregon." *Savage Rapids Dam Sediment Evaluation Study* (2001): 1-37

Summary

Savage Rapids Dam is located in southwestern Oregon, on the Rogue River, 5 miles upstream from the town of Grants Pass. The dam, owned by the Grants Pass Irrigation District (GPID), is 39 feet high and has been diverting irrigation flows since its construction in 1921. Fish ladders on the dam are old, do not meet current National Marine Fisheries Service (NMFS) fisheries criteria, and delay migrating fish. In addition, the fish screens on the north side of the dam do not comply with current NMFS fisheries criteria. Construction of two pumping plants to deliver irrigation water and removal of the dam are proposed to alleviate these fish passage problems. The pumping plants would be located immediately downstream from the fish ladders to enable GPID to deliver water to its patrons through the existing irrigation canals. The process leading to this proposal is documented in a planning report/final environmental statement (PR/FES) filed on August 30, 1995. The PR/FES focused only on salmon and steelhead passage concerns at the dam and associated diversion facilities. The Bureau of Reclamation planned to do a detailed sediment study as part of predesign activities if the Congress approved removal of the dam and provided the necessary funding. The purpose of this study was to determine the potential sediment-related impacts associated with removing the dam.

Cost/Funding: Not Provided

Amount of Sediment: 200,000 cubic yards

18.Sediment Build-up Causes Environmental Concerns

Location: Jackson County, North Carolina, United States
Waterbody/Dam: N/A
Parties Involved: U.S. Fish and Wildlife Services
Methods Used/Proposed: Dredging, removing the dam
Citation:
Johnson, Becky. "Sediment Build-up Causes Environmental Concern." Smoky Mountain News. N.p., 18 July 2007. Web. 16 July 2012.

Summary

Removal of the Dillsboro Dam by unleashing of sediment backed behind the dam. Estimates peg accumulated sediment behind the dam at more than 100,000 cubic yards. Duke Power initially was not going to remove the sediment before taking out the dam, but instead planned to let it wash down stream in stages as the dam came down. “The plan for Dillsboro Dam removal calls for the sediment, or sand, behind the dam to be allowed to move down river as it would have naturally,” said Fred Alexander, the Duke Power spokesperson who works out of the utility’s Franklin office. “The proposal from Duke initially was they could flush the sediment downstream, but because of our concern for the Appalachian elktoe mussel, an endangered species downstream from the dam, we think it is best to go ahead and get that sediment removed and no subject the lower part of the river to any more sedimentation,” Cantrell said.

Cost/Funding: Not Provided

Amount of Sediment: more than 100,000 cubic yards

19.Sediment Task Force Recommendations

Location: United States
Waterbody/Dam: Susquehanna River Dams (464 miles)
Parties Involved: Susquehanna River Basin Commission Sediment Task Force
Methods Used/Proposed: Stream restoration and stabilization, sediment trapping structures, sediment transport assessment, stream bank/channel stability assessment, riparian buffers, natural and reconstructed wetlands
Citation:
Sediment Task Force Recommendations. Rep. no. 221. Susquehanna River Basin Commission Sediment Task Force, June 2002. Web. 16 July 2012.

Summary

Riverine management recommendations are focused on stream restoration and stabilization, riparian buffers, and natural and constructed wetlands in the Susquehanna River. As is the case with the upland recommendations, emphasis is placed on the use of best management practices (BMPs) and natural systems to slow the speed of water runoff, thus limiting its erosive effects. Since energy builds as water moves downstream toward the Bay, equal attention must be paid to streambeds and floodways as is paid to flow originating from land sources.

Upland recommendations address agricultural, forest, mining and urban lands, as well as transportation systems. To date, most BMPs have focused on nutrient pollution, particularly those on agricultural lands. BMPs will have to be expanded to address both nutrients and sediments, and existing practices must be evaluated to determine their effectiveness in controlling both. For urban lands, recommendations are made for promoting innovative, environmentally-sensitive site design measures, ground-water recharge, improved water quality, stream channel protection, and enhanced watershed management of stormwater and floodways.

First, a feasibility study is recommended to determine if dredging the reservoirs is a viable option to maintain or reduce the volume of sediment currently trapped behind the dams. Other alternatives, including sediment bypassing, sediment fixing, and modified dam operations, were considered, but dismissed.

Cost/Funding: Not Provided

Amount of Sediment: As of 1990, the total amount of sediment trapped by the dams was estimated at 259 million tons.

20.Sediment Trap Assessment, Saginaw River, Michigan

Location: Saginaw, Michigan, United States
Waterbody/Dam: Saginaw River
Waterbody/Dam Size: 22.4 miles
Parties Involved: U.S. Army Corps of Engineers, Detroit District
Methods Used/Proposed: Sediment trapping
Citation:
Sediment Trap Assessment Saginaw River, Michigan. Rep. Madison: W.F. Baird & Associates, 2001. W.F. Baird & Associates Ltd., Dec. 2001. Web. 16 July 2012

Summary

This report describes the assessment of sediment traps along the Saginaw River, MI, using existing numerical models and theoretical analysis. The studies indicated that most of the clay and silt from upstream passes through the federal channel and settles in Saginaw Bay, while most of sand settles in the river over the entire length of the channel.

A theoretical analysis was conducted on bottom shear stress. Shear stress is usually used to describe the hydrodynamic force acting on the sediment bed. Bottom shear stress can be determined by the following formula:

Comparing the model results with the theoretical analysis, it was found that the trap efficiency estimated using the theoretical analysis (called "theoretical efficiency" below) was generally close to that estimated using the HEC-6 model (called "modeling Efficiency" below). However, the theoretical efficiency of total sediment is less than modeling efficiency. This probably results from different incoming sediment data used in the theoretical analysis and the HEC-6 modeling. The theoretical analysis was based on the total incoming sediment load at the upstream boundary of the HEC-6 model, which is significantly less than the sediment load passing through the upstream edge of the traps in the model because sediment erosion occurs in the upstream reaches of the river and more sediment is carried downstream.

In summary, the proposed sediment traps capture incoming sediment with varying degrees of success depending on the trap dimensions and incoming grain sizes. These traps are located in the river segment where there is a sediment deposition environment. The developed theoretical analysis and HEC-6 modeling can be used for sediment trap design and assessment of trap efficiency. The theoretical analysis approach was verified by the HEC-6 modeling results and can be used to quickly and roughly assess trap efficiency. The HEC-6 model requires more effort to prepare the input data and process output data and can be used to assess the trap efficiency for final design.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

21. Using Adaptive Management at Glen Canyon Dam

Location: Colorado River, Arizona, United States
Dam: Glen Canyon Dam (1,560ft x 710ft)
Waterbody: Colorado River (1,450 miles)
Parties Involved: U.S Department of the Interior's Bureau of Reclamation, U.S. Geological Survey's
Methods Used/Proposed: Pipeline to transport sediment
Citation:

Kubly, Dennis M. "Using Adaptive Management at Glen Canyon Dam." *Renewable Energy World.Com*. N.p., 21 Oct. 2009. Web. 16 July 2012. <http://www.renewableenergyworld.com/rea/news/article/2009/10/using-adaptive-management-at-glen-canyon-dam>.

Summary

Glen Canyon Dam is located on the Colorado River and the dam's main purpose is to store and release water to generate electricity. In 1992, Congress passed the Grand Canyon Protection Act which required operation of Glen Canyon Dam to protect natural resources while continuing to deliver water for hydroelectricity. Since the Colorado River is now controlled, sediment has now collected behind the dam and affects area beaches and wildlife both below the dam, namely, the fine sediment downstream that forms sandbars and habitat for rearing of native fish. One such fish is the endangered humpback chub whose whole population resides here and has seen a 50% decline in adult abundance in the area. Currently the scientists are testing whether high flow releases can release some of the sediments and they can be used to rebuild the beaches. If the water is released at high flow, it will create some movement of some sediment behind the dam, but it will also agitate some of the sand below the dam and replenish some of the beaches that had eroded. There is concern that the sediments that are used to replenish the beaches will erode sediment that is above the natural flow lines of the river. The Adaptive Management Program has done a feasibility assessment for a pipeline to transport fine sediments upstream of the dam that will either empty at the bottom of the dam or 16 miles downstream. There has been no action on this assessment from this point.

Cost/Funding: This appraisal-level assessment indicates an initial cost range of $140 million to $430 million, plus $3.6 million to $17 million a year for operations. In addition to the large commitment to capitol funds, reclamation would have to determine where the money would come from for operations. However, this must be compared with the estimated cost increases of $15.2 million to $44.2 million as a result of changing operation of the dam to accommodate the preferred alternative in the 1995 EIS, as well as the financial cost to utilities (as a result of lost generation) of $89.1 million per year

Amount of Sediment: Not Provided

22.Managing Sediment in Utah's Reservoir

Location: Utah Reservoirs, Utah
Waterbody/Dam: Wide Hollow Reservoir, Gunlock Reservoir, Millsite Reservoir, Piute Reservoir, Otter Creek Reservoir, First Dam, Quail Creek Diversion Dam
Waterbody/Dam Size: N/A
Parties Involved: Utah Department of Natural Resources
Methods Used/Proposed: Upstream trapping, construction, mining, logging, grazing
Citation:
Utah Division of Water Resources, comp. *Managing Sediment in Utah's Reservoirs*. Rep. Utah Department of Natural Resources, Mar. 2010. Web. 16 July 2012.

Summary

Utah has a long and continuing tradition of watershed management, which, in addition to other benefits, reduces erosion. Today's efforts are sponsored by a cadre of federal, state and local Parties. Other than this, Utah does not have any coordinated efforts to assess or manage reservoir sedimentation. In addition to watershed management, there are methods to deal with sedimentation which are not being employed. Dam owners would benefit from implementing these methods in order to keep reservoirs sustainable.

Several sediment management methods are described in this chapter. Optimal results will require some combination of methods. The chapter also discusses how to deal with sediment at diversion dams and other water infrastructure. Watershed management can significantly reduce the amount of sediment that reaches a reservoir. Such management involves protecting the ground from erosion with vegetation, land terracing, and channel stabilization. It also includes the control and scheduling of activities such as construction, mining, logging, and grazing. Cooperation among state and federal Parties that manage public lands, such as with the Utah Partners for Conservation and Development, helps fund and implement projects that limit erosion. Upstream trapping is another way to reduce the amount of sediment reaching the reservoir. This includes constructing hydraulic structures such as natural vegetation filters, check dams, detention basins and upstream reservoirs that trap sediment. Another option is to build the reservoir off of the main stream channel and selectively divert the waters that fill it. This entails directing clear water into the reservoir, primarily during non-flood conditions, while sediment-laden waters are bypassed. Constructing wetlands upstream of the reservoir also helps remove sediment from the stream.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

23.Reservoir Sedimentation Handbook

Location: N/A
Waterbody: N/A
Size Waterbody: N/A
Parties involved: N/A
Methods Used/Proposed: Sustainable sediment management
Citation:
Morris, Gregory L. and Fan, Jiahua. 1998. *Reservoir Sedimentation Handbook,* McGraw-Hill Book Co., New York.

Summary

This handbook seeks to generate an awareness of sedimentation problems, outlining practical strategies for their identification, analysis and management. Basic concepts and tools are presented which, when applied in an integrated manner, can achieve *sustainable sediment management* in reservoirs. Sedimentation is the single process that all reservoirs worldwide share in common, to differing degrees, and the management strategies and techniques presented are applicable to reservoirs of all ages, types, and sizes. An understanding of these principles will also aid in the effective design and management of sediment-trapping structures such as debris basins and detention ponds.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

OVERSEAS

1. China's Challenge

Location: Chang Jiang, Yangzi/Huang He
Waterbody: the Yangtze River (3,915 mi)/Yellow Sea
Dam: Gezhouba Dam (8,514 ft x 154 ft)
Three Gorges Dam (7,661 ft x 594 ft)
Parties Involved: N/A
Methods Used/Proposed: Drawdown, flushing, sluicing, turbidity currents, dredging
Citation:
DiFrancesco, Kara. "China's Challenge." *Water Power Magazine* Apr. 2001: 26-28.

Summary

Objective: to maximize hydropower production and the environmental concerns for maintaining the ecological health of the downstream fish reserve utilizing turbidity currents to passing sediment through the Jinsha dams appears to be the most viable sediment management option.

Precipitation patterns result in highly variable seasonal sediment yields, sediment transported occurs during wet season between May and October. The high sediment yields pose threats to the performance of the two existing dams on the Yangtze mainstem (Gezhouba and Three Gorges Dam). Every year starting from 2003, approximately 100-150 million tons of sediment has been trapped in the Three Gorges reservoir. The four-dam cascade partially under construction in the high sediment yield portion of the Jinsha Jiang above the Three Gorges dam poses particular concern for the upper Yangtze Rare and Endemic Fish Nature Reserve. Two of the four dams China Three Gorges Corporation plans to build are already under construction (Xiluodu, XD, and Xiangjiana, XJB), while the most upstream dams are still in planning phases (Wudongde, WDD, and Baihetan, BHT). When completed, the four-dam cascade will provide 43km3 of water storage capacity, with an installed hydropower capacity of 38,500 MW, about double that of the Three Gorges Dam. Upon completion of the cascade the majority of sediment is trapped in the most upstream dam, Wudongde, with less than 4% of sediment in Xiangjiaba's drainage basin passed downstream. The most upstream dam, Wudongde, experiences the greatest sedimentation impacts which affect the performance of the entire cascade due to the coordinated operation scheme for the dams.

Management options: Implementing sediment management strategies requires assessment of the short term loses versus long term gains of sediment management, in term so both economic performance and downstream sediment impacts. The four main sedimentation control strategies utilized:

I. Drawdown and Flushing
II. Storing the clear water and releasing (sluicing) the turbid water
III. Releasing turbidity currents
IV. Dredging

Utilizing turbidity currents presents an opportunity to release sediments through a dam without drawing down the reservoir, thus resulting in much less significant hydropower losses.

Releasing turbidity currents by strategically opening the bottom sluice gates to pass highly concentrated flows through the reservoir presents the best possibility to release sediment downstream with minimal effect to operations and in line with the downstream environmental objectives. A potential strategy to address these issues is to use the most upstream reservoir to create optimal conditions for inducing turbidity currents in the downstream dams.

Cost/Funding: Not Provided

Amount of Sediment: Approximately 100-150 million tons annually

2. *Going Full Circle*

Location: Pakistan, Japan, Switzerland, United States, Nepal, South Africa, Puerto Rico
Waterbody/Dam:
Pakistan: Tarbela Dam
California: Cogswell Dam
Japan: Katagiri Dam, Miwa Dam
Switzeland: Gebidum Dam
South Africa: Nagle Dam, First Falls Dam
Puerto Rico: Fajardo Dam
Nepal: Kulekhani Reservoir
Parties Involved: N/A
Methods Used/Proposed: Re-vegetation, warping, contour farming, check dams, bypassing, sluicing, density current venting, dredging, dry excavation, hydro-suction, drawdown flushing, pressure flushing
Citation:
Annandale, George . "Going Full Circle." *Water Power Magazine* Apr. 2001: 30-34.

Summary

Conventional Civil Engineering Design. Design life and the life cycle approaches. Overall concept: reduce the amount of sediment flowing into a reservoir; create conditions that will prevent or minimize the deposition of sediment in a reservoir. Dams need to be constructed so operators have the flexibility to regularly remove sediments from reservoirs.

Practical Methods proposed to reduce sediment yield from catchments:

Re-vegetation: used but not as effective

Warping: technique often used in China where river water with high sediment loads is diverted onto agricultural land. The sediment deposition on the land enhances its agricultural value. However, in large rivers the amount of sediment diverted is only a small portion of the total annual sediment load so it does not necessarily significantly reduce the amount of sediment carried by a river.

Contour farming: benefits agriculture but contribution to reduce sediment yield is small.

Check Dams: implemented as sediment management measure upstream of dams. Require regular maintenance such as removal of deposited sediment. Check dams are generally applied in series to increase the amount of sediment they can capture.

Bypassing: divert sediment carrying water around reservoirs and prevent it from entering and depositing sediment in the reservoirs. Use of bypass tunnels, modification of river channels and using off-channel storage.

Implemented in Switzerland (5 bypass tunnel schemes) and Japan (4 bypass tunnel schemes).

Sluicing: sediment laden flows are released through a dam before the sediment particles can settle. Consists of maintaining high sediment transport carrying capacities in the water flowing through a reservoir.

Density Current Venting: deposition of this sediment can be prevented by releasing the density current downstream of the dam. This is accomplished by installing low levee gates at the dam.

Dredging:
Dry Excavation: Removal of deposited sediment by dry excavation consists of draining the reservoir and using conventional excavation equipment to load deposited sediment into trucks for removal from the reservoir.

Hydro-suction: employs dredging equipment with sufficient hydrostatic head over a dam to create suction at the upstream end of the discharge pipe. This suction is then used to remove the deposited sediment.

Drawdown Flushing: complete drawdown of a reservoir to re-suspend deposited sediment and flush it downstream.

Pressure Flushing: used to remove sediment directly upstream of an outlet by opening the outlet without drawing down the water surface elevation.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

3. Life of Maithon Reservoir, India

Location: Damodar River, India
Watebody: Barakar River (140 miles)
Parties Involved: N/A
Methods Used/Proposed: Rising reservoir bed levels, filling the dead storage with silt, siltation trap
Citation
Chaudhuri, Dipankar. "Life of Maithon Reservoir on Ground of Sedimentation: Case Study in India." *Journal of Hydraulic Engineering* (2006): 875-880.

Summary

Barakar is the main tributary of the Damodar River, in which two multipurpose reservoirs at Tilaiya and at Maithon have been built up in series. The Maithon Reservoir was first ponded in 1957 just after impounding the Tilaiya Reservoir in 1953. Sedimentation studies were done to determine the trap efficiency and the silt contribution.

What was done: Filling of Dead Storage:

To get an idea of the time required to fill the dead storage zone of the reservoir with silt, a sediment distribution study was carried out by different methods. The trigonometric method is a graphical method, in which capacities at different elevations are reduced in the ratio of depth of reservoir with reference to sediment zero elevation and that with reference to original streambed level.

Rising of Reservoir Bed Levels: It is time to take care of regular flushing operations through the under sluices to create a channel in the reservoir, which will transport the silts downstream without settling at the upstream mouth of the sluices. Similarly, it is presumed that reservoir bed level at sediment zero level of 125.6 million tons will encroach the elevation of the center line of by the year 2022. It is also to note that the water supply intake of the Chitaranjan Locomotive Workshop at Chitaranjan, State West Bengal, India exists around the reservoir elevation of 134.1 feet, which may be affected beyond the year 2046 due to the deposition of sediment.

Future Strategies: From the above scenario, it was determined that a siltation trap should be constructed immediately at the upstream of Maithon. Therefore it has been proposed to construct Balpahari Dam at about 50 km upstream of the Maithon Reservoir having catchments of 4,400 km^2. There will definitely be an impact upon siltation at the Maithon Reservoir due to construction. This study shows that the existing sediment deposition rate at the Maithon Reservoir will be reduced to about 1.5 mm^3/year due to implementation of the Balpahari project.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

4. *Measures against Reservoir Sedimentation Switzerland*

Location: N/A
Waterboday: N/A
Parties Involved: N/A
Methods Used/Proposed: Building new dam
Citation:
Jenzer Althaus , Jolanda , Giovanni De Cesare, and Anton Schleiss. "Measures Against Reservoir Sedimentation." *Energy Planet* [France] 26 June 2009: n. pag. *The Energy Center's Newsletter*. Web. 15 May 2010.

Summary

The process of sedimentation is a severe threat to the artificial lakes serving as reservoirs for hydro-power production, drinking water supply or flood protection. A potential solution is to release the sediments out of the reservoir in a continuous way in order to assimilate the natural conditions before the dam construction. This can be done without losing water volume, by releasing sediments through the turbines. To get the sediments entrained in the turbined water, they need to be kept in suspension right in front of the water intake. Additionally there is potential to increase the reservoir capacity by the construction of new dams.

Because of the ecological and operational aspects due to the increased sediments impact, an upper limit of sediment concentration needs to be defined, and the outflowing sediment concentration has to be regularly monitored and controlled. The sediment transport capacity in headrace tunnels and penstocks has to be evaluated as well.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

5. *Reservoir of Fear, China*

Location: India
Waterbody/Dam: Three Georges Dam, Yangtze River Basin (3,915 miles)
Parties Involved: N/A
Methods Used/Proposed: Failing dam
Citation:
Oster, Shai. Wall Street Journal [New York, N.Y.] 29 Aug 2007: A.1.

Summary

After a year after completion of the project, the Yangtze River Basin has problems including landslides, water pollution and suggestions that the dam could contribute to the very flooding it was built to prevent. The massive weight behind the Three Gorges Dam has begun to erode the Yangtze's steep shores at several spots along with frequent fluctuations in water levels, has triggered a series of landslides and weakened the ground under Miaohe, a village 10 miles up the reservoir. Additional dangers: as the dam blocks silt heading downstream, the Yangtze River estuary region is shrinking and sea water is coming further inland. Across the country, millions of tons of raw sewage, industrial waste and fertilizer runoff have turned lakes into algae-covered cesspools. According to official statistics, more than half of China's major waterways are so polluted that fish are dying or water is unsafe for drinking or irrigation. More than 300 million people -- almost one-quarter of the population -- lack access to clean drinking water. The changes can be seen here in Miaohe, where villagers have grown oranges from gnarled trees and farmed the area's steeply terraced rice paddies for generations. Miaohe's 100 or so residents narrowly avoided the mass relocations that accompanied the dam's construction, when some 1.3 million people moved from their homes to make way for the reservoir. After early May rains raised reservoir levels again, there were four landslides in five days not far from Miaohe village. Villagers say they heard timbers in their houses began to split. In June 2003, two weeks after the Yangtze River was impounded and the reservoir began to fill. While water levels rose, passing 300 feet and approaching 450 feet, the valley's slopes started eroding under the pressure of the water.

Cost/Funding: $22 billion

Amount of Sediment: The Yangtze carries some 500 million metric tons of silt into the gorges each year.

6. *Reservoir Sedimentation and Sediment Management in Japan*

Location: Ibaraki-ken, Japan
Waterbody: N/A
Parties Involved: N/A
Methods Used/Proposed: Sediment flushing, bypassing, excavating, dredging, discharging turbid water, emptying the dam
Citation:

Kashiwai, Josuke. *Reservoir Sedimentation and Sediment Management in Japan*. Tech. Hydraulic Engineering Research Group, Incorporated Administrative Agency, Public Works Research Institute, n.d. Web. 16 July 2012.

Summary

Issue in Japan: rapid loss of sediment capacity compared to original estimates; aging of reservoirs; in planning sedimentation condition and specific site conditions where the sediment inflow volume is too large to plan the sediment capacity.

What has been done?

I. Mountain and foot of a mountain area, alluvial fan –steep and rapid flow
   a. hillside works: reducing sediment yield from hillside slope
   b. check dam: conserving forest area, preventing excess sediment flow to areas downstream
   c. retarding basin: preventing excess sediment flow to areas downstream
   d. countermeasures for reservoir sedimentation: reducing reservoir sedimentation

II. Areas downstream
   a. foot protection works: stabilizing embankment
   b. groundsill: preventing scoring, stabilizing riverbed
   c. prohibition of sand and gravel removal: preventing riverbed degradation
   d. riverbed excavation: preventing riverbed aggradation, conserving water quality
   e. spur dike: restoration of pools

III. Coastal area

   Most of the activities have executed for the problems of coastal erosion from 60's. Several reasons are considered for the erosion such as littoral transport direction change by coastal structures, sediment supply reduction by sand and gravel removal in rivers and dam construction etc. Including: wave absorbing works, jetty, offshore breakwater, artificial reef, head land , sand bypass, artificial nourishment

Methods around dam reservoirs:

I. Sediment flushing

   Draw down operation is executed for flushing large amount of sediments. Partially draw down operation is also executed to control released sediment volume or recover store water.

II. Sediment bypassing

   There are both cases. Bypassing wide range of grain size and fine sediment only.

III. Excavating and dredging

60% of removed sediment is effectively used. Some dams have tried to resettle in river area of dam downstream for flushing during flood.

IV. Discharging turbid water

Outlet conduits, selective withdrawal facilities or special structures to release turbid bottom water are used.

V. Empty dam

Gateless bottom outlets are placed near riverbed elevation if a dam is planed only flood control. Main purpose of the operation or test operation is different by each example. Results of the operation or test operation, however, have various phases such as countermeasures of sedimentation, sediment supply method to the areas downstream, influential activity on river eco-system conditions and so on. We have to find the position of the activity in the sediment transport system. That may be obtained by the concept of integrated sediment system management.

Cost/Funding: Not Provided

Amount of Sediment: Total volume of resent reported annual sedimentation is about 20 million m^3. Other survey shows annual removal volume from reservoirs is about 3.9 million m^3.

7. Reservoir Sedimentation Management in Asia

Location: Japan, China, India
Watebody/Dam:
China: Dujiangyan, Three Gorges Dam, Tianjiawan Reservoir
Japan: Asahi Dam, Dashidaira Reservoir
India: Baira Reservoir, Uri Hydropower Project
Parties Involved: Department of River & Coastal Engineering, Hydro-soft Technology Institute, Foundation of River & Watershed Environmental Management
Methods Used/Proposed: Mechanical hydraulic dredging
Citation:
Jian Liu, Bingyi Liu, Jazuo Ashida, Reservoir Sedimentation Management in Asia
Accessed this paper via Database on 7/16/2012. However, this is no longer available. Please contact USACE for an electronic copy of this paper.

Summary

This research was done in several Asian nations. China and India are losing 2.3% to .5% storage capacity annual because of low forest cover and erosion. About 86,000 reservoirs with a total capacity of 560 billion cubic meters were constructed by the end of 1999. The area of erosion is 3.67 million square kilometers. The soil erosion is widely distributed throughout China. Mechanical hydraulic dredging such as siphon and airlift system is employed for fine and medium sediments. The siphon system makes use of difference between water level upstream and downstream of dam to remove sediment. The dredging cost is relatively cheap. Dredging unit cost .045-.22 (RMB/cubic meters). From this research it is recommended that the sedimentation strategies should be worked out during the planning and design phases for sustainable use. For the reservoirs with very high sedimentation rates, the decommissioning of dams and dredging such as siphon dredging and mechanical dredging are likely good choices. In addition, the environmental impacts should be considered comprehensively when the sediment flushing and dredging measures are performed.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

8. Sediment Bound Nutrient, Sudan Savanna Zone of Ghana

Location: Sudan savanna zone, Upper East Region of Ghana
Waterbody: Dua, Doba, Zebilla, Kumpalgogo, and Bugri Reservoirs
Parties Involved: Department of Crop and Soil Sciences
Methods Used/Proposed: sampling
Citation:
Amegashie, Bright K., Charles Quansah, Wilson A. Agyare, Lulseged Tamene, and Paul L.G. Vlek. *Lakes & Reservoirs: Research and Management* (2011): 61-76. Blackwell Publishing Asia Pty Ltd, 2011. Web. 16 July 2012.

Summary

Issue in Sudan, Savanna zone of Ghana: many small reservoirs were constructed to capture the water from rainfall. However, most of them may not last for half of their expected useful design lifetime because of the off-site siltation effects of erosion from their catchments. Study involved five representative small reservoirs in the Upper East Region of Ghana. Variety of sampling was taken at all five locations. Certain soil chemical and physical analysis was determined after analyzing the data collected. Differences in soil type, topography, rainfall-run-off characteristics, crop cover, organic matter content of soils and soil management practices, among other factors, can result in considerable spatial variability in the nutrient content of the various catchment soils and reservoir sediments.

Sediments, organic materials and nutrients transported from watersheds to reservoirs are a primary cause of water quality degradation. These pollutants pose a potential threat to human and livestock health, cause decreased reservoir volume because of sedimentation and result in lost user benefits. Catchment area protection is needed to control erosion from the catchments and to reduce both on-site (fertility and productivity loss) and off-site (sedimentation and pollution) impacts of erosion. These measures may include adopting appropriate soil and water conservation practices, such as afforestation, improved vegetative cover with recommended cover and forage species, sustainable land management practices, and vegetative barriers (vetiver) around reservoirs. Desilted nutrient-rich sediments could be used as a soil amendment to improve the productivity of catchment soils. This possibility will require field experimentation to ascertain the benefits of these sediments in enhancing crop yields and biomass production. However, the heavy metal, pollutant and pathogen contents of the desilted sediments must be ascertained through further studies before they are used freely as soil amendments.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

9. Sediment Management at Naodehai Reservoir, China

Location: Liu River in China
Waterbody: Naodehai Reservoir
Parties Involved: Chaoyang Research Institute of Measurement Technology
Methods Used/Proposed: Reforestation and debris dams construction, drawdown flushing
Citation:
World Water and Environmental Resources Congress 2003. Downloaded from ascelibrary.org by WPC on 07/06/12

Summary

China has the world's biggest annual loss rate of reservoir storage capacity because of the low forest cover and high erosion. A lot of sediment control measures such as catchment management, routing, flushing and dredging have been developed and used to overcome the reservoir sedimentation problems. The catchment management mainly includes watershed management and water and soil conservation projects such as plantation and debris dams. The water and soil conservation is the most fundamental step to reduce the amount of sediment entering a reservoir, though it is very expensive. Routing, which generally consists of sluicing, bypassing, off-stream reservoir, sediment excluding structures and release of density current, is an effective approach for reducing sediment deposition in a reservoir. The sluicing operation mode is used for the reservoirs where large inflows and low water levels are available. This mode is generally performed by keeping the reservoir at a low water level to pass through the high sediment water during the flood season. The efficiency of sediment removal by sluicing is less than that by flushing, but it is better choice for a multipurpose project. Flushing that re-entrains deposited sediments and passes the sediment-laden flow through low level outlets in the dam is the most economical method to restore the lost storage capacity. This requires lowering water level in the reservoir and consumes significant quantities of water, but it is capable of removing even coarse sediments under certain circumstances. Dredging is very expensive and it should be seen as a last resort as the removal and disposal of existing deposits often create new social and environmental problems.

Hydrosuction sediment removal system is widely used for small and medium-sized reservoirs. The hydrosuction system makes use of the difference between water levels upstream and downstream of a dam to remove sediment through a floating or submerged pipeline linked to an outlet or discharging over the dam. In order to reduce the environmental impacts of flushing and density currents on downstream river channel, the mitigating measures such as fish refuge works, bank protective works and flushing in concert with other reservoirs on the same river have been taken since 1970s.

In order to reduce the sediment yield and deposition in the downstream channel, the catchment management, such as construction of debris dams, reforestation and modification of the reservoir operation mode have been studied and performed since 1971. Reforestation and debris dams are further planned and constructed to reduce the sediment yield in the basin. The 6.5-15m high debris dam generally creates a storage capacity of 0.1 to 20 mm^3, and there are 2 to 5 outlets in

each sediment detention basin. The full drawdown flushing is the most effective approach to restore the storage capacity, and it has been proved by the practice of Naodehai reservoir.

In this study, the experience of the sediment management at Naodehai reservoir was introduced. It was found that the reservoir has maintained 80% of the original capacity after 60 years of operation. This has been achieved mainly due to the unique operation modes of storing clear water in dry season and sluicing muddy water in flood season since 1971. The major environmental impact of the operation model is the sediment deposition in the downstream channels with flat gradient and large width. The countermeasures have been studied and executed to reduce the deposition in the river channel.

Cost/Funding: Not Provided

Amount of Sediment: Average Annual Sediment Yield is 10.47 million ton

10.Sediment Management Options for the Lower Ebro River and its Delta

Location: Zaragoza, Spain
Waterbody: Ebro River
Parties Involved: N/A
Methods Used/Proposed: Defense structures, restoring sediment fluxes
Citation:
Rovira A, Ibàñez C (2007): Sediment Management Options for the Lower Ebro River and its Delta. J Soils Sediments 7 (5) 285–295 Albert Rovira and Carles Ibàñez, Aquatic Ecosystems Unit, IRTA, Apartat de correus 200, 43540 Sant Carles de la Ràpita, Catalonia, Spain
Link: http://dx.doi.org/10.1065/jss2007.08.211

Summary

A sediment management plan for the lower Ebro River and delta is being developed in order to (1) restore the sediment continuity of the fluvial system by means of a new concept of reservoir management; (2) minimize the sediment imbalance within the lower Ebro River; (3) stop the coastal retreat of the river mouth area; (4) offset the elevation loss due to sea level rise and delta plain subsidence.

A preliminary study focused on the technical and economical viability to transfer the sediments deposited into the Riba-Roja reservoir was conducted. In this study two different approaches have been considered in order to stop or mitigate the impacts of sediment deficit on the delta:

I. Classical engineering approach: impounding the low-lying areas by means of defense structures.
    a. Very expensive
    b. Does not solve the present fluvial sediment deficit of the lower Ebro River and delta caused by dams which will cause the progressive degradation of the fluvial system
II. The ecological engineering approach: restoring the sediment fluxes to the delta to stop coastal retreat and maintain land elevation in a relative sea level rise scenario.
    a. The most sustainable alternative
    b. Implies a chance in dam management
    c. Restoration of the sediment flux of the lower Ebro River by means of both the removal of the sediment trapped behind the dams, and the effective transport of the by-passed sediment to the river mouth and delta plain
        i. Three major elements
            1. Application of some kind of technology to remove and by-pass sediment stored in the dams
            2. The definition of a specific flow regime to transport the sediment from the river to the delta
            3. Establishment of a controlled system to deliver part of the sediment to the delta plain

The restoration of the sediment continuity in the lower Ebro River depends on both the availability and the quality of sediments stored in the reservoirs and the amount of sediment removed from them. However, the possibility of evacuation and remobilization mainly depends on the exploitation licenses of the private hydropower companies which usually are managing the dams. At present, discharges released from Riba-Roja reservoir are a function of hydropower production and water demand (i.e. irrigation cycle), since economical and social values prevail over ecological and morphological needs.

The different options analyzed to transfer the sediment were: the generation of flushing floods; the construction of a by-pass system (canal or pipe); and the mechanic dredging and transfer of sediment by road or boat. Study concluded that the partial restoration of sediment fluxes in the lower Ebro River and its delta is technically feasible and environmentally desirable, but further detailed studies need to be carried out before the plan can be implemented.

The 'flushing flood' method has the lower costs and consists in partially or totally emptying the reservoir in order to erode the stored sediment, and evacuate them through the bottom outlets by using the water column pressure (in the first case) or by temporally restoring the water flow through the reservoir bed.

Cost/Funding: in the northern Gulf of Mexico the average cost of sediment dredging for wetland restoration is about US$ 40,000/ha

Amount of Sediment: Total annual suspended sediment load was estimated at approximately 20–30 million t/yr for the end of the 19th century (Varela et al. 1986, Ibáñez et al. 1996), while around 0.15–0.30 million t/yr are transported at present.

11.Sediment Management Round Table Discussion

Location: Central Europe, United Kingdom, Czech Republic, Germany
Waterbody: Danube Delta/Elbe Basin (678 miles)/Humber River (38.5 miles)
Parties Involved: European River Commissions, User Groups, Scientists, River Basin Managers
Methods Used/Proposed: Flushing, dredging, relocation
Citation:
"Report on the SedNet Round Table Discussion ." *Sediment Management-an essential element of River Basin Management Plans* (2006): 1-28.

Summary

Danube River Basin, Europe: Sediment needs to be flushed from reservoirs to keep them functioning and to increase flood protection capacity. The aim of hydropower producers is to find sustainable solutions to this issue as it is realized that the flushing results in high downstream sediment loads, thus increasing turbidity which may impact on fish breeding. Material that needs to be dredged from the estuary for maintaining the nautical depth should remain in the system according to a dredging plan. While it is nowadays also used for construction purposes, it should in future be exclusively relocated in areas that are strongly eroded, e.g. in the estuary and at the coast, in order to decrease the negative annual sediment balance.

The Elbe Basin, Central Europe: Besides the maintenance and repair of river-engineering works, the active management of sediments, both by dredging/ relocation and artificial bedload supply, is also part of the maintenance of the 600-km freshwater reach that serves as a Federal waterway. Relocation in the upper part of the estuary has been the main pillar of the management concept since the mid-1990s. The relocation regime and conditions were agreed upon. For instance, the relocated material has to meet certain contamination thresholds for sediments. Open water disposal is banned in the summer season.

The Humber Case, United Kingdom: Sedimentation within the River Humber/Humber estuary reduces depth, affecting the safe passage of vessels. Dredging is therefore required.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

12.Sediment Management, Lavey Run-of-Rover, Switzerland

Location: Switzerland, France
Waterbody: Rhone River (505 miles) at Lavey
Parties Involved: N/A
Methods Used/Proposed: Flushing, sluicing, hydraulic modeling
Citation:

Bieri, Martin , Michael Muller, Jean-Louis Boillat, and Anton Schleiss. "Modeling of Sediment Management for the Lavey Run-of-River HPP in Switzerland." *Journal of Hydraulic Engineering* 1 (2012): 340-347.

Summary

Reservoir sedimentation hinders the operation of the Lavey run-of-river hydropower plant (HPP) on the Rhone River in Switzerland. Deposits upstream of the gated weir and the lateral water intake reduce the flood release capacity and entrain sediments into the power tunnel. To improve sediment management an additional water intake and a training wall for improving flushing was set up. The performance of the enhancement project was tested on a physical model.

Findings were that for economic reasons (i.e., water and energy losses) and ecologic reasons (i.e., effect on downstream habitat), flushing operations should be as short and infrequent as possible. A flushing scenario with maximum efficiency could be identified by physical modeling tests. Data obtained from sedimentation and flushing monitoring with prototype data validated the hydraulic model.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

13.Sedimentation and Dredging of Guanting Reservoir

Location: Yongding River, China
Waterbody: Guanting Reservoir
Parties Involved: N/A
Methods Used/Proposed: dredging, elevating the dam
Citation:
Yang, Xiaoqing, Shanzheng Li, and Shiqi Zhang. "The Sedimentation and Dredging of Guanting Reservoir." *INTERNATIONAL JOURNAL OF SEDIMENT RESEARCH* 18, No.2 (2003): 130-137.

Summary

The main tasks of the Guanting Reservoir on the Yongding River were flood control and water supply to Beijing. Of the total original reservoir storage capacity of 2.27×10^9 m^3 (after rebuilt), 0.651×10^9 m^3 in the Yongding Zone is lost due to sedimentation and 0.252×10^9 m^3 in the Guishui Zone cannot be used due to the sand bar at the mouth of the Guishui River. Dredging is performed to deal with the sedimentation of Guanting Reservoir. A dredged channel on the mouth bar between the two parts of the reservoir (Yongding Zone and Guishui Zone) to resume their connection and a dike to guide most sediment from upstream of the Yongding River to the Guishui Zone are suggested. To enhance the flood control capacity of the reservoir and insure the safety of Beijing, the elevation of the dam was raised from 485.0m to 492.0 m in 1986, and the reservoir storage capacity was increased from 2.27×10^9 m^3 to 4.16×10^9 m^3.

The main contributions to the reduction of the annual sediment load to the Guanting Reservoir are as follows:
(1) Construction of hydraulic projects. Numerous dams and reservoirs have been built upstream and on tributaries (2) Development of irrigation system. Irrigated farm land reached 253.3×10^3 ha by 1978. About 19×10^6 t of sediment has been diverted onto farmland yearly, which accounts for about 34% of the reduction of the incoming sediment load to Guanting Reservoir. (3) Deposition in the river channel. The volume of sediment deposited in the upstream river channel accounts for about 24% of the reduction of the incoming sediment load to Guanting Reservoir. (4) Soil and water conservation works. Soil and water conservation works on the upstream basin area have been actively applied.

The sedimentation in the reservoir induces serious problems and impacts the reservoir functions as follows:
(1) The sediment deposition in the reservoir, (0.651×10^9 m^3, and equivalent to the capacity of several tens of middle sized reservoirs) occupied some flood control capacity and decreased the flood control function.
(2) The influence of the mouth bar.
(3) The head of the deposition delta has advanced quickly and has reached the dam.
(4) The deposition has also developed upstream.
The main factors affecting the deposition and maintenance of the dredged channel are as follows:
(1) Incoming flow and sediment discharge. The more incoming flow and sediment, the more deposition will result in the dredged channel.

(2) The width and the bottom elevation of the dredged channel. The deposition in the dredged channel with different widths from 15 to 500 m has been simulated. The results show that the wider the channel, the more volume and the more deposition there will be.
(3) The location of the dredged channel and main channel shifting.
(4) The operation of the reservoir. A higher water level in the reservoir would cause more sediment deposition in the upper reach, and, therefore, less sediment deposition in the dredged channel
(5) To reduce the amount of sediment transported toward the dredged channel, a dike to divert most of the sediment coming from upstream directly to the Guishui Zone is being considered.
(6) To deal with the deposition in the dam area and to insure operation of the dam dredging in deep water is required.

Dredging has been selected to deal with reservoir sedimentation. A dredged channel through the mouth bar placed from 500 m upstream of cross section G-1002 to the left side of cross section Y-1009 to connect the two reservoir zones and a dike to guide most of the sediment from upstream to the Guishui Zone were found to be effective sediment management measures.

The reservoir sedimentation has seriously impacted the water supply and flood control of Beijing. One of the main problems is the mouth bar that cuts off the flow between the Yongding and Guishui Zones. Dredging is considered as a primary measure to improve the current situation. Factors affecting the deposition and maintenance of the dredged channel:

(1) Incoming flow and sediment discharge. The more incoming flow and sediment, the more deposition will result in the dredged channel.
(2) The width and the bottom elevation of the dredged channel. The wider the channel, the more volume and the more deposition there will be. Intervals between dredging will vary.
(3) The location of the dredged channel and main channel shifting. If the dredged channel is close to the main channel, a large amount of sediment would directly enter and deposit in the dredged channel. On the other hand, if the main channel shifts the deposition in the dredged channel would be reduced, but more sediment would be transported to the dam site and increase the deposition there.
(4) The operation of the reservoir. A higher water level in the reservoir would cause more sediment deposition in the upper reach, and, therefore, less sediment deposition in the dredged channel. But this would accelerate deposition upstream.
(5) To reduce the amount of sediment transported toward the dredged channel, a dike to divert most of the sediment is being considered. Different lengths, locations, and alignments of the dike have been studied in models. The results show that the dike can effectively guide most of the sediment reducing the amount of sediment deposited in the dredged channel.
(6) To deal with the deposition in the dam area and to insure operation of the dam dredging in deep water is required.

Cost/Funding: Not Provided

Amount of Sediment: Not Provided

LITERATURE SEARCH FINDINGS

Purpose:

The Literature Search was conducted to evaluate reservoir sedimentation issues in United States and worldwide, specifically the significant decline in the its storage capacity. Through this research we found that world's reservoirs are losing an average of 1% of their storage capacity annually. Different scientists and researchers conducted studies to identify the causes and management strategies that they believe can help restore some of the storage capacity, and prevent further decline.

Developing Sediment Management Strategies/Alternatives:

As sediment management strategies being developed, we must evaluate our goals and site specific information. We first need to identify the need for sediment management and its purpose. It is important to understand where the sediment comes from, its size, contaminants and deposits. Specifically, the particle size gradation, spatial distribution of reservoir sediment, the chemical composition of reservoir sediment, the rate at which the reservoir sediment would erode following dam removal, expected rate at which eroded reservoir sediment would be transported downstream and the location and magnitude of sediment deposition downstream from the dam.

Once alternatives and strategies have been developed, it is vital that they are evaluated economically and environmentally. The capitol costs and future operation and maintenance requirements must be identified as well as site specific permitting requirements. We must determine if the extra cost incurred in undertaking sediment management activities worthwhile in terms of extending the productive life of a dam and whether it is economical to extend the life of a dam indefinitely. We also must determine the loss of sediment downstream from the dam and whether it results in channel and tributary degradation and causes changes in benthic and aquatic habitats to those more suited to a clearer water discharge. It is also important to take into consideration the time and effort it would take to implement the alternatives.

Proposed Alternatives:

There are various mechanical removal alternatives that can be used to solve the sedimentation problems. One alternative offered by many experts is removing sediment via dredging and transferring the sediment to another location. The dredged desilted nutrient-rich sediments can be used for mine reclamation, shoreline/near-shore restoration, as a soil amendment to improve the productivity of catchment soils, for habitat development uses, beach nourishment, landfill capping, recreational fill, and commercial uses. However, studies show that dredging is very expensive and should be seen as a last resort as the removal and disposal of existing deposits often create new social and environmental problems. Another alternative is installment of sediment trap (holes) which captures incoming sediment with varying degrees of success depending on the trap dimensions and incoming grain sizes. Removing the deposited sediment by dry excavation is another option which consists of draining the reservoir and using conventional excavation equipment to load deposited sediment into trucks for removal from the reservoir.

Other alternatives include replacing lost storage by increasing the dam height or removing the dam altogether to construct a larger dam which will increase the reservoir capacity. Temporarily lowering the dam to dredge or changing the purpose of the dam all together is another alternative.

Reduction of Sediment Yield:

Other findings show that reducing the sediment yield from the watershed can be done via use of soil and water conservation practices such as afforestation, improved vegetative cover and forage species, sustainable land management practices, land terracing, channel stabilization, and vegetative barriers (vetiver) around reservoirs. It also includes the control and scheduling of activities such as construction, mining, logging, and grazing. Cooperation among state and federal Parties that manage public lands, helps fund and implement projects that limit erosion.

Upstream trapping is another way to reduce the amount of sediment reaching the reservoir. This includes constructing hydraulic structures such as natural vegetation filters, check dams, detention basins and upstream reservoirs that trap sediment. Check Dams are implemented as sediment management measure upstream of dams and require regular maintenance such as removal of deposited sediment. Check dams are generally applied in series to increase the amount of sediment they can capture.

Minimizing Sediment Deposition

An alternative to minimize sediment deposition is to build the reservoir off of the main stream channel and selectively divert the waters that fill it. Additionally, the sediment load can be decreased by drawdown flushing. Studies show that drawdown flushing involves a complete drawdown of a reservoir to re-suspend deposited sediment and flush it downstream. Draw down operation is executed for flushing large amount of sediments. Partially draw down operation is also executed to control released sediment volume or recover store water. Another method is pressure flushing which is used to remove sediment directly upstream of an outlet by opening the outlet without drawing down the water surface elevation. Researchers found that flushing that re-entrains deposited sediments and passes the sediment-laden flow through low level outlets in the dam is the most economical method to restore the lost storage capacity. This requires lowering water level in the reservoir and consumes significant quantities of water, but it is capable of removing even coarse sediments under certain circumstances. However, for economic reasons (i.e., water and energy losses) and ecologic reasons (i.e., effect on downstream habitat), flushing operations should be as short and infrequent as possible. A flushing scenario with maximum efficiency could be identified by physical modeling tests.

Another alternative is density current venting where deposition of sediment is prevented by releasing the density current downstream of the dam. This is accomplished by installing low levee gates at the dam.

Also, utilizing turbidity currents presents an opportunity to release sediments through a dam without drawing down the reservoir, thus resulting in much less significant hydropower losses. Releasing turbidity currents by strategically opening the bottom sluice gates to pass highly concentrated flows through the reservoir presents the best possibility to release sediment downstream with minimal effect to operations and in line with the downstream environmental objectives. A potential strategy to address these issues is to use the most upstream reservoir to create optimal conditions for inducing turbidity currents in the downstream dams.
Release the sediments out of the reservoir in a continuous way in order to assimilate the natural conditions before the dam construction. This can be done without losing water volume, by releasing sediments through the turbines. To get the sediments entrained in the turbined water, they need to be kept in suspension right in front of the water intake.

Another alternative is sluicing which consists of sediment laden flows being released through a dam before the sediment particles can settle. This process consists of maintaining high sediment transport carrying capacities in the water flowing through a reservoir. Sluicing operation mode is used for the reservoirs where large inflows and low water levels are available. This mode is generally performed by keeping the reservoir at a low water level to pass through the high sediment water during the flood season. The efficiency of sediment removal by sluicing is less than that by flushing, but it is better choice for a multipurpose project.

Another common solution found is the bypassing process during which the sediment carrying water is diverted around reservoirs to prevent it from entering and depositing sediment in the reservoirs. This is done via use of bypass tunnels, modification of river channels and using off-channel storage.

Research shows that sediment can be also removed with hydro-suction dredging – a sediment removal system is widely used for small and medium-sized reservoirs. In this process, the deposited sediment is dredged and transported to either a downstream receiving stream or to a holding or treatment basin. This alternative employs dredging equipment with sufficient hydrostatic head over a dam to create suction at the upstream end of the discharge pipe. This suction is then used to remove the deposited sediment. However, upper limit of sediment concentration needs to be defined, and the outflowing sediment concentration has to be regularly monitored and controlled.

From the research found, especially overseas, warping technique was found to be often used where river water with high sediment loads is diverted onto agricultural land. The sediment deposition on the land enhances its agricultural value. However, in large rivers the amount of sediment diverted is only a small portion of the total annual sediment load so it does not necessarily significantly reduce the amount of sediment carried by a river.

Attachment H-1:
Evaluation of Reservoir Sediment Management Implementation

	File Name	Action Type	Notes
	Domestic		
1	Capital Lake Adaptive Management Plan Final Report	*Dredging	
2	Condition of Sixmile Creek and Watershed	*Hard Engineering Structure *Remove the Dam	
3	Dredging slated for Russell plant dam	*Dredging	
4	Ecological-Economic Assessment of a Sediment-Producing Stream Behind Lower Granite Dam or	*Dredging	
5	Grove Lake Sediment Bypass	*Dredging	Few other options were abandoned due to infeasibility or logistics issues
6	Louisiana Coastal Restoration	*Hydraulic Transport of sediment	
7	Hydrosuction Sediment Removal	*Hydrosuction Sediment Removal System (HSRS)	Bypassing or dredging
8	Hydrosuction Sediment-Removal Systems (HSRS) – Principles and Field Test	*Hydrosuction Sediment Removal System (HSRS)	Bypassing or dredging
9	Lessons from a Dam Failure	*Rebuilding the Dam	
10	Nebraska: Valentine Mill Pond - Innovative System Clears Up Sediment Problem in Lake	*Hydrosuction Sediment Removal System (HSRS)	
11	Potential for Increasing Storage Capacity in Los Padres Resdervoir	Dredging	
12	Regional Sediment Management	*Regional Approaches to Sediment Management	
13	Reservoir Conservation RESCON Volume I	*Research Study	
14	Reservoir Conservation RESCON Volume II	*Flushing *Hydrosuction Sediment Removal System (HSRS) *Dredging & Trucking	
15	Robles Diversion Dam High Flow and Sediment Bypass Sructure	*High Flow Bypass (HFB)	
16	San Clemente Dam to come down	*Removing Dam	Other options included rerouting the river via a bypass to avoid the accumulated sediment. Dam removal is set to begin January 2013 and finish in 3 years. This would gave greatest benefit to the river ecosystem
17	Savage Rapids Dam Sediment Evaluation Study	*Removing Dam *Construction of 2 Pumping Plants	This proposal was documented and filed on August 30. 1995
18	Sediment Build-up Causes Environmental Concern	*Dredging *Removing Dam	

	File Name	Action Type	Notes
19	Sediment Task Force Recommendations	*Stream Restoration and Stabilization *Sediment Trapping Structures *Sediment Transport Assessment *Stream Bank/Channel Stability Assessment *Riparian Buffers *Natural and Reconstructed Wetlands	
20	Sediment Trap Assessment, Saginaw River, Michigan	*Sediment Trap	Study of model
21	Using Adaptive Management at Glen Canyon Dam	*Pipeline to Transport Sediment	
22	Managing Sediment in Utah's Reservoir	*Upstream Trapping *Construction, Mining, Logging, Grazing	
23	Reservoir Sedimentation Handbook 1.04	*Sustainable Sediment Management	management strategies and techniques
	Overseas		
1	China's Challenge	*Drawdown/Flushing/Sluicing/Releasing turbidity currents/Dredging	
2	Going Full Circle	Re-vegetation/Warping/Contour Farming/Check Dam/Bypassing/Sluicing/Density Current Venting/Dredging/Dry Excavation/Hydro-Suction/Drawdown Flushing/Pressure Flushing	
3	Life of Maithon Reservoir, India	*Rising of Reservoir Bed Levels *Fill the dead storage zone with silt *Siltation Trap	
4	Measures against Reservoir Sedimentation Switzerland	*Building New Dam	
5	Reservoir in Fear, China	*Failing Dam that is Contributing to Flooding	
6	Reservoir Sedimentation and Sediment Management in Japan	*Sediment Flushing/Sediment Bypassing/Excavating and Dredging/Discharging Turbid Water/Emptying the Dam	
7	Reservoir Sedimentation Management in Asia	*Mechanical Hydraulic Dredging (Siphon & Airlift Systems)	
8	Sediment Bound Nutrient, Sudan Savanna Zone of Ghana	*Sampling	
9	Sediment Management in Naodehai Reservoir, China	*Reforestation and Debris Dams Constructed *Full Drawdown Flushing	
10	Sediment Management Options for the Lower Ebro River and its Delta	*Defense Structures *Restoring Sediment Fluxes	
11	Sediment Management Round Table Discussion	*Flushing Sediment *Dredging *Relocation *Active Management of Sediment	
12	Sediment Management, Lavey Run-of-Rover, Switzerland	*Flushing & Sluicing *Hydraulic Modeling	
13	Sedimentation and Dredging of Guanting Reservoir	*Dredging *Elevation of the Dam	

Attachment H-2:
Literature Search Overview Presentation

Lower Susquehanna River Watershed Assessment

Watershed/Reservoir Sediment Management Literature Search

Findings

Date of Presentation: September 24, 2012

US Army Corps of Engineers
BUILDING STRONG®

Purpose of the Literature Search

- Review, analyze, and synthesize literature on managing watershed/reservoir sedimentation.
- Findings and lessons learned will be incorporated into refining sediment/nutrient management strategies for LSRWA.
- Help us Brainstorm Ideas.

Methodology

- Reviewed Sediment Task Force Findings
- Conducted Database Literature Search
  - Findings
  - Trends
  - Conclusions

Sediment Task Force

Sediment Task Force

Who were they?

- ’99 - ’01
- Chaired by Susquehanna River Basin Commission
- Multi-agency, Multijurisdictional group
- Tasks:
  - *Review of existing studies*- Susquehanna sediment transport and storage;
  - Make *recommendations on management options* to address the issues;
  - *Symposium* of experts and policy makers; and
  - Recommend areas of *study, research, or demonstration*

Sediment Task Force
What did they do?

- ***Met for 18 months to bring together expertise on*:**
  - ***Sediment loads*** in the basin
  - Implications of sediment loading /reservoir capacity to ***Chesapeake Bay Program goals***;
  - Effectiveness of various *management technologies or practices*;
  - Analysis of ***reservoir***, ***riverine*** & ***upland*** *sediment management options;*
  - Susquehanna sediment management issues and their ***cumulative impacts to*** *Bay* watershed and restoration efforts; and
  - Recommended ***sediment monitoring*** *and* ***demonstration projects*.**

Sedment Task Force

Findings (Dec, 2000)

1. Human influenced sediment loading is a problem.
2. Loads in early 1900's were 2-3 times larger (land use, BMP's, dams).
3. Benefits of dams will be lost once at steady state:
   - Increased loads
   - More scouring.
4. Steady State ~ 20 years???
5. Sediment transport is a natural process that has been aggravated by human activity. Management focus: reduce human impacts.

Sediment Task Force
Findings Cont'd (Dec, 2000)

6. Sediment transport is aggravated by catastrophic storm events.
7. Reducing loads to local streams, rivers and lakes has value.
8. Decreasing loads over time will restore Bay water quality and habitats; and
9. Need more knowledge of sediment and effectiveness of management options to support a comprehensive management strategy.

Sediment Task Force
Recommendations

Upland Management

- ► Agriculture Uplands: BMP's and clean water practices
- ► Urban Uplands: BMP's
- ► Transportation Systems: BMP's, ditch management
- ► Forestry Uplands: Expansion; harvesting BMPs
- ► Mining Uplands: Reclaim/reforest abandoned mine land

Sediment Task Force
Recommendations

Riverine Management

- Stream Restoration & Stabilization
- Sediment Trapping Structures (Impoundments/dams)
- Sediment Transport Assessments (Monitoring and Modeling)
- Stream Bank/Channel Stability Assessments (Monitoring and Modeling)
- Riparian Buffers
- Natural & Reconstructed Wetlands

Sediment Task Force
Recommendations (June, 2002)

Reservoir Management

- ***Sediment Bypassing:*** Would result in a base load condition that exceeds the current base load into the Bay. Counter to the currently accepted goal of reducing sediment input to the Bay.
- ***Sediment Fixing***: Would not mitigate scouring or change the amount of sediment passing through the system or add capacity.
- ***Modified Dam Operations***: Unclear if this would accomplish anything in the interest of sediment control other than as a form of bypassing.
- ***Dredging:*** Supports study to maintain/reduce trapping capacity.

Database Literature Search

Research Databases Used

- Google Scholar
- The Wall Street Journal
- ProQuest
- Academic Search Premier (EBSCO)
- ScienceDirect
- GreenFile (EBSCO)
- EnvironetBASE
- Agricola
- GEOBASE

Findings

- 100+ articles (National and International) were reviewed
- A sub-set were determined to be most relevant to sediment management and were summarized:
  - Studies/Modeling
  - Technology
  - Alternative Analysis
  - Recommendations
  - Implemented Actions

Domestic Results

Capital Lake Adaptive Management Plan

Location: Capital Lake/Deschutes River Olympia, Washington

Problem: Sediment is carried downstream from the Deschutes River and is trapped by the dam that forms Capital Lake. Flood risk, water quality issues.

Proposed work: Dredging, open water placement, beneficial re-use.

Cost: Infrastructure -$2-4 million

Maintenance -$39.8-$134.7 million (over 50 years)

Sediment Load: 875,000 cubic yards needs to be removed. Annual Rate is about 35,000 cubic yards

Year: 2009

Sixmile Creek and Watershed

Location: Six Mile Creek, Tompkins County, Brooktondale New York

Problem: High load of suspended sediment, a result of erosion along the main channel and tributaries, downstream to the dams and impacting water supply.

Proposed Work: use of hard engineering structures to control the channel location or channel erosion control using natural channel design, dam removal, dredging.

Cost: N/A

Sediment Load: Several hundred thousand cubic yards

Year: 2007

Russell Plant Dam

Location: Russell Plant Dam, Westfield River in Russell, Massachusetts

Problem: 1,200 cubic yards of sediment has built up over the past 8 years.

What Has Been Done: Dredging the dam by lowering the dam over 24 hours, then dredging the material. The goal after dredging is complete is to produce approximately 4.5 million kilowatts of energy .

Cost: N/A

Sediment Load: 1,200 cubic yards have accumulated over the past 8 years

Year: 2009

Lower Granite Dam

Location: Lower Granite Dam on the Lower Snake River

Problem: With approximately 611,680 cubic meters of sedimentation collecting annually, it has interfered with navigation and flood control operations

What Has Been Done: Dredging has taken place but the amount of dredging can be reduced by using several best management alternatives after finding the critical sediment producing watersheds from upstream.

Cost: N/A

Sediment Load: 611,680 cubic meters of sedimentation collecting annually

Year: 1995

Grove Lake

Location: Grove Lake, Northeastern Nebraska

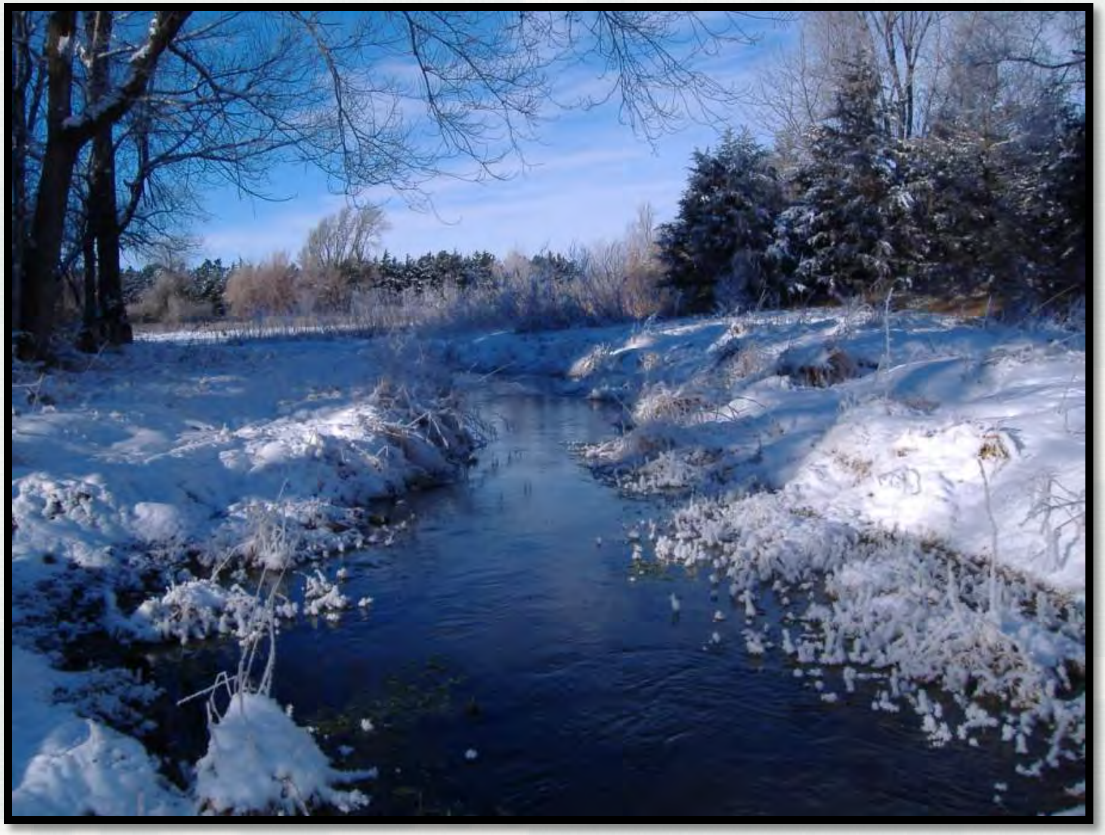
Problem: Large amounts of sediments have created a delta in the inlet of the lake due to large amounts of agricultural grazing in the Verdigre Creek Watershed above the lake, fisheries impacts

What Has Been Done:

--Install a siphon in the lake that would transport sediment and discharge it below the dam

-Currently siphon bypasses 50% of sediment entering lake.

-If remaining material is dredged in addition to being siphoned, it is predicted that the life of the lake will be 100+ years.



Cost: $42,000 (siphon option)

Sediment Load: 2466 cubic meters annually

Year: 2004

Louisiana Coastal Restoration

Location: Louisiana

Problem: N/A

Proposed Work: Application of Long Distance Conveyance (LDC) of Dredged Sediments to Louisiana Coastal Restoration. LDC projects are defined as involving hydraulic transport of slurry (mixture of sediment and water) through pipelines for distances of 16 km (10 miles) or greater. Long distance transport is a mature technology that has been used efficiently for applications like coal and iron ore transport.

Cost: N/A

Sediment Load: N/A

Year: 2011

Hydrosuction Sediment Removal System (HSRS)

Location: Woodside I & Woodside II Dams and Lake Atkinson, on the Elkhorn River, in Nebraska

Problem: Annual sediment load

What was Done: bypassing or dredging to move the annual sediment load.

Cost: Costs for pipeline and installation vary from about $160,000 for short dredging systems to about $865,000 for the longer bypassing systems

Sediment Load: 170 Tons/Day

Year: N/A

IVEX Dam

Location: IVEX Dam, Chagrin River, Northeastern Ohio

Problem: Failure of the dam occurred because of a combination of the following factors: inadequate spillway design, lack of emergency spillway, large loss of capacity from a large amount of sedimentation (86% over 152 years), and poor dam maintenance. The dam failure caused rapid incision of the stream bank and this changed the course of the river westward along the bedrock.

Proposed Work: N/A

Cost: $1-2.5 million

Sediment Load: 1,770 metric tons annually

Year: failure of the Dam occurred in 1994

Nebraska Valentine Mill Pond

Location: Nebraska

Problem: The capacity of the pond has decreased from 30 acres to 15 acres due to sedimentation

What Has Been Done:

-Mechanical excavation of sediment

-Hydrosuction sediment removal system which is a pipeline that catches the sediment as it enters the pond and travels around the dam and is discharged further down the creek

Cost: $1.6 million

Sediment Load: 60 tons of sediment daily

Year: 2003

Neosho Basin

Location: Neosho Basin, Kansas

Problem: Sedimentation and poor water quality are affecting reservoirs and have the potential to reduce their reliability as a source of water.

What Has Been Done: Dredging

Proposed Future Action:

-Sediment Removal

-Reallocation

-Structural Restoration (dams, diversion structures, treatment facilities)

-Flushing

Cost: N/A

Sediment Load: N/A

Year: 2008

Los Padres Dam

Location:

Problem: Dam's capacity has decreased from 3,030 acre-feet to 1,760 acre-feet which are due to sedimentation

Proposed Work

-Dredging

-Raising Reservoir Levels

-Increasing Capacity of the Dam

-Removing the Dam

-Building a New Dam

Cost: N/A

Sediment Load: N/A

Year: 2009

Regional Sediment Management (RSM)

- 1. To examine, apply and evaluate opportunities, practices, tools, benefits and impediments to applying regional approaches to sediment management.
- 2. Maintaining the navigability of ports and water
- 3. Dredged material, sediment, and watershed managers working together
- Protecting the environment;
- Conservation and restoration of estuaries and associated resources;
- Protecting water quality;
- Maintaining reservoir capacity ;
- Reducing flood and coastal storm damage;
- Managing watersheds;
- Managing coasts.

Reservoir Conservation RESCON
Volume I & Volume II (manual)

- **Managing Reservoir Sedimentation**
- **RESCON model: Technical and Economic Feasibility of various alternatives**
- **Alternatives Categories:**
  - **Reduce sediment inflows into the reservoir;**
  - **Manage sediments within the reservoir;**
  - **Evacuate sediments from the reservoir;**
  - **Replace lost storage**
- **Each Category has environmental and economic benefits and consequences.**

Year: 2003

Robles Diversion Dam

Location: Robles Diversion Dam, Ventura, California

Problem: the storage behind the dam has been significantly reduced by deposition of coarse sediment

Proposed Work:

-Hydraulic model study of the proposed High Flow Bypass spillway

-Froude-scale model was tested

-Improve upstream fish passage

Cost: N/A

Sediment Load: N/A

Year: 2008

San Clemente Dam

Location: San Clemente Dam on the Carmel River

Problem: The dam is 106 feet tall concrete arch and the reservoir it creates originally held 1,425 acre-feet of water but has now been reduced to 125 acre-feet due to sedimentation.

-Dam safety issue

Proposed Work:

-Dam Removal in January 2013

-Another alternative evaluated: Rerouting the river via bypass to avoid the accumulated sediment

-Reinforcing the current dam by adding support with rock or concrete structures

Cost: $84 million

Sediment Load: Today the reservoir has been filled by more than 2.5 million cubic yards of sediment, leaving a reservoir storage capacity of approximately 70 acre-feet as of 2008.

Year: 2009

Savage Rapids Dam

Location: Savage Rapids Dam, Southwestern Oregon, on the Rogue River

Problem: the dam has been diverting irrigation flows; fish ladders are old and do not meet the NMFS criteria

Proposed Work:

-Construction of two pumping plants to deliver irrigation water & removal of the dam

-Detailed sediment study

Cost: N/A

Sediment Load:200,000 cubic yards

Year: N/A

Dillsboro Dam

Location: Dillsboro Dam

Problem: Sediment and sand behind the dam

Proposed Work:

-Dam Removal

-Dredging

Cost: N/A

Sediment Load: more than 100,000 cubic yards

Year: 2007

Saginaw River, Michigan

Location: Saginaw River, Michigan

Problem: Sediment Trap

Proposed Work:

-Theoretical Model to evaluate the efficiency of the sediment traps

Cost: N/A

Sediment Load: N/A

Year: 2001

Glen Canyon Dam

Location: Glen Canyon Dam on the Colorado River

Problem: sediment has now collected behind the dam and affects area beaches and wildlife both below the dam

Proposed Work:

-High flow releases

-Pipeline to transport sediment

Cost:

-Initial cost: $140-$430 million/yr

-Operations: $3.6-$17 million/yr

-Utilities: $89.1 million/yr

Sediment Load: N/A

Year: 2009

Utah's Reservoirs

Location: Various Reservoirs in Utah

Problem: Utah does not have any coordinated efforts to assess or manage reservoir sedimentation.

Proposed Work:

-Watershed Management

-Construction

-Mining

-Logging

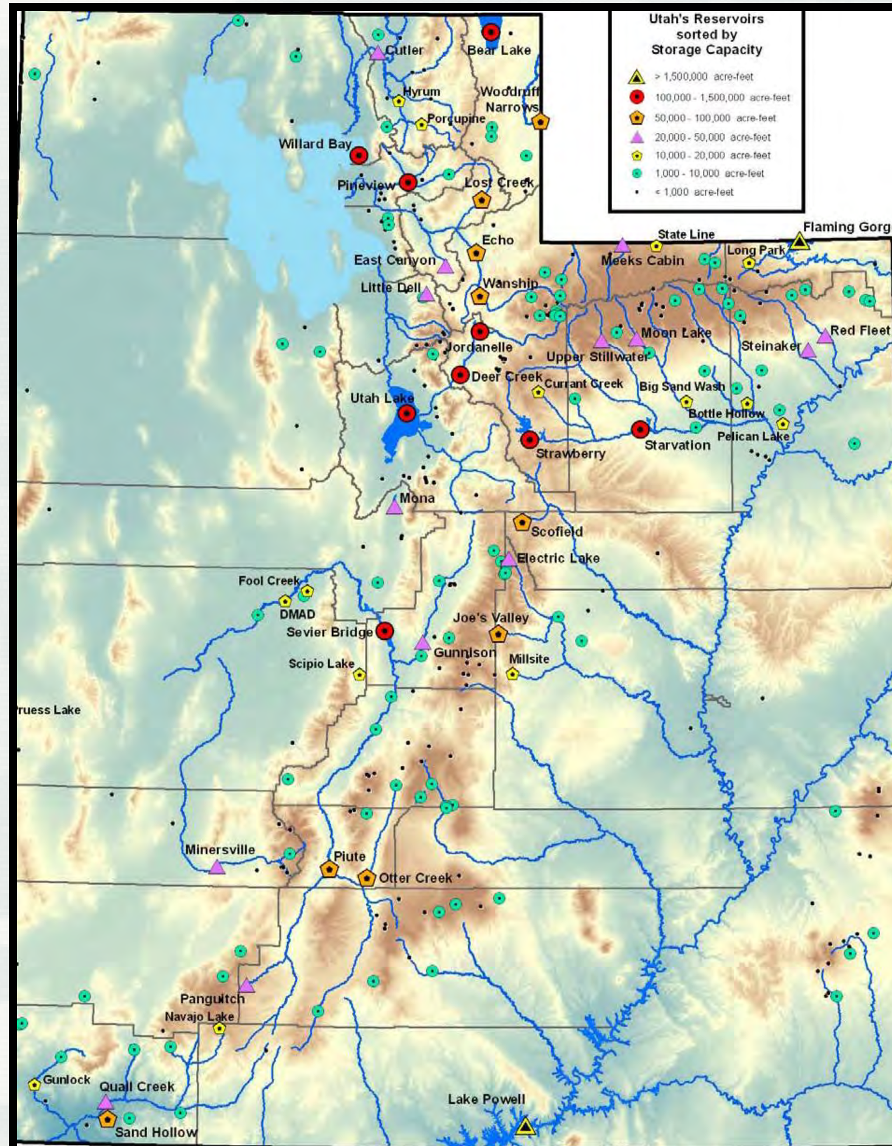
-Grazing

-Upstream Trapping

Cost: N/A

Sediment Load: Varies upon location

Year: 2010



International

Gezhouba & Three Gorges Dam

Location: Yangtze mainstem, China

Problem: The high sediment yields pose threats to the performance of the two dams

Proposed Work:

-Drawdown & Flushing

-Sluicing (Wash or rinse freely with a stream or shower of water)

-Releasing turbidity currents

-Dredging

Cost: N/A

Sediment Load: 100-150 million tons annually

Year: 2011

Going Full Circle (Discussion)

- **<u>Practical Methods Recommended:</u>**
  - Re-vegetation
  - Warping
  - Contour Farming
  - Check Dam
  - Bypassing (Implemented in **Switzerland** (5 bypass tunnel schemes) and **Japan** (4 bypass tunnel schemes))
  - Sluicing (Wash or rinse freely with a stream or shower of water)
  - Density Current Venting
  - Dredging
  - Dry Excavation
  - Hydro Suction
  - Drawdown Flushing
  - Pressure Flushing
- **<u>Year:</u>** 2011

Maithon Reservoir

Location: Maithon Reservoir, India

Problem: Sediment

Proposed Work:

-Rising of Reservoir Bed Levels
-Fill the dead storage zone with silt
-Siltation Trap

Cost: 2.8 mm^3/ year

Sediment Load: N/A

Year: 2006

Measures Against Reservoir Sedimentation (research study)

- **Location:** Switzerland
- **Problem:** The process of sedimentation is a severe threat to the artificial lakes serving as reservoirs for hydro-power production, drinking water supply or flood protection. It is a long-term problem with potential important economic consequences, which therefore requires a sustainable solution
- **Proposed Work:**
  - Release the sediments out of the reservoir in a continuous way in order to assimilate the natural conditions before the dam construction.
  - The momentum fluxes (jets or plumes) and the energy head of these water transfer tunnels can be used to create a rotational upward flow,
  - Define the upper limit of sediment concentration
- **Cost:** N/A
- **Sediment Load:** N/A
- **Year:** 2009

Yangtze River Basin

Location: Yangtze River Basin, China

Problem: The massive weight behind the Three Gorges Dam has begun to erode the Yangtze's steep shores at several spot, along with frequent fluctuations in water levels, has triggered a series of landslides and weakened the ground under Miaohe, village 10 miles up the reservoir. Additional dangers: as the dam blocks silt heading downstream, the Yangtze River estuary region is shrinking and sea water is coming further inland.

Work has been Done: New Dam

Cost: N/A

Sediment Load: 500 million metric tons of silt annually

Year: 2007

Reservoir Sedimentation and Sediment Management in Japan

- **Location:** Japan
- **Problem:** Rapid loss of sediment capacity, aging of reservoirs .
- **Work has been Done:**
  - Sediment Flushing
  - Sediment Bypassing
  - Excavating Turbid Water
  - Empty Dam
- **Cost:** N/A
- **Sediment Load:** 20 million m^3 annually
- **Year:** N/A

Naodehai Reservoir

- **Location:** Naodehai Reservoir, on the Liu River in China
- **Problem:** Reduce the sediment yield and deposition in the downstream channel
  Work has been Done:
  - -Reforestation
  - -Construction of Debris Dams
  - -Full Drawdown Flushing
- **Cost:** N/A
- **Sediment Load:** 261 million m^3 annually
- **Year:** 2004

Lower Ebro River

- **Location:** Spain
- **Problem:** The construction of dams has disrupted the sediment transport
- continuity, so the lower Ebro River and its delta are facing a sediment deficit
- **Proposed Work:**

  -Impounding the low-lying areas by means of defense structures

  -Restoring the sediment fluxes to the delta to stop coastal retreat and maintain land elevation
- **Cost:** Average cost of sediment dredging for wetland restoration is about US$ 40,000/ha, excluding additional activities such as construction of protective structures, planting, re-contouring, and monitoring
- **Sediment Load:** N/A
- **Year:** 2007

Sediment Management Round Table Discussion

- **<u>Danube River Basin, Europe</u>**
  - Need Sediment Flushing
- **<u>Elbe Basin, Central Europe</u>**
  - Maintenance and report of river-engineering works

Rhone River

Location: Rhone River, Switzerland

Problem: reservoir sedimentation resulting from bed and suspended load, endangers the safe and economic operation

Proposed Work:

-Flushing

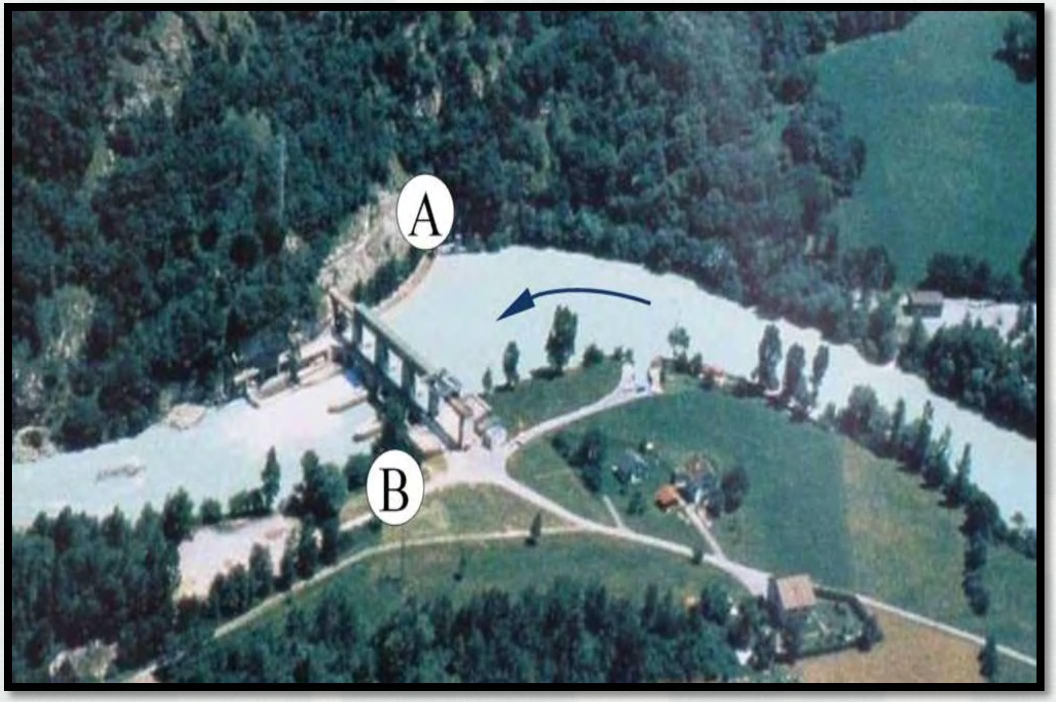
-Sluicing (Wash or rinse freely with a stream or shower of water)

-Hydraulic Model

Cost: N/A

Sediment Load: N/A

Year: 2012



Guanting Reservoir

Location: Guanting Reservoir on the Yongding River, China

Problem: reservoir storage capacity

What Has Been Done:

-Dredging

-Construction of hydraulic projects

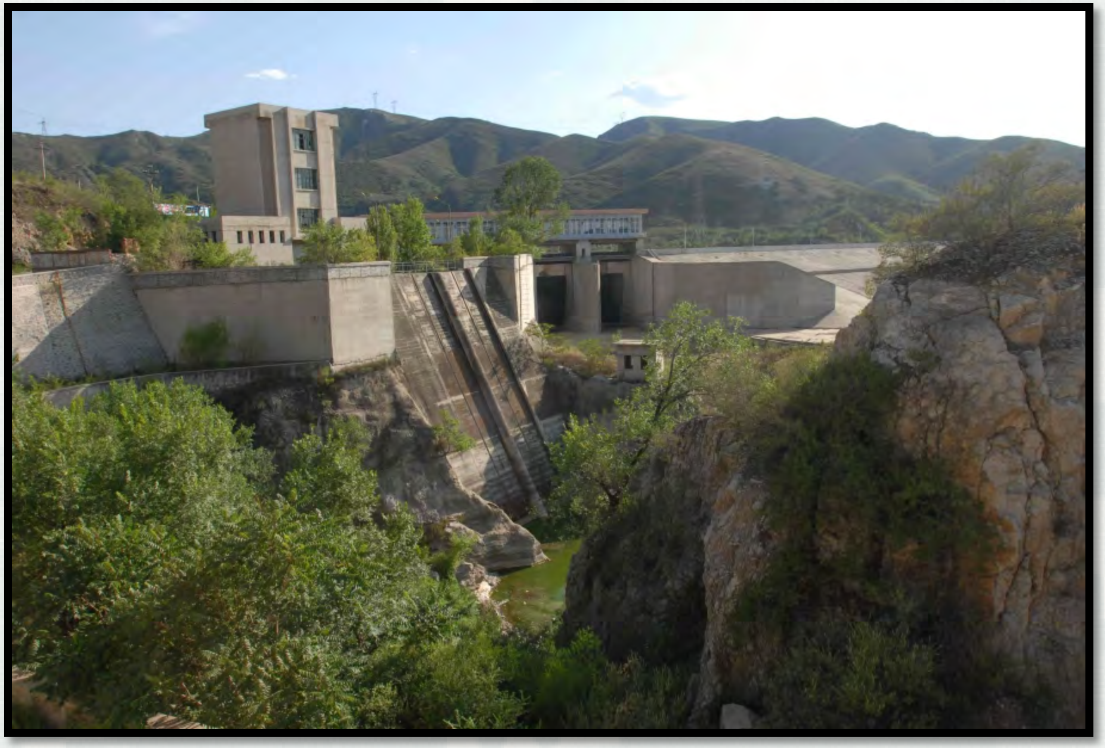
_building dams and reservoirs upstream

-Development of irrigation system

Cost: N/A

Sediment Load: N/A

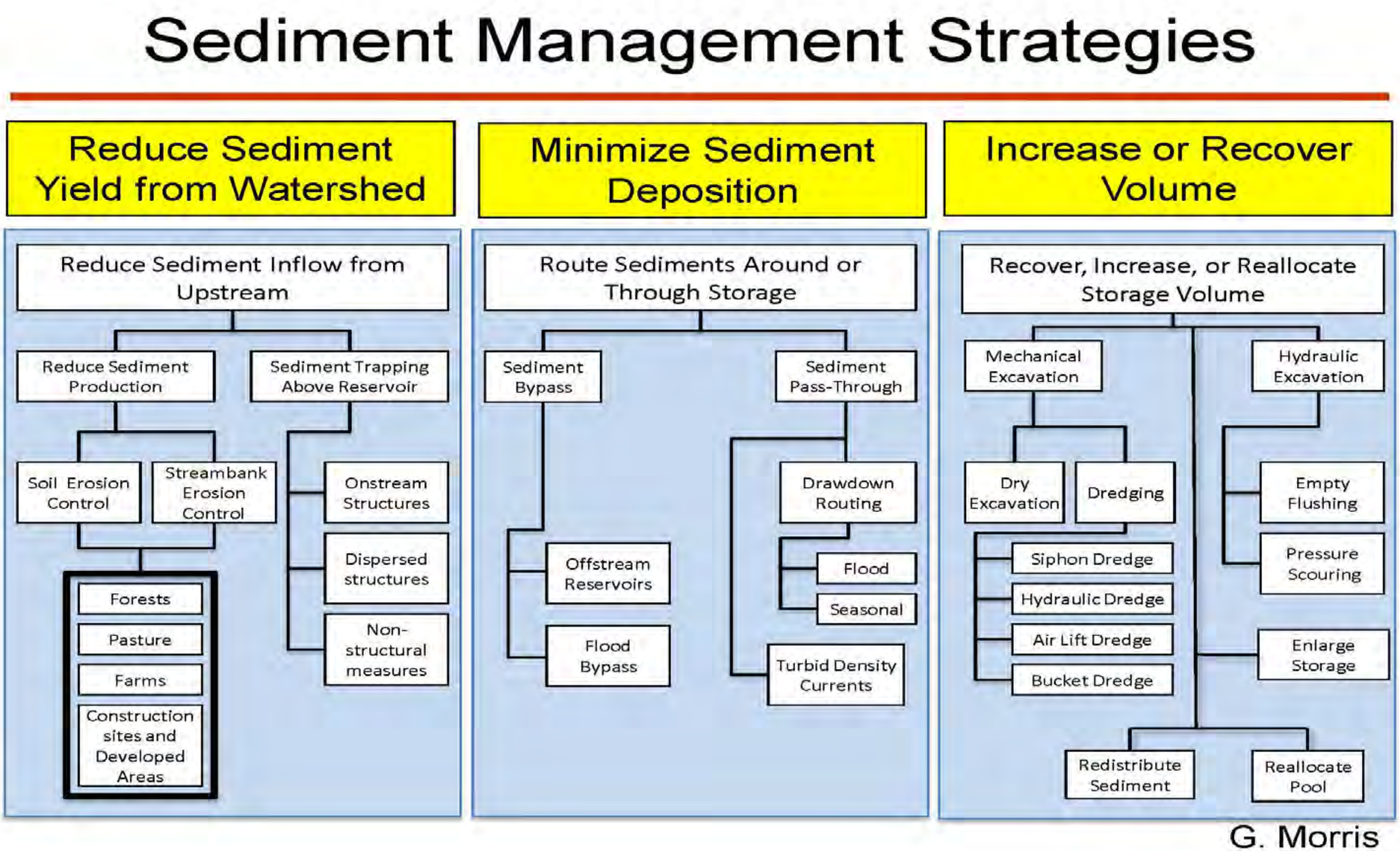
Year: 2004



Lit Search
Themes, Findings, Conclusions

- Reservoir sedimentation (declining storage) is a worldwide problem
- Trends like climate change and population growth are exacerbating problem
- Comprehensive, long-term sediment management is needed EVERYWHERE.
- New dams, have sediment management built in.

Lit Search
Themes, Findings, Conclusions



Lit Search
Themes, Findings, Conclusions

- ► **<u>Goals</u>** - What is driving the need for sediment management drives the solution:
  - Losing purpose/function of the dam (economics)?
  - Restoring natural sediment flow (environmental)?
- ► **<u>It's all about the sediment</u> -**
  - Where they are coming from?
  - Where they are depositing?
  - Sediment size and chemical characterization?
  - Contaminants; land-use history?
  - Particle size gradation and spatial distribution?
  - Erodability- Rate sediment would erode following dam removal? Transported downstream?
  - Location and magnitude of sediment deposition downstream?
  - Value of sediments behind the dam?
  - Precipitation patterns: when is sediment transported?

Lit Search
Themes, Findings, Conclusions

- **Effectiveness** - How effective is strategy at improving sedimentation?
- **Economic** -
  - Capital costs for strategy ?
  - Future operation and maintenance requirements?
- **Optimization/Adaptive Management** –
  - ✓ Modeling before implementation
  - ✓ Monitor effects of the implementation
  - ✓ Adjust activities to optimize effectiveness
  - ✓ Continuously improve system performance

Lit Search
Themes, Findings, Conclusions

- **<u>Environmental</u>** -
  - Permitting requirements?
  - Impacts?
- **<u>Schedule</u>** -
  - How much time is required for solution to be implemented?
  - Long term problems often need long-term solutions.
  - Implementation sequence: long and short-term implementation?
- **<u>Integrated sediment system management</u>**-
  - Multi-faceted problem requires multi-faceted solution most have combinations.
- **<u>Benefits</u>** –
  - Costs incurred worthwhile?

Lit Search
Themes, Findings, Conclusions

- **Dredging (i.e. increasing or recovering volume)**

- ▶ O&M
- ▶ Contamination
- ▶ Dredging can be reduced by using BMP’s and finding the critical sediment producing watersheds from upstream.
- ▶ Dredging is very expensive nomally is a last resort: often create new social and environmental problems .
- ▶ Tactical Dredging
- ▶ Beneficial re-use
  - Soil amendments (agriculture, mining etc.)
  - Habitat development/beach nourishment
  - Commercial (bricks, geotextile container fill groins, landfill capping, tiles, glass, cement blocks

Lit Search
Themes, Findings, Conclusions

By-passing - Routing sediments around or through storage

- **The technology to by-pass and transport sediments has been developed**
- **Long Distance Conveyance** hydraulic transport of through pipelines (>10 miles)
- **Hydrosuction sediment removal**
  - Dredging equipment with hydrostatic head over a dam to create suction at the upstream end.
  - Difference between water levels upstream and downstream of dam to remove sediment through a floating or submerged pipeline linked to an outlet or discharging over the dam.
  - **Hydrosuction dredging,** deposited sediment dredged and transported downstream or to a treatment basin.
  - **Hydrosuction bypassing**, incoming sediment is transported without deposition past the dam to the downstream receiving stream.

Lit Search
Themes, Findings, Conclusions

By-passing - Routing sediments around or through storage

- Pipeline diameter selection, and head size
- Environmental Impacts
  - Increased turbidity levels downstream?
  - Changes in water chemistry?
  - Impacts of sediment-removal upstream?
  - Regulatory agencies should be contacted early
- Ecological and operational aspects an upper limit of sediment concentration needs to be defined
- Out-flowing sediment concentration has to be regularly monitored and controlled.

LSRWA Goals and Objectives

1. **Evaluate strategies to manage sediment and associated nutrient delivery to the Chesapeake Bay.**
   - Strategies will incorporate input from Maryland, New York, and Pennsylvania Total Maximum Daily Load (TMDL) Watershed Implementation Plans.
   - Strategies will incorporate evaluations of sediment storage capacity at the three hydroelectric dams on the Lower Susquehanna River.
   - Strategies will evaluate types of sediment delivered and associated effects on the Chesapeake Bay.

2. **Evaluate strategies to manage sediment and associated nutrients available for transport during high flow storm events to reduce impacts to the Chesapeake Bay.**

3. **Determine the effects to the Chesapeake Bay due to the loss of sediment and nutrient storage behind the hydroelectric dams on the Lower Susquehanna River.**

Appendix I:
Stakeholder Involvement

Attachment I-1:
Stakeholder Outreach Plan

Attachment I-2:
Stakeholder Coordination Tracking

Attachment I-3:
Press Releases

Attachment I-4:
Study Initiation Notice

Attachment I-5:
Resource Agency Coordination

Attachment I-6:
Quarterly Meeting Summaries

Attachment I-7:
Stakeholder Review Comments and Responses

Attachment I-8:
Public Comments and Responses

Attachment I-1:
Stakeholder Outreach Plan

February 2012

Lower Susquehanna River Watershed Assessment
Stakeholder Outreach Plan

Background

The Lower Susquehanna River Watershed Assessment (LSRWA) is a multi-agency effort to comprehensively forecast and evaluate sediment and associated nutrient loads to the system of hydroelectric dams located on the Susquehanna River above the Chesapeake Bay. The assessment will analyze hydrodynamic and sedimentation processes and interactions within the Lower Susquehanna River watershed, consider structural and non-structural strategies for sediment and nutrient management, and assess cumulative impacts of future conditions and sediment and nutrient management strategies on the Chesapeake Bay.

The LSRWA team includes:

- U.S. Army Corps of Engineers, Baltimore District (USACE) (federal sponsor);
- Maryland Department of the Environment (MDE) (non-federal sponsor);
- Maryland Department of Natural Resources (MDNR, including the Maryland Geological Survey (MGS));
- U.S. Geological Survey (USGS);
- U.S. Army Corps of Engineers, Engineer Research and Development Center (ERDC);
- Susquehanna River Basin Commission (SRBC);
- The Nature Conservancy (TNC); and
- U.S. Environmental Protection Agency – Chesapeake Bay Program (EPA-CBP).

The LSRWA will not directly lead to implementation of specific actions to manage sediments and associated nutrients in the lower Susquehanna River; instead it will provide information to be further evaluated by stakeholders. Stakeholders are defined as all interested state and federal agencies, local governments, non-governmental organizations (NGO's), business groups, and the general public. Therefore no formal National Environmental Policy Act (NEPA) compliance is required. Consequently, stakeholders' involvement in the assessment can be more flexible and less formal. Though no formal NEPA compliance is required, the LSRWA team recognizes that it is imperative to involve the stakeholders and interested agencies in order for the LSRWA to be a useful tool to the Chesapeake Bay community. This involvement would include transferring knowledge gained during this assessment to all stakeholders, incorporating the management efforts and activities of others in the watershed, and receiving feedback on the sediment and nutrient management strategies that are developed.

In addition to the LSRWA team members identified above, the following stakeholders will most likely be interested in the contents and management recommendations of the LSRWA:

- U.S. Department of Interior – U.S. Fish and Wildlife Service,
- U.S. Department of Agriculture – Natural Resources Conservation Service,

- National Oceanic and Atmospheric Administration – Restoration Center,
- National Marine Fisheries Service – Habitat Conservation Division,
- Maryland governor's office,
- Pennsylvania governor's office,
- New York governor's office,
- MD local (state/county/city) governments,
- PA local (state/county/city) governments,
- NY local (state/county/city) governments,
- MD congressional representatives,
- PA congressional representatives,
- NY congressional representatives,
- Pennsylvania Department of Environmental Protection,
- Pennsylvania Department of Conservation and Natural Resources,
- Pennsylvania Fish and Boat Commission,
- Lower Susquehanna Riverkeeper,
- Coastal Conservation Association Maryland
- Exelon Corporation,
- University of Maryland Center for Environmental Science,
- Chesapeake Bay area universities, colleges, and research institutions,
- Chesapeake Bay Research Consortium,
- Maryland Waterman's Association,
- Chesapeake Bay Commercial Fishermen's Association,
- Chesapeake Bay Foundation (CBF),
- Oyster Recovery Partnership, Inc.,
- Industry and trade groups,
- Media, both traditional and social media outlets, and
- Interested individuals.

This plan describes the approach for involving these stakeholders in the LSRWA.

Goal of This Plan

The goal of stakeholder involvement and coordination is to create, facilitate, and maintain open channels of communication with stakeholders to allow for full consideration of stakeholder views and information in the decision-making process. This outreach plan outlines procedures necessary to accomplish these goals. Activities under this plan will help to accomplish the following:

1. Make information about assessment findings and recommended management strategies readily available;
2. Provide forums for making stakeholders' wishes, needs, and concerns known to decision-makers proactively as management strategies are being developed; and
3. Incorporate/acknowledge stakeholder views in the final watershed assessment.

Outreach Strategy

This stakeholder outreach plan provides an overall strategy to involve interested stakeholders in the LSRWA process. The LSRWA team will maintain coordination with federal, state, and local agencies as well as interest groups and Congressional staff during the development of the LSRWA plan. Stakeholder meetings and inter-agency workshops will be used to coordinate stakeholder involvement in the development of the assessment; it is expected that these will be held on the same day but with separately invited audiences. In addition, the appropriate members of the team will hold meetings with federal, state, and municipal officials, as needed. Team members will issue stakeholders notices, respond to media and stakeholder inquiries, and coordinate and communicate with various committees and organizations as necessary. LSRWA information will also be shared via email distribution lists and a website to be hosted by MDNR.

Stakeholder Concerns Previously Identified

During the development of the LSRWA scope of work (May 2009 - June 2011), a stakeholder meeting was held in October 2009. Based on comments at that meeting, follow-up discussions between the LSRWA team with stakeholders, and other outreach activities, many concerns were identified. Below is a compilation of those previously identified concerns regarding sediment and nutrient management strategies in the lower Susquehanna River:

1. Cost of implementation and any follow-on maintenance activities;
2. Responsibility for implementation;
3. Funding sources for implementation;
4. Technical soundness and accuracy of forecasting tools (i.e., models);
5. Environmental impacts of recommended strategies (dredging, by-passing sediments, watershed actions, etc);
6. Impacts to the Chesapeake Bay and EPA-designated total maximum daily load (TMDL) allocations if dams no longer trap sediments;
7. Feasibility of management strategies (e.g., large amount sediments to remove on a continual basis);
8. Risks of storm events scouring sediments from behind dams and associated impacts to the Bay; and
9. Risks of no action.

This team anticipates that these as well as other concerns, yet to be communicated, will arise during stakeholder outreach activities and will be addressed in the LSRWA as comprehensively as possible.

Stakeholder Outreach Mechanisms

USACE and MDE/MDNR will lead a coordinated effort to actively communicate with the media, stakeholders, and elected officials.

a. Press Releases

In general, news releases will be made jointly by USACE, MDE, and MDNR; however, if issued individually, they will be pre-coordinated with the other lead agencies (USACE, MDE, and

MDNR). News releases will be distributed to applicable local and national media outlets, including newspapers, journals, television, and pertinent social media outlets.

b. Website, Fact Sheets, and Stakeholder Outreach Documents

The team will develop and maintain a website to inform stakeholders regarding progress on the assessment. MDNR will host the website. All material on the website will be previewed and approved by the lead agencies (MDE, MDNR, and USACE) before being posted on the website. Other agencies may be asked to review materials, depending on the content. Materials expected to go on the website include:

- Statement of the assessment goals and objectives,
- List of team members and roles,
- Minutes from the quarterly team meetings,
- Pertinent PowerPoint presentations,
- Approved technical reports,
- Stakeholder outreach plan.
- Project management plan,
- Assessment's legal cost-sharing agreement, and
- Calendar of events.

c. Quarterly Team Meetings

The LSRWA team will meet quarterly to discuss, coordinate, and review technical and non-technical components of the assessment as well as management activities. These meetings will be open to stakeholders.

d. Inter-Agency Workshops and Stakeholders Meetings

The LSRWA team will set up stakeholder meetings/workshops at appropriate times during the assessment. LSRWA team members will make presentations and assist in workshops to generate information for stakeholder and inter-agency meetings. It is anticipated that there will be two meetings, one when modeling findings are completed and preliminary strategies are developed (fall 2013), and a second meeting when the LSRWA plan is released for stakeholder review (summer 2014).

Prior to each meeting, USACE will develop a detailed work plan, including roles and responsibilities, location(s), coordinated messages, handouts, meeting materials and displays, timeline sequence, and points of contact. This work plan will be coordinated with MDE and MDNR, as well as pertinent LSRWA team members. The purpose of the stakeholder meetings will be to provide information about the LSRWA plan and obtain stakeholder input regarding its content.

The team will provide the draft report on CD to interested stakeholders and libraries. The report will also be made available on the project's website to download.

e. Other Chesapeake Bay Meetings

Throughout the duration of the assessment, the LSRWA team will coordinate with other pertinent Chesapeake Bay groups that meet regularly to be included on their agendas to provide updates and get feedback on the LSRWA. Depending on the type of meeting, the most appropriate assessment team member (i.e., the assessment team member who is already attending or a part of that particular Chesapeake Bay group) could provide the update. The LSRWA team member will report feedback received from these other Chesapeake Bay groups to the rest of the LSRWA team so that this feedback can be incorporated into LSRWA report. PowerPoint slides will be updated after each quarterly team meeting (USACE lead) so that they can be utilized by LSRWA team members for this purpose.

f. Email Updates

Throughout the duration of the assessment, email updates will be sent out, periodically, to interested stakeholders. An email distribution list was started by the original Sediment Task Force (included interested stakeholders) that SRBC headed up in 1999 and 2000. USACE has been updating this list since 2009 with people requesting to be updated on the sedimentation issue. USACE will continue to have the lead on keeping this email distribution list up to date and sending out email updates of study progress and news.

g. Agency Coordination

As stated earlier, no formal NEPA compliance is required of this assessment. However, the LSRWA is being conducted under Section 729 of the Water Resources Development Act of 1986, as amended. This law requires USACE to coordinate the development of the assessment with certain federal agencies. USACE will send out cooperating agency letters in February 2012; these letters will ask these federal agencies to identify the level of involvement they would like to have in the assessment. This involvement could include (but is not limited too) participation in inter-agency workshops, provision of background data and technical expertise, and other reviews as necessary. MDE and MDNR will review the cooperating agency letters prior to the formal transmittal.

Documentation

The LSRWA report will include a compilation of efforts made to acquire stakeholder input and the information and opinions expressed prior to arriving at a final document with recommended management strategies. The stakeholder involvement section of the report will show how stakeholder input was used in the planning and decision-making process.

At this time, a 45-day review period is anticipated for the draft document. A comment-response document will be developed and included as an appendix to the final report.

Attachment I-2:
Stakeholder Coordination Tracking

Stakeholder Coordination - Tracking					
Date	**Stakeholder/Audience**	**Method**	**Notes**	**Comments**	**Response/Follow up**
27-Sep-11	Wide-General Public	Press Release	MDE-Press Release	No specific feedback	
30-Nov-11	CBP Modeling Workgroup	Presentation	J. Halka (MGS) gave presentation providing an update on study	No specific feedback	
1-Dec-11	All interested stakeholders	Email	A. Compton (USACE) emailed large group update on study; sent Nov 2011 meeting summary and press release and had both posted to public website.	Several requests to be added to the is email distribution list and to attend quarterly meeting	Those who requested to be added to email list/invited to quarterly meeting were added.
2-Jan-12	CBP STAC meeting quarterly	Presentation	B. Michael (DNR) gave presentation providing an update on study	No specific feedback	
2-Jan-12	Citizen Advisory Committee-DMMP	Presentation	J. Halka (MGS) gave presentation providing an update on study	No specific feedback	
23-Jan-12	LSRWA Quarterly meeting	Email & presentations	Members of Press attended; general public and Exelon	Documented in meeting summary	Documented in meeting summary
1-Feb-12	State and Federal Agencies	Mail	USACE mailed Agency coordination letters	1. USGS requested that J. Blomquist be added as POC. 2. PAFBC requested that M. Hendricks be added as POC. 3. PADEP requested that K. Bardell be POC	Those who requested to be added to email list/invited to quarterly meeting were added.
13-Feb-12	All interested stakeholders	Email	C. O'Neill (USACE) emailed Study Initiation Notice	1. (PADEP) requested to be notified.	Added to distribution list.
13-Feb-12	CBP Water Quality Goal Implementation Team Meeting	Presentation	Presentation on study by B. Michael (DNR)	No specific feedback	
17-Apr-12	CBP Modeling Workgroup Quarterly Review meeting	Presentation	C. Cerco (USACE) gave presentation on study update and his modeling work	No specific feedback; group on board with methodology.	
30-Apr-12	LSRWA Quarterly meeting	Email & presentations	General public, Exelon, and several new agencies attended (NOAA, PADEP, PAD DCNR).	Documented in meeting summary	Documented in meeting summary
25-May-12	All interested stakeholders	Email & presentations	Compton emailed meeting summary from April quarterly meeting and had it posted to public website.	No specific feedback	
7-Aug-12	LSRWA Quarterly meeting	Email & presentations	General public, Exelon, and several new agencies attended (NOAA, PADEP, PAD DCNR).	Documented in meeting summary	Documented in meeting summary
30-Aug-12	All interested stakeholders	Email	Team Statement regarding how LSRWA will incorporate USGS finding/recent report: Flux of nitrogen, phosphorus, and suspended sediment from the Susquehanna River Basin to the Chesapeake Bay during Tropical Storm Lee, September 2011, as an indicator of the effects of reservoir sedimentation on water quality	No specific feedback	

Stakeholder Coordination - Tracking					
Date	**Stakeholder/Audience**	**Method**	**Notes**	**Comments**	**Response/Follow up**
30-Aug-12	All interested stakeholders	Email	Compton emailed meeting summary/presentations from April quarterly meeting	No specific feedback	
4-Sep-12	All interested stakeholders	Email	Compton emailed meeting summary from August quarterly meeting and had it posted to public website.	No specific feedback	
24-Sep-12	LSRWA Brainstorming meeting- All interested stakeholders	Email & presentations	general public, Exelon, and several new agencies attended (NOAA, PADEP, PAD DCNR).	Documented in meeting summary	Documented in meeting summary
16-Nov-12	All interested stakeholders	Email	Compton emailed meeting summary from Sept 24 Brainstorming meeting	No specific feedback	
30-Nov-12	Citizen Advisory Committee- Chesapeake Bay Commission	Presentation	Compton, Helfrich (Lower Susquehanna Riverkeeper) and Seaman (DNR) provided update to group and sat on Q&A panel. Other LSRWA team members were in audience as well to answer questions.	Group had questions about Exelon involvement in LSRWA and potential for involvement in implementation of sediment management solutions. Expressed concern over timing of study, since it will not lead directly to implementation and how this fits into FERC relicensing of Conowingo and the timing of the Dam reaching steady state.	Several group members were added to LSRWA email distribution list that requested this.
3-Dec-12	Upper Western Shore Tributary Team.	Presentation	M. Rowe (MDE) provided and update to this group after Mike Langland and Bob Hirsch presented talks on the reservoirs and potential implications once filled.	(1) Baltimore City was there and expressed some concerned about a sediment by-pass option in that it could impact their drinking water intakes on the Susquehanna. One good thing is they tend to pull water during low flow conditions and bypass would likely be conducted during high flows. (2)Some marina owners were there and expressed concern about bypass causing sedimentation and increased dredging need in their slips.	City did want to stay apprised of team activities but not necessarily start attending team meetings . Baltimore city rep added to distribution list.
4-Dec-12	Chesapeake Bay Program Scientific and Technical Advisory Committee (STAC)	Presentation	B. Michael (DNR) gave presentation providing an update on study	STAC would like to review and have input on sediment management options. STAC also feels that the modeling work should account for Climate Change	B. Michael will bring up the issue of Climate Change to modelers
11-Dec-12	Chesapeake Bay Program Science, Technology and Report (STAR)	Presentation	B. Michael (DNR) gave presentation providing an update on study	No specific comments	

Stakeholder Coordination - Tracking					
Date	**Stakeholder/Audience**	**Method**	**Notes**	**Comments**	**Response/Follow up**
4-Jan-13	State Water Quality Advisory Committee	Presentation	B. Michael (DNR) gave presentation providing an update on study	No specific comments	
13-Jan-13	Chesapeake Bay Program Modeling Workgroup	Presentation	C. Cerco gave presentation on study update and his modeling work	Lee Currey (chairman) indicated he would like to see more extensive presentation of the effects projected by our scenarios (as opposed to the simple time series and longitudinal plots presented up to now).	ERDC is producing color surface plots for key scenarios.
14-Jan-13	Hughes Center for Agro Ecology	Presentation	B. Michael (DNR) gave presentation providing an update on study	No specific comments	
22-Jan-13	Chesapeake Bay Program Analytical Methods and Quality Assurance Workgroup	Presentation	B. Michael (DNR) gave presentation providing an update on study	No specific comments	
6-Feb-13	MPA Citizens Advisory Committee	Presentation	B. Michael (DNR) gave presentation providing an update on study	No specific comments	
11-Feb-13	LSRWA Quarterly meeting	Email & presentations	Various state, federal agencies, NGO's	Documented in meeting summary	Documented in meeting summary
12-Mar-13	Sportsmen-Conservation Leaders Briefing	Presentation	B. Michael (DNR) gave presentation providing an update on study	No specific comments	
26-Mar-13	NMFS	Letter	Placed on public website and emailed to stakeholders	Expressed concerns of by-passing options and potential impacts to fish spawning habitat	LSRWA team will include these concerns during concept development
28-Mar-13	All interested stakeholders	Email	Compton emailed meeting summary/presentations from February quarterly meeting	No specific comments	
17-Apr-13	Focused on Maryland Counties	Public meeting hosted by Nanticoke Watershed Alliance in Dorchester County, MD.	No one from LSRWA team attended in person.	Group shared concerns over costs implementing WIPS and implications of Conowingo filling	
18-Apr-13	Soil Conservation Committee Meeting	Presentation	B. Michael (DNR) gave presentation providing an update on study	No specific comments	
20-Apr-13	Democratic Club of Kent County Meeting	Presentation	B. Michael (DNR) gave presentation providing an update on study	No specific comments	
3-May-13	Chesapeake Bay Trust Board Meeting	Presentation	B. Michael (DNR) gave presentation providing an update on study	No specific comments	
13-May-13	LSRWA Quarterly meeting	Email & presentations	Various state, federal agencies, NGO's	Documented in meeting summary	Documented in meeting summary
17-Jul-13	Soil Conservation District's Annual meeting	Presentation	B. Michael (DNR) gave presentation providing an update on study	Want to be kept updated on status of study	
13-Aug-13	LSRWA Quarterly meeting	Email & presentations	Various state, federal agencies, NGO's	Documented in meeting summary	Documented in meeting summary
9-Sep-13	Upper Western Shore Trib Team meeting	Presentation	M. Rowe gave a presentation	Question on how we are going to notify the public when the report is available for public review	Team has to work out details on specifics of rollout of report and public meeting

Stakeholder Coordination - Tracking					
Date	**Stakeholder/Audience**	**Method**	**Notes**	**Comments**	**Response/Follow up**
27-Sep-13	All interested stakeholders	Email	Compton emailed meeting summary/presentations from August quarterly meeting	No specific comments	
13-Nov-13	Informational Open House Harford County Community College	Presentation	B. Michael (DNR) gave presentation providing an update on study	No specific comments	
12-Dec-13	Mt. Airy Water and Sewer Board	Presentation	B. Michael (DNR) gave presentation providing an update on study	No specific comments	
12-Dec-13	Susquehanna River Basin Commission Board Meeting	Presentation	B. Michael (DNR) gave presentation providing an update on study	No specific comments	
16-Jan-14	LSRWA Quarterly meeting	Email & presentations	Various state, federal agencies, NGO's	Documented in meeting summary	Documented in meeting summary
20-Feb-14	Tidal Fisheries Advisory Commission	Presentation	S. Seaman (MDNR gave update to this group.	No specific feedback.	
24-Feb-14	All interested stakeholders	Email	Compton emailed meeting summary/presentations from January quarterly meeting	No specific comments	
5-May-14	U.S. Senator Cardin and Subcommittee on Water and Wildlife	Field hearing	Hearing held at the Conowingo Dam Visitors Center and Recreation Office. Panelists included Col. Jordan (USACE); Joe Gill (MDNR); Genevieve LaRouche (USFWS); Dr. Boesch (UMD); Vicky Wills (Exelon); and Richard Gray (Mayor of Lancaster, PA).	Focused on "Finding Cooperative Solutions to Environmental Concerns with the Conowingo Dam to Improve the Health of the Chesapeake Bay”	
21-Jun-14	Dorchester Shoreline Erosion Group	Presentation	Bruce Michael (DNR) gave update on report findings	No specific comments	
5-Sep-14	State Water Quality Advisory Committee	Presentation	Bruce Michael (DNR) gave update on report findings	No specific comments	
8-Sep-14	Harry Hughes Center for Agro-Ecology Board Meeting	Presentation	Bruce Michael (DNR) gave update on report findings	No specific comments	
19-Sep-14	Tidewater Environmental Health Association Meeting	Presentation	Bruce Michael (DNR) gave update on report findings	No specific comments	
6-Nov-14	Dredge Material Management Program (DMMP) Committee Meeting	Presentation	Bruce Michael (DNR) gave update on report findings	No specific comments	
7-Nov-14	Chesapeake Bay Commission Board Meeting	Presentation	Bruce Michael (DNR) gave update on report findings	No specific comments	
10-Nov-14	Congressional	Email	Gross sent notification of upcoming release of the draft report	No specific comments	
10-Nov-14	LSRWA quarterly meeting and stakeholder group, other stakeholders	Email	Gross sent notification of upcoming release of the draft report	No specific comments	
10-Nov-14	Regional media	Email	Gross sent notification of upcoming release of the draft report and information for a media call	No specific comments	
12-Nov-14	Regional media	Phone call	Pre-release media call	No specific Comments	
12-Nov-14	Regional media/public	Email	Gross sent press release with link to draft report/study web site	No specific Comments	

Stakeholder Coordination - Tracking					
Date	**Stakeholder/Audience**	**Method**	**Notes**	**Comments**	**Response/Follow up**
21-Nov-14	Maryland Public Television (MPT) audience	Television interview	Anna Compton interviewed by State Circle, MPT, on report findings	No specific Comments	
21-Nov-14	Maryland Water Monitoring Council Annual Meeting	Presentation	Bruce Michael (DNR) gave presentation, "Conowingo Dam Impacts to the Chesapeake Bay", at annual conference	No specific Comments	
4-Dec-14	Regional media	Email	Reminder media advisory for the public meeting	No specific Comments	
5-7-Dec-14	Public	Public notices in newspapers	Ran notice of public meeting in 11 newspapers, running either Friday, Saturday or Sunday, leading up to the meeting.	No specific Comments	
9-Dec-14	Public Meeting (also available via webinar and telephone) - all interested stakeholders	Presentation/Webinar	Powerpoint presentation on report findings, panel discussion, and public question and answer period	Questions and comments for Q&A submitted via comment cards or through webinar	Responses to all questions included in Final Report Appendix I, Attachment I-8
14-Jan-15	Chesapeake Bay Program Modeling Quarterly Review Meeting	Presentation	Bruce Michael gave update on report findings	No specific comments	
16-Jan-15	Metropolitan Washington Council of Government's Chesapeake Bay & Water Resources Policy Committee	Presentation	Bruce Michael gave update on report findings	No specific comments	
29-Jan-15	Maryland House of Delegates Environment and Transportation Committee	Testimony	Col. Jordan (USACE), Dr. Boesch (UMD), and Vicky Will (Exelon) gave testimony on report findings and the status of Conowingo Dam; Rich Batiuk (USEPA) joined the panel for Q&As.	Jay Jacobs of Caroline, Kent, Cecil and Queen Anne counties was concerned that the report downplays the real threat of Conowingo and believes that dredging behind the dam should be a priority.	
17-Feb-15	Harford County, Environmental Advisory Board Meeting	Presentation	Bruce Michael gave update on report findings	No specific comments	
2-Apr-15	North Point Peninsula Community Meeting	Presentation	Bruce Michael gave update on report findings	No specific comments	
16-Apr-15	National Public Radio audience	Radio interview	Radio interview on "Maryland's Conowingo Dam Debate" on the Kojo Mnamdi Show with panelists including Mark Bryer (Nature Consevancy).	No specific comments	

Attachment I-3:
Press Releases

Attachment I-3: Press Releases
Table of Contents

http://textonly.mde.state.md.us/programs/PressRoom/Pages/092711.aspx

MARYLAND THE DEPARTMENT OF THE ENVIRONMENT

Press Release

Media Contacts:

MDE: Jay Apperson, 410-537-3003

DNR: Josh Davidsburg, 410-260-8002

USACE: Chris Augsburger, 410-962-2809

Study on Sediment behind Conowingo Dam Launched *Lower Susquehanna River Watershed Assessment to address sediment accumulation, potential for storms to affect water quality, aquatic life in Chesapeake Bay*

BALTIMORE, MD (September 27, 2011) – Governor Martin O'Malley and Col. Dave Anderson, Commander of the U.S. Army Corps of Engineers, Baltimore District, today announced the launch of a study of strategies to protect the Chesapeake Bay from sediment and other pollutants from the lower Susquehanna River watershed, including those that accumulate behind the Conowingo Dam.

"We must do everything we can to protect the health of our Bay for our children and theirs," said Governor O'Malley. "We are pleased to announce this series of studies to assess how a strong storm could affect our ability to protect the Bay from sediment and other pollutants. Tropical Storm Lee provided a vivid demonstration of the need to take steps to head off what could be a catastrophic event causing immediate and enormous damage to our restoration processes. The time to address this threat is now."

The Lower Susquehanna River Watershed Assessment – Phase I will provide critical information to address concerns that a strong storm could scour vast amounts of the Susquehanna sediments and negate progress made in restoring the Chesapeake Bay.

The storm surge from Tropical Storm Lee earlier this month delivered an estimated 4 million tons of scoured sediment from the lower Susquehanna River watershed to the Bay, along with excess nutrients, nitrogen and phosphorus. The last high-flow event of this magnitude was Tropical Storm Agnes in 1972, which devastated the Bay by smothering underwater grasses and oyster beds.

Experts from the Maryland Departments of the Environment and Natural Resources, the Corps, the Susquehanna River Basin Commission, and the Nature Conservancy will team up for the new study. The study will evaluate the millions of tons of lower Susquehanna River sediment stored behind the Conowingo Dam and three other hydroelectric dams on the Susquehanna River. It will also assess strategies to manage and reduce sediment from the lower Susquehanna mainstem watershed. The watershed implementation plans for Maryland and Pennsylvania that are being developed to meet the Chesapeake Bay "pollution diet" will be integrated into the assessment.

Experts from the Corps' Baltimore District and their Engineer Research and Development Center will use cutting-edge modeling techniques to simulate sediment transport and deposition through the river and Bay system, with the goal of evaluating structural and nonstructural strategies for sediment management.

“The Chesapeake Bay is one of the world's most important estuaries. This study demonstrates the commitment of our partnership to develop coordinated solutions across multiple stakeholders that will help protect the Bay,” said Colonel Anderson.

U.S. Environmental Protection Agency water quality standards established for Chesapeake Bay assume that upstream storage in the Susquehanna watershed will continue to trap substantial amounts of sediment and pollutants through at least 2025. If that is not possible, the States in the Susquehanna Basin (New York, Pennsylvania, and Maryland) will be required to identify and implement other pollution control measures to meet the EPA-imposed standards.

Of the dams on the Susquehanna River that are in the study area, only the Conowingo Dam has any remaining capacity for storing sediment. The Conowingo Dam, which is the closest of the dams to the entrance to the Chesapeake Bay, can trap about 2 million tons of sediment out of the approximately 3 million tons that reach its pool area yearly. But it is estimated that the reservoir’s capacity to store sediments will be reached in 15 to 20 years under current conditions. At that time, sediment and nutrient inputs to the Bay would increase dramatically, threatening efforts to improve Bay water quality and increase the health of aquatic life.

The assessment will develop broad, planning-level strategies and anticipated impacts and benefits to the Chesapeake Bay. While the study will not result in a single, recommended plan, it will provide essential information to be further evaluated by the States and federal government.

The assessment will cost $1.4 million over the three-year period. The $344,000 non-federal share of the project will be met in services provided by the Maryland Departments of the Environment and Natural Resources, the Susquehanna River Basin Commission and the Nature Conservancy.

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Lower Susquehanna River Watershed Assessment Team Statement on USGS Report on Conowingo Scouring and Susquehanna River Nutrient and Sediment Delivery

August 7, 2012

The Lower Susquehanna River Watershed Assessment (LSRWA) team held its quarterly meeting on August 7, 2012, at the Maryland Department of the Environment in Baltimore, MD.

In addition to updated reports on the continuing technical studies, Dr. Robert Hirsch, a senior research hydrologist from the U.S. Geological Survey (USGS), presented preliminary findings from his research on the impact of recent high flow events on the Susquehanna River to the Chesapeake Bay. Results from his analysis indicate an acceleration of scouring activity in the Conowingo Reservoir that is causing greater discharge of sediments and nutrients to the Chesapeake Bay. Dr. Hirsch's report, which was recently released by the USGS (http://pubs.usgs.gov/sir/2012/5185/) notes that Conowingo's sediment storage capacity is currently about 90% filled, is further diminishing and moving toward a more steady state (sediment output will equal sediment input). Consequently, we are seeing higher sediment and nutrient loads to the Bay quicker than previously expected. Dr. Hirsch's analysis indicates that this trend will continue and even increase with Susquehanna River flows less than 400,000 cubic feet per second, which had been previously thought to be the trigger level for storm scouring activity. Dr. Hirsch emphasized that this accelerated scouring should be of more relevance to managers than simply trying to estimate when Conowingo will be filled to capacity (at steady state) as we are already experiencing greater sediment and nutrient loads that will continue unless appropriate actions are taken. Excessive sediment and nutrient loads carried past the dam to the Chesapeake Bay can limit water clarity and deplete dissolved oxygen, harming aquatic life and create problems for recreation and navigation.

Dr. Hirsch's message highlighted the importance of the LSRWA team's work. For the past year, LSRWA modelers have been developing a series of models to link incoming sediment and associated nutrient projections to the system of hydroelectric dams (including Conowingo) in the lower Susquehanna River and forecast impacts to living resources in the Chesapeake Bay. For the LSRWA's next major component, a workgroup of the team will convene in September to identify and evaluate potential strategies to manage incoming sediment from the watershed and extend the sediment-holding capacity behind Conowingo Dam.

http://www.usgs.gov/newsroom/article.asp?ID=3385&from=rss_home

Increased Sediment and Nutrients Delivered to Bay as Susquehanna Reservoirs Near Sediment Capacity

Released: 8/30/2012 9:00:00 AM

Contact Information:
U.S. Department of the Interior, U.S. Geological Survey
Office of Communications and Publishing
12201 Sunrise Valley Dr, MS 119
Reston, VA 20192

Bob Hirsch
Phone: (703) 648-5888

Kara Capelli
Phone: (571) 420-9408

This USGS report can be found online.

Reservoirs near the mouth of the Susquehanna River just above Chesapeake Bay are nearly at capacity in their ability to trap sediment. As a result, large storms are already delivering increasingly more suspended sediment and nutrients to the Bay, which may negatively impact restoration efforts.

Too many nutrients rob the Bay of oxygen needed for fish and, along with sediment, cloud the waters, disturbing the habitat of underwater plants crucial for aquatic life and waterfowl.

"The upstream reservoirs have served previously to help reduce nutrient pollutant loads to the Chesapeake Bay by trapping sediment and the pollutants attached to them behind dams," explained USGS Director Marcia McNutt. "Now that these reservoirs are filling to capacity with sediment, they have become much less effective at preventing nutrient-rich sediments from reaching the Bay. Further progress in meeting the goals for improving water quality in the Chesapeake will be more difficult to achieve as a result."

"It has been understood for many years that as the reservoirs on the Lower

Susquehanna River fill with sediment, there will be a substantial decrease in their ability to limit the influx of sediment and nutrients, especially phosphorus, to the Chesapeake Bay," said Bob Hirsch, research hydrologist and author of the report. "Analysis of USGS water quality data from the Susquehanna River, particularly the data from Tropical Storm Lee in September 2011, provides evidence that the increases in nutrient and sediment delivery are not just a theoretical issue for future consideration, but are already underway."

According to a new USGS report, the Susquehanna River delivered more phosphorus and sediment to the Bay during 2011 than from than any other year since monitoring began in 1978. Flooding from Tropical Storm Lee made up a large fraction of the Susquehanna River's inputs to the Bay for both 2011 and over the last decade. During the flooding the Susquehanna River delivered about 2 percent of total water to the Bay for the last decade; however, it delivered 5 percent of the nitrogen, 22 percent of the phosphorus, and 39 percent of the suspended sediment.

According to the report, from 1996-2011 total phosphorus moving into the Bay has increased by 55 percent, and suspended sediment has increased by 97 percent. Over this time period, total nitrogen decreased by about 3 percent overall, but showed increases during large events.

These results represent the combined effects of the changes in sediment within the reservoirs, as well as changes in the sources of these constituents upstream. Another recent USGS study reported about a 25 percent reduction in nutrients and sediment concentrations just upstream of the reservoirs, reflecting the benefit of actions to improve water quality in the upper portion of the Susquehanna River watershed.

"Progress on reducing loadings of these pollutants from the Susquehanna River Basin depends on efforts made to limit the loadings in the watershed, as well as the effects of the downstream reservoirs," said Hirsch. "In general, the changes we have observed in the reservoirs and the resulting greater impact of storms are already overshadowing the ongoing progress being made in the watershed to reduce the amount of nutrients and sediments entering the Bay."

Sediment and nutrient loadings from the Susquehanna River are crucial to understanding the status and progress of water quality in the Chesapeake Bay. On average, the Susquehanna River contributes nearly 41 percent of the nitrogen, 25 percent of the phosphorus, and 27 percent of the sediment load to the Bay.

"The findings of this USGS study increase the urgency of identifying and implementing effective management options for addressing the filling reservoirs," said Bruce Michael, director, Resource Assessment Service for the Maryland Department of Natural Resources. "The Lower Susquehanna River Watershed Assessment study, a 3-year partnership of federal, state, private sector, and non-governmental organizations, is developing potential management options for extending the sediment-holding capacity of the reservoirs. The USGS information is critical for guiding the strategies undertaken by the Chesapeake Bay Program to assure that the actions taken in the watershed will serve to meet restoration goals."

The lower reaches of the Susquehanna River, just upstream from Chesapeake Bay, include three reservoirs: Safe Harbor Dam and Holtwood Dam in Pennsylvania and Conowingo Dam in Maryland. Over the past several decades these reservoirs have been gradually filling with sediment.

While the reservoirs are filling, they are a trap for sediment and the nutrients attached to that sediment. As a reservoir approaches its sediment storage capacity, it can't hold as much sediment. When reservoirs are near capacity, significant flow events, such as flooding from Tropical Storm Lee, have greater potential to cause scour, or the sudden removal of large amounts of sediment, allowing that sediment and attached nutrients to flow out of the reservoirs and into the Bay.

Additionally, as the reservoir becomes filled, the channel that water flows through gets smaller. As a result, for any given amount of flow, the water moves through the channel faster, further increasing the likelihood of scour. Higher velocities also result in lower rates of settling, decreasing the amount of sediment that will be deposited.

This new report is based on 34 years of monitoring streamflow and water quality for the Susquehanna River by the USGS and its state and local partners. The report compares nutrients and sediment behavior during high flow events, such as the flood after Tropical Storm Lee in September of 2011, the high flows of March 2011, and Hurricane Ivan in 2004, with high flow conditions of the past.

This research was conducted as part of The USGS National Research Program in Water Resources and the USGS Chesapeake Bay Ecosystems Program. The report, titled *Flux of nitrogen, phosphorus, and suspended sediment from the Susquehanna River Basin to the Chesapeake Bay during Tropical Storm Lee, September 2011, as an indicator of the effects of reservoir sedimentation on water quality*, can be found online.

Information about the Lower Susquehanna River Watershed Assessment is available online.

Results of monitoring in the Chesapeake Bay watershed are available online.

Press Release

U.S. ARMY CORPS OF ENGINEERS BUILDING STRONG®

For Immediate Release:
Date: Nov. 13, 2014

Contact: Sarah Gross
410-962-9015 or Sarah.d.gross@usace.army.mil

New report released for public comment analyzes sediment and pollution flow impacts to Chesapeake Bay from watershed, Conowingo Dam – names watershed-wide reduction strategies as key

The Lower Susquehanna River Watershed Assessment (LSRWA) report released for public comment, Nov. 13, 2014, indicates that the reservoir behind the Conowingo Dam is trapping smaller amounts of sediment and has essentially reached its limit to trap in the long term. However, a large majority of the pollution to the Chesapeake Bay from the Susquehanna River comes from runoff from pollution sources from the upstream drainage area or watershed, as opposed to the sediment and associated nutrients collected behind the dam.

The inter-agency draft report was released by the U.S. Army Corps of Engineers (USACE) and non-federal sponsor the Maryland Department of the Environment (MDE).

Another major finding of the draft report indicates that nutrients that enter the river upstream of the dams and attach to particles of sediment and then flow downstream to the Bay have a bigger impact on water quality than the sediment, itself. Nutrient pollution has a lingering effect that leads to algae blooms and dead zones that have the potential to suffocate and stress marine life. The report includes consideration of management strategies, and recommendations for future opportunities. View the executive summary, full report with appendices, and associated graphics, and information on how to make a comment at http://bit.ly/LSRWA.

Modeling in the report shows that managing sediment through dredging, bypassing or dam operational changes, alone, do not effectively offset the adverse impacts to water quality from the loss of capacity for the dam to trap sediment in the long term. The report suggests that strategies to reduce nutrient pollution at its source from throughout the Bay drainage area are more effective at addressing impacts to the Bay.

The report underwent multiple peer reviews, including an independent, scientific peer review sponsored by the Chesapeake Bay Program partnership's Scientific and Technical Advisory Committee.

"We worked with a team of inter-agency experts, using current scientific information and the best modeling tools available in order to understand the complex relationship between river flow and sediment and ecological resources," said Col. Trey Jordan, USACE Baltimore District commander. "Our partners undertaking ongoing efforts to restore the Chesapeake Bay and its surrounding watershed are now armed with better science to make decisions to protect water quality, habitat and aquatic life."

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The study area consists of the Lower Susquehanna River Watershed from Sunbury, Penn., to the confluence with the Chesapeake Bay and includes the Holtwood, Safe Harbor, and Conowingo hydroelectric dams located on the lower Susquehanna River. Much of the modeling efforts were focused on the Conowingo Dam, as it is the largest dam and reservoir closest to the Chesapeake Bay with remaining capacity left to trap sediment.

"This study shows that while the build up of sediment behind the Conowingo Dam does impact water quality in the Bay, following through on the blueprint to clean up the Chesapeake Bay and its tributaries will have a much greater and longer-lasting effect on water quality than addressing the Conowingo Dam problem alone," said Robert M. Summers, MDE secretary. "Addressing the sediment behind the dams is part of the complete solution needed to restore the Bay and its tributaries, as is the work that upstream states are doing to reduce pollution in the first place. But we will not meet our Bay restoration goals without following through on our efforts to control pollution from Maryland and the rest of the watershed as well."

Major recommendations in the report include quantifying the full impact on Chesapeake Bay water quality and living resources based on new understandings in the report; integrating findings from the report into ongoing analyses and development of watershed implementation plans as part of the Chesapeake Bay Total Maximum Daily Loads assessments; developing and implementing management options that offset impacts to the upper Chesapeake Bay ecosystem from increased sediment-associated nutrient loads; and committing to enhanced long-term monitoring and analysis of sediment and nutrient processes in the watersheds to promote adaptive management into the future.

A public comment period on the draft report is now open until Jan. 9, 2015. Interested parties can submit comments via:

- E-mail to LSRWAcomments@usace.army.mil.
- Letter postmarked by Jan 9, 2015, to: U.S. Army Corps of Engineers, Baltimore District, Attn: Anna Compton , P.O. Box 1715, Baltimore, MD 21203.
- A public meeting and webinar held Dec. 9 at Harford Community College in Bel Air, Md., from 7 – 9 p.m. Details on the public meeting and log-in information for the webinar will be posted on the website, as well as other meeting materials.

Once the comment period closes and comments have been addressed, as appropriate, a final report anticipated for summer 2015 will be published to better inform stakeholders undertaking efforts to restore the Chesapeake Bay.

The LSRWA inter-agency team is comprised of the USACE Engineering Research and Development Center, U.S. Geological Survey, Susquehanna River Basin Commission, Nature Conservancy, Chesapeake Bay Program, Maryland Department of Natural Resources, and Maryland Geological Survey.

The intent of this report was to analyze the movement of sediment and associated nutrient loads and impacts within the lower Susquehanna watershed to the upper Chesapeake Bay.

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LSRWA directly contributes to Executive Order 13508 goals to restore clean water, recover habitat, and sustain fish and wildlife; and was authorized by Section 729 of the Water Resources Development Act of 1986, as amended. The total cost of the study is approximately $1.38 million. Funding was received in 2009, and after scoping and partnership agreements laid the groundwork, the assessment began in 2011.

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Additional media contacts for LSRWA team partners:

Jay Apperson, MDE, 410-537-3003, Jay.apperson@maryland.gov

Kristen Peterson, Maryland DNR, 410-260-8002, Kristen.peterson@maryland.gov

Margaret Enloe, Chesapeake Bay Program Partnership, 410-267-5740, Menloe@chesapeakeBay.net http://www.army.mil/article/138370/Army_Corps__partners__release_report_that_analyzes_sediment_flow_impacts_to_Chesapeake_Bay/

Army Corps, partners, release report that analyzes sediment flow impacts to Chesapeake Bay

November 14, 2014

By Sarah Gross

Sediment plumes traveling down to Chesapeake Bay, NASA satellite image, Sept. 12, 2011.

With startling imagery of sediment plumes making their way to the Chesapeake Bay from upstream sources after major storms, great focus has centered around where this pollution comes from and what steps can be taken to manage it.

Shortly after Tropical Storm Lee hit the East Coast in 2011, the groundwork was laid to begin analyzing the movement of sediment, and associated nutrient loads, and impacts within the 26,000-

square-mile Lower Susquehanna River Watershed to the upper Chesapeake Bay.

"We worked with a team of inter-agency experts, using current scientific information and the best modeling tools available in order to understand the complex relationship between river flow and sediment, and ecological resources," said Col. Trey Jordan, U.S. Army Corps of Engineers (USACE), Baltimore District commander. "Our partners undertaking ongoing efforts to restore the Chesapeake Bay and its surrounding watershed are now armed with better science to make decisions to protect water quality, habitat and aquatic life."

A draft report was released Nov. 13, 2014, by USACE and non-federal sponsor the Maryland Department of the Environment (MDE).

The team looked at impacts from the lower Susquehanna watershed from Sunbury, Pennsylvania, to the confluence with the Chesapeake Bay, including three hydroelectric dams located on the lower Susquehanna River - Holtwood, Safe Harbor, and Conowingo.

Since their construction, the reservoirs behind these dams have been capturing sediment flowing down the Susquehanna River, reducing nitrogen and phosphorous from entering the Chesapeake Bay. Recent studies, however, have questioned the capacity left for these reservoirs to continue to act as "pollution gates."

The new report confirmed that during periods of low-water flow, or non-storm events, the three reservoirs actually act as sediment traps and aid in the health of the Bay until the next high-flow or storm event occurs.

This report also indicates that although these reservoirs are trapping smaller amounts of sediment and have essentially reached their limit to capture these associated pollutants in the long term, the large majority of the pollution to the Chesapeake Bay during large storm events comes from runoff from pollution sources from the upstream drainage area, as opposed to from behind the dams.

For example, between 2008 and 2011, this study estimated that 13 percent of the Susquehanna River's sediment load came from the reservoir behind the Conowingo Dam -- the largest dam and reservoir closest to the Chesapeake Bay. The remaining 87 percent originated from the broader watershed -- runoff from land, floodplain, and streams. These estimates include sediment loads from Tropical Storm Lee.

"Addressing the sediment behind the dams is part of the complete solution needed to restore the Bay and its tributaries, as is the work that upstream states are doing to reduce pollution in the first place," said Robert M. Summers, MDE secretary. "But, we will not meet our Bay restoration goals without following through on our efforts to control pollution from Maryland and the rest of the watershed as well."

The team identified and evaluated 38 different sediment management strategies as part of the assessment, beyond pre-existing watershed implementation plans that Bay jurisdictional partners are executing. Strategies evaluated include large-scale dredging efforts to remove sediment from the reservoirs, and routing sediment around or through the reservoirs by making modifications to the operation of the dams.

"Our modeling indicates that dredging the sediment yields minimal, short-lived water quality improvements due to the constant deposition of sediment and associated nutrients that come from the watershed," said Anna Compton, USACE biologist and study manager. "Dredging would entail simply keeping up with this deposition."

The report also indicates that while these sediment plumes are alarming, it is actually the nutrients that attach to the sediments that lead to algae blooms and dead zones, which may suffocate marine life. Therefore, it is recommended that management opportunities in the watershed that reduce nutrient delivery to the Bay as opposed to sediment only are likely more effective at reducing impacts to water quality, low dissolved oxygen, and aquatic life from high-flow events.

"The assessment produced numerous products that are available now to assist in future watershed planning and management efforts," said Compton.

Major recommendations include quantifying the full impact on Chesapeake Bay water quality and living resources based on new understandings in the report; integrating findings from the report into ongoing analyses and development of watershed implementation plans as part of the Chesapeake Bay Total Maximum Daily Loads assessments; developing and implementing management options that offset impacts to the upper Chesapeake Bay ecosystem from increased sediment-associated nutrient loads; and committing to enhanced long-term monitoring and analysis of sediment and nutrient processes in the watersheds to promote adaptive management into the future.

The draft peer-reviewed report is now open to public comment until Jan. 9, 2015. A public meeting will be held Dec. 9 in Maryland. Once comments are incorporated, the final report is anticipated for release in summer 2015.

The Lower Susquehanna River Watershed Assessment team is also comprised of the USACE Engineering Research and Development Center, U.S. Geological Survey, Susquehanna River Basin

Commission, Nature Conservancy, Chesapeake Bay Program, Maryland Department of Natural Resources, and Maryland Geological Survey.

http://news.maryland.gov/mde/2014/11/18/department-of-the-environment-solicits-comment-schedules-public-hearing-on-water-quality-certification-application-for-proposed-conowingo-dam-relicensing/

MARYLAND THE DEPARTMENT OF THE ENVIRONMENT

Department of the Environment solicits comment, schedules public hearing on Water Quality Certification application for proposed Conowingo Dam relicensing

Posted by Jesse McKinney

November 18, 2014 in Chesapeake Bay, Clean Water, Press releases

MEDIA CONTACT:

Jay Apperson, MDE

410-537-3003

jay.apperson@maryland.gov

FOR IMMEDIATE RELEASE:

Department of the Environment solicits comment, schedules public hearing on Water Quality Certification application for proposed Conowingo Dam relicensing

Applicant must show project will comply with State water quality standards; MDE states intention to deny application due to insufficient information

Baltimore, MD (November 18, 2014) -

The Maryland Department of the Environment has issued public notice of the Proposed Relicensing of the Conowingo Hydroelectric Project Application for Water Quality Certification. The purpose of the notice is to solicit comments from the public and to announce the scheduling of a public hearing.

The Federal Energy Regulatory Commission (FERC) has issued a one-year extension of the current license for the operation of the Conowingo Dam. Under federal law and as part of FERC's relicensing process, Exelon is required to obtain a Clean Water Act, Section 401 Water Quality Certification from MDE for the continued operation of the facility. Issuance of a Water Quality Certification is contingent upon the applicant demonstrating to MDE that the project will comply with State water quality standards. At this time, although no final determination has been made MDE intends to deny the application due to insufficient information provided by the applicant regarding the impacts of the activity on State water quality standards.

The insufficiency of information is reflected in the draft Lower Susquehanna River Watershed Assessment report. The draft report found that the loss of long-term sediment trapping capacity at the Conowingo Dam is causing impacts to the health of the

Chesapeake Bay ecosystem. It also found that additional nutrient pollution associated with these changed conditions in the lower Susquehanna River system could result in Maryland not being able to meet Chesapeake Bay water quality standards, even with full implementation of Watershed Implementation Plans by 2025, in some of the Bay's deeper northern waters. The draft report recommends additional study to quantity the full impact on Bay water quality caused by conditions at the Conowingo Dam. Enhanced monitoring is planned over the next two years.

If it is ultimately determined that the project cannot comply with State water quality standards, the applicant could be required to mitigate the impacts to water quality through, for example, actions taken at the facility or by offsetting the facility's impacts with pollution reduction activities at other locations in the watershed.

Exelon filed its Water Quality Certification application on January 31, 2014. The State must act within one year of receipt of the application or it waives its right to make a decision. Notice of the application, solicitation of public comments and the scheduling of a public hearing were published in the Maryland Register. A public hearing on this application is scheduled for January 7, 2015, at MDE's Baltimore headquarters. Written comments may also be submitted. All comments must be received by the close of business on January 7, 2015.

Information on the notice, including information on submitting written comments, is on MDE's website at http://bit.ly/MDEConowingowqc.

Media Advisory

U.S. ARMY CORPS OF ENGINEERS BUILDING STRONG®

For Immediate Release:
Date: Dec. 4, 2014

RSVP to: Sarah Gross
410-962-9015 or Sarah.d.gross@usace.army.mil

Public Meeting: Report on sediment and pollution flow impacts to Chesapeake Bay from watershed, Conowingo Dam

What: Public meeting and webinar to discuss and to provide the opportunity to comment on the Nov. 13 release of the inter-agency Lower Susquehanna River Watershed Assessment (LSRWA) draft report.

Who:

- Rich Batiuk, Chesapeake Bay Program Office – U.S. Environmental Protection Agency, Associate Director for Science, Analysis and Implementation;
- Mark Bryer, The Nature Conservancy, Chesapeake Bay Program Director;
- Anna Compton, U.S. Army Corps of Engineers, Biologist and LSRWA Study Manager;
- Mike Langland, U.S. Geological Survey, Scientist;
- Bruce Michael, Maryland Department of Natural Resources, Resource Assessment Service Director and LSRWA Study Team Maryland State Representative;
- Matthew Rowe, Maryland Department of the Environment, Deputy Director of Science Services Administration

Detail: The draft LSRWA report indicates that the reservoir behind the Conowingo Dam is trapping smaller amounts of sediment and has essentially reached its limit to trap in the long term. However, a large majority of the pollution to the Chesapeake Bay from the Susquehanna River comes from runoff from pollution sources from the upstream watershed, as opposed to behind the dam. Nutrient pollution, not the sediment, has a lingering effect that leads to algae blooms and dead zones. Modeling in the report shows that managing sediment through dredging, bypassing or dam operational changes, alone, do not effectively offset the adverse impacts to water quality from the loss of capacity for the dam to trap sediment in the long term. The report suggests that strategies to reduce nutrient pollution at its source from throughout the Bay drainage area are more effective at addressing impacts to the Bay.

When: Dec. 9, 2014, 7 – 9 p.m.

Where: Harford Community College, Chesapeake Center: 401 Thomas Run Rd, Bel Air, MD 21015

If attending via webinar, details can be found online at http://bit.ly/LSRWA.

-more-

Why:
This report outlines potential ways to better protect water quality, habitat and aquatic life in the lower Susquehanna River and Chesapeake Bay and offers information to better inform decision makers and stakeholders undertaking ongoing efforts to restore the Chesapeake Bay and its surrounding watershed. Public comment period is open until Jan. 9, 2015. A final report is anticipated for release in summer 2015.

NOTE: Media, please RSVP to Sarah Gross by Dec. 8 to ensure adequate space and equipment is set aside in the meeting area. Should there be inclement weather, please call 443-412-2322 to ensure the college is open. Should the college be closed, the meeting will be rescheduled for the following day, Dec. 10.

###

http://news.maryland.gov/mde/2014/12/08/water-quality-certification-application-for-proposed-conowingo-dam-relicensing-withdrawn-january-7-water-quality-certification-public-hearing-canceled-exelon-agrees-to-fund-additional-study/

MARYLAND THE DEPARTMENT OF THE ENVIRONMENT

Water Quality Certification application for proposed Conowingo Dam relicensing withdrawn, January 7 Water Quality Certification public hearing canceled, Exelon agrees to fund additional study

Posted by Jesse McKinney on December 8, 2014 in Conowingo Dam, Press releases

MEDIA CONTACTS:

Jay Apperson, MDE
(410) 537-3003
jay.apperson@maryland.gov

Water Quality Certification application for proposed Conowingo Dam relicensing withdrawn, January 7 Water Quality Certification public hearing canceled, Exelon agrees to fund additional study

Exelon agrees to provide up to $3.5 million for additional study of effects of Conowingo Dam on Chesapeake Bay water quality; previously scheduled public hearing on company's application canceled, company says it must refile application within 90 days

BALTIMORE, MD (December 8, 2014) –

Recognizing the Maryland Department of the Environment's position that more information on the effects of the Conowingo Dam is needed before it can be determined whether the facility complies with State water quality standards, Exelon Corporation has withdrawn its application for the Water Quality Certification that is required as part of the relicensing process for the dam and has agreed to fund additional study of the issue.

MDE had stated its intention to deny the Proposed Relicensing of the Conowingo Hydroelectric Project Application for Water Quality Certification application due to insufficient information provided by the applicant. The company said it will work with MDE to coordinate the refiling of its application within 90 days. It has also agreed to provide up to $3.5 million to study the effects of sediment related to the Dam on water quality in the Susquehanna River and the Chesapeake Bay.

MDE had scheduled a public hearing on Exelon's application for Water Quality Certification for Jan. 7, 2015, at the Department's Baltimore headquarters. Due to the withdrawal of the application by Exelon, the hearing on the application is canceled. This action does not affect the scheduled public meeting on the Lower Susquehanna River Watershed Assessment draft report. The public meeting on that draft report will still be held at 7 p.m. tomorrow, Dec. 9, at Harford Community College.

The Federal Energy Regulatory Commission (FERC) has issued a one-year extension of the current license for the operation of the Conowingo Dam. Under federal law and as part of FERC's relicensing process, Exelon is required to obtain a Clean Water Act, Section 401 Water Quality Certification from MDE for the continued operation of the facility. Issuance of a Water Quality Certification is contingent upon the applicant demonstrating to MDE that the project will comply with State water quality standards. In issuing notice of the application, solicitation of public comments and scheduling of a public hearing, MDE stated the Department's intent to deny the application due to insufficient information provided by the applicant regarding the impacts of the activity on State water quality standards.

The insufficiency of information is reflected in the draft Lower Susquehanna River Watershed Assessment report. The draft report found that the loss of long-term sediment trapping capacity at the Conowingo Dam is causing impacts to the health of the Chesapeake Bay ecosystem. It also found that additional nutrient pollution associated with these changed conditions in the lower Susquehanna River system could result in Maryland not being able to meet Chesapeake Bay water quality standards, even with full implementation of Watershed Implementation Plans by 2025, in some of the Bay's deeper northern waters. The draft report recommends additional study to quantify the full impact on Bay water quality caused by conditions at the Conowingo Dam.

Exelon has agreed to provide up to $3.5 million for additional study. A study plan has been prepared with input by MDE, Exelon, the Maryland Department of Natural Resources, the U.S. Geological Survey, the University of Maryland Center for Environmental Science, the U.S. Environmental Protection Agency Chesapeake Bay Program and the U.S. Army Corps of Engineers. Enhanced monitoring is planned over the next two years.

Exelon cited its understanding of FERC policy requiring that an applicant resubmit its request for Water Quality Certification within 90 days of date of withdrawal in stating its intention to refile an application within that time period. It is possible that a refiled application or applications might also be withdrawn, followed by the resubmission of applications.

If it is ultimately determined that the project cannot comply with State water quality standards, the applicant could be required to mitigate the impacts to water quality through, for example, actions taken at the facility or by offsetting the facility's impacts with pollution reduction activities at other locations in the watershed.

http://www.usgs.gov/newsroom/article.asp?ID=4129

Conowingo Dam Above 90 Percent Capacity For Sediment Storage

Released: 2/18/2015 10:28:22 AM

Contact Information:
U.S. Department of the Interior, U.S. Geological Survey
Office of Communications and Publishing
12201 Sunrise Valley Dr, MS 119
Reston, VA 20192

Michael Langland
Phone: 717-730-6953

Hannah Hamilton
Phone: 703-648-4356

The full report is available online

The Conowingo Dam on the Susquehanna River is at about 92 percent capacity for sediment storage according to new U.S. Geological Survey research.

Since the dam's construction in 1929, sediment and nutrients have been building up behind it, being released periodically downriver and into the Chesapeake Bay, especially during high flow events.

"Storage capacity in Conowingo Reservoir continues to decrease, and ultimately that means more nutrients and sediment will flow into the Bay," says Mike Langland, a USGS scientist and author of the study. "Understanding the sediments and nutrients flowing into the Bay from the Susquehanna River is critical to monitoring and managing the health of the Bay."

Previous research has shown that having excess nutrients in the Bay depletes the water of oxygen needed to maintain healthy populations of fish, crabs, and oysters. Additionally, the nutrients, along with sediment, cloud the water, disturbing the habitat of underwater plants crucial for aquatic life and waterfowl.

At full sediment-storage capacity, the Conowingo Reservoir will be about one-half filled with sediment, with the remainder--about 49 billion gallons--flowing water. That amount of sediment could fill approximately 265,000 rail cars, which if lined up would stretch more than 4,000 miles.

The Susquehanna River is the largest tributary to Chesapeake Bay and transports about half of the total freshwater input to the Bay, along with substantial amounts of sediment, nitrogen and phosphorus.

Measuring the capacity of the dam to hold sediments and nutrients contributes to an improved understanding of factors that influence the health of the Chesapeake Bay.

Three hydroelectric dams and their associated reservoirs on the lower Susquehanna River have been impacting sediment and nutrient transport since construction in the early 1900's. Previous USGS studies have shown the two upstream reservoirs have reached their sediment storage capacity and the most downstream dam and reservoir, the Conowingo, was also losing its ability to trap nutrients and sediment from reaching the Chesapeake Bay. A 2012 USGS report revealed that, even though the Conowingo reservoir had not yet reached its maximum storage capacity, it had begun to lose its phosphorus and sediment-trapping ability, with increasing amounts going into the Bay.

Due to the concerns about increasing nutrient and sediments loads flowing into the Bay, the U.S. Army Corps of Engineers, working with several partners, will soon be releasing ,the Lower Susquehanna River Watershed Assessment. The study suggests several sediment-management options for the reservoirs on the Lower Susquehanna River and indicated additional monitoring and research are needed to support management decisions.

The long-term analysis (1900-2012) conducted for this new USGS study reported here revealed how past practices affected sediment transport in the Susquehanna River Basin.

The USGS study, in addition to providing the current estimate of sediment capacity also provides a longer-term (100 years) analysis of sediment flowing into the reservoirs.

Sediment loads transported over the past 100 years in the Susquehanna River into the reservoirs have decreased from 8.7 million tons per year in the early part of the 20th century to the current level of about 3.5 million tons. The declines of sediment into the reservoirs since the 1950s are most likely related to introduction of soil conservation practices, land reverting back to forest, and better management of stockpiled coal piles.

Since construction of Conowingo Dam was completed in 1929, an average 70 percent of the transported sediment reaching the upper Chesapeake Bay is from the Susquehanna watershed. The additional 30 percent of the sediment is being scoured, or removed from sediment deposited in the reservoirs.

From 1929 through 2012, approximately 470 million tons of sediment was transported down the Susquehanna River into the reservoir system. Of that number, approximately 290 million tons were trapped behind dams in the reservoirs, and approximately 180 million tons were transported to Chesapeake Bay. The reservoirs are continuously losing their ability to trap sediment and more is flowing into the Bay.

Information from this report and new partner studies will be used by the U.S. Environmental Protection Agency Chesapeake Bay Program and the state partners in considering options to reduce nutrient and sediment loads to help meet the requirements of the Chesapeake Bay Total Maximum Daily Load.

The study, **Sediment Transport and Capacity Change in Three Reservoirs, Lower Susquehanna River Basin, Pennsylvania and Maryland, 1900–2012 Open-File Report 2014-1235** is available online.

Additional information on USGS Susquehanna results and Chesapeake Studies can be found online.

Attachment I-4:
Study Initiation Notice

FEB 10 2012

Study Initiation Notice

Lower Susquehanna River Watershed Assessment

The purpose of this notice is to announce the recent initiation of the U.S. Army Corps of Engineers, Baltimore District's (USACE) Lower Susquehanna River Watershed Assessment (LSRWA). In partnership with Maryland Department of the Environment (MDE), Maryland Department of Natural Resources (MDNR), U.S. Geological Survey (USGS), The Nature Conservancy (TNC), and the Susquehanna River Basin Commission (SRBC), USACE is conducting the watershed assessment under Section 729 of the Water Resources Development Act of 1986, as amended. Enclosed is the executive summary of the project management plan (PMP) for the LSRWA, which includes a map of the study area.

The LSRWA is a multi-agency effort to comprehensively forecast and evaluate sediment and associated nutrient loads to the system of hydroelectric dams located on the Susquehanna River above the Chesapeake Bay. The assessment will also include an analysis of hydrodynamic and sedimentation processes and interactions, consideration of structural and non-structural strategies for sediment and nutrient management and an assessment of management strategies on future conditions in the lower Susquehanna River Watershed and Upper Chesapeake Bay. The official geographic area of the study is the lower Susquehanna River watershed, which flows into the Susquehanna River from Sunbury, Pennsylvania, down to the mouth at Havre de Grace, Maryland.

The LSRWA partners plan to meet quarterly to discuss, coordinate, and review technical and non-technical components of the assessment as well as management activities. These meetings will be open to the public and interested stakeholders; you will find an updated calendar of events at the project website along with the detailed PMP (http://bit.ly/LowerSusquehannaRiver). The project website will include various technical and management information as it becomes available.

Public meetings/workshops will also be coordinated by the LSRWA partners at appropriate times during the assessment. It is anticipated that there will be at least two public meetings over the course of the 3-year study – one when preliminary strategies for sediment and nutrient management strategies are developed (fall 2013), and a second meeting when the LSRWA report is released for public review (summer 2014). The purpose of the public meetings will be to provide information about the LSRWA report and obtain public input regarding its content.

If you have any questions regarding this project, please email eyesonthebay@yahoo.com or please contact Ms. Anna M. Compton at (410) 962-4633 or by e-mail at anna.m.compton@usace.army.mil. Correspondence can be provided by mail to:

U.S. Army Corps of Engineers, Baltimore District
ATTN: CENAB-PL-P (Compton)
P.O. Box 1715
Baltimore, Maryland 21203-1715

Amy M Guise

Amy M. Guise
Chief, Civil Project Development Branch

Attachment I-5:
Resource Agency Coordination

Attachment I-5: Resource Agency Coordination
Table of Contents

FEB 1 0 2012

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If you have any questions regarding this project, please email eyesonthebay@yahoo.com or please contact Ms. Anna M. Compton at (410) 962-4633 or by e-mail at anna.m.compton@usace.army.mil. Correspondence can be provided by mail to:

U.S. Army Corps of Engineers, Baltimore District
ATTN: CENAB-PL-P (Compton)
P.O. Box 1715
Baltimore, Maryland 21203-1715

Amy M. Guise

Amy M. Guise
Chief, Civil Project Development Branch

LSRWA:
Agency Coordination Letter Distribution List:

NOAA
Mr. John Nichols
National Marine Fisheries Service
NOAA Chesapeake Bay Field Office
410 Severn Avenue, Suite 107A
Annapolis, MD 21403-0279

Peyton Robertson
Director
NOAA Chesapeake Bay Program Office
410 Severn Avenue
Annapolis, MD 212403

NRCS
Leonard Jordan
Regional Conservationist – East
USDA, NRCS
14th and Independence Avenue, SW, Room 6004-S
Washington, DC 20250

New York Department of Environmental Conservation
Kenneth P. Lynch
Regional Director, Region 7
615 Erie Boulevard West
Syracuse, NY 13204-2400

Pennsylvania Department of Environmental Protection
Rachel Diamond
Regional Director, Southcentral Region
Pennsylvania Department of Environmental Protection
909 Elmerton Avenue
Harrisburg, PA 17110

Pennsylvania Department of Conservation and Natural Resources
Richard J. Allan
Secretary
Pennsylvania Department of Conservation and Natural Resources
Rachel Carson State Office Building
PO Box 8767
400 Market Street

Harrisburg, PA 17101

<u>Pennsylvania Fish and Boat Commission</u>
Douglas Austen
Executive Director
1601 Elmerton Avenue
PO Box 67000
Harrisburg, PA 17106

<u>Susquehanna River Basin Commission</u>
Paul O. Swartz
Executive Director
1721 North Front Street
Harrisburg, PA 17102-2391

<u>U.S. Fish and Wildlife Service</u>
Ms. Genevieve LaRouche
Field Supervisor
U.S. Fish and Wildlife Service
Chesapeake Bay Field Office
177 Admiral Cochrane Drive
Annapolis, Maryland 21014

<u>USEPA</u>
William Early
Regional Administrator
U.S. EPA, Region III
1650 Arch Street
Philadelphia, PA 19103

<u>USGS</u>
Bob Shedlock
Director
USGS MD-DE-DC Water Science Center
5522 Research Park Drive
Baltimore, MD 21228

James Campbell, Director
U.S. Geological Survey PA Water Science Center
215 Limekiln Road
New Cumberland, Pennsylvania 17070

Copy Furnish (cc)
<u>Maryland Department of the Environment</u>
Mr. Herb Sachs

Maryland Department of the Environment
1800 Washington Blvd.
Baltimore, MD 21230

Maryland Department of Natural Resources
Mr. Bruce Michael
Maryland Department of Natural Resources
Tawes State Office Building
580 Taylor Ave., C-4
Annapolis, MD 21401

Chesapeake Bay Program
Nicholas A. DiPasquale,
Director, Chesapeake Bay Program Office
US Environmental Protection Agency
410 Severn Avenue
Annapolis MD 21403

DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1715
BALTIMORE, MARYLAND 21203-1715

REPLY TO
ATTENTION OF

FEB 29 2012

Planning Division

Mr. John Nichols
Fishery Biologist
National Marine Fisheries Service
NOAA Chesapeake Bay Field Office
410 Severn Avenue, Suite 107A
Annapolis, MD 21403-0279

Dear Mr. Nichols:

This letter is to inform you of the recent initiation of the U.S. Army Corps of Engineers, Baltimore District's (USACE) Lower Susquehanna River Watershed Assessment (LSRWA). In partnership with Maryland Department of the Environment (MDE), Maryland Department of Natural Resources (MDNR), U.S. Geological Survey (USGS), The Nature Conservancy (TNC), and the Susquehanna River Basin Commission (SRBC), USACE is conducting the watershed assessment under Section 729 of the Water Resources Development Act of 1986, as amended. Enclosed is the executive summary of the project management plan (PMP) for the LSRWA which includes a map of the study area.

The LSRWA is a multi-agency effort to comprehensively forecast and evaluate sediment and associated nutrient loads to the system of hydroelectric dams located on the Susquehanna River above the Chesapeake Bay. The assessment will also include an analysis of hydrodynamic and sedimentation processes and interactions, consideration of structural and non-structural strategies for sediment and nutrient management and an assessment of management strategies on future conditions in the lower Susquehanna River Watershed and Upper Chesapeake Bay. The official geographic area of the study is the lower Susquehanna River watershed, which flows into the Susquehanna River from Sunbury, Pennsylvania, down to the mouth at Havre de Grace, Maryland.

The LSRWA partners plan to meet quarterly to discuss, coordinate, and review technical and non-technical components of the assessment as well as management activities. These meetings will be open to the public and interested stakeholders; you will find an updated calendar of events at the project website along with the detailed PMP (http://bit.ly/LowerSusquehannaRiver). The project website will include various technical and management information as it becomes available.

Public meetings/workshops will also be coordinated by the LSRWA partners at appropriate times during the assessment. It is anticipated that there will be at least two public meetings over the course of the 3-year study; one when preliminary strategies for sediment and nutrient management are developed (Fall 2013), and a second meeting when the LSRWA report is released for public review (Summer 2014). The purpose of the public meetings will be to provide information about the LSRWA report and obtain public input regarding its content.

It is our intent that the efforts of this watershed assessment provide value to you in your agency's water resource planning and management efforts, and complement and support your other ongoing efforts.

Please inform our office of the degree with which your agency would like to be involved with the LSRWA within 30 days of the date of this letter. If you have any questions, please call Mr. Daniel Bierly at (410) 962-6139 or via email at Daniel.M.Bierly@usace.army.mil.

Sincerely,

Amy M. Guise

Enclosure

Amy M. Guise
Chief, Civil Project Development Branch

CF:
CPD READING FILE
CENAB-PP-C
MDE, Herb Sachs
MDNR, Bruce Michael

COMPTON/4633/nrs/CENAB-PL-P
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O'NEILL/CENAB-PP-C
BIERLY/CENAB-PL-P
GUISE/CENAB-PL-P

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DEPARTMENT OF THE ARMY
BALTIMORE DISTRICT, CORPS OF ENGINEERS
P. O. BOX 1715
BALTIMORE, MARYLAND 21203-1715

REPLY TO
ATTENTION OF

Planning Division

FEB 29 2012

William Early
Regional Administrator
U.S. EPA, Region III
1650 Arch Street
Philadelphia, PA 19103

Dear Mr. Early:

This letter is to inform you of the recent initiation of the U.S. Army Corps of Engineers, Baltimore District's (USACE) Lower Susquehanna River Watershed Assessment (LSRWA). In partnership with Maryland Department of the Environment (MDE), Maryland Department of Natural Resources (MDNR), U.S. Geological Survey (USGS), The Nature Conservancy (TNC), and the Susquehanna River Basin Commission (SRBC), USACE is conducting the watershed assessment under Section 729 of the Water Resources Development Act of 1986, as amended. Enclosed is the executive summary of the project management plan (PMP) for the LSRWA which includes a map of the study area.

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It is our intent that the efforts of this watershed assessment provide value to you in your agency's water resource planning and management efforts, and complement and support your other ongoing efforts. We appreciate EPA's direct and immediate interest in the LSRWA and we look forward to working closely with the Federal, State, and other agencies of the Chesapeake Bay Program in sharing the study's results.

Please inform our office of the degree with which your agency would like to be involved with the LSRWA within 30 days of the date of this letter. If you have any questions, please call Mr. Daniel Bierly at (410) 962-6139 or via email at Daniel.M.Bierly@usace.army.mil.

Sincerely,

Amy M. Guise
Chief, Civil Project Development Branch

Enclosure

CF:
CPD READING FILE
CENAB-PP-C
MDE, Herb Sachs
MDNR, Bruce Michael
EPA-CBPO, Nicholas DiPasquale

BIERLY/6139/nrs/CENAB-PL-P

see NOAA O'NEILL/CENAB-PP-C

BIERLY/CENAB-PL-P

GUISE/CENAB-PL-P

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Lower Susquehanna River Watershed Assessment

Executive Summary

The U.S. Army Corps of Engineers, Baltimore District (USACE), and the Maryland Department of the Environment have partnered to conduct the Lower Susquehanna River Watershed Assessment – Phase I. The Phase I assessment will comprehensively forecast and evaluate sediment loads to the system of four hydroelectric dams located on the Susquehanna River just above the Chesapeake Bay; analyze hydrodynamic and sedimentation processes and interactions within the Lower Susquehanna River watershed, consider structural and non-structural strategies for sediment management, and assess cumulative impacts of future conditions and sediment management strategies on the Upper Chesapeake Bay (page ES-2). Assuming adequate annual appropriations, Phase I will cost $1.4M, cost-shared 75% Federal/25% non-Federal, over 3 years. Phase II, to be scoped at a later date subject to sponsorship and funding, would utilize these results to formulate a Lower Susquehanna River Sediment Management Plan.

Critical components of the Phase I Watershed Assessment include:

- Integration of the Maryland and Pennsylvania Watershed Implementation Plans for nitrogen, phosphorus and sediment reduction, as required to meet the Chesapeake Bay Total Maximum Daily Loads,

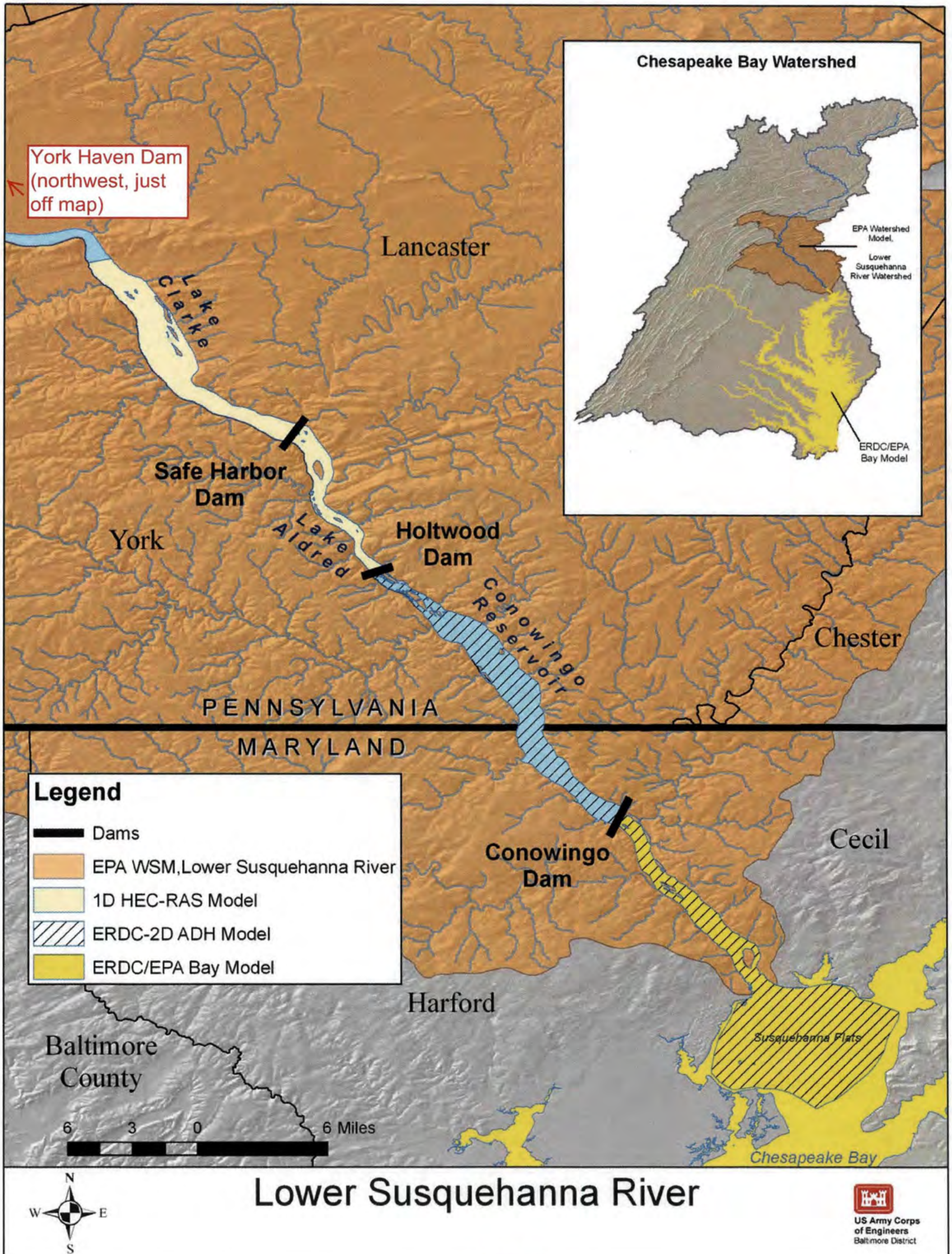
- Use of engineering models to link incoming sediment and associated nutrient projections to in-reservoir processes at the hydroelectric dams and forecast impacts to living resources in the Upper Chesapeake Bay,

- Identification of watershed-wide sediment management strategies, and

- Use of the U.S. Environmental Protection Agency's Chesapeake Bay Program water quality model to assess cumulative impacts of the various sediment management strategies to the Upper Chesapeake Bay.

Federal agencies share a renewed commitment to restore the Chesapeake Bay embodied in President Obama's Executive Order 13508, Chesapeake Bay Protection and Restoration (May 2009). This Executive Order established the Federal Leadership Committee, through which the Fiscal Year 2011 Federal Action Strategy was endorsed. This document specifically assigns USACE the "lead" role to "advance studies to evaluate the management of sediments" [in the Lower Susquehanna River Watershed, page ES-3].

USACE and the Maryland Department of the Environment, through collaboration with the Maryland Department of Natural Resources, Maryland Geological Survey, Commonwealth of Pennsylvania, U.S. Environmental Protection Agency, U.S. Geological Survey, Susquehanna River Basin Commission, The Nature Conservancy, and others seek to integrate water resources management in the Lower Susquehanna River Basin to ensure sustainable restoration of the Chesapeake Bay, the largest estuary in the United States.


York Haven Dam (northwest, just off map)
Chesapeake Bay Watershed
EPA Watershed Model, Lower Susquehanna River Watershed
ERDC/EPA Bay Model
Lancaster
Lake Clarke
Safe Harbor Dam
York
Lake Aldred
Holtwood Dam
Conowingo Reservoir
Chester
PENNSYLVANIA
MARYLAND
Legend
Dams
EPA WSM,Lower Susquehanna River
1D HEC-RAS Model
ERDC-2D ADH Model
ERDC/EPA Bay Model
Conowingo Dam
Cecil
Harford
Baltimore County
Susquehanna Flats
6 3 0 6 Miles
Chesapeake Bay
Lower Susquehanna River
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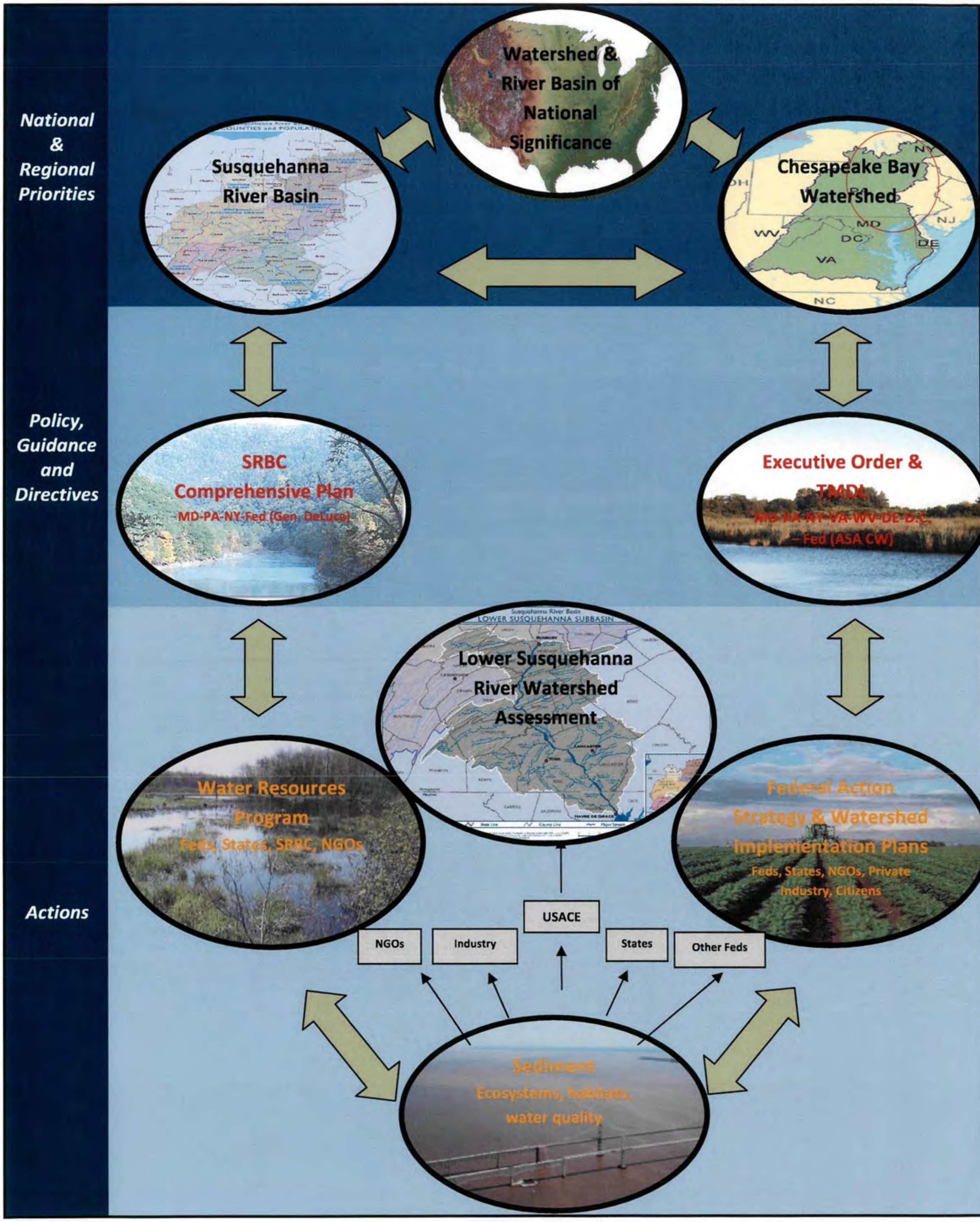
S
US Army Corps of Engineers
Baltimore District

WATERSHED CONTEXT FOR CHESAPEAKE BAY & USACE ACTIONS



Pennsylvania Fish & Boat Commission

established 1866

Bureau of Fisheries
Division of Fish Production Services
1735 Shiloh Road
State College, PA 16801
(814) 353-2226 Fax: (814) 355-8264

March 16, 2012

Amy Guise
Planning Division
Department of the Army
Baltimore District Corps of Engineers
P.O. Box 1715
Baltimore, MD 21203-1715

Re: Lower Susquehanna River Watershed Assessment

Dear Ms. Guise:

Thank you for notifying us of the LSRWA. The Pennsylvania Fish and Boat Commission is indeed very interested in the sediment issue in the Susquehanna River and the Chesapeake Bay. We manage fishes and other aquatic organisms in commonwealth waters. In addition to important fisheries for resident fishes, we have been attempting to restore migratory species for many years. Thus far, our efforts have focused primarily on American shad, however, we intend to focus on American eels and river herring in the coming years. Working with other resource partners (PA DEP, SRBC, USFWS, MD DNR and NOAA) we now have operating fishways at all four lower river hydroelectric dams and a planned fishway for the inflatable dam at Sunbury.

Naturally, we are interested in anything that impacts these fisheries and the habitats that support them. While we do not see ourselves as active players in this effort, we would like to be kept informed of your progress and perhaps attend some but not all of your meetings.

Please add the following individuals to your mailing list:
Michael L. Hendricks
Unit Leader, Anadromous Fish Restoration Unit
1735 Shiloh Rd.
State College, PA 16801
814-353-2226
mihendrick@pa.gov

Geoffrey Smith
Susquehanna River Biologist
PFBC
P.O. Box 67000
Harrisburg, PA 17106-7000
717-265-7837
geofsmith@pa.gov

Sincerely,

Michael L. Hendricks
Leader, Anadromous Fish Research Unit
Division of Research

cc: A.Shiels
L. Young
D.Miko
G. Smith
J. Tryninewski

United States Department of the Interior

U.S. GEOLOGICAL SURVEY
MD-DE-DC Water Science Center
5522 Research Park Drive
Baltimore, MD 21228
(443) 498-5503
rjshedlo@usgs.gov

Amy M. Guise
Chief Civil Project Development Branch
Department of the Army
Baltimore District, Corps of Engineers
P.O. Box 1715
Baltimore, MD 21203-1715

Amy
Dear ~~Ms. Guise~~,

Thank you for the information regarding the Lower Susquehanna River Watershed Assessment. To date our Water Science Center has had a number of opportunities to exchange information and ideas with the LSRWA team. Most of our work has been through Bruce Michael of Maryland Department of Natural Resources. We would welcome the opportunity to become more involved in the LSRWA process due to our long-term monitoring of nutrient and sediment fluxes from the Susquehanna River.

I would recommend that you consider including Joel Blomquist (jdblomqu@usgs.gov, 443-498-5560) as the USGS representative for the MD-DE-DC Water Science Center on your team. We will be happy to continue to provide technical exchange, review, and comments on the LSRWA products.

Thank you.

Sincerely,
Robert J. Shedlock
Robert J. Shedlock
Center Director

UNITED STATES DEPARTMENT OF COMMERCE
National Oceanic and Atmospheric Administration
NATIONAL MARINE FISHERIES SERVICE
NORTHEAST REGION
55 Great Republic Drive
Gloucester, MA 01930-2276

MAR 26 2013

Ms. Anna Compton
US Army Corps of Engineers
Baltimore District
P.O. Box 1715
Baltimore, MD 21203-1715

Dear Ms. Compton:

On February 11, 2013, the Corps of Engineers, Baltimore District presented a document entitled "Reservoir Sediment Management Strategies", at the Quarterly Meeting of the Lower Susquehanna River Watershed Assessment Team. We appreciate the opportunity to outline foreseeable issues with two of the management strategy "sediment bypass" options presented in this document. These options include the hydraulic pumping of reservoir material to "sediment starved areas" of the upper Chesapeake Bay; and the hydraulic pumping of reservoir material past the Conowingo Dam into the Susquehanna Flats and northern Chesapeake Bay. We also outline alternatives to sediment bypassing that will minimize impacts to fish habitat in the Upper Chesapeake Bay.

Importance of the Upper Chesapeake Bay and lower Susquehanna River

The upper Chesapeake Bay north of Worton Point in Kent County, and Robins Point in Harford County (mainstem and tidal tributaries) and the lower Susquehanna River below Conowingo Dam are documented spawning and nursery ground for seven species of anadromous fish, including striped bass (*Morone saxatitis*), white perch (*Morone americana*), yellow perch (*Perca flavescens*), American shad (*Alosa spadissima*), alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), and hickory shad (*Alosa mediocris*) (Lippson, 1973, O'Dell et al., 1975). Physical features of this area include; 1) abundance of shallow depths (<3 feet, mean low water); particularly in the Susquehanna Flats area; 2) low spring salinities (< 2ppt); 3) abundance of coarse bottom substrate of sand, gravel, and cobble; and 4) the tidal/freshwater discharge circulatory retention of planktonic eggs and larvae associated with the Bay mainstem Estuarine Turbidity Maximum (ETM)(North and Houde, 2001). Together, this makes the upper Bay and lower Susquehanna River the most important migratory fish spawning ground in the Chesapeake Bay.

The upper Chesapeake Bay spawning zone is also a documented nursery habitat for numerous other commercially and ecologically important finfish that spawn in Bay waters, or in nearshore coastal waters off the mouth of the Bay. These include Atlantic menhaden (*Brevoortia tyrannus*), bluefish (*Pomatomus saltatrix*), spot (*Leiostomus xanthurus*), Atlantic croaker (*Micopogon undulatus*), winter flounder (*Pseudoharengus americanus*), and bay anchovy (*Anchoa mitchilli*) (Lippson, 1973). High water column detritus and zooplankton content associated with the ETM make this nursery critical to maintenance of stock abundance for these mid-Atlantic species.

Dense and resilient beds of submerged aquatic vegetation (SAV) in the Susquehanna Flats and lower Susquehanna River also enhance the nursery ground qualities of the upper Bay spawning zone during the growing season, providing cover and forage habitat for juvenile finfish. Susquehanna Flats SAV has been stable and resilient for more than two decades, providing ecological stability to this area dating back the late 1980s of the post-Hurricane Agnus period. Because the Susquehanna Flats are the receiving waters for freshwater influx from the Susquehanna River, SAV in this area provides critical benefits that enhance ecological conditions locally in the spawning zone, and throughout the upper and middle sections of the Chesapeake Bay. These benefits include stabilizing surficial sediments, thereby sustaining water clarity in the bed areas; sequestering large amount of nitrogen and phosphorus throughout the growing season, thereby reducing concentrations of inorganic nutrients available for eutrophying phytoplankton blooms; and removing inorganic nitrogen from the estuarine system by promoting sediment biogeochemical processes such as denitrification.

Foreseeable issues with sediment bypassing options

The Chesapeake Bay has a nutrient and sediment loading problem which threatens the current and future health of this system. Nitrogen, phosphorus, and nutrient laden fine sediments transported to the Bay in freshwater discharge annually contribute to sustaining the high water column nutrient levels in mainstem and tributary waters, while nutrients settling to bottom substrates are recycled back to the water column through biogeochemical and geochemical processes (Cornwell & Owens, 1999; Boynton, Stankelis, Rohland, and Frank, 1999). Systemic ecological effects from eutrophication play multiple roles in degrading estuarine fish habitat.

Because the Susquehanna River carries almost 50% of freshwater discharge to the Chesapeake Bay, it is responsible for most of the nutrient loading problem in this system. Consequently, we are participating in the LSRWA process to assist with selection of solutions for reducing nutrient and sediment discharge from the Susquehanna River. We believe that selection of sediment management strategies should be in concert with the state TMDL reduction strategies. More importantly, we intend to recommend solutions that will protect and conserve the habitat integrity and high fishery values of the upper Chesapeake Bay spawning/nursery zone.

Conceptual reservoir sediment bypass options presented at the LSRWA quarterly meeting, and listed above, can adversely impact habitat integrity within the upper Chesapeake Bay spawning/zone. It is estimated that more than 193 million cubic yards of material is retained behind Conowingo Dam (Ann Swanson, electronic communication to LSRWA Team, 2/12/2013); with 85% silt content near the dam, and 55% silt content in upper reaches (Steve Scott, estimates provided during the August 7, 2012 LSRWA Quarterly Meeting). Hydraulic pumping of liquid slurry of such material to Susquehanna Flats will be impractical to control, and subsequent release and spreading of material will have far reaching effects on spawning substrate and SAV. Furthermore, much of the nutrient content of this material will be released to the water column of the upper Bay, contrary to state TMDL reduction strategies. These actions will result in negative impacts to sensitive finfish habitat, critical to resources of ecological and commercial importance to the Chesapeake Bay, and of broader scale importance to the mid-

Atlantic region. As such, we have significant concerns with the inclusion of sediment bypass options among the LSRWA sediment management options.

Alternative sediment reservoir management strategies
In our view, upland-based alternatives for sediment management will have the least impacts to out trust resources. Upland disposal of reservoir sediments/nutrients will provide a unique opportunity to remove fine-grain sediment and associated nutrient pollutants from the Chesapeake Bay system. Preferred upland-based options provided in the sediment management strategy document include 1) reclamation of quarries, mines, other disturbed fastland areas (including Shirley Plantation); 2) landfills; 2) innovative reuse, such as that provided by Harbor Rock, soil manufacture; and, 3) purchase of land for constructing containment facilities.

If water-based management strategies are selected, they should be located outside the upper Chesapeake Bay mainstem and tributaries anadromous fish spawning/nursery zone, including the Susquehanna Flats. Fringe or tidal tributary pocket marsh creation with reservoir material in other areas of the Bay system and Susquehanna River, including areas within and upstream of the Conowingo Pool should be considered. Such an option should consider the direct and indirect impacts to existing fish resources and habitats at a proposed site; the wave energy or riverine flow climate of the site (high energy sites should be avoided, requiring excessive amounts of armoring to retain placed material); and the physical and chemical make-up of reservoir material to be used.

Should tidal marsh creation be explored, material should be at least 70% sand in composition, and have predominant grain-size comparable to receiving sediments at the marsh creation site. Material containing excessive amounts of clay and silts is not acceptable for placement in aquatic systems for marsh creation because of its instability, and excessive rock armoring that is required to contain it. Keying in on predominantly sandy reservoir material will likely require mechanical handling and separation methods prior to placement at the marsh creation site.

Due to the large amount of material retained by the Safe Harbor, Holtwood, and Conowingo reservoirs, and the complexity of the sediment management strategies, we believe that multiple options will be required to restore reservoir trapping efficiency to a significant level.

Alternative sediment management strategies
Even with reservoir sediment trapping efficiency restored, nutrients will continue to be discharged to the upper Chesapeake Bay during high flow events. In particular, dissolved and colloidal forms of nutrients, which tend not to settle, will be components on post-sediment removal loading. It is, therefore, imperative that state and federal efforts continue to reduce nutrient and sediment loading to the Susquehanna River mainstem by applying land-based and drainage basin-based Best Management Practices within tributaries to the river. This option should be included, by default, with other options selected to reduce Chesapeake Bay loading levels.

Thank you for the opportunity to provide comments on this important initiative. If you have any questions, please contact me at (978) 281-9131; or, John Nichols at our Habitat Annapolis Field Office; John.Nichols@NOAA.GOV, or, (410) 267-5675.

Sincerely,

Christopher Boelke
Field Office Supervisor
Habitat Conservation Division

LITERATURE CITED

Boynton, W.R., R.M. Stankelis, F.M. Rohland, and J.M. Frank. 1999. A mapping survey of the sediment-water oxygen and nutrient exchanges in the upper Chesapeake Bay. Final Report to Maryland Port Administration. University of Maryland, Center for Environmental Science, Chesapeake Biological Laboratory, Solomons, MD.

Cornwell, Jeffrey, and M. Owens. 1999. The nutrient chemistry of sediment dredging: sediment nutrient inventories and fluxes. Final Report to Maryland Port Aministration. UMCES Report TS-187-99. University of Maryland System, Center for Environmental Studies, Horn Point Laboratory, Cambridge, MD.

Lippson, Alice Jane. 1973. *The Chesapeake Bay in Maryland: An Atlas of Natural Resources.* The Johns Hopkins Press, Baltimore.

North, E.W., and E.D. Houde. 2001. Retention of white perch and striped bass larvae: biological physical interactions in the Chesapeake Bay Estuarine Turbidity Maximum. Estuaries 24(5): 756-69.

O'Dell, Jay, J. Gabor, and R. Dintaman. 1975. Survey of anadromous fish spawning areas. Completion Report, Project AFC-8, *for*: Upper Chesapeake Bay Drainage. Maryland Department of Natural Resources, Annapolis.

Attachment I-6:
Quarterly Meeting Summaries

(Meeting enclosures such as handouts and presentations are located on the project website, http://bit.ly/LowerSusquehannaRiver)

Attachment I-6: Quarterly Meeting Summaries
Table of Contents

November 29, 2011

Memorandum for the Record

Subject: Lower Susquehanna River Watershed Assessment (LSRWA) Kick-Off Team Meeting
Location: MDE, Montgomery Park Building, Aqua Conference Room
Date: November 2, 2011
Attendees:

Agency	Name	Email	Phone
USEPA	Gary Shenk	GShenk@chesapeakebay.net	410 267 5745
MDE	Herb Sachs	hsachs@mde.state.md.us	410-537-4499
MDE	Matt Rowe	mrowe@mde.state.md.us	410-537-3578
MDE	Secretary Robert Summers		
MDE	Tim Fox	tfox@mde.state.md.us	410-537-3958
MDNR	Bruce Michael	bmichael@dnr.state.md.us	410-260-8627
MDNR	Shawn Seaman	sseaman@dnr.state.md.us	410-260-8662
MGS	Jeff Halka	jhalka@dnr.state.md.us	410-554-5503
SRBC	Andrew Gavin	agavin@srbc.net	717-238-0423x107
SRBC	Dave Ladd	dladd@srbc.net	717-238-0425x204
SRBC	John Balay	jbalay@SRBC.NET	717-238-0423 x217
TNC	Kathy Boomer	Kboomer@tnc.org	607-280-3720
TNC	Mark Bryer	mbryer@tnc.org	301-897-8570
USACE	Anna Compton	Anna.M.Compton@usace.army.mil	410-962-4633
USACE	Bob Blama	Robert.N.Blama@usace.army.mil	410-962-6068
USACE	Carey Nagoda	Carey.M.Nagoda@usace.army.mil	410-962-6761
USACE	Chris Spaur	Christopher.C.Spaur@usace.army.mil	410-962-6134
USACE	Claire O'Neill	Claire.D.O'Neill@usace.army.mil	410-962-0876
USACE	Dan Bierly	daniel.m.bierly@usace.army.mil	410-962-6139
USACE	Robert Pace	Robert.S.Pace@usace.army.mil	410-962-4900
USACE-ERDC	Carl Cerco	Carl.F.Cerco@erdc.usace.army.mil	601-634-4207
USACE-ERDC	Steve Scott	Steve.H.Scott@usace.army.mil	601-634-2371
USGS	Mike Langland	langland@usgs.gov	717-730-6953

Action Items:

A. Claire will email the team the "Roles and Responsibilities" spreadsheet to get input; compile and send out to team once completed.
B. Anna will send the LSRWA Team email distribution list to all team members.
C. Shawn Seaman will contact Michael Helfrich to notify him of quarterly meetings to see if he can attend.
D. Bruce Michael will have the lead in coordinating with SRBC, MDE, and MGS to set up a website where any products of the assessment can be kept to keep stakeholders informed.
E. Anna will prepare a brief public involvement plan to layout how the LSRWA will be coordinated with stakeholders and will send out the team for review.
F. Anna will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups.
G. Anna will send out an update to via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of LSRWA kick-off meeting and study start and will periodically update this group as the LSRWA progresses.
H. Anna will send out revised goals to the team for one final review and team approval.
I. Steve will coordinate with Bruce to obtain digitized maps of SAV data in the Susquehanna flats area.
J. Bruce will share results of the suspended sediment sampling taken at Conowingo outfall (taken during high flow events this year) with the team.
K. Mark and Anna will coordinate to conduct a literature search providing info on best management practices around the nation and world for reservoir sedimentation.
L. Matt will keep team informed on Innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies.
M. Claire will follow up with individual team members to develop a schedule for work to be conducted this year.
N. Shawn will provide a summary of Exelon study findings.

Discussion:

1. <u>Opening Remarks</u> Secretary Summers welcomed the group and discussed the impacts of Tropical Storm Lee on the Chesapeake Bay and that this time we had a close call in regards to not seeing the same extreme impacts similar to that of what we saw with Tropical Storm Agnes. He also thanked Herb for his efforts in executing an agreement to initiate this effort. Robert Pace noted that the Chesapeake Bay Community is concerned and energized in regards to managing sediments in the Chesapeake Bay due to the Total Maximum Daily Load (TMDL) process that has been ongoing in the watershed. USACE HQ is very tuned into the LSRWA and there is Assistant Secretary of the Army-level commitment as well due to the Chesapeake Bay executive order. Herb mentioned that there are a lot of efforts going on around the Bay that we can incorporate into the LSRWA such as the hydrologic studies going on below Harrisburg, fractured rock studies, and FERC Conowingo Dam relicensing studies. Study needs to consider NY and PA TMDLs.

2. Finalization of Cost-Sharing Agreement/Study Name Change Claire noted that a legal cost-sharing agreement was executed in September between USACE and MDE. MDE will have sub-agreements with SRBC, TNC, MD DNR, and MGS which are all contributing funds as in-kind services (tasks) to the assessment. The study received $250K in federal funding which can be used in Fiscal Year (FY) 12 even though it was received in FY11. Claire noted that FY12 funding is still uncertain. If Congress passes a USACE appropriations bill then the project is not expected to get additional funding. However, if USACE is under continuing resolution for the entire year, then additional funding may be forthcoming. The FY13 budget is currently being prepared and will be released in the first week of February. In order to receive more funding in the future, it is imperative that the team make good progress and expend any Federal funds that are received in a timely manner. Bruce noted that the state will be matching the federal funds received this year as in-kind services (25%) in line with the cost-sharing agreement (75 federal/25 non-federal). Claire mentioned that it is acceptable for the state to be spending at a faster or slower rate than the Federal funds are expended, as long as at the end of the assessment the 75-25 cost-sharing is maintained. Claire will be tracking this closely with Herb to ensure that the match does not get inordinately out of balance. .

   Anna noted that during the review process of the legal cost-sharing agreement and the project management plan for the study the name of the study changed to the Lower Susquehanna River Watershed Assessment in order to reflect that the study is a more holistic, comprehensive evaluation of sediment management within the lower Susquehanna River watershed.

3. Roles and Responsibilities This is a large team with many agencies involved, conducting activities for the assessment. In order to aid in communication so everyone has a good understanding of the roles and responsibilities of each person/agency, Claire prepared a spreadsheet which will be filled out by all team members. Claire will provide the spreadsheet electronically to the team after the meeting and all team members will provide their role/responsibility; Claire will compile and send out to the whole team.

4. Communication The team agreed to meet on a quarterly basis. Smaller meetings will be coordinated on a more frequent basis as needed depending on the need as tasks are underway for the assessment. Anna will send out the an email distribution list which includes all team members of the entire assessment team so anyone on the team can initiate a meeting outside of the quarterly time frame or communicate questions, concerns, etc.

   There was much discussion on public involvement/communicating to stakeholders outside of the team. Since no formal National Environmental Protection Act (NEPA) is being conducted for the LSRWA because no specific (implementation) actions will be recommended; public involvement is more flexible and can be less formal. The consensus was that getting input early and often from all stakeholders was very important to the LSWRA in order to have buy-in and have a good understanding of the public concerns of proposed strategies to manage sediments in the lower Susquehanna River.

However, it is important to have internal meetings as well when results and decisions are not quite ready to be vetted by the public and still need team consensus. Ideas included:

- Coordinating with Michael Helfrich (lower Susquehanna Riverkeeper) to attend quarterly meetings as he is very tuned into public view points on this issue.

- Inviting public/stakeholders to quarterly meetings.

- Setting up public meetings/workshops at appropriate times during the Assessment.

- Coordinating with other Chesapeake Bay groups that meet regularly to be included on the agenda to provide updates and get feedback on the assessment. Depending on the type of meeting, the most appropriate assessment team member (i.e., the assessment team member who is already attending or a part of that particular Chesapeake Bay group, etc.) could provide the update. Herb mentioned presenting to the House Environmental Matters Committee and Dave mentioned presenting updates at the SRBC quarterly meetings. PowerPoint slides will be updated after each assessment quarterly meeting to be utilized by anyone on the team providing updates to another Chesapeake Bay group.

- Utilizing the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, NGO and state and counties representatives) that SRBC headed up in 1999 and 2000. Anna has been updating this list since 2009 with people requesting to be updated on this issue.

- Setting up a website where any products (factsheets, meeting summaries, reports, etc) of the Assessment and meeting summaries can be posted. MDNR will look into whether they can do this as an in-kind service. Chris noted that Baltimore District is not well suited to this task due to stringent department of defense security rules with website. John noted that SRBC could potentially take this task on as well.

All of these ideas will be summarized into a brief public involvement plan that will be vetted and refined by the team.

5. <u>Review Assessment Goals</u> The team revisited the goals that were developed for the study early on in the scoping process of the LSRWA in order to refine these goals. The purpose of the goals are to create bounds and focus for the team on what will be accomplished with the LSRWA and to communicate to stakeholders what the LSRWA will accomplish. Below are the goals the team worked up at the meeting which will be finalized after the meeting following one more team review.

1. Evaluate strategies to manage sediment and associated nutrient delivery to the Chesapeake Bay.
   - Strategies will incorporate input from Maryland, New York, and Pennsylvania Total Maximum Daily Load Watershed Implementation Plans
   - Strategies will incorporate evaluations of sediment storage capacity at the four hydroelectric dams on the Lower Susquehanna River.
   - Strategies will evaluate types of sediment delivery and associated impacts to Chesapeake Bay
2. Evaluate strategies to manage sediment and associated nutrients available for transport during high flow storm events; to reduce impacts to the Chesapeake Bay.
3. Determine the effects to the Chesapeake Bay from the loss of sediment and nutrient storage from behind the hydroelectric dams on the Lower Susquehanna River.

6. Conowingo Dam Relicensing Status Shawn provided an update to the group on the Federal Energy Regulatory Commission (FERC) relicensing process that the Conowingo Dam is undergoing as it relates to the LSRWA. The new license is required by 2014. In order to obtain the license, Exelon, the owner and operator of the dam, must undertake a variety of studies as requested by state and federal resource agencies to get an understanding of impacts of the dam. Several of the requested studies deal with sediment transport and accumulation in the dam system which relates to LSWRA efforts. At this time, most of the relicensing studies dealing with sediment transport and accumulation undertaken by Exelon are simply a compilation of existing literature and data. Their study findings were that 400,000 cfs (cubic feet per second) is not the threshold where sediments are scoured from behind the Conowingo Dam and that overall Tropical Storm Agnes did not scour sediments but ended up depositing more sediment behind Conowingo Dam. Mike said that this latter finding is not supported by USGS at this time.

   Comments on the studies from the resource agencies are due in the Feb-March 2012 timeframe and in the April-May 2012 time frame; FERC will make a decision if further sediments studies are warranted by Exelon in order to obtain a new license. In order for Conowingo Dam to be relicensed, all study findings must be approved FERC along with USFWS, and MDE must issue a Section 401 water quality certification.

7. New Data (Susquehanna Flats)/Potential Cost Savings Steve noted that upon review of Exelon data and reports for their FERC relicensing process of Conowingo Dam, he found that Exelon had already conducted bathymetric surveys of Conowingo Reservoir after Tropical Storm Lee, so this effort would not need to be conducted under the LSRWA scope. Mike will be reviewing that bathymetric data as it relates to the LSRWA under his scope of work. Steve noted that Exelon has also conducted bathymetry in the flats area below the Conowingo Dam; therefore, with the Exelon survey data and the NOAA depth chart data, conducting bathymetric surveys below the dam in the flats area is no longer required for LSRWA.

   In regards to the potential need for a three-dimensional (3D) model Steve noted that a desktop analysis could be performed instead of conducting model runs to get an understanding of 3D effects, resulting in a cost savings of approximately $20K for the pertinent LSRWA task. During the 2D/3D study, Steve will also begin building the mesh for the models; this will save time and be a cost savings in the long run.

These adjustments to scope produce approximately $100K in savings.

8. SRBC Related Efforts John and Andrew updated the group on efforts that SRBC is undertaking that could be integrated with the LSRWA efforts.

- FERC Relicensing activities – SRBC reviewed the Conowingo initial study report - *Sediment Introduction and Transport* and will provide comments to partners in advance of ultimate Feb/Mar 2012 comment deadline.

- Conowingo Pond Management Plan – SRBC conducted a drought exercise, in cooperation with modeling contractor (Hydrologics) and stakeholders (power facilities, water suppliers, resource agencies, etc.), on October 3, 2011 in accordance with annual recommendations in this plan. This near real-time gaming exercise simulates evolving drought conditions and interactive operational scenarios to evaluate low flow management in the Conowingo Pond.

- Susquehanna River Flow Management Project – This effort has several objectives related to the LSRWA including forming a stakeholder group (power facilities, water suppliers, resource agencies, etc.) with interest in flow-related issues in the lower Susquehanna River. In cooperation with a modeling contractor, the project aims to develop an hourly time step component of the existing OASIS hydrologic model for the entire lower 55-mile reach of the Susquehanna (Conowingo Dam to the Three Mile Island intake). Through the stakeholder process, SRBC will use the model to simulate alternatives for balancing environmental flow performance factors with operational constraints to develop flow recommendations for the lower 55-mile reach of the Susquehanna. Recommendations will be used by SRBC, 401 certification agencies, etc. in making recommendations to FERC as part of relicensing process. The project will be initiated once the modeling contractor has been secured.

- Lower Susquehanna River Mainstem Monitoring Project – SRBC is currently designing a pilot monitoring study for the lower mainstem, which will assist with determining locations/methods for establishing an annual monitoring program to be paired with the annual monitoring conducted on the free-flowing portions of the Susquehanna River above Harrisburg (Large Rivers Project). Currently SRBC is considering an approach that assesses the free-flowing portion of the river as it approaches, and transitions into, a pool behind one of the dams with detailed data collection to be conducted in the pool as well. Data to be collected may include water quality (continuous and grab samples), fish/macroinvertebrates, habitat, periphyton/diatoms/algae, etc.

- Susquehanna River Basin Early Warning System – SRBC is upgrading the real-time monitoring stations on the Lower Susquehanna River with a goal of having a new web tool up and running in the first half of 2012.

- Lower Susquehanna Source Water Protection Partnership – SRBC in coordination with PADEP, are looking to convene a meeting in February 2012, to start building a framework for a sustainable workgroup that covers drinking water issues in the lower Susquehanna region. SRBC and PADEP have held a number of county-level meetings with a range of stakeholders over the past year dealing with local water quality issues of concern related to drinking water (sedimentation is high on the list).

- TMDL Data Collection and Development – As part of a contract with PADEP, SRBC is collecting data and modeling conditions in a number of watersheds in the lower Susquehanna basin for the development of local waterbody TMDLs (Conestoga, West Conewago, Octoraro, several urban watersheds, etc.). TMDLs cover a range of sources/causes, such as nutrient and sediment impairments from agricultural and urban pollution.

9. <u>Tropical Storm Lee Impacts</u> The team discussed the impacts of Tropical Storm Lee which scoured sediments, and what the impacts would be to the LSRWA scope.

   Mike Langland of USGS noted that Tropical Storm Lee scoured approximately 4 to 5 million tons out of Conowingo Dam into the Chesapeake Bay which is approximately 2 years of sediment/nutrient storage capacity. Mike reiterated that Exelon's consultant resurveyed bathymetry after the storm event behind Conowingo Dam. They utilized the same technique that USGS would have utilized and took measurements of velocity as well as refined bathymetry transects. Mike expects to obtain these datasets soon; as part of his scope, he will review these datasets to look for changes in bathymetry compared to the last time the reservoir was surveyed in 2008.

   Mike noted in the past, USGS utilized a 1D HEC-6 model to assess sediment deposition and transport in the entire reservoir system including sediments from the watersheds. Mike noted that there were shortcomings to this model. As part of his LSRWA efforts, Mike will construct and calibrate an updated 1D HEC-RAS model that will route inflowing sediment through the reservoirs, accounting for both sediment deposition and erosion in the upper reservoirs. The output of this model will provide boundary conditions for the 2D model simulations that Steve will be conducting as part of his scope in the Conowingo Reservoir.

   Gary Shenk will be conducting model runs utilizing the Chesapeake Bay Program's watershed model (CBP WSM), which will take into account watershed loads (same model utilized for TMDLs). He noted that he had concerns about the connections of the models (1D HEC-RAS, 2D, EPA WSM) in that there could be varying sediment rating curves and varying boundary conditions meaning potential differences in sediment loads that these models predict. Communication of this issue will be important in case the two models (1D HEC-RAS and EPA WSM) have varying results; differences in models will need to be communicated (input data, purposes, methodology, etc.). Steve offered that he could run both boundary conditions (1D HECRAS and EPA WSM) when he conducts his 2D model simulations to see how the Conowingo bed reacts. Gary suggested that the relative difference in sediment load estimated by scenarios from the CBP WSM be applied to the rating curve rather than using two different models of sediment delivery to force the reservoir models.

Mike noted that there is not much data on sediment transported between the four reservoirs (some data was collected in the 1950's). Additional samples may need to be collected during a high-flow event to better understand flow versus particle size.

Bruce noted that there was minimal scouring during the spring 2011 high flow events. However, this was the worst year on record for hypoxia and second highest flow on record. High mortality has been seen in oysters.

Jeff noted that scouring occurred during Tropical Storm Lee from behind the Conowingo dam; these sediments appeared to bypass the upper Bay and accumulated more in the middle Bay. The approach channels to the C&D Canal were scoured according to Philadelphia District, and there did not appear to be significant burial of organisms since sediment was widely dispersed.

Steve noted that he needs some sediment (bottom) samples below the dam in areas where bedrock has sediment buried on top of it, rather than just where bedrock is exposed (bedrock is exposed for quite a ways downstream). Steve asked if submerged aquatic vegetation (SAV) data is available in the Susquehanna flats area which he needs in order to account for SAV impacts when he models sediment transport and deposition in this area. Bruce noted that annual SAV areal flyovers are done every year and digitized; however, due to poor water clarity in the upper Bay, areal flyovers this year have been delayed. Field observations have noted that some SAV beds in the flats area have been ripped along edges; however, overall the beds are still intact. The group discussed that SAV beds are highly dynamic from year to year, so modeling should utilize SAV data appropriate to the time period being modeled.

Carl asked if sediment sampling occurred at the Conowingo Dam that involved size fractionation and chemical analyses (this is a task scoped under the LSRWA that is a supplement to the regular sampling USGS conducts at the Conowingo outfall funded by MDNR). Bruce noted that this sampling occurred during the March-April high flow events, as well as during the Tropical Storm Lee event. Bruce noted that the results of this sampling would be available in 2-3 weeks and that he would share results with the team.

Bob Blama asked if sediment sampling had been done behind Conowingo Dam to determine chemical constituents of sediments. This is important if we are going to be evaluating placement or re-use of these sediments and to communicate to stakeholders. Jeff and Mike explained that sampling was done in 2001 to determine physical/chemical constituents with a finalized report of data available in 2006. The assumption in the scope for the LSWRA is that this data would be adequate for the level of analyses (broader) that is being undertaken in this effort. Any future detailed investigation of dredging/construction alternatives would probably include bottom sampling.

There was discussion on the literature search task for this study. Mark noted that TNC has been involved with various groups looking at best management practices for dealing with reservoir sedimentation and sediment management around the world. Anna noted that it will be important to review literature compiled from the Sediment Task Force (1999-2000), as well as more recent literature dealing with sediment management practices and incorporate those ideas into the LSRWA; this was a task scoped in the LSRWA and USACE currently has the lead. The consensus was that USACE will still have the lead in preparing a literature search, however, TNC would supplement this task with information they obtain from best management practices around the world.

Matt noted that reaching out to MPA would be good as they head up the innovative re-use committee that looks at innovative dredging method sand re-use of dredged material. Since Matt is a committee member, he will keep the LSRWA team informed on this group's findings.

10. Prioritize Tasks and Schedule The team was provided handouts of the study approach, schedule, map, and modeling scenarios that were developed during scoping process. Claire noted that with the limited study funding, it is important to layout what tasks will be accomplished this year and to put dates on these tasks. The consensus was:

    Federally funded tasks (totaling $220K):

    - Mike Langland – (1) conduct QA / QC of Exelon 2011 Conowingo Pond survey; (2) build HEC-RAS model; and (3) compile data to support study modeling efforts.
    - Carl Cerco – assemble water quality data.
    - Steve Scott – (1) conduct 2D / 3D study; (2) initial numerical mesh construction; and (3) 2D AdH data assembly and initial hydrodynamic simulation.
    - ERDC team (coordinated by Steve Scott) – conduct SEDflume field data collection and analysis.

    Non-Federally funded tasks (no $ specified):

    - Bruce (MDNR) – fund USGS to conduct suspended sampling monitoring at Conowingo Dam.
    - Jeff – sediment sampling below Conowingo Dam in flats area.
    - Shawn – summary of Exelon findings.

    Claire will work with team members individually to schedule out these tasks and provide schedule to entire team for review.

11. Wrap Up The next meeting will be 23 January 2012.

Anna Compton

Study Manager

February 16, 2012

Memorandum for the Record

Subject: Lower Susquehanna River Watershed Assessment (LSRWA) Quarterly Team Meeting
Location: MDE, Montgomery Park Building, Aqua Conference Room
Date: January 23, 2012

Attendees:

Agency	Name	Email	Phone
Bay Journal	Tom Horton	swanfull@gmail.com	410-726-7282
Coastal Conservation	Bob Fantom	Bobthefantom@verizon.net	
Exelon	Bob Matty	Robert.matty@exeloncorp.com	610765-5514
Exelon	Mary Helen Marsh	MaryHelen.Marsh@exeloncorp.com	
Gomez and Sullivan	Gary Lemay	glemay@gomezandsullivan.com	603-428-4960
Gomez and Sullivan	Tom Sullivan	tsullivan@gomezandsullivan.com	603-428-4960
Lower Susquehanna RiverKeeper	Michael Helfrich	LowSusRiver@hotmail.com	717-779-7915
MDE	Herb Sachs	hsachs@mde.state.md.us	410-537-4499
MDE	John Smith	jsmith@mde.state.md.us	410-537-4109
MDE	Matt Rowe	mrowe@mde.state.md.us	410-537-3578
MDE	Tim Fox	tfox@mde.state.md.us	410-537-3958
MDNR	Bruce Michael	bmichael@dnr.state.md.us	410-260-8627
MDNR	Shawn Seaman	sseaman@dnr.state.md.us	410-260-8662
MGS	Jeff Halka	jhalka@dnr.state.md.us	410-554-5503
SRBC	Dave Ladd	dladd@srbc.net	717-238-0425x204
SRBC	John Balay	jbalay@srbc.net	717-238-0423 x217
SRBC	Andy Gavin	agavin@srbc.net	717-238-0423 x107
URS	Marjorie Zeff	Marjorie.zeff@urs.com	215-367-2549
USACE	Andrea Takash	Andrea.M.Takash@usace.army.mil	410-962-2626

USACE	Anna Compton	Anna.M.Compton@usace.army.mil	410-962-4633
USACE	Bob Blama	Robert.N.Blama@usace.army.mil	410-962-6068
USACE	Chris Spaur	Christopher.C.Spaur@usace.army.mil	410-962-6134
USACE	Claire O'Neill	Claire.D.O'Neill@usace.army.mil	410-962-0876
USACE-ERDC	Carl Cerco	Carl.F.Cerco@erdc.usace.army.mil	601-634-4207
USACE-ERDC	Steve Scott	Steve.H.Scott@usace.army.mil	601-634-2371
USGS	Mike Langland	langland@usgs.gov	717-730-6953

The meeting agenda is provided as an enclosure to this memorandum.

Action Items:

A. Bruce will integrate comments from the team to refine the LSRWA (public) website.
B. Steve will coordinate with Bruce to obtain digitized maps of SAV data in the Susquehanna flats area.
C. Bruce will share results of the suspended sediment sampling taken at Conowingo outfall (taken during high flow events this year) with the team. [**Update**: MDNR provided the data to Carl Cerco]
D. Anna will update the map in the LSRWA PowerPoint presentation to remove the York Haven Dam.
E. Bruce will send the LSRWA website link to the team.
F. Bruce will update the LSRWA website with recommended changes from the team.
G. The team will send Bruce documents and links that should be posted on the LSRWA website.
H. The MDE FTP website will be utilized to share internal draft documents within the team; Matt will be the point of contact for this FTP site.
I. Dave will send a hyperlink to the SRBC publication 239 (the 2006 sediment analysis report) to the team. [**Update**: Link sent January 24, 2012]
J. Claire will coordinate monthly conference calls to discuss modeling activities.
K. Shawn will notify team when most recent Exelon study reports are released.
L. Claire will work with Mike Langland to execute funding for USGS for LSRWA efforts.

Ongoing Action Items

A. Anna will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups.
B. Anna will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of updates from the quarterly meeting.
C. Mark and Anna will coordinate to conduct a literature search providing info on best management practices around the nation and world for reservoir sedimentation.
D. Matt will keep team informed on Innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies.

Discussion:

1. Welcome and Opening Remarks:

   Herb Sachs welcomed the group. He noted that after the press release (September 2011) announcing that the study has started, feedback has been positive and there has been a lot of interest. The name of the study changed to the Lower Susquehanna River Watershed Assessment in order to communicate more effectively that this study is a more comprehensive evaluation of sediment management within the lower Susquehanna River watershed versus just a Conowingo reservoir sediment study. There have been questions in regard to how this effort, looking at the issue of sedimentation, the dams, and the Chesapeake Bay, will be different this time around. Herb said that his response to this question is that the atmosphere is different this time around because of the ongoing regulatory actions being taken through the total maximum daily load (TMDL) process and all of the other ongoing efforts and investments being made in Chesapeake Bay restoration. More recently there has not been much interest or inquiry in regard to the LSRWA and it is important (for future funding and support of this study's recommendations) that we continue to communicate our efforts to all stakeholders and get feedback.

   Herb provided a copy of the latest issue of the *Chesapeake Bay Quarterly* which has two articles discussing sedimentation, the Conowingo Dam, implications to the Chesapeake Bay and the LSRWA effort.

   Discussion ensued about the status of federal funding for this study. Claire summarized that we should know if the study received funding for FY12 by mid-February. [**Update**: $300,000 received in February 2012.] The FY13 budget will be coming out in a few weeks and then we will know if there if there will be funding available for next FY. [**Update**: This project is not in the president's FY13 budget.]

2. Review of Action Items from November 2011 Meeting:

   The team reviewed action items from the last quarterly meeting:

   A. Claire will email the team the "Roles and Responsibilities" spreadsheet to get input; compile and send out to team once completed.
      Status Complete- Spreadsheet is finalized and can be posted to website.

   B. Anna will send the LSRWA Team email distribution list to all team members.
      Status Complete.

   C. Shawn Seaman will contact Michael Helfrich to notify him of quarterly meetings to see if he can attend.
      Status Complete. Michael will be added to the distribution list so he will automatically be invited to future quarterly meetings.

   D. Bruce Michael will have the lead in coordinating with SRBC, MDE, and MGS to set up a website where any products of the assessment can be kept to keep stakeholders informed.

Status Ongoing. The website has been set up at the following address: http://bit.ly/LowerSusquehannaRiver. See discussion on website in meeting summary below.

E. Anna will prepare a brief public involvement plan to layout how the LSRWA will be coordinated with stakeholders and will send out the team for review.

Status Ongoing. See discussion on public involvement plan in meeting summary below.

F. Anna will send out revised goals to the team for one final review and team approval.

Status Complete. Goals have been finalized and can be posted to website.

G. Steve will coordinate with Bruce to obtain digitized maps of SAV data in the Susquehanna flats area.

Status Ongoing. SAV mapping was not done until November 2011 due to sediment plumes that obstructed visibility from the large storms that occurred earlier in 2011. Maps should be available for download from the "Eyes on the Bay" website by the end of February. Anecdotal evidence shows that SAV beds are still intact and were not damaged from storm events.

H. Bruce will share results of the suspended sediment sampling taken at Conowingo outfall (taken during high flow events this year) with the team.

Status Ongoing. The data is being reviewed and formatted by USGS. Data should be available by mid-February.

I. Claire will follow up with individual team members to develop a schedule for work to be conducted this year.

Status Complete. The team has provided input on schedule. As tasks are completed and progress on the study continues the schedule will be updated. See discussion on schedule in meeting summary below.

J. Shawn will provide a summary of Exelon study findings.

Status Complete. Exelon was able to attend meeting so they provided an update at the quarterly meeting. See discussion on Exelon study findings in meeting summary below.

3. Communication and Coordination:

A. Public Involvement Plan

At the previous quarterly meeting there was much discussion on public involvement/communicating to stakeholders outside of the team. Based on this discussion, Anna drafted a public involvement plan to capture how the LSRWA team would engage the public and agencies. The team reviewed the plan and provided the following comments:

- Add a general timeline of when the team anticipates public meetings;

- The terms “public” and “stakeholders” should be clearly defined;
- Funding sources for recommendations that are developed during the assessment should be added as a public concern;
- NY, PA, and MD state offices should be added to the list of groups likely to be interested in project;
- The final public involvement plan document should be added to the LSRWA website; and
- Clearly define how the public involvement will be documented in the LSRWA report (lay out a chronology of all activities).

Dave added that it is important as we finalize the watershed assessment that we make sure refer back to the public outreach plan, and follow what we have laid out to engage the public in the LSRWA.

Tom Horton commented that with the 40-year anniversary of Tropical Storm Agnes occurring this year, the media would most likely be interested in running a story on that storm event and the current efforts going on now. This represents a good opportunity for the assessment to get some publicity.

Herb mentioned that he, Secretary Summers (MDE) and Paul Swartz (executive director of SRBC) met with the Maryland delegation from the Eastern Shore. He noted that feedback from these meetings was that there is a lot of interest in water quality in the Bay; farmers feel like they are being picked on (it will be important to engage agriculture groups in study); and the costs of the implementation of the TMDL and the proposed “flush tax” to cover the cost of implementation of TMDL.

Bruce noted that the MD legislature is in session now (through April 9, 2012) and there will be many opportunities to present where we are in this study to MD legislators.

B. <u>LSRWA Presentation Feedback from Recent Meetings</u>
Jeff presented an update of the study to the Chesapeake Bay Program (CBP) Modeling Subcommittee on November 30, 2011. No specific feedback was received. Jeff noted that this is a good group to stay in touch with and they were very receptive to the study. Jeff also presented at the Citizens Advisory Committee for the Dredged Material Management Program as well.

Bruce presented an update of the study at the CBP Scientific and Technical Advisory quarterly committee meeting in January 2012. The group wants to be kept informed. Also a copy of the LSRWA PowerPoint presentation was sent to Ann Swanson of the Chesapeake Bay Commission for her use.

There was discussion on the map in the presentation showing the study area for the LSRWA. There is a system of four hydroelectric dams on the lower Susquehanna River. The northernmost dam is the York Haven Dam which is not included in the modeling scopes for the assessment due to the fact that it is a “run of the river” dam that does not trap sediments in any significant way. The consensus was to remove this dam from the map in the presentation to clarify this point. However, in background discussion in the

LSRWA report, this dam should be mentioned and the reason why it is not included in the study/area scope of the assessment.

C. Public MDNR Website Demo
Bruce pulled up the newly developed website for the LSRWA and requested feedback from the team. Below are team recommendations for website:

- Shorten the URL address;
  [**Update**: Address is now http://bit.ly/LowerSusquehannaRiver]
- Add legal cost-sharing agreement;
- Add project management plan;
- Add a link to MDNR's "Eyes on the Bay" website;
- Add a link to the historical Sediment Task Force website
- Add a link to historical Sediment Task Force documents (but add caveat noting evolution of thought on sediment management and that these are "historic"; ;
- Add links to specific related efforts going on in the Bay (i.e. TMDL, SRBC WQ efforts, etc.);
- Add LSRWA PowerPoint presentation;
- Add LSRWA team roles and responsibilities spreadsheet;
- Add LSRWA goals and objectives;
- Add media articles/press releases discussing LSRWA;
- Add calendar of events;
- Add all quarterly meeting agendas and meeting minutes;
- Add stakeholder outreach plan; and
- Add a tab for technical reports

All appropriate materials (in list above) will be sent to Bruce by the LSRWA team to be uploaded onto website.

D. Need for Internal Website for Sharing
Claire mentioned that the primary purpose of the LSRWA website is to share information with the public. She asked the team if there is a need to have an internal website to share draft documents and information that are not ready to be posted on the public website but are too large to email to team members. Matt noted that MDE has an ftp website that can be used for this purpose; he will send a link out for the team's use.

4. Summary of Exelon Studies
Shawn explained to the group that the Conowingo Dam has been undergoing the 5-year Federal Energy Regulatory Commission (FERC) relicensing process. Out of this relicensing process, Exelon (owner and operator of Conowingo Dam) was required to conduct several studies that relate to sediment accumulation and transport. Year 2 study reports are due by January 23, 2012. Several contractors of Exelon attended the quarterly meeting and provided results of these studies to the LSRWA team.

Marjie from URS explained that the objective of the sediment transport and accumulation study they conducted was to provide data that will be useful in the future development of an overall sediment management strategy for the Susquehanna River and Chesapeake Bay.

Three tasks conducted to meet this objective were: (1) review and compile existing information; (2) quantitatively assess sediment-related impacts of Conowingo dam on downstream habitat; and (3) evaluate options to manage sediment at Conowingo (completed, but not discussed at this meeting).

Under Task 1, Exelon determined that the underlying assumptions of previous studies which warrant reevaluation were: (1) that flood events of 400,000 cubic feet per second (cfs) trigger scour in the lower Susquehanna reservoirs; (2) that Lake Clarke and Lake Aldred are at steady-state equilibrium with respect to sediment trapping; and (3) Tropical Storm Agnes was associated with major scour event in Conowingo reservoir.

Under Task 2, a HEC-6 analysis of scour (and trapping efficiency) during major storm events was conducted. Findings were that the Conowingo and Clarke reservoirs trap sand received from upstream; Lake Aldred passes sand received from two major tributaries down to the Conowing Pond; silt/clay passes through the reservoir system; and minor scour occurs in Lakes Aldred and Clarke. Conclusions drawn from this HEC-6 analysis were: (1) the Exelon findings do not support the conclusions in scientific literature that the catastrophic impact to Chesapeake Bay from Agnes was due to scour from Conowingo reservoir; (2) Lake Clarke is not in equilibrium (i.e., it is still trapping sediment), though Lake Aldred is in equilibrium; and (3) the Exelon analysis contradicts the scour regression model which utilizes a 400,000-cfs scour threshold.

Mike Langland noted that in general he concurred with the findings of the second conclusion in that in the short term these upper reservoirs are not at steady state (year to year). However, in the long term (20 years), they are at steady state (trapping of sediments is negligible). It is still important to incorporate the upper two reservoirs into the modeling and ensure that the time frame (long term or short term) is well communicated. Tom noted that public perception is important in regards to short-term, episodic events.

Michael Helfrich added that the HEC-6 model utilized by Exelon in the analysis has shortfalls (recognized by USGS in their own reports). These shortfalls are important to keep in mind when using HEC-6 as a tool and extrapolating results to sedimentation within this system. Mike Langland added that as part of this study, the HEC-6 model will be updated and calibrated with better data to allow for more accurate predictions for the watershed assessment.

Marjie added that it is important to think about the sedimentary record when conducting sediment analysis and accumulation studies; for example, are the large quantities of reservoir bottom scour recognized as a source of suspended sediment at Conowingo Dam by grain size distribution?

Gary went over the findings from the recent bathymetric surveys that were conducted in the Conowingo Reservoir. The objectives of these surveys were: (1) create a thorough bed elevation map of Conowingo Pond; (2) determine where and to what extent Conowingo Pond's sediment/bathymetric profile has changed since the 2008 USGS survey; and (3) establish a physical "baseline" benchmark to better inform future sediment management decisions.

Bathymetric and water velocity data were collected in Conowingo Pond in October 2011 (< 6 weeks after flows receded from Tropical Storm Lee). The same (26) transects surveyed by past USGS surveys were utilized as well as 33 additional transects and 5 longitudinal profiles. This 2011 data was plotted against 2008 data (most recent USGS bathymetric survey) for each transect.

In general, findings of this survey are: (1) upstream areas of Conowingo reservoir are in dynamic equilibrium; (2) in downstream areas of Conowingo Reservoir, deposition outweighed scour; (3) average cross-section depths generally decreased by 1 foot to 3.5 feet; (4) deposition occurred around banks/edges and scour occurred in the main channel; (5) the river appeared to shift toward the dam's spillway in the farthest downstream cross-sections; (6) Conowingo Reservoir accumulated approximately 5,870 acre-ft of sediment between the fall 2008 survey and the 2011 survey; and (7) net sediment deposition between the 2008 and 2011 surveys was 8.67 million tons. This net sediment deposition translates to approximately 2.9 million tons of deposition per year; historic deposition rates have ranged from 3.1 million tons/yr from 1929-1958, to 2.5 million tons/yr from 1958-1993, to 1.5 million tons/yr from 1996-2008 (Langland 2009). [**Update**: Exelon has since identified some QA-QC changes that alter the total water volume deposition changes. The revised numbers will be released in a memo to the LRWSA group and Exelon relicensing stakeholders in the near future. The updated numbers resulted in less deposition than previously estimated, but did not change the conclusion that there was net deposition between 2008 and 2011.]

Bruce added that Tropical Storm Lee scoured approximately 4 million tons of sediments. If this event had not occurred then deposition measured in these surveys would have been much higher this year.

5. <u>LSRWA Technical Analysis Updates</u>

   A. <u>Chesapeake Bay Program Partnership Model (Chesapeake Bay Environmental Modeling Package – CBEMP)</u>
   Carl gave a briefing on data assembly for the CBEMP application to the Bay downstream of Conowingo Dam. Carl explained that he was searching primarily for data that would help with the water quality modeling effort as this is the primary application of this model to the LSRWA. He described several datasets he has located and several known datasets that are missing; a summary of his findings was handed out at the meeting (enclosure 2). The largest missing piece is the data collected in 2011 (suspended solids flowing over Conowingo Dam, sampled for particulate nitrogen and phosphorus). Bruce noted that data was collected by USGS, and is currently being reviewed and formatted. It will be available by the end of the January.

   Dave mentioned the SRBC publication 239, a 2006 report, which contains a full physical examination and chemical analyses of the sediments behind three dams on the lower

Susquehanna River in 2000. Dave noted that he would be sure to get a link for the report to the team.

B. Sediment Transport Modeling Update
Steve noted that the his scope for the LSRWA currently lays out a plan to utilize a 2D adaptive hydrodynamic (ADH) model to model the Conowingo Reservoir and Susquehanna flats. One of his first tasks is to conduct a desktop analysis to determine if there are any significant 3D effects in the system, which would require the need for a 3D model. He has started this analysis. He is also building the mesh for the models which will include a hydrodynamics component and a sediment transport model. Another task that will commence soon (May 2012) is the SedFlume analysis which will consist of a team going out and collecting data (sediment bed samples) from the Conowingo Reservoir. This analysis will determine the erodability of the sediments in this area. Due to limited initial funding, approximately half of the planned samples will be collected ($60K vs. $120K worth of effort) unless further funds are provided this fiscal year.

C. HEC-RAS Modeling Update
Mike Langland provided an update on his efforts which include constructing and calibrating an updated 1D HEC-RAS model that will route inflowing sediment through the reservoirs, accounting for both sediment deposition and erosion. The output of this model will provide boundary conditions for the 2D model simulations that Steve will be conducting as part of his scope in the Conowingo Reservoir.

The HEC-6 model was constructed and utilized in 1990 to model the lower Susquehanna reservoirs. The model was used to estimate 1987 annual and monthly sediment loads and trap efficiency and the model was also used to simulate sediment transport during the June 1972 storm event (Tropical Storm Agnes). The model was calibrated and performed poorly in both scenarios.

For the LSRWA effort, a HEC-RAS model will need to calibrate transport of sediment and sediment size classes to a base year and also will need to simulate transport of sediment and sediment size classes over high-flow event hydrograph(s) and sediment reduction scenarios, incorporating total maximum daily load data from the watershed implementation plan.

The original HEC-6 model had 13 sediment size classes. Based on review of particle size results, this new model with simulate 1 sand, 2 silt and 2 clay sizes. There is very little sand movement so there is no need to simulate sand transport at a very refined level.

In the literature, there is no documentation on the selection of sediment computation algorithms. Thus, algorithm selection will need to be revisited in this effort to simulate high-flow event transport functions.

Mike noted that he has looked at the feasibility of using data for the new HEC-RAS model. Geometric data (e.g., channel cross-sections 2008 and 2011) will likely be used.

The 2011 data has greater resolution. Sediment particle size distribution and transport data collected since 1990 will also be utilized.

In coordination with Steve and his modeling efforts the HEC-RAS output will be an hourly time step, which suits the needs of the 2D ADH model. This effort will model all three reservoirs (Aldred, Clarke, and Conowingo) and the simulation period will cover the September 2011 high flow event and yet-to-be specified period(s) for annual loads.

In regards to reservoir sediment, Mike has pulled all historical sediment concentrations, loads and particle size data from Harrisburg, Marietta, Conestoga Creek, Pequea Creek, and Conowingo. The data will be used to build the QC model input files. He is also building a geospatial data base that will contain the locational data and results of sediment cores analyzed by USGS.

Tom Sullivan asked how this HEC-RAS modeling effort will improve upon the HEC-6 effort done in the past. Mike explained that we will have new data with the bathymetric surveys and updated algorithms. Steve added that the models will all be validated and we are working in relative changes (relative effects over time of increasing capacity) vs. absolute change at one point in time. Tom noted that it will be important to communicate the calibration process.

Claire said that with all the modeling efforts going on it will be important for modelers to communicate often to keep on task. She will coordinate monthly (teleconference) meetings to discuss modeling activities.

6. Review Schedule for 2012

   Claire provided a handout of the most updated schedule for the study. Prior to the meeting she received input from the team in order to update the schedule. A few of the activities were revised based on meeting discussions; enclosure 3 represents the project schedule as of the team meeting.

7. Wrap Up The next meeting will be April 30, 2012, 10-12:30, at MDE.

Anna Compton

Study Manager

Enclosures: 1. Meeting Agenda
2. Summary of Water Quality Data
3. Project Schedule dated 23 January 2012

LOWER SUSQUEHANNA RIVER WATERSHED ASSESSMENT
QUARTERLY TEAM MEETING

MDE, Montgomery Park Building, Aqua Conference Room
January 23, 2012

Meeting Agenda

		Lead
10:00	Welcome and Opening Remarks	Sachs
10:05	Introductions	All
10:10	Review of Action Items from November Meeting	O'Neill
10:30	Communication and Coordination	
	Public Involvement Plan	Compton
	PowerPoint Presentation – Feedback from Recent Meetings	Halka, Michael
	Public MDNR Website Demo	Michael
	Include PowerPoint presentation, goals and objectives, roles and responsibilities, meeting notes?	
	Need for Internal Website for Sharing	O'Neill
11:00	Summary of Exelon Study	Seaman/Exelon
11:10	LSRWA Technical Analyses	
(10 min)	CBEMP Modeling Update	Cerco
(15 min)	Sediment Transport Modeling Update	Scott
(10 min)	HEC-RAS Modeling Update	Langland
11:45	Review Schedule for 2012	O'Neill
11:55	Wrap Up	Compton
	Action Items/Summary	
	Next Meeting	

Call-In Information: (410) 537- 4281 (no password required)

Expected Attendees:

MDE: Herb Sachs; Matt Rowe, Tim Fox, Adam Rettig
MDNR: Bruce Michael, Shawn Seaman
MGS: Jeff Halka
SRBC: John Balay, David Ladd, Andrew Gavin
USACE: Anna Compton, Bob Blama, Carey Nagoda, Chris Spaur, Claire O'Neill, Dan Bierly
ERDC: Carl Cerco, Steve Scott
USEPA: Gary Shenk
USGS: Mike Langland, Ed Koerkle

Exelon: Gary LeMay, Mary Helen Marsh, Robert Matty, Margie Zeff
Lower Susquehanna Riverkeeper: Michael Helfrich

Unable to attend = TNC

Action Items from November Meeting:

A. Claire will email the team the "Roles and Responsibilities" spreadsheet to get input; compile and send out to team once completed.
B. Anna will send the LSRWA Team email distribution list to all team members.
C. Shawn Seaman will contact Michael Helfrich to notify him of quarterly meetings to see if he can attend.
D. Bruce Michael will have the lead in coordinating with SRBC, MDE, and MGS to set up a website where any products of the assessment can be kept to keep stakeholders informed.
E. Anna will prepare a brief public involvement plan to layout how the LSRWA will be coordinated with stakeholders and will send out the team for review.
F. Anna will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups.
G. Anna will send out an update to via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of LSRWA kick-off meeting and study start and will periodically update this group as the LSRWA progresses.
H. Anna will send out revised goals to the team for one final review and team approval.
I. Steve will coordinate with Bruce to obtain digitized maps of SAV data in the Susquehanna flats area.
J. Bruce will share results of the suspended sediment sampling taken at Conowingo outfall (taken during high flow events this year) with the team.
K. Mark and Anna will coordinate to conduct a literature search providing info on best management practices around the nation and world for reservoir sedimentation.
L. Matt will keep team informed on Innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies.
M. Claire will follow up with individual team members to develop a schedule for work to be conducted this year.
N. Shawn will provide a summary of Exelon study findings.

MEMORANDUM FOR THE RECORD

SUBJECT: Lower Susquehanna River Watershed Assessment
Quarterly Team Meeting, 30 April 2012

1. On 30 April 2012, agency team members met to discuss ongoing and completed activities for the Lower Susquehanna River Watershed Assessment (LSRWA). The meeting was hosted by the Maryland Department of the Environment (MDE) in their Aqua Conference Room at the Montgomery Park Building in Baltimore, Maryland. The meeting started at 10:10 am and continued through 12:30 pm. The meeting attendees are listed in the table below.

Agency	Name	Email Address	Phone
Exelon Generation	Bob Matty	robert.matty@exeloncorp.com	610-765-5514
Exelon -- Gomez and Sullivan	Gary Lemay	glemay@gomezandsullivan.com	603-428-4960
Exelon -- URS Corp.	Marjorie Zeff	marjorie.zeff@urs.com	215-367-2549
Lower Susquehanna Riverkeeper	Michael Helfrich	LowSusRiver@hotmail.com	717-779-7915
MDE	Herb Sachs	hsachs@mde.state.md.us	410-537-4499
MDE	John Smith	jsmith@mde.state.md.us	410-537-4109
MDE	Tim Fox	tfox@mde.state.md.us	410-537-3958
MDNR	Bruce Michael	bmichael@dnr.state.md.us	410-260-8627
MGS	Jeff Halka	jhalka@dnr.state.md.us	410-554-5503
NOAA-NMFS	John Nichols	john.nichols@noaa.gov	410-267-5675
SRBC	David Ladd	dladd@srbc.net	717-238-0425x204
SRBC	John Balay	jbalay@srbc.net	717-238-0423 x217
TNC	Kathy Boomer	kboomer@tnc.org	
USACE	Andrea Takash	andrea.m.takash@usace.army.mil	410-962-2626
USACE	Carey Nagoda	carey.m.nagoda@usace.army.mil	410-962-6761
USACE	Chris Spaur	christopher.c.spaur@usace.army.mil	410-962-6134
USACE	Claire O'Neill	claire.d.o'neill@usace.army.mil	410-962-0876
USACE	Dan Bierly	daniel.m.bierly@usace.army.mil	410-962-6139
USGS	Mike Langland	langland@usgs.gov	717-730-6953

In addition, a number of team members listened in via the conference line; those listening were:

Agency	Name	Email Address	Phone
PADEP	Patricia Buckley	pbuckley@pa.gov	717-772-1675
PADEP	Ted Tesler	thtesler@pa.gov	717-772-5621
PA DCNR	Ray Zomok	rzomok@pa.gov	
SRBC	Andrew Gavin	agavin@srbc.net	717-238-0423x107
TNC	Mark Bryer	mbryer@tnc.org	301-897-8570
USACE-ERDC	Carl Cerco	carl.f.cerco@erdc.usace.army.mil	601-634-4207
USACE-ERDC	Steve Scott	steve.h.scott@usace.army.mil	601-634-2371
USGS	Ed Koerkle	ekoerkle@usgs.gov	

The meeting agenda is provided as enclosure 1 to this memorandum.

2. Welcome and Opening Remarks – After a brief introduction of the meeting attendees, Herb Sachs welcomed the LSRWA agency group. Herb noted the low flow conditions in the Susquehanna River.

3. Review of Action Items from January 2012 Meeting – For the first meeting discussion, the team reviewed the January 2012 action items as well as the ongoing action items.

Action Items from January Meeting:

A. Bruce will integrate comments from the team to refine the LSRWA (public) website.
Status – Completed.

B. Steve will coordinate with Bruce to obtain digitized maps of SAV data in the Susquehanna flats area.
Status – Maps have been provided; Steve Scott still needs to download them and will do so shortly.

C. Bruce will share results of the suspended sediment sampling taken at Conowingo outfall (taken during high flow events this year) with the team. [**Update**: MDNR provided the data to Carl Cerco]
Status – Completed.

D. Anna will update the map in the LSRWA PowerPoint presentation to remove the York Haven Dam.
Status – Completed.

E. Bruce will send the LSRWA website link to the team.
Status – Completed.

F. Bruce will update the LSRWA website with recommended changes from the team.
Status – Completed.

G. The team will send Bruce documents and links that should be posted on the LSRWA website.
Status – Ongoing; future documents and links should be sent to Bruce Michael.

H. The MDE FTP website will be utilized to share internal draft documents within the team; Matt will be the point of contact for this FTP site.
Status – Ongoing; sharing of future documents will go through the MDE ftp website.

I. Dave will send a hyperlink to the SRBC publication 239 (the 2006 sediment analysis report) to the team. [**Update**: Link sent January 24, 2012]
Status – Completed.

J. Claire will coordinate monthly conference calls to discuss modeling activities.
Status – Completed.

K. Shawn will notify team when most recent Exelon study reports are released.
Status – Recent report was sent out to team; ongoing action.

L. Claire will work with Mike Langland to execute funding for USGS for LSRWA efforts.
Status – Paperwork is completed on the USGS end and is on its way to USACE [Update: Completed documents were delivered on April 30th.]

Ongoing Action Items

A. Anna will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups.

B. Anna will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of updates from the quarterly meeting.

C. Mark and Anna will coordinate to conduct a literature search providing info on best management practices around the nation and world for reservoir sedimentation.

D. Matt will keep team informed on innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies.

4. Communication and Coordination – Claire mentioned that USACE had sent out standard USACE study coordination letters to various Federal and state environmental resource agencies in February 2012. These letters had been coordinated with Bruce and Herb in advance. As a result of this coordination, we have added several new agency team members, some of whom attended or listened into the quarterly team meeting. In particular, we have several new representatives from Pennsylvania, as well as the National Marine Fisheries Service.

Since the last quarterly meeting, there have been no official presentations of the project PowerPoint slides. Herb mentioned that Tim Fox will be attending the 1 May 2012 meeting of the innovative re-use committee.

Herb asked about the status of the Federal funding for the watershed assessment. Claire indicated that the assessment has received funding to cover the activities through FY12, with some funds (roughly $50,000) for the first part of FY13. The project is not in the president's budget that was released in February 2012. However, for this fiscal year, the study received funds from a general pot of money and it is hoped that the same result will happen in FY13; the allocation of these funds is determined by USACE Headquarters staff. Herb and Michael Helfrich asked what they could do to help with the budget situation. Claire explained that while in the past Congressional earmarks were an avenue to funding for non-budgeted studies, earmarks are not acceptable to Congress this fiscal year [**Action** = Claire will discuss funding needs for FY13 with Herb].

Recently, there was a workshop on the short-term impacts of Tropical Storms Irene and Lee. Bob Hirsch from USGS reported on significant load of sediments and nutrients from high-flow events and that impacts will be more severe in the future. Subsequently, the window for action is closing. There will be a follow-up workshop in the fall. Bruce indicated that we will send the workshop information to the LSRWA agency group [**Note:** The link to the April 19, 2012 CBP Storm Effects Topical Meeting has been added to the LSRWA website]. Mike Langland reminded the group that Bob Hirsch will be invited to the next quarterly meeting to make a presentation on his findings [**Action** = Mike to invite Bob; update: Bob has put us on his schedule for August 7th].

5. LSRWA Technical Analyses – The various modeling leads provided updates on their technical analyses.

A. CBEMP Modeling Update and Data Report – Carl's data report was sent out for comment in early April. So far, comments have been received from SRBC and Chris Spaur (USACE). Marjorie Zeff mentioned that she would be sending a suggestion for improving the report on 30 April. Carl noted that he would need 2 weeks to finalize the report.

Carl's analysis shows that as the flow over Conowingo gets larger, the composition of the transported materials starts to resemble the reservoir bed material. His work indicates that we have sufficient data to characterize material coming over the spillway, and that it is a good dataset for water quality modeling.

B. Sediment Transport Modeling – Steve Scott updated the agency LSWRA team on his sediment transport modeling using the PowerPoint presentation in enclosure 2. Two separate models were developed, one for Conowingo and one for the Susquehanna Flats. Steve used the 2008 and 2011 bathymetric surveys of Conowingo Pond extensively in his analysis. NOAA nautical charts were used for the Susquehanna Flats area. All data was converted to NGVD (National Geodetic Vertical Datum) 1929.

To date, Steve has completed an evaluation of the importance of three-dimensional effects in Conowingo sedimentation. Three-dimensional effects can result from density-gradient currents, wind-generated currents, and reservoir discharges at multiple depths. These effects are important when the reservoir inflows are low, when flow velocities are low since turbulence and mixing are at a minimum, and when there are a high reservoir residence times. Steve's approach to the analysis was to evaluate sediment availability to the reservoir when the three-dimensional impacts may be significant. Since flows greater than 30,000 cubic feet per second (cfs) have a very low retention time (5 days or less), it can be assumed that there is sufficient mixing at these flow levels.

In addition, Steve looked at the total sediment load coming into Conowingo Pond. Of about 4.28 million tons of annual sediment inflow, only 0.22 million tons happens during flows of less than 30,000 cfs. So, the bottom line is that Conowingo Pond is exposed to only 5 percent of the total annual sediment load during low flow conditions. Steve concluded that although three-dimensional effects do occur, they are negligible. Hence, for the flow levels that we are interested in, a three-dimensional model is not warranted. Steve mentioned that the 30,000-cfs cut-off value could have been as low as 20,000 cfs.

Steve then described the development of the two-dimensional models. There are 11,432 nodes in the Conowingo Pond model with the density of nodes increasing closer to the dam. The model includes routines for the power plant operations as well as the flood gates. Flows less than 86,000 cfs are routed through the power plant, while the flood gates open at higher flows. When flows reach as high as 400,000 cfs, the power plant no longer functions for flow passage. Steve's presentation included several slides showing the 2008 bathymetry, water depths and velocities at a flow of 700,000 cfs, and velocities at two lower levels of discharge. Steve showed a short movie showing how the velocities in the reservoir change with high flow operations.

The Susquehanna Flats two-dimensional model has 8,587 nodes in it, with the density of nodes increasing as you go up the river toward the Conowingo Dam. Steve's presentation included several slides showing the model bathymetry, as well as water depth and velocity at a flow of 100,000 cfs. The submerged aquatic vegetation patch at the mouth of the river was quite evident in these slides (large roughly circular area in red, showing as deflecting flow). The SAV bed is modeled with 3 feet of grass plus 2 feet of water. Bruce Michael mentioned that the SAV area is roughly 12,000 acres in size, and is the largest contiguous SAV bed in the Chesapeake Bay. This bed has been steadily growing, although it took a hit with Tropical Storms Irene and Lee. Jeff Halka asked whether Steve could decrease the SAV canopy height seasonally. Steve noted that yes, they can. Bruce indicated that Lee Karrh from his staff would have information on the SAV winter dieback.

Steve mentioned that the two-dimensional models can be run on a PC although he will be using a supercomputer for added speed of turnaround time. Steve also reported that the ERDC field crew returned from the sediment core sampling recently. Lots of good data were collected; Steve has started the SEDflume data analysis.

C. <u>HEC-RAS Modeling</u> – USGS's Mike Langland and Ed Koerkle shared the status of their HEC-RAS modeling work using the PowerPoint presentation in enclosure 3. The HEC-RAS model extends from the Marietta gage at the upstream end to Conowingo Pond at the downstream end. Within this reach, there are two major flow inputs, the Conestoga River and Pequea Creek. To date, the USGS work has focused on evaluating the sediment input data, model geometry and hydraulics, and modeling sediment transport.

Using sediment input and instantaneous discharge data, Mike developed four transport curves (Marietta, Conestoga River, Pequea Creek, and Conowingo). The curves were developed by ranking the flow values and then showing the associated sediment concentration values. The resultant curves had R^2 values ranging from 0.65 to 0.70. Mike also summarized the particle size transport data for Conowingo. This data included 391 samples of sand/fines and 16 samples of sand/silt/clays. Mike noted that he would prefer to have more particle size data for this analysis.

While there was a HEC-6 model done in the mid-1990's, it didn't perform well so USGS started the HEC-RAS model from scratch. The model uses LIDAR data from Maryland and Pennsylvania, as well as recent bathymetry data (1996 and 2008 datasets). Ed is also using some flood insurance data to fill in where bathymetry data wasn't available (the alternative would have been assuming a trapezoidal channel). In some cases, this results in "mixed" data; however, these areas are primarily in areas where Ed doesn't expect much problems. Ed tried to use some supplemental data from Gomez and Sullivan; unfortunately, there were significant elevation discrepancies with other data, so the supplemental data was not used. The only remaining area with potential issues is the Washington Borough flats. The HEC-RAS model is expected to be operational in June 2012.

D. <u>MGS Data Collection</u> – Jeff Halka noted that the MGS survey crew hoped to be out sampling surficial sediments for grain sizes this week. The crew is squeezing it in between two other major jobs. Consequently, if they can't make it this week, there may be a delay in collecting the samples [<u>Update</u>: The MGS crew made it out on 2 May and Jeff began the lab work on 3 May]. Once the samples are collected, it will take about 4 weeks to complete the follow-on analyses.

E. <u>Exelon Activities</u> – Gary Lemay from Gomez and Sullivan (an Exelon contractor) brought the group up to date on some recent corrections to their sediment calculations presented at the January 2012 quarterly meeting. Specific numbers that were revised are bolded below:

(1) the accumulation of **3,434** acre-feet of sediment in Conowingo Pond between fall 2008 and fall 2011 surveys;
(2) the 3,434 acre-feet is equivalent to **5.07** million tons (using an assumed density of 67.8 pounds per cubic feet);
(3) the 3,434 acre-feet is equivalent to an average of **1.69** million tons of deposition per year; and

(4) assuming Conowingo Pond's steady-state volume is 142,000 acre-feet, there is approximately **21,800** acre-feet of remaining sediment capacity.

Gary showed a longitudinal profile of the Conowingo Pond and the difference in average depth between the 2008 and 2011 (post-Lee) surveys. The profile showed some slight scouring in the upper end of the reservoir, and significant deposition in the lower 3 miles. Gary's presentation also included a graph of time versus the remaining sediment capacity. This graph indicates that the Conowingo Pond is approaching a sediment volume equilibrium value, and is acting less effectively as a sediment trap. Currently, the reservoir is in a pattern of net deposition, with periodic sediment re-suspension occurring during high flows. As the reservoir fills, re-suspension may occur at a lower flow, theoretically. Gary and Marjie noted that while there is likely less sediment being trapped than the previously suggested "linear filling" hypothesis would predict, Conowingo Pond will continue to trap this reduced amount well into the future.

As a follow-on to the Exelon presentation, there was significant discussion among the meeting attendees about the meaning of the results. One attendee postulated that meeting the TMDL (total maximum daily load) targets will become more difficult. Another suggested that prior to this analysis, scientists thought that there was 10 to 15 more years before Conowingo reached this point, but it is becoming clearer that Conowingo's time as an effective sediment trap is running out. The agency group agreed that a statement on these findings and the repercussions, needs to be developed this summer to get out a consistent message to policymakers, the public, and media [**Action** = Herb and Bruce to draft preliminary statement]. Part of this effort will include some additional checking of storm flow and scour events. One suggestion was to make a presentation at the December 2012 Susquehanna River Basin Commission meeting.

6. <u>Review of Schedule for 2012</u> – Claire provided a handout of the most recent schedule for the assessment, and reviewed the activities coming up in the next 3 to 4 months. Steve Scott noted that the 2D-3D comparison report will be combined with the SEDflume data report and should be completed by 1 June. Carl Cerco expects to finalize the CBEMP data report 2 weeks ahead of schedule by 15 May. Based on the meeting discussions and follow-up conversations, all other tasks are on schedule, as noted in the project schedule dated 16 April (enclosure 5).

7. <u>Wrap Up</u> – Claire will draft up notes for the group's review. Following this, the notes and presentations will be posted to the project website. The next meeting will be held August 7, 2012, 10-12:30, at MDE. Bob Hirsch from USGS has been invited to make a presentation. The next modeling conference call will be on June 7, 2012, starting at 2:00 pm (EDT, 1:00 pm CDT).

Claire D. O'Neill, P.E.
Project Manager

Enclosures:
1. Meeting Agenda
2. Steve Scott Presentation
3. Mike Langland/Ed Koerkle Presentation
4. Gary Lemay Presentation
5. Project Schedule dated 16 April 2012

LOWER SUSQUEHANNA RIVER WATERSHED ASSESSMENT
QUARTERLY TEAM MEETING

MDE, Montgomery Park Building, Aqua Conference Room
April 30, 2012

Meeting Agenda

		Lead
10:00	Welcome and Opening Remarks	Sachs
10:05	Introductions	All
10:10	Review of Action Items from January Meeting	O'Neill
10:20	Communication and Coordination	
	USACE Agency Coordination Letters	O'Neill/Bierly
	PowerPoint Presentation – Feedback from Recent Meetings	All
	Project Website Update	Michael
10:30	LSRWA Technical Analyses	
(10 min)	CBEMP Modeling Update	Cerco
(5 min)	Data Report – Major Comments?	All
(30 min)	Sediment Transport Modeling Update	Scott
(20 min)	HEC-RAS Modeling Update	Langland/Koerkle
(5 min)	MGS Data Collection	Halka
(5 min)	Exelon Activities	LeMay
11:45	Review of Schedule for 2012	O'Neill
11:55	Wrap Up	O'Neill
	Action Items/Summary	
	Next Meeting	

Call-In Information: (410) 537- 4281 (no password required)

Expected Attendees:

MDE: Herb Sachs; Tim Fox, Adam Rettig
MDNR: Bruce Michael, Shawn Seaman
MGS: Jeff Halka
SRBC: John Balay, David Ladd, Andrew Gavin
USACE: Bob Blama, Carey Nagoda, Chris Spaur, Claire O'Neill, Dan Bierly
ERDC: Carl Cerco, Steve Scott
TNC: Mary Bryer, Kathy Boomer
USEPA: Gary Shenk
USGS: Mike Langland, Ed Koerkle

Exelon: Gary LeMay, Robert Matty
Lower Susquehanna Riverkeeper: Michael Helfrich
PA Agencies: Patricia Buckley, Raymond Zomok

MEMORANDUM FOR THE RECORD

SUBJECT: Lower Susquehanna River Watershed Assessment
Quarterly Team Meeting, 7 August 2012

1. On 7 August 2012, agency team members met to discuss ongoing and completed activities for the Lower Susquehanna River Watershed Assessment (LSRWA). The meeting was hosted by the Maryland Department of the Environment (MDE) in their Terra Conference Room at the Montgomery Park Building in Baltimore, Maryland. The meeting started at 10:30 am and continued through 1:00 pm. The meeting attendees are listed in the table below.

2.

Team Meeting Sign-In Sheet			
07 August 2012			
Agency	**Name**	**Email Address**	**Phone**
Exelon -- Gomez and Sullivan	Gary Lemay	glemay@gomezandsullivan.com	603-428-4960
Exelon -- URS Corp.	Marjorie Zeff	marjorie.zeff@urs.com	215-367-2549
Lower Susquehanna Riverkeeper	Michael Helfrich	LowSusRiver@hotmail.com	717-779-7915
MDE	Herb Sachs	hsachs@mde.state.md.us	410-537-4499
MDE	John Smith	jsmith@mde.state.md.us	410-537-4109
MDE	Matt Rowe	mrowe@mde.state.md.us	410-537-3578
MDE	Tim Fox	tfox@mde.state.md.us	410-537-3958
MDNR	Bruce Michael	bmichael@dnr.state.md.us	410-260-8627
MGS	Jeff Halka	jhalka@dnr.state.md.us	410-554-5503
SRBC	David Ladd	dladd@srbc.net	717-238-0425x204
SRBC	John Balay	jbalay@srbc.net	717-238-0423 x217
TNC	Kathy Boomer	kboomer@tnc.org	
TNC	Mark Bryer	mbryer@tnc.org	301-897-8570
USACE	Andrea Takash	andrea.m.takash@usace.army.mil	410-962-2626
USACE	Anna Compton	anna.m.compton@usace.army.mil	410-962-4633
USACE	Tom Lazco	thomas.d.lazco@usace.army.mil	410-962-6773
USACE	Chris Spaur	christopher.c.spaur@usace.army.mil	410-962-6134
USACE	Claire O'Neill	claire.d.o'neill@usace.army.mil	410-962-0876
USGS	Bob Hirsch	rhirsch@usgs.gov	703-648-5888
USGS	Mike Langland	langland@usgs.gov	717-730-6953
MDE	Maria Schuler	mschuler@mde.state.md.us	410-262-6160
Chesapeake Conservancy	Jeff Allenby	jallenby@chesapeakeconservancy.org	443-321-3160
USACE	Robert Pace	robert.s.pace@usace.army.mil	410-962-4900
Baltimore Sun	Tim Wheeler	tim.wheeler@baltsun.com	410-260-8002
The Conservation Fund	Bill Crouch	bcrouch@conservationfund.org	410-274-8427
DNR	Josh Davidsburg	jdavidsburg@dnr.state.md.us	410-260-8002
Exelon	Mary Helen Marsh	maryhelen.marsh@exeloncorp.com	610-765-5572
Exelon-Gomez and Sullivan	Tom Sullivan	tsullivan@gomezandsullivan.com	603-428-4960
Exelon	Kimberly Long	kimberly.long@exeloncorp.com	717-629-4198

In addition, a number of team members listened in via the conference line; those listening were:

Agency	Name	Email Address	Phone
PADEP	Patricia Buckley	pbuckley@pa.gov	717-772-1675
PADEP	Ted Tesler	thtesler@pa.gov	717-772-5621
SRBC	Andrew Gavin	agavin@srbc.net	717-238-0423x107
USACE-ERDC	Carl Cerco	carl.f.cerco@erdc.usace.army.mil	601-634-4207
USACE-ERDC	Steve Scott	steve.h.scott@usace.army.mil	601-634-2371
EPA	Lew Linker	LLinker@chesapeakebay.net	410-267-5714
NMFS	John Nichols	john.nichols@noaa.gov	410-267-5675

The meeting agenda is provided as enclosure 1 to this memorandum.

<u>Action Items</u> –

a. Anna will email out the draft mission statement to the team and the team will provide any further comments to the statement.
b. Anna will revise goals and objectives to state "three" vs. "four" hydroelectric dams to accurately reflect the study area of the assessment.
c. Mike will resolve issues with HEC-RAS modeling and will have a workable boundary condition file by the end of August.
d. Bruce will invite Harbor Rock to the September sediment management strategy brainstorming meeting.
e. Bob Hirsch will share draft press release on recent TS Lee study findings by USGS with selected agencies for review and input.
f. Claire will coordinate a sediment management strategy brainstorming meeting for September.
g. Claire will coordinate the next quarterly meeting for sometime in late October/early November.
h. Herb and Bruce to draft preliminary statement regarding Conowingo's time as an effective sediment trap running out to be reviewed by LSRWA team and posted to project website.

3. <u>Welcome and Opening Remarks</u> – After a brief introduction of the meeting attendees, Herb Sachs welcomed the LSRWA agency group. He noted that he would be retiring but would still be involved on the periphery as a volunteer, on an as-needed basis. Matt Rowe will now fill in as Herb's role on the LSRWA team. Herb discussed the recent interest in our study and a sense of urgency because of USGS findings coming out in regards to the Conowingo Dam filling sooner than expected. Herb explained that the governor of MD is up to speed on the latest findings and wants to make sure that the LSRWA moves forward.

4. <u>Review of Action Items from April 2012 Meeting</u> – For the first meeting discussion, the team reviewed the April 2012 action items as well as the ongoing action items.

Action Items from April Meeting:

A. Claire will discuss funding needs for FY13 with Herb.
Status-Ongoing; USACE does not know if federal funding for FY13 will be received for this study. The project is not in the President's budget that was released in February 2012. However, for this fiscal year, the study received funds from a general USACE pot of money, and it is hoped that the same action will happen in FY13. The allocation of these funds is determined by Headquarters USACE staff. These funding discussions will continue.

B. Mike will invite Bob Hirsch to attend August quarterly meeting to give presentation on his findings.-*Status-Complete; Bob attended the meeting and presented his findings.*

C. Herb and Bruce to draft preliminary statement regarding Conowingo's time as an effective sediment trap running out, with the intent that we have a consistent message to policymakers, the public, and media. *Status ongoing; Bruce and Herb needed further input from the team so this is an agenda item for today's meeting.*

<u>Ongoing Action Items from Previous Meetings:</u>

D. The MDE FTP website will be utilized to share internal draft documents within the team; Matt will be the point of contact for this FTP site.
Status – Ongoing; FTP is set up and any future draft documents will go through the MDE ftp website.

E. Shawn will notify team when most recent Exelon study reports are released. *Status – Recent report was sent out to team; ongoing action. Shawn was not in attendance so Tom let the group know that the Exelon application for the Conowingo dam license will be filed with FERC at the end of August and all required studies will be completed by the end of September with the exception of two fish studies.*

F. Anna will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups. *Status – Ongoing.*

G. Anna will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of updates from the quarterly meeting. *Status – Ongoing.*

H. Mark and Anna will coordinate to conduct a literature search providing info on best management practices around the nation and world for reservoir sedimentation. *Status – Ongoing; Anna and Mark will present findings at the next LSRWA meeting.*

I. Matt will keep team informed on innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies. *Status – Ongoing. One company, Harbor Rock has presented ideas for beneficial re-use of dredged material. Their concepts may be technically feasible, but the financing may be difficult. This is a group that could present to the LSRWA team.*

J. The team will send Bruce documents and links that should be posted on the LSRWA website. *Status – Ongoing*

5. Communication and Coordination –Since the last quarterly meeting, there have been no official presentations of the project PowerPoint slides. Michael noted that the slides are up on the Lower Susquehanna Riverkeeper website.

Project Website Update – Bruce noted that all presentations that have been presented to this group at quarterly meetings, meeting summaries and applicable website links have been uploaded to the project website. The USGS report on Tropical Storm Lee will not be uploaded to the website until it is finalized.

Mission Statement Review – Anna noted that the group had worked up specific goals and objectives for the study; however, there was an interest in working up a mission statement as well. This would be an over-arching statement to communicate the purpose of the study to the public. This statement would go on the project website. The team commented on the draft statement and the following is what was developed at the meeting:

"To comprehensively forecast and evaluate sediment and associated nutrient loads into and from the system of hydroelectric dams located on the Lower Susquehanna River above the Chesapeake Bay and consider structural and non-structural strategies to manage these loads to protect water quality and aquatic life in the Chesapeake Bay."

Determine the effects to the Chesapeake Bay due to the loss of sediment and nutrient storage behind the hydroelectric dams on the Lower Susquehanna River

The team will provide any further comments to the draft mission statement after the meeting in order to finalize the statement.

Jeff noted that the goals and objectives contained the statement "four hydroelectric dams" when it should be "three" due to the fact that the LSRWA modeling only encompasses three hydroelectric dams on the Susquehanna. Anna will make this change to the goals and objectives.

Herb noted that we needed to be clear on the expectations of this study. This study is evaluating options and presenting them, but it will not lead directly to construction to maintain Conowingo's sediment/nutrient trapping capacity which may disappoint some people. Efforts will need to occur after this study to implement any solution developed from this study along with additional resources. Herb noted that the TMDL goal is that sediment load allocations will be met by 2025. However these loads are based on Conowingo Dam still trapping a portion of the sediments entering the Bay, but we now know the Conowingo Reservoir will most likely not continue to trap sediments through 2025. Bruce noted that there is no one single agency or group that will have the ability to address this problem.

Review Plan – Anna noted that a review plan has been prepared by USACE for LSRWA to lay out the scope and level of review for the study. The draft report will need to undergo agency technical review (ATR) before it is released to the public for review. ATR involves review by USACE senior staff that are outside of the Baltimore District. USACE will be responsible for coordinating with the ATR team and consolidating responses to ATR comments; however, the whole LSRWA team will be responsible for working up responses to comments. ATR will occur on the draft document and public review comments. ATR will occur on the final document only if there are significant public comments. ATR is a cost-shared component of the study. The review plan is currently at USACE's division office for final approval but we do not anticipate any changes to the review plan. Anna will let everyone know when the review plan has been approved by USACE's North Atlantic Division.

6. <u>USGS Presentation on the Susquehanna River and the Impacts of Tropical Storm Lee</u> – Bob Hirsch from USGS presented to the group "Nitrogen, phosphorus, and suspended sediment fluxes from the Susquehanna River to the Bay in Tropical Storm (TS) Lee 2011– results and implications."

Bob Hirsch's presentation is provided as enclosure 2 to this memorandum.

Bob noted that the reservoirs initially had high trap efficiency. Eventually, steady state will occur (sediment output will equal input). What we see now is evidence that we are reaching a 100-percent full asymptote. Original prediction by Langland and Hanly in 1997 was that the reservoirs would be "full" in 17-20 years (all other things being equal). Once the reservoirs are full, it is predicted that we would see a total nitrogen (TN) flux increase of 2 percent; total phosphorus (TP) flux increase of 70 percent, and a suspended sediment (SS) flux increase of 250 percent.

Findings of this study were that TS Lee wasn't an unusual event even though it was a large rain event. Bob does not see any historical change in the frequency of high flow events but the behavior of the reservoir system has changed in response to these high flow events. There is a lower scour threshold as the reservoir fills up. Conowingo filling up is a current issue, not a future issue.

TN concentrations are continuing to decline at most discharges; however, at very high flows, they are showing some increase. Flow-normalized flux continues to fall (down about 16 percent since its high in 1987). Year to year variability in actual TN flux is increasing (standard deviation about double for 2002-2011 vs. 1978-2001). TS Lee TN flux was about 42,000 tons compared to the 2011 water year of 135,000 tons of TN, while the past decade average was 79,000 tons/year and the past 34-year average was 71,000 tons/year. TN flux change since 1996 was -3.2 percent.

Since 1996, TP increases were observed at high discharges for all seasons but particularly the tropical storm season. Small increases in TP at moderate discharges (April – July) were observed while small decreases were observed at moderate to low discharges other parts of the year. At the Marietta, PA gage, decreasing levels of TP were observed which can be correlated to management measures in the watershed. TP concentrations are relatively stable at moderate and low flows but at very high flows they have increased greatly in the past 15 years. Flux continues to rise and is becoming more and more episodic. These changes are almost certainly related to the decreasing capacity of Conowingo Reservoir. TS Lee flux for TP was about 10,600 tons. The 2011 water year flux for TP was 17,400 tons. The past decade average for TP was 4,800 tons/year. The past 34-year average was 3,300 tons/year.

For SS, little to no change in flux at most discharges and times of year. However large increases were observed for events above 100,000 cubic feet per second (cfs). SS was observed to be highest in Hurricane Ivan, TS Lee was second highest. TS Lee SS flux was estimated at about 19.0 million tons. The 2011 water year was 24.3 million tons for SS. The past decade average was 4.8 million tons.

The past 34-year average was 2.5 million tons. Flow-normalized flux is rising very steeply and variability is increasing.

Based on their findings the USGS hypothesis is that as the reservoirs fill, for any given discharge, there is less cross-sectional area, resulting in greater velocity. This leads to a decrease in the scour threshold (and thus, more frequent scouring) as well as leading to a decrease in the amount of deposition at lower discharges. The 1997 predictions (TN flux increase of 2 percent; TP flux increase of 70 percent, SS flux increase of 250 percent) in comparison to predictions with observed changes in flux since 1996 from this recent study are now, TN flux decrease of 3.2 percent, TP flux increase of 55 percent, and a SS flux increase of 97 percent.

The trapping of TP and SS by the reservoir system is decreasing. Scour is becoming more frequent and larger. There is an increasing role of high flow events for TN, TP, and SS inputs to the Bay. The "filling" of the reservoirs is asymptotic and stochastic. Findings are that the system is in transition to "full." Over the coming decades, the state of the reservoirs may be the main driver of TP and SS inputs to the Bay.

Bob noted that these findings are still considered draft. The final report will be released by USGS in the next few weeks. USGS will be putting out a news release when the report is published (the report will be posted electronically). They will decide who to include in the review process of this news release. They may want quotes from various agencies. They may also include a link to the LSRWA website and a statement about the study.

Lew mentioned that the decrease in TN could be related to the decreased amount of TN available from atmospheric deposition.

Bruce noted that SAV beds in the Bay weathered TS Lee better than TS Agnes, most likely because of the robustness of the existing bed now compared to when Agnes hit. Dissolved oxygen levels were good this year as well. DNR is evaluating the health of SAV in the Susquehanna flats to determine if there are any lingering effects from TS Lee.

Carl commented that he suspects that a lot of the nutrients going over from Conowingo aren't biologically available. We need to have more research to understand what percentage of the nutrients entering the bay from the reservoirs is biologically available.

7. <u>Coordinated Message based on USGS Presentation-Brainstorming</u> – There was discussion on drafting a statement regarding Conowingo's time as an effective sediment trap running out, based on USGS recent findings, with the intent that the LSRWA team has a consistent message to policymakers, the public, and media.

The following comments were offered in regards to messaging:

- The USGS study shows that the system is dynamic and complex.
- With these findings do we have a way to accelerate study? It appears we don't have the luxury of waiting?
- We need to understand the problem and should not jump to conclusions about what will happen if the Conowingo is no longer trapping sediments.

- We need to be cautious in how we communicate results as there could be impacts to the Bay TMDL.
- The USGS work shows the importance of the watershed assessment and we should not predict now what will happen to the Bay
- A lot is riding on this study efforts; we need to get it right.

Pat noted that any public message that Pennsylvania is a part of would need to go through their press office

Herb and Bruce agreed to draft a preliminary statement that would be reviewed by the LSRWA team. USGS is doing a formal news release; therefore, the LSRWA team statement would not be a news release, but instead would be posted on the LSRWA website and distributed via email to stakeholders.

Michael Helfrich asked about the trapping efficiency of the dam and if that would be determined based on new data. Mike Langland noted that we know the filling rate so we can show the remaining capacity and discuss in terms of the lack of capacity. We can assume that where trapping is going away, scouring is occurring.

8. LSRWA Technical Analyses – The various team members provided updates on their technical analyses.

MGS Data Collection – Jeff Halka noted that the crew made it out on 2 May to collect sediment samples in the Susquehanna flats. Analyses were completed and distributed to the group. Marji asked about sea-level rise evidence. Jeff noted that there is not a lot of historical grain-size and bathymetry data for the flats. Not much sand goes into the center. Water quality is good. If flats get deeper from storm scouring, we will see impacts to SAV.

HEC-RAS Modeling – USGS's Mike Langland shared the status of their HEC-RAS modeling work. The HEC-RAS model has three main components: (1) geometry, (2) hydraulics, and (3) sediment transport.

To account for geometry in the system, there were three options. The first option was to adapt the HEC-6 model constructed by USGS in the mid-1990's. This option was ruled out early because this model did not perform well. The second alternative was to convert the HEC-2 model to a HEC-RAS model. This option was ruled out because only 75 percent of the study area from Marietta to Conowingo had coverage, missing about half of Conowingo Reservoir to the dam. The third and selected option was to construct a new HEC-RAS model using LIDAR data from Maryland and Pennsylvania, as well as recent bathymetry data (1996 and 2008 datasets) and flood insurance data to fill in where bathymetry data wasn't available.

To account for hydraulics in the system, daily mean stream flows were pulled from four sites (Marietta, Conestoga, Pequea, and Conowingo) from 1996-2011. Gates were added for each of the reservoirs to help the flow simulation. Steady-state runs were made for annual mean flow, 300,000 cfs, 400,000 cfs, and 750,000 cfs. The model performed reasonably well at Safe Harbor and Conowingo, but there were problems at Holtwood. The simulations used pool elevations as boundary conditions. Unsteady state (varying stream flow) has been less successful due to the fact that Mike does not have daily operational data for the turbine and spillway gates. This data would need to be obtained from power companies to incorporate in the model.

To account for sediment transport, Mike performed a series of tasks: (1) computed daily sediment loads for the four sites which will serve as one of the boundary files; (2) compiled estimated daily temperature data (temperature effects sediment settling); (3) built bed composition files; (4) input shear stress and erosion rates of sediments from sedflume data) for each reservoir; and (5) constructed sediment distribution with changing loads. First model runs indicate low velocities and high sheer stress resulting from an overestimation of deposition.

Mike identified two issues for resolution – unsteady state flow modeling and overestimation of deposition. He will talk with Stan Gibson about the sediment simulations using quasi-steady state and gate operations. He anticipates having a workable boundary condition file to ERDC for the 2D ADH efforts by the end of August, and will continue work on documenting the model. He will have more detailed info at the next quarterly meeting.

CBEMP Modeling Update and Data Report – Carl is in a holding pattern right now for his efforts on the study. He has been working with EPA and they have determined four modeling runs that can be done with the CBP WSM model.

Sediment Transport Modeling – Steve Scott updated the agency LSWRA team on his sediment transport modeling using the PowerPoint presentation in enclosure 3.

Steve discussed his SedFlume field activities and data analysis, and provided preliminary sediment transport results with SedFlume data.

SedFlume is a portable laboratory flume that evaluates erosion rate and critical shear of cohesive sediments. Samples (sediment cores) were collected from eight locations in Conowingo Reservoir. The entire core was analyzed; erosion rate coefficients, exponents, and critical shear stress for erosion along with bulk density and particle size distribution, were determined.

Based on the results of the SedFlume data analysis, the sediment transport model domain was divided into areas using the change in sediment properties (average sediment size fractions) as determined by the collected data.

A preliminary sediment transport simulation was run to evaluate the 2008-2011 Susquehanna River flows (run included the period-of-record TS Lee event). Sediment inflows were estimated from previous HEC-6 modeling.

Steve simulated sediment load in and out of Conowingo Reservoir from 2008-2011 using assumptions on critical shear stress and erosion from the SedFlume analysis. His findings were that total sediments into reservoir during this time period were approximately 12 million tons, and sediments out of the reservoir were 16.6 million tons. Net scour was 4.6 million tons. Steve noted that scour occurred at >350,000 cfs flows and that his results of sediment transport parallel Bob Hirsch's results. When Conowingo is at capacity the dam will fill, scour, fill, scour.

Gary asked if Steve planned to compare the 2008-2011 data results to the 2011 bathymetry data that Exelon collected; Steve explained that this data was indeed included in the his analysis.

Exelon Activities – Claire noted that she sent out the Exelon Conowingo Pond Bathymetric Survey Analysis report for review to the LSRWA team for review and will consolidate comments to provide to Exelon.

Tom let the group know that the Exelon license application for Conowingo dam will be filed with FERC at the end of August and all required studies will be completed by the end of September with the exception of two fish studies.

Literature Search Update – Anna, Mark, and Kathy are working on the literature search. Findings will be presented at the next meeting in September which will be a brainstorming session to begin developing strategies to manage sediments in the Lower Susquehanna River watershed. Anna reminded the group that a draft outline of the report was distributed via email for comment. This outline will be discussed at the next quarterly meeting. The team needs to determine what sections will go in the report and leads for each section. There is no time in the schedule for report writing, only review of the report so we need to start writing now.

9. Wrap Up – Anna will draft up notes for the group's review. Following this, the notes and presentations will be posted to the project website. The next quarterly meeting date will be coordinated by Claire for sometime in late October/early November. The next modeling conference call will be on September 6th, starting at 2:00 pm (EDT, 1:00 pm CDT). Claire will coordinate a sediment management strategy brainstorming meeting for sometime in September.

Anna Compton,
Study Manager

Enclosures:
1. Meeting Agenda
2. Bob Hirsch Presentation
3. Steve Scott Presentation

LOWER SUSQUEHANNA RIVER WATERSHED ASSESSMENT
QUARTERLY TEAM MEETING

MDE, Montgomery Park Building, Aqua Conference Room
August 7, 2012

Meeting Agenda

Lead

10:00 Welcome and Opening Remarks .... Sachs

10:05 Introductions .... All

10:10 Review of Action Items from April Meeting .... O'Neill

10:20 Communication and Coordination
- PowerPoint Presentation – Feedback from Recent Meetings .... All
- Project Website Update .... Michael
- Mission Statement Review .... Compton
- USACE Review Plan .... Compton

10:30 USGS Presentation on the Susquehanna River and the Impacts of Tropical Storm Lee High Flow Events .... Bob Hirsch

11:15 Coordinated Message based on USGS Presentation – Brainstorming .... Michael/O'Neill
- What is Message?
- How Should Message Be Distributed?

11:30 LSRWA Technical Analyses
- (3-5 min) MGS Data Collection .... Halka
- (3-5 min) CBEMP Modeling Update .... Cerco
- (30 min) Sediment Transport Modeling Update – SEDFlume Presentation .... Scott
- (3-5 min) HEC-RAS Modeling Update .... Langland
- (5 min) Exelon Activities – Conowingo Relicensing Update .... LeMay/Seaman
- (3-5 min) Literature Search Update .... Compton

12:20 Review of Schedule for 2012 .... O'Neill
- Funding Priorities for Fall-Winter 2012 .... O'Neill
- Report Preparation .... Compton

12:40 Wrap Up .... O'Neill
- Action Items/Summary
- Next Meeting

Call-In Information: (410) 537- 4281 (no password required)

Expected Attendees:

MDE: Herb Sachs; Tim Fox, Matt Rowe, John Smith
MDNR: Bruce Michael, Shawn Seaman
MGS: Jeff Halka
SRBC: John Balay, David Ladd, Andrew Gavin
USACE: Chris Spaur, Claire O'Neill, Andrea Takash, Robert Pace, Tom Laczo
ERDC: Carl Cerco, Steve Scott
TNC: Mark Bryer, Kathy Boomer
USEPA: Gary Shenk
USGS: Mike Langland, Bob Hirsch

Exelon: Gary LeMay, Kimberly Long, Tom Sullivan, Marjorie Zeff
Lower Susquehanna Riverkeeper: Michael Helfrich
PA Agencies: Patricia Buckley, Raymond Zomok

Action Items from April Meeting:

A. Claire will discuss funding needs for FY13 with Herb.
B. Mike will invite Bob Hirsch to attend August quarterly meeting to give presentation on his findings.
C. Herb and Bruce to draft preliminary statement regarding Conowingo's time as an effective sediment trap running out, with the intent that we have a consistent message to policymakers, the public, and media.

Ongoing Action Items from Previous Meetings:

D. The MDE FTP website will be utilized to share internal draft documents within the team; Matt will be the point of contact for this FTP site.
   Status – Ongoing; sharing of future documents will go through the MDE ftp website.
E. Shawn will notify team when most recent Exelon study reports are released.
   Status – Recent report was sent out to team; ongoing action.
F. Anna will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups.
G. Anna will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of updates from the quarterly meeting.
H. Mark and Anna will coordinate to conduct a literature search providing info on best management practices around the nation and world for reservoir sedimentation.
I. Matt will keep team informed on innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies.

MEMORANDUM FOR THE RECORD

SUBJECT: Lower Susquehanna River Watershed Assessment
Brainstorming Meeting, 24 September 2012

1. On September 24, 2012 agency team members met to discuss and brainstorm ideas for potential sediment management strategies for the Lower Susquehanna River Watershed Assessment (LSRWA). The meeting was hosted by the Maryland Department of the Environment (MDE) at the Montgomery Park Building in Baltimore, Maryland. The meeting attendees are listed below.

2.

Team Meeting Sign-In Sheet			
24 September 2012			
Agency	**Name**	**Email Address**	**Phone**
Exelon -- URS Corp.	Marjorie Zeff	marjorie.zeff@urs.com	215-367-2549
Lower Susquehanna Riverkeeper	Michael Helfrich	LowSusRiver@hotmail.com	717-779-7915
MDE	Herb Sachs	sachsh@verizon.net	
MDE	John Smith	jsmith@mde.state.md.us	410-537-4109
MDE	Matt Rowe	mrowe@mde.state.md.us	410-537-3578
MDE	Tim Fox	tfox@mde.state.md.us	410-537-3958
MGS	Jeff Halka	jhalka@dnr.state.md.us	410-554-5503
SRBC	John Balay	jbalay@srbc.net	717-238-0423 x217
TNC	Kathy Boomer	kboomer@tnc.org	
USACE	Anna Compton	anna.m.compton@usace.army.mil	410-962-4633
USACE	Tom Lazco	thomas.d.lazco@usace.army.mil	410-962-6773
USACE	Chris Spaur	christopher.c.spaur@usace.army.mil	410-962-6134
USACE	Claire O'Neill	claire.d.o'neill@usace.army.mil	410-962-0876
USGS	Mike Langland	langland@usgs.gov	717-730-6953
Chesapeake Conservancy	Jeff Allenby	jallenby@chesapeakeconservancy.org	443-321-3160
The Conservation Fund	Bill Crouch	bcrouch@conservationfund.org	410-274-8427
Exelon	Mary Helen Marsh	maryhelen.marsh@exeloncorp.com	610-765-5572
Exelon	Kimberly Long	kimberly.long@exeloncorp.com	717-629-4198
USACE-ERDC	Carl Cerco	carl.f.cerco@erdc.usace.army.mil	601-634-4207
USACE-ERDC	Steve Scott	steve.h.scott@usace.army.mil	601-634-2371
NOAA-NMFS	John Nichols	john.nichols@noaa.gov	410-267-5675
PADEP	Patricia Buckley	pbuckley@pa.gov	717-772-1675
Gomez and Sullivan	Kirk Smith	ksmith@gomezandsullivan.com	
Pat Noonan	Conservation Fund	P.noonan@conservationfund.org	
Fran Flanigan	Consultant-MPA	frances.flanigan@verizon.net	
Jeff Otto	HarborRock	info@HarborRock.com	
Danielle Aloisio	USACE	danielle.m.aloisio@usace.army.mil	
Harry Kleiser	Terranear	Hkleiser@terranearpmc.com	
Lake Savers	John Tucci	jtucci@lake-savers.com	269-383-3400
Brinjac	Steve Zeller	szeller@brinjac.com	717-233-4502
Clean Flo	Brian Kling	bkling@clean-flo.com	1-800-328-6656
Loon Landing, LLC	Jeri Epstein	jepstein@loonlandingadvisors.com	202-467-4832

The meeting agenda is provided as enclosure 1 to this memorandum.

Action Items –

a. Matt Rowe will compare the results from the analysis of sediment cores taken from behind the Conowingo dam in 2006 to the decision framework criteria laid out in the 2007 IRC report to help the team better understand the suitability of the sediments in the lower Susquehanna river watershed for innovative reuse options.
b. Claire will compile questions from the group on floating islands, post-meeting and she will transmit to Brinjac Engineering to respond. [Note: Carl Cerco was the only one who sent questions in for Brinjac; those questions were forwarded to Steve Zeller on 25 September, and Steve responded directly back to Carl.]
c. Anna noted that the group needs to begin making decisions on what sediment management strategies we want to focus on for this effort. She will create a spreadsheet of compiled sediment management strategies so this group can begin evaluating and screening sediment management strategies in more detail at the next meeting.

3. Welcome – After a brief introduction of the meeting attendees, Claire O'Neill welcomed the LSRWA agency group and noted that the purpose of the meeting was to hear about potential sediment strategies that could be applied to the Lower Susquehanna River watershed and brainstorm ideas.

4. Results of Literature Search – Anna noted that a literature search was conducted on managing watershed/reservoir sedimentation. Findings and lessons learned from the literature will be incorporated into refining sediment/nutrient management strategies for the study. Anna noted that this search is considered "preliminary" due to the fact that as the study moves forwards certain strategies may warrant further research if there is an interest in evaluating the strategy in more detail.

   The Sediment Task Force (original group that convened in 1999-2001 to investigate this issue) findings were summarized. The task force primarily recommended sediment management strategies in the watershed (BMPs, etc.) however the group did recommend a dredging feasibility study to deal with the large amounts of sediments existing behind the dams on the Susquehanna. The sediment task force ruled out bypassing because this would result in a base load condition that exceeds the current base load into the Bay which is counter to the currently accepted goal of reducing sediment input to the Bay. The sediment task force also ruled out modifying dam operations because of potential impacts to the their primary purpose of hydropower and because it was unclear if modified operation could accomplish anything in the interest of sediment management other than as a form of bypassing.

   Anna noted that a database literature search was also done. In general, sediment management strategies fell into three categories: (1) reducing sediment yield from the watershed (reducing sediment inflow from upstream of reservoirs); (2) minimizing sediment deposition (routing sediments around or through storage); and (3) increasing or recovering volume (recover, increase or reallocate storage volume of reservoir.) Common factors that sediment management managers around the world look at when evaluating and implementing sediment management solutions are the goals, what is in the sediment, effectiveness of strategies, capital costs and maintenance costs, how to optimize sediment management strategies, environmental impacts, implementation sequence (short- and long-term solutions), benefits, and combining strategies to be successful.

The sediment management strategy of dredging has been implemented. However it is often seen a last resort, because dredging is expensive and often creates new social and environmental problems.

The technology to bypass and transport sediments has been developed and has many pros and cons, and there are a variety of methods available. Normally, an upper limit of sediment concentration (that would be bypassed) is defined by managers to account for ecological aspects (how much sediment can the receiving water body tolerate) and operational aspects (how much sediment can the bypassing system handle moving). Anna noted that we should keep the goals and objectives in mind to frame how we evaluate sediment management strategies and determine which ones we ultimately recommend.

The presentation of literature search findings is included as enclosure 2 to this memorandum.

5. Harbor Rock, Presentation and Q&A – Jeff Otto provided a presentation on a potential sediment management solution: innovative reuse of dredged material. Specifically dredging sediments from behind the dams on the lower Susquehanna River and converting the material to lightweight aggregate (LWA) to be sold commercially as construction material. After Jeff's presentation, there was much discussion and questions.

Jeff noted that during the processing of dredged material to LWA (firing in a kiln at high temperatures) the organic content of the sediment is vaporized while metal content remains bound to the aggregate (below amounts deemed harmful to the environment); therefore, the costs of disposal of unusable material is essentially zero. In the lower Susquehanna River, it is estimated that 3 million tons of sediment travel down the Susquehanna annually and their estimate is that this could be converted into 2.7 million tons of LWA (the difference would be organic material that is vaporized – a 10-perent loss). Costs are estimated to be $60-75 million a year which includes capital repayment. A facility to process the dredged material can vary in size based on the amount of material that managers want to process. Jeff noted that bigger is often better because regardless of the amount of material, you would need the same amount of operators working at the processing facility. A demonstration project at the Cox Creek dredged material containment facility (DMCF), has been up and running since 2007. It would take approximately 4-5 years to permit and build a Susquehanna sediment management facility. There was also discussion on the legal aspect of the government subsidizing a commercial operation and if this would be cause for concern.

The HarborRock presentation is included as enclosure 3 to this memorandum.

6. Brinjac Engineering, Biological Dredging and Floating Islands, Presentation and Q&A - Stephen Zeller provided a presentation on the concept of Biological Dredging to augment/optimize any dredging sediment management strategy that is implemented. This technology would

complement a dredging solution, if implemented. Once installed this system could provide impacts to the sediment in 9-15 months. The biological dredging system can be installed in approximately 6-9 months to begin impacting sediments through reduction and compaction. The cost estimate is a capital investment of about $18 million and annual operations and maintenance cost of $1.011 million. There is potential for nutrient credits of about $1 million which could assist in offsetting annual operations and maintenance and/or capital costs.

The concept involves a three-fold approach: floating and submerged coral islands, laminar-flow diffusers and bacterial augmentation. Total area impacted would be 2 square miles with diffusers and 1 square mile with diffusers and floating wetlands/coral. The biological dredging system (coral/diffusers/bacteria) would be anchored to the river bottom along with large floating islands placed on the surface near dredging operations and this system would biologically dredge the sediments to uptake nutrients and pollutants reducing and compacting organic sediments to reduce the release of these constituents into the water column. This system would thereby reduce the impacts of dredging, by acting as an in-situ water quality treatment system and provide a compaction and reduction to the sediment layer, before dredging, so that dredging is ultimately more efficient and cost-effective.

The islands utilize an artificial wetland matrix made of inert recycled plastic that supports/allows biofilm growth and this along with the diffusers would support the establishment of biofilm and periphyton growth which benefits aquatic life. This biological dredging system can effectively reduce sediment overflows by compacting the sediment layer and potentially reducing the organic sediment layer making sediments less likely to move during storm events (not withstanding extreme storm events like Hurricanes Lee and Sandy). The primary benefit of this technology is during non-storm flow periods and the reduction of the sediment layer pre-and-post storm events to reduce overall sediment movement to the Bay.

The islands would require regular harvesting and the diffusers would require annual maintenance along with annual bacteria dosing to stimulate periphyton growth all of which incurs an annual operations and maintenance cost. A heavily laden storm flow with silt in it would overwhelm this system as the entire river itself is laden with silt.

Carl had several questions in regards to what data is available on the floating island technology and its impacts on nutrients/sedimentation in the water column.

Discussion ensued on the size/amount of islands that would be required for the amount of sediments that could potentially be dredged from this large river system (6000 acres or 250 Million sq ft of wetlands coral and 12,500 ft^2 of Leviathan Floating Wetlands) for the Conowingo Dam is estimated.

Steve noted that the biggest concern is not the size of the river but the flow. High velocities could impact the anchors of the floating islands (hydraulic analysis for this component is included in the estimated capital costs). As far as potential areas where islands could be placed, it could be anywhere in the lower Susquehanna River system, not just behind Conowingo dam. The benefits of biological dredging also include restoration of major fisheries, reduced water treatment costs for major water utilities on the river by improving water quality, reducing pollutants in the river, reducing TSS/TDS and increasing DO in the water column.

Claire noted that due to time, anyone with specific questions on the floating islands should be sent to her and she will work up a list of questions to transmit to Brinjac Engineering.

The Brinjac Engineering presentation is too large to include as an enclosure to this memorandum, however, it is posted on the LSRWA website at the following location: http://mddnr.chesapeakebay.net/LSRWA/Docs/Brinjac%20presentation%20092412%20and%20more.pdf

Data on nutrient removal capabilities of this technology and engineering studies to support the efficacy of this technology are included in the Brinjac Engineering presentation. A factsheet with additional information is included as enclosure 4 to this memorandum.

Additionally, a published article on floating islands entitled, "The ability of vegetated floating islands to improve water quality in natural and constructed wetlands: a review" and can be found at the following location: www.iwaponline.com

7. Innovative Reuse Committee (IRC) Update - Fran Flanigan noted that she is a consultant for the MPA and facilitates the Innovative Reuse Committee (IRC) which is a group that meets to evaluate ways to innovatively reuse dredged material from the shipping channels in Chesapeake Bay. She noted that in 2001, the MD legislature enacted a law banning open water placement of dredged material after 2010. Any material from the Baltimore Harbor is considered "contaminated" and must be treated as such when dealing with disposal and use of dredged material. Approximately 500,000 cubic yards of material needs to be managed annually. MPA is required to have 20 years of placement lined up.

Fran noted that HarborRock is first in line for innovative reuse implementation to process dredged material. A demonstration project has been set up at Cox Creek DMCF (as discussed in Section 5.) No major technical issues have arisen yet. Toxin levels look good and a minor air quality permit would be required.

Fran noted that there is a report available, *Independent Technical Review Team (2009). Sediment in Baltimore Harbor: Quality and Suitability for Innovative Reuse. An Independent Technical Review*, which the IRC uses as a guide. This effort involved a national team of independent experts examining historical data for levels of metals and organic contamination in sediments that may be dredged from Baltimore Harbor shipping channels, including off-channel sites and harbor approach channels in the Chesapeake Bay. Summarizing this data helps authorities as they manage large amounts of sediment taken from these channels. This independent team evaluated the suitability of dredged sediments for innovative reuse to provide managers with a scientifically sound basis for determining potential innovative reuse options, the team assembled data and information to construct a frame for risk analysis and decision-making. The document has been uploaded to the LSRWA website located here:
http://mddnr.chesapeakebay.net/LSRWA/Docs/Dredge_ReportandAppendices_Print.pdf

There was discussion that the results from the analysis of sediment cores taken from behind the Conowingo dam in 2006 need to be compared to the decision framework criteria laid out by this

2007 IRC report. This way the suitability of the sediments in the lower Susquehanna River watershed for innovative reuse options could be better understood (i.e., do sediments behind dams meet beneficial reuse standards?). Matt Rowe said that he could do this comparison between the results of the two reports.

Discussion ensued on sediment management options that could be evaluated including agricultural applications and landfill cover. There was also consensus that the entire lower Susquehanna River watershed including areas further upstream need to be focused on when thinking about where and how to manage sediments. The group agreed that bypassing needs to be evaluated in more detail as well as island restoration in the Bay or island expansion within Conowingo Reservoir. Fran noted that MD legislation limits this concept to the restoration of historic islands not the creation of new islands. A diversified/combination approach for sediment management should be evaluated. Agitation dredging and tactical dredging were also mentioned as potentially viable strategies.

Anna noted that the group needs to begin making decisions on what sediment management strategies we want to focus on for this effort. She will create a spreadsheet of sediment management strategies compiled from the literature search and discussion today so that this group can begin evaluating and screening sediment management strategies in more detail at the next meeting.

8. Wrap Up – Anna will draft up notes for the group's review. Following this, the notes and presentations will be posted to the project website. The next quarterly meeting date will be coordinated by Claire for sometime in November.

Anna Compton,
Study Manager

Enclosures:
1. Meeting Agenda
2. Anna Compton Presentation
3. Jeff Otto Presentation
4. Brinjac Engineering- Biological Dredging Summary

LOWER SUSQUEHANNA RIVER WATERSHED ASSESSMENT
ALTERNATIVE BRAINSTORMING MEETING

MDE, Montgomery Park Building, Terra Conference Room
September 24, 2012

Meeting Agenda

		Lead
10:00	Welcome	O'Neill
10:05	Results of Literature Search	Compton/Bryer
10:20	Harbor Rock, Presentation and Q&A	Jeff Otto
10:50	Brinjack Engineering, Floating Islands, Presentation and Q&A	Stephen Zeller
11:20	Innovative Re-Use Committee Update	Flanigan/Blazer
11:30	Brainstorming	All
12:30	Next Steps	O'Neill
12:45	Wrap Up Action Items/Summary Next Meeting	O'Neill

Call-In Information: (410) 537- 4281 (no password required)

Expected Attendees:

MDE: Herb Sachs; Tim Fox, Matt Rowe, John Smith
MDNR: Bruce Michael, Shawn Seaman
MGS: Jeff Halka
SRBC: John Balay, Andrew Gavin
USACE: Chris Spaur, Claire O'Neill, Anna Compton, Tom Laczo, Dan Bierly, Danielle Aloisio
ERDC: Carl Cerco, Steve Scott
TNC: Mark Bryer, Kathy Boomer
USEPA:
USGS: Mike Langland

Exelon: Gary LeMay, Kimberly Long, Tom Sullivan, Marjorie Zeff
Lower Susquehanna Riverkeeper: Michael Helfrich
PA Agencies: Patricia Buckley
Alliance for the Chesapeake Bay: Fran Flanigan
MPA: Dave Blazer
Harbor Rock: Jeff Otto

MEMORANDUM FOR THE RECORD

SUBJECT: Lower Susquehanna River Watershed Assessment
Quarterly Meeting, November 19, 2012

1. On November 19, 2012 agency team members met to discuss ongoing and completed activities for the Lower Susquehanna River Watershed Assessment (LSRWA). The meeting was hosted by the Maryland Department of the Environment (MDE) in their Terra Conference Room at the Montgomery Park Building in Baltimore, Maryland. The meeting started at 10:00 am and continued through 1:00 pm. The meeting attendees are listed in the table below.

2.

Lower Susquehanna River Watershed Assessment Team Meeting Sign-In Sheet			
November 19, 2012			
Agency	**Name**	**Email Address**	**Phone**
Exelon -- Gomez and Sullivan	Gary Lemay	glemay@gomezandsullivan.com	603-428-4960
Exelon -- URS Corp.	Marjorie Zeff	marjorie.zeff@urs.com	215-367-2549
Lower Susquehanna Riverkeeper	Michael Helfrich	LowSusRiver@hotmail.com	717-779-7915
MDE	Herb Sachs	sachsh@verizon.net	
MDE	John Smith	jsmith@mde.state.md.us	410-537-4109
MDE	Matt Rowe	mrowe@mde.state.md.us	410-537-3578
MDE	Tim Fox	tfox@mde.state.md.us	410-537-3958
MDNR	Bruce Michael	bmichael@dnr.state.md.us	410-260-8627
MDNR	Shawn Seaman	sseaman@dnr.state.md.us	410-260-8662
MGS	Jeff Halka	jhalka@dnr.state.md.us	410-554-5503
SRBC	John Balay	jbalay@srbc.net	717-238-0423 x217
TNC	Kathy Boomer	kboomer@tnc.org	607-280-3720
USACE	Anna Compton	anna.m.compton@usace.army.mil	410-962-4633
USACE	Tom Lazco	thomas.d.lazco@usace.army.mil	410-962-6773
USACE	Chris Spaur	christopher.c.spaur@usace.army.mil	410-962-6134
USACE	Claire O'Neill	claire.d.o'neill@usace.army.mil	410-962-0876
USACE	Ashley Williams	ashley.a.williams@usace.army.mil	410-962-6139
USACE-ERDC	Carl Cerco	carl.f.cerco@erdc.usace.army.mil	601-634-4207
USACE-ERDC	Steve Scott	steve.h.scott@usace.army.mil	601-634-2371
USGS	Mike Langland	langland@usgs.gov	717-730-6953
The Conservation Fund	Bill Crouch	bcrouch@conservationfund.org	410-274-8427
DNR	Bob Sadzinksi	bsadzinski@dnr.state.md.us	
Exelon	Mary Helen Marsh	maryhelen.marsh@exeloncorp.com	610-765-5572
Exelon-Gomez and Sullivan	Tom Sullivan	tsullivan@gomezandsullivan.com	603-428-4960
USACE-ERDC	Carl Cerco	carl.f.cerco@erdc.usace.army.mil	601-634-4207
USACE-ERDC	Steve Scott	steve.h.scott@usace.army.mil	601-634-2371
NOAA-NMFS	John Nichols	john.nichols@noaa.gov	410-267-5675
PADEP	Patricia Buckley	pbuckley@pa.gov	717-772-1675
EPA, Chesapeake Bay Program	Lew Linker	llinker@chesapeakebay.net	
NMFS	John Nichols	john.nichols@noaa.gov	410-267-5675
Chesapeake Bay Commission	Bevin Buchheister	bevinb@chesbay.us	410-730-9030

The meeting agenda is provided as enclosure 1 to this memorandum.

Action Items from August Quarterly Meeting:

A. Anna will email out the draft mission statement to the team and the team will provide any further comments to the statement. *Status: Complete.*

B. Anna will revise goals and objectives to state “three” vs. “four” hydroelectric dams to accurately reflect the study area of the assessment. *Status: Complete.*

C. Mike will resolve issues with HEC-RAS modeling and will have a workable boundary condition file by the end of August. *Status: Complete. Mike gave a presentation with results at today’s meeting which is included as Enclosure 2 to this memorandum.*

D. Bruce will invite Harbor Rock to the September sediment management strategy brainstorming meeting. *Status: Complete.*

E. Bob Hirsch will share draft press release on recent TS Lee study findings by USGS with selected agencies for review and input. *Status: Complete. Press release was published in September 2012.*

F. Claire will coordinate a sediment management strategy brainstorming meeting for September. *Status: Complete. Brainstorm meeting was held on September 24, 2012.*

G. Claire will coordinate the next quarterly meeting for sometime in late October/early November. *Status: Complete.*

H. Herb and Bruce to draft preliminary statement regarding Conowingo’s time as an effective sediment trap running out to be reviewed by LSRWA team and posted to project website. *Status: Complete. Statement located on project website: http://mddnr.chesapeakebay.net/LSRWA/agendas.cfm under the “News” header.*

Action Items from September (Brainstorming) Meeting:

A. Matt Rowe will compare the results from the analysis of sediment cores taken from behind the Conowingo dam in 2006 to the decision framework criteria laid out in the 2007 IRC report to help the team better understand the suitability of the sediments in the lower Susquehanna river watershed for innovative reuse options. *Status: Complete. Tim gave a presentation with results which is included as Enclosure 6 to this memorandum.*

B. Claire will compile questions from the group on floating islands, post-meeting and she will transmit to Brinjac Engineering to respond. *Status: Complete. Carl Cerco was the only one who sent questions in for Brinjac; those questions were forwarded to Steve Zeller on 25 September, and Steve responded directly back to Carl.*

C. Anna will create a spreadsheet of compiled sediment management strategies so this group can begin evaluating and screening sediment management strategies in more detail at the next meeting. *Status: Complete. Spreadsheet was distributed to all stakeholders via email and input was requested by November 29, 2012.*

Ongoing Action Items from Previous Meetings:

A. The MDE FTP website will be utilized to share internal draft documents within the team; Matt will be the point of contact for this FTP site. *Status: Ongoing. Sharing of future documents will go through the MDE ftp website.*

B. Shawn will notify team when most recent Exelon study reports are released. *Status: Ongoing.*

C. Anna will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups. *Status: Ongoing.*

D. Anna will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of updates from the quarterly meeting. *Status: Ongoing.*

E. Matt will keep team informed on innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies. *Status: Ongoing.*

Action Items –

a. Michael Helfrich will coordinate with MD, CBP and the MD county coalition to set up a meeting to present dam implications to TMDL to MD counties.
b. Mike Langland will let Claire know if his final report will be a stand- alone document or if it will be written collaboratively with Steve Scott to be included with the ADH modeling report.
c. Carl Cerco will have CBP WSM modeling runs of existing/baseline conditions completed by mid-December.
d. UMCES report entitled "Effect of Timing of Extreme Storms on Chesapeake Bay Submerged aquatic vegetation" will be saved on LSRWA website. *Status: Complete. Document saved here here:* http://mddnr.chesapeakebay.net/LSRWA/Docs/Wang%20and%20Linker.pdf

3. Welcome – After a brief introduction of the meeting attendees, Claire O'Neill welcomed the LSRWA agency group and noted that the purpose of the meeting was to provide updates on recent activities within the LSRWA. Herb noted that communication of what study activities to all stakeholders is very important especially as we enter the legislative session in January. The more progress and information we provide, the more we will be able to garner public/political support. Bruce added that our study along with Bay-wide TMDL and FERC relicensing of Conowingo dam has a lot of interest. The LSRWA website has proven to be an effective tool to keep the public informed. Many state and regional groups as well as well as the governor of Maryland wants to know what can be done to accelerate this study's efforts.

   There was discussion on local government outreach. Michael Helfrich noted that there are several MD counties forming a coalition with lawyers out of concern about the sediments behind the dams on the lower Susquehanna River and whether the efforts required by the Maryland counties under the Maryland County WIPs will be effective due to increased scouring and loads from the Susquehanna. Currently the law firm Funk and Bolton is proposing and accepting money from counties for a study to be conducted by this law firm on Bay TMDL.

Michael added that there has been concern raised by this coalition that MD has county WIPs while PA does not. Pat Buckley noted that PA has "WIP planning targets" in lieu of "county WIPs," Bruce added that for the 2017 CBP Mid Point Assessment of the Bay TMDL, the CBP Water Quality Goal Implementation Team (WQGIT) has recognized/prioritized Conowingo filling impacts as one of the top issues to be addressed by the 2017 Mid Point Assessment. Michael noted that he attended the Cecil County Commissioners' meeting and they requested to be educated on dam implications to TMDL and WIPs. Bruce noted that he, or other Maryland state agency representatives, could participate in a meeting with the counties. Michael will determine who from this Maryland county coalition should be contacted to coordinate a meeting and will let Bruce know. In addition to this, Michael will contact CBP to determine if CBP wishes to follow through on reaching out to the counties.

4. HEC-RAS Modeling Update – Mike Langland provided a presentation on building a HEC-RAS model to simulate sediment transport through the three lower Susquehanna River reservoirs. Mike's presentation is included as enclosure 2 to this memorandum.

   Mike noted that Conowingo Dam was constructed in 1929 and since then the Conowingo reservoir has been filling with sediment and has 10 to 15 percent storage capacity remaining. Overall sediment from the watershed has been decreasing (about 2/3 less).

   The objectives of his efforts were to construct, calibrate, and validate a 1-D sediment model for the entire Reservoir system (~33 miles). The goal is to simulate the loads in and out of reservoirs, show bed-form change, and particle size distribution. Ultimately the outputs of this modeling effort will produce input boundary condition files for Conowingo Reservoir for the USACE 2-D ADH model

   There are two models, one showing long-term depositional changes and one showing short-term scouring. The two models provide a range of uncertainty in the boundary condition files. Mike noted that there is more sand upstream and silts and clays are more prevalent closer to the dam for all three reservoirs. Also during TS Lee, scour occurred in all three reservoirs. Both models indicate that the upper two reservoirs still play a "role" in sediment transport. The estimated total sediment transport from the modeling was most likely underestimated but reasonable.

   Mike was trying to calibrate the scour model to TS Lee and the depositional model to Bob Hirsch's modeling/USGS estimator. There is still some fundamental things wrong with the predictions of the model. HEC-RAS is not simulating silts and clays well and it does not show interaction with the bed well. Overall, he couldn't get the model to deposit enough sediment generally, and couldn't get enough scour from TS Lee. Additionally, the HEC-RAS model is not sensitive to gate operations. More specifically:

   - 2008-2011 bathymetry data indicates both deposition and scour in the same cross section, however the model simulates only one occurrence;
   - silts and clay were modeled about two times lower (lack of deposition) than expected based on the literature values and the 2-D model, and could not adjust values;
   - the model only allows one critical shear stress (force of water acting on the channel sides and bed required to mobilize sediments), SEDFLUME data (collected earlier this year by ERDC) indicates wide variability (8x); and finally,

- the model shows that increasing the critical shear results in an increase in scour which is a contradictory effect.

The model is 99% built and Mike continues to work with the HEC group to work out bugs. Right now this is the product we have to work with.

Mike noted he is preparing the report (the presentation he gave is an overview of what report will include) and that he and Steve might prepare a joint report for their modeling efforts. He will let Claire know the format of the final report.

5. 2D ADH Modeling Update– Steve Scott provided a presentation on his 2D ADH modeling efforts. Recent tasks have focused on model validation to ensure that the model can adequately replicate sediment transport characteristics representative of the lower Susquehanna River system. Steve's presentation is included as enclosure 3 to this memorandum.

The validation criteria he used were USGS' studies on the Conowingo Reservoir (annual load and scour predictions); measured suspended sediment concentrations out of Conowingo; and trap efficiency calculations.

The simulations he ran to validate the model included (1) 2008 – 2011 simulation of flows through Conowingo Reservoir and (2) inflowing sediment concentrations provided by USGS (HEC-RAS) output. Two HEC-RAS simulations were run: (1) minimum scour load from upper two reservoirs and (2) maximum scour load from upper two reservoirs.

The USGS validation criteria included (1) an estimation of 3 – 4 million tons of scour for TS Lee (2) an estimation of 1.5 million tons of sediment deposited per year and (3) a trap efficiency range of 50 to 70%.

For the first simulation AdH results for sediment inflow /outflow predicted a total inflow of 22 million tons, 50 percent from TS Lee. The AdH results for sediment storage predicted a total of 1.5 million tons/year, deposition up to 3.7 years, scour at 3.5 million tons during the TS Lee event and deposition of 3 million tons. The AdH results for trap efficiency predicted a total of 60 percent trap efficiency during depositional flows. The AdH results for maximum critical shear stress was 1.4 million tons/year, deposition up to 3.7 year, scour 2 million tons (Lee Event), and deposition of 3.5 million tons.

For the second simulations AdH results for sediment inflow /outflow predicted a total inflow of 25 million tons, 50 percent from TS Lee. The AdH results for sediment storage predicted a total of 1.7 million tons/year; deposition up to 3.7 years; scour at 3.5 million tons during TS Lee event and deposition of 4 million tons. The AdH results predicted a total of 60 percent trap efficiency during depositional flows.

In conclusion, USGS predictions included scour: of 3.0 to 4.0 million tons, a deposition rate at 1.5 million tons per year while the AdH results identified a scour of 2.0 -3.5 million tons; deposition rate at 1.4 to 1.7 tons per year and a trap efficiency at approximately 60 percent.

Steve noted that the bottom line is that at this time, the 2D ADH model is up and running and is an accurate representation of the system. He noted that he has considered input loads that will be provided to him from Mike Langland's work (HEC-RAS); despite the bugs that Mike mentioned, simulations will provide an accurate representation of relative changes to the system.

6. CBEMP Modeling Update – Carl Cerco provided a presentation on the estimated effects of Conowingo infill on the current conditions in Chesapeake Bay utilizing the CBP Watershed Model (WSM). This effort is establishing existing conditions and future conditions to assist in answering the question of what will happen to Chesapeake Bay when reservoirs are full and no longer trapping solids? Carl noted that it is a very preliminary look and any results should be shared with discretion in that results are still very rough. Carl's presentation is included as enclosure 4 to this memorandum.

Carl found through his efforts that in general on any day, outflow volume, solids concentration, and solids load can be greater or less than inflow. On average, outflow exceeds inflow by 18 m^3/s; inflowing solids concentration exceeds outflow by 3.3 mg/L; and 711 tonnes/day (260,000 tonnes/year) solids are retained by Conowingo reservoir (Note that 1 tonne= 1 metric ton=1,000 kilograms= 2,204.6 pounds). The variation in outflow vs. inflow occurs at flows less than 3,000 m^3/s. At higher flows, the relationship is 1-to-1. Overall, the inflowing solids concentration is approximately 33 percent greater than the out-flowing concentration, meaning that the Conowingo Reservoir is still retaining solids. The inflowing solids load is approximately 20 percent larger than the out -flowing load. The difference between inflowing and out-flowing concentrations is unrelated to flow. At this stage of WSM calibration, scouring does not occur. Few scouring events (flow > 400,000 ft3/s) are expected during the model application period, in any event."

The basic assumptions that were used for scenarios run with the model include (1) no scouring occurs in the model (2) limited scouring during the application period (1991-2000 hydrology) is expected in any event; (3) the reservoir acting as a sink for solids (and nutrients in solid form); (4) the first approach to examining the effect of Conowingo infill is to eliminate it from the WSM system; and (5) the water quality model (WQM) receives loads directly from the Susquehanna River as it enters Conowingo.

Conditions that were used for this modeling run (future once Conowingo is no longer trapping solids) were: (1) ten years of hydrology, 1991-2000; (2)base conditions from the 2010 CBP progress run (land use, point sources, atmospheric loads etc.); (3) phase 5.3.2 Watershed Model (same phase of the WSM and same calibration status of the WQM as used for TMDL determination); and (4) Conowingo Reservoir eliminated (direct loads to Conowingo also eliminated).

Taking those assumptions and conditions into account Carl ran the model and examined the effects of key water quality constituents (SAV, DO, chlorophyll, light extinction) at four mainstem stations.

After running the model and analyzing results, Carl reported that CB1 (segment of Northern Bay just below Conowingo Dam) showed the greatest impact on chlorophyll (increases up to 4 to 5 μg/L during summer). CB2 showed a lot of fluctuations but, on first impression, little net change. Carl concluded that light limitation is the dominant factor here. CB3 and CB4 show less chlorophyll in spring, possibly indicating increased light limitation. Increases of approximately 0.5 μg/L characterize these stations in summer. In general, as you travel down the Bay the loads disperse and impacts to light decrease.

Carl noted that he observed decreases in bottom dissolved oxygen of 0.1-0.2 mg/L at CB2.2, CB3.3C and CB4.2C. Larger decreases occur in CB1.1, but this station in general, exhibited few DO problems. Station CB3 is by the Chesapeake Bay Bridge; this is currently the worst place for DO in the Bay. Any drop in DO at this location is a serious problem.

Increases in light attenuation are "flashy" reflecting loading events. Increases range over two orders of magnitude. Range is 10 m^{-1} in CB1 (uncommon) to 0.1 m^{-1} at CB4.2.

Results revealed that SAV at CB-1 in particular, showed a loss of 4 sq km or 7percent (losses are largely confined to this region) and system-wide the modeling predicted a loss of 5.7 sq km or 1percent.

Carl noted that the next steps for his modeling efforts are: (1) to conduct a complete examination of 2010 CBP Progress Run scenario (re-run with direct loads to Conowingo reservoir); (2) run TMDL scenario with Conowingo storage eliminated (i.e,. once WIPs are implemented how will this impact Conowingo infill and Chesapeake Bay); (3)to run results of the TMDL scenario through the CBP processor which examines water quality standards; (4) to perform one or two scenarios with a storm event during SAV growing season; and (5) time and resources permitting, to examine scour and deposition using ADH (bathymetry circa 1991 – 2000, present bathymetry, reservoir full).

There was discussion on the impacts of reservoir operations on loading. Lew Linker noted that WSM should show some scouring. The WSM has a "good to excellent" calibration of sediment over the entire range of observed loading from 1985 to 2005; achieving this is due to user-specified model parameters for both scour and deposition, and M, the erosion rate for scour. So on the few occasions when we do have very high flows, we see in the observed data and in the simulation that the TSS loads are higher at Conowingo than they are for all the inputs to the Conowingo Reservoir; this is evidence that scour is occurring in the simulation. Carl explained that indeed WSM is applied over the period 1985-2005. For this project, we are looking at 1991-2000 hydrology. During this shorter period, there is only one instance, of a few days duration, when flows are high enough to generate scour. Carl did not see evidence of scour during this 3 or 4 day event although scour may be present during high-flow intervals outside the 1991-2000 period. In summary, Carl did not see evidence of scour in the WSM loads during the 1991-2000 interval, nor was significant scour expected.

Michael Helfrich expressed concern over using 260,000 tons per year solids being retained by Conowingo. Is this too conservative? Carl noted that the CBP WSM has a crude representation of scour/deposition. Michael expressed concern that if we only have money for a few more model runs by CBP, they must be done using the 1.5 million tons per year of current sediment trapping. This figure does not need to be calculated in a model, it should be easily extrapolated from the bathymetric measurements. He respects the efforts to build models that represent reality so that we can input BMP's for evaluation, but he is concerned about limited funds being used to run models using figures that do not represent reality. He also raised concerns about this information being shared publicly, as misinformation of this type can easily be confused and misused by members of the public. Anna/Claire noted that any material posted on the website will have draft/preliminary clearly stated so that the public knows these are still working numbers. Also Carl's presentation will be an enclosure to this memorandum and won't be a stand-alone document distributed publicly.

Carl noted that CBP is revisiting Conowingo scour. Carl noted that the WSM is providing us a sense of magnitude and is an initial run. He will have more runs completed by mid-December.

There was discussion on the volatile suspended solids (organic/living or previously living solids) that the CBP WSM modeling run predicted. Carl noted that VSS are produced in the reservoir itself under low-flow conditions because of long water residence time facilitating this. We can assume that the quantity of VSS produced is reduced if there is no reservoir. With reduced residence time, there's less time to form VSS. Michael noted that the system will never really be full due to scouring so there will always be time for VSS to form.

7. Review of Modeling Scenarios – Claire O'Neill provided a modeling scenario handout to the group which is included as enclosure 5 to this memorandum. Claire noted that due to limited funds and time there has been much discussion on which modeling scenarios should be prioritized and run first, and how those scenarios would be run. This handout lays out team discussion on the various modeling input options and resolution. After reviewing the options, it was agreed that using the CBP WSM input would provide a big picture or macro view of the problem right now. This input can be done relatively simply and in a short timeframe. The primary focus of this work is to assess the sediment impacts on the upper Bay area. The four scenarios to run by Carl are as follows:

1. 2010 land uses with 1991-2000 flow values and 1991-2000 Conowingo capacity;
2. Watershed implementation plans (WIPs) in place with 1991-2000 flow values and 1991-2000 Conowingo capacity;
3. 2010 land uses with 1991-2000 flow values and Conowingo storage full; and
4. WIPs in place with 1991-2000 flow values and Conowingo storage full

For the purposes of evaluating the effectiveness of alternatives, the HEC-RAS/AdH input is required (i.e., micro view). The HEC-RAS/AdH input is focused on 2008-2011 flow values and current bathymetry so it is a more accurate representation of the existing conditions. Using this input will result in more detailed information about the geographic distribution of sediments as well as the impacts to the upper Bay area.

8. Sediment Core Composition – Tim Fox provided a presentation on Susquehanna River sediment and metals screening thresholds. Tim's presentation is included as enclosure 6 to this memorandum.

At the last LSRWA meeting there was discussion on the 2009 report. *Sediment in Baltimore Harbor: Quality and Suitability for Innovative Reuse. An Independent Technical Review.* This effort involved a national team of independent experts examining historical data for levels of metals and organic contamination in sediments that may be dredged from Baltimore Harbor shipping channels, including off-channel sites and harbor approach channels in the Chesapeake Bay. Summarizing this data helps the regional agencies as they manage large amounts of sediment taken from these channels. This independent team evaluated the suitability of dredged sediments for innovative reuse to provide managers with a scientifically sound basis for determining potential innovative reuse options. In this evaluation, the team assembled data and information to construct a framework for risk analysis and decision-making.

There was discussion at the last LSRWA meeting that the results from the analysis of sediment cores taken from behind the Conowingo dam in 2006 need to be compared to the decision framework criteria laid out by this 2009 IRC report. This way the suitability of the sediments in the lower Susquehanna River watershed for innovative reuse options could be better understood (i.e., do sediments behind dams meet beneficial reuse standards?).

Tim noted that MDE conducted a comparison between the results of the two reports. The assumptions they made were that they did not take depth into account and if any core exceeded a use threshold at any depth, then the site did not meet that use threshold (i.e., this analysis was very conservative).

MDE's analysis revealed that most metals in the sediment cores were below MD residential reuse thresholds which include uses such as upland reclamation and manufactured topsoil for landscaping. There were some instances where arsenic, chromium and cadmium were above MD residential reuse thresholds meaning that some of the sediments from behind Conowingo would not be acceptable for this kind of reuse. MDE's; findings were similar to the IRC (2009) report in that site specific assessments may be needed for sediment reuse potential and there could be some regulatory issues.

There was not much time for discussion results will be discussed further in future meetings.

9. <u>Strategy for Alternative Development-</u> Anna noted a spreadsheet of compiled sediment management strategies was developed so this group can begin evaluating and screening sediment management strategies in more detail at the next meeting. This spreadsheet is included as enclosure 7 to this memorandum.

This spreadsheet was distributed to all stakeholders via email and input was requested by November 29, 2012. The LSRWA team will use this document as a starting point to develop, evaluate, compare and screen sediment management strategies.

Once we know baseline conditions and future conditions if no action is taken, we can begin to screen strategies. Management strategies are organized into three categories: watershed (e.g. BMP's); routing sediments (e.g., by-passing/reservoir operations); and recovering volume (e.g., dredging).

The team will need to determine the viable options through a screening process; then the viable options will need to be modeled and compared. Collaboration on these strategies is critical. Strategies ultimately will have costs identified and recommendations for implementation as well as entities to implement. Currently, the strategies listed in this spreadsheet are very generic. It will take time to create more specific strategies.

There was discussion about by-passing during less critical times, such as during the winter. We know that Tropical Storm Agnes had big, negative impacts on SAV because the storm hit during the SAV growing season. However the 1996 winter event and the more recent Tropical Storm Lee event which were outside of the SAV growing season, did not appear to have the same negative impacts. Lew noted that the Bay TMDL water quality standards trump TMDL load requirements so even though loads added during the winter would contradict Bay TMDL they would positively impact water quality standards (in comparison to loads entering system during spring/summer). Bruce mentioned a report done by UMCES entitled *"Effect of Timing of Extreme Storms on Chesapeake Bay Submerged Aquatic Vegetation"* which discussed storm impacts on SAV. It is on the LSRWA website here: http://mddnr.chesapeakebay.net/LSRWA/Docs/Wang%20and%20Linker.pdf

Wrap Up – Anna will draft up notes for the group's review. Following this, the notes and presentations will be posted to the project website. The next quarterly meeting date will be February 11, 2013.

Anna Compton,
Study Manager

Enclosures:
1. Meeting Agenda
2. Mike Langland Presentation
3. Steve Scott Presentation
4. Carl Cerco Presentation
5. Modeling scenario summary
6. Tim Fox presentation
7. Sediment Management Strategy Spreadsheet

LOWER SUSQUEHANNA RIVER WATERSHED ASSESSMENT
QUARTERLY TEAM MEETING

MDE, Montgomery Park Building, Terra Conference Room
November 19, 2012

Meeting Agenda

		Lead
10:00	Welcome and Introductions	All
10:05	Review of Action Items from August/September Meetings	O'Neill
LSRWA Technical Analyses		
10:15	HEC-RAS Modeling Update	Langland
10:45	Sediment Transport Modeling Update	Scott
11:15	CBEMP Modeling Update	Cerco
12:15	Review of Modeling Scenarios	O'Neill
12:25	Sediment Core Comparison	Rowe
12:35	Strategy for Alternative Development	Compton
12:45	Communication and Coordination Updates	Compton
12:50	Review of Schedule/Budget for 2012-13	O'Neill
12:55	Wrap Up Action Items/Summary Next Meeting	O'Neill

Call-In Information: (410) 537- 4281 (no password required)

Expected Attendees:

MDE: Herb Sachs; Tim Fox, Matt Rowe, John Smith (phone)
MDNR: Bruce Michael, Shawn Seaman
MGS: Jeff Halka
SRBC: John Balay, Andrew Gavin
USACE: Anna Compton, Bob Blama, Chris Spaur, Claire O'Neill, Ashley Williams, Danielle Aloisio, Tom Laczo
ERDC: Carl Cerco, Steve Scott
TNC: Mark Bryer, Kathy Boomer
USEPA: Gary Shenk, Lewis Linker
USGS: Mike Langland

Exelon: Mary Helen Marsh, Kimberly Long, Bob Matty
Lower Susquehanna Riverkeeper: Michael Helfrich
PA Agencies: Patricia Buckley, Raymond Zomok

Action Items from August Meeting:

A. Anna will email out the draft mission statement to the team and the team will provide any further comments to the statement.
B. Anna will revise goals and objectives to state "three" vs. "four" hydroelectric dams to accurately reflect the study area of the assessment.
C. Mike will resolve issues with HEC-RAS modeling and will have a workable boundary condition file by the end of August.
D. Bruce will invite Harbor Rock to the September sediment management strategy brainstorming meeting.
E. Bob Hirsch will share draft press release on recent TS Lee study findings by USGS with selected agencies for review and input.
F. Claire will coordinate a sediment management strategy brainstorming meeting for September.
G. Claire will coordinate the next quarterly meeting for sometime in late October/early November.
H. Herb and Bruce to draft preliminary statement regarding Conowingo's time as an effective sediment trap running out to be reviewed by LSRWA team and posted to project website.

Action Items from September Meeting:

A. Matt Rowe will compare the results from the analysis of sediment cores taken from behind the Conowingo dam in 2006 to the decision framework criteria laid out in the 2007 IRC report to help the team better understand the suitability of the sediments in the lower Susquehanna river watershed for innovative reuse options.
B. Claire will compile questions from the group on floating islands, post-meeting and she will transmit to Brinjac Engineering to respond. [Note: Carl Cerco was the only one who sent questions in for Brinjac; those questions were forwarded to Steve Zeller on 25 September, and Steve responded directly back to Carl.]
C. Anna noted that the group needs to begin making decisions on what sediment management strategies we want to focus on for this effort. She will create a spreadsheet of compiled sediment management strategies so this group can begin evaluating and screening sediment management strategies in more detail at the next meeting.

Ongoing Action Items from Previous Meetings:

A. The MDE FTP website will be utilized to share internal draft documents within the team; Matt will be the point of contact for this FTP site.
   Status – Ongoing; sharing of future documents will go through the MDE ftp website.
B. Shawn will notify team when most recent Exelon study reports are released.
   Status – Recent report was sent out to team; ongoing action.
C. Anna will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups.
D. Anna will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of updates from the quarterly meeting.
E. Matt will keep team informed on innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies.

MEMORANDUM FOR THE RECORD

SUBJECT: Lower Susquehanna River Watershed Assessment
Quarterly Meeting, February 11, 2013

1. On February 11 2013 agency team members met to discuss ongoing and completed activities for the Lower Susquehanna River Watershed Assessment (LSRWA). The meeting was hosted by the Chesapeake Bay Program, in their Fish Shack, Conference Room in Annapolis, Maryland. The meeting started at 10:00 am and continued through 1:00 pm. The meeting attendees are listed in the table below.

2.

Lower Susquehanna River Watershed Assessment Team Meeting Sign-In Sheet			
February 11, 2013			
Agency	**Name**	**Email Address**	**Phone**
Baltimore City Res.Nat.Resources	Kelly Spencer	kspencer@baltimorecity.gov	410-795-6151
Chesapeake Bay Commission	Ann Swanson	aswanson@chesbay.us	410-263-3420
Chesapeake Bay Foundation	Beth McGee	bmcgee@cbf.org	443-482-2157
Chesapeake Conservancy	Jeff Allenby	jallenby@chesapeakeconservancy.org	443-321-3160
Chesapeake Research Consortium	Amanda Pruzinsky	apruzinsky@chesapeaskebay.net	410-267-5766
EPA, Chesapeake Bay Program	Gary Shenk	GShenk@chesapeakebay.net	410-267-5745
EPA, Chesapeake Bay Program	Lew Linker	llinker@chesapeakebay.net	410-267-5741
Exelon	Kimberly Long	kimberly.long@exeloncorp.com	610-756-5572
Exelon	Mary Helen Marsh	maryhelen.marsh@exeloncorp.com	610-765-5572
Exelon - Gomez and Sullivan	Gary Lemay	glemay@gomezandsullivan.com	603-428-4960
Exelon - URS Corp.	Marjorie Zeff	marjorie.zeff@urs.com	215-367-2549
Exelon-Gomez and Sullivan	Tom Sullivan	tsullivan@gomezandsullivan.com	603-428-4960
Lower Susquehanna Riverkeeper	Michael Helfrich	LowSusRiver@hotmail.com	717-779-7915
MDE	Herb Sachs	sachsh@verizon.net	
MDE	Matt Rowe	mrowe@mde.state.md.us	410-537-3578
MDE	Stacy Boyles	sboyles@mde.state.md.us	410-537-3583
MDE	Tim Fox	tfox@mde.state.md.us	410-537-3958
MDNR	Bob Sadzinksi	bsadzinski@dnr.state.md.us	
MDNR	Bruce Michael	bmichael@dnr.state.md.us	410-260-8627
MGS	Jeff Halka	jhalka@dnr.state.md.us	410-554-5503
NOAA-NMFS	John Nichols	john.nichols@noaa.gov	410-267-5675
PA DCNR	Ray Zomok	rzomok@pa.gov	
PADEP	Patricia Buckley	pbuckley@pa.gov	717-772-1675
PADEP	Ted Tesler	thtesler@pa.gov	717-772-5621
SRBC	Andrew Gavin	agavin@srbc.net	717-238-0423x107
SRBC	David Ladd	dladd@srbc.net	717-238-0425x204
SRBC	John Balay	jbalay@srbc.net	717-238-0423 x217
TNC	Kathy Boomer	kboomer@tnc.org	607-280-3720
TNC	Mark Bryer	mbryer@tnc.org	301-897-8570
UMCES	Bill Dennison	dennison@umces.edu	410-221-2004
USACE	Anna Compton	anna.m.compton@usace.army.mil	410-962-4633
USACE	Ashley Williams	ashley.a.williams@usace.army.mil	410-962-2809
USACE	Bob Blama	robert.n.blama@usace.army.mil	410-962-6068
USACE	Chris Spaur	christopher.c.spaur@usace.army.mil	410-962-6134
USACE	Claire O'Neill	claire.d.o'neill@usace.army.mil	410-962-0876
USACE	Danielle Aloisio	danielle.m.aloisio@usace.army.mil	410-962-6064
USACE	Joe DaVia	joespeh.davia@usace.army.mil	410-962-5691
USACE	Maria Franks	maria.m.franks@usace.army.mil	410-962-3140
USACE	Tom Lazco	thomas.d.lazco@usace.army.mil	410-962-6773
USACE-ERDC	Carl Cerco	carl.f.cerco@erdc.usace.army.mil	601-634-4207
USACE-ERDC	Steve Scott	steve.h.scott@usace.army.mil	601-634-2371
USGS	Mike Langland	langland@usgs.gov	717-730-6953

The meeting agenda is provided as enclosure 1 to this memorandum.

Status of Action Items from November Quarterly Meeting:

A. Michael Helfrich will coordinate with MD, Chesapeake Bay Program (CBP) and the MD county coalition to set up a meeting to present dam implications to total maximum daily loads (TMDL) to MD counties. *Status: Ongoing. Michael Helfrich coordinated this task with Bruce Michael; Bruce has reported LSRWA activities to multiple groups and counties over the last 6 weeks. His message to counties was to keep in perspective that they still need to do their work regarding sedimentation from the watershed (meeting TMDLs) while the issue of sediments and nutrients trapped behind the dams and how to manage them are still being dealt with. Bruce noted that Bob Summers, MDE Secretary, has made presentations to the MD legislative committees as well.*

B. Mike Langland will let Claire know if his final report will be a stand- alone document or if it will be written collaboratively with Steve Scott to be included with the ADH modeling report. *Status: Complete. There will be one report with results from both models; USACE will include the report as an appendix to the LSRWA report.*

C. Carl Cerco will have CBP WSM modeling runs of existing/baseline conditions completed by mid-December. *Status: Complete. The following scenarios have been run: (1) What is the system's current condition? (2) What is the system's condition if the WIPs are in full effect? and (3) What is the system's condition if a large scour event occurs?*

<u>Ongoing Action Items from Previous Meetings</u>:

A. The MDE FTP website will be utilized to share internal draft documents within the team; Matt will be the point of contact for this FTP site. *Status: Ongoing. Sharing of future documents will go through the MDE ftp website.*

B. Shawn will notify team when most recent Exelon study reports are released. *Status: Ongoing. Tom Sullivan, a contractor of Exelon noted that the Exelon has filed the license for Conowingo Dam with FERC.*

C. Anna will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups. *Status: Ongoing.*

D. Anna will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of updates from the quarterly meeting. *Status: Ongoing.*

E. Matt will keep team informed on innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies. *Status: Ongoing.*

<u>Action Items from this (February 11) Quarterly meeting</u> –

a. Claire will coordinate the next quarterly meeting for May.

b. Anna will send out the spreadsheet tracking all stakeholder coordination to the group. Anyone making a presentation on LSRWA should let her know so the spreadsheet can be kept up to date; if any specific comments/concerns are raised, this should be noted as well.

c. John Nichols will submit written comments on behalf of NMFS addressing his agency's concerns over sediment bypassing management strategy.

d. Danielle will add Blackwater Wildlife Refuge as a potential placement option to evaluate.

e. Bruce will work with Gary on potential "no-till" acres available in the watershed and evaluate impacts to sediment loads if all no-till acres were implemented in the watershed via modeling.

f. Carl will complete runs for the following scenarios: What happens when the reservoir fills? What happens when the reservoir fills and WIPs are in full effect? What is the system's condition if a large scour event occurs in spring, summer or fall? These are the final existing and future without project conditions scenarios.

g. Carl, Steve and Lewis will work together to determine where nutrients are scoured from in the reservoir (at what depths) and will conduct a sensitivity analysis looking at bioavailability of nutrients in various forms (species) by Berner activity class or other means).

h. Michael and Carl will have a follow-up phone call to discuss the estimated loads that Carl is using for his modeling efforts that will be entering the Bay once Conowingo is full and will report back to the group if these estimated loads will be revised at all.

i. Modeling efforts cannot predict impacts to SAV from physical burial by sediments. These impacts should be considered and described by other means, perhaps qualitatively, by the LSRWA agency group.

j. Matt will check in with MDE to see how sediment bypassing (for open water placement or allowing sediments to relocate to sediment-starved areas) would be permitted and the stance of his agency on permitting for such activities.

k. Pat will determine and report back to the group what the PA department of Environmental Protection (DEP) stance is on sediment criteria for landfills ("clean" vs. "waste"). More specifically, we have data from 2000, is this too old? If so, what are expectations of the agency regarding data to determine appropriateness of sediment at a landfill?

l. The concept of a permanent pipeline should be investigated further and examples around the country should be looked at by the LSRWA agency group.

m. Michael will forward info to Danielle on Funkhauser Quarry.

n. Michael will forward Danielle the questions he had about some of the reservoir sediment management options that were presented but could not be addressed at the meeting due to time limitations.

o. The LSRWA agency group needs to determine next steps for developing reservoir sediment management options.

p. John Balay will look further into agitation dredging (coupled with electric generation releases) of fine material; it is expected this would be done outside of ecologically critical time periods.

q. The LSRWA agency group should quantify any habitat restored or enhanced downstream in Bay or elsewhere (e.g. terrestrial) as a project benefit; considerations should be given on how to do this.

3. Welcome – After a brief introduction of the meeting attendees, Claire O'Neill welcomed the LSRWA agency group and noted that the purpose of the meeting was to provide updates on recent activities within the LSRWA.

4. Review of Modeling Scenarios and Schedule –

   Claire went over the modeling run scenarios. The focus of modeling up to this point has been to forecast existing/baseline conditions, as well as future-without-project conditions. Getting an understanding of the conditions of the system if no action is taken will be used to compare sediment management strategies developed by the group.

   Enclosure 2 provides a summary of modeling scenarios.

   The following scenarios have been run:

   - What is the system's current condition? (2010 land uses with 1991-2000 flow values and 1991-2000 Conowingo capacity);
   - What is the system's condition if the WIPs are in full effect? (Watershed implementation plans (WIPs) in place with 1991-2000 flow values and 1991-2000 Conowingo capacity); and
   - What is the system's condition if a large scour event occurs? WIPs in place with Jan 1996 scour event flow values and Conowingo storage full.

The following scenarios are projected to be completed by the end of February in time for a smaller team meeting in March:

- What happens when the reservoir fills? (2010 land uses with 1991-2000 flow values and Conowingo storage full)
- What happens when the reservoir fills and WIPs are in full effect? (WIPs in place with 1991-2000 flow values and Conowingo storage full)

- What is the system's condition if a large scour event occurs in spring, summer or fall? (WIPs in place with Jan 96 scour event flow values in spring summer and fall and Conowingo storage full.

These scenarios represent all of the existing/baseline conditions and future-without-project conditions that were planned for the LSRWA effort.

5. <u>CBEMP Modeling update</u>–

Carl Cerco provided a presentation on the estimated effects of scouring event on the Chesapeake Bay. Carl's presentation is included as enclosure 3 to this memorandum It is important to note that at this time all modeling results are considered Draft/Preliminary and may be revised in future runs.

Carl noted that his previous efforts involved running modeling scenarios that removed Conowingo from the system to understand what it would look like with all sediments flowing into the bay and no longer being trapped by Conowingo. With this latest simulation, Carl looked at what the system would look like (i.e., impacts on water quality) if there were a scouring event. More specifically, he took the system's current condition (Conowingo still trapping) with WIPs in place, using bathymetry from after the 1996 scour event.

His modeling predicted that after storm event nutrients continue to have effects on the Bay for years. Conversely, solids (not including nutrients they contain) from scour events are inert after deposition. Solids are materials like sand, silt, and clay. Although they are subject to some resuspension, once they are deposited on the bottom, the effect on mineral sediments (solids) on the Bay essentially cease. After deposition, biological processes transform particulate nutrients, and nutrients adsorbed to sediments into dissolved forms which diffuse into the overlying water and are bioavailable and affect Bay water quality. Nutrients take years to undergo burial to a depth where they are no longer an influence on surface waters. His modeling predicts that as the years go by, the impacts to water quality decrease after a scouring event. Carl explained that when comparing predicted changes to water quality it appears that a full dam (no longer trapping sediments and most sediments/nutrients going over dam) is WORSE than a storm-scouring event.

Draft/Preliminary Modeling predictions show that:

- Scour contributes substantial quantities of solids, nitrogen, and phosphorus relative to storm loads descending through the watershed.
- The effects of solids scoured during a winter storm pass quickly and are barely visible by the following summer.
- The effects of scoured nutrients persist for years due to deposition in bottom sediments and subsequent recycling. The effects diminish over time.
- Maximum summer-average effects of a winter scour event on TMDL conditions are ≈ 0.3 μg/L. Chlorophyll a, 0.05 mg/L Dissolved oxygen, 0.01 /m.
- A winter scour event has no computed impact on SAV (Effects such as burial or physical damage are not computable with Carl's model). These findings are consistent with studies of impacts of previous large-storm events obtained by CBP.

Carl described two potential patterns for the future. One is a filled reservoir in the absence of scour events. Deposition is minimized, and solids and nutrients flow continuously to the bay causing chronic environmental problems. A second pattern involves one or more scour events. The impact of the scour event diminishes with time. Scour events are self-mitigating. Scour from a subsequent storm is diminished following a major event which scours the reservoir and increases volume. However, the increased volume has little effect on solids retention during non-storm periods.

Upcoming modeling activities include 2D ADH runs by Steve Scott to predict loads from a full reservoir. These predicted loads will tell us about overflow from a filled reservoir and about scour of a filled reservoir. Concurrently, CBP has modified HSPF to produce storm scour consistent with the latest USGS estimates. Also, CBP has produced hydrodynamics and watershed model (WSM) runs that move the 1996 storm to different months (spring and summer). The following runs are planned in addition to a run with scour from the January 1996 storm: (1 no winter storm; (2) storm moved to June; and (3) storm moved to October.

Bill Dennison noted that Carl's findings resonate with his findings and observations. He asked if there have been any efforts to evaluate the legacy of nutrients coming across the dams and their impacts. There was discussion on particulate nitrogen and phosphorus. Carl noted that particulate nitrogen is all organic (labeled inert and slow refractory). If nutrients are scoured off the bottom of the reservoir, they are labeled as either refractory or inert; this is done empirically. If CBP has time, it would be beneficial to have a sensitivity analysis looking at assumed ratios of nutrients (refractory, labile, or inert). Bill Dennison asked if these assigned ratios could change over time as the reservoir fills. Lewis Linker noted that greater than 10-cm (centimeter) depth of sediment is assumed to be inert. We can extrapolate at what depth we scour and where. Carl noted that Steve Scott's 2D ADH modeling could give us this information by telling us at what depth sediments are scouring.

Michael Helfrich asked if Carl's model has been re-run using 1.5-2 million tons per year of current sediment trapping per the latest USGS and Exelon estimates (from 2008 and 2011 bathymetry surveys) vs. 260,000 tons per year that Carl presented last time. His concern was that we are underestimating water quality impacts. Carl noted that he has not adjusted his model using these higher loads estimated from bathymetry surveys. He and Michael will have a follow-up phone call to discuss this in more detail, so as to come to an understanding of the most appropriate loads to use for modeling purposes.

Carl noted that his modeling efforts predict impacts to water quality parameters; it cannot predict impacts to SAV from physical burial by sediments. He noted that these impacts should be considered and described but cannot be determined quantitatively.

6. <u>Conowingo and Hurricane Sandy Rapid Assessment</u> –

Bill Dennison provided a presentation entitled "Responding to Major Storm Impacts: Ecological Impacts of Hurricane Sandy on Chesapeake & Delmarva Coastal Bays". Bill's presentation is included as enclosure 4 to this memorandum.

Bill noted that the National Fish and Wildlife Foundation established a Hurricane Sandy Wildlife Response Fund, and that UMCES and MDNR partnered to conduct a rapid assessment of impacts of Sandy on the Chesapeake and Delmarva coastal bays. A report was developed and finalized; it can be found at the following link: http://www.mdcoastalbays.org/files/pdfs_pdf/HurricaneSandyAssessment-Final-1.pdf

A link to the report will also be provided on the LSRWA website. Bill noted that Hurricane Sandy (October 2012), unlike Tropical Storm Lee (September 2011), was essentially a non-event due to the position, duration and timing of the storm. There was less wind with Sandy so less storm surge. Sandy occurred later in the "eco-calendar," so there were less ecological impacts. During Hurricane Sandy, the intense precipitation was limited to the Maryland portion of the Susquehanna watershed, while nearly the entire Susquehanna watershed experienced high levels of rainfall during the Lee event. As a result, the sediment plume from Lee was quite extensive; with Sandy, this was not the case. The Sandy plume appears to have been restricted to the mainstem of Chesapeake Bay (based on photographs and collected data) versus extending into tributaries. Bill noted that in light of this evidence, the opinion of UMCES is that counties still need to do their work with TMDLs and reduce the sediment impacts from the watershed to the tributaries. Bill noted that the timing of storm impacts affects phosphorus deposits downstream of dams; phosphorus is released back into the system, thus impacting water quality. Also, in light of the USGS report (Hirsch report) which indicates that the dam is getting closer to filling, there will be higher suspended sediment input and new scour thresholds for storm events. The Susquehanna flats act as a filter or trap. Sandy legacy sediments (including trapped fines and silts in the flats) were observed to be resuspended from subsequent wind events after Sandy. After Sandy, there were some observed barren areas in the SAV bed.

Bill observed that because of climate change, there will be more frequent and larger storm events. The LSRWA group should incorporate climate changes into its analysis of sediment management strategies. Bill also recommended that because of additional scouring from future storm events due to the Conowingo becoming full, the LSRWA group should investigate sediment bypassing and dredging options to maintain capacity of Conowingo Dam.

7. Update on Reservoir Sediment Management Scenarios –

Danielle Aloisio provided a presentation on USACE analysis of reservoir sediment management scenarios. Additionally, she provided a handout which lays out placement options for dredged material that were evaluated. Danielle's presentation is included as enclosure 5, and the handout is included as enclosure 6 to this memorandum.

Danielle explained that her team was the lead at looking specifically at "in-reservoir" sediment management strategies (versus watershed strategies). Recent activities included conducting an initial investigation to identify sediment removal and placement options for sediments behind the three dams on the lower Susquehanna River and providing recommendations based on this initial investigation.

She and her team conducted a desktop analysis of the study area (approximately a 100-mile radius); this analysis included calling potential placement site owners and conducting site visits. As far as dredging options, there are two options: (1) mechanical and (2) hydraulic. The pros of mechanical dredging are lessening the need for dewatering and the ability to access tight spots. The cons are double-handling of material which would incur extra costs. Once material is removed from behind the reservoirs, it would need to be placed somewhere. Options for placement include: (1) beneficial re-use (construction materials, island creation, fringe wetland creation, etc.); (2) open water (release downstream, pump downstream, ocean placement, etc.); and (3) upland placement (quarries, landfills, purchased land).

Pumping downstream or bypassing along with ocean water placement could have could have regulatory (i.e. permitting) issues. One option for island restoration is teardrop islands within the Susquehanna River and upper bay. Regarding placement sites, most places want the material dry. For the landfill placement option, Pennsylvania DEP has limits on what sediment can be placed in landfills. Sediment is either clean or waste based on certain criteria; if material is considered waste, there is special handling which adds more cost.

Fringe wetlands can accept non-sandy material (i.e., silts and clays) and sandy materials. If sandy materials were to be used containment would be minimal. If silts or clays were used then materials such as coir logs, hay bales, etc would need to be implemented as well to ensure the wetlands would be contained. IF the non-sandy materials were not contained they would erode away due to flow. .

Costs for removal and placement of sediment are based on the quantity of sediment you are looking to move and the distance you are looking to go for placement. Very rough costs for mechanical dredging with trucking is ($40 to $70/cubic yard (cy)); hydraulic pumping downstream, $6-$18/cy; hydraulic pumping up to 5 miles, $15-$25/cy; and tipping fee, $4-$35/cy.

Danielle noted that based on their preliminary findings, quarries appear to be the best option due to: (1) the fact that they can accept wet or dry material; (2) large quantities could be placed; and (3) there are several quarries nearby that can have material pumped in directly from Conowingo Reservoir. Landfills are still an acceptable option; however, they have many qualifiers including cost, transportation, quantity limitations, and environmental regulations. Island restoration has many environmental regulations that could add costs; transportation costs to purchased land could be high.

Before any of these concepts are implemented, the following would need to be considered: (1) more up-to-date chemical analysis; (2) state environmental standards that need to be met and approved; (3) grain size of the material; (4) accessibility and distance to placement sites; and (5) tipping fees.

Danielle noted there are several questions that need to be answered by the LSRWA agency group in order to further consider reservoir placement options:

- How much material is planned to be removed?
- How often will material be removed?
- When would removal begin?

The handout of "placement" options provides details on placement capacity, pumping distance, tipping fees and limitations. A pumping distance of 5 miles or less is considered "acceptable." Longer distances than that require electric boosters, etc, which would add costs.

There was discussion on the idea of a permanent pipeline. Is there data around the country about a permanent pipeline, safety, costs, etc? Mississippi has permanent pipelines that move sediments into river deltas; this should be investigated. *Some research after the meeting was done and there is a Louisiana state funded dredging project that is pumping sand long distance (22 miles) to Scofield Island, west of the Mississippi River's mouth, so the technology is there. The dredge pipe runs six miles upriver from the dredge before crossing the levee, cutting under two roadways and a small canal. The project is estimated to cost around 100 million dollars.*

Bob noted that there is no permanent pipeline anywhere in Chesapeake Bay. He estimated that you could move 2,000 cubic yards per day with a 16- top 18-inch pipe. Factors like the size of the pump, time of year restrictions and type of sediments you are pumping affect how much sediment you can remove. Dave Ladd asked about dredges and floating pipelines in the reservoir and where access would be? Bob explained that you could get a dredge in there and you could move it; however, the farther you go from placement site, the more costly these activities become.

There was discussion on Blackwater Wildlife Refuge as a potential placement site. Bill Dennison noted that Blackwater is really losing area and needs material. Bob said that there would be many issues to deal with (costs, regulatory, etc). Chris noted that while this would be expensive and challenging, it could provide great ecological benefits. Preliminary studies looking into this were conducted under the DMMP and Chesapeake Marshlands studies. However, it was agreed that Blackwater should be added to the list to be investigated. Bruce noted that there most likely will be multiple solutions, and the key will be finding partners to pay for options.

Michael asked about Funkhauser quarry as a potential placement site. Danielle noted that they could not find information on this quarry perhaps ownership has changed or they have the wrong address. Michael agreed to provide the contact information as a follow-up to the meeting.

8. Update on Reservoir Operational Strategies –

John Balay provided the group an update on reservoir operational strategies. More specifically, these are sediment management strategies that would alter the way the reservoirs are operated to manage sediment. For example, opening crest gates and sluicing sediment to allow it to flow past the dam could be one strategy. The handout John provided is included as enclosure 7 to this memorandum.

John's analysis focused only on Conowingo Dam. It also only focused on altering the operations of the dam, not the structure. He provided data on the existing operations and infrastructure of the dam. He noted that because of the various user groups (hydroelectric, nuclear, public water supply and recreational), the reservoir elevation is maintained within a specified range throughout the year so as not to conflict with minimum elevation requirements to meet the needs of these user groups. Maintaining the reservoir above these minimum elevations to meet user group needs is a constraint on altering the operations of the reservoir to management sediment.

The sediment task force (original group that met in 1999-2001) recommendations dropped modifying dam operations as an alternative noting that it would impact the primary purpose of electric generation and the potential benefits would be limited. Also there is limited hydraulic and storage capacity associated with the dam. There is no intermediate setting on the crest gates; they are either open or closed (using a gate will only impact a bit more than a 38-foot section of the channel, which is the gate width, but will use up to 4,000 cfs (cubic feet per second) of flow). You cannot use all the gates to pass sediment unless flows are extremely high. The bottom line is that there are very limited options for sediment management through altering the dam operations since it is a run-of-river facility at flows greater than 86,000 cfs. John concluded that they will look further into agitation dredging (coupled with electric generation releases) of fine material outside of ecologically critical time periods. Chris asked whether physical modification of the dam should be considered because we'd be seeking to have the dam do something it wasn't designed/constructed for.

There was discussion of the effects of passing sediments downstream. Michael Helfrich noted that bypassing in winter (i.e., non-ecologically critical months) would impact TMDL loads. Would bypassing be considered open water placement? Are dam releases considered releases of pollutants? Mark Bryer noted that we should quantify the habitat being provided downstream along with terrestrial benefits of land use. John Nichols said it was important to think about impacts to the already existing habitat such as the SAV beds, etc. We want to reduce impacts to existing habitat such as spawning fish habitat. John will provide written comments on today's proceedings about creating habitat downstream. He has migratory fish concerns. We want to restore and enhance spawning habitat in the upper bay. Chris Spaur noted that the status and trends of existing habitat should impact our decisions; at its simplest it's important to remember that the Bay is growing by hundreds of acres per year. As far as Chris knows, there is no trend information on shallow water habitat, but presumably it's increasing in area as Bay grows. Bill Dennison noted that impacts to SAV species are nuanced; freshwater species are resilient to temperature while saltwater species are not. SAV is doing well wetland marshes are not.

9. <u>Update on Watershed Sediment Management Strategies-</u>

Bruce Michael provided the group an update on watershed sediment management strategies. He provided a handout which compares best management practices (BMP) and efficiencies developed by CBP; this handout is included as enclosure 8 to this memorandum.

Bruce noted that when it comes to watershed sediment management strategies, the most cost-effective BMP according to CBP is "no till" agriculture. More emphasis should be placed on the counties doing this option. Chris Spaur asked if herbicide-resistant weeds had been considered at all in the analysis thus far; herbicide resistant pigweed is a growing problem in the southeast. . Bruce said they had not. Pat Buckley noted that the PA WIPs already rely heavily on agricultural BMPs. Bruce noted that what we are investigating BMPs for is to go above and beyond what states are doing with WIPs to meet TMDL. Exelon relicensing could add funding to implement agricultural BMPs in the watershed. There was discussion on how much acreage was available to implement no-till BMPs and with varying funding scenarios what amount of nutrient reduction that would get us (CBP modeling runs would need to be done to get an understanding of this).

10. <u>Budget Update and Wrap Up</u> –

Claire noted that there is no FY13 federal budget yet. USACE was able to reprogram some funding to the study and MD also provided some direct cash funds. At this time we have enough funds to get us through approximately April-May to complete modeling scenarios 1-5:

1. What is the system's current condition?
2. What is the system's condition if the WIPs are in full effect?
3. What happens when the reservoir fills?
4. What happens when the reservoir fills and WIPs are in full effect?
5. What is the system's condition if a large scour event occurs in spring, summer, or fall?

Anna will draft up notes for the group's review. Following this, the notes and presentations will be posted to the project website. Claire will set up a doodle poll to determine the date for next quarterly meeting which will sometime in May.

Anna Compton,
Study Manager

Enclosures:
1. Meeting Agenda
2. Modeling scenario summary
3. Carl Cerco Presentation
4. Bill Dennison Presentation
5. Danielle Aloisio Presentation
6. Lower Susquehanna Placement Options Handout
7. Update on Reservoir Operational Strategies Handout
8. Non-Point Source Best Management Practices and Efficiencies Handout

LOWER SUSQUEHANNA RIVER WATERSHED ASSESSMENT
QUARTERLY TEAM MEETING

CBP, Fish Shack, Annapolis/Eastport, Maryland
February 11, 2013

Meeting Agenda

		Lead
10:00	Welcome and Introductions	All
10:05	Review of Action Items from Prior Meetings Communication and Coordination Updates for Situational Awareness	O'Neill
LSRWA Technical Analyses		
10:15	Review of Modeling Scenarios and Schedule	O'Neill
10:20	CBEMP Modeling Update	Cerco
11:00	Conowingo and Hurricane Sandy Rapid Assessment	Dennison
11:15	Update on Reservoir Sediment Management Strategies	Aloisio
12:00	Update on Reservoir Operational Strategies	Balay
12:10	Update on Watershed Sediment Management Strategies	Rowe/Michael
12:20	Budget Update	O'Neill
12:25	Wrap Up Action Items/Summary Next Meeting	O'Neill

Call-In Information: (877) 336-139, access code = 6452843#, security code = 1234#

Expected Attendees:

MDE: Herb Sachs; Tim Fox, Matt Rowe, Stacy Boyles
MDNR: Bruce Michael, Bob Sadzinski
MGS: Jeff Halka
SRBC: John Balay, Andrew Gavin, Dave Ladd
USACE: Anna Compton, Bob Blama, Chris Spaur, Claire O'Neill, Ashley Williams, Danielle Aloisio, Tom Laczo, Dan Bierly
ERDC: Carl Cerco, Steve Scott
TNC: Mark Bryer, Kathy Boomer
USEPA: Gary Shenk, Lewis Linker
USGS: Mike Langland, Joel Blomquist

Exelon: Mary Helen Marsh, Kimberly Long, Bob Matty, Gary LeMay
Lower Susquehanna Riverkeeper: Michael Helfrich
PA Agencies: Patricia Buckley, Raymond Zomok

Action Items from November Quarterly Meeting:

A. Michael Helfrich will coordinate with MD, CBP and the MD county coalition to set up a meeting to present dam implications to TMDL to MD counties. *Status:*

B. Mike Langland will let Claire know if his final report will be a stand- alone document or if it will be written collaboratively with Steve Scott to be included with the ADH modeling report. *Status:*

C. Carl Cerco will have CBP WSM modeling runs of existing/baseline conditions completed by mid-December. *Status:*

D. UMCES report entitled *Effect of Timing of Extreme Storms on Chesapeake Bay Submerged Aquatic Vegetation* will be saved on LSRWA website. *Status: Complete.* Document saved at: http://mddnr.chesapeakebay.net/LSRWA/Docs/Wang%20and%20Linker.pdf

Ongoing Action Items from Previous Meetings:

A. The MDE FTP website will be utilized to share internal draft documents within the team; Matt will be the point of contact for this FTP site. *Status: Ongoing. Sharing of future documents will go through the MDE ftp website.*

B. Shawn will notify team when most recent Exelon study reports are released. *Status: Ongoing.*

C. Anna will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups. *Status: Ongoing.*

D. Anna will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of updates from the quarterly meeting. *Status: Ongoing.*

E. Matt will keep team informed on innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies. *Status: Ongoing.*

Action Items –

a. Michael Helfrich will coordinate with MD, CBP and the MD county coalition to set up a meeting to present dam implications to TMDL to MD counties.
b. Mike Langland will let Claire know if his final report will be a stand- alone document or if it will be written collaboratively with Steve Scott to be included with the ADH modeling report.
c. Carl Cerco will have CBP WSM modeling runs of existing/baseline conditions completed by mid-December.
d. UMCES report entitled "Effect of Timing of Extreme Storms on Chesapeake Bay Submerged aquatic vegetation" will be saved on LSRWA website. *Status: Complete. Document saved here here:* http://mddnr.chesapeakebay.net/LSRWA/Docs/Wang%20and%20Linker.pdf

MEMORANDUM FOR THE RECORD

SUBJECT: Lower Susquehanna River Watershed Assessment
Quarterly Meeting, May 13, 2013

1. On May 13, 2013 agency team members met to discuss ongoing and completed activities for the Lower Susquehanna River Watershed Assessment (LSRWA). The meeting was hosted by the Maryland Department of the Environment (MDE) in their Terra Conference Room at the Montgomery Park Building in Baltimore, Maryland. The meeting started at 10:00 am and continued through 1:00 pm. The meeting attendees are listed in the table below.

2.

Lower Susquehanna River Watershed Assessment Team Meeting Sign-In Sheet			
May 13, 2013			
Agency	**Name**	**Email Address**	**Phone**
American Geophysical Union	Harry Furukawa	hfurukawa@agu.org	202-777-7430
American Geophysical Union	Julia Galkiewicz	jgalkiewicz@agu.org	202-777-7488
City of Baltimore, DPW	Prakash Mistry	Prakash.Mistry@baltimorecity.gov	410-396-0732
City of Baltimore, DPW	Clark Howells	clark.howells@baltimorecity.gov	410-396-1586
City of Baltimore, DPW	James Price	James.Price@baltimorecity.gov	410-396-0539
Chesapeake Bay Commission	Manel Raub	mraub@chesbay.us	
Chesapeake Bay Foundation	Beth McGee	bmcgee@cbf.org	443-482-2157
Chesapeake Conservancy	Jeff Allenby	jallenby@chesapeakeconservancy.org	443-321-3160
EPA, Chesapeake Bay Program	Lew Linker	llinker@chesapeakebay.net	410-267-5741
Exelon	Anne Linder	anne.linder@exeloncorp.com	410-470-4540
Exelon	Kimberly Long	kimberly.long@exeloncorp.com	610-756-5572
Exelon	Mary Helen Marsh	maryhelen.marsh@exeloncorp.com	610-765-5572
Exelon - Gomez and Sullivan	Gary Lemay	glemay@gomezandsullivan.com	603-428-4960
Exelon - URS Corp.	Marjorie Zeff	marjorie.zeff@urs.com	215-367-2549
Exelon-Gomez and Sullivan	Tom Sullivan	tsullivan@gomezandsullivan.com	603-428-4960
Lower Susquehanna Riverkeeper	Michael Helfrich	LowSusRiver@hotmail.com	717-779-7915
MDE	Herb Sachs	sachsh@verizon.net	
MDE	John Smith	jsmith@mde.state.md.us	410-537-4109
MDE	Matt Rowe	mrowe@mde.state.md.us	410-537-3578
MDE	Tim Fox	tfox@mde.state.md.us	410-537-3958
MDNR	Bob Sadzinksi	bsadzinski@dnr.state.md.us	
MDNR	Bruce Michael	bmichael@dnr.state.md.us	410-260-8627
MGS	Jeff Halka	jhalka@dnr.state.md.us	410-554-5503
NOAA-NMFS	John Nichols	john.nichols@noaa.gov	410-267-5675
PADEP	Patricia Buckley	pbuckley@pa.gov	717-772-1675
PADEP	Ted Tesler	thtesler@pa.gov	717-772-5621
SRBC	Andrew Gavin	agavin@srbc.net	717-238-0423x107
SRBC	David Ladd	dladd@srbc.net	717-238-0425x204
SRBC	John Balay	jbalay@srbc.net	717-238-0423 x217
TNC	Kathy Boomer	kboomer@tnc.org	607-280-3720
TNC	Mark Bryer	mbryer@tnc.org	301-897-8570
USFWS	George Ruddy	george_ruddy@fws.gov	410-573-4528
USACE	Anna Compton	anna.m.compton@usace.army.mil	410-962-4633
USACE	Ashley Williams	ashley.a.williams@usace.army.mil	410-962-2809
USACE	Bob Blama	robert.n.blama@usace.army.mil	410-962-6068
USACE	Chris Spaur	christopher.c.spaur@usace.army.mil	410-962-6134
USACE	Claire O'Neill	claire.d.o'neill@usace.army.mil	410-962-0876
USACE	Tom Lazco	thomas.d.lazco@usace.army.mil	410-962-6773
USACE	Steve Elinsky	Steve.Elinsky@usace.army.mil	410-962-4503
USACE-ERDC	Carl Cerco	carl.f.cerco@erdc.usace.army.mil	601-634-4207
USACE-ERDC	Steve Scott	steve.h.scott@usace.army.mil	601-634-2371
USGS	Mike Langland	langland@usgs.gov	717-730-6953
Versar	Steve Schreiner		

The meeting agenda is provided as enclosure 1 to this memorandum.

Status of Action Items from February Quarterly Meeting:

a. Claire O'Neill will coordinate the next quarterly meeting for February. *Status: Done. Meeting occurring today.*

b. John Nichols will submit written comments on behalf of NMFS addressing his agency's concerns over sediment bypassing management strategy. *Status: Done. Anna Compton will distribute letter to group and have it posted on website. Bottom line of letter is that NMFS has substantial concerns about the impacts of any sediment bypassing or release options to shallow and open water habitats, including SAV and spawning grounds for fish. Chris Spaur noted that it is important to consider natural and anthropogenic status and trends of habitats and environmental conditions. Chesapeake Bay is naturally growing by hundreds of acres per year as a consequence of sea-level rise and shoreline erosion; this should be factored into considerations over impacts to shallow water and open water habitats.*

c. Danielle Aloisio will add Blackwater Wildlife Refuge as a potential placement option to evaluate. *Status: Done. See Enclosure 5.*

d. Carl Cerco will complete runs for the following scenarios: What happens when the reservoir fills? What happens when the reservoir fills and WIPs are in full effect? What is the system's condition if a large scour event occurs in spring, summer or fall? These are the final existing and future without project conditions scenarios. *Status: Complete. Carl presented this information at this meeting. See Enclosures 2 and 3 and discussion under #6.*

e. Michael Helfrich and Carl Cerco will have a follow-up phone call to discuss the estimated loads that Carl is using for his modeling efforts that will be entering the Bay once Conowingo is full and will report back to the group if these estimated loads will be revised at all. *Status: Complete. There is now agreement on estimated loads being used for modeling efforts.*

f. Matt Rowe will check in with MDE to see how sediment bypassing (for open water placement or allowing sediments to relocate to sediment-starved areas) would be permitted and the stance of his agency on permitting for such activities. *Status: Complete. Based on discussions with MDE permitting folks, they explained that if sediment bypassing were done as passive transport (e.g., via flushing, sluicing or agitation dredging instead of through a pipeline) a permit may not be required. If bypassing were actively transported via a pipeline or through a tunnel, then a permit would be required. To make any conclusive permitting decisions, more details would be required. For planning purposes for this an Assessment, we can use the assumptions laid out by MDE permitting folks. A water quality certificate and perhaps tidal wetlands permit/authorization would be required for the placement site of the material if it ended up being used as fill in the water (island, wetlands, etc.). Chris Spaur noted that USACE does not require permit for water releases from its reservoirs done as part of normal operation/maintenance activities.*

g. Pat Buckley will determine and report back to the group what the PA Department of Environmental Protection (DEP) stance is on sediment criteria for landfills ("clean" vs. "waste"). More specifically, we have data from 2000, is this too old? If so, what are expectations of the agency regarding data to determine appropriateness of sediment at a landfill? *Status: Complete. Pat provided a point of contact (Steve Socash) within PA DEP. The bottom line is that sediments from a river the size of Susquehanna can be considered, "clean" or "regulated" fill or "other waste." Per PA DEP's management of fill policy, they generally do not require chemical analysis of soils/sediments where there has not been evidence of a spill or release (i.e., these sediments could then be used in an unrestricted manner as clean fill). However, with large rivers like the Susquehanna, this would qualify as being subject to a spill or release, requiring chemical analysis to determine if clean fill requirements had been met. The 2000 sediment sampling data (averages) were compared to the concentration limits that PA DEP uses for clean fill standards: The sampled sediments meet clean fill limits for all organics and inorganics. A few parameters were not tested for in 2000 that PA DEP requires. For planning purposes, we can assume that the sediments behind the dams can be considered "clean fill" appropriate for landfill placement; however, sampling would most likely be required in the future if this option were to be implemented.*

h. The concept of a permanent pipeline should be investigated further and examples around the country should be looked at by the LSRWA agency group. *Status: Complete. Permanent pipelines are included in the LSRWA analysis. No permanent pipelines exist in Chesapeake Bay but there are examples in places like Louisiana.*

i. Michael Helfrich will forward info to Danielle Aloisio on Funkhauser Quarry. *Status: Ongoing. Bob Blama is now taking over for Danielle. Funkhauser Quarry is not on the placement option list yet. Resolution is for Bob to call the quarry.*

j. Michael Helfrich will forward Danielle Aloisio the questions he had about some of the reservoir sediment management options that were presented but could not be addressed at the meeting due to time limitations. *Status Complete.*

k. John Balay will look further into agitation dredging (coupled with electric generation releases) of fine material; it is expected this would be done outside of ecologically critical time periods. *Status Complete. See Enclosure 9 and Discussion #9.*

<u>Ongoing Action Items from Previous Meetings</u>:

A. The MDE FTP website will be utilized to share internal draft documents within the team; Matt will be the point of contact for this FTP site. *Status: Ongoing. Sharing of future documents will go through the MDE ftp website.*

B. Shawn will notify team when most recent Exelon study reports are released. *Status: Ongoing. Tom Sullivan, a contractor of Exelon noted that the Exelon has filed the license for Conowingo Dam with FERC.*

C. Anna will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups. *Status: Ongoing.*

D. Anna will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of updates from the quarterly meeting. *Status: Ongoing.*

E. Matt will keep team informed on innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies. *Status: Ongoing.*

F. Anna will send out the spreadsheet tracking all stakeholder coordination to the group. Anyone making a presentation on LSRWA should let her know so the spreadsheet can be kept up to date; if any specific comments/concerns are raised, this should be noted as well. *Status: Ongoing*

G. Bruce Michael will work with CBP on potential "no-till" acres available in the watershed and evaluate impacts to sediment loads if all no-till acres were implemented in the watershed via modeling as well as develop costs. *Status: Ongoing. See discussion under #10.*

H. Carl Cerco, Steve Scott and Lewis Linker will work together to determine where nutrients are scoured from in the reservoir (at what depths) and will conduct a sensitivity analysis looking at bioavailability of nutrients in various forms (species) by Berner activity class or other means). *Status: Ongoing.*

I. Modeling efforts cannot predict impacts to SAV from physical burial by sediments. These impacts should be considered and described by other means, perhaps qualitatively, by the LSRWA agency group. *Status: Ongoing. Bruce Michael has provided the UMCES (Mike Kemp) SAV historical mapping and trends over last 10 years in Susquehanna Flats. This information will need to be incorporated into to the assessment to provide a qualitative discussion of impacts.*

J. The LSRWA agency group needs to determine next steps for developing reservoir sediment management options. *Status: Ongoing.*

K. The LSRWA agency group should quantify any habitat restored or enhanced downstream in the Bay or elsewhere (e.g., terrestrial) as a project benefit; considerations should be given on how to do this. *Status: Ongoing.*

L. Bruce Michael and Claire O'Neill will keep the LSRWA agency group updated on the Susquehanna policy group put together by Governor O'Malley. *Status: Ongoing.*

<u>Action Items from this (May 13) Quarterly meeting</u> –

a. Claire will coordinate the next quarterly meeting for August 2013.

b. Anna will distribute NMFS agency letter discussing concerns over sediment bypassing management strategy to group and have it posted on website.

c. Bob Blama will call the Funkhauser Quarry to get more information on utilizing this as a placement option.

d. Michael Helfrich will touch base with Jeff Cornwell (UMCES) to get his opinion on phosphorus bioavailability in sediments as it relates to the LSRWA study.

f. The group will review the baseline and future conditions summary spreadsheet (Enclosure 3) and provide comments back to Anna Compton and Carl Cerco.

g. Lewis Linker and Carl Cerco will work with CBP partners to integrate the CBP's assessment procedure ("Stoplight plots") into the LSRWA key modeling scenarios to provide a means to communicate/explain impacts to Chesapeake Bay from the various full reservoir and storm scouring scenarios.

h. The LSRWA agency group will develop a screening process for reservoir sediment management options that are worth developing further.

i. The LSRWA agency group will direct any questions on sediment bypass tunneling to Kathy Boomer.

j. Kathy Boomer will write up a section on sediment bypass tunneling for the LSRWA report.

k. Exelon will review and provide comments on SRBC's write-up of altering reservoir operations as a sediment management strategy (Enclosure 9). Exelon will comment on the write-up to make sure dam operations are adequately covered.

3. Welcome – After a brief introduction of the meeting attendees, Claire O'Neill welcomed the LSRWA agency group and noted that the purpose of the meeting was to provide updates on recent activities within the LSRWA.

4. Funding Update – Claire O'Neill noted that there is no FY13 federal budget yet. The Office of Management and Budget (OMB) has not released funding yet. At this time we are still using non-federal money to keep the study moving. If we don't get expected funding, we cannot complete study on time.

5. Communication and Coordination Updates – Bruce Michael let the group know that Governor O'Malley put together a high-level Susquehanna policy group with various federal and non-federal agencies. The purpose of this non-technical group is to review sediment management scenarios provided by the LSRWA group and look at funding scenarios for implementation of these scenarios. Chris Spaur asked whether this would effectively constitute a parallel effort that we need to then incorporate consideration of in the LSRWA study. Bruce said that would not be the case; the policy group would utilize what we produce.

6. Summary of Existing and Future Conditions – Carl Cerco provided a presentation on the estimated effects of scouring event on the Chesapeake Bay. Carl's presentation is included as enclosure 2 to this memorandum. It is important to note that at this time all modeling results are considered draft/preliminary and may be revised in future runs. These scenarios represent the final runs to complete all of the existing/baseline conditions and future-without-project conditions that were planned for the LSRWA effort.

The following conditions were presented:

(1) What happens when the reservoir fills?
(2) What happens when the reservoir fills and WIPs are in full effect?
(3) What is the system's condition if a large scour event occurs in spring, summer, or fall?

Utilizing ADH loads (computes sediment erosion, deposition, and transport in Conowingo Reservoir) from the application period of 2008–2011, there were two erosion (scouring) events: Tropical Storm Lee and a small event in March 2011. There are three ADH runs based on 2008–2011 hydrology:

(1) existing (2011) bathymetry,
(2) projected "reservoir full" bathymetry, and
(3) bathymetry surveyed following 1996 scour event.

Carl used scour computed by ADH 2008–2011 to estimate scour during the January 1996 storm which falls in the Chesapeake Bay Environmental Model Package (CBEMP) application period, 1991–2000.

Carl noted that as of 2011, the reservoir is virtually full. However, even when the reservoir is full, it still appears to be depositing under non-scouring flows. Under normal hydrologic conditions (non-scouring), sediment that flows into reservoir system does not necessarily leave the reservoir system and flow into Chesapeake Bay. What we see are events. Erosion events are becoming more frequent with more material. The reservoir tends to mitigate itself. When a scour event happens, more room is made available in the reservoir for deposition.

Carl discussed the water quality implications next. His modeling predicts what happens in the Bay if watershed implementation plans (WIPS) are in place, reservoir is full and there is a storm event. As in past modeling runs, monitoring station CB3.3C is where he looks at water quality impacts. This site is used because it sits at the head of the deep trench that runs up the center of most of the bay. It is a critical location for water quality conditions. In particular, the bottom is virtually anoxic in summer. The Total maximum daily loads (TMDLs) hinge on meeting DO standards in bottom waters in the vicinity of CB3.3C. Consequently, changes in DO at this location are critical compared to changes to other monitoring stations closer to Conowingo where DO is usually in excess of standards. In addition to DO concerns, CB3.3C has elevated chlorophyll concentrations and is just downstream of the turbidity maximum so it is a good station to characterize the upper bay water quality. He noted that as a storm goes by, they produce an enormous temporary spike in solids in the water column (solids are materials like sand, silt, and clay) but they are inert after deposition on the bottom and don't cause further water quality impacts. Light attenuation impacts are short-lived. Nutrients from the scouring event are recycled and there impacts persist for years. Lewis Linker asked about nutrient loads. Carl noted that he evaluated nutrients based on Tropical Storm Lee (2011). The 1996 storm event nutrient composition was different than Tropical Storm Lee (i.e., percentages of nutrients associated with solids varied). Carl noted that implications of this are that we may be overestimating nutrient loads from 1996 event by a factor of 2. We will need to acknowledge this level of uncertainty in the LSRWA report.

Carl then went over modeling results looking at the timing of a storm event. The Chesapeake Bay Program (CBP) modified the Hydrological Simulation Program--Fortran (HSPF) to produce storm scour consistent with the latest USGS estimates. Also, CBP has produced hydrodynamics and watershed model (WSM) runs that move the 1996 storm to different months (spring and summer). Utilizing HSPF and CBP WSM allows Carl to look at runoff and scour. Carl made runs using the scour conditions from the January 1996 storm: (1) winter storm; (2) storm moved to June; and (3) storm moved to October. Carl noted that he looked at the impacts of the entire storm event, not just scouring. What you see is a pulse (the impact of the storm passing). There is a big pulse in January but the impact on light is negligible. An October storm appeared to have minimal impacts. Even in June long-term impacts appeared negligible; impacts appeared short-lived. A June event has the most observed effects.

Lew Linker noted that the results may not represent effects on SAV; a period of reduced light could really impact SAV. Carl noted that for the final report these final outputs need to be remedied. There is an interesting spatial extent of chlorophyll; during a January event, impacts are seen all the way to the mouth of Potomac; in June, the spatial extent goes further south to the mouth of the Rappahannock. There was discussion on nitrogen (N) and phosphorus (P) loads. We have N loads delivered from the storm runoff, minimal from scour of bottom sediment in Conowingo Pond. We don't have information on the specific N and P amounts, just a percent of the total loads. Bioavailability of these nutrients is important information. There was discussion that Jeff Cornwell (UMCES) has some numbers on P and bioavailability. Michael Helfrich noted that he has had discussion with Jeff Cornwell and will discuss with him further his opinion and what data he has readily available that we may be able to use to allow us to make some assumptions to refine amount of phosphorus that are bioavailable in sediments. Chris Spaur noted that collecting biogeochemical data to fill information voids was considered during study scoping, but eliminated in order to control overall study costs.

Anna Compton passed out a spreadsheet that recaps all six baseline and future conditions modeling runs that Carl Cerco has evaluated. This spreadsheet is included as enclosure 3 to this memorandum. For each condition, modeling runs were made based on varied land use, hydrology, bathymetry and scouring, and the effects to water quality as well changes to sediment and nutrient loads that were observed. There was not much time to go over the spreadsheet so the group needs to review and provide written comments back to Anna and Carl Cerco. There was discussion on Condition 3 (system condition when WIPs are in full effect, reservoirs are still trapping and a scour event occurs) in comparison to Condition 5 (system condition when WIPs are in full effect, reservoirs are full and a scour event occurs). It appears that these conditions have similar effects to water quality and sediment nutrient loading. There was discussion on benefit versus cost. Based on what was presented, it appears from the modeling that there is not much difference in effects whether the reservoir is completely full or in its current nearly full condition. Does this lead us to the conclusion that if we try to increase capacity by minor amounts, we will not see much benefit? What about maintaining status quo? Is it worth the investment? What are we going to get for reducing sediment volume?

To further understand modeling predictions and their impacts, there was discussion on stoplight plots that the CBP has developed. This is a CBP assessment procedure that analyzes the impacts of load scenarios on water quality of a Bay segments and whether they reach attainment or not (meeting TMDLs). Lewis Linker noted that we would probably want to run all of our key LSRWA scenarios (conditions) using the stoplight plots to show the effects to water quality by bay segment with the predictions of Carl's model.

Michael Helfrich noted that Carl's modeling is using the 4th biggest event we have on record to show storm scouring (the 1996 winter storm event). What about the storms that have occurred on record that were larger than this event? Also the loads (nutrient and solids) shown in Condition 6 (scour event in summer, fall, and winter) are less than loads in Conditions 3-5, which all included a simulation of the same storm event; why is this? Carl explained that Condition 6 used HSPF and CBP WSM model (which can take into account sediments from the watershed as well) while Conditions 3-5 used the ADH model, so results vary and should not be compared directly. Condition 6 sheds light on impact of the timing of event while Conditions 2-5 show impacts of a full reservoir, WIPs in place, and a storm event.

There was discussion about Condition #2 (What is the system's condition if the WIPs are in full effect and reservoirs are still trapping) in that the loads on Carl's spreadsheet appear smaller than the loads full implementation of the PA WIPS (per TMDL) will obtain. For example Carl predicts the average solids load over the 10-yr period) is 2,307 metric ton/d but the TMDL is 2,417 metric tons/day; Carl predicts the average nitrogen load is 46.1 metric ton/d, while TMDL is 93.2 metric tons/day; Carl predicts phosphorus is 3.9 metric tons/d, while TMDL is 4.25 metric tons/day Carl will check spreadsheet/loads to clarify modeling predictions..

Herb has concerns about communicating this information to the general public. Up until now, the public information has been that the dam is trapping and it will eventually fill, but once it fills we will see more nutrients and sediment in Chesapeake Bay. We need to be clear on what the models are predicting. There was discussion on the concept model Carl presented (slide 5 of Enclosure 2), showing that scouring of reservoirs is negative to water quality in Chesapeake Bay; however, scouring does create capacity behind the dams to keep sediments and nutrients out of Chesapeake Bay for a period of time.

7. <u>Update on Reservoir Sediment Management Scenarios</u> –

Bob Blama provided a presentation on USACE's analysis of reservoir sediment management scenarios. This was a follow-up to what was presented at the February quarterly meeting. Tom Laczo provided a handout which lays out the placement options for dredged material that have been evaluated thus far. This was also an update to what was presented at the February quarterly meeting. Bob's presentation is included as enclosure 4, and the placement options handout is included as enclosure 5 to this memorandum. Bob also provided two handouts, one describing hydraulic and mechanical dredging, and the other describing the process of drying dredged material for placement (i.e., dewatering). These are included as enclosures 6 and 7 to this memorandum.

Tom noted that placement options have been organized into three categories: (1) beneficial use, (2) open water, and (3) upland. Every placement option has pros and cons which are listed in the table in regards to feasibility, environmental impacts and costs.

Bob walked the group through the various placement site possibilities for sediments behind the dams and the differences between hydraulic and mechanical dredging. He noted that he did not recommend island creation (tear drop islands) and fringe wetland creation in the Susquehanna River because they would not be able to use the volume of sediments we are looking at for placement. To pump downstream, we would need to pump for several months to remove material. In discussions with abandoned mine owners, there was not an interest in the material because of limitations on their mining permits. In doing an informal screening, not many placement options are left. Quarries seem to be feasible. We also need to think about a placement site to dewater the material. If you need to hydraulically pump material more than 5 miles, you will need a booster which adds to the project cost. When transporting material, considerations such as topography of the land come into play; for example, material is easier to pipe over flat versus hilly land. At Conowingo, the topography out of reservoir is uphill.

There was discussion on the large number of reservoir sediment management scenarios/alternatives we have. We need to work on screening these.

8. <u>Sediment Bypass (Tunneling) Strategies</u>

Kathy Boomer provided the group an overview of sediment bypass (tunneling) strategies. Her presentation is included as enclosure 8 to this memorandum.

This technology has been implemented in places like Japan and Switzerland, in the form of bypassing sediments downstream or to a placement site, via a tunnel. With this technology, there is a lot of control on the size of material that you are targeting to move. There are yearly maintenance costs to repair these tunnels. Advantages are that it is a long-term sediment management solution to extend the storage capacity of reservoirs. Disadvantages are that it is does not provide a solution for already stored sediments (it moves sediments that have not deposited yet), the technology is still in development, and it appears very costly. However, it is difficult to fully estimate costs due to the limited use of this technology.

The use of bypass tunnels depends on your goals. For example, entities that have looked at implementing or have implemented bypassing tunnels, normally have a goal of extending the life of water storage capacity in the reservoir, protecting turbines or restoring sediment supply for downstream habitat value. For the LSRWA study, the goal is protection of downstream water quality. In the short-term, bypass tunnels do not offer much in meeting our goals. Scour events are still likely to occur. A sediment bypass tunnel system likely will not offer much more benefit from "run-of-river" equilibrium conditions. After a scour event, however, a long-term management strategy could be implemented with a sediment bypass tunnel with delivery of a more desired sediment composition to the downstream area.

For the LSRWA report, Kathy Boomer will write up the section on sediment bypass tunneling.

9. <u>Update on Reservoir Operational Strategies-</u>

John Balay provided the group an update on reservoir operational sediment management strategies. He provided a handout with a write-up describing and summarizing implementation considerations and constraints, and conclusions regarding the utilization of reservoir operations to manage sediment in the lower Susquehanna River which is included as enclosure 9 to this memorandum.

John analyzed altering the structure of the three hydroelectric dams on the lower Susquehanna River to meet the LSRWA sediment management goals. None of the three hydroelectric dams currently contain outlet works that would permit sediment releases during favorable hydrologic conditions.

He explained that release of sediment through the turbines, in excess of what is transported normally during generation operations at higher streamflows could cause significant damage to the existing structure (Note that following the quarterly meeting, Exelon representatives indicated that the potential for turbine damage may not be that significant). Existing gates at Safe Harbor and Conowingo are designed for flood operations and, as such, provide little opportunity for sediment management. Retrofitting the existing dam structures with sluice gates or other bottom outlet works would be difficult without compromising the dams' structural integrity.

Many of the sediment management strategies that alter operations would significantly impact power generation and water supply operations.

Of the various methods to manage sediments via altering the operations of the reservoir, agitation dredging garnered the most discussion. This type of dredging includes the removal of bottom material from a selected area by using equipment to raise it temporarily in the water column and currents to carry it away. Agitation dredging could be considered an operational alternative when conducted in conjunction with typical or modified dam operations. This particular operation would focus on fine sediments typically concentrated in downstream portions of each of the lower Susquehanna River reservoirs. The bulk of agitated suspended bed sediment would be in the lower half of the water column. To transport the suspended material, hydropower intakes would need to be open at the highest flow possible, which is 86,000 cfs (cubic feet per second) at Conowingo. At this hydraulic capacity, it is unlikely that there would be adequate flow velocity in the lower portions of the reservoirs to transport agitated sediment. Also, there was discussion on dredging being dangerous if we agitate during high flows.

The cumulative effect of competing water uses, operational limitations, and structural constraints make altering reservoir operations very difficult, for sediment management. That coupled with the limited spatial and volumetric effects of sediment movement do not justify the significant implementation costs required. John concluded that the combination of these factors warrant that reservoir operations alternatives be dropped from further consideration.

Any further comments to these operational strategies should be sent to John. In particular, Exelon the owner and operator of Conowingo will comment on the write-up to make sure that the dam operations are adequately covered.

10. Update on Watershed Sediment Management Strategies-

Bruce Michael provided the group an update on the development of watershed sediment management strategies. Bruce noted that when it comes to watershed sediment management strategies, the most cost-effective best management practice (BMP) according to CBP is "no till" agriculture. Bruce noted that he is continuing to investigate this BMP for the LSRWA effort. The idea is to go above and beyond what the states are doing with WIPs to meet the TMDLs. The specific scenario he is investigating is the "maximum feasible" scenario in the watershed, that is, what is the maximum feasible amount of acres that could be implemented, what would it cost, and what would the impacts be to sediments. An analysis needs to be done on cost and acres available in the watershed to implement this type of strategy. Bruce noted that implementation costs won't be released until next winter by CBP. He could work with CBP to get preliminary numbers for inclusion in the LSRWA analysis. BMP efficiency numbers already exist. For LSRWA effort we would focus on the most efficient BMP to reduce sediment. There was a discussion on population growth (i.e., acres available now may not be available years down the road due to development). This analysis includes acres available right now. Claire noted that we need costs and acres developed in the next few weeks. In June we are scheduled to develop and decided what sediment management modeling scenarios what we want to run for LSRWA effort.

11. WIP Scenarios and Nutrient Loads –

Lewis Linker provided the group an update on WIP scenarios and nutrient loads that CBP is working on. He provided a presentation which is included as enclosure 10 to this memorandum. Lewis noted that the sediment loads predicted from CBP modeling are changing all the time but do have long-term trends. He discussed loads from the watershed model (WSM) version 5.3.2 and discussed four scenarios. The 1985 "High Historical Load Scenario" uses 1985 land uses, animal numbers, atmospheric deposition, point source loads and a 10-year (1991–2000) hydrology. This scenario has the highest historical delivered load estimates of nutrients and sediment to the Bay. The "2011 Progress Scenario" uses 2011 land uses, animal numbers, atmospheric deposition, point source loads and the 10-year, 1991–2000 hydrology. The "2010 WIP" scenario estimates the nutrient and sediment loads with 2010 WIPs throughout the Chesapeake Bay watershed. The scenario included accounting for all the WIP BMPs based on a 2010 land use, permitted loads and atmospheric deposition. The "All Forest Scenario" uses an all-forest land use and current estimated atmospheric deposition loads for the 1991–2000 period and represents estimated loads with maximum reductions on the land. This scenario has loads greater than a pristine scenario, which would have reduced atmospheric deposition loads.

Lew presented loads (total phosphorus, total nitrogen, and total suspended solids) from each of these scenarios at the Conowingo and Marietta monitoring stations. The 1985 scenario had the highest predicted loads for all three parameters, followed by the 2011 progress scenario, the 2010 WIP scenario and finally the all forest scenario.

12. Alternatives Framework

Claire provided a handout which is a flowchart that lays out a framework of sediment management alternatives to assist the LSRWA team with organizing the large amount of sediment management alternatives involved in this study. This handout is included as enclosure 11 to this memorandum. Ideally each representative sediment management alternative would have a cost associated with it as well as volume of sediment that could be removed/moved ($/cubic yard).

13. Wrap Up –

Anna will draft up notes for the group's review. Following this, the notes and presentations will be posted to the project website. Claire will set up a doodle poll to determine the date for next quarterly meeting which will be sometime in August.

Anna Compton,
Study Manager/Biologist

Enclosures: 1. Meeting Agenda
2. Summary of Existing and Future Conditions- Carl Cerco Presentation

3. Baseline and Future Conditions spreadsheet.
4. Reservoir Sediment Management Options – Bob Blama Presentation
5. Lower Susquehanna Placement Options Handout
6. Dredging Handout
7. Dewatering/Drying Handout
8. Sediment By-pass tunnels–Kathy Boomer Presentation
9. Altering Reservoir operations handout
10. WIP Scenarios and Nutrient Loading -Lewis Linker Presentation
11. Sediment Management Alternatives Framework

LOWER SUSQUEHANNA RIVER WATERSHED ASSESSMENT
QUARTERLY TEAM MEETING

MDE Aqua Conference Room, Baltimore, Maryland
May 13, 2013

Meeting Agenda

Time	Item	Lead
10:00	Welcome and Introductions	All
10:05	Review of Action Items from Prior Meetings Funding Update Communication and Coordination Updates for Situational Awareness Conowingo Policy Group Meeting on 22 April 2013	O'Neill
	<u>LSRWA Technical Analyses</u>	
10:20	Summary of Existing and Future Conditions	Cerco/Comption
10:50	Update on Reservoir Sediment Management Strategies	Blama/Laczo
11:20	Sediment Bypass Strategies	Boomer
11:35	Update on Reservoir Operational Strategies	Balay
11:45	No-Till Acreage Strategy	Michael
11:55	WIP Scenarios and Nutrient Loads	Linker
12:15	Alternatives Framework	Compton/O'Neill
12:25	Meeting Wrap-Up Action Items/Summary/Schedule Ahead Next Meeting	O'Neill

Call-In Information: (877) 336-139, access code = 6452843#, security code = 1234#

<u>Expected Attendees:</u>

MDE: Herb Sachs; Tim Fox, Matt Rowe
MDNR: Bruce Michael, Bob Sadzinski, Shawn Seaman
MGS: Jeff Halka
SRBC: John Balay, Andrew Gavin, Dave Ladd
USACE: Anna Compton, Bob Blama, Chris Spaur, Claire O'Neill, Tom Laczo, Dan Bierly
ERDC: Carl Cerco, Steve Scott
TNC: Mark Bryer, Kathy Boomer
USEPA: Gary Shenk, Lewis Linker
USGS: Mike Langland, Joel Blomquist

Exelon: Mary Helen Marsh, Kimberly Long, Gary LeMay
Lower Susquehanna Riverkeeper: Michael Helfrich
PA Agencies: Patricia Buckley, Raymond Zomok

Action Items from February 2013 Quarterly Meeting:

a. Claire will coordinate the next quarterly meeting for May.

b. Anna will send out the spreadsheet tracking all stakeholder coordination to the group. Anyone making a presentation on LSRWA should let her know so the spreadsheet can be kept up to date; if any specific comments/concerns are raised, this should be noted as well.

c. John Nichols will submit written comments on behalf of NMFS addressing his agency's concerns over sediment bypassing management strategy.

d. Danielle will add Blackwater Wildlife Refuge as a potential placement option to evaluate.

e. Bruce will work with Gary on potential "no-till" acres available in the watershed and evaluate impacts to sediment loads if all no-till acres were implemented in the watershed via modeling.

f. Carl will complete runs for the following scenarios: What happens when the reservoir fills? What happens when the reservoir fills and WIPs are in full effect? What is the system's condition if a large scour event occurs in spring, summer or fall? These are the final existing and future without project conditions scenarios.

g. Carl, Steve and Lewis will work together to determine where nutrients are scoured from in the reservoir (at what depths) and will conduct a sensitivity analysis looking at bioavailability of nutrients in various forms (species) by Berner activity class or other means).

h. Michael and Carl will have a follow-up phone call to discuss the estimated loads that Carl is using for his modeling efforts that will be entering the Bay once Conowingo is full and will report back to the group if these estimated loads will be revised at all.

i. Modeling efforts cannot predict impacts to SAV from physical burial by sediments. These impacts should be considered and described by other means, perhaps qualitatively, by the LSRWA agency group.

j. Matt will check in with MDE to see how sediment bypassing (for open water placement or allowing sediments to relocate to sediment-starved areas) would be permitted and the stance of his agency on permitting for such activities.

k. Pat will determine and report back to the group what the PA department of Environmental Protection (DEP) stance is on sediment criteria for landfills ("clean" vs. "waste"). More specifically, we have data from 2000, is this too old? If so, what are expectations of the agency regarding data to determine appropriateness of sediment at a landfill?

l. The concept of a permanent pipeline should be investigated further and examples around the country should be looked at by the LSRWA agency group.

m. Michael will forward info to Danielle on Funkhauser Quarry.

n. Michael will forward Danielle the questions he had about some of the reservoir sediment management options that were presented but could not be addressed at the meeting due to time limitations.

o. The LSRWA agency group needs to determine next steps for developing reservoir sediment management options.

p. John Balay will look further into agitation dredging (coupled with electric generation releases) of fine material; it is expected this would be done outside of ecologically critical time periods.

q. The LSRWA agency group should quantify any habitat restored or enhanced downstream in Bay or elsewhere (e.g. terrestrial) as a project benefit; considerations should be given on how to do this.

<u>Ongoing/Action Items from Previous Meetings</u>:

a. The MDE FTP website will be utilized to share internal draft documents within the team; Matt will be the point of contact for this FTP site. *Status: Ongoing. Sharing of future documents will go through the MDE ftp website.*

b. Shawn will notify team when most recent Exelon study reports are released. Status: *Ongoing. Tom Sullivan, a contractor of Exelon noted that the Exelon has filed the license for Conowingo Dam with FERC.*

c. Anna will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups. *Status: Ongoing.*

d. Anna will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of updates from the quarterly meeting. *Status: Ongoing.*

e. Matt will keep team informed on innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies. *Status: Ongoing.*

f. Michael Helfrich will coordinate with MD, Chesapeake Bay Program (CBP) and the MD county coalition to set up a meeting to present dam implications to total maximum daily loads (TMDL) to MD counties. *Status: Ongoing. Michael Helfrich coordinated this task with Bruce Michael; Bruce has reported LSRWA activities to multiple groups and counties over the last 6 weeks. His message to counties was to keep in perspective that they still need to do their work regarding sedimentation from the watershed (meeting TMDLs) while the issue of sediments and nutrients trapped behind the dams and how to manage them are still being dealt with. Bruce noted that Bob Summers, MDE Secretary, has made presentations to the MD legislative committees as well.*

MEMORANDUM FOR THE RECORD

SUBJECT: Lower Susquehanna River Watershed Assessment
Quarterly Meeting, August 15, 2013

1. On August 15, 2013 agency team members met to discuss ongoing and completed activities for the Lower Susquehanna River Watershed Assessment (LSRWA). The meeting was hosted by the Maryland Department of the Environment (MDE) in their Terra Conference Room at the Montgomery Park Building in Baltimore, Maryland. The meeting started at 10:00 am and continued through 2:00 pm. The meeting attendees are listed in the table below.

2.

Lower Susquehanna River Watershed Assessment Team Meeting Sign-In Sheet			
August 15, 2013			
Agency	**Name**	**Email Address**	**Phone**
American Geophysical Union	Harry Furukawa	hfurukawa@agu.org	202-777-7430
City of Baltimore, DPW	Prakash Mistry	Prakash.Mistry@baltimorecity.gov	410-396-0732
City of Baltimore, DPW	Clark Howells	clark.howells@baltimorecity.gov	410-795-6151
City of Baltimore, DPW	James Price	James.Price@baltimorecity.gov	410-396-0539
Chesapeake Bay Commission	Ann Swanson	aswanson@chesbay.us	410-263-3420
Chesapeake Bay Foundation	Beth McGee	bmcgee@cbf.org	443-482-2157
EPA, Chesapeake Bay Program	Lew Linker	llinker@chesapeakebay.net	410-267-5741
Exelon	Kimberly Long	kimberly.long@exeloncorp.com	610-756-5572
Gomez and Sullivan	Kirk Smith		
Exelon - Gomez and Sullivan	Gary Lemay	glemay@gomezandsullivan.com	603-428-4960
Exelon - URS Corp.	Marjorie Zeff	marjorie.zeff@urs.com	215-367-2549
Exelon-Gomez and Sullivan	Tom Sullivan	tsullivan@gomezandsullivan.com	603-428-4960
Lower Susquehanna Riverkeeper	Michael Helfrich	LowSusRiver@hotmail.com	717-779-7915
MDE	Herb Sachs	sachsh@verizon.net	410-537-4499
MDE	John Smith	jsmith@mde.state.md.us	410-537-4109
MDE	Matt Rowe	mrowe@mde.state.md.us	410-537-3578
MDE	Tim Fox	tfox@mde.state.md.us	410-537-3958
MDE	Lee Currey	lee.currey@maryland.gov	410-537-3913
MDNR	Bob Sadzinksi	bsadzinski@dnr.state.md.us	
MDNR	Bruce Michael	bmichael@dnr.state.md.us	410-260-8627
MDNR	Shawn Seaman	sseaman@dnr.state.md.us	410-260-8662
MDAGO	Brent Bolea	bbolea@energy.state.md.us	410-260-7578
MPA	David Blazer	dblazer@marylandports.com	410-726-2235
NOAA-NMFS	Christopher Boelke	christopher.boelke@noaa.gov	
PADEP	Patricia Buckley	pbuckley@pa.gov	717-772-1675
PADEP	Ted Tesler	thtesler@pa.gov	717-772-5621
SRBC	David Ladd	dladd@srbc.net	717-238-0425x204
SRBC	John Balay	jbalay@srbc.net	717-238-0423 x217
TNC	Kathy Boomer	kboomer@tnc.org	607-280-3720
USFWS	George Ruddy	george_ruddy@fws.gov	410-573-4528
USFWS	Robbie Callahan	Carl.Callahan@fws.gov	410-573-4524
USFWS	Genevieve LaRouche	genevieve_larouche@fws.gov	202-341-5882
USACE	Anna Compton	anna.m.compton@usace.army.mil	410-962-4633
USACE	Dan Bierly	daniel.m.bierly@usace.army.mil	410-962-6139
USACE	Bob Blama	robert.n.blama@usace.army.mil	410-962-6068
USACE	Chris Spaur	christopher.c.spaur@usace.army.mil	410-962-6134
USACE	Claire O'Neill	claire.d.o'neill@usace.army.mil	410-962-0876
USACE	Tom Lazco	thomas.d.lazco@usace.army.mil	410-962-6773
USACE	Steve Elinsky	Steve.Elinsky@usace.army.mil	410-962-4503
USACE-ERDC	Carl Cerco	carl.f.cerco@erdc.usace.army.mil	601-634-4207
USACE-ERDC	Steve Scott	steve.h.scott@usace.army.mil	601-634-2371
USGS	Mike Langland	langland@usgs.gov	717-730-6953

The meeting agenda is provided as enclosure 1 to this memorandum.

Status of Action Items from May Quarterly Meeting:

a. Michael Helfrich will forward info to Danielle Aloisio on Funkhauser Quarry. *Status. Complete. No point of contact is available due to abandoned conditions, see response to "d" for more info.*

b. Claire will coordinate the next quarterly meeting for August 2013. Status: *Complete. Meeting occurred today.*

c. Anna will distribute NMFS agency letter discussing concerns over sediment bypassing management strategy to group and have it posted on website. *Status Complete.*

d. Bob Blama will call the Funkhauser Quarry to get more information on utilizing this as a sediment placement option. *Status Complete. While no POC was provided (it is an abandoned quarry), USACE did some preliminary calculations; volume is very limited, only 3 million cubic yards (mcy), and access to the quarry is a big concern. Michael Helfrich noted that he thought this would be a good place for a staging area. The LSRWA report/spreadsheets with potential alternatives have been updated with this info.*

e. Michael Helfrich will touch base with Jeff Cornwell (UMCES) to get his opinion on phosphorus bioavailability in sediments as it relates to the LSRWA study. *Status. Complete. Chris Spaur updated the group on this item. He noted that he will prepare a write up for the report and will run it by Jeff Cornwell for comments. Chris noted that during study scoping in 2010/2011, water column and sediment nutrient-content data needs were discussed and evaluated. Anna and Chris coordinated with Carl Cerco, Steve Scott, Mike Langland, and Joel Bloomquist (USGS) for this purpose. The group determined that data on nutrient (and sediment) in water outflows from Conowingo Pond was inadequate, and collecting data to fill gaps was scoped into the study. It was recognized that it would be useful to have additional information on Conowingo Pond bottom sediment biogeochemistry, particularly with regard to phosphorus. However, it was determined that existing information/data was adequate for study modeling purposes, and it was decided to not undertake such investigations in light of need to control study costs. With regard to (P) phosphorus biogeochemistry, Carl had identified Jordan and others (2008) as presenting a concept applicable to utilize for our situation. P is generally bound to iron in fine-grained sediments in oxygenated freshwater and of limited bioavailability. Under anoxic/hypoxic conditions iron is reduced and P can become more bioavailable. P rebinds to iron in sediments if oxygen is again present. P adsorbed to Conowingo Pond bottom sediments would remain bound to those sediments in the freshwater uppermost Bay. In saltwater, biogeochemical conditions change. Jordan and others (2008) indicate that as salinities increase above about 3-4 ppt/psu (parts per thousand/practical salinity units, P is increasingly released from sediments and becomes mobile and bioavailable to living resources, which is likely due to increased sulfate concentrations in marine water water (e.g., Caraco, N., J. Cole, and G. Likens, 1989. Evidence for Sulphate-controlled Phosphorus Release from Sediments of Aquatic Systems. Nature 341:316–318.). The upper Bay remains generally below salinities of 3 ppt all year south to about the Sassafras River on the Eastern Shore and Bush River on the Western Shore.*

Chris noted that in the original scoping, the purposeful removal/release of sand from Conowingo Pond into the Bay was considered, but not the current bypassing alternative that could release fine-grained sediments into the upper Bay. The Bay model has determined that a release of Conowingo bottom sediments into the upper Bay in fall/winter would have fewer impacts to Bay water quality than in spring/summer, in part because the microbially-facilitated P release mechanisms occur more slowly in winter months. The winter timing allows for sediment deposition and P burial and long-term storage to occur before warm water conditions enhance P release in suspended and surface sediments. Additionally UMCES work has shown that there are less negative impacts when excessive flows enter the Upper Bay system during late fall/winter months because the life cycles for the species of concern are such that they are less susceptible to degraded water quality at this time. Mike Helfrich asked what depth P would need to be buried and how we would know whether waves would scour bottom. Chris said that MGS (1988) maps the upper Bay and shows that the channel on the west side as depositional so this region is presumably burial. Also, during the SAV growing season, large SAV beds would provide wave protection in the bed vicinity. During non-growing season when non-persistent SAV is absent, this wouldn't be the case though.

Chris offered to provide information summarizing 2010/2011 nutrient scoping to anyone that was interested, as well as copies of Jordan and others (2008). MGS report is available online:

Jordan, T.E., J.C. Cornwell, W.R. Boynton, and J.T. Anderson. 2008. Changes in phosphorus biogeochemistry along an estuarine salinity gradient: the iron conveyor belt. Limnology and Oceanography, 53(1): 172-184.

Maryland Geological Survey. 1988. The surficial sediments of Chesapeake Bay, Maryland: physical characteristics and sediment budget. Report of Investigations No. 48. Maryland Geological Survey.

Beth asked about what species of phosphorus we are including in the water quality model. Carl said that his model, Chesapeake Bay Environmental Model Package (CBEMP) assumes a split of inorganic and organic P. This split is based on collected historical data. The model assumes that inorganic P is not bioavailable (as long as the water column is oxygenated); and that inorganic P stays bound to sediments. In the upper Bay conditions are oxygenated so this is a good assumption. Organic P gets split into two types: a smaller, more readily mobilized labile type and a refractory type which constitutes most of the organic P which decomposes so slowly it is considered essential unavailable to the biological community. Based on these conditions it is assumed that the the majority of P that comes over Conowingo is not bioavailable.

f. The group will review the baseline and future conditions summary spreadsheet and provide comments back to Anna Compton and Carl Cerco. *Status ongoing. Carl and Anna still are working on updating and finalizing summary spreadsheet. Anna will send out once completed.*

g. Lewis Linker and Carl Cerco will work with CBP partners to integrate the CBP's assessment procedure ("Stoplight plots") into the LSRWA key modeling scenarios to provide a means to communicate/explain impacts to Chesapeake Bay from the various full reservoir and storm scouring scenarios. *Status: Complete. Lew will discuss this analysis; see Section 11.*

h. The LSRWA agency group will develop a screening process for reservoir sediment management options that are worth developing further. *Status Ongoing. Once the team sees modeling results, sediment management screening process can be further refined and lead to recommendations.*

i. The LSRWA agency group will direct any questions on sediment bypass tunneling to Kathy Boomer. *Status Complete.*

j. Kathy Boomer will write up a section on sediment bypass tunneling for the LSRWA report. *Status Complete.*

<u>Ongoing Action Items from Previous Meetings</u>:

A. The MDE FTP website will be utilized to share internal draft documents within the team; Matt will be the point of contact for this FTP site. *Status: Ongoing. Sharing of future documents will go through the MDE ftp website.*

B. Shawn Seaman will keep team posted on FERC relicensing of Conowingo dam status. *Status: Ongoing. Shawn noted that currently MD and PA are negotiating with Exelon. August 2nd was last MD meeting. MD and PA will have some joint and also some separate meetings with Exelon in regards to relicensing process and negotiations.*

C. Anna Compton will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups. *Status: Ongoing.*

D. Anna Compton will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of updates from the quarterly meeting. *Status: Ongoing.*

E. Matt Rowe will keep team informed on innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies. *Status: Ongoing.*

F. Anna Compton will send out the spreadsheet tracking all stakeholder coordination to the group. Anyone making a presentation on LSRWA should let her know so the spreadsheet can be kept up to date; if any specific comments/concerns are raised, this should be noted as well. *Status: Ongoing.*

G. Bruce Michael will work with the Chesapeake Bay Program (CBP) on potential "no-till" acres available in the watershed and evaluate impacts to sediment loads if all no-till acres were implemented in the watershed via modeling as well as develop costs. *Status: Ongoing. See discussion under #6.*

H. Carl Cerco, Steve Scott and Lewis Linker will work together to determine where nutrients are scoured from in the reservoir (at what depths) and will conduct a sensitivity analysis looking at bioavailability of nutrients in various forms (species) by Berner activity class or other means). *Status: Complete. It was determined that this task will not be completed at this time. Investigating the locations and depths from which sediment is eroded will not yield much. The problem is we have little or no information about the reactivity of bottom material. In the Chesapeake Bay modeling package (CBEMP), we partition particulate nutrients carried over the dam into various classes of composition and reactivity based on a combination of observations, experience, and judgment. If we are uncertain about the composition of material eroded from the bottom, we could do some sensitivity runs where we vary the partitioning and/or reactivity of the loads. However we couldn't state with certainty that the "sensitivity loads" would be any more realistic than the loads we are using now, but we could examine the risks involved in our current assumptions. This option is available for the future especially if more data is collected for instance for a feasibility level analysis of implementing some kind of management action.*

I. Modeling efforts cannot predict impacts to SAV from physical burial by sediments. These impacts should be considered and described by other means, perhaps qualitatively, by the LSRWA agency group. *Status: Ongoing. Bruce Michael has provided the UMCES (Mike Kemp) SAV historical mapping and trends over last 10 years in Susquehanna Flats. This information will need to be incorporated into the assessment to provide a qualitative discussion of impacts. Bruce noted that in looking at what happened to SAV during TS Lee, high flows ripped up SAV from the periphery. It appears that there was damage from the physical impacts of the storm versus burial of SAV by scoured sediments. Mike Kemp is looking at other storm examples. Bruce will follow up with Mike Kemp and provide a write-up for report. Chris Spaur reminded the group that we don't have wave energy in our modeling. Chris can email past efforts on characterization of wave energy undertaken during the Chesapeake Bay Shoreline Erosion study.*

J. The LSRWA agency group needs to determine next steps for developing reservoir sediment management options. *Status: Ongoing. Representative alternatives were identified for costs; some alternatives identified for sediment transport/WQ modeling; results discussed in Sections 5, 6, 8, 9, and 10.*

K. The LSRWA agency group should quantify any habitat restored or enhanced downstream in the Bay or elsewhere (e.g., terrestrial) as a project benefit; considerations should be given on how to do this. *Status: Ongoing.*

L. Bruce Michael and Claire O'Neill will keep the LSRWA agency group updated on the Susquehanna policy group put together by Governor O'Malley. *Status: Ongoing. Bruce noted that the Conowingo policy group met in April. There are no more meetings planned until more results from LSRWA are available.*

M. Exelon will review and provide comments on SRBC's write-up of altering reservoir operations as a sediment management strategy. Exelon will comment on the write-up to make sure dam operations are adequately covered. *Status Ongoing. John Balay will follow up with Exelon to ensure they have no further comments on reservoir operations section.*

<u>Action Items from this (August 15) Quarterly meeting</u> –

a. Chris Spaur will provide information summarizing the 2010/2011 LSRWA nutrient scoping to anyone that is interested, as well as copies of Jordan and others (2008) and a link to MGS report. This info also could be placed on the LSRWA website. Chris will also prepare a write-up on phosphorus biogeochemistry in the Bay for the LSRWA report.
b. Claire O'Neill will provide to the group all of the factsheets/ back-up documentation to show how costs were developed for each representative sediment management alternative.
c. Matt Rowe will look into Stancills quarry and their existing permits to see if they have any constraints or concerns with groundwater contamination. This may need to be marked as a limitation for this potential placement site.
d. Bruce Michael will be providing a write-up that lays out this watershed sediment management scenario in more detail in September.
e. Mike Langland will provide data to the group related to grain size and nutrients based on his analysis of the sediment core data.
f. Steve Scott will alter his graphs to depict areas of concern in red.
g. Carl Cerco will look into the suspended sediment and nutrient loads that Michael Helfrich has provided to determine if the loads need to be revised for his CBEMP modeling runs.
h. Anna Compton will work with the modeler's to develop a summary table compiling all sediment management modeling scenarios and results.
i. Anna Compton will draft up notes for the group's review and then post to the project website.
j. Claire O'Neill will set up a doodle poll to determine the date for next quarterly meeting which will be sometime in November.

3. <u>Introductions</u> - After a brief introduction of the meeting attendees, Claire O'Neill welcomed the LSRWA agency group and noted that the purpose of the meeting was to provide updates on recent activities within the LSRWA.

4. <u>Funding Update</u> – Claire O'Neill noted that FY13 federal budget funding arrived in July. This assessment received $300,000. While the assessment is still due $126,000 in Federal funds in FY14 to complete, if those funds are not readily available, the assessment has access to non-Federal funds to complete the analyses.

5. Update on Sediment Management Strategies – Costs - Claire O'Neill provided a handout, laying out a summary of costs for representative sediment management alternatives and an example "factsheet" which provides the back-up documentation to show how costs were developed for each representative sediment management alternative (Enclosure 2).

For the past year, the USACE-Baltimore District staff has been focused on developing concept design and costs for in-reservoir sediment management alternatives. At the February quarterly meeting, Bob Blama and Danielle Aloisio presented a matrix with many in-reservoir options. This matrix summarized field visits and telephone coordination that they had with potential placement sites. From this coordination, it was determined that the majority of potential placement sites that had accessibility and capacity were closer to Conowingo Reservoir. From that matrix, the assessment team selected a set of representative alternatives for the concept-level design and cost development for each of the categories to give us a sense of the costs for each category of alternatives. The alternatives came from four categories: (1) innovative re-use, (2) open water placement, (3) upland placement, and (4) watershed management. At this time, USACE is still waiting for Harbor Rock and MDNR to supply details for categories #1 and #4, so the presentation focused on alternatives in categories #2 and #3.

For the open-water and upland placement representative alternatives, Tom Laczo from the USACE staff compiled the available information and laid out possible logistics and infrastructure investment for three levels of one-time removal: 1 million cubic yards, 3 million cubic yards, and 5 million cubic yard to get a sense of unit costs for the various concepts. Each alternative has a detailed factsheet laying out the logistics. Items that were considered included the type of dredging, transport mechanism, the need for drying and consolidation of the material, type of placement, and real estate required. For example, depending on how you dredge, there is more or less water which impacts the amount of land you might need, time for drying and placement site.

The information was then compiled into a summary spreadsheet (one worksheet for each volume considered). During the meeting, Claire explained parts of the worksheet. Across the top are the four categories of representative alternatives, then under open water placement and upland placement there are individual alternatives. The first section physically describes those alternatives, including the type of dredging, the eventual placement site, and the transport method. Claire noted that for the hydraulic dredging alternatives involving trucking or barging, that large areas for drying the material would be required. Tom explained how rotational drying was considered if it were needed for any of the upland placement sites. For example, a temporary placement site could be divided into cells and while one cell(s) had material drying and consolidating other cells could receive new material while other cells could have material removed and transported to final destination. The concept is that cells would be rotated until the final destination placement site is at capacity. Tom noted that the drying time was aggressive (i.e., in reality, drying could take longer than assumed for this exercise).

The worksheet goes on to lay out some operational assumptions, investment costs, and annual/removal costs. Cost values are presented as a range between a low and high value. Tom Sullivan asked whether contingency was included in the calculations; Claire noted that a specific contingency was not added to the cost calculations but that the USACE staff took that into consideration in the low-high assessment. The worksheet illustrates that the annualized (one-time investment costs (based on a 50-year project life and the Federal project interest rate) are much less than the operational removal costs if the removal is done a yearly basis. In the lower half of the worksheet, the costs are calculated on a per cubic yard basis and major limitations are described. Claire noted that these limitations are not all encompassing and could be expanded. At the very bottom of the spreadsheet, the major assumptions are outlined. Anna noted that the tipping fees were based on recently collected data and there was discussion that these tipping fees could be negotiated. Claire reiterated that the costs developed are concept-level only, and that a feasibility study would be required to determine more detailed design and cost analyses if an entity was looking to implement any of these alternatives.

For the meeting, the attendees were provided with the summary spreadsheet and a sample detailed worksheet for an open water placement site. After hearing Claire's presentation, the meeting attendees were interested in seeing all of the detailed worksheets, so Claire agreed to follow up and provide those to everyone. Comments on the cost summary spreadsheet and the detailed worksheets were requested to be provided by 6 September 2013.

There was discussion on Stancills quarry as a potential placement site. There was a question if there would be water quality/groundwater issues. Bob Blama said when he talked with them, they said their permits were good. Matt Rowe said he could look into Stancills quarry and their existing permits. This may need to be marked as a limitation for this potential placement site. Matt noted that freshwater dredged material doesn't have the same constraints as saltwater dredged material (i.e., less potential for groundwater contamination).

Dave Ladd asked about combining of alternatives. Claire noted that the project partners will look into this further when they look to develop recommendations.

6. Watershed Sediment Management Strategies - Bruce Michael provided the group an update on the development of watershed sediment management strategies for LSRWA.

He noted that the TMDL process set nutrient (nitrogen and phosphorus) and sediment load allocations for each state, that when implemented by the year 2025, would eventually meet Bay water quality standards for dissolved oxygen, water clarity, and chlorophyll, an indicator of algal biomass. Each state was required to develop watershed implementation plans (WIPs) that provides reasonable assurance to EPA that they will meet their load allocations. The WIP defines specific best management practices (BMP) and how they are to be funded throughout the watershed.

The total sediment load allocation of 6,453.61M lbs/year for the entire watershed is not defined in the state WIPs. For the Susquehanna River watershed, Pennsylvania, New York and Maryland it is anticipated that the specific BMP implementation defined for meeting nitrogen and phosphorus load allocations are expected to exceed the sediment load allocation by 62M lbs/year by 2025 with full WIP implementation. The Chesapeake Bay Program watershed model (WSM) estimates that NY provides 317M/year lbs sediment load, PA 2,200M/year lbs sediment load and MD 68M/year lbs sediment load to the Bay.

An analysis was conducted to compare predicted 2025 WIP BMP levels (of TSS) to the predicted "E3" (everything, everywhere, by everyone) BMP levels (of TSS) in this basin. The analysis found that TSS load reductions (E3 scenario) above and beyond the Susquehanna River WIP BMP levels in the three states are 62M lbs/year. The TSS planning targets are the cap load allocations needed to meet clarity and SAV goals. Bruce noted that this delta of 62M lbs/year sediment should be considered in the LSRWA sediment management options.

It is estimated that the maximum additional delivered TSS load reduction (beyond the WIPs) is estimated to be 190M lbs/year. This includes the 62M lbs/year not accounted for in the WIPs. The "E3" scenario is a what-if scenario of watershed conditions. There are no cost and few physical limitations to implementing BMPs in "E3" scenario. Generally, "E3" implementation levels and their associated reductions in nutrients and sediment could not be achieved for many practices, programs and control technologies when considering physical limitations and participation levels.

For this analysis, it is assumed that the three states will meet their TMDL target load allocations for nutrients, and therefore, sediments. The EPA Chesapeake Bay Program provided data comparing non-wastewater BMP levels between the 2025 WIPs and a modified "E3" condition. "E3" conditions were primarily applied to the agriculture and forestry sectors since these are generally more cost-effective sectors with respect to TSS load reductions.

The BMP comparison lists implementation by major BMP category as absolute units, e.g., acres and as a percent level of implementation. The percent level of implementation is the cumulative planned acres compared to the total domain of acres available for the BMP. For several BMPs, this level would be 100 percent for the "E3" boundary condition.

For the objective of looking at acres in the lower Susquehanna River watershed beyond WIP implementation that might be available for additional sediment BMP implementation, Bruce and his team considered "upgrading" BMPs – rather than just additional implementation of BMPs specified in the current WIPs. The focus was on agriculture and forestry BMPs (opposed to stormwater) because of the relative cost-effectiveness.

In summary, the theoretical maximum additional delivered TSS load reduction (beyond the WIPs) is estimated to be 190M lbs/year. This is the model-estimated delta in loads between the two BMP scenarios – the 2025 WIPs and the 2025 WIPs with sediment "E3" scenario. Cost estimates for the BMP implementation, for both the 62 M lbs/year and 190 M lbs/year, are still under evaluation. The three states have different BMP cost estimates. As you approach the "E3" scenario, BMP implementation costs will theoretically increase as few acres will be available for implementation and the least expensive BMPs will have been implemented first. MDNR is working on developing a low and high cost range for BMP implementation.

As an initial rough estimate of sediment costs, MDE developed a list of Chesapeake Bay Program-approved BMPs, the load reduction, annual cost, cost efficiency and cost per pound. For each BMP, a low, medium and high cost per pound of sediment reduction was estimated. The low cost of cost per pound estimates ($3.87) were averaged and the high cost of cost per pound estimates ($105.72) for delivered sediment loads was utilized. Average costs were used to calculate a range of costs necessary to reduce additional sediment delivered to the Susquehanna River above and beyond WIP implementation using the "E3" scenario estimate of a 190M lbs/year sediment or 95,000 tons sediment/year.

The maximum available sediment per year that could be reduced by additional BMP implementation above and beyond the WIP implementation throughout the lower Susquehanna River Watershed is approximately 95,000 tons/year. This is about an order of magnitude less than what is estimated to flow over the Conowingo Dam into the Chesapeake Bay on a average annual basis (approximately, 1M tons/year).

Lee Currey noted that this analysis should make sure that the technical assumptions on costs for the period of analysis are consistent. Bruce noted that different BMP's do have different costs.

Bruce will be providing a write-up that lays out this watershed sediment management scenario in more detail in September.

7. Reservoir Transport - Mike Langland provided a presentation on reservoir transport which is included as Enclosure 3 to this memorandum. It is important to note that what was presented should be considered draft and is subject to change.

Mike first discussed his recent data compilation and findings on sediment transport (flood frequencies, sediment transport rates, trapping, and delivery). Overall, historically data there has been declining sediment transport into the Susquehanna river/reservoir system since the 1900's due to changes in sediment management throughout the watershed. He noted that historically as flow increases (i.e. during a storm event) sediment loads increase from the watershed and the loads that are scoured from behind the reservoirs increase as well. In general for the majority of flows, scour of sediments from behind the reservoirs influences about 22-25 percent of the total loads entering the Bay during an event (the rest is from the watershed). Scour from the reservoir occurs only when flows are above 380,000-400,000 cfs which has a reoccurrence interval of (1 in 4 chance or a "25-year storm").

Through time reservoirs have trapped more sediment. As the reservoirs fill with sediment they trap less sediment. Reservoir trapping efficiency has decreased from 75-80 percent to 55-60 percent currently (i.e. the amount of sediment that Conowingo is still currently trapping). In the future trapping efficiency is projected to maintain this 55-60% efficiency because storm scouring will still occur creating room for more trapping to occur on a cyclic basis. Mike noted that Tropical Storm Agnes was a massive change to the norm of trapping and scouring. He noted that this storm (1972) had about 15 million tons entering the reservoir system and those 15 million tons scoured by the storm plus an additional 15 million tons from the watershed entering the system. This is significantly higher loading and scouring than other observed storms.

Mike then discussed information that he collected on particle size distribution and location. He presented coring data collected throughout the reservoirs and focused on Conowingo cores. Through this analysis of data, he was able to determine the particle sizes and spatial distribution of the sediment. He observed that the trend is that there is a higher percentage of sand as you travel away from the reservoir. Fines (silts and clays) are being replaced with sands. For example in the lower portion of the reservoir in 1990, the area had about 5 percent sand; in 2012 it is projected to have about 20 percent sand. There was discussion of the bed armoring over time. Heavier material takes more time to remove (higher storm flows required). Presumably storms remove the silts and clays (easier to transport) leaving behind the heavier sands. For example, it is estimated that fines begin to move out of the reservoir when flows are around 250,000 cfs but sands do not start to move until flows are more like 500,000–700,000 cfs. Approximately, 400,000 cfs is an average of the flow it takes to scour sediment out of the reservoirs when you take into account all particle sizes.

We are not going to see much change in trends as Conowingo enters an equilibrium state. Trapping efficiency (55-60%) won't change and there will not be a whole lot of difference in the amount of loads we see entering the Bay now from the reservoir than we could anticipate in the future.

In summary, long-term sediment transport rates into/out of reservoirs from the watershed are declining due to improvements in sediment/nutrient management in the watershed. Historical data indicates decreasing trapping efficiency over time. Increasing discharge (flows) results in increasing scour (i.e. more sediment scoured and added to total Bay sediment/nutrient loads).

When flows are 400,000-700,000 cfs approximately 23 percent of the total load to Chesapeake Bay is from scouring of sediment from behind the dams; the remainder is from loading from the watershed. Overall sand is moving and displacing fines down-gradient in Conowingo Reservoir. If this trend continues, fewer silts and clays (fines) will be scoured in future events due to a combination of reasons, first, deposition onto the bed may be reduced due to changes in water column settling velocities as the reservoir continues to fill, and second, the state's WIP plans likely will result in less fines transported into the reservoirs in the future. While spatially the areas of Conowingo reservoir where conditions are suitable for fines to be deposited would remain the same as today, the volume deposited could be less. However, fines would be scoured more readily under lower flows (however still fairly infrequent events, 250,000 cfs or greater) thus likely increasing conveyance of fines over the dam under lower flow conditions. Because these lower flow conditions occur more frequently than higher flow conditions (250,000 cfs vs. 400,000 cfs or greater), we'd expect a trend of less volume/mass of fines building up in the reservoir to be available for scour during these higher flow conditions (more infrequent events). Thus, during major scouring events there could be a trend of reduced fines being scoured.

Conowingo Reservoir is in or close to dynamic equilibrium phase (~93 percent filled). Even at 93% full the trapping efficiency still remains at 55-60 percent. Conowingo will never be at 100 percent full due to periodic storm events scouring sediments creating room for more trapping. Consequently, this “dynamic equilibrium” is what state the reservoir is in now and will most likely remain into the future.

There was discussion on the percent of coal that is in these sediments. Mike noted that coal is considered to be either sand or silt in this analysis depending on its particle size; therefore, some of the sand and silt could be coal. There was discussion on the depths of the cores taken. Mike noted that x-ray equipment is utilized to analyze the cores. Mike’s analysis methods will be included in his technical report write-up.

There was a question if it was possible to characterize phosphorus trends (associated with grain size). We need to connect this analysis with Bob Hirsch (USGS) findings. Mike will provide data to group related to grain size and nutrients.

Mike presented some additional data looking at estimated scour that the modeling has predicted compared to actual scour that has been observed from collected data before and after storm events, and specifically scour thresholds in the system. Scour threshold is a term that the modelers have been using to describe the average rate of flow required to begin scouring sediments out of the reservoir system. ADH predicts that the scour threshold is between 380,000-400,000 cfs. The USGS scour threshold computation based on data collected from past events, is around 400,000 cfs.

In general fines, start to move around 250,000 cfs but 400,000 cfs is when a real increase in scour and large amounts of sediment loads are observed.

8. Sediment Management Modeling - Steve Scott provided a presentation on sediment transport and various sediment management scenarios which are included as Enclosure 4 and Enclosure 5 to this memorandum. It is important to note that what was presented should be considered draft and is subject to change.

The first modeling scenario that Steve went over was a run on the ADH model looking at the sediment management alternative of agitation dredging. The goal of agitation dredging is to transport bed sediments through the dam (outlet structures) by re-suspending reservoir bed sediments. This procedure requires high pressure water jets or diffusers to re-suspend bed sediments upstream of the dam, and then adequate flow velocity to transport re-suspended sediment through the dam's outlet structures. Sediment-transport ability is a function of sediment particle size and bed shear stress. Steve used the ADH model to compute: bed shear stress for varying flows through Conowingo; shear velocity to evaluate turbulence required to maintain sediment in suspension; computed percentage of sediment remaining in suspension as a function of flow. His findings were that a minimum discharge of 150,000 cfs is required to ensure that sediments are transported through the dam during agitation dredging. He noted that flows greater than 150,000 cfs occur on an average of 12 days per year in this system. Also these high flows come most often in spring when we don't want sediment in the system because that is a critical time of year for living resources.

The next modeling scenario that Steve went over was a dredging sediment management scenario. The goal of dredging is to reduce scour potential (the amount of sediment available to be transported during a storm event) and increase deposition in the reservoir. The analysis methods included using computed sediment transport through Conowingo with 2011 bathymetry and 2008 – 2011 Susquehanna River flows; the removal of 3 million cubic yards from a depositional area 1.0 to 1.5 miles above the Conowingo Dam; then re-computing sediment transport within the dredged area; and finally comparing the results (2011 bathymetry vs. 2011 bathymetry with dredged area). Steve noted that the dredge area was selected because large amounts sediment still naturally deposit at this location. Results of this run were that with dredging there is a 3-percent reduction in scour (2.98 million tons vs. 2.71 million tons) over the 4 year flow record. Also dredging results in a 6-percent increase in sedimentation, i.e., deposition within the reservoir (4.02 to 4.28 million tons).

The next modeling scenario that Steve went over was a sediment by-passing sediment management alternative. Using the ADH model, he evaluated the impacts of sediment bypassing operations (dredging and passing sediment downstream through a pipe around the dam) on water quality below Conowingo Dam. The assumptions for this analysis were one run that included 2.4 million tons bypassed over 3 months time (90 days) and 2.4 million tons bypassed over 9 months time (270 days). Results of this run were that he observed an increase in suspended sediment concentration from 12 to 176 mg/l for the 90-day bypassing operation below the dam and an increase in suspended sediment concentration from 12 to 66 mg/l for the 270-day bypassing operation.

9. Sediment Transport Summary - Steve Scott provided a presentation summarizing ADH modeling findings which is included as Enclosure 6 to this memorandum. It is important to note that what was presented should be considered draft and is subject to change.

Steve has conducted several runs on with varying bathymetries of Conowingo Reservoir (1996, 2008, 2011, full, and 3 mcy removed). Over time the sediment load out of the reservoir (outflow) and scour load have increased while net deposition from the watershed to the reservoir has decreased. The 2011 and "full" bathymetry runs have essentially the same outflow, scour load and net deposition suggesting that the reservoir in its current state is at equilibrium. If the reservoir is dredged, it does have some influence on scour load and sedimentation. Steve noted 31 mcy of sediment (25 million tons) has deposited in Conowingo from 1996 to 2011.

Steve noted that as scour increases, net deposition decreases as bathymetry fills. Storms have a huge influence on the system. For example, Tropical Storm Lee provided 65 percent of the sediment load that year to the bay and 80 percent of that came from the watershed. He noted that the upper two reservoirs will scour and sediments will make their way down the system. He explained that the inflow load is total load that comes in from the watershed and upper two reservoirs. He also confirmed that 3 million tons is a good number to use as long-term average annual for inflow.

His findings were that: (1) scour load in Conowingo increased from 1.8 to 3 million tons from 1996 to 2011; (2) deposition in Conowingo decreased from 6 to 4 million tons from 1996 – 2011; (3) the 2011 bathymetry run compared to "full condition" indicates very little change in sediment transport i.e. the dam in its current state is acting full or at "dynamic equilibrium"; (4) dredging 3 million cubic yards resulted in a bed scour reduction (scoured sediment transported during a storm event) of 10 percent (3 percent per million cubic yards removed); and (5) dredging 3 million cubic yards resulted in a 1.3 percent reduction of outflow load (outflow load is inflowing load from watershed plus bed scour load) to the bay (0.44 percent per million cubic yards removed).

Based on comparisons between the 1996 and 2011 simulations for every million cubic yards dredged, the scour potential is reduced by 3 percent and the deposition potential increases by 6 percent; the net benefit of dredging to the Bay is reduction of scour plus increase in reservoir sedimentation. Dredging the reservoir back to 1996 bathymetry (this equates to a removal of 31 million cubic yards) has a net benefit of 2 million tons or load reduction to the Bay of 9 percent.

There was discussion on the sand deposition and coarsening downstream trend and how that would likely be expected even with a dredging program.

Chris suggested that Steve alter the coloring in his graphs because typically red signifies concern. He recommended that for bathymetry/hydrograph, darker blues should represent deep water and lighter blues represent shallow water, with shade/color of blue changing along gradient correlating to bathymetry. If the issue of concern is scour or currents, then to connote strong current or scour in color should probably follow convention: red means lots of concern, yellow less concern, and green no concern. This green/yellow/red convention can also apply to any other issues of concern that you might depict (excess sedimentation, contaminants, etc.). Strength of currents/scour could also be well-depicted using arrows of different sizes/boldness, etc. Steve will alter graphs to depict areas of concern with red.

10. <u>Water Quality Results</u> – Carl Cerco provided a presentation on his most recent modeling runs (CBEMP) which is included as Enclosure 7 to this memorandum. It is important to note that what was presented should be considered draft and is subject to change.

Carl noted that two dredging scenarios, removing 3 mcy, one time and removing 31 mcy were run to evaluate water quality effects. What remains to be run is a bypassing sediment management scenario of 3 mcy of sediment to predict water quality effects; this run is due to be completed in mid-September.

Carl explained that the CBEMP is run for 1991-2000 hydrologic period with WIPs in place. The model runs include loads from a major scour event (January 1996) which is added to the CBP WSM loads from the watershed. Scour is computed by ADH which utilizes 2008-2011 hydrology including TS Lee, and these loads are provided to Carl for input into the CBEMP model. Nutrient composition of solids (i.e., nutrients associated with sediments) is based on collected data during TS Lee.

Carl first presented a conceptual map of the system that he had developed. He explained that the system is event-oriented. The sedimentation rate of the reservoir system is independent of bathymetry of the reservoir (i.e, how full it is); however scour, (i.e., how much sediment is moved during a storm event) is strongly dependent on bathymetry. With the WIPs in place sediment loads to the system are decreasing as well as deposition of sediment in the reservoirs. Scour events pour sediments and nutrients downstream but also increase depths (thus affecting bathymetry) in the reservoir diminishing subsequent events by making more room for sediments to deposit.

Carl then went over modeling results. He noted that water quality focuses on bioavailable phosphorus. Monitoring station CB3 is important because if the TMDL is met here the Bay will just meet the TMDL threshold.

In general, dredging 3 mcy will improve summer-average bottom DO (dissolved oxygen) in the deep trench of the Bay, Potomac River, and Baltimore Harbor by 0.02 to 0.04 mg/l based on a 1996 scour event. Dredging 31 mcy will improve summer average bottom DO in the deep trench of the bay, Potomac River, and Baltimore Harbor by 0.04 to 0.06 mg/l based on a 1996 scour event. Dredging 3 mcy will reduce SAV growing-season chlorophyll a by 0.02 to 0.05 ugm/l in a large expanse of the bay, extending from Baltimore Harbor past the mouth of the Potomac River, based on a 1996 scour event. The magnitude of chlorophyll a reduction from dredging 31 mcy is comparable to dredging 3 mcy, based on a 1996 scour event. The improvement is more extensive and prolonged, however.

Carl noted that reductions in light extinction, averaged over the SAV growing season, obtained by dredging are limited on the order of 0.01 / m. The primary reason for the minimal impact is the occurrence of the storm in January. By the time the SAV growing season begins, the solids load from the storm has largely settled out. The improvements that do result are primarily downstream of the SAV habitat in Susquehanna Flats. This effect has multiple potential causes. The predominant reason is that the high flows associated with the January storm carry eroded material downstream, past the Flats, and into the turbidity maximum where material is trapped. Reductions in erosion caused by dredging therefore reduce the amount of particles and associated nutrients carried into the turbidity maximum."

There was discussion on why the 1996 storm event was used? There have been several larger flood events on record which would represent a worst case scenario. Carl noted that 1996 was utilized because it is in the hydrologic period that matches the TMDL model runs; also we have made runs and know that a June storm event is the worst case scenario (worst time of year) for an event. Michael Helfrich had concerns of showing this small amount of benefits to the public in light of the fact that the suspended sediment being utilized as input parameters for the model were low compared to data he had seen before (he had provided the source from PA). Carl noted he would look into the loads and data that Michael had provided previously to determine if the loads need to be revised for his modeling runs.

There was discussion on how the modeling runs will tie into the sediment management strategy development and concept costs. Anna and Claire noted that the sediment management strategy development was an exercise to develop unit costs and determine how some of these strategies could be implemented and they became "representative" sediment management alternatives. Many other alternatives or variations of these alternatives could be explored. The modeling runs at this time do not match each of the developed "representative" strategies/alternatives. The modeling predictions inform the managers of the relative changes to the system of implementing some general variation of these strategies to help refine and understand how implementation of these different management actions will affect the Bay. This strategy development process will need to be further refined as more information from the modeling comes in and is understood.

11. <u>What Does This All Mean? Stoplight Plots</u> - Lewis Linker provided a presentation on his most recent modeling runs which is included as Enclosure 8 to this memorandum. It is important to note that what was presented should be considered draft and is subject to change.

Lewis noted that the "stoplight plot" analysis presented utilizes Steve Scott's ADH modeling predictions on loads from lower Susquehanna River reservoir system and Carl's recent CBEMP modeling scenarios predictions to assess what the water quality outputs do to meeting TMDL attainment throughout Chesapeake Bay in response to loading from the January 1996 scouring event. The past presentation in April did not utilize loads from the ADH modeling work and represented an increase in TP and TSS loads estimated in Hirsch (2012) for current infill conditions (50 percent TP and 100 percent TSS increase in load from Conowingo Pool).

TMDL allocations (and ultimately achievement of TMDL) for nutrients and sediments for the Bay were developed utilizing an airshed model and the Chesapeake Bay watershed model (WSM) to determine existing nutrient and sediment loads to the Bay as well as loads under different management actions. Outputs from the WSM model were than input into the Water Quality and Sediment Transport Model (WQSTM) of the Bay to determine the influence on Chesapeake Bay water quality from these loads. A criteria assessment procedure was used to evaluate the WQSTM predicted water quality effects to each segment of the Bay to determine if the predicted water quality effects (over space and time) met water quality standards for each segment, and if not how far off that segment was from meeting water quality standards.

Lewis noted that healthy living resource habitats are the base metric in determining what water quality (and associated TMDL allocations) should be. Water quality standards in deep water, deep channel, open water, and shallow water dissolved oxygen (DO) are key for protection of living resources in the Bay. Chlorophyll and SAV/clarity standards are also designed to protect living resources.

Lewis noted that in this most recent analysis the following scenarios were run:
(1) TMDL (WIPS implemented);
(2) TMDL with scour from Tropical Storm Lee, with nutrient levels scoured from January 1996 event;
(3) TMDL with scour from January 1996 event with nutrients scoured from January 1996;
(4) No January 1996 scour event;
(5) TMDL with Tropical Storm Lee levels of scoured nutrients with January event moved to June;
(6) TMDL with Tropical Storm Lee level of scoured nutrients with January Storm occurring in October;
(7) TMDL with January 1996 event level of scoured nutrients moved to June;
(8) TMDL with January 1996 event level of scoured nutrients moved to October.

Lewis evaluated the predictions of these modeling scenarios to see if water quality changes would prevent certain segments of the Bay from being in attainment per TMDL requirements.

When the WSM alone (his analysis in April 2013) is used to represent scour from the completely full state of Conowingo, loads are set at 250 percent (TSS) 100 percent (TP), and 0 percent (TN) above loads that we currently see now. That is, once Conowingo is "full" this is the amount of additional loads we could expect. What we have learned from recent ADH and CBEMP modeling runs is that a more complete estimate of the influence of Conowingo on Chesapeake water quality would fully include the episodic scour that occurs at flows greater than ~400,000 cfs.

Under the April 2013 stoplight analysis several Deep Water and Deep Channel DO segments were "red" i.e. not in attainment. The ADH/CBEMP modeling simulation is an improved representation of the dynamic nature of Conowingo scour/infill system with the simulation of the high flow event of the 1996 scouring event. With this scenario no effects from Conowingo are seen before a 400,000 cfs storm. Then the greatest influence on Chesapeake water quality is estimated during the contiguous 3-year period (1996-1998) immediately after the 1996 scour event and a subdued to no-effect influence is estimated in the subsequent 3 - year period of 1998 - 2000. Estimates with the simulation of the 1996 scour event are less detrimental in time and space than previous April 2013 estimates which represented more frequent loads of sediment and nutrients due to moderate flow events. At the (CB4MH) Deep Channel location the estimated effect of the 400,000 cfs event (January 1996 storm event) was a decrease in DO attainment of about 1% or less for the 3 years following the storm (using the 1996-1998 hydrology).

The No-Storm scenario provides an estimate of the influence high flow scour events like the 1996 storm event have on Chesapeake water quality and generally increase nonattainment of Deep Channel DO standards by about 0.5 to 1.5 percent. The January 1996 event transposed to June is the most detrimental to DO followed in decreasing influence by the January event, the October event, and the No-Storm event scenarios.

In the Deep Water area (CB4MH), no effects from Conowingo are estimated before a 400,000 cfs storm event, with greatest influence on water quality estimated during the contiguous 3-year period containing the storm, and a subdued to no-effect influence in the subsequent 3-year period after the storm. As in the Deep Channel, estimates with the current scenario method are less detrimental in time and space than previous April 2013 estimates. The estimated effect of the 400,000 cfs event (January 1996 storm event) was a decrease in DO attainment of 0.5% or less for the 3 years following the storm followed by a decrease in DO attainment of about 0.4% in the subsequent 3 year period.

For the Open Water DO water quality standard there is no change in response from Conowingo influence and full attainment of TMDL for all Conowingo scenarios is primarily due to reaeration of the surface waters represented by the Open Water DO standard.

In conclusion, the previous (April 2013) scenarios which assumed that once Conowingo is completely "full" we will see a 70 percent increase in P and a 250 percent increase in TSS and under current infi1l conditions have an estimated 50 percent increase in TP and a 100 percent increase in TSS (Hirsch, 2012) fail to fully represent the dynamic nature of large storm scour on Chesapeake water quality. The scour of Conowingo reservoir by a high flow event such as the January 1996 scour event under current infill conditions is estimated to have an ephemeral detrimental influence of at most about 1 percent nonattainment for a few years.

12. <u>Future Modeling Scenarios</u> – Anna Compton noted that currently there are no further modeling scenarios planned for Steve Scott (ADH); Carl Cerco (CBEMP) will be running two by-passing scenarios and Lew Linker (stoplight analysis) will be running by-passing and dredging scenarios. The goal is to complete all modeling runs by mid-September.

Anna Compton will be working with the modelers to develop a summary table compiling all sediment management modeling scenarios and results.

13. <u>Wrap Up</u> – Claire O'Neill reviewed the schedule for this effort which is included as Enclosure 9 to this memorandum. Claire noted that overall the study has kept on schedule up to this point. Activities occurring now include modeling sediment management scenarios which is scheduled to be completed in September unless new scenarios are developed. Concurrently sediment management strategies development is scheduled to be completed in September as well. All technical work and technical write-ups are scheduled to be completed by Mid-October and recommendations are to be developed by November. A draft report is scheduled to be compiled by the end of the calendar year with review commencing in January. The report will go through many iterations of review before it can be released publicly. The target date for a draft final report submitted for public review is August 2014. There was a question about peer review of the document. Claire noted that the document is required to go through USACE agency technical review (ATR) which will be various reviewers from outside of USACE Baltimore District. There is another level of peer review USACE has which is called Independent External Peer review (IEPR) which is non-USACE, technical review. This level of review is not required for LSRWA, it is normally required for high dollar decision/implementation documents. However, if a governor requests that a document goes through IEPR than that could prompt this type of review for LSRWA. .

Anna will draft up notes for the group's review. Following this, the notes and presentations will be posted to the project website. Claire will set up a doodle poll to determine the date for next quarterly meeting which will be sometime in November.

Anna Compton,
Study Manager/Biologist

Enclosures:
1. Meeting Agenda
2. Summary of Representative Sediment Management Alternatives.
3. Reservoir Transport – Mike Langland Presentation
4. Sediment Management ADH modeling – Steve Scott Presentation
5. Sediment By-passing ADH modeling- Steve Scott Presentation
6. Modeling Summary- ADH modeling Steve Scott Presentation
7. CBEMP modeling results- Carl Cerco Presentation
8. Stoplight analysis-Lewis Linker Presentation
9. LSRWA Schedule

LOWER SUSQUEHANNA RIVER WATERSHED ASSESSMENT
QUARTERLY TEAM MEETING

MDE Aqua Conference Room, Baltimore, Maryland
August 15, 2013

Meeting Agenda

Time	Item	Lead
10:00	Welcome and Introductions	All
10:05	Review of Action Items from Prior Meetings Funding Update Communication and Coordination Updates for Situational Awareness	O'Neill
10:20	Conowingo Re-licensing Update	Michael
LSRWA Technical Analyses		
10:30	Update on Reservoir Sediment Management Strategies – Costs	O'Neill/Laczo
10:45	Watershed Sediment Management Strategies	Michael
10:55	Reservoir Transport	Langland
11:10	Sediment Management Modeling – one-time 3Mcy removal, 26Mcy removal (1996 bathymetry), intermediate removal volume, bypassing	
11:10	Sediment Transport Results Sediment Management Bypassing Model Summary	Scott
11:40	Water Quality Results	Cerco
12:10	What Does All This Mean? Stoplight Plots	Linker/Cerco
12:40	Future Modeling Scenarios	Compton
12:45	Meeting Wrap-Up Schedule Ahead Action Items/Summary Review of Team Calendar Next Meeting	O'Neill

Call-In Information: (877) 336-1839, access code = 6452843#, security code = 1234#

Expected Attendees:

MDE: Herb Sachs; Tim Fox, Matt Rowe
MDNR: Bruce Michael, Bob Sadzinski, Shawn Seaman
MGS: Rich Ortt
SRBC: John Balay, Andrew Gavin, Dave Ladd
USACE: Anna Compton, Bob Blama, Chris Spaur, Claire O'Neill, Tom Laczo, Dan Bierly
ERDC: Carl Cerco, Steve Scott
TNC: Mark Bryer, Kathy Boomer
USEPA: Gary Shenk, Lewis Linker
USGS: Mike Langland, Joel Blomquist
NOAA: Chris Boelke
Exelon: Mary Helen Marsh, Kimberly Long, Gary LeMay
Lower Susquehanna Riverkeeper: Michael Helfrich
PA Agencies: Patricia Buckley, Raymond Zomok

Action Items from Previous Meetings:

a. Michael Helfrich will forward info to Danielle Aloisio on Funkhauser Quarry. *Status: Completed. No point of contact is available due to abandoned condition, but see response to "d" below.*
b. Claire will coordinate the next quarterly meeting for August 2013. *Status: Complete. Meeting was scheduled for 15 August 2013.*
c. Anna will distribute NMFS agency letter discussing concerns over sediment bypassing management strategy to group and have it posted on website. *Status: Complete.*
d. Bob Blama will call the Funkhauser Quarry to get more information on utilizing this as a placement option. *Status: Completed. While no POC was provided, USACE did some preliminary calculations; volume is very limited (only 3 million cubic yards) and access to the quarry is a big concern. Spreadsheet for potential alternatives is being updated.*
e. Michael Helfrich will touch base with Jeff Cornwell (UMCES) to get his opinion on phosphorus bioavailability in sediments as it relates to the LSRWA study. *Status: Complete. Chris Spaur to update the group at the meeting.*
f. The group will review the baseline and future conditions summary spreadsheet (Enclosure 3) and provide comments back to Anna Compton and Carl Cerco. *Status: Complete. Anna Compton to update the group at the meeting.*
g. Lewis Linker and Carl Cerco will work with CBP partners to integrate the CBP's assessment procedure ("Stoplight plots") into the LSRWA key modeling scenarios to provide a means to communicate/explain impacts to Chesapeake Bay from the various full reservoir and storm scouring scenarios. *Status: Ongoing. Discussion item for August meeting.*
h. The LSRWA agency group will develop a screening process for reservoir sediment management options that are worth developing further. *Status: Ongoing. Once we get the modeling outputs, screening process can be further refined and lead to recommendations.*
i. The LSRWA agency group will direct any questions on sediment bypass tunneling to Kathy Boomer. *Status: Complete.*
j. Kathy Boomer will write up a section on sediment bypass tunneling for the LSRWA report. *Status: Complete.*
k. Exelon will review and provide comments on SRBC's write-up of altering reservoir operations as a sediment management strategy (Enclosure 9). Exelon will comment on the write-up to make sure dam operations are adequately covered. *Status: Ongoing. SRBC to update at the meeting.*

<u>Ongoing Action Items from Previous Meetings</u>:

A. The MDE FTP website will be utilized to share internal draft documents within the team; Matt will be the point of contact for this FTP site. *Status: Ongoing. Sharing of future documents will go through the MDE ftp website.*

B. Shawn will notify team when most recent Exelon study reports are released. *Status: Ongoing. Tom Sullivan, a contractor of Exelon noted that the Exelon has filed the license for Conowingo Dam with FERC.*

C. Anna will update PowerPoint slides after each quarterly meeting to be utilized by anyone on the team providing updates to other Chesapeake Bay groups. *Status: Ongoing.*

D. Anna will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of updates from the quarterly meeting. *Status: Ongoing.*

E. Matt will keep team informed on innovative re-use committee findings to potentially incorporate ideas/innovative techniques into LSRWA strategies. *Status: Ongoing.*

F. Anna will send out the spreadsheet tracking all stakeholder coordination to the group. Anyone making a presentation on LSRWA should let her know so the spreadsheet can be kept up to date; if any specific comments/concerns are raised, this should be noted as well. *Status: Ongoing*

G. Bruce Michael will work with CBP on potential "no-till" acres available in the watershed and evaluate impacts to sediment loads if all no-till acres were implemented in the watershed via modeling as well as develop costs. *Status: Ongoing. Bruce Michael to update the group at the meeting.*

H. Carl Cerco, Steve Scott and Lewis Linker will work together to determine where nutrients are scoured from in the reservoir (at what depths) and will conduct a sensitivity analysis looking at bioavailability of nutrients in various forms (species) by Berner activity class or other means). *Status: Ongoing.*

I. Modeling efforts cannot predict impacts to SAV from physical burial by sediments. These impacts should be considered and described by other means, perhaps qualitatively, by the LSRWA agency group. *Status: Ongoing. Bruce Michael has provided the UMCES (Mike Kemp) SAV historical mapping and trends over last 10 years in Susquehanna Flats. This information will need to be incorporated into to the assessment to provide a qualitative discussion of impacts.*

J. The LSRWA agency group needs to determine next steps for developing reservoir sediment management options. *Status: Completed. Representative alternatives identified for costs; some alternatives identified for transport/WQ modeling; results to be discussed at the August meeting.*

K. The LSRWA agency group should quantify any habitat restored or enhanced downstream in the Bay or elsewhere (e.g., terrestrial) as a project benefit; considerations should be given on how to do this. *Status: Ongoing. But opportunities for quantification are very limited.*

L. Bruce Michael and Claire O'Neill will keep the LSRWA agency group updated on the Susquehanna policy group put together by Governor O'Malley. *Status: Ongoing.*

MEMORANDUM FOR THE RECORD

SUBJECT: Lower Susquehanna River Watershed Assessment
Quarterly Meeting, January 16, 2014

1. On January 16, 2014 agency team members met to discuss ongoing and completed activities for the Lower Susquehanna River Watershed Assessment (LSRWA). The meeting was hosted by the Maryland Department of the Environment (MDE) in their Terra Conference Room at the Montgomery Park Building in Baltimore, Maryland. The meeting started at 10:00 am and continued through 1:00 pm. The meeting attendees are listed in the table below.

2.

Lower Susquehanna River Watershed Assessment Team Meeting Sign-In Sheet			
January 16, 2014			
Agency	**Name**	**Email Address**	**Phone**
City of Baltimore, DPW	Prakash Mistry	Prakash.Mistry@baltimorecity.gov	410-396-0732
City of Baltimore, DPW	Clark Howells	clark.howells@baltimorecity.gov	410-795-6151
Chesapeake Conservancy	Jeff Allenby	jallenby@chesapeakeconservancy.org	443-321-3160
EPA, Chesapeake Bay Program	Lew Linker	llinker@chesapeakebay.net	410-267-5741
Exelon	Kimberly Long	kimberly.long@exeloncorp.com	610-756-5572
Gomez and Sullivan	Kirk Smith		
Exelon - Gomez and Sullivan	Gary Lemay	glemay@gomezandsullivan.com	603-428-4960
Exelon - URS Corp.	Marjorie Zeff	marjorie.zeff@urs.com	215-367-2549
Exelon-Gomez and Sullivan	Tom Sullivan	tsullivan@gomezandsullivan.com	603-428-4960
Lower Susquehanna Riverkeeper	Michael Helfrich	LowSusRiver@hotmail.com	717-779-7915
MES	Jeff Halka	jhalk@menv.com	240-459-5015
MDNR	Shawn Seaman	sseaman@dnr.state.md.us	410-260-8662
MDE	Herb Sachs	sachsh@verizon.net	410-537-4499
MDE	John Smith	jsmith@mde.state.md.us	410-537-4109
MDE	Matt Rowe	mrowe@mde.state.md.us	410-537-3578
MDE	Tim Fox	tfox@mde.state.md.us	410-537-3958
MDNR	Bob Sadzinksi	bsadzinski@dnr.state.md.us	
MDNR	Bruce Michael	bmichael@dnr.state.md.us	410-260-8627
MDNR	Shawn Seaman	sseaman@dnr.state.md.us	410-260-8662
MDAGO	Brent Bolea	bbolea@energy.state.md.us	410-260-7578
PA DCNR	Ray Zomok	rzomok@pa.gov	
SRBC	John Balay	jbalay@srbc.net	717-238-0423 x217
TNC	Kathy Boomer	kboomer@tnc.org	607-280-3720
TNC	Mark Bryer	mbryer@tnc.org	301-897-8570
USFWS	George Ruddy	george_ruddy@fws.gov	410-573-4528
USACE	Anna Compton	anna.m.compton@usace.army.mil	410-962-4633
USACE	Ashley Williams	ashley.a.williams@usace.army.mil	410-962-2809
USACE	Dan Bierly	daniel.m.bierly@usace.army.mil	410-962-6139
USACE	Bob Blama	robert.n.blama@usace.army.mil	410-962-6068
USACE	Chris Spaur	christopher.c.spaur@usace.army.mil	410-962-6134
USACE	Claire O'Neill	claire.d.o'neill@usace.army.mil	410-962-0876
USACE	Kim Gross	Kimberly .u.gross@usace.army.mil	
USACE	Tom Lazco	thomas.d.lazco@usace.army.mil	410-962-6773
USACE-ERDC	Carl Cerco	carl.f.cerco@erdc.usace.army.mil	601-634-4207
USACE-ERDC	Steve Scott	steve.h.scott@usace.army.mil	601-634-2371
USGS	Mike Langland	langland@usgs.gov	717-730-6953
USGS	Joel Blomqu	jdblomqu@usgs.gov	
Versar	Steve Schreiner		

The meeting agenda is provided as enclosure 1 to this memorandum.

Action Items from August 15, 2013 Quarterly Meeting –

a. Chris Spaur will provide information summarizing the 2010/2011 LSRWA nutrient scoping to anyone that is interested, as well as copies of Jordan and others (2008) and a link to MGS report. This info also could be placed on the LSRWA website. Chris will also prepare a write-up on phosphorus biogeochemistry in the Bay for the LSRWA report. *Status: Completed.*

b. Claire O'Neill will provide to the group all of the factsheets/ back-up documentation to show how costs were developed for each representative sediment management alternative. *Status: Completed.*

c. Matt Rowe will look into Stancills quarry and their existing permits to see if they have any constraints or concerns with groundwater contamination. This may need to be marked as a limitation for this potential placement site. *Completed.*

d. Bruce Michael will be providing a write-up that lays out this watershed sediment management scenario in more detail in September. *Completed.*

e. Mike Langland will provide data to the group related to grain size and nutrients based on his analysis of the sediment core data. *Completed.*

f. Steve Scott will alter his graphs to depict areas of concern in red. *Completed.*

g. Carl Cerco will look into the suspended sediment and nutrient loads that Michael Helfrich has provided to determine if the loads need to be revised for his CBEMP modeling runs. *Completed.*

h. Anna Compton will work with the modelers to develop a summary table compiling all sediment management modeling scenarios and results. *Status: Mostly complete only updates required are Linker/stoplight numbers.*

i. Anna Compton will draft up notes for the group's review and then post to the project website. *Status Complete.*

j. Claire O'Neill will set up a doodle poll to determine the date for next quarterly meeting which will be sometime in November. *Status: Completed. Quarterly meeting scheduled for 16 January 2014.*

3. Introductions - After a brief introduction of the meeting attendees, Claire O'Neill welcomed the LSRWA agency group and noted that the purpose of the meeting was to provide updates on recent activities within the LSRWA. She noted that this is the last planned Quarterly meeting since the study is wrapping up.

4. Funding Update – Claire O'Neill noted that this study is not in the FY14 federal budget that was just passed. However there is potential for some federal funding to be reprogrammed to the study but that won't be known for one to two more months. There is available federal funding to get through March. If the study does not receive any federal funds there is also non-federal funding available. There should not be any funding problems to complete the assessment unless there are major scope changes.

5. Update on Conowingo Relicensing – Bruce Michael informed the group that FERC has granted one more extension for filing comments to Exelon's application for a license of Conowingo dam. Comments are now due on January 31, 2014. Bruce noted sediment still remains as the state's

number one concern. Exelon has until January 31, 2014 to submit a 401 water quality certification (WQC) request to MDE. MDE has up to one year to issue/evaluate the 401 WQC request which will include a public notice. FERC is expected to complete an EIS and this process is anticipated to take 10-12 months. The EIS process includes public review. Agencies have requested that FERC include Muddy Run pump facility and York Haven in the EIS to evaluate impacts of these three facilities as a system instead of on an individual basis. The anticipated timeline is that a FERC license for Conowingo will be issued in early 2015.

6. Stoplight Plot/TMDL Analysis – Lewis Linker provided a presentation on his dissolved oxygen (DO) Water Quality Standard Attainment Analysis of the estimated influence of Conowingo infill on Chesapeake DO using linked watershed model, ADH and water quality and sediment transport model simulations. His presentation is included as Enclosure 2 to this memorandum.

Lew noted that this was a time and space assessment to determine what impacts Conowingo has on attainment of TMDL's. He noted that episodic (storm scouring) exceedances are allowed and accounted for in achievement of TMDL's. Attainment is evaluated on a Bay segment by segment curve basis (curve includes variances and decision rules to determine whether a segment is in attainment or not and there are allowable exceedances in space and/or time for nonattainment). In general, decision makers aren't interested in particular time and space attainment they want to know if a segment is in attainment or not. Some segments have different habitat types such as deep water, deep channel, open water, and shallow water. Each of these habitat types have different water quality needs and are key for protection of living resources.

Lew noted that nonattainment of 1% is above allowable criteria and the overall analysis procedure includes 1% uncertainty. Lew discussed the results of the 9 scenarios he and his team ran including sediment management scenarios and scenarios showing no action.

There was a lot of discussion on Lew's work and that some of the concepts and language were difficult to grasp. There was a comment that Lew should present his numbers with at least one significant figure to show variance in results. Also there was a lot of discussion on the hydrologic periods that Lew used to evaluate findings and that he should be sure to explain in his report differences in time periods he used and why. Additionally, it was recommended that the existing condition scenario (LSRWA-4) should show results of all segments that have nonattainment. One last recommendation was to be sure include attainment numbers in report of a scouring event in summer and fall. Right now we know a storm event has more detrimental effects in summer than fall than winter but Lew only provides attainment numbers for a winter event which is the best case scenario and provides the least impact to meeting water quality criteria.

Lew's work concludes that if the WIPs are in effect and there is a storm event in the winter with all dams at a dynamic equilibrium ("full") there are three upper bay segments that will still be in non-attainment.

There was a question about how long nonattainment would last. Lew noted that this depends on things like future rain events, etc., but ultimately effects diminish over time so typically it would last 1-2 years.

Lew noted that sediment management strategies like dredging shows some attainment improvement but strategies like bypassing hurt attainment because of nutrient recycling.

Lew noted that outside of LSRWA effort the Chesapeake Bay Program is looking at scouring events of smaller magnitude (down to 150,000 cfs) as predicted by Hirsch (2012) analysis. LSRWA work focused on scouring events larger 400,000 cfs.

7. Report Discussion – Anna Compton provided a presentation on LSRWA recent and upcoming tasks which is included as Enclosure 3 to this memorandum.

Anna noted that the draft report is under development. Since August the team has wrapped up modeling scenarios and all four modeling reports have been drafted and reviewed by the LSRWA team. The team plans to release a consolidated draft report for the quarterly agency group to review, targeting the end of February. Anna emphasized that this draft report is preliminary and subject to change. The report needs to go through required technical, policy and legal review before official public release but the LSRWA team wanted to get a version out to the quarterly agency group for early feedback on preliminary findings. This draft version of the report will not be put on the LSRWA public website but instead will be put on an FTP site. Access instructions will be out via email to the quarterly group once the draft report is ready for distribution to the group. There will be a main report summarizing all the technical work with multiple appendices providing more details on technical work.

Anna discussed some of the big picture preliminary findings that have come out of the LSRWA efforts thus far. Regarding the current and future state of the reservoirs modeling results have shown that all reservoirs including Conowingo have limited trapping capacity that is greatly reduced from historical trapping and are at a "dynamic equilibrium" state in which the net change in sedimentation (deposition during low flows and scour during floods) will remain relatively constant in the future.

Regarding effects to Chesapeake Bay from the current state of the reservoirs it appears that WIP implementation has a larger influence on the Bay meeting water quality standards in comparison to the influence of the trapping capacity and dynamics of the reservoirs and during storm events the majority of sediments entering the Bay originate from the watershed. However the trapping capacity and dynamics of the reservoirs do influence water quality and it is estimated that with full implementation of WIPs, three regions of the Bay (segments) will NOT be in water quality attainment (i.e., meet standards) for dissolved oxygen due to increased nutrients when the most current state of the reservoir system is taken into account and there is a scour event. Finally the solids from a scour event appear to settle quickly but DO impacts from scour could persist for multiple seasons with diminishing magnitude due to nutrient storage in the scoured bed sediments remaining and recycling between bed sediments and the water column. Nutrients appear to be the most detrimental factor from scour to water quality and need to be further monitored and analyzed.

In regards to solutions (i.e. nutrient and sediment management strategies) bypassing strategies appear to be lower in costs but have high environmental/water quality impacts and additional watershed measures for controllable sediment mitigation beyond the WIPs appear to be higher in cost and ultimately a low influence on reducing amount of sediment available for a storm event.

Increasing or recovering storage volume of reservoirs via dredging or other means appears the most feasible as there are upland sites available with large capacity to place sediments to reduce sediments available for scour during a storm. It appears that when sediment is strategically removed from the reservoirs there is an observed influence on scour load (reduction) and deposition (increase) and an observed reduction in impacts on water quality for a future similar storm event. However any removal would most likely be required annually to achieve influence on Bay water quality and this influence is minimized due to loads from the watershed during a scour event (i.e., must remove a lot and often to observe an influence).

The estimated cost range for suite of sediment management alternatives evaluated was $5-89/cubic yard; $15 - $267 million annually. This is for removal of 3 million cubic yards (approximate estimate of what is entering system on an annual basis) and includes alternatives like bypassing which as stated earlier are low cost but would most likely not be acceptable due to estimated water quality impacts.

In regards to the modeling tools Anna noted that any mathematical models applied to simulate complex physical processes, will have uncertainties. The team believes that the tools used for this effort represent the best tools currently available for evaluating sediment and nutrient dynamics and management strategies in the lower Susquehanna River watershed and Bay as a system and informing management decisions. The Bay watershed model and the Bay water quality model are the same peer-reviewed models as were used to set the Bay-wide TMDL requirements. Additionally all model documentation will be going through many iterations of review. One final thought about modeling is that major scour events are infrequent and each has unique characteristics. Application of these models to multiple events is desirable and would reduce uncertainty. However, the availability of complete data sets describing additional scour events is limited.

Lastly Anna went over the final section of the report which is intended to layout future needs of the watershed (i.e. recommendations.) This section of the report has not been developed yet. Recommendations could entail additional monitoring, enhanced assessment on nutrient contribution and Bay impacts, or actual implementation recommendations. Developing recommendations and a path forward will be challenging since potential solutions are high cost and long-term, sediments and nutrients originate throughout the watershed and entities that have the resources, abilities, purview to implement will need to be assessed.

8. Wrap Up – Claire O'Neill noted that this is the last LSRWA quarterly agency meeting since study efforts are wrapping up. There will be a public meeting once the draft report is ready for public review and this group would be notified of details of that meeting (once planned). She also noted that she is retired and Kim Gross would be taking over as USACE project manager for the remainder of the effort. Lastly, Anna will draft up notes for the group's review. Following this, the notes and presentations will be posted to the project website.

Anna Compton,
Study Manager/Biologist

Enclosures:
1. Meeting Agenda
2. Stoplight analysis-Lewis Linker Presentation
9. LSRWA Update-Anna Compton Presentation

Enclosures (handouts and presentations) from the Quarterly Meeting Summaries are available at the following location: http://bit.ly/LowerSusquehannaRiver

Attachment I-7:
Stakeholder Review Comments and Responses

Attachment I-7
Table of Contents

Review of the Lower Susquehanna Watershed Assessment

STAC Review Report

August 2014

Annapolis, Maryland

STAC Publication 14-006

About the Scientific and Technical Advisory Committee

The Scientific and Technical Advisory Committee (STAC) provides scientific and technical guidance to the Chesapeake Bay Program (CBP) on measures to restore and protect the Chesapeake Bay. Since its creation in December 1984, STAC has worked to enhance scientific communication and outreach throughout the Chesapeake Bay watershed and beyond. STAC provides scientific and technical advice in various ways, including (1) technical reports and papers, (2) discussion groups, (3) assistance in organizing merit reviews of CBP programs and projects, (4) technical workshops, and (5) interaction between STAC members and the CBP. Through professional and academic contacts and organizational networks of its members, STAC ensures close cooperation among and between the various research institutions and management agencies represented in the Watershed. For additional information about STAC, please visit the STAC website at www.chesapeake.org/stac.

Publication Date: August, 2014

Publication Number: 14-006

Suggested Citation:

Friedrichs, C., T. Dillaha, J. Gray, R. Hirsch, A. Miller, D. Newburn, J. Pizzuto, L. Sanford, J. Testa, G. Van Houtven, and P. Wilcock. 2014. Review of the Lower Susquehanna River Watershed Assessment. Chesapeake Bay Program Scientific and Technical Advisory Committee Report. No. 14-006, Edgewater, MD. 40 pp.

Cover graphic from: www.flickr.com

STAC Administrative Support Provided by:

Chesapeake Research Consortium, Inc.
645 Contees Wharf Road
Edgewater, MD 21037
Telephone: 410-798-1283; 301-261-4500
Fax: 410-798-0816
http://www.chesapeake.org

Table of Contents **Page**

REVIEW OF THE LOWER SUSQUEHANNA RIVER WATERSHED ASSESSMENT

Review Team:

Carl Friedrichs (Lead), Virginia Institute of Marine Science
Theo Dillaha, Virginia Tech
John Gray, U.S. Geological Survey
Robert Hirsch, U.S. Geological Survey
Andrew Miller, University of Maryland
David Newburn, University of Maryland
James Pizzuto, University of Delaware
Larry Sanford, University of Maryland Center for Environmental Science
Jeremy Testa, University of Maryland Center for Environmental Science
George Van Houtven, RTI International
Peter Wilcock, Johns Hopkins University

INTRODUCTION AND EXECUTIVE SUMMARY

Background

The Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) assembled a team of 11 professionals with backgrounds in resource economics, and watershed, riverine, and estuarine processes to review the Lower Susquehanna River Watershed Assessment report. As stated in the first five sentences of the LSRWA report's Executive Summary (p. ES-1), "The U.S. Army Corps of Engineers, Baltimore District (USACE), and the Maryland Department of the Environment (MDE) partnered to conduct the Lower Susquehanna River Watershed Assessment (LSRWA). This assessment concludes with this watershed assessment report to better inform all stakeholders undertaking efforts to restore the Chesapeake Bay. The purpose of this assessment was to analyze the movement of sediment and associated nutrient loads within the lower Susquehanna watershed through the series of hydroelectric dams (Safe Harbor, Holtwood, and Conowingo) located on the lower Susquehanna River to the upper Chesapeake Bay. This included analyzing hydrodynamic and sedimentation processes and interactions within the lower Susquehanna River watershed, considering strategies for sediment management, and assessing cumulative impacts of future conditions and sediment management strategies on the upper Chesapeake Bay. The need for this assessment is to understand how to better protect water quality, habitat and aquatic life in the lower Susquehanna River and Chesapeake Bay."

As summarized in the letter to the review team from the STAC Executive Secretary, "The [LSRWA] report includes a main text (>200 p.) summarizing all of the analyses conducted and conclusions from those analyses. Thereafter are four technical sections (Appendices A-D) and input data and literature for each of these technical sections (Appendices E-H). The report also contains miscellaneous information in Appendices I (Stakeholder Involvement) and J (Overview of LSRWA Plan Formulation, including Descriptions of sediment management strategies evaluation and costs and a Summary Table of Major (14) Modeling Scenarios and Results). The technical sections are: Appendix A: Sediment Reservoir Transport Simulation of Three

Reservoirs in the Lower Susquehanna River Basin, Pennsylvania using HEC-RAS - Langland/USGS report (31 pp., plus sub-appendices); Appendix B: Sediment Transport Characteristics of Conowingo Reservoir - Scott/ERDC report (57 pp., plus sub-appendices); Appendix C: Application of the CBEM Package to Examine the Impacts of Sediment Scour in Conowingo Reservoir on Water Quality in the Chesapeake Bay - Cerco/ERDC report (124 pp.), with individual results for all CBEM scenarios available on request; and Appendix D: Estimated Influence of Conowingo Infill on the Chesapeake Total Maximum Daily Load - Linker/EPA report (28 pp.).

The charge from STAC to the review team was: "You should focus your comments on the following [questions], but you are encouraged to provide additional comment that would improve the analyses, report, or its recommendations." The body of review is thus organized into sections in response to that series of questions. Below is a general reaction of the review team to the LSRWA report followed by an Executive Summary of the review team's responses to the series of questions. Following the Executive Summary, the expanded responses to the series of questions is provided.

General reaction of the review team to the LSRWA report

The majority of the reviewers of the LSRWA report agree that its authors have done a commendable job in trying to address an extremely challenging set of issues. The authors have assembled a considerable body of useful observational data, applied sophisticated models, and "chained" the results together to assess the impacts of recent hydrologic and water quality processes on the Lower Susquehanna River and the Chesapeake Bay. Overall, the results of the study are reasonable, the major conclusions are important, and the report's recommendations are by-and-large appropriate and productive. It is obvious that considerable and thoughtful effort has gone into accrual and presentation of the widely disparate types of information used in this report. The project was an enormous effort with multiple participants, and the authors did an impressive job bringing together a wide range of information to support their report.

The science associated with assessing the evolving condition of the Lower Susquehanna River and its effects on the Chesapeake Bay is exceptionally challenging. As far as the reviewers are aware, the Conowingo situation is truly unique. A major reservoir that had been an effective trap for fine sediment and associated nutrients has largely transitioned to one that no longer has an ability to perform this long-term function. It is likely that this kind of transition has never been well documented before, and there are not analogous systems for which modeling efforts have previously attempted to predict how a system will behave as it moves through this transition. The science that needs to be done here is at the cutting edge of what sediment transport and water quality science has ever accomplished in the past. Thus, there are no standard models and protocols for such a study, and the existing capabilities are understandably limited. Hence, it is not surprising that the review team identified many sections of the report that would benefit from revisions, corrections and/or additional analysis.

Although the constructive criticisms provided by the reviewers are significant, they do not fundamentally undermine the importance of key conclusions and recommendations that follow logically from the findings of the LSRWA study. As interpreted and modified by the review team, these (A) conclusions and (B) recommendations include: (A1) The Conowingo Reservoir is essentially at full capacity and is no longer a long-term sink helping to prevent sediment-associated nutrients (primarily particulate phosphorus) from entering the Chesapeake Bay. (A2) Increases in particulate phosphorus loads entering the Bay as a result of the full reservoir are likely causing significant impacts to the health of the Chesapeake Bay ecosystem. (A3) Sources of nutrients upstream of the Conowingo reservoir have far more impact on the Chesapeake Bay ecosystem than do the increases in nutrients caused by scour plus reduced deposition in the reservoir. (A4) Managing sediment via large-scale dredging, bypassing and/or operational changes are clearly not cost-effective ways to offset Chesapeake Bay water quality impacts from the loss of long-term trapping of sediment-associated nutrients. (B1) As soon as possible, follow-up studies should more fully quantify the impact on Chesapeake Bay water quality from increases in sediment-associated nutrients brought about by reservoir infilling. (B2) There is no compelling reason to reduce sediment loads *per se* from the Susquehanna watershed to compensate for increased sediment passing out of the Conowingo reservoir. Nutrients are the main problem, not sediments. (B3) Additional particulate phosphorus load reductions from the Susquehanna watershed (beyond present WIPs) should be considered to compensate for changes to the Conowingo.

Executive Summary

Question 1: Does the main report clearly define the goals, strategies, and the results/conclusions of the study, and also present adequate background material at a level suitable for understanding by non-technical audiences?

The goals stated in the main report (which stress both sediment and nutrient management) are inconsistent with the methodological approach taken by LSRWA (which mainly emphasized sediment) and appear not to be the study's original goals. This review recommends that the original goals of the study (i.e., sediment management to extend the life of Conowingo Dam more than nutrient management to protect Chesapeake Bay water quality) be presented in the introduction followed by a fuller explanation of how and why the focus of the study evolved in time. Both the Executive Summary and Chapter 9 of the main report (entitled "Assessment Findings") present four categories of conclusions that generally correspond to each other. Within the individual context of the Executive Summary or Chapter 9, each set of conclusions is well written and easy to follow and understand. Their general content also includes the most important results and conclusions of the study. However, the phrasing, main emphasis, and ordering of these four categories is different in the Executive Summary versus Chapter 9, which is unnecessarily distracting. This review recommends that the four categories of main results/conclusions be presented in the same order in both the Executive Summary and in Chapter 9 and the headers be made more consistent and compelling. (Note that the answers to this question did not address the scientific validity of the study's results/conclusions in detail; that is the focus of Questions 3 and 4.) Although the background material within the main report is indeed presented at a level suitable for non-technical audiences, this review recommends that large portions of the background material (specifically all of Chapter 2, 50+ pages in length) be moved to an Appendix. The remainder of the main report never refers to Chapter 2. A non-technical end-user of the present report who attempted to read it in sequential order would likely be side-tracked by Chapter 2, and find it harder to locate the key material and findings of the LSRWA.

Question 2: Are the alternative sediment management approaches clearly described and documented? Does this background material provide supporting evidence for the finding and conclusions of the study with regard to alternative sediment management approaches?

Where clearly defined as methods for reducing the cubic yards of total sediment present in the reservoir, the alternative sediment management approaches were found by the large majority of the reviewers to be well-documented, well-described, and comprehensive. It should be emphasized that the positive comments regarding the analysis and comparison of alternative sediment management approaches depend on the fact that the main conclusions regarding the alternative sediment management approaches did not critically depend on the fidelity of the HEC-RAS and AdH models. As a result, the uncertainties in the reservoir modeling process should not have much influence on the overall findings. It must also be stressed early and repeatedly that the dollar costs associated with alternative sediment management approaches specifically focus on the cost of reducing the amount of total sediment behind the dam, not on the cost of managing the impact of associated nutrients on the Chesapeake Bay. Further analysis would be required to appropriately rank the alternative strategies based on a more environmentally relevant total cost in terms of dollars per pound of nitrogen and/or phosphorus reduction.

Questions 3 & 4: Does the main report provide clear, supporting evidence for the results, findings, and conclusions of the study? Does the report adequately identify key uncertainties in the model applications which, with better information, could change the predicted outcomes of the alternative management scenarios evaluated in this study?

The most important conclusions which follow logically from the findings of the LSRWA study are generally well-supported by the overall content of the study. Nonetheless, there are many areas that can be improved. The comments in this section focus on specific aspects of the study that are key sources of uncertainty but have not been fully explained as such in the main report. This section of the review also highlights some sections of the report that are most likely erroneous and/or are most in need of improvement or additional explanation. Although the report lists and discusses sources of uncertainty, it expresses the expected confidence intervals on its model predictions less often. Although there is no single accepted procedure for reporting uncertainty in the context of scenario modeling, a part of the report should more explicitly explain why confidence intervals on predictions are generally not provided.

Key areas of concern which are expanded upon in response to Questions 3 and 4 include: (1) Stated sediment discharges from the Conowingo Dam are inconsistent with the literature. The report authors should either correct their numbers or present a clear explanation that reconciles why their estimates are significantly different from other estimates that are based on analysis of observed data. (2) Reduced deposition associated with reservoir infilling has been neglected. The fundamental issue motivating the LSRWA study is that the net trapping efficiency of Conowingo Reservoir has decreased dramatically over the past 15 to 20 years. Net trapping efficiency is the sum of increases in average annual scour and decreases in average annual deposition. However, the simulations and calculations in the study only considered the increase in scour. (3) Grain size effects within and exiting the reservoir were not sufficiently considered. The combination of two grain size effects – (i) changing grain size in time in the reservoir and (ii) the greater effects of fine sediment in transporting nutrients - mean that the effects of the reservoir on water quality have not reached a full dynamic equilibrium. However, the report did not address whether reservoirs were in dynamic equilibrium with respect to nutrients other than by assuming that if sediment was at equilibrium, then nutrients were also. (4) Limitations of the HEC-RAS and AdH models were not made sufficiently clear in the main report. The HEC-RAS modeling effort was largely unsuccessful, and the HEC-RAS simulation was largely abandoned as an integral part of the main report. Although consistent with four observed, integrated sediment-related properties of the system, the AdH model was not fully validated, and the AdH model was forced by boundary conditions outside the range of observed values. This means that the AdH model alone was not reliably predictive, and until the AdH model has been improved, observations should instead be emphasized to support the most important conclusions of the LSRWA study.

Question 5: Are the recommended follow-up evaluations and analyses (Section 9.1) complete and comprehensive as well as clearly stated to enable the next phase of work to continue under the Partnership's Midpoint Assessment?

Many of recommendations for future work and modeling tool enhancement are very good and are consistent with the views of this review. However, the recommendations as presently written over emphasize the significance of sediment (relative to nutrients) and do not include some important additional possibilities. One of the outcomes of this study should be to identify areas where our scientific understanding may be insufficient to achieve management goals, and to suggest future scientific studies to provide this knowledge. Follow-up studies need to consider the full range of hydrologic conditions, from moderate to high flows, which generally do not result in scour (but still reduce the deposition of sediment-associated nutrients in the reservoir), all the way up to the very high but very rare events that do result in scour. The emphasis in the future should shift from the relative vague impact of additional "sediments and associated nutrients" to the differential impact of specific particulate and dissolved nutrients.

A key question is how to proceed to do the "adjusting" of the TMDL milestones to account for increased sediment-associated nutrients passing out of the reservoir. Key recommendations of this review in this regard include: (i) that the effect of the change in overall "trapping capacity" must be accounted for (the LSRWA analysis done so far relates only to increased scour and not to total trapping capacity), (ii) priority should be given to accounting for the added particulate phosphorus, and (iii) the additional sediment load (other than associated nutrients) should NOT be an additional burden on TMDLs. Calculations by Hirsch suggest that the net loss of trapping efficiency by Conowingo may be in the range of 2300 tons of phosphorus per year. The basic question facing the midpoint assessment then is: what would it take in terms of upstream phosphorus management in order to overcome the impact of ~2300 tons of phosphorus? This estimate is not highly accurate. The team that did the LSRWA report has the simulation expertise and capacity to test these estimates, but they have not yet performed this specific simulation. The follow up to this LSRWA effort really needs to address these estimates and replace them with better ones if they can (including uncertainty bounds).

This review supports enhanced long-term monitoring of the flux of sediment and associated nutrient flux in the lower Susquehanna River system. This LSRWA report certainly makes the case that it is needed, as there was inadequate observed data to sufficiently understand nutrient transport dynamics or for model calibration and validation. Updated technology should play a key role in enhanced long-term monitoring of the Lower Susquehanna/upper Chesapeake Bay (and other river/estuarine transitions in the Chesapeake Bay system). There are a variety of technologies that can be applied using *in situ* sensors to collect an essentially continuous record of sediment concentrations and flux for use in inferring sediment-associated nutrient transport, including inference of grain size distribution.

Question 6: Do the technical appendices provide the necessary documentation for the models and their applications in support of the study's results, findings, and conclusions?

As described above in response to Questions 3 and 4: (i) the HEC-RAS modeling effort was ultimately unsuccessful, and results of the HEC-RAS simulation did not form an integral part of the main report, and (ii) the existing application of the AdH model, although generally consistent with the validation data used, was not reliably predictive beyond constraints provided by a few integrated observations of sediment-related properties of the system. Additional comments from individual reviewers directed toward the HEC-RAS and AdH modeling efforts beyond the items discussed in response to Questions 3 and 4 are included in this section as responses to Appendix A and B. Appendix C and Appendix D of the LSRWA Draft Report describes applications of the Chesapeake Bay Environmental Modeling Package (CBEMP) to estimate changes arising from additional scour from behind Conowingo Dam during large events. Unlike the AdH and HEC-RAS models, which are relative new model systems that had not been applied before to the Lower Susquehanna environment, the CBEMP model has a decades-long history of applications and evolutionary improvements within the Chesapeake Bay system, including numerous peer-reviewed publications assessing its performance in this specific environment. The application of the CBEMP model to the LSRWA effort is generally well done, and the conclusions are reasonably supported, especially given that the LSRWA was intended as an exploratory analysis.

Additional comments on the appendices and main report

The last section of the review contains additional comments from individual reviewers referring (i) to the remaining appendices and (ii) to more isolated issues within the main report, with the latter specified by page number. Although these are individual issues that were not necessarily identified by multiple reviewers, these remaining comments are nonetheless important and should also be considered by the LSRWA authors in any revisions and/or follow up analyses.

SYNTHESIS OF INDIVIDUAL REVIEWERS' COMMENTS

Question 1: Does the main report clearly define the goals, strategies, and the results/conclusions of the study, and also present adequate background material at a level suitable for understanding by non-technical audiences?

<u>**Goals and Strategies**</u>

Although clearly stated on p.10, the goals declared in the main report (which stress both sediment and nutrient management) are inconsistent with the methodological approach taken by LSRWA (which mainly emphasized sediment). The main report's Introduction (p.10) states that: "…the specific goals and objectives for the LSRWA effort were: 1. Generate and evaluate strategies to manage sediment and associated nutrient loads delivered to Chesapeake Bay… 2. Generate and evaluate strategies to manage sediment and associated nutrients available for transport during high-flow storm events to reduce impacts on Chesapeake Bay. 3. Determine the effects to Chesapeake Bay due to the loss of sediment and associated nutrient storage within the reservoirs on the lower Susquehanna River." Note that the above goals statement repeatedly weights "sediment and associated nutrient(s)" equally. Yet the study put much more of its effort into addressing issues of sediment management to extend the life of Conowingo Dam as opposed to nutrient management to protect Chesapeake Bay water quality. In fact, there is very little content in the overall LSRWA effort which focuses on managing nutrients. The inconsistency between the stated goals and the general strategies followed is an issue that propagates throughout the analysis for the entire assessment.

Although the word "goal" does not appear in the Executive Summary, the Executive Summary does state (on p.ES-1), "The purpose of this assessment was to analyze the movement of sediment and associated nutrient loads within the lower Susquehanna watershed through the series of hydroelectric dams (Safe Harbor, Holtwood, and Conowingo) located on the lower Susquehanna River to the upper Chesapeake Bay. This included analyzing hydrodynamic and sedimentation processes and interactions within the lower Susquehanna River watershed, considering strategies for sediment management, and assessing cumulative impacts of future conditions and sediment management strategies on the upper Chesapeake Bay." A similar "purpose" statement appears in the Introduction on pp.5-6. Note that the word "nutrient" appears only once in the above statement, and the purpose of the study was mainly to address "sediment management". The above quote seems to be a more realistic statement of the actual goals of the study.

It appears that the goals as presently listed in the Introduction to the main report were not the original goals of the study. Page ES-4 states, "The conclusion that the primary impact to living resources in Chesapeake Bay was from nutrients and not sediments, was not determined until late in the assessment process… Management opportunities in the Chesapeake Bay watershed to reduce nutrient delivery are likely to be more effective than sediment reduction opportunities at reducing impacts to the Chesapeake Bay water quality and aquatic life from scour events, but these management opportunities were not investigated in detail during this assessment." By crafting a goals statement that reflects findings from late in the study, the report's authors may have unintentionally undermined the connection between the study's goals and approach. The assessment actually focuses much more on the movement of sediment and options for sediment removal from the Conowingo reservoir rather than managing the associated nutrients to improve water quality.

This review recommends that the "original goals" of the study (i.e., sediment management to extend the life of Conowingo Dam more than nutrient management to protect Chesapeake Bay water quality) be presented in the introduction followed by a fuller explanation of how and why the focus of the study evolved in time. Presently, the report only briefly states that during the course of the study it became clear that nutrients were more important than sediment. More background is needed in the introduction regarding how and why this judgment was made and how the course of the study then evolved.

Results and Conclusions

Both the Executive Summary and Chapter 9 of the main report (entitled "Assessment Findings") present four categories of conclusions that generally correspond to each other. Within the individual context of the Executive Summary or Chapter 9, each set of conclusions is well written and easy to follow and understand. Their general content also includes the most important results and conclusions of the study. However, the phrasing, main emphasis, and ordering of these four categories is different in the Executive Summary versus Chapter 9, which is unnecessarily distracting. Also, the most meaningful aspect of each category of findings is not necessarily used as the header for its respective category. Note that in this section of the review, the scientific validity of the study's results/conclusions is not addressed in detail; that is the focus of Questions 3 and 4.

This review recommends that the four categories of main results/conclusions be presented in the same order in both the Executive Summary and in Chapter 9 and the headers be made more consistent and compelling. Working from the ordering of the main findings as presented in Chapter 9, the following changes are recommended. The title "Finding #1: Conditions in the Lower Susquehanna reservoir system are different than previously understood" (p. 189) is simultaneously vague and obvious. The subheading that immediately follows: "Conowingo Reservoir is essentially at full capacity; a state of dynamic equilibrium now exists" is much more meaningful and to the point. A choice similar to the first bold heading in the Executive Summary (p. ES-1) – i.e., "Loss of Long-Term Trapping Capacity for Sediment-Associated Nutrients" could also be a good choice. One of these two (or another similarly meaningful header) should be used in both sections.

"Finding #2: The loss of long-term sediment trapping capacity is causing impacts to the health of the Chesapeake Bay ecosystem" (p. 192) aligns with the third heading in the Executive Summary ("Nutrients, Not Sediment, Have the Greatest Impact on Bay Aquatic Life", p. ES-3). Again, the Executive Summary header is more meaningful. They should be made consistent and both be listed second (or both third) among the main findings. Finding #3 – which might be slightly rephrased to "Sources upstream of Conowingo Dam deliver more nutrients and therefore have more impact on the upper Chesapeake Bay ecosystem than do the sediment-associated nutrients associated with the Conowingo Dam" (p. 193) – corresponds mainly to the second heading in the Executive Summary ("Watershed is the Principal Source of Sediment", p. ES-2). In this case, the spirit of the finding in Chapter 9 is more appropriate because it emphasizes nutrients. Again, they should be made consistent and both be listed third (or both second).

"Finding #4: Managing sediment via large-scale dredging, bypassing, and dam operational changes, by itself does not provide sufficient benefits to offset the upper Chesapeake Bay water quality impacts from the loss of long-term sediment trapping capacity" (p. 195) corresponds to the fourth heading in the Executive Summary ("Sediment Management Strategies", p. ES-3). These are problematic in that the phrase "Sediment Management Strategies" is not a conclusion, while Finding #4 as phrased in Chapter 9 is not strictly true. Repeated large-scale dredging and removal of accumulated sediment and isolated placement elsewhere would indeed restore sediment trapping ability of the reservoirs and associated water quality benefits to the upper Chesapeake Bay. The (valid) compromising issue is cost effectiveness. Thus, the fourth header/finding needs to be rewritten, perhaps to something with a meaning along the lines of "Managing sediment via large-scale dredging, bypassing, and dam operational changes is not a cost-effective approach to offsetting the upper Chesapeake Bay water quality impacts from the loss of long-term capacity for trapping sediment-associated nutrients".

Background Material

Although the background material is indeed presented at a level suitable for non-technical audiences, this review recommends that large portions of the background material contained in the main report (specifically all of Chapter 2) be moved to an appendix. The level of sophistication of Chapter 2 is suitable for scientifically literate audiences who are not necessarily well-versed in the environmental issues and technical approaches specific to Chesapeake Bay restoration. One reviewer noted approvingly that the level is well suited to an introductory course on Chesapeake Bay taught at their university. However, multiple reviewers also noted that the placing of so much background material (52 pages) in Chapter 2, immediately following the report's Introduction, is actually counterproductive.

The remainder of the main report never refers to Chapter 2. In contrast, the other Chapters refer to each other, and the sub-sections of the report's Introduction (Chapter 1) explicitly mirror the next several report chapters. Sections 1.1-1.3 and 1.5 "Project Authorization/Project Sponsors and Partners/Study Area/Significance" are analogous to Chapter 3 "Management Activities in the Watershed", Section 1.10 "Assessment Approach" (p. 13) is analogous to Chapter 4 "Modeling Tools and Applications", Section 1.6 "Problem Background" (p. 8) is analogous to Chapter 5 "Problem Identification"), and Section 1.9 "Assessment Products" (p. 10) is analogous to Chapter 6 "Development of Sediment Management Strategies"). Thus Chapter 2 notably interrupts the flow of the report and seems to be an awkward add-on.

A non-technical end-user of the present report who attempted to read it in sequential order would likely be side-tracked by Chapter 2, and find it harder to locate the key material and findings of the LSRWA. They might logically assume that Chapter 2 was part of the information that was input to the models used to complete the Assessment, when it actually contains free-standing information compiled separately from the rest of the project. Removing Chapter 2 from the main body of the report will make the main report much more manageable for end-users, reducing its length of the text by 25%, from over 200 pages to less than 150 pages. The average length of the remaining eight chapters of text would then be 19 pages each, compared with the unwieldy 50+ pages of Chapter 2. Nonetheless, it is not recommended that the background information in Chapter 2 be deleted from the Assessment as a whole. The material contained in Chapter 2 is generally well-written, useful information that, within the context of the Appendices, could be helpful to some readers to better understand this complex subject. It would be most logical to change Chapter 2 into Appendix A, but its precise location may be left to the authors.

Question 2: Are the alternative sediment management approaches clearly described and documented? Does this background material provide supporting evidence for the finding and conclusions of the study with regard to alternative sediment management approaches?

Where clearly defined as methods for reducing the cubic yards of total sediment present in the reservoir, the alternative sediment management approaches were found by the large majority of the reviewers to be well-documented, well-described, and comprehensive. However, the distinction between strategies, sediment management alternatives, representative alternatives, and scenarios should be made clearer at an earlier stage of the report. Multiple reviewers found these concepts difficult to separate as they initially read through the report. It should be emphasized that the positive comments regarding the analysis and comparison of alternative sediment management approaches depend on the fact that the main conclusions regarding the alternative sediment management approaches did not critically depend on the fidelity of the HEC-RAS and AdH models. The alternative management scenarios are actually only weakly coupled to the reservoir transport models; they are clear consequences instead of the long-term sediment budget as constrained by observations. As a result, the uncertainties in the reservoir modeling process should not have much influence on the overall findings.

It must also be stressed early and repeatedly that the monetary costs associated with alternative sediment management approaches specifically focus on the cost of reducing the amount of total sediment behind the dam, not on the cost of managing the impact of associated nutrients on the Chesapeake Bay. Consider, for example, scenarios 2C (open water placement, bypassing) and 3A (upland placement, Stancill Quarry) in Table 6-6 (p. 168). The estimated unit costs are only $6-12 per cubic yard for scenario 2C with bypass dredging, whereas the costs are $23-35 per cubic yard for scenario 3A with upland placement. This makes it seem that upland placement is about 3x more expensive than bypassing. However, it relies on the implicit assumption that a ton of sediment that is bypassed has the same environmental impact as a ton of sediment that is dredged and placed upland in a landfill. Even a ton of sediment that is removed is not uniformly equal given that nutrient (primarily P) loads are tied most closely to clay-sized sediment.

Although it is not specifically described as such in the draft report, the overall economic analysis in the LSRWA is in essence a cost-effectiveness analysis (CEA). In contrast to cost-benefit analysis in which the positive and negative impacts of alternatives are expressed and directly compared in monetary terms, CEA expresses some key impacts in non-monetary but still quantitative terms. One of the common challenges faced when conducting a CEA is that key impacts are often multi-dimensional and therefore difficult to fully capture and summarize in a single indicator. In specific parts of the main report and appendices (e.g., Table 6-10 in the main report entitled "Sediment Management Strategy Summary Matrix" and appendix attachment J-3 "Summary Table of Sediment Management Alternatives' Evaluation"), environmental impacts are presented side-by-side with the dollar costs of reducing cubic yards of sediment in the reservoir. In such a context, it is sufficiently clear that the "cheaper" alternatives are not the "better" alternatives.

This review recommends that further caveats be included throughout the report to clarify that the dollar-based cost estimates regarding alternative sediment management approaches are specifically for reducing cubic yards of total sediment in the reservoir, not for achieving broader goals regarding nutrient reductions. The dollar-based cost estimates in Table 6-6 are reported in the Executive Summary (p. ES-4) and elsewhere in the assessment report. Wherever the dollar-based cost estimates are stated, their meaning with regard to increasing reservoir capacity rather than improving water quality should be more clearly indicated. The report should also emphasize that further analysis would be required to appropriately rank the alternative strategies based on a more environmentally relevant total cost in terms of dollars per pound of nitrogen and/or phosphorus reduction.

There are an enormous number of potential management alternatives, far too many to consider in depth for a program of this size and scope. Narrowing them down to a reasonable number of representative examples, then further limiting those examples by a scoping analysis to a set that might be worth further study, was an appropriate approach to handle this complexity. Unfortunately, an artifact of the categorization techniques used to make sense of the multiple potential scenarios is an artificial limitation of cross-category considerations and benefits. Combinations of different scenarios and management approaches might actually be the best possible approach, either in parallel or sequentially. For example, a one-time major dredging in the region just upstream of the dam, followed by bypassing from further upstream to slow subsequent infill, might have longer lasting effects. These more complex scenarios are clearly beyond the scope of this report, but they should be mentioned and acknowledged as worthy of exploration.

The economic analysis and comparison of the alternatives could be further enhanced by considering, and at least discussing in qualitative terms, other possible co-benefits (and possibly co-costs) of the alternatives. For example, in addition to reducing loads to the Bay, many of the BMPs provide other ecosystem service benefits such as improved water quality upstream from the Bay, carbon sequestration, water storage/flood control, recreation benefits, etc. (see USEPA report EPA/600/R-11/001 for an analysis that includes some of these co-benefits). These co-benefits could meaningfully offset some the costs associated with the BMP alternatives; therefore, they should be acknowledged in the report. Similarly, dredging activities may entail aesthetic disamenities (i.e., external costs), which would have the opposite effect by increasing the total costs of this set of alternatives.

Question 3 & 4: Does the main report provide clear, supporting evidence for the results, findings, and conclusions of the study? Does the report adequately identify key uncertainties in the model applications which, with better information, could change the predicted outcomes of the alternative management scenarios evaluated in this study?

As discussed in the introduction to this review, the most important conclusions which follow logically from the findings of the LSRWA study are generally well-supported by the overall content of the study. Nonetheless, there are many areas that can be improved. The comments in this section focus on specific aspects of the study that are key sources of uncertainty but have not been fully explained as such in the main report. This section of the review also highlights some sections of the report that are most likely erroneous and/or are most in need of improvement or additional explanation.

General uncertainty

Although the report lists and discusses sources of uncertainty, it expresses the expected confidence intervals on its model predictions less often. For example, if storm sediment transport can hardly be measured to within +/- 50%, model predictions can hardly be expected to be better (for example, in Appendix A, an error of about this range is indicated for predicting reservoir scour). Ideally, ranges should be provided for all model predictions (rather than a specific number). Although there is no single accepted procedure for reporting uncertainty in the context of scenario modeling, a part of the report should more explicitly explain why confidence intervals on predictions are generally not provided.

Statistics inferring a 10% change in transport might be (well) within the uncertainty of the total-transport values. References to differentials as small as 0.1% (for example, see table 6.7) imply accuracies in characterizing the sedimentary system that could not be confirmed by any type of measurement known by the reviewers. However, if qualified as model results and indications are in relative terms, there may be value in such numbers as long as all such values are qualified as "well within measurement error." Hence, "we cannot infer any significant change" should be stated up-front based on results of such analyses. In many of the modeled scenarios, the changes in attainment of water quality criteria with fairly large management actions would appear to a non-technical reader to be very small. For instance, p. 135 states: "…estimated…non-attainment…of 1 percent, 4 percent, 8, percent, 3 percent…" One should ask if such estimates are statistically significant. Similarly, in appendix A, p. 25, the net deposition model indicated that ~2.1 million tons net deposition in the reservoirs occurred in 2008-11. This is the difference of two order-of-magnitude larger numbers (22.3M tons entered the reservoir, 20.2M tons entered the Bay). There is a rule-of-thumb in sedimentology: ±10% in concentration or transport is 'within error'. Does the precision of the computed difference fall within the margin of error in these metrics?

Propagation of uncertainty in model predictions from the reservoir sediment transport prediction to those of the Bay Ecological Model may be significant. If optimally constrained by observations, reservoir calculations may have reasonable accuracy and precision when averaged over longer timescales, but less accuracy over shorter timescales. However, the key timescales for many biological processes are much shorter than those of an annual sediment budget, and this could be a major source of uncertainty in the predictions of the efficacy of the sediment management scenarios. This disparity in process timescales is important to address in the text and in the conclusions of the study.

Anoxic volume days appears to be a variable that is relatively more sensitive to the model scenarios presented in the report (e.g., Table 6-8). This suggests something alluded to in the report on several occasions, that a large fraction of the deep water in Chesapeake Bay is sitting on the threshold of being anoxic, and seemingly small changes in concentration (0.2 mg/l) lead to substantial relative changes in anoxic volume. It is worth clearly stating that the high sensitivity of this one criteria to small changes in load stands out among the other variables (e.g., chlorophyll-a, chl-a). It strikes the reviewers that changes in chlorophyll and dissolved oxygen associated with "normal" inter-annual variability in climate and nutrient loading are much higher than those associated with additional Conowingo Dam-derived nutrients as simulated here. One might conclude that given this fact, that the potential effects of dam-derived particulates are trivial. Given the quantifiable effects on chl-a and DO derived from these model simulations, however, it may be worth emphasizing that it would be difficult to tease out the Dam effects from observations given natural variations in load, flow, chl-a, and DO, and that the models are therefore necessary for assessment and prediction.

Stated sediment discharges from the Conowingo Dam are inconsistent with the literature

On p. 113 the report states, “A close inspection of the model simulation results indicate that trace erosion does occur at lower flows (150,000 to 300,000 cfs), which is a 1- to 2-year flow event. This finding is consistent with prior findings reported by Hirsch (2012).” The Hirsch (2012) findings are different from what is expressed here. The relevant statement from Hirsch (2012) is: “The discharge at which the increase [i.e., the increase in suspended sediment concentrations at the dam] occurs is impossible to identify with precision, though it lies in the range of about 175,000 to 300,000 cfs. Furthermore, the relative roles of the two processes that likely are occurring – decreased deposition and increased scour – cannot be determined from this analysis.”

In the second paragraph of p. 190, the report states that “…a major scour event will occur once every 4 to 5 years, and minor scour events with trace amounts of erosion will occur every 2-3 years (150,000 to 300,000 cfs)…” The statement that minor scour events will occur every 2-3 years is incorrect on two counts. First, the events in excess of 150,000 cfs happen on average about 3 times per year (not once every two to three years). The number of such days (with daily mean discharge between 150,000 and 300,000) is about 11 days per year. In contrast, days with daily mean discharge greater than 400,000 cfs happen about 0.45 days per year. Second, it is not clear that the increase in sediment loads in the 150,000 to 300,000 cfs range is really a result of scour. It may be that it is mostly a result of a decrease in the amount of deposition that occurs at these flows. The statement overall seems intended to downplay the importance of these moderately high flow days, but they do make a substantial difference in the trend in net outflows of sediment and phosphorus to the Bay. The impacts of changes must be viewed as a product of magnitude and frequency. The magnitude of the change at the 400,000+ cfs range is large, but the frequency is small. The magnitude of changes in the 150,000 to 400,000 cfs range is smaller, but the frequency is much higher.

Also on p. 190, the report indicates that, “The total sediment outflow load through the dam… increased by about 10 percent from 1996 to 2011…” These results are so strongly at odds with other published numbers on this subject that some explanation and discussion is certainly required. Hirsch (2012) reports an increase in flow-normalized flux over the period 1996-2011 of 97 percent (see Table 3 of Hirsch). Also, Langland and Hainly (1997) published an estimate of change in average flux from about 1997 to the time the reservoir is full of 250%. Reporting a 10% increase in light of these two other findings appears erroneous.

At bottom of p. 190 the text reports on reductions in TN, TP, and TSS as 19, 55, and 37%, respectively, for the past 30 years for loads “to the lower Susquehanna River”, referenced to http://cbrim.er.usgs.gov. This could mean loads delivered to the upstream end of the reservoir system or loads delivered at the downstream end where the river enters the Chesapeake Bay. At the Marietta site (above the reservoirs), the actual results were downward trends of 29.9, 40.1, and 44.8%, respectively, while at Conowingo the USGS reports 22.3, 0.8, and 10%. In either case, these numbers are different from those mentioned in this report. An additional issue here is that the USGS values are trends in flow-adjusted concentration, expressed in percentage terms. The text is referring to trends in nutrient and sediment loads and not trends in concentrations.

For each of the above cases, the report authors should either correct their numbers or present a clear explanation that reconciles why their estimates are significantly different from other estimates that are based on analysis of observed data.

Reduced deposition associated with reservoir infilling has been neglected

The fundamental issue motivating the LSRWA study is that the net trapping efficiency of Conowingo Reservoir has decreased dramatically over the past 15 to 20 years. Net trapping efficiency is the sum of increases in average annual scour and decreases in average annual deposition. However, the simulations and calculations in the study only considered the increase in scour.

Based on the use of WRTDS (a published statistical method for evaluating fluxes and trends in fluxes, a method that is central to two of the publications cited by the LSRWA, i.e., Hirsch, 2012 and Zhang et al., 2013), the estimated flow-normalized flux of TP out of Conowingo Dam between the 1996 condition and the 2011 condition has increased by 3.65 tons/day (going from 6.64 to 10.29 tons/day). This increase equates to a 5329 ton increase over the four year simulation period. In the LSRWA report, the simulation of scour is captured as a single event with a total magnitude of 2600 tons (see Table 5-9 scenario 3). Based on these two numbers, it would be logical to conclude that the remainder of the increase over the 1996 to 2011 period would be the difference between 5329 and 2600 tons, which is 2729 tons. This suggests that about half of the increase in loading of TP to the Bay comes in days with discharges below 400,000 cfs. Without having the model simulate the full range of changes due to the loss of trapping efficiency, the report's authors have introduced a large uncertainty into the results, and it is one that surely leads to an underestimate of the impact of the filling of Conowingo.

This issue underlies a significant weakness in the report, which is that it focuses its inquiry on the impact of large, but infrequent, scour events rather on the total impact of the change in trapping efficiency of the reservoir system. The flaw in the logic of the report is expressed, for example, on p. 137: "Generally speaking, when flow is below the scour threshold, sediment is estimated to settle out when in dynamic equilibrium. Consequently, water quality in the Bay is the same as it would be if the reservoirs were still filling as long as there is no scour event." This same logical flaw appears again on p. 142: "...without storms, the reservoirs will continue to trap sediments in the short term at rates consistent with today", and on p. 190: "…major scour events will occur once every 4 to 5 years, and minor scour events with trace amounts of erosion will occur every 2-3 years (150,000 to 300,000 cfs) and at all other times, the reservoir will continue to trap sediment and associated nutrients."

The review recommends that all statements that indicate that reservoir trapping of sediment and associated nutrients is unchanged in the absence of scour be removed. In addition, a discussion should be added to the report that clearly states that decreases in the average annual deposition in the reservoir in the absence of scour have not been considered and that the added transport of sediment-associated nutrients past Conowingo Dam due to decreased deposition may be as large as that added due to increased scour.

Grain size effects within and exiting the reservoir were not sufficiently considered

It is reasonable to expect that the texture of the sediment behind the dam will continue to coarsen through successive scour events and deposition interludes. The report states in several places that less sand exits the dam at the downstream end than enters the reservoir at the upstream end (e.g., p. 191), both because it deposits first at the upstream end and because it is much more prone to settle out of suspension or transport as bedload after it is remobilized. The reservoirs are not in a final state of dynamic equilibrium if the sediment entering the reservoirs is coarser than the sediment leaving. The reservoirs appear to be preferentially storing sand and, with scour, exchanging that sand for silts and clays. Over time, this implies even a "full" reservoir will gradually fill with sand at the expense of fines. This progressive change in grain size will gradually change the threshold conditions for sediment entrainment and change the grain size of sediments that are typically mobilized by scour. But how long with this transition take? Thus, the dynamic equilibrium that is described in the report is changing over time, and it would be worthwhile to try to predict how many cycles of deposition and scour might be required before the dynamic equilibrium becomes less dynamic.

Nutrients associated with fine sediments, not with the total load of sediments, are the main water quality concerns. The report acknowledges that sand-sorbed P is more or less inconsequential in P transport. However, all sediment-discharge values are expressed as "total loads." Since P transport is closely tied to fines, and presumably very closely tied to clay-size particles, transport metrics computed for fines, and particularly for clay-size particles, might yield different conclusions than those derived from "total" load comparisons. It is also important to clearly define what is meant by total load. Sedimentological nomenclature denotes "total load" as all material in transport, be it defined as bedload plus suspended load (with caveats), or bed-material load plus washload (no caveats) (ASTM International, 1997, Terminology for Fluvial Sediment; Diplas et al., 2008, p. 306 at: http://water.usgs.gov/osw/techniques/Diplas_Kuhnle_others.pdf). It is not clear that "total load" refers to either of these metrics in the LSRWA report.

The combination of these two above grain size effects, (i) changing grain size in time and (ii) the greater effects of fine sediment in transporting nutrients, mean that the effects of the reservoir on water quality have not reached a full dynamic equilibrium. However, the report did not address whether reservoirs were in dynamic equilibrium with respect to nutrients other than by assuming that if sediment was at equilibrium, then nutrients were also. Although information was provided in the report on particle-size distributions in reservoir bed sediments and sampled streamflow, and on the relevance of particle size to P concentrations, there was no tie-together and possible revision of load values to indicate how the interplay of these metrics might result in changes to a fundamentally important metric, fine-sediment (particularly clay-size material) transport to the Bay. In reality, as the reservoir evolves in time toward containing a larger and larger fraction of sand, the sediment scoured during large events should progressively contain fewer fines and fewer associated nutrients.

The review recommends that the concept of dynamic equilibrium be clearly qualified in the report to indicate it does not yet apply to sediment grain size, and thus it does not yet fully apply to the flux of fine sediment or associated nutrients.

Limitations of HEC-RAS model were not made sufficiently clear in the main report

The HEC-RAS modeling effort was largely unsuccessful, and the HEC-RAS simulation was largely abandoned as an integral part of the main report. Reasons for this are listed on pp. 22-24 of Appendix A (Section 6.0 Model Uncertainty and Limitations). Apparently the primary reason why the HEC-RAS modeling failed had to do with sediment calculations: fall velocity estimates appeared to be off and could not be corrected and, for the cohesive model, only a single critical shear stress could be defined for the cohesive sediment bed. Critical shear stress simulations produced contradictory results, which remained unresolved. A member of the review panel familiar with the RAS model has also found that RAS, in the beta version used in the LSRWA study, simply makes incorrect calculations. Although HEC-RAS results were used to supply sediment to the upstream end of the 2d AdH model, this use of RAS output was fortunately of minor significance to the overall LSRWA effort. Upstream inputs to the Conowingo Reservoir could also be estimated from empirical analysis using USGS transport data.

Another source of inconsistencies between the HEC-RAS application and USGS transport estimates may be associated with the different definitions of bed-material load, washload, suspended load, bedload, and total load. The transport equations available in HEC-RAS produce bed-material load data. Bed-material load is that material in transport – suspended or as bedload – that is characteristic of the material composing the bed. The remainder, which is not characteristic of the bed, is washload, and washload is substantial in this system. Estimates from equations/models based on bed-material size data and hydraulic information do not include the washload component. Empirically derived "total load" estimates, on the other hand, are actually suspended-sediment loads, as is the output from the Estimator model. Suspended load is operationally defined as being computed from material captured by a suspended-sediment sampler. It includes the washload component. This is a distinction that seems to be fundamentally important to the LSRWA with respect to the interpretation of modeled and empirical suspended-sediment transport data. Conversely, most if not all output from the equations and models other than the empirically-based Estimator model and transport curves is expressed as bed-material load. Using different output metrics from various models amounts to computing "apples and oranges" in sediment and nutrient transport.

Presently, the description of the conclusions associated with HEC-RAS in Chapter 4 of the main text seems to underplay its poor performance. For example, p. 81 of the main report states, "For the LSRWA effort, the HEC-RAS model outputs were deemed acceptable because they provided relative understanding of the physical process of the upper two reservoirs…" This positive statement appears inconsistent with the analysis of HEC-RAS performance as assessed by this review. This review recommends that the failure of the HEC-RAS model be reported more clearly and fully in the Chapter 4 of the main report.

Although consistent with four observed, integrated sediment-related properties of the system, the AdH model was not fully validated

The AdH model was not calibrated, but instead the authors use what they refer to as a validation approach. Their use of the term validation differs from what is considered to be the norm in which a model is calibrated using part of a data set (typically part of a period for which data are available) and then evaluated, or validated, by applying the calibrated model to the balance of the data set. In their approach, four different parameter choices (defined primarily by the critical shear stress of the bed sediment) were used in four simulations and the model calculations were compared to simple, integrated properties of the system (net erosion and deposition cumulated over four years, average annual sediment retention during non-storm years, estimated reservoir scour for different events, and percent sand in sediment discharge). One of the four simulations was then selected for further work based on (i) net erosion and deposition for the entire reservoir, cumulated over four years (targeted to a net deposition of 3.0 to 4.0 million tons), (ii) estimated reservoir scour for different events (targeted to the USGS scour curve), (iii) sediment retention of about 1.0 to 1.5 million tons per year during the non-storm period, and (iv) percent sand in sediment discharge over Conowingo Dam less than 10%. That is, only four scalar quantities were used to validate the model. This is slim verification for such a large and detailed model. What one can conclude is that a suite of parameters and boundary conditions for a large, detailed, and complicated model with many possible interactions was found to come roughly close to mimicking the gross behavior of the system based on matching four simple, integral measurements.

Although many other aspects of the model can be evaluated, no further information is given in that regard. No information is provided regarding whether more detailed internal results of the model (e.g., patterns of local scour and deposition) were evaluated for plausibility and consistency. The major reason for using a 2d model is to capture both lateral and along-stream changes. Reservoir bed elevations are available from 2008 and 2011, which provides an opportunity to evaluate model performance. But it is not clear that these elevations were used in this way. No information is given regarding whether other combinations of parameters might have produced similarly good integral results. It remains unresolved whether the match between model and measurement was a case of getting the right answer for the wrong reasons.

Another aspect of this AdH discussion that could be improved is the effect of the uncertainties in AdH predictions near the Dam face. These uncertainties take two forms – the overly simple approximation of the boundary condition at the dam that is acknowledged in the text, and related problems associated with 3D flow effects very near the dam. How far away from the Dam are the predictions of flow and sediment transport likely to be affected? Will these uncertainties affect predictions of scour significantly, or are the primary scour zones outside the region of influence?

This review recommends that the limitations of the AdH application as described above be made much clearer in both Appendix A and the main report.

AdH was forced by boundary conditions outside the range of observed values

The tenuous nature of the model validation is made more uncertain by the fact that the values for the key boundary condition (critical bed shear stress for sediment entrainment) in the final selected model fell largely outside the range of values measured by the SEDFLUME or were unmeasured and taken from the literature. The critical stress reported from SEDFLUME had a median value of 0.083 lbf/ft^2, while the critical stress used for the top foot of the reservoir sediment in the selected AdH model was reported as 0.03 – 0.06 lbf/ft^2, largely outside the range of the measured SEDFLUME values. The critical stresses used in the model for sediment one-to-two feet and two-to-three feet below the surface were 0.1 lbf/ft^2 and 0.14 lbf/ft^2, respectively. These depths were unsampled in the field, and the critical stress values were taken from the literature.

Because sediment transport has a threshold and is a nonlinear function of flow, errors in the bottom boundary condition will, in general, produce large errors in calculated transport rate and morphodynamic change. Even though a set of parameters was selected that provided rough similarity to the observed net scour and deposition over the four year run time, this provides no assurance that the predicted patterns and timing of transport, scour, and deposition match reality. Thus the application of the AdH model does not extend the empirical understanding provided by existing reservoir bathymetry and stream gaging.

Rather than attempt to further refine the sediment bottom boundary conditions with direct measurements, a more promising approach would be to collect suspended sediment measurements in the reservoir and evaluate the choice of model boundary conditions by comparing a time series of transport calculations against observations. This could provide direct calibration, *in situ*, of model performance. The extensive and spatially explicit output from a model such as AdH provides many varied opportunities for evaluating model performance. Does the model aggrade where we see aggradation and degrade where we see degradation?

The AdH model alone was not reliably predictive; observations should be emphasized

The AdH application in this study has been developed to the point that scour and deposition is consistent with what is already known from survey and sampling observations. However, the AdH model application does not refine that empirical understanding. The uncalibrated and weakly constrained model application provides an essentially heuristic basis for scenario evaluation, and the AdH model has not, as yet, added substantial new understanding of the sediment dynamics of the reservoir. The modeling does not strongly reinforce the existence of a scour threshold at 300,000 and 400,000 cfs. At best, it can be said that an uncalibrated model was found that produces results that are consistent with that particular threshold. Other choices of model input (including bed sediment parameters more in the range observed by SEDFLUME) would likely produce a different scour threshold.

The report would be more convincing if some of the observational data in the Appendices were incorporated into the main report, particularly those that bear on the time-varying sediment budget. This is really the heart of the matter, and highly sophisticated (but weakly constrained) models are not essential to illustrate what is happening. Many of the important conclusions of the report regarding sediment and nutrient delivery from the reservoirs are direct consequences of the sediment budget of the system and its evolution through time (i.e., the amount of sediment delivered by the watershed and trapped by the reservoirs and how these amounts have varied over the last several decades). Even if the fidelity of the models can be questioned, the observational data are compelling.

At present, the conceptual weaknesses of the models and the inherent uncertainty in model results are not well-described or acknowledged in the main report. Many of the basic conclusions of the study are direct consequences of the long-term sediment budget of the watershed and reservoir system, and while supported by the model results, are independent of the weaknesses of the modeling, and therefore citing them would strengthen the conclusions. These can be easily added. The uncertainties are discussed more openly in Appendix A, and it is recommended to expand that discussion and move some to the main report.

Question 5: Are the recommended follow-up evaluations and analyses (Section 9.1) complete and comprehensive as well as clearly stated to enable the next phase of work to continue under the Partnership's Midpoint Assessment?

Many of recommendations for future work and modeling tool enhancement are very good and are consistent with the views of this review. Alternate and/or improved models should continue to be pursued in future work in combination with additional data collection. Predictions from multiple models should be compared, including relatively simple models (e.g., the analytical model presented at the beginning of Appendix C). However, the recommendations as presently written over emphasize the significance of sediment (relative to nutrients) and do not include some important additional possibilities. Recommendations #1 and #4 (reproduced below as 5.1 and 5.4), should be expanded to acknowledge the need to develop improved scientific understanding of several key issues, rather than simply collecting more data and developing better models. One of the outcomes of this study should be to identify areas where our scientific understanding may be insufficient to achieve management goals, and to suggest future scientific studies to provide this knowledge. The goal of these studies is not simply to provide monitoring data for analysis or model calibration, but to provide the conceptual understanding of the system that will lead to the improvement of models.

> **<u>5.1. Before 2017, quantify the full impact on Chesapeake Bay aquatic resources and water quality from the changed conditions in the lower Susquehanna River and reservoirs</u>:**

Throughout the text following Recommendation 1, "sediment and associated nutrients" should be changed to "sediment-associated nutrients". A key finding of the LSRWA study that has large ramifications for management activities is that sediment-associated nutrients have a much larger impact on Bay water quality than the sediments themselves (see additional discussion of this issue within Section 5.2 below). In addition, Recommendation 1.2 would be better written as something like: "Determine the quantity and nature of the sediment-associated nutrients transported downstream under current conditions (dynamic equilibrium) versus conditions that prevailed in previous times when the reservoirs had substantial trapping ability." Follow-up studies need to consider the full range of hydrologic conditions, from moderate to high flows, which generally do not result in scour (but still reduce the deposition of sediment-associated nutrients in the reservoir), all the way up to the very high but very rare events that do result in scour (see additional discussion above under the header “Reduced deposition associated with reservoir infilling has been neglected”).

The filling of Conowingo has relatively less impact on nitrogen inputs to the Bay (because so much of the total nitrogen load to the Bay is in the dissolved form) but it does cause a substantial increase in the particulate phosphorus inputs. Ecosystem studies of the Chesapeake Bay based on present-day algal communities indicate that Bay hypoxia is more sensitive to dissolved nitrogen input than particulate phosphorus input, so perhaps the hypoxia is presently relatively insensitive to particulate phosphorus from Conowingo. Alternatively, a resulting shift toward higher P:N ratio in the nutrients input to the Bay could result possibly in a shift in the types of phytoplankton. This is speculation - but could a higher P:N ratio cause a shift towards more blue-green algae that have an ability to fix N from the atmosphere, so that even with decreasing N loads from the watershed, the N available in the Bay might not decline due to this ecological shift? In any case, the emphasis in the future should shift from the relatively vague impact of additional “sediments and associated nutrients” to the differential impact of specific particulate and dissolved nutrients.

Future studies should also test the sensitivity of the biogeochemical model simulations to the reactivity of the scoured material for both nutrient release and water column and sediment respiration, which are linked. The latter influences DO directly. This could potentially require additional state variables to represent different pools of particulate matter in the sediments and water-column. Surely, scoured materials and other solids are deposited in sediments, where diagenesis releases nutrients back to the water column to fuel algal growth. But before these materials are deposited in sediments, they could fuel respiration directly in the water-column. They should also contribute to sediment oxygen demand, or in the case that sulfides are released to the water column from sediments, to lagged water column oxygen demand.

Also, where do the nutrient-containing particles flowing past the dam in large flow events go? Are they trapped in the turbidity maximum? Do they escape to the mid-Bay, and if so, under what flow conditions? Are the present parameterizations of transport behavior adequate to address these questions?

5.2. U.S. EPA and Bay watershed jurisdictional partners should integrate findings from the LSRWA into their ongoing analyses and development of the seven watershed jurisdictions’ Phase III WIPs as part of Chesapeake Bay TMDL 2017 mid-point assessment:

One of the most important statements in the LSRWA report is found on p. 75. It says: “EPA stated within Appendix T of the 2010 Chesapeake Bay TMDL that ‘if future monitoring shows the trapping capacity of the dam is reduced, then EPA would consider adjusting Pennsylvania, Maryland, and New York 2-year milestones loads based on the new delivered loads’ (USEPA, 2012). In practical terms, this means that nutrient and sediment loads from the Pennsylvania, Maryland, and New York portions of the Susquehanna River basin would have to be further reduced to offset the increase in sediment and associated nutrient loads in order to achieve the established TMDL allocations and achieve the states’ Chesapeake Bay.” It seems clear that analyses of the monitoring data have indeed shown that the trapping capacity of the dam has significantly reduced. Now the question is how to proceed to do the "adjusting" of the TMDL milestones. That issue is thus the following: how much of a decrease in loads delivered to the reservoirs and/or increase in reservoir trapping efficiency would be required? Key recommendations of this review in this regard include: (i) that the effect of the change in overall "trapping capacity" must be accounted for (the LSRWA analysis done so far relates only to increased scour and not to total trapping capacity), (ii) priority should be given to accounting for the added particulate phosphorus, and (iii) the additional sediment load (other than associated nutrients) should NOT be an additional burden on TMDLs. The logic behind this resistance to including treating the sediment load as a penalty is expanded upon in the following two subsections:

The negative impacts of sediment input to the Chesapeake Bay (relative to nutrients) are overstated by present TMDLs and are overemphasized in management priorities

TMDL requirements for sediment loads are most likely overly restrictive. The water quality simulations conducted as part of the LSRWA study further support the conclusion that sediment alone does not have as great an impact on Bay aquatic life and attainment of water quality standards as previously thought. More generally, the common wisdom that sediment input in itself is a problem with respect to water quality is perplexing given that sediment loads in the late 1800's and early 1900's were much higher than they are now, yet Chesapeake Bay water clarity and overall quality were much better then than now.

An underlying assumption at the start of the LSRWA study, and indeed of the CBP in general, is that all sediment is bad. However, it is stated in several places in this report and in the broader literature that some sediments are actually good, important components of the estuarine ecosystem. Certain fishes and most healthy SAV beds need sand as a substrate for reproduction and growth. Even estuarine fine sediments are essential to certain habitats, such as tidal wetlands, and a further reduction in supply of fines to tidal wetlands threatens their sustainability in the face of coastal erosion and/or sea level rise. It is true that turbidity due to fine sediment input can locally limit SAV, but this report clearly points out that turbidity insults associated with scour from the Conowingo reservoir are temporary. Perhaps it is time to revisit the TMDL for sediment, especially sand, and especially in the context of the sediment behind the dam and in the lower Susquehanna and upper Bay.

Given the relatively minor impact of sediments in general (separate from their associated nutrients) to Bay water quality, it is especially clear that the additional sediments (separate from nutrients) associated with the filling of the Conowingo reservoir are particularly insignificant to overall Bay health. The reasonable (albeit approximate) estimate that ~90% of sediments originate from sources other than scour from the Conowingo reservoir suggests that completely mitigating the loss of sediment (but not nutrient) trapping in the Conowingo would solve only around 10% of what is already a minor problem. It is important to further note that minimum water clarity required by TMDLs for SAV habit is obtained in every scenario in Table 5-9, regardless of whether or not the Conowingo reservoir is full or whether or not WIPs are fully in place. Requiring further reductions in sediment input (separate from nutrients) elsewhere to compensate for loss of Conowingo storage, given the expense involved, is not cost-effective.

The overall negative impact of sediment scoured or otherwise moved or bypassed out of the Conowingo reservoir and into the Bay may be further reduced by the fact that it is sandier than sediment otherwise introduced to the Bay. As the "full" Conowingo reservoir evolves, it will continue to get sandier with time. Parts of the lower Susquehanna and upper Bay are sand-starved at present. Sand is a limiting resource for several types of important habitat in the upper Bay and lower Susquehanna, and it is far less likely to harbor high N or P loads. If sand could be bypassed around the dam without entraining significant fines its impacts might be more positive than negative.

The effectiveness of BMPs in reducing sediment loads to the Bay may be overstated by present TMDLs:

The description in Table 5-6 of almost constant flux to the Bay despite major reductions in upstream sources over time is a major point to be considered in thinking about future impacts of BMPs. What is true here might also be true at the watershed scale. Similar results have been seen in historical reconstructions of sediment yields from other watersheds. Reductions have been made in sources, but about the same amount of sediment continues to flow out, which is a small percentage of the amount mobilized upstream, and which appears insensitive to changes in that source amount. This is ultimately a result of massive watershed storage of sediment. Thus, the possibility that sediment BMPs may not lead to a major reduction in sediment coming from the upstream watershed needs to be considered as a real possibility in considering management actions. Models alone cannot answer this question, only more direct measurement in places downstream of BMPs can fully demonstrate whether they are effective.

This issue is again important in the context of statements made on p. 141 indicating that anticipated future changes include increased frequency of scour events associated with climate change but continued decline in watershed loads due to BMP implementation. Given the enormous volume of sediment in various storage compartments in the watershed, greater frequency of scour events may well lead to greater amounts of remobilized sediment, especially as the vast majority of sediment that moves is carried in big storms. Even if WIPs are fully implemented, they may not counter the influence of greater storm frequency, nor is it clear that they would be as effective as assumed even in the absence of greater storm frequency. The amount of sediment in storage with potential for remobilization is orders of magnitude higher than the typical annual load, and even if one believes that stream restoration can be effective in mitigating in-stream sources, there is no way that stream restoration projects will ever be built over enough of the cumulative length of the upstream drainage network to really mitigate this potential source.

The broader question of whether WIPs will actually be effective for sediment on the time scale important to managers is one that is a subject of debate among geomorphologists, and cannot be assumed to be true simply because existing TMDLs are predicated on that assumption. The significant uncertainties in predicting the effects of BMPs on watershed sediment yield must be acknowledged. The Chesapeake Bay Watershed Model, though highly sophisticated, does not account for long-term storage of either water or sediment, and these processes have an important influence on the lag time before improvements can be expected from the WIP process.

5.3. Develop and implement management options that offset impacts to the upper Chesapeake Bay ecosystem from increased nutrient and sediment loads:

It is suggested here that, once more, the phrase “nutrient and sediment loads” in the above recommendation be changed to “sediment-associated nutrients”. This suggestion is consistent with the statement found in the main report two paragraphs below this recommendation (p. 200), but with an added insertion in square brackets: “Nutrient load reduction management and mitigation options are likely to be more effective and provide more management flexibility when compared to relying solely on sediment management options. As such, it is likely more appropriate and cost-effective to increase management actions targeted toward nutrients above and beyond WIP implementation in the Susquehanna River watershed [rather than expand sediment control BMPs in general]. It is therefore recommended to conduct further analysis and modeling to understand costs and water quality influence of controllable nutrient mitigation measures beyond the jurisdictions’ WIPs.” This paragraph goes on to list a number of nutrient reduction strategies. These are fine, but the list is somewhat limited. In terms of overall implications for managing Bay eutrophication there needs to be particular attention to non-point source nutrient management, especially to limiting application of phosphorus to soils where the P levels are already above their agronomic optimum, changing the manner in which chemical fertilizers and manure are applied to the landscape, and also the use of cover crops.

In his work, Hirsch has found that total phosphorus flux to the upper Chesapeake Bay is up by about 51% between 1996 and 2012, representing an increase of about 1300 tons/year. This increase is happening while upstream management actions are taking place to reduce TP flux. During this same period the flux from upstream (measured at Marietta) has been decreasing (in the neighborhood of 1000 tons/year) and most of that since about 2004. This suggests that the net loss of trapping efficiency by Conowingo may be in the range of 2300 tons of phosphorus per year. The basic question is then, what would it take in terms of upstream phosphorus management in order to overcome the impact of ~2300 tons of phosphorus? This estimate is not highly accurate. The team that did the LSRWA report has the simulation expertise and capacity to test these estimates, but they have not yet performed this specific simulation. The follow up to this LSRWA effort really needs to address these estimates and replace them with better ones if they can (including uncertainty bounds).

A statement made in the center of p. 133 is revealing in this context. This is the statement that, though the January 1996 storm simulations do indicate adverse impacts of scour from behind the dam on the Bay TMDL, these impacts are far less than the impacts of not implementing the WIPs already agreed to by the States. Furthermore, the following paragraph on p. 133 provides a first order estimate of the additional watershed nutrient load reductions (using a combination of N and P) that would be needed to offset the DO non-attainment caused by the scour loads. This is one of the most important pieces of information in the report.

5.4. Commit to enhanced long-term monitoring and analysis of sediment and nutrient processes in the lower Susquehanna River system and upper Chesapeake Bay to promote adaptive management:

This review supports enhanced long-term monitoring of the flux of sediment and associated nutrient flux in the lower Susquehanna River system. This LSRWA report certainly makes the case that it is needed, as there was inadequate observed data to sufficiently understand nutrient transport dynamics or for model calibration and validation. Nonetheless, Recommendation #4 should be rephrased to explicitly include studies designed to develop the conceptual scientific understanding needed to manage the lower Susquehanna River system and upper Chesapeake Bay. Gathering data and analyzing it is not enough.

Regardless, updated technology should play a key role in enhanced long-term monitoring of the Lower Susquehanna/upper Chesapeake Bay (and other river/estuarine transitions in the Chesapeake Bay system). There are a variety of technologies that can be applied using *in situ* sensors to collect an essentially continuous record of sediment concentrations and flux for use in inferring sediment-associated nutrient transport, including inference of grain size distribution. Turbidity, laser, densimetric, and hydroacoustic technologies have been/are being evaluated, and some are being integrated into operational monitoring programs (see for example Gray and Gartner, 2009 at: http://water.usgs.gov/osw/techniques/2008WR007063.pdf). Sediment hydroacoustics arguably is the most robust of the technologies for rivers that convey low-to-moderate sediment concentrations, such as the Susquehanna River and presumably most Bay tributaries. Finally, an *in situ* hydroacoustic monitoring system also can provide index-velocity information for computing and/or improving water-discharge computations.

Continued monthly sampling throughout the basin is important, but it is also crucial that sample collection includes a substantial effort to collect data from moderate to high discharge events (including likely scour events but also events that are well below the scour threshold). It is also important to sample within the reservoirs and not just above and below. In particular, suspended sediment and particulate nutrient samples from within the reservoir should help in identifying the discharge at which reservoir scour begins. Further, with new technologies it should be possible to collect water samples in the reservoir during floods. These measurements need not be collected in a complete transect for the purpose of providing the entire sediment flux. Rather, they would provide an indication of the flow, in a time series, at which reservoir scour becomes significant. This, more than the mass balance between inflow and outflow sediment, could be more useful in determining the appropriate bottom boundary condition for models. That is, the bottom boundary condition for substantial bed entrainment would be calibrated to the flows at which this actually happens.

Question 6: Do the technical appendices provide the necessary documentation for the models and their applications in support of the study's results, findings, and conclusions?

APPENDICIES

Below is a summary of review comments specifically directed at the Appendices, beyond those insights provided in earlier sections that indirectly addressed the Appendix contents.

<u>Appendix A</u>

As described above in the section of this review entitled “Limitations of HEC-RAS model…”, the HEC-RAS modeling effort was ultimately unsuccessful, and results of the HEC-RAS simulation did not form an integral part of the main report. Additional comments from individual reviewers directed at Appendix A beyond the items discussed in the earlier review section are included here.

The Estimator model was used in Appendix A in spite of the fact that its originator, Dr. Tim Cohn, has indicated his doubt as to whether it is adequate for use with “hysteretic” suspended sediment. Although it well may “work” in this relatively large river – larger rivers with smaller peak-to-base-flow discharge ratios and more languid precipitation-runoff responses tend to exhibit less hysteresis in suspended-sediment concentrations than smaller rivers – additional analysis might be required to confirm or refute that assumption.

Concern was expressed regarding the exclusion from the sediment transport curve of the high suspended-sediment concentration value (2,890 mg/L, at USGS gage 01578310 [Conowingo] on 9/8/2011) in Appendix A, p. 12, Figure 7. There is rumor of a similar ‘high outlier’ in 2004. The transport curve in Figure 7 may well effectively be discontinuous with a major break around 400,000 ft^3/s. The two transport-curve sections might be nearly parallel. It is possible that the present curve is valid for flows ~≤ 400,000 ft^3/s, and the new curve that would reflect natural increasingly sediment-laden flows plus scoured material is valid for flows ~> 400,000 ft^3/s. A promising approach would be to develop a particle size-to-flow relation and apply it to the transport curve resulting in two (or three) curves, including a fines-transport curve (the principal metric of interest). The concept is graphically similar if mechanistically dissimilar from a discontinuous suspended sediment transport curve that has been shown to occur when flows transition between subcritical and supercritical regimes.

Should the p. 13 Reference to Table 2 be to Table 3?

The p. 36 Summary of USGS sediment concentration and load estimates: there is no period of continuous data collection at Marietta and only a few years between 1979 and 1992 at Conowingo, so how are they estimating comparative sediment loads? The text says USGS has been estimating sediment loads at Marietta and Conowingo since 1987 but does not say how.

The ESTIMATOR was used to project changing sediment load over time. However, in looking at the USGS NWIS site there is only very limited information about actual sediment concentration and load data collected – a number of years during the period between 1979 and 1992 at Marietta, and presumably grab samples, but apparently no continuous record at Conowingo. Given all of this there is some skepticism about how well we really know the comparison between sediment loads at the two stations, especially going back to the early 20th century.

Appendix B

As described above in the three earlier sections focusing on limitations in the AdH model, this review concludes that the existing application of the AdH model was not reliably predictive beyond constraints provided by a few integrated observations of sediment-related properties of the system. The AdH model is only loosely validated and insufficient data are available to confidently evaluate model performance. In its current state, based on the information presented, the AdH model is not capable of extending the information on reservoir performance previously available from bathymetric surveys and stream gaging. Additional comments from individual reviewers directed at Appendix B beyond the items discussed in response to Questions 3 and 4 are included here.

The SEDFLUME results from a small number of cores account for a large fraction of Appendix B. But there is insufficient explanation as to how these results were translated into the parameter set utilized in the six material zones in the model. Given the variability within each core from one shallow layer to the next, and given the variation in particle sizes longitudinally as well as variation laterally across the reservoir in depth and modeled velocity, perhaps there is no way at this point to account for spatial patterns beyond the simple selection of six longitudinal zones; and perhaps it ultimately does not make much difference what choices one makes. But it is odd that so much space was devoted to the empirical results without explanation as to how they were actually applied or what difference the spatial pattern of parameter values within different zones might make, particularly given that a 2d model is being used. In calibrating the model, the authors varied critical shear stress parameters at shallow depths and maximum scour depth to keep the model from scouring too much sediment, but the discussion of how this was done did not make much reference to differences among zones or within zones. The way this issue was handled is not explicitly addressed in the text even though the small number of cores is identified as a source of uncertainty.

p. 4 Figure 1 shows in graphical form the same information that is provided in Table 5-6 of the main report but in each case the citation simply says "provided by USGS". How do we know that by 1959 (first paragraph, p. 5) there was a relatively constant inflow of 3.2 million tons/yr of sediment flowing into Conowingo?

pp.5-6 The Exelon revised HEC-6 study concluded that scouring flows above 400,000 cfs were net depositional in Conowingo? Not net erosional? Given conclusions provided elsewhere in both the main report and appendices, this is confusing.

p. 22 Under model validation the statement is made that "The maximum sample depth was only about 12 inches due to highly consolidated sediments in deeper layers preventing penetration of the sampling tube." If this is the case what does it say about the actual potential for scour in a large flood event?

p. 23 Here it says that although samples represented only the top foot of sediment, the model sediment bed was about three feet. It appears from later discussion of choices made for calibration purposes that the three-foot depth had to be modified in order to match better with other information. The choices made here are not always clear.

p. 25 This shows the flow-concentration curve for Conowingo and highlights both the variability at high flow and the existence of only a single point at the upper end of the curve. It would seem appropriate to try to quantify the uncertainty associated with use of this curve and develop a range of values in order to see how this uncertainty might affect conclusions and comparisons.

The USGS curve for prediction of scour as a function of Q has upper and lower bounds; so should the sediment concentration rating curve.

p. 27 The major trend was that most of the scour occurred in the upper 1/3 of the reservoir where there is more sand which constitutes 50% or more of total bed sediment. A significant amount of deposition occurred just upstream of the eastern end of the dam. Was this mostly fines or more sand? What is the effect of the changes here on the particle-size distribution of the deposit as a whole?

p. 28 Model validation involved a parametric model study where bed-property values were manipulated and results compared with USGS scour load prediction. Was any consideration given to whether properties might vary with depth or distance from the shoreline?

p. 29 The choice of limiting depth available for scour to one foot seems like a reasonable one for a lower bound, given what was learned from coring and laboratory tests.

p. 31 When fitting parameters to compute erosion rate – is it not possible to develop some scheme for projecting variation in relevant material properties either longitudinally or laterally? Given that a 2d model is being used and given the spatial patterns of texture and cohesion, this seems like an element that ought to be considered – or else reasons why it cannot be done should be articulated.

p. 33 The authors argue that the uncertainty associated with applications of AdH is made manageable by basing conclusions largely on simulations of management scenarios in which only one variable is changed. This amounts to saying, in effect, 'the model worked OK for a hindcast, even though we had to use boundary conditions that were outside of the measured range or unknown, and we have not documented that the internal workings of the model are making reasonable predictions. So, if we only change one part of the model we can hope that it will reliably calculate the change in system performance.' However, one application of the AdH model was to evaluate scour and deposition relative to different reservoir bathymetry. These applications are not of the change-one-thing-only management scenario type and instead directly depend on the fidelity of the selected model.

p. 33 In discussing role of alternative bathymetry – do these alternatives assume spatially invariant bed material properties?

p. 37 Do these flow fields try to account for the change in flow distribution at the outlet when the gates are opened during high flows? It is pointed out elsewhere that dam operations should be incorporated in the model for future studies – this would seem to imply that this is not the case here.

p. 44 The 2008 to 2011 period was somewhat atypical in terms of the frequency of days above the 400,000 cfs scour threshold. If we look at the frequency of days over 400,000 cfs during the 4-year simulation period it comes out to an average of 1 day per year above the threshold. If we look at the entire period from 1977 through 2012 the frequency of days above the threshold is about 0.5 days per year. Thus, the choice of 2008-2011 as the simulation period will overstate the importance of scour increases as compared to a simulation period that was more typical.

p. 60 In discussion of limitations posed owing to need for a more sophisticated approach to simulating flocculation – is there any way to estimate how much difference this might make to overall conclusions?

In the same paragraph it is suggested that field methods are needed for sampling storm concentrations or turbidity over the entire storm hydrograph. Presumably standard methods can be used for the samples for either concentration or turbidity without having a human operator have to stick a bottle in the flow (as apparently was the case for the single sample taken near the peak during Agnes). Is the issue one of how to deploy sensors or automated samplers in the vicinity of the various gates built to accommodate high flow?

Appendix B-1, Figure 3: One must be careful of drawing straight lines in log-log space that depict a transport curve. At some point, the relation must tail to the right, given that sediment concentrations have absolute limits.

Appendix B-1, Section 5-1: The total annual estimated sediment yield delivered to downstream reservoirs is cited here as 4.2 million tons; but there are multiple other estimates in these documents, mostly less than this value – there needs to be more consistency among these cited values, or else an explanation as to why they are different.

Attachment B-1: "Evaluation of Uncertainties in Conowingo Reservoir Sediment Transport Modeling" -- This section is misnamed. The section provides a useful discussion of different elements of flow and transport through reservoirs. Its basic purpose is to justify the use of a depth-averaged 2d model (AdH) rather than a fully 3d model for the simulation. Their conclusion that a 2d model is sufficient is reasonable (assuming proper calibration/validation). Alas, although uncertainties play a small role in the discussion (basically relating to uncertainties that might arise from reducing 3d flow field to 2d), the section provides no discussion of overall "Uncertainties in Conowingo Reservoir Sediment Transport Modeling." This is unfortunate, because those uncertainties are large and largely unexplored in the study.

Appendix B-1, Section 9: This section presents an AdH model of flow and transport on Susquehanna Flats. No discussion is given of any calibration or testing of the model in this environment, and one must presume that it is uncalibrated and untested. The roughness assigned to the flats with SAV and without SAV (winter) is sufficiently large that the majority of the flow and sediment transport occurs through the dredged channel. This is a reasonable result. The authors then reach a conclusion that is unsupported by the model and quite possibly incorrect: "the relatively higher bed roughness of the shallow flats will tend to continue to route the majority of the flow through the dredged navigation channel below Havre de Grace. Thus, discharge of sediment from Conowingo Dam due to bypassing or flushing operations will have minimal impact on the flats area, with sedimentation occurring in the dredged navigation channel or below the flats area." Just because most of the water and sediment go through the channel does not mean there will be no impact to the flats. If flow extends on to the flats, the authors have not demonstrated in any way that sediment carried in that flow will not deposit on the flats.

In fact, this is how floodplains are formed. If turbid water is being discharged from the dam, one can deposit sediment wherever the water goes. Estimates can be made from the sediment concentration and residence time of water over the flats.
Appendix B-2, Summary and Conclusions. This section is misnamed and should be changed to only “Summary”. There are no conclusions stated here.

Appendix B-4 includes the following on its first page: “…sediment in transport in suspension is directly related to sediment particle size and the degree of turbulence.” Density could also be a factor, particularly if it is true that some 10% of reservoir sediments are coal particles.

Appendices C & D

Appendices C and D of the LSRWA Draft Report describe application of the Chesapeake Bay Environmental Modeling Package (CBEMP) to estimate changes arising from additional scour from behind Conowingo Dam during large events. Unlike the AdH and HEC-RAS models, which are relatively new model systems that had not been applied before to the Lower Susquehanna environment, the CBEMP model has a decades-long history of applications and evolutionary improvements to the Chesapeake Bay system, including numerous peer-reviewed publications assessing its performance in this specific environment. The application of the CBEMP model to the LSRWA effort is generally well done; the writing is clear, the organization is logical, and the text is supported with extensive figures and tables. The conclusions are reasonably supported, especially given that the LSRWA was intended as an exploratory analysis. The data attachments to Appendix C are particularly useful, although they are not specifically reviewed here.

One significant area could use a bit more attention. The period of the CBEMP model simulations is different from the period of the HEC-RAS/ADH scour simulations. The watershed loading scenarios are not the actual scenarios observed during the CBEMP simulation period, but rather projections based on expectations for watershed management practices under two different conditions (2010 implementation and TMDL achieved). The major storm simulation presented uses sediment-associated nutrient concentrations from a different storm entirely, not the simulated storm. As a result of all of these juxtapositions and substitutions, it is unclear exactly what is being simulated and why – the runs do not ever appear to be representative of actual conditions. While the final scenarios make sense and are very revealing, the reasoning behind their construction is hard to follow. A summary of the PHILOSOPHY of scenario construction, not just its mechanics, would help. This description should occur right after the introduction of the modeling tools used, and it should be addressed to an audience that is not familiar with standard practice in the CBP.

As an example of the confusion that can result, it is stated on p. 3 that “the 1991-2000 hydrologic record is retained for this study”. But in the next paragraph, it is stated that the 2010 progress run and the TMDL run of the watershed model are used to specify daily nutrient and solids loads for different scenarios. How can nutrient and solids loads from 2010 and a hypothetical TMDL condition be applied to a 1991-2000 hydrology – doesn’t the hydrology largely drive the loads? Or do the 2010 and TMDL runs specify instead relationships between hydrology and loading that are transportable to different time periods? CBP modeling insiders probably understand this approach, but it will be hard for outsiders to grasp.

Table 3.1 details how the June storm scenario included a "transfer of the load record, hydrodynamic record, and the hydrodynamics". Does this mean that the simulation started on June 1st (with June sunlight and temperature), but included the hydrologic and hydrodynamic forcing as if it were January 1st? Or is it something else? Clearer language should be provided to describe how these runs were actually done. These details are important, because in Appendix C, p. 86, Figure 6-27, it is shown that the impact of the simulated 1996 storm on light attenuation was different in the tidal Bay for the 3 seasons tested, and one may wonder if this is only a biological effect of load.

Interestingly, the long-term impacts of the October Storm on DO seem less than the January storm (-0.25 in Jan from 1997-1999, -0.1 in October from 1997-1999, Figure 6-31). Why would this be? Is more of the January load processed that summer and cycled through the system, while much of the October load is buried over winter? This seems like a point worth investigating.

In Appendix C, there is no mention about how the diagensis (decay) rates for the scoured materials differ from the diagenesis rates of the algal-derived organic material, or how decay rates of the scoured material are treated in general. This is a central aspect of this study, as it controls the nutrient release rates that drive the responses seen for chlorophyll and DO in the numerous simulations reported here. Please include these values.

In Appendix C, p. 25, last sentence: the reviewer could not seem to find the results of these scenarios. They are important, given the fact that 2011 sediment nutrient content is probably more representative of future scour loads than 1996. If these results were missed, please reference the table that describes these different scenarios, or specifically identify the scenarios if they are few enough.

On a positive note, the Analytic Model presented in section 2 of Appendix C is quite well done and is a very useful tool for describing overall expectations and for informing the conceptual model. It would be straightforward (in the future, not for this effort) to expand this model to multiple spatial segments and sediment types in the reservoir, to aid in more realistic screening analyses. This expanded analytical approach would also provide a valuable grounding for more complex numerical analyses in the future.

ADDITIONAL COMMENTS ON THE APPENDICES AND MAIN REPORT

Appendix E

Table 1.2 and the introduction to Appendix E indicate that bathymetric data were acquired in Susquehanna Flats. They were not; only sediment grain size data were acquired.

Appendix H

A question that was not addressed in the report is related to the various techniques for sediment management explored in the literature review of Appendix H. While different kinds of power dredging are mentioned in the Appendix and in the body of the report, a technique known as hydro-suction dredging is mentioned several times in the Appendix but not mentioned explicitly in the report. This technique would be especially useful for sediment bypassing, because it makes use of the huge natural head difference between the reservoir and the river below the dam to maintain flow through a dredging pipe or bypass tunnel. Was this technique considered in figuring the relatively low cost of bypassing, or not? Would it make a difference?

The literature review in Appendix H ignored nutrients.

Appendix J

Are all the costs adjusted for inflation and expressed in constant dollars? The discussion of the BMP costs in J-1 indicates that all these costs are converted and expressed in 2010 dollars using the CPI. Was the same process used for the reported cost values in J-2 for the other alternatives? The main body of the report should clearly state the dollar years and inflation adjustment method.

The economic analysis uses a different interest rate (or discount rate) for the watershed BMP versus dredging scenarios. Specifically, p. 14 in Appendix J says “estimates of annualized costs reflect a 5% discount rate” for the watershed BMP scenario. However, p. 167 in Section 6 says that “annualized one-time investment costs are based on a 50-year project life and the fiscal year 2014 federal interest rate of 3.5 percent” for the dredging scenarios. Appendix J-2 shows the detailed calculations for dredging scenarios based on the 3.5% interest rate. Proper economic analysis should use the same interest rate to compare across the scenarios. The current analysis makes the watershed BMP approach seems more expensive based on using the higher 5% interest rate.

The 50-year project life for the dredging and bypassing alternatives is considerable longer than the range of project lives used for most BMPs. That may well be correct and appropriate, but it deserves some justification and explanation, since it could be an influential assumption.

The current analysis provides a breakdown of the total estimated costs by the three states in Table 3 on page 6 in Appendix J (also used as Table 6-3). But this summary by state/jurisdiction in not highly informative because it just reflects that Pennsylvania is the largest state.

Attachments 2 and 3 on pp. 12-13 in Appendix J show the costs by practice across the three states. However, the current information does not make it possible to assess the variation in cost-effectiveness of the various urban and agricultural BMPs in meaningful terms, such as the dollars per cubic yard of sediment removal. Importantly, the cost-effectiveness between practice types typically varies by one or two orders of magnitude. Hence, the current analysis aggregates all practices types and reports an overall cost estimate at $3.5 billion in Table 3 (or Table 6-3). Then the report provides an overall average cost effectiveness of $256-$597 per cubic yard in Table 6-6, and seems to imply that this watershed BMP approach is supposedly the most expensive. But this assessment that aggregates all practice types may overlook the high degree of heterogeneity in costs between practice types.

At a minimum, the watershed BMP scenario should provide separate scenarios for the agricultural versus urban BMPs. Compare, for example, the costs for agricultural BMPs in Attachment 2 versus urban BMPs in Attachment 3. This shows that urban represents about 90% of the total costs compared to about 10% for agricultural BMPs. But it is unlikely that urban represents 90% of the sediment load. In fact, there are two urban BMPs (urban infiltration BMPs and filtering BMPs) that represent over $2.5 billion, which is two-thirds of the total costs. The unit costs on these two urban BMPs are much higher than other BMPs, but the analysis is aggregated into a single number for cost-effectiveness of this alternative scenario.

Attachments 2 and 3 would be more informative if it included additional columns that provided both the cost-effectiveness in $/cubic yard (or $/ton of sediment) and the total amount of cubic yards (or tons of sediment) for each practice type. The former would provide the ranking in cost-effectiveness by practice type, and the latter would reveal how important this practice is for the overall load reduction. This would allow for a better assessment of the most effective suite of practice types, while not including those practices that are most inefficient. Alternative watershed scenarios could then be designed that look at the option of 100% of the E3 scenario (current analysis) versus another scenario that only adopts 50% of the sediment reduction for the E3 scenario using the most efficient suite of practices. The most effective 50% will be competitive with the dredging scenarios given the extreme heterogeneity in unit costs for ag BMPs in Exhibit 1 on p. 15 and urban BMPs in Exhibit 6 on p. 35 (varies from $0 per acre for conservation tillage to $2,351 per acre for the urban filtering BMP). There is even extreme variation in unit costs within agriculture BMPs that ranges over several orders of magnitude. This further confirms the need to provide disaggregated analysis on the cost effectiveness in $/cubic year by practice type.

There are numerous citations provided in Attachment 4 of the Appendix J on pp. 14-44. But there is no corresponding “References” section to provide the detailed info on these citations.

Attachment 4 of Appendix J on pp. 29-33 includes detailed information on “Septic Systems”. However, septic systems are not discussed at all in the corresponding tables for the cost analysis in Attachments 2 and 3. This needs to be clarified. Future analysis should include septic systems particularly if the analysis is expanded to nutrient management options (not solely sediment strategies) because septic systems are an important nutrient load in rural Pennsylvania.

Other recommended edits/specific concerns for main report, by page number:

ES-2 In multiple places in the main report (ES-2, p. 10, p. 110, p. 141), there is a statement regarding dynamic equilibrium that says, “This state is a periodic cycle.” This statement is very misleading, there is nothing periodic or cyclic about it. The driving event (high flow events of about an annual exceedance probability of 0.2 – a “5-year flood”) is a random event and is not periodic. They may happen in rapid succession or there may be many years between them. All mentions of the equilibrium state being “periodic” should be removed.

ES-3 2nd paragraph: the text beginning with “Modeling done for this….” is confusing. It states that under current conditions, half of the deep-channel habitat is unsuitable. This is then compared to the 2025 conditions with full WIP implementation and increased scour that suggests that attainment in 3 of the 92 segments will not be achieved due to extra loads of nutrients. It is implied that full WIP implementation should lead to completely healthy deep-water habitat, but a new reader would not necessarily catch this. Perhaps a more straightforward way to write this is to state something like "currently half of the deep-channel habitat is unsuitable for life (non-attainment), and given full WIP implementation in 2025 (which should yield 100% attainment), deep-channel habitat in 3 of the 92 Bay segments (X % of deep channel habitat) will remain as unsuitable habitat due to elevated nutrient loads from dam scour".

ES-3 4th paragraph: The last sentence (starting "Given…") is a run-on sentence.

p. 6 "The Susquehanna River is the nation's 16th largest river, and the source of the freshest water …" What is meant by freshest water? Typo?

p. 8 "All reservoirs act as a sink….." A sink of what? Sediment? Perhaps it is obvious, but it is helpful to state clearly.

p. 8 "Due to flow deceleration as the water enters the reservoir, sediment transport capacity decreases, and the coarser fractions of the incoming sediment deposited in the reservoir form a delta near the entrance to the reservoir." Awkward sentence – tenses.

p. 8 Last sentence of 5th paragraph: It is worth adding to the last sentence that nutrient-laden sediments are more harmful because they can be utilized to fuel additional algal growth in the tidal waters of the Bay.

p. 9 Last complete paragraph: if the Susquehanna load is 3.1 million tons and 1.2 million tons is released then 59.4% is trapped, not 55%.

pp. 15-16 The flow charts in Figures 1.5 and 1.6 are repetitive but slightly inconsistent. Figure 1.6 makes more sense and may be sufficient.

p. 16 In notes under Figure 1-6, should "partners of this LSRWA effort" be changed to "partners outside of this LSRWA effort"?

p. 24 3rd paragraph: Would be clearer or more mechanistic to say "…than about 0.3 knots because water movement tends to be slowed by frictional forces in shallow water…"

p. 26 "Snow events" do not cause floods. SnowMELT may.

p. 28 Define saprolite or show in Figure 2-5.

p. 32 "Phosphorus binds to ~~river~~ fine sediments and is delivered to the Bay with sediment."

p. 32 (1) 2nd sentence: "Ammonia" should be "Ammonium". (2) 2nd sentence: It is worth noting that although ammonium tends to be less abundant than nitrate in surface waters, it is by far the dominant dissolved N form in deeper waters during warm months. (3) True, nitrite generally contributes little to TN, but nitrite can accumulate to significant concentrations during some times and places, including the region of the pycnocline during mid-summer and after hypoxia/anoxia breakdown in fall. Perhaps adding a line to the sentence to say "….and contributes little to TN for most times and places". (4) It is worth adding that organic nitrogen comes in both particulate and dissolved forms.

p. 34 A factual problem is the statement that indicates that TN, TP, and SS loads from Conowingo have been increasing since the mid-1990's. This is certainly true for TP and SS but for TN the trends have continued to be downward (Hirsch, 2012 reports a decrease of about 3 percent).

p. 36 Should define hypoxia in Figure 2-10 (<2.0 mg/L).

p. 37 Section 2.5.2, 2nd sentence – statement is misleading and should be deleted unless qualified by explaining that because of different designated uses and water quality criteria it is not surprising there is a difference in violations. As is, statement is comparing apples and oranges.

p. 45 Figure 2-14 is not clear as to whether or not the metrics are total over a decade or per year.

p. 46 Many species of plankton are capable of motility. Change "and are passively carried" to "and are, by in large, passively carried".

p. 69 Chapter 3 mentions 3 Chesapeake Bay agreements, which may have been true when this section was written. However, doesn't the Watershed Agreement signed in June 2014 count as the 4th Chesapeake Bay agreement?

p. 72 2nd to last paragraph: The word "special" should be "spatial".

p. 81 "The HEC-RAS model may not be suitable for ….. , active scour and deposition, and particle size." What does this mean with respect to "particle size"? That the model cannot represent particle size well? Explain so meaning is clear.

p. 81 3rd paragraph: Were the boundary conditions generated for the HEC-RAS simulation also used to drive the AdH model? Or was model output from HEC-RAS simulation for the upper two reservoirs used to create the boundary conditions for AdH? Please clarify.

pp. 81-83 The models are stated to be "well developed, widely accepted, and peer reviewed. Yet there are virtually no references in Sections 4.1 or 4.2. References are needed here to demonstrate that HEC-RAS and AdH are indeed peer-reviewed models.

pp. 84-85 Figure 4-3 and 4-4: The mesh in all or part of these figures is almost impossible to see – provide insets at larger scale. Insets in the appendix show this more effectively.

pp. 87-89 In Chapter 4, the description of the method for using the 2008-2011 HEC-RAS and ADH predicted scour in the CBEMP 1991-2000 model runs is confusing. It is simply stated that the reader should see Appendix C for the details. More description should be provided in the text of Chapter 4, at least a better overview of the approach and justification for this somewhat tricky (but justifiable) maneuver.

p. 89 “Since the ADH application period was 2008 to 2011 while the CBEMP application period was 1991 to 2000, an algorithm was applied to adjust estimated loads from the ADH for use in the CBEMP (see Appendix C for details on this algorithm).” This algorithm is not obvious in Appendix C. Should briefly explain here and then explain better in Appendix C.

p. 92 “documented in Chapter 3”(?) Is this a typo?

pp. 97-100 Table 4.2 seems a bit out of context in Chapter 4, referring as it does almost entirely to material in Chapter 6. Although not a requirement, this table would make more sense in Chapter 6 where it is directly discussed.

p. 112 Are the values in Table 5-4 adjusted for variations in flow?

p. 113 In Table 5-5 change “Additional” to “Additional Calculated” and change “Transport” to “Scour-Induced Transport”.

p. 114 Figure 5-4 presents exact same data as Table 5-5. Eliminate.

p. 114 Bottom: annual influx of sediment to Conowingo is here described as 3.8 million tons/yr over the last 20 years with 2 million being trapped. Elsewhere in the document we see different numbers ranging between 3 million and 4.2 million tons. If there are different estimates arrived at in different ways this needs to be made clear.

p. 115 Table 5-6 does not explain how the historical loads or more recent loads were calculated – it simply says that the results were calculated by USGS. More explanation is needed. Also indicate that Hurricane Agnes flows were excluded if they were indeed omitted.

p. 131 The reasoning for using the particular combinations of predicted scour, nutrient loading, and water quality modeling to test for the effects of scour is unclear. The procedure was likely valid, but better explanation is needed.

p. 135 paragraph 4: It would help if there was some discussion of why two upper Eastern Shore segments (CHSMH and EASMH) had non-attainment in Scenario 3. Does low-DO water advect into them from the mainstem or is nutrient availability enhanced by the breakdown of scoured solids that end up in these tributaries?

p. 138 Paragraph 2: Oysters are discussed here within a section that otherwise discussed the modeling and simulation activities. Is there a description of how model analysis was used in this report to determine flow and management effects on oysters? Whatever the case, it should be clearly stated where the oyster effects fit into this report and whether or not model simulations were used to understand effects on oysters.

p. 138 “Nitrogen loads…exceed phosphorus loads…” Given that P concentrations tend to be an order of magnitude lower than those for N, the statement does not tell the reader much, and might unduly impress those lacking an understanding of nutrient concentrations and dynamics.
p. 146 Sources of information here are based on “personal communication” with Kevin DeBell, Greg Busch, John Rhoderick, and Jeff Sweeney. It would be better to document and provide references for the original reports used for the BMP unit costs rather than only personal communication. Page 4 in Appendix J-1 similarly only provides personal communications.

p. 167 “This methodology was not applicable for the watershed management representative alternative since management strategies (e.g., BMPs) once implemented, continue to remove/reduce sediment.” This statement is not true for many BMPs. For example, vegetative buffers self-destruct if they receive excessive sediment – same with most BMPs that trap sediment rather than reducing its generation. As a result of this incorrect assumption, one might question whether costs are one time.

p. 175 3rd paragraph: The word “waters” on line 4 of this paragraph should be “water”.

p. 180 “costs of bypassing (diminished DO, increased chlorophyll) are roughly 10 times greater than the benefits gained from reducing scour.” Indicate exactly where these data are contained in the report. A similar statement also appears in the Executive Summary and on p. 181 and p. 197.

p. 192 In the first summary statement below finding #2, the “upper Chesapeake Bay” ecosystem is highlighted to be the area impacted by the dam. “upper” is an ambiguous word in this case, as the simulations suggest that effects can be seen south of the Bay Bridge (e.g., Appendix C).

p. 193 Second paragraph, line 5: should “frequently not unsuitable” be “frequently unsuitable”?

p. 200 Reference to additional management activities that can provide long-term storage includes mention of floodplain restoration. If this refers to floodplain excavation, there is some concern about this appearing as a recommendation without much more study than has been conducted to date. If it refers to some other form of floodplain restoration some explanatory language would be helpful.

p. 201 The report does not make the case for use in adaptive management, as adaptive management is mentioned for the first time in this recommendation. Adaptive management is not mentioned anywhere but in this recommendation. Thus, the phrase should be deleted here.

Literature Cited

Available at the CRC/STAC offices

Lower Susquehanna River Watershed Assessment Team Responses to the "Review of the LSRWA: Scientific and Technical Advisory Committee Review Report"
August 2014
Annapolis, Maryland
STAC Publication 14-006

Background
As requested by the Lower Susquehanna River Watershed Assessment (LSRWA) Team in the fall of 2013, the Chesapeake Bay Program partnership's Scientific and Technical Advisory Committee's (STAC) sponsored an independent scientific peer review of the June 2014 draft LSRWA report and its supporting technical appendices. STAC responded to a series of charge questions posed by the LSRWA team during their review in a report entitled "*Review of the Lower Susquehanna Watershed Assessment: STAC Review Report.*[1]" A complete copy of the STAC Review Report is provided in Attachment I-7 of Appendix I of the LSRWA report.

<u>Overall Comments and Responses</u>

-The LSRWA Team's responses below are framed around the charge questions (**in bold)** posed to STAC**.** Specific excerpts from the STAC review report are included in text denoted by <u>From STAC.</u> The response is included in text denoted by *LSRWA response;* response is in *italics.* If language in the main LSRWA report or any of the appendices was altered due to a STAC comment, this is indicated in the respective LSRWA response as well.

Question 1: Does the main report clearly define the goals, strategies, and the results/conclusions of the study, and also present adequate background material at a level suitable for understanding by non-technical audiences?

A. <u>From STAC</u> "The goals stated in the main report (which stress both sediment and nutrient management) are inconsistent with the methodological approach taken by LSRWA (which mainly emphasized sediment) and appear not to be the study's original goals."
…"The inconsistency between the stated goals and the general strategies followed is an issue that propagates throughout the analysis for the entire assessment."
…"It appears that the goals as presently listed in the Introduction to the main report were not the original goals of the study.

LSRWA response: The LSRWA goals were deliberated and established by the LSRWA team back in 2011. The study goals have never changed. The study was always focused on sediments and associated nutrients. The strong nutrient emphasis/importance became apparent near the end of study once the full suite of model scenarios were run and evaluated. The study did evaluate nutrient loads and transport processes via the Chesapeake Bay Environmental Modeling Package (CBEMP).

[1] Chesapeake Bay Program Scientific and Technical Advisory Committee. 2014. *Review of the Lower Susquehanna Watershed Assessment: STAC Review Report. August 2014. STAC Publication 14-006. Annapolis, Maryland.*

B. From STAC: "Both the Executive Summary and Chapter 9 of the main report (entitled "Assessment Findings") present four categories of conclusions that generally correspond to each other. Within the individual context of the Executive Summary or Chapter 9, each set of conclusions is well written and easy to follow and understand. Their general content also includes the most important results and conclusions of the study. However, the phrasing, main emphasis, and ordering of these four categories is different in the Executive Summary versus Chapter 9, which is unnecessarily distracting. This review recommends that the four categories of main results/conclusions be presented in the same order in both the Executive Summary and in Chapter 9 and the headers be made more consistent and compelling."
…."However, the phrasing, main emphasis, and ordering of these four categories is different in the Executive Summary versus Chapter 9, which is unnecessarily distracting."

LSRWA response: The Executive Summary and Chapter 9 headings have now been made consistent as much as possible. The executive summary and Chapter 9 (findings) have different purposes. The executive summary's purpose is to be a standalone document that summarizes the study background, process, findings and recommendations, while Chapter 9 focuses on findings.

C. From STAC "Although the background material within the main report is indeed presented at a level suitable for non-technical audiences, this review recommends that large portions of the background material (specifically all of Chapter 2, 50+ pages in length) be moved to an Appendix. The remainder of the main report never refers to Chapter 2."

LSRWA response: Section 2 has been removed from the main report and made into a supporting technical Appendix as recommended.

Question 2: Are the alternative sediment management approaches clearly described and documented? Does this background material provide supporting evidence for the finding and conclusions of the study with regard to alternative sediment management approaches?

A. From STAC "Further analysis would be required to appropriately rank the alternative strategies based on a more environmentally relevant total cost in terms of dollars per pound of nitrogen and/or phosphorus reduction."

LSRWA response: The LSRWA team agrees that costs in the report focus on sediment management removal/reduction. Nutrient reduction specific strategies and associated costs warrant further analysis. The premise for sediment management strategy development was: "The focus was on managing and evaluating sediment loads with the understanding that there are nutrients associated with those sediment loads; thus, in managing sediments, one is also managing nutrients. However, it must be noted that the relatively low importance of sediment from the dam as a stressor to Chesapeake Bay water quality and aquatic life versus nutrients was not known until late in the study process. For that reason, management measures focused primarily or solely on nutrients were not considered in this assessment."

B. From STAC: "This review recommends that further caveats be included throughout the report to clarify that the dollar-based cost estimates regarding alternative sediment management approaches are specifically for reducing cubic yards of total sediment in the reservoir, not for achieving broader goals regarding nutrient reductions. The dollar-based cost estimates in Table 6-6 are reported in the Executive Summary (p. ES-4) and elsewhere in the assessment report. Wherever the dollar-based cost estimates are stated, their meaning with regard to increasing reservoir capacity rather than improving water quality should be more clearly indicated. The report should also emphasize that further analysis would be required to appropriately rank the alternative strategies based on a more environmentally relevant total cost in terms of dollars per pound of nitrogen and/or phosphorus reduction."

LSRWA response: The premise for sediment management development is stated in report:

> *"This assessment included a survey-level screening of management strategies to address the additional loads to Chesapeake Bay from the reservoirs' bed sediment scour. The focus was on managing and evaluating sediment loads with the understanding that there are nutrients associated with those sediment loads. The reason for this is that nutrients are contained within the dam sediments..."*

The evaluation included upland and in-reservoir strategies along with impacts to water quality and costs associated with those improvements. The LSRWA team agrees that the costs presented do not correspond with and were not calculated for strategies focused on nutrient removal/reduction only, and that more analysis is warranted on nutrient specific reductions and costs. This is included as a recommendation in the report.

C. From STAC: "For example, a one-time major dredging in the region just upstream of the dam, followed by bypassing from further upstream to slow subsequent infill, might have longer lasting effects. These more complex scenarios are clearly beyond the scope of this report, but they should be mentioned and acknowledged as worthy of exploration."

LSRWA response: The LSRWA Team agrees with STAC comment/recommendation. The following language was added to the Chapter on Developing Sediment Management strategies:

> *"The alternatives were selected to offer a realistic range of costs for potential solutions. Whereas the representative alternatives were chosen due to their apparent viability relative to other similar strategies, no rigorous comparisons were conducted nor were the alternatives optimized (e.g. to more effective) through a detailed design process. Furthermore more complex alternatives were not developed (e.g. combining additional BMP's in conjunction with dredging)."*

D. From STAC "The economic analysis and comparison of the alternatives could be further enhanced by considering, and at least discussing in qualitative terms, other possible co-benefits (and possibly co-costs) of the alternatives. For example, in addition to reducing loads to the Bay, many of the BMPs provide other ecosystem service benefits such as improved water quality upstream from the Bay, carbon sequestration; water storage/flood control, recreation benefits, etc. (see USEPA report EPA/600/R-11/001 for an analysis that includes some of these co-benefits)."
LSRWA response: The LSRWA Team agrees this would be a valuable exercise, however, conducting such an evaluation was but not within the scope of this current effort. More site-

specific analyses would be required to back-up statements about ecosystem service benefits that are mentioned above. The evaluation of sediment management strategies in the assessment focused on water quality impacts, with some consideration of impacts to SAV. Other environmental and social impacts were only minimally evaluated or not evaluated at all. A full investigation of environmental impacts (possibly co-costs) along with co-benefits could be performed in any future, project-specific NEPA effort.

E. From STAC: "Similarly, dredging activities may entail aesthetic disamenities (i.e., external costs), which would have the opposite effect by increasing the total costs of this set of alternatives."
LSRWA response: The LSRWA Team agrees but more site-specific analyses would be required to back-up these statements and were outside of the scope of this effort. The following language added to the Chapter on Developing Sediment Management strategies:

> *"It should be noted that the LSRWA effort was a watershed assessment and not a detailed investigation of a specific project alternative(s) proposed for implementation. That latter would likely require preparation of a NEPA document. The evaluation of sediment management strategies in the assessment focused on water quality impacts, with some consideration of impacts to SAV. Other environmental and social impacts were only minimally evaluated or not evaluated at all. A full investigation of environmental impacts would be performed in any future, project-specific NEPA effort."*

Questions 3 & 4: Does the main report provide clear, supporting evidence for the results, findings, and conclusions of the study? Does the report adequately identify key uncertainties in the model applications which, with better information, could change the predicted outcomes of the alternative management scenarios evaluated in this study?

A. From STAC: **"**Although there is no single accepted procedure for reporting uncertainty in the context of scenario modeling, a part of the report should more explicitly explain why confidence intervals on predictions are generally not provided."
…"Although the report lists and discusses sources of uncertainty, it expresses the expected confidence intervals on its model predictions less often. For example, if storm sediment transport can hardly be measured to within +/- 50%, model predictions can hardly be expected to be better (for example, in Appendix A, an error of about this range is indicated for predicting reservoir scour)."

LSRWA response: Sources of uncertainty were identified for each of the model analyses and ranges for some of the modeling estimates in the main report were provided where they were available. Unfortunately, as noted in the STAC review comment above, methods of uncertainty estimates for an integrated model system, as was used in the LSRWA which combines four large and complex models of the watershed, airshed, reservoir, and estuary, have yet to be developed. In any case, the level of uncertainty analysis in the LSRWA was consistent with what was applied in the model scenario analyses supporting development of the 2010 Chesapeake Bay TMDL. Quantifying uncertainty in application of linked complex mechanistic models of this type is extremely difficult to impossible. The standard technique involves making a large number of simulations with varying inputs and examining the resulting change in outputs. The resources to *do this were unavailable to this study. In fact, we do not know of any comparable study where uncertainty was rigorously examined in this fashion. The authors put a lot of effort into describing sources of uncertainty and potential impacts. The readers will have to consider these and create value judgments regarding model uncertainty. For the specific HEC-RAS example, the highest predicted error for scour in table A3 is about 50%. However scour is only about 30% of total sediment transport, so the scour error is actually about 15% of total sediment transport. The following language was added in the introduction to the Modeling Tools and Application Chapter of the main report:*

> *"In regards to uncertainty model results can be reported with extensive precision, consistent with the precision of the computers on which the models are executed. Despite the precision, model results are inherently uncertain for a host of reasons including uncertain inputs, variance in model parameters, and approximations in model representations of prototype processes. The uncertainty in model results can be described in quantitative and qualitative fashions. Quantitative measures are usually generated through multiple model runs with alternate sets of inputs and/or parameters. The number of model runs quickly multiplies so that this type of quantitative uncertainty analysis is impractical for complex models with numerous parameters and extensive computational demands. A qualitative, descriptive uncertainty analysis is the practical alternative in these instances which is what was done for this LSRWA effort."*

B. <u>From STAC</u>: **"**1) Stated sediment discharges from the Conowingo Dam are inconsistent with the literature. The report authors should either correct their numbers or present a clear explanation that reconciles why their estimates are significantly different from other estimates that are based on analysis of observed data." "… Also on p. 190, the report indicates that,' The total sediment outflow load through the dam… increased by about 10 percent from 1996 to 2011…' These results are so strongly at odds with other published numbers on this subject that some explanation and discussion is certainly required.

LSRWA response: We are not sure exactly what is meant by literature values. There are not sufficient measurements of the inflowing sediment to the Conowingo reservoir to develop either an observed time history or a reliable rating curve. There are some observations of sediment load into the entire 3 reservoir system, but the mitigation of these loads by the presence of the upper 2 reservoirs must be modeled. Given these uncertainties, the modelers elected to allow a relatively high inflowing sediment load into the Conowingo reservoir; so that the scour potential was maximized (a low load could reduce scour potential by making sediment supply limiting). Regarding comment on the 10% increase from 1996-2011, hydrology is key. Language is already included that this 10% is specific to a 4 year AdH simulation period (2008-2011) of hydrology comparing 1996 bathymetry to 2011 bathymetry. This statement in the report means that, for the same 4 year water and sediment inflow hydrograph, model runs using the 2011 starting bathymetry yielded 10% more sediment exiting the Conowingo reservoir than did model runs using the 1996 starting bathymetry. This is somewhat different than conditions forming the bases of various analyses of Hainly, Hirsh, and Langland investigative studies.

C. <u>From STAC</u>: "Reduced deposition associated with reservoir infilling has been neglected. The fundamental issue motivating the LSRWA study is that the net trapping efficiency of Conowingo

Reservoir has decreased dramatically over the past 15 to 20 years. Net trapping efficiency is the sum of increases in average annual scour and decreases in average annual deposition. However, the simulations and calculations in the study only considered the increase in scour….”…….“This issue underlies a significant weakness in the report, which is that it focuses its inquiry on the impact of large, but infrequent, scour events rather on the total impact of the change in trapping efficiency of the reservoir system. The review recommends that all statements that indicate that reservoir trapping of sediment and associated nutrients is unchanged in the absence of scour be removed”

LSRWA Response: Both increases in scour and decreases in deposition were modeled by AdH. There are no artificial constraints on the model to retain a constant rate of deposition. The LSRWA Team agrees that the Chesapeake Bay impacts were primarily evaluated in the context of NET scour events or additional scour over varying bathymetries. However 1996, 2008, 2011 and full reservoir deposition were simulated, compared and presented in report. Perhaps the concept of dynamic equilibrium needs to be emphasized more in these statements, the time scale that we are referring to here is important.

“Dynamic equilibrium does not imply equality of sediment inflow and outflow on a daily, monthly, or even annual basis, or similar time scale. It implies a balance between sediment inflow and outflow over a long time period (years to decades) defined by the frequency and timing of scouring events. Sediments (and associated nutrients) that accumulate between high flow events are scoured away during storm events, whereby accumulation begins again. Over time, there is no net storage or filling occurring in the reservoirs.”
The LSRWA team agrees with the STAC comment that lower flows will cause scour as the reservoir fills. The report language has been edited to state that:

> *“The study did not differentiate between increased scour and less deposition as a reason for an increase in solids at lesser flows but most likely is a combination of both.”*

D. <u>From STAC</u>: “Grain size effects within and exiting the reservoir were not sufficiently considered. The combination of two grain size effects – (i) changing grain size in time in the reservoir and (ii) the greater effects of fine sediment in transporting nutrients - mean that the effects of the reservoir on water quality have not reached a full dynamic equilibrium. However, the report did not address whether reservoirs were in dynamic equilibrium with respect to nutrients other than by assuming that if sediment was at equilibrium, then nutrients were also. “…Grain size effects within and exiting the reservoir were not sufficiently considered….” “ The review recommends that the concept of dynamic equilibrium be clearly qualified in the report to indicate it does not yet apply to sediment grain size, and thus it does not yet fully apply to the flux of fine sediment or associated nutrients.” “…Thus, the dynamic equilibrium that is described in the report is changing over time, and it would be worthwhile to try to predict how many cycles of deposition and scour might be required before the dynamic equilibrium becomes less dynamic.”

*LSRWA Response**:** The LSRWA Team deliberated much on concept of dynamic equilibrium, which the report defines in simplest terms as no more long-term net trapping. Dynamic* *equilibrium also means, even at this end state, things in the reservoir will still change, for example grain size. In general we can agree that grain size and nutrient composition/flux will continue to change over time. But the overall definition of dynamic equilibrium as utilized in the report is adequate for the purposes of presenting the finding that long-term net trapping has ceased.*

Grain size implications are an interesting consideration. USGS indicates that a study done by Bricker (USGS) indicated that it would take 5,000 years for grain size to shift fully to sand and larger grain sizes. The grain size of the reservoir bed may change over time as the reservoir fills. Grain size was not considered explicitly (although grain size sorting was implicitly modeled). However, these effects, although important, are likely impossible to meaningfully quantify without significantly more and better field and laboratory observational data. These grain size effects fall well within the uncertainties of what is known. A qualitative discussion of grain size effects could be helpful, but attempts to quantify this are limited. This limitation is not due so much to the fidelity of the model as it is due to the uncertainty of the data. Grain size shifts and effects can be simulated with the AdH model, but the model cannot be validated to observed data, because there are not sufficient observed data to validate to (to within a reasonable range of uncertainty). So this must be considered qualitatively, as a discussion. How might this trend alter the load of fines downstream and hence the water quality? Although it might allow less storage of fines over time, it might also prevent the mass erosion of older stored fines, if they are buried under sands. A conceptual analytic model might be of some use here, or even some parametric numerical model runs, as long as it was made clear that these are unvalidated runs.

Regarding nutrient composition, the data to develop a nutrient budget based on possible alteration in grain size does not exist. We were fortunate to find data on particle nutrient content without regard to grain size. Determination whether the reservoir is in equilibrium or not with regard to nutrients is an impossible task. We would need a historical record of particle nutrient composition and content, a comprehensive accounting of nutrient storage and loss in the bottom sediments, and projections of future trends in nutrient load and particle composition. Any statement as to whether the reservoir is in equilibrium with regard to nutrients is speculative. The report does not state "assumed that if sediment was at equilibrium, then nutrients were also." The report is rightfully silent on this topic.

E. From STAC: "The HEC-RAS modeling effort was largely unsuccessful, and the HEC-RAS simulation was largely abandoned as an integral part of the main report." "Limitations of HEC-RAS model were not made sufficiently clear in the main report".

LSRWA response: The LSRWA team disagrees that HEC-RAS was largely unsuccessful. The team knew it had its flaws for this system, which is why the team used a 2D AdH model for Conowingo. However, application of this model helped the team understand conceptually that there is still scouring and deposition in the upper two reservoirs. Also, HEC-RAS was successful in calibrating the hydraulic (flow) for the simulation period and size distribution. It provided AdH a valid starting point for inflow into Conowingo Reservoir. These inflow numbers were increased due to the problems with mathematical computations in HEC-RAS related to sediment *transport. The issue was the magnitude of the sediment transported at Conowingo. Language has been revised in HEC-RAS discussion of the main report to read:*

> *"For the LSRWA effort, the HEC-RAS model outputs provided a relative understanding of the reservoir sediment dynamics, indicating all three reservoirs are active with respect to scour and deposition even in a dynamic equilibrium state (the upper two which have been considered to be in dynamic equilibrium for decades). Additionally the boundary-condition data from the HEC-RAS model were helpful in the calibration of the AdH model, especially by improving information on the inputs into Conowingo Reservoir."*

HEC-RAS is designed primarily for non-cohesive sediment transport (sands and coarse silts) with additional, but limited, capability to simulate processes of cohesive sediment transport (generally medium silts to fine clays). Thus the model may not be suitable for all reservoir simulations, especially in areas of highly variable bed shear stress (the force of water required to move bed sediments) and active scour and deposition. Limitations of the model most likely resulted in 1) less than expected deposition for the 2008-2011 simulation and 2) less than expected erosion (scour) for the Tropical Storm Lee seven day event simulation, when compared to other approaches and estimates. If a more detailed evaluation of the upper two reservoirs is required in the future, application of the AdH would be more appropriate.

F. <u>From STAC</u>: "The AdH model was not fully validated, and the AdH model was forced by boundary conditions outside the range of observed values. This means that the AdH model alone was not reliably predictive, and until the AdH model has been improved, observations should instead be emphasized to support the most important conclusions of the LSRWA study…." "Although consistent with four observed, integrated sediment-related properties of the system, the AdH model was not fully validated…" "The AdH model was not calibrated, but instead the authors use what they refer to as a validation approach…" "The tenuous nature of the model validation is made more uncertain by the fact that the values for the key boundary condition (critical bed shear stress for sediment entrainment) in the final selected model fell largely outside the range of values measured by the SEDFLUME or were unmeasured and taken from the literature."

LSRWA response: Not sure what is meant here by "fully" validated. Estimated data from AdH was compared to the actual measured data at Conowingo for total load transport and particle size. The validation of the AdH model was limited, primarily because the quantity and quality of the available field data are limited. Further validation against this limited data would create a misleading impression of confidence, since the uncertainties associated with the observations do not allow for "full" calibration and validation. The model was shown to match several integrated quantities well, which demonstrates that the general sediment scour and deposition behavior of the reservoir is well represented in the model Then, the model was subjected to gross sensitivity experiments, to determine the expected trends and behavoir of the reservoir and expected future behavior. These trends are consistent with what is known about the historic behavior of the reservoir.

The validation to integrated properties is undertaken partly because there are not sufficient data to validate the mode better. To do this, one would require a much more comprehensive history of sediment loading, a wider selection of SEDLUME cores, more information on settling velocities, consolidation rates, bioturbation, etc. That is, both the stratigraphic history and the processes that govern stratigraphic development must be observed. Since these data don't exist, the model is validated to the degree that the data allow, and the model is relied upon only inasmuch as it predicts "integrated" results (i.e. fraction of total load being eroded, sediment equilibrium arguments).

The critical shear stress was utilized essentially as a calibration parameter. The erosion rate constants and exponents were indeed taken from the SEDFLUME results, but the critical shear was increased beyond what was observed in the surficial SEDFLUME layers. There may be some allowance for this inasmuch as the SEDFLUME data may have been collected when the reservoir was in a less consolidated state than when the tropical storm event took place. But, in reality, these values were adjusted because these adjustments resulted in the best qualitative and quantitative fit against the observations.

It is true that the model could be improved, but it is not true that the model is of little use. It provides valuable insight into the sediment dynamics of the reservoir that is consistent with what is known. It also provides supporting evidence for the general conclusion that the reservoir is in dynamic equilibrium with respect to sediment storage and release over long term (multi-year) time scales. The AdH modeling effort is not designed to be reliably predictive in all aspects of sediment behavior, since the paucity of available field data make this effort beyond the skill of any model. Rather, the AdH effort is designed such that the main thing it seeks to evaluate is the general character of the sediment storage and release trend of the reservoir (i.e. whether the reservoir is approaching dynamic equilibrium) and approximately what percentage of the outflow from large storm events is associated with scour. With respect to these questions, the AdH model demonstrates the ability to predict what is known, and the future predictions are consistent with the observed trends. So the question is, are these general conclusions likely to change significantly, even if more data were available and better model validation were achieved? Although we disagree that the model is of little value, we agree that it is worth thinking through the possibilities associated with this question.

G. <u>From STAC</u>: "References to differentials as small as 0.1% (for example, see table 6.7) imply accuracies in characterizing the sedimentary system that could not be confirmed by any type of measurement known by the reviewers. However, if qualified as model results and indications are in relative terms, there may be value in such numbers as long as all such values are qualified as "well within measurement error." Hence, "we cannot infer any significant change" should be stated up-front based on results of such analyses. In many of the modeled scenarios, the changes in attainment of water quality criteria with fairly large management actions would appear to a non-technical reader to be very small. For instance, p. 135 states: "…estimated…non-attainment…of 1 percent, 4 percent, 8, percent, 3 percent…" One should ask if such estimates are statistically significant."

LSRWA response: The LSRWA Team agrees with the main point that since all of the water quality assessment results estimated in the LSRWA Report with estimated relative differences *ranging from 0.1 percent to 8 percent are from relative differences with a base scenario, the scenario estimates, though seemingly small, have merit. In most cases the base scenario was the Chesapeake Bay TMDL Watershed Implementation Plan (WIP) Scenario, which is estimated to fully attain the state's Chesapeake water quality standards. The base scenario was compared to key scenarios of Conowingo infill generating the percent differences described in the LSRWA Report. Existing language in main report states:*

> *"EPA provided a first order estimate of the degree of Susquehanna River watershed nutrient pollutant load reduction needed to avoid estimated increases in DO nonattainment of 1 percent in the deep-water and deep-channel areas; this analysis is described further in Appendix D. A rough estimate of the load reduction needed Bay-wide is about 2,200 tons of TN (4.4 million pounds) and 205 tons of TP (0.41 million pounds) to offset the DO nonattainment in the deep channel and deep water areas. Estimates of the nitrogen and phosphorus pollutant load reductions from the Susquehanna River watershed needed to offset the 1-percent increase in DO nonattainment are about 1,200 tons of nitrogen (2.4 million pounds) and 135 tons of phosphorus (0.27 million pounds)."*

H. <u>From STAC</u>: "Similarly, in appendix A, p. 25, the net deposition model indicated that ~2.1 million tons net deposition in the reservoirs occurred in 2008-11. This is the difference of two order-of-magnitude larger numbers (22.3M tons entered the reservoir, 20.2M tons entered the Bay). There is a rule-of-thumb in sedimentology: ±10% in concentration or transport is 'within error'. Does the precision of the computed difference fall within the margin of error in these metrics?"

LSRWA response: The HEC-RAS model did not perform well when compared to actual data. However the LSRWA team was testing for "significant change." Error bounds are presented in Appendix A (Attachment 1) for estimate of equation based regression scour and sediment loads transported into and out of the reservoir. This is just a simple subtraction of the in's and out's of Conowingo reservoir. The team already surmised that the estimate was under predicting the amount of deposition. It does fall within 10% of the metrics as presented, but that does not mean it's correct. It is also important to note that much of this load is "wash load" in that it passes through the reservoir without significant interaction with the bed. Therefore, with respect to erosion and deposition dynamics, the "within error" calculation should not include the wash load. .

I. <u>From STAC:</u> "If optimally constrained by observations, reservoir calculations may have reasonable accuracy and precision when averaged over longer timescales, but less accuracy over shorter timescales. However, the key timescales for many biological processes are much shorter than those of an annual sediment budget, and this could be a major source of uncertainty in the predictions of the efficacy of the sediment management scenarios. This disparity in process timescales is important to address in the text and in the conclusions of the study."

LSRWA response: This is a good point. Regarding the AdH model, utilizing erosion rates characterized by the SEDFLUME observations, erosion tends to occur rapidly in response to a rapid rise in the hydrograph. Hence, the eroded sediment from a rapid rise is pulsed rapidly *into the Bay. So, although the results are presented as integrated quantities, the model output to the ecological model does include this rapid pulse. The CBEMP model results ultimately hang on the assessment of attainment of water quality standards. Since the DO water quality standards have a space and time assessment that's considered to be relevant to living resources in the designated uses of Chesapeake Deep Water, Deep Channel, and other regions of the Chesapeake, the issue was largely addressed in the development adoption of the states' Chesapeake Bay water quality standards.*

J. <u>From STAC</u> "Anoxic volume days appears to be a variable that is relatively more sensitive to the model scenarios presented in the report (e.g., Table 6-8). This suggests something alluded to in the report on several occasions that a large fraction of the deep water in Chesapeake Bay is sitting on the threshold of being anoxic, and seemingly small changes in concentration (0.2 mg/l) lead to substantial relative changes in anoxic volume. It is worth clearly stating that the high sensitivity of this one criteria to small changes in load stands out among the other variables (e.g., chlorophyll-a, chl-a). It strikes the reviewers that changes in chlorophyll and dissolved oxygen associated with "normal" inter-annual variability in climate and nutrient loading are much higher than those associated with additional Conowingo Dam-derived nutrients as simulated here. One might conclude that given this fact, that the potential effects of dam-derived particulates are trivial."

LSRWA response: At places and times, the predicted response of Chesapeake Bay water quality conditions to scoured Conowingo nutrients is indeed small compared to inter-annual variability. Relatively small changes in dissolved oxygen can trigger a failure to meet rigorous state adopted Chesapeake Bay water quality standards. So even apparently small changes can be consequential. As suggested by the reviewers, it is the summer hypoxic period that is of concern and small difference in DO during this period make big differences to living resources as reflected in the development of the DO water quality standards.

The following language has been added to Appendix D:

> *"The Deep-Water and Deep-Channel DO water quality standards are on a knife-edge of attainment with the State Watershed Implementation Plans (WIPs). Achieving the Deep-Water and Deep-Channel DO standards in the 2010 TMDL was difficult and required management actions that went far beyond what was needed for sediment and chlorophyll (except in the case of James chlorophyll). The annual difference in DO generally ranges from about 12 mg/l in the winter to near hypoxia/anoxia conditions in the summer in the Deep-Water and Deep-Channel regions of the Chesapeake largely due to DO solubility differences with temperature and also due to the summertime presence of the pycnocline. But it is the summer hypoxic period that is of concern and a small difference in DO during this period makes big differences to living resources as reflected in the development of the DO water quality standards."*

K. <u>From STAC</u>: "The relevant statement from Hirsch (2012) is:' The discharge at which the increase [i.e., the increase in suspended sediment concentrations at the dam] occurs is impossible to identify with precision, though it lies in the range of about 175,000 to 300,000 cfs.

Furthermore, the relative roles of the two processes that likely are occurring – decreased deposition and increased scour – cannot be determined from this analysis.' "

LSRWA response: The reference to Hirsch has been removed from the text.

L. From STAC: "First, the events in excess of 150,000 cfs happen on average about 3 times per year (not once every two to three years). The number of such days (with daily mean discharge between 150,000 and 300,000) is about 11 days per year. Second, it is not clear that the increase in sediment loads in the 150,000 to 300,000 cfs range is really a result of scour."
LSRWA response: The LSRWA team disagrees with this comment regarding flow frequency. USGS calculations of the hydrologic record (Appendix A, Attachment 1) show that exceedance numbers for a 150,000 cfs is about once every year, 300,000 cfs is about every 2.1 years. The LSRWA Team agrees that we do not fully understand what is going on at the lower and more moderate flows which is why the report contains a recommendation to evaluate this more closely.
The report language revised to state:

> *"On average, in this dynamic equilibrium state, a major scour event will occur once every 4 to 5 years. Minor scour events with trace amounts of erosion will occur every 1-2 years (150,000-300,000 cfs); while at lower flows sediment (and associated nutrients) will accumulate until an erosion event occurs again. In the flow range of 150,000-300,000 cfs it is not fully understood if this increase in sediment load to the Bay is due to an increase in scour or due to a decrease in deposition in the reservoir itself; it very likely could be a combination of both and warrants further study."*

M. From STAC: "At bottom of p. 190 the text reports on reductions in TN, TP, and TSS as 19, 55, and 37%, respectively, for the past 30 years for loads "to the lower Susquehanna River", referenced to http://cbrim.er.usgs.gov. This could mean loads delivered to the upstream end of the reservoir system or loads delivered at the downstream end where the river enters the Chesapeake Bay."
LSRWA response: The STAC comment is correct about trends in flow-adjusted concentration. WRTDS can estimate trends in loads, but it currently cannot estimate error ranges around the estimates. Until that is resolved USGS will not publish trend in loads.
The report language has been revised to read:

> *"Over the past 30 years, due to widespread implementation of regulatory and voluntary nutrient and sediment reduction strategies, nutrient and sediment loads to the lower Susquehanna River are significantly lower than what was delivered in the mid 1980s. Flow adjusted concentrations of total nitrogen (TN), total phosphorus (TP), and suspended sediment concentration declined by 30, 40, and 45 percent, respectively between 1985 and 2012 at Marietta, PA (see http://cbrim.er.usgs.gov/)."*

N. From STAC: "Nutrients associated with fine sediments, not with the total load of sediments, are the main water quality concerns. The report acknowledges that sand-sorbed P is more or less inconsequential in P transport. However, all sediment-discharge values are expressed as "total loads." Since P transport is closely tied to fines, and presumably very closely tied to clay-size particles, transport metrics computed for fines, and particularly for clay-size particles, might yield different conclusions than those derived from "total" load comparisons. It is also important to clearly define what is meant by total load. Sedimentological nomenclature denotes "total load" as all material in transport, be it defined as bed load plus suspended load (with caveats), or bed-material load plus washload"

LSRWA Response: the report is referring to bed load plus washload, all sediment available. This is further refined in outputs as bed load and loads out of the reservoir, or total delivered load. For HEC-RAS specifically, transport equations in HEC-RAS are designed to move bed load. However, a transport curve with properties of the cohesive sediments is also included in the estimation of total transport from one cross-section to another in each time step. In addition, bed load transport is not a substantial part of the total load (<10%).

Language has been added to the main report's glossary clarifying that total load includes all material in transport (includes bed load plus washload (sediment) load).

Question 5: Are the recommended follow-up evaluations and analyses (Section 9.1) complete and comprehensive as well as clearly stated to enable the next phase of work to continue under the Partnership's Midpoint Assessment?

A. <u>From STAC</u>: "One of the outcomes of this study should be to identify areas where our scientific understanding may be insufficient to achieve management goals, and to suggest future scientific studies to provide this knowledge. Follow-up studies need to consider the full range of hydrologic conditions, from moderate to high flows, which generally do not result in scour (but still reduce the deposition of sediment-associated nutrients in the reservoir), all the way up to the very high but very rare events that do result in scour. The emphasis in the future should shift from the relative vague impact of additional "sediments and associated nutrients" to the differential impact of specific particulate and dissolved nutrients."

LSRWA Response: The LSRWA team fully agrees. Studies are now underway by USGS, MDE, and Exelon entitled "Lower Susquehanna River Integrated Sediment and Nutrient Monitoring Program focused on the Conowingo and the other two Lower Susquehanna reservoirs that are examining the fate and effects of nutrients mobilized from the Conowingo Reservoir from very high (>400,000 cfs) and moderately high flows (>100,000<400,00 cfs). The studies will be used to support Chesapeake Bay Program (CBP) partnership decisions on Conowingo infill offsets as part of the Partnership's Chesapeake Bay TMDL 2017 Midpoint Assessment. The ongoing research and field work on the mobilization and fate of nutrient from the Conowingo Pool will be applied to an integrated analysis using the CBP's partnership's suite of Chesapeake Bay watershed and estuarine water quality/sediment transport management models. Recommendations 1 and 4 already include language on evaluating moderate and lower flows and understanding bioavailability of different forms of nutrients.

The following language has been added to Recommendation #1, bullet #1:

> *"Determine the detailed characteristics and bioavailability of sediments and associated nutrients likely to be scoured within Conowingo Reservoir. The*

emphasis in the future should shift from the relative vague impact of additional "sediments and associated nutrients" to the differential impact of specific particulate and dissolved nutrients."

B. From STAC: "A key question is how to proceed to do the "adjusting" of the TMDL milestones to account for increased sediment-associated nutrients passing out of the reservoir. "…That issue is thus the following: how much of a decrease in loads delivered to the reservoirs and/or increase in reservoir trapping efficiency would be required? The logic behind this resistance to including treating the sediment load as a penalty is expanded upon in the following two subsections: The negative impacts of sediment input to the Chesapeake Bay (relative to nutrients) are overstated by present TMDLs and are overemphasized in management priorities…"
"…Key recommendations of this review in this regard include: (i) that the effect of the change in overall "trapping capacity" must be accounted for (the LSRWA analysis done so far relates only to increased scour and not to total trapping capacity), (ii) priority should be given to accounting for the added particulate phosphorus, and (iii) the additional sediment load (other than associated nutrients) should NOT be an additional burden on TMDLs. Calculations by Hirsch suggest that the net loss of trapping efficiency by Conowingo may be in the range of 2300 tons of phosphorus per year. The basic question facing the midpoint assessment then is: what would it take in terms of upstream phosphorus management in order to overcome the impact of ~2300 tons of phosphorus? This estimate is not highly accurate. The team that did the LSRWA report has the simulation expertise and capacity to test these estimates, but they have not yet performed this specific simulation. The follow up to this LSRWA effort really needs to address these estimates and replace them with better ones if they can (including uncertainty bounds)..."
"…The effectiveness of BMPs in reducing sediment loads to the Bay may be overstated by present TMDLs." "…The possibility that sediment BMPs may not lead to a major reduction in sediment coming from the upstream watershed needs to be considered as a real possibility in considering management actions. Models alone cannot answer this question; only more direct measurement in places downstream of BMPs can fully demonstrate whether they are effective..."

LSRWA response: Once the "Lower Susquehanna River Integrated Sediment and Nutrient Monitoring Program" studies examining the fate and transport of nutrients, including both phosphorus and nitrogen forms from Conowingo infill are complete in 2016, the Chesapeake Bay Program partnership will work with the LSRWA modelers to incorporate the new salient information into the full suite of the CBP partnership's Chesapeake Bay watershed and estuarine water quality/sediment transport models. Analysis and review of the synthesis of research, field work, and modeling will enable a complex and comprehensive quantification and programmatic evaluation of the options for Conowingo infill offsets by the CBP partners as part of the Partnership's Chesapeake Bay TMDL 2017 Midpoint Assessment. Ultimately a decision of how to achieve the states' Chesapeake Bay water quality standards in the presence of the current dynamic equilibrium in the Conowingo Reservoir will be made by the Partnership in 2017.

The LSRWA team notes that sediment management is important throughout Chesapeake Bay watershed to improve freshwater river habitat impaired by excess sediment, maintain floodwater conveyance, improve water supply quality, reduce reservoir infill and in the case reducing silts and clays, improve water clarity and support survival and growth of SAV resources in tidal *headwaters. It's important to note that the 2010 Chesapeake Bay TMDL does not manage for sand erosion input loads, only the fines, and recognizes that the sand erosion can be beneficial to habitat and SAV resources.*

The LSRWA team agrees with the STAC comment regarding the effectiveness of BMPs in reducing sediment loads to the Bay and that it may be overstated by present Chesapeake Bay TMDL. As previously described, sediment management is important throughout the watershed. Nevertheless, because of sediment storage throughout the watershed the lag time for sediment (and associated nutrients) delivered to the Chesapeake tidal waters could be on the order of decades to centuries. Decision rules in the Partnership development Chesapeake Bay TMDL and the jurisdictions developed WIPs account for sediment load reductions at the tidal Bay as soon as the sediment management BMP is established. While there are obvious disconnects between science and the practice, the Chesapeake Bay TMDL and the jurisdictions WIPs encourage implementation of management practices that reduce sediment and nutrient loads in the tidal Chesapeake Bay. Both share the core goal of the implementation of all required practices, treatments, and technologies by 2025 needed to achieve all the states' Chesapeake water quality standards. The establishment of the practices is what's required by 2025, not water quality standard attainment. There is an explicit understanding in the Chesapeake Bay TMDL that because of sediment and nutrient lag times, water quality standards attainment will lag management implementation. Regarding how to determine the effectiveness of BMP's; monitoring alone might not answer that question. The question of scale and the fact that the vast majority of streams have huge sediments supplies from disruptive historical land use practices, make this extremely difficult to detect change.

C. From STAC: "There are a variety of technologies that can be applied using *in situ* sensors to collect an essentially continuous record of sediment concentrations and flux for use in inferring sediment-associated nutrient transport, including inference of grain size distribution."

LSRWA Response: USGS is trying to secure long-term funding to get an instrument deployed (a partner is required to match 50/50). In the short-term Exelon will be funding the placement of in situ monitors at Marietta, Holtwood, and Conowingo locations.

D. From STAC: In addition, Recommendation 1.2 would be better written as something like: "Determine the quantity and nature of the sediment-associated nutrients transported downstream under current conditions (dynamic equilibrium) versus conditions that prevailed in previous times when the reservoirs had substantial trapping ability.

LSRWA response: The report text language revised as recommended in the above STAC comment.

E. From STAC: "Could a higher P:N ratio cause a shift towards more blue-green algae that have an ability to fix N from the atmosphere, so that even with decreasing N loads from the watershed, the N available in the Bay might not decline due to this ecological shift? In any case, the emphasis in the future should shift from the relatively vague impact of additional "sediments and associated nutrients" to the differential impact of specific particulate and dissolved nutrients. Future studies should also test the sensitivity of the biogeochemical model simulations to the reactivity of the scoured material for both nutrient release and water column and sediment respiration, which are linked. The latter influences DO directly. This could potentially require additional state variables to represent different pools of particulate matter in the sediments and water-column. Surely, scoured materials and other solids are deposited in sediments, where diagenesis releases nutrients back to the water column to fuel algal growth. But before these materials are deposited in sediments, they could fuel respiration directly in the water-column. They should also contribute to sediment oxygen demand, or in the case that sulfides are released to the water column from sediments, to lagged water column oxygen demand."

LSRWA response: The nutrient limiting to phytoplankton production varies with time and location throughout the Chesapeake Bay. In the future, the CBP partners could look at modeled response of nutrient limitation to alterations in the Conowingo Reservoir nutrient budget. The composition and reactivity of the particulate materials carried out of Conowingo Reservoir are large sources of uncertainty, as acknowledged in the report and in subsequent presentations and meetings. A study is planned to specifically address these issues. A study is also planned to examine the fate of and transport of particles swept over the Conowingo outfall into the Bay. Additional efforts with the model are not warranted until the results of these studies are available.

F. From STAC: "Develop and implement management options that offset impacts to the upper Chesapeake Bay ecosystem from increased nutrient and sediment loads. "It is suggested here that, once more, the phrase "nutrient and sediment loads" in the above recommendation be changed to "sediment-associated nutrients".

LSRWA response: The report text language revised as recommended above in STAC comment.

Question 6: Do the technical appendices provide the necessary documentation for the models and their applications in support of the study's results, findings, and conclusions?

Appendix A

A. From STAC: "The Estimator model was used in Appendix A in spite of the fact that its originator, Dr. Tim Cohn, has indicated his doubt as to whether it is adequate for use with "hysteretic" suspended sediment. Although it well may "work" in this relatively large river – larger rivers with smaller peak-to-base-flow discharge ratios and more languid precipitation-runoff responses tend to exhibit less hysteresis in suspended-sediment concentrations than smaller rivers – additional analysis might be required to confirm or refute that assumption."

LSRWA response: The USGS recently conducted a comparison of load estimations using both ESTIMATOR and WRTDS for the 9 major streams in the Chesapeake Bay watershed. Results indicted very good load and trend estimates with both models although WRTDS had a lower error and variance. The problem with ESTIMATOR is with "runaway quadratic estimations" where due the use of squared terms, if a high value is associated with a high flow value then a non-linear fit is needed for the relation. This can sometimes lead a bias and overestimation of load.

B. From STAC: “Concern was expressed regarding the exclusion from the sediment transport curve of the high suspended-sediment concentration value (2,890 mg/L, at USGS gage 01578310 [Conowingo] on 9/8/2011) in Appendix A, p. 12, Figure 7. There is rumor of a similar ‘high outlier’ in 2004. The transport curve in Figure 7 may well effectively be discontinuous with a major break around 400,000 ft3/s. The two transport-curve sections might be nearly parallel. It is possible that the present curve is valid for flows ~≤ 400,000 ft3/s, and the new curve that would reflect natural increasingly sediment-laden flows plus scoured material is valid for flows ~> 400,000 ft3/s.”

LSRWA response: The graph has been updated to include this point.

C. From STAC: “A promising approach would be to develop a particle size-to-flow relation and apply it to the transport curve resulting in two (or three) curves, including a fines-transport curve (the principal metric of interest). The concept is graphically similar if mechanistically dissimilar from a discontinuous suspended sediment transport curve that has been shown to occur when flows transition between subcritical and supercritical regimes.”

LSRWA response: This was attempted to help build a transport curve for the HES-RAS model, but the lack of and the variability of the particle size data did not produce a discernible relationship.

D. From STAC: “The ESTIMATOR was used to project changing sediment load over time. However, in looking at the USGS NWIS site there is only very limited information about actual sediment concentration and load data collected – a number of years during the period between 1979 and 1992 at Marietta, and presumably grab samples, but apparently no continuous record at Conowingo. Given all of this there is some skepticism about how well we really know the comparison between sediment loads at the two stations, especially going back to the early 20th century. “

LSRWA response: The comparison going back to the 20th century was based on various studies, including data from other agencies, compiled yields, and extrapolation from long-term flow record at Harrisburg, PA to Marietta, PA then mass balance to upper Chesapeake Bay. The estimated loads definitely have large errors, but does provide an indication of past to current historical trends.

Appendix B

A. From STAC: “The SEDFLUME results from a small number of cores account for a large fraction of Appendix B. But there is insufficient explanation as to how these results were translated into the parameter set utilized in the six material zones in the model. Given the variability within each core from one shallow layer to the next, and given the variation in particle sizes longitudinally as well as variation laterally across the reservoir in depth and modeled velocity, perhaps there is no way at this point to account for spatial patterns beyond the simple selection of six longitudinal zones; and perhaps it ultimately does not make much difference what choices one makes. But it is odd that so much space was devoted to the empirical results without explanation as to how they were actually applied or what difference the spatial pattern of parameter values within different zones might make, particularly given that a 2d model is being used. In calibrating the model, the authors varied critical shear stress parameters at shallow depths and maximum scour depth to keep the model from scouring too much sediment, but the discussion of how this was done did not make much reference to differences among zones or within zones. The way this issue was handled is not explicitly addressed in the text even though the small number of cores is identified as a source of uncertainty."

LSRWA Response: The critical shear stress was utilized essentially as a calibration parameter. The erosion rate constants and exponents were indeed taken from the SEDFLUME results, but the critical shear was increased beyond what was observed in the surficial SEDFLUME layers. There may be some allowance for this inasmuch as the SEDFLUME data may have been collected when the reservoir was in a less consolidated state than when the tropical storm event took place. But, in reality, these values were adjusted because these adjustments resulted in the best qualitative and quantitative fit against the observations.

B. From STAC: "p. 4 Figure 1 shows in graphical form the same information that is provided in Table 5-6 of the main report but in each case the citation simply says "provided by USGS". How do we know that by 1959 (first paragraph, p. 5) there was a relatively constant inflow of 3.2 million tons/yr of sediment flowing into Conowingo?"

LSRWA Response: This information is gleaned from the 2009 USGS report referenced in the document. The report can be found here: http://pubs.usgs.gov/sir/2009/5110/pdf/sir2009-5110.pdf.

C. From STAC: "pp.5-6 The Exelon revised HEC-6 study concluded that scouring flows above 400,000 cfs were net depositional in Conowingo? Not net erosional? Given conclusions provided elsewhere in both the main report and appendices, this is confusing."

LSRWA Response: Page 27 of the report discusses some of the reasons for this. The basic idea is that scour does not necessarily equate to net scour. For example, the upper section of the reservoir appears to scour, but a significant part of this material is sand, which appears to redeposit within the reservoir in the lower reach.

D. From STAC: "p. 22 Under model validation the statement is made that "The maximum sample depth was only about 12 inches due to highly consolidated sediments in deeper layers preventing penetration of the sampling tube." If this is the case what does it say about the actual potential for scour in a large flood event?"

LSRWA Response: It implies that there may be a practical limit for the total volume of scour. However, for his study, this practical limit was not systematically investigated further, as the large historical event studied here (in 2011) did not achieve this level of scour in the reservoir.

E. From STAC: "p. 23 Here it says that although samples represented only the top foot of sediment, the model sediment bed was about three feet. It appears from later discussion of choices made for calibration purposes that the three-foot depth had to be modified in order to match better with other information. The choices made here are not always clear."

LSRWA Response: The erosion properties at depth were unobtainable due to the inability to achieve core penetration. This implies that these sediments are stiffer than the surficial sediment, but not necessarily unerodable. Therefore, the model was supplied with layers at depth that were, in general, less erodible than the surficial layers. The properties of the deeper layer had to be approximated.

F. From STAC: "p. 25 This shows the flow-concentration curve for Conowingo and highlights both the variability at high flow and the existence of only a single point at the upper end of the curve. It would seem appropriate to try to quantify the uncertainty associated with use of this curve and develop a range of values in order to see how this uncertainty might affect conclusions and comparisons. The USGS curve for prediction of scour as a function of Q has upper and lower bounds; so should the sediment concentration rating curve."

LSRWA Response: This curve is for sediment outflow from the reservoir. Although significant uncertainty is indeed present in the data, a formal uncertainly analysis was not undertaken, because the data were not utilized significantly in the validation of the model. The primary use of the rating curve data was to extract grain size trends (that were qualitatively compared to model data) and to estimate integrated quantities, such as net sediment load. Although there was no formal uncertainty analysis, a general discussion of uncertainties in the data, including the hysteresis effect, is included.

G. From STAC: "p. 27 The major trend was that most of the scour occurred in the upper 1/3 of the reservoir where there is more sand which constitutes 50% or more of total bed sediment. A significant amount of deposition occurred just upstream of the eastern end of the dam. Was this mostly fines or more sand? What is the effect of the changes here on the particle-size distribution of the deposit as a whole?"

LSRWA Response: It is not known for certain, but some indirect evidence, as well as general sediment principles, implies that this deposited material is mostly sand. This indicates a redistributional effect within the reservoir with respect to sand, at least for this particular flow event. This implies a preferential trend toward the storage of coarser sediments over time. However, the increased availability of these sandy sediments in the lower reaches of the reservoir may also make them more likely to be available for transport out of the reservoir for large flow events in the future, so the trend could be more complex than it seems.

H. From STAC: "p. 28 Model validation involved a parametric model study where bed-property values were manipulated and results compared with USGS scour load prediction. Was any consideration given to whether properties might vary with depth or distance from the shoreline?"

LSRWA Response: Consideration was given for the variation of properties both spatially (based on the spatial distribution of the SEDFLUME samples) and at depth into the bed (based on variation of the SEDFLUME properties with depth into the cores, and also based on the observed trends toward a stiffer bed at depth into the bed).

I. <u>From STAC</u>: "p. 29 The choice of limiting depth available for scour to one foot seems like a reasonable one for a lower bound, given what was learned from coring and laboratory tests."

LSRWA Response: Only if it can be assumed that the limit of penetration implies the presence of a very stiff substrate. However, it is possible to have a layer that is difficult to penetrate with a push or gravity core, while still potentially erodible with higher shear stress (for example, sand rich substrate can exhibit this property).

J. <u>From STAC:</u> "p. 31 When fitting parameters to compute erosion rate – is it not possible to develop some scheme for projecting variation in relevant material properties either longitudinally or laterally? Given that a 2d model is being used and given the spatial patterns of texture and cohesion, this seems like an element that ought to be considered – or else reasons why it cannot be done should be articulated."

LSRWA Response: See response to I. There is variability in the applied properties, based on the SEDLFUME core distribution. The critical shear was indeed adjusted (essentially calibrated) in a more general sense, but the other erosion properties were assigned the distribution of values dictated by the SEDFLUME cores. Figure 10 on page 20 shows how the distribution of cores was applied at Zones in the model.

K. <u>From STAC</u>: "p. 33 The authors argue that the uncertainty associated with applications of AdH is made manageable by basing conclusions largely on simulations of management scenarios in which only one variable is changed. This amounts to saying, in effect, 'the model worked OK for a hind cast, even though we had to use boundary conditions that were outside of the measured range or unknown, and we have not documented that the internal workings of the model are making reasonable predictions. So, if we only change one part of the model we can hope that it will reliably calculate the change in system performance.' However, one application of the AdH model was to evaluate scour and deposition relative to different reservoir bathymetry. These applications are not of the change-one-thing-only management scenario type and instead directly depend on the fidelity of the selected model."

LSRWA Response: Although the model is only validated to integral quantities, they are 3 separate integral quantities. The models general agreement with all of these quantities demonstrates that, at least in a bulk sense, the model is behaving as the real reservoir does, and for similar reasons. So the model results can be relied upon to make these same types of integral predictions as long as the forcing conditions that the model is subjected to are not extended far outside of the existing conditions (and they are not in this exercise).

L. <u>From STAC</u>: "p. 33 In discussing role of alternative bathymetry – do these alternatives assume spatially invariant bed material properties?"

LSRWA Response: No. They assume the same property distribution that was used in the model validation, which in turn is based on the SEDFLUME core data (see response to J).

M. <u>From STAC</u>: "p. 37 Do these flow fields try to account for the change in flow distribution at the outlet when the gates are opened during high flows? It is pointed out elsewhere that dam operations should be incorporated in the model for future studies – this would seem to imply that this is not the case here."

LSRWA Response: No. the dam operations are not included. Hence, the influence of dam operations on the distribution and storage conditions of sediments in the lowermost reaches of the reservoir (especially sandy sediments) must be considered an additional source of uncertainty in the results.

N. From STAC: "p. 44 The 2008 to 2011 period was somewhat atypical in terms of the frequency of days above the 400,000 cfs scour threshold. If we look at the frequency of days over 400,000 cfs during the 4-year simulation period it comes out to an average of 1 day per year above the threshold. If we look at the entire period from 1977 through 2012 the frequency of days above the threshold is about 0.5 days per year. Thus, the choice of 2008-2011 as the simulation period will overstate the importance of scour increases as compared to a simulation period that was more typical."

LSRWA Response: Possibly. However, a more conclusive way to estimate this might be to integrate the inflow hydrograph against the net scour curve for the entire period of record, annualize the result, and compare this to same annualized quantity for the 2008-2011 hydrograph. This was not done for this study, however, as the focus of the study was just to establish the sensitivity of a given inflowing hydrograph and sediment load to changes in reservoir bathymetry.

O. From STAC: "p. 60 In discussion of limitations posed owing to need for a more sophisticated approach to simulating flocculation – is there any way to estimate how much difference this might make to overall conclusions?" "In the same paragraph it is suggested that field methods are needed for sampling storm concentrations or turbidity over the entire storm hydrograph. Presumably standard methods can be used for the samples for either concentration or turbidity without having a human operator have to stick a bottle in the flow (as apparently was the case for the single sample taken near the peak during Agnes). Is the issue one of how to deploy sensors or automated samplers in the vicinity of the various gates built to accommodate high flow?"

LSRWA Response: Some investigation of the influence of flocculation was made by simply investigating different settling velocity values. However, the implementation of a robust flocculation model would allow for less parameterization of the model, which improves its predictive reliability. There are methods available for collecting data during high discharge conditions, so this could be done if the investment were made.

P. From STAC: "Appendix B-1, Figure 3: One must be careful of drawing straight lines in log-log space that depict a transport curve. At some point, the relation must tail to the right, given that sediment concentrations have absolute limits."

LSRWA Response: This is true, although these limits are above the well above the concentrations given here.

Q. From STAC: "Appendix B-1, Section 5-1: The total annual estimated sediment yield delivered to downstream reservoirs is cited here as 4.2 million tons; but there are multiple other estimates in these documents, mostly less than this value – there needs to be more consistency among these cited values, or else an explanation as to why they are different."

LSRWA Response: I think the confusion might lie in the fact that this section is discussing an estimate of the sediment load into the uppermost of the 3 reservoirs (i.e. the discharge from the river into the reservoir system) whereas in other places in the report the sediment load being discussed is either sediment load from the upper two reservoirs into Conowingo, or the sediment load from the Conowingo into the Bay.

R. From STAC: "Attachment B-1: "Evaluation of Uncertainties in Conowingo Reservoir Sediment Transport Modeling" -- This section is misnamed. The section provides a useful discussion of different elements of flow and transport through reservoirs. Its basic purpose is to justify the use of a depth-averaged 2d model (AdH) rather than a fully 3d model for the simulation. Their conclusion that a 2d model is sufficient is reasonable (assuming proper calibration/validation). Alas, although uncertainties play a small role in the discussion (basically relating to uncertainties that might arise from reducing 3d flow field to 2d), the section provides no discussion of overall "Uncertainties in Conowingo Reservoir Sediment Transport Modeling." This is unfortunate, because those uncertainties are large and largely unexplored in the study."

LSRWA Response: General uncertainty is discussed throughout the report. Uncertainty is not formally quantified in the report, partly because the paucity of available data might render any such formal quantification deceptively meaningful. That is, without sufficient data, even the attempt to quantify uncertainty is, well, uncertain. This section discusses, among other things, the limitations of using a Quasi 3d model (where sediment stratification effects are represented in a semi-analytic sense) rather than a fully 3D model. Hence, it is a useful supplementary document that goes into some detail about the general processes that govern reservoir sedimentation, and how the modeling framework selected influences the results of the modeling.

S. <u>From STAC</u>: "Appendix B-1, Section 9: This section presents an AdH model of flow and transport on Susquehanna Flats. No discussion is given of any calibration or testing of the model in this environment, and one must presume that it is uncalibrated and untested. The roughness assigned to the flats with SAV and without SAV (winter) is sufficiently large that the majority of the flow and sediment transport occurs through the dredged channel. This is a reasonable result. The authors then reach a conclusion that is unsupported by the model and quite possibly incorrect: "the relatively higher bed roughness of the shallow flats will tend to continue to route the majority of the flow through the dredged navigation channel below Havre de Grace. Thus, discharge of sediment from Conowingo Dam due to bypassing or flushing operations will have minimal impact on the flats area, with sedimentation occurring in the dredged navigation channel or below the flats area." Just because most of the water and sediment go through the channel does not mean there will be no impact to the flats. If flow extends on to the flats, the authors have not demonstrated in any way that sediment carried in that flow will not deposit on the flats. In fact, this is how floodplains are formed. If turbid water is being discharged from the dam, one can deposit sediment wherever the water goes. Estimates can be made from the sediment concentration and residence time of water over the flats."

LSRWA Response: We agree in principle. The fact that flow is diverted to the main channel does not mean that deposition of fines will not take place in the SAV areas. The model does not show much deposition there, and deposition is being modeled there, but, as the reviewer points out, the model was not validated, So this effort may require some more work and further consideration, or at least further examination of the existing model results.

T. From STAC: "Appendix B-2, Summary and Conclusions. This section is misnamed and should be changed to only "Summary". There are no conclusions stated here."

LSRWA Response: Concur.

U. From STAC: "Appendix B-4 includes the following on its first page: "…sediment in transport in suspension is directly related to sediment particle size and the degree of turbulence." Density could also be a factor, particularly if it is true that some 10% of reservoir sediments are coal particles."

LSRWA Response: Concur.

Appendix C and D

A. From STAC: "One significant area could use a bit more attention. The period of the CBEMP model simulations is different from the period of the HEC-RAS/ADH scour simulations. The watershed loading scenarios are not the actual scenarios observed during the CBEMP simulation period, but rather projections based on expectations for watershed management practices under two different conditions (2010 implementation and TMDL achieved). The major storm simulation presented uses sediment-associated nutrient concentrations from a different storm entirely, not the simulated storm. As a result of all of these juxtapositions and substitutions, it is unclear exactly what is being simulated and why – the runs do not ever appear to be representative of actual conditions. While the final scenarios make sense and are very revealing, the reasoning behind their construction is hard to follow. A summary of the PHILOSOPHY of scenario construction, not just its mechanics, would help. This description should occur right after the introduction of the modeling tools used, and it should be addressed to an audience that is not familiar with standard practice in the CBP."

LSRWA response: The following language was inserted in Appendix C at the head of Chapter 3 Scenario Procedure and Listing Overview.

> *"The LSRWA makes use of existing tools and methodologies as well as new tools and applications developed specifically for this study. The use of existing models and practices is advantageous to the study since these tools could not be developed within the time and budget limitations of the LSRWA. The individual models within Chesapeake Bay Environmental Model Package (Watershed*

Model, Hydrodynamic Model, and Water Quality Model) are documented, have been extensively reviewed, and have lengthy application histories. The use of these existing tools provides some disadvantages and constraints, however, notably in the period emphasized in their application.

The AdH model, which computed sediment fate and transport in the Conowingo Reservoir, was a new application created especially for this study. AdH was applied over the period 2008 – 2011, in order to take advantage of recent data collected in the reservoir. The application included the Tropical Storm Lee event, which resulted in notable scour and provided an excellent opportunity for model calibration and validation. This period was not represented in the CBEMP, however, for which the primary application period was 1991 – 2000. The resources necessary to acquire raw observations, create model input decks, execute and validate the individual models within the CBEMP for the years 2008 – 2011 was beyond the scope of the LSRWA. Consequently, means were required to transfer information from the 2008 – 2011 AdH application to the 1991 – 2000 CBEMP. The crucial transfer involved combining scour computed by AdH for TS Lee with watershed loads computed by the WSM model for a January 1996 flood and scour event represented by the CBEMP.

The WSM provides computations of volumetric flow and associated sediment and nutrient loads throughout the watershed and at the entry points to Chesapeake Bay. Flow computations are based on precipitation, evapotranspiration, snow melt, and other processes. Loads are the result of land use, management practices, point-source waste loads and additional factors. The loads computed for 1991 – 2000 are no longer current and are not the loads utilized in the TMDL computation. To emphasize current conditions, a synthetic set of loads was created from the WSM based on 1991 – 2000 flows but 2010 land use and management practices. The set of loads is designated the "2010 Progress Run." The TMDL loads are a second set of synthetic loads created with the WSM. In this case, the 1991 – 2000 flows are paired with land uses and management practices sufficient to meet the TMDL limitations.

The AdH model provides computations of sediment load due to bottom scour, but not the load of associated nutrients. Limited observations of sediment-associated nutrients are available at the Conowingo outfall during the 1996 flood event. The composition of solids eroded from the bottom are difficult to glean from these observations, however, since samples at the outfall represent the mixture of solids washed down from the watershed and eroded from the bottom and as with the watershed loads, these observations may no longer represent current conditions. Consequently, the nutrients associated with scoured solids for use in scenarios was derived from observations of nutrients in the bottom sediments of Conowingo Reservoir.

Major storm events occur at different times of the year. In order to examine the effect of seasonality of storm loads on Chesapeake Bay, the January 1996 storm *was moved, within the model framework, to June and to October. The loads were moved directly from January to the other months. No adjustment was made for the potential effects of seasonal alterations in land uses. New Chesapeake Bay hydrodynamic model runs were completed based on the revised flows, to account for alterations in flow regime and stratification within the Bay.*"

B. <u>From STAC</u>: "Interestingly, the long-term impacts of the October Storm on DO seem less than the January storm (-0.25 in Jan from 1997-1999, -0.1 in October from 1997-1999, Figure 6-31). Why would this be? Is more of the January load processed that summer and cycled through the system, while much of the October load is buried over winter? This seems like a point worth investigating."

LSRWA Response: Good points for additional clarification. The text of Appendix D will be expanded to clarify these points as suggested: "The water quality effects in the October and January periods are diminished because of colder temperatures and decreased primary productivity, resulting in less interception of nutrient loads by algae. In the fall and winter a greater portion of the storm- pulsed nutrient load is transported down the Bay to be discharged at the ocean boundary or is lost though denitrification or deep burial in sediments. The long-term impacts of the October Storm on DO were estimated to be less than the January storm (see Figure 6-31 of Appendix C). This is because the simulated January storm load of particulate nutrients scoured from the Conowingo Reservoir was processed during that summer and cycled through the system, while much of the simulated October 1996 storm load was buried or discharged out of the Chesapeake Bay over the simulated 1996-97 winter before the particulate nutrient load was ultimately expressed as a depression of DO in the simulated 1997 summer."

<u>Appendix E</u>

A. From <u>STAC</u>: "…indicates that bathymetric data were acquired in Susquehanna Flats. They were not…"

LSRWA Response: The Appendix language has been revised to state that only sediment grain size data were acquired (vs. bathymetry).

<u>Appendix H</u>

A. From <u>STAC</u>: "A technique known as hydro-suction dredging is mentioned several times in the Appendix but not mentioned explicitly in the report. This technique would be especially useful for sediment bypassing, because it makes use of the huge natural head difference between the reservoir and the river below the dam to maintain flow through a dredging pipe or bypass tunnel. Was this technique considered in figuring the relatively low cost of bypassing, or not? Would it make a difference?"

LSRWA Response: By-passing could be done by various dredging techniques. The LSRWA team used past costs from actual projects of more traditional hydraulic dredging which were presented in the report. Costs for the specific Hydrosuction dredging technique could be investigated in the future but were not in the scope of this effort.

<u>Appendix J</u>

A. <u>From STAC:</u> “The economic analysis uses a different interest rate (or discount rate) for the watershed BMP versus dredging scenarios. Specifically, p. 14 in Appendix J says “estimates of annualized costs reflect a 5% discount rate” for the watershed BMP scenario. However, p. 167 in Section 6 says that “annualized one-time investment costs are based on a 50-year project life and the fiscal year 2014 federal interest rate of 3.5 percent” for the dredging scenarios. Appendix J-2 shows the detailed calculations for dredging scenarios based on the 3.5% interest rate. Proper economic analysis should use the same interest rate to compare across the scenarios.”

LSRWA response: This is an artifact of cost development. The LSRWA team depended heavily on the Chesapeake Bay TMDL work done by the jurisdiction watershed partners in development of their Watershed Implementation Plans (WIP) to develop these watershed management strategies. LSRWA effort utilized costs developed (and processes used to develop these) through Chesapeake Bay TMDL and WIP development processes that were already available for BMP costs. As described in Section 5.2, “the LSRWA team relied heavily on the Bay TMDL work done by CBP and state partners to develop the watershed management strategies. As such, the LSRWA team adopted the CBP methodology and unit costs as the representative alternative for a watershed management strategy; additional cost and design analyses were not undertaken.” Dredging/by-passing alternatives (i.e. increasing or recovering storage volume) were developed by LSRWA team using the 3.5% rate, which was the federal interest rate when costs were developed in the Federal Fiscal Year 2014. Language has been added to the main report to clarify this difference. The costs and the BMPs for the E3 scenario were developed years before the Lower Susquehanna River Assessment Project was initiated. At this point in time it would not be feasible for the Bay Program to re-calculate the costs of the E3 BMPs for a project other than the one for which they were originally intended.

B. <u>From STAC:</u> “Attachments 2 and 3 on pp. 12-13 in Appendix J show the costs by practice across the three states. However, the current information does not make it possible to assess the variation in cost-effectiveness of the various urban and agricultural BMPs in meaningful terms, such as the dollars per cubic yard of sediment removal. Importantly, the cost-effectiveness between practice types typically varies by one or two orders of magnitude. Hence, the current analysis aggregates all practices types and reports an overall cost estimate at $3.5 billion in Table 3 (or Table 6-3). Then the report provides an overall average cost effectiveness of $256-$597 per cubic yard in Table 6-6, and seems to imply that this watershed BMP approach is supposedly the most expensive. But this assessment that aggregates all practice types may overlook the high degree of heterogeneity in costs between practice types.” “…At a minimum, the watershed BMP scenario should provide separate scenarios for the agricultural versus urban BMPs. Compare, for example, the costs for agricultural BMPs in Attachment 2 versus urban BMPs in Attachment 3. This shows that urban represents about 90% of the total costs compared to about 10% for agricultural BMPs. But it is unlikely that urban represents 90% of the sediment load. In fact, there are two urban BMPs (urban infiltration BMPs and filtering BMPs) that represent over $2.5 billion, which is two-thirds of the total costs. The unit costs on these two urban BMPs are much higher than other BMPs, but the analysis is aggregated into a single number for cost-effectiveness of this alternative scenario.

LSRWA response: Unfortunately, the per-unit reductions in delivered sediment for the E3 scenario were not available for the E3 scenario. It should be noted that the per-unit reductions *of each BMP are a function of the number of units implemented, the location of implementation, the programmed efficiencies or land use changes associated with each BMP and the interactions of all the BMPs in a given scenario. If it is important to have the per-unit reductions for the E3 scenario, funding should be provided to the Bay Program for staff time and model runs to develop them. Although this would provide useful information, it is a very complicated request that would be time consuming and costly to address. In order to address this properly the Chesapeake Bay Program partners would need to perform a series of model runs to implement each BMP separately and to the extent outlined in the E3 scenario then assess the sediment reduction and the available BMP units remaining following that model run. This process would have to be repeated again for each BMP until all the BMPs are implemented on all available land, because once a BMP is implemented on a given land use it is no longer available for another BMP. Therefore, the LSRWA team cannot accommodate this request due to the time and resources necessary to run the Chesapeake Bay watershed model for all potential BMP scenarios.*

C. <u>From STAC:</u> Attachments 2 and 3 would be more informative if it included additional columns that provided both the cost-effectiveness in $/cubic yard (or $/ton of sediment) and the total amount of cubic yards (or tons of sediment) for each practice type. The former would provide the ranking in cost-effectiveness by practice type, and the latter would reveal how important this practice is for the overall load reduction. This would allow for a better assessment of the most effective suite of practice types, while not including those practices that are most inefficient. Alternative watershed scenarios could then be designed that look at the option of 100% of the E3 scenario (current analysis) versus another scenario that only adopts 50% of the sediment reduction for the E3 scenario using the most efficient suite of practices. The most effective 50% will be competitive with the dredging scenarios given the extreme heterogeneity in unit costs for ag BMPs in Exhibit 1 on p. 15 and urban BMPs in Exhibit 6 on p. 35 (varies from $0 per acre for conservation tillage to $2,351 per acre for the urban filtering BMP). There is even extreme variation in unit costs within agriculture BMPs that ranges over several orders of magnitude. This further confirms the need to provide disaggregated analysis on the cost effectiveness in $/cubic yard by practice type.

LSRWA response: As stated above, the information needed to address this comment is not currently available. If a "disaggregated analysis on the cost effectiveness" by practice type is needed, funding would have to be provided to the Bay Program for staff time and model runs.

D. <u>From STAC:</u> "There are numerous citations provided in Attachment 4 of the Appendix J on pp. 14-44. But there is no corresponding "References" section to provide the detailed info on these citations."

LSRWA response: References provided.

E. <u>From STAC</u>: "Attachment 4 of Appendix J on pp. 29-33 includes detailed information on "Septic Systems." However, septic systems are not discussed at all in the corresponding tables for the cost analysis in Attachments 2 and 3. This needs to be clarified. Future analysis should include septic systems particularly if the analysis is expanded to nutrient management options (not solely sediment strategies) because septic systems are an important nutrient load in rural Pennsylvania. "

LSRWA response: Concur that septic systems should be included in future analyses if nutrient management options are expanded. Appendix 4 is simply providing background information on U.S. Environmental Protection Agency Approved Best Management Practices which includes septic systems though they were not analyzed under this assessment other than documenting that these are approved and a possible BMP to be investigated in the future.

Other recommended edits/specific concerns for main report, by page number:

1. From STAC: "ES-2 In multiple places in the main report (ES-2, p. 10, p. 110, p. 141), there is a statement regarding dynamic equilibrium that says, "This state is a periodic cycle." This statement is very misleading, there is nothing periodic or cyclic about it. The driving event (high flow events of about an annual exceedance probability of 0.2 – a "5-year flood") is a random event and is not periodic. They may happen in rapid succession or there may be many years between them. All mentions of the equilibrium state being "periodic" should be removed."

LSRWA Response: No report language altered: The LSRWA Team deliberated for quite some time on how to depict/describe this important concept of dynamic equilibrium to a non-technical audience. Though the storm event may happen in rapid succession or over many years (the average is every 4-5 years which is reported), the process when a storm does occur, still stands, during a storm of this magnitude there is scouring causing mass erosion. Post storm and during lower flows there is trapping and filling, i.e. a cycle that occurs on a periodic basis (on average every 4-5 years).

2. From STAC: "ES-3 2nd paragraph: the text beginning with "Modeling done for this…." is confusing. It states that under current conditions, half of the deep-channel habitat is unsuitable. This is then compared to the 2025 conditions with full WIP implementation and increased scour that suggests that attainment in 3 of the 92 segments will not be achieved due to extra loads of nutrients. It is implied that full WIP implementation should lead to completely healthy deep-water habitat, but a new reader would not necessarily catch this. Perhaps a more straightforward way to write this is to state something like "currently half of the deep-channel habitat is unsuitable for life (non-attainment), and given full WIP implementation in 2025 (which should yield 100% attainment), deep-channel habitat in 3 of the 92 Bay segments (X % of deep channel habitat) will remain as unsuitable habitat due to elevated nutrient loads from dam scour".

LSRWA Response: Language altered to be clearer: "Modeling done for this assessment estimated that currently more than half of the deep-channel habitat in the Bay is frequently not suitable for healthy aquatic life. However, it was estimated that with full implementation of the WIPs by 2025 (which should yield 100% suitable habitat for aquatic life), DO levels required to protect aquatic life in the Bay's deeper northern waters will not be achieved (in 3 of the 92 Bay segments) due to loads of extra nutrients associated with increased frequency and the amount of scoured sediments."

3. From STAC: "ES-3 4th paragraph: The last sentence (starting "Given…") is a run-on sentence."

LSRWA Response: Sentence fixed: "The primary impact to the Bay from the Susquehanna River watershed and the high river flows moving through the series of reservoirs is dissolved oxygen and impaired water clarity from algal growth. It is the nutrients associated with the sediments that are the most detrimental factor from scoured loads to healthy Bay habitats versus sediment alone."

4. From STAC: "p. 6 "The Susquehanna River is the nation's 16th largest river, and the source of the freshest water …" What is meant by freshest water? Typo?"

LSRWA Response: Sentence fixed:"and the largest source of fresh water."

5. From STAC: p. 8 "All reservoirs act as a sink….." A sink of what? Sediment? Perhaps it is obvious, but it is helpful to state clearly."

LSRWA Response: "sediment" added in front of "sink.'

6. From STAC: "p. 8 "Due to flow deceleration as the water enters the reservoir, sediment transport capacity decreases, and the coarser fractions of the incoming sediment deposited in the reservoir form a delta near the entrance to the reservoir." Awkward sentence – tenses."

LSRWA Response: Sentence fixed: "Due to flow deceleration as water enters the reservoir, sediment transport capacity decreases, and coarser fractions of the incoming sediment deposits in the reservoir forming a delta near the entrance to the reservoir."

7. From STAC: "p. 8 Last sentence of 5th paragraph: It is worth adding to the last sentence that nutrient-laden sediments are more harmful because they can be utilized to fuel additional algal growth in the tidal waters of the Bay."

LSRWA Response: Suggested language added.

8. From STAC: "p. 9 Last complete paragraph: if the Susquehanna load is 3.1 million tons and 1.2 million tons is released then 59.4% is trapped, not 55%."

LSRWA Response: Percentage fixed. On average the rate is 55-60% if the hydrologic record is evaluated over the last 30 years.

9. From STAC: "pp. 15-16 The flow charts in Figures 1.5 and 1.6 are repetitive but slightly inconsistent. Figure 1.6 makes more sense and may be sufficient."

LSRWA Response: No change. 1-5 and 1-6 are similar but have slightly different purposes. Both are conceptual graphics summarizing the overall (1) modeling components (2) analytical approach of the study for a non-technical audience.

10. From STAC: "p. 16 In notes under Figure 1-6, should "partners of this LSRWA effort" be changed to "partners outside of this LSRWA effort"?

LSRWA Response: Language changed as suggested above.

11. From STAC: "p. 24 3rd paragraph: Would be clearer or more mechanistic to say "…than about 0.3 knots because water movement tends to be slowed by frictional forces in shallow water…"

LSRWA Response: Language changed as suggested above.

12. From STAC: "p. 26 "Snow events" do not cause floods. SnowMELT may."

LSRWA Response: Language changed to snow melt as suggested above.

13. From STAC: "p. 28 Define saprolite or show in Figure 2-5."

LSRWA Response: Definition added. "The rock in much of the Piedmont is deeply buried below the surface by crumbling rock that has weathered in place known of as saprolite. Saprolite in the Piedmont can be tens of feet thick. Hard rock in the Piedmont is naturally exposed in landscape settings where the saprolite weathers away, such as along stream valleys and on steep hilltops. Human activities have greatly increased exposures of Piedmont rocks at locations such as roadcuts and quarries.

14. From STAC: "p. 32 "Phosphorus binds to ~~river~~ fine sediments and is delivered to the Bay with sediment."

LSRWA Response: Language changed as suggested above.

15. From STAC: "p. 32 (1) 2nd sentence: "Ammonia" should be "Ammonium". (2) 2nd sentence: It is worth noting that although ammonium tends to be less abundant than nitrate in surface waters, it is by far the dominant dissolved N form in deeper waters during warm months. (3) True, nitrite generally contributes little to TN, but nitrite can accumulate to significant concentrations during some times and places, including the region of the pycnocline during mid-summer and after hypoxia/anoxia breakdown in fall. Perhaps adding a line to the sentence to say "….and contributes little to TN for most times and places". (4) It is worth adding that organic nitrogen comes in both particulate and dissolved forms."

LSRWA Response: Language revised: *"Total nitrogen (TN) includes nitrate, nitrite, ammonia, and organic nitrogen. As typically measured in labs and for the purposes of this section, ammonia also includes ammonium. Nitrate is the primary form of nitrogen in dissolved form in surface waters. Ammonia is a dissolved form of nitrogen that occurs in surface waters less commonly than nitrate. However, ammonia is the dominant dissolved nitrogen form in deeper waters during warm months. Nitrite is generally unstable in surface water and contributes little to TN for most times and places. Organic nitrogen (mostly from plant material, but also including organic contaminants) occurs in both particulate and dissolved forms, and can constitute a substantial portion of the TN in surface waters. However, it is typically of limited bioavailability, and often of minimal importance with regard to water quality. Conversely, nitrate and ammonia are biologically available and their concentration is very important for water quality (USGS, 1999; Friedrichs et al, 2014)."*

16. From STAC: "p. 34 A factual problem is the statement that indicates that TN, TP, and SS loads from Conowingo have been increasing since the mid-1990's. This is certainly true for TP and SS but for TN the trends have continued to be downward (Hirsch, 2012 reports a decrease of about 3 percent)."

LSRWA Response: Language revised to more accurately summarize what cited references state: "Monitoring of nutrients in the Susquehanna River has shown that the flow-adjusted annual concentrations of TN, TP, and suspended sediment delivered to the dams have been generally decreasing since the mid-1980s. With corrections to account for year-to-year variation in river flows, over the 20-year period from 1990 to 2010, TN and sediment loads delivered to the Bay from the Susquehanna River showed statistically significant declines of 26 percent and 17 percent, respectively. TP loads declined by 7% over this time period, but the trend was not statistically significant (Langland et al., 2012). Environmental management measures in the watershed contributed to this decrease. However, one study has indicated that loads of particulate nitrogen, particulate phosphorus, and suspended sediment from the reservoir system to the Chesapeake Bay are increasing, and attributes this to decreasing trapping capacity of Conowingo Reservoir (Zhang et al., 2013)."

17. From STAC: "p. 36 Should define hypoxia in Figure 2-10 (<2.0 mg/L)."

LSRWA Response: Footnote added to figure.

18. From STAC: "p. 37 Section 2.5.2, 2nd sentence – statement is misleading and should be deleted unless qualified by explaining that because of different designated uses and water quality criteria it is not surprising there is a difference in violations. As is, statement is comparing apples and oranges."

LSRWA Response: Statement deleted.

19. From STAC: "p. 45 Figure 2-14 is not clear as to whether or not the metrics are total over a decade or per year."

LSRWA Response: A footnote was added: These amounts are representing annual averages during a particular decade.

20. From STAC: "p. 46 Many species of plankton are capable of motility. Change "and are passively carried" to "and are, by in large, passively carried".

LSRWA Response: Language changed as suggested above.

21. From STAC: "p. 69 Chapter 3 mentions 3 Chesapeake Bay agreements, which may have been true when this section was written. However, doesn't the Watershed Agreement sign in June 2014 count as the 4th Chesapeake Bay agreement?"

LSRWA Response: Correct. Language revised "…. three additional agreements have been adopted since that time."

22. From STAC: "p. 72 2nd to last paragraph: The word "special" should be "spatial".

LSRWA Response: Language changed as suggested above.

23. From STAC: "p. 81 "The HEC-RAS model may not be suitable for ….. , active scour and deposition, and particle size." What does this mean with respect to "particle size"? That the model cannot represent particle size well? Explain so meaning is clear."

LSRWA Response: First sentence of this paragraph discusses this: HEC-RAS is designed primarily for non-cohesive sediment transport (sands and coarse silts) with additional, but limited, capability to simulate processes of cohesive sediment transport (generally medium silts to fine clays). The model actually did well predicting major particle size. This sentence revised to say: "The HEC-RAS model may not be suitable for all reservoir simulations, especially in areas of highly variable bed shear stress (the force of water required to move bed sediments) and active scour and deposition."

24. From STAC: "p. 81 3rd paragraph: Were the boundary conditions generated for the HEC-RAS simulation also used to drive the AdH model? Or was model output from HEC-RAS simulation for the upper two reservoirs used to create the boundary conditions for AdH? Please clarify."

LSRWA Response: All simulations were conducted with the same Susquehanna River flow and inflowing sediment boundary conditions. The 4-year flow period from 2008 to 2011 was simulated in the AdH model. The flow and sediment entering the upstream model boundary (channel below the dam on Lake Aldred) were provided by the USGS from HEC-RAS model simulations of the 4-year flow record. These simulations included all three reservoirs, thus the sediment output from HEC-RAS included bed sediment scour from the upper two reservoirs. The sediment rating curve in the HEC-RAS simulations was developed by the USGS from suspended sediment measurements in the Susquehanna River above the reservoir system. The HEC-RAS outputs (boundary) conditions for flow, sediment load and particle sizes were given to AdH for ERDC use. Ultimately for AdH, ERDC created their own boundary conditions for Conowingo; however HEC-RAS input was a good starting point. The HEC RAS simulations for the upper two reservoirs were used to drive AdH, although the sediment discharge was increased over what HEC-RAS reported, in order to err on the side of higher sediment discharge.

25. From STAC: "pp. 81-83 The models are stated to be "well developed, widely accepted, and peer reviewed. Yet there are virtually no references in Sections 4.1 or 4.2. References are needed here to demonstrate that HEC-RAS and AdH are indeed peer-reviewed models."

LSRWA Response: Language revised to state: "The models were selected because they were well developed, widely accepted, and have had wide use and application." Do not agree that the main report is the place to discuss these models's use in other applications. The models (AdH and HEC-RAS) are built from theory based on scientific and research. They have had millions of dollars invested in them and have been applied by many studies around the country and world. The use of the latter two models has resulted in the successful construction and operation of hundreds of water resource management structures and systems.

A few examples for HEC-RAS use-
The HEC-RAS model data has been used for the Sacramento River Flood Project (CA); Comprehensive Study of Sacramento and San Joaquin River Basin (CA); White Oak Bayou Federal Flood Damage Reduction Project(TX); Mobile Bed Modeling of the Cowlitz River (WA); Flood Plain Modeling in the Kansas River Basin (KS); Flood Cyclone JFY 2010 Mini-Project Indonesia; and Flood Hazard Mapping in the Nan River Basin, Nan Province, Thailand.

HEC-RAS model data use outside of the U.S. Army Corps Engineers (USACE) includes the following:
Endensco, Inc. used HEC-2/HEC-RAS for hydraulic and hydrologic analysis of Route 1 Neabsco Creek in Prince William County, Virginia. The data was peer reviewed by the Virginia Department of Transportation.

NMP Engineering Incorporated performed a hydraulic study of Terrapin Branch. HEC-RAS was used for three design alternatives for the proposed bridge. The data was peer reviewed by the Maryland State Highway Administration.

WBCM was the lead design consultant for Corman Construction who designed and constructed the Hampstead Bypass Project using HEC-RAS to size bridge openings. The data was peer reviewed by the Maryland State Highway Administration.

For AdH:
The AdH model data has been used to construct the Moose Creek Floodway on the Chena River, a joint effort by the Coastal and Hydraulics Lab at the Engineering and Research Development Center and Alaska District Corps of Engineers; and the Jacksonville Harbor (FL) Navigation Project.

Regarding peer review for any USACE study involving construction of large water resource projects (such as those listed above), the models undergo review by the (1) USACE District conducting the study/modeling, (2) another USACE District (3) an independent (non-USACE) panel of reviewers that are designated experts from private companies and academia (4) any local, state, federal, or non-governmental organization requesting to be a cooperating agency on a study (5) general public and (6) USACE headquarters and division offices.

26. <u>From STAC:</u> "pp. 84-85 Figure 4-3 and 4-4: The mesh in all or part of these figures is almost impossible to see – provide insets at larger scale. Insets in the appendix show this more effectively."

LSRWA Response: Figures 4-3 and 4-4 are copied exactly from Appendix B.

27. <u>From STAC:</u> "pp. 87-89 In Chapter 4, the description of the method for using the 2008-2011 HEC-RAS and ADH predicted scour in the CBEMP 1991-2000 model runs is confusing. It is simply stated that the reader should see Appendix C for the details. More description should be provided in the text of Chapter 4, at least a better overview of the approach and justification for this somewhat tricky (but justifiable) maneuver."

LSRWA Response: Chapter 4 of Appendix C, Load Computation and Summary is largely devoted to explaining the derivation of scour loads. A paragraph was added at the end of Section 4.3.4 of main report: "Since the AdH application period was 2008 to 2011 while the CBEMP application period was 1991 to 2000, a procedure was employed to adjust estimated loads of scour from AdH for use in the CBEMP. A procedure to apply ADH calculations to the 1996 storm was developed based on the volumetric flow in excess of the threshold for mass erosion (400,000 cfs). The year 2011 contained two erosion events, an un-named event in March and Tropical Storm Lee, in September. The excess volume for each event was computed by integrating flow over time for the period during which flow exceeded 400,000 cfs. The amount of sediment eroded during each event was taken as the difference between computed loads entering and leaving Conowingo Reservoir. Sediment loads leaving the reservoir in excess of loads entering were taken as evidence of net erosion from the Conowingo reservoir bottom. Net erosion for January 1996 was calculated by linear interpolation of the two 2011 events, using excess volume as the basis for the interpolation (See Appendix C for more detail)."

28. <u>From STAC:</u> "p. 89 "Since the ADH application period was 2008 to 2011 while the CBEMP application period was 1991 to 2000, an algorithm was applied to adjust estimated loads from the ADH for use in the CBEMP (see Appendix C for details on this algorithm)." This algorithm is not obvious in Appendix C. Should briefly explain here and then explain better in Appendix C."

LSRWA Response: See Response above (#27).

29. <u>From STAC:</u> "p. 92 "documented in Chapter 3"(?) Is this a typo?"

LSRWA Response: Language changed to "discussed in Chapter 3"

30. <u>From STAC:</u> "pp. 97-100 Table 4.2 seems a bit out of context in Chapter 4, referring as it does almost entirely to material in Chapter 6. Although not a requirement, this table would make more sense in Chapter 6 where it is directly discussed."

LSRWA Response: Will leave as is. The idea was to introduce scenarios to reader here and provide results in Chapter 6.

31. <u>From STAC:</u> "p. 112 Are the values in Table 5-4 adjusted for variations in flow?"

LSRWA Response: These values are the total values associated with the 2008-2011 hydrograph: hence variations in flow are implicitly integrated into the analysis.

32. p. 113 In Table 5-5 change "Additional" to "Additional Calculated" and change "Transport" to "Scour-Induced Transport".

LSRWA Response: Will change to "Additional Calculated" but NOT change the Transport to "Scour Induced Transport". The increase could be due to a reduction in deposition.

33. <u>From STAC:</u> "p. 114 Figure 5-4 presents exact same data as Table 5-5. Eliminate."

LSRWA Response: Will leave. Figure provides a visual of curve.

34. <u>From STAC:</u> "p. 114 Bottom: annual influx of sediment to Conowingo is here described as 3.8 million tons/yr over the last 20 years with 2 million being trapped. Elsewhere in the document we see different numbers ranging between 3 million and 4.2 million tons. If there are different estimates arrived at in different ways this needs to be made clear."

LSRWA Response: Estimates always vary depending on total hydrologic years being evaluated. Will ensure that years of evaluation are included in each instance to make this clear. If averages were cited from a reference (for example Langland, 2009) in the LSRWA report those averages with appropriate hydrologic years evaluated are noted.

35. <u>From STAC:</u> "p. 115 Table 5-6 does not explain how the historical loads or more recent loads were calculated – it simply says that the results were calculated by USGS. More explanation is needed. Also indicate that Hurricane Agnes flows were excluded if they were indeed omitted."

LSRWA Response: This table is directly from Appendix A where further explanation is provided. Footnote revised to state that 1972 (year of Hurricane Agnes, not included) and (see Appendix A).

36. <u>From STAC:</u> "p. 131 The reasoning for using the particular combinations of predicted scour, nutrient loading, and water quality modeling to test for the effects of scour is unclear. The procedure was likely valid, but better explanation is needed."

LSRWA Response: The first paragraph under "Scour impacts" lays out the procedure in summary terms. Appendix C provides more detail on each scenario, what went into each scenario and why.

37. <u>From STAC:</u> "p. 135 paragraph 4: It would help if there was some discussion of why two upper Eastern Shore segments (CHSMH and EASMH) had non-attainment in Scenario 3. Does low-DO water advect into them from the mainstem or is nutrient availability enhanced by the breakdown of scoured solids that end up in these tributaries?"

LSRWA Response: Good point and discussion will be expanded to describe the region of contiguous Deep Water and Deep Channel waters in the segments of CH3MH, CB4MH, EASMH, and CHSMH. Language added to Appendix D: "The segments of CH3MH, CB4MH, EASMH, and CHSMH are in a region of contiguous Deep-Water and Deep- Channel waters. These CB segments have similar depths so that advection from gravitational circulation as well as tidal dispersion plays a role in the continuous area of hypoxia among these CB segments."

38. <u>From STAC:</u> "p. 138 Paragraph 2: Oysters are discussed here within a section that otherwise discussed the modeling and simulation activities. Is there a description of how model analysis was used in this report to determine flow and management effects on oysters? Whatever the case, it should be clearly stated where the oyster effects fit into this report and whether or not model simulations were used to understand effects on oysters."

LSRWA Response: No specific modeling simulations were run to quantify oyster impacts. However this resource is of high interest so this qualitative language was added. This paragraph was deleted from this section since the context here is specific LSRWA simulation results (i.e. quantified results). Section 2.7.4 discusses oysters and impacts from storm events summarizing a DNR report on effects from Tropical Storm Lee.

39. <u>From STAC:</u> "p. 138 "Nitrogen loads…exceed phosphorus loads…" Given that P concentrations tend to be an order of magnitude lower than those for N, the statement does not tell the reader much, and might unduly impress those lacking an understanding of nutrient concentrations and dynamics. "

LSRWA Response: A large body of work links Chesapeake Bay hypoxia to nitrogen loading (e.g. Hagy, J., W. Boynton, C. Keefe, and K. Wood. 2004. Hypoxia in Chesapeake Bay, 1950 – 2001: Long-term changes in relation to nutrient loading and river flow. Estuaries 27(4):634-658.; Murphy, R., W. Kemp, and W. Ball. 2011. Long-term trends in Chesapeake Bay seasonal hypoxia, stratification, and nutrient loading. Estuaries and Coasts 34:1293-1309.) Consequently, the notion that scoured nitrogen loads exceed scoured phosphorus loads is exceedingly important. This is not misleading at all. What is misleading is the continued emphasis on phosphorus loading, often to the exclusion of any consideration of nitrogen. However, as discussed in the LSRWA recommendations, an understanding of the relative bioavailability of this Nitrogen (versus total loads) warrants scrutiny to inform management decisions of the Bay.

40. <u>From STAC:</u> "p. 146 Sources of information here are based on "personal communication" with Kevin DeBell, Greg Busch, John Rhoderick, and Jeff Sweeney. It would be better to document and provide references for the original reports used for the BMP unit costs rather than only personal communication. Page 4 in Appendix J-1 similarly only provides personal communications."

LSRWA Response: As described in Section 5.2, "the LSRWA team relied heavily on the Bay TMDL work done by CBP and state partners to develop the watershed management strategies. As such, the LSRWA team adopted the CBP methodology and unit costs as the representative alternative for a watershed management strategy; additional cost and design analyses were not undertaken." Citations are included where appropriate (e.g. U.S. Environmental Protection Agency (U.S. EPA). 2010) however personal communication by LSRWA team was required to ensure that LSRWA interpretations of Chesapeake Bay Program work on watershed BMP's/strategies were accurate.

41. <u>From STAC: "</u>p. 167 "This methodology was not applicable for the watershed management representative alternative since management strategies (e.g., BMPs) once implemented, continue to remove/reduce sediment." This statement is not true for many BMPs. For example, vegetative buffers self-destruct if they receive excessive sediment – same with most BMPs that trap sediment rather than reducing its generation. As a result of this incorrect assumption, one might question whether costs are one time."

LSRWA Response: This statement is generalizing here. Nuance added. Language revised to state: "This methodology was not applicable for the watershed management representative alternative since management strategies (e.g., BMPs) once implemented, continue to remove or *reduce sediment (although many BMPs will need to be cleaned out and maintained to continue to be effective)." The point here is order of magnitude. Cleaning out multiple BMPs after a storm is nowhere near what it would cost to annually dredge at the scale discussed.*

42. From STAC: "p. 175 3rd paragraph: The word "waters" on line 4 of this paragraph should be "water"."

LSRWA Response: Language changed as suggested above.

43. From STAC: "p. 180 "costs of bypassing (diminished DO, increased chlorophyll) are roughly 10 times greater than the benefits gained from reducing scour." Indicate exactly where these data are contained in the report. A similar statement also appears in the Executive Summary and on p. 181 and p. 197."

LSRWA response: This comes from Bay model simulations, Appendix C. Language added to main report.

44. From STAC: "p. 192 In the first summary statement below finding #2, the "upper Chesapeake Bay" ecosystem is highlighted to be the area impacted by the dam. "upper" is an ambiguous word in this case, as the simulations suggest that effects can be seen south of the Bay Bridge (e.g., Appendix C)."

LSRWA response: Report is generalizing here, which is appropriate for this Chapter since it is providing "big picture" findings. Actual attainment issues were seen in 3 of the upper Bay segments which is discussed in detail and depicted via figures in the main report and Appendix C and D. Report attempts to provide geographic coverage of Bay consistent with how Bay Program defines areas of Chesapeake Bay.

45. From STAC: "p. 193 Second paragraph, line 5: should "frequently not unsuitable" be "frequently unsuitable"?"

LSRWA Response: Language changed as suggested above.

46. From STAC: "p. 200 Reference to additional management activities that can provide long-term storage includes mention of floodplain restoration. If this refers to floodplain excavation, there is some concern about this appearing as a recommendation without much more study than has been conducted to date. If it refers to some other form of floodplain restoration some explanatory language would be helpful."

LSRWA Response: Will delete specific mention since floodplain restoration is just one example thus is not necessary in context here.

47. From STAC: "p. 201 The report does not make the case for use in adaptive management, as adaptive management is mentioned for the first time in this recommendation. Adaptive management is not mentioned anywhere but in this recommendation. Thus, the phrase should be deleted here."

LSRWA Response: Will leave as is. The section below makes a case for adaptive management in that long-term monitoring will confirm if management practices are actually effective (or not) thus allowing management to be altered in the future.

Colleen Hicks
Manager Regulatory
and Licensing, Hydro
Exelon Power

300 Exelon Way
Kennett Square, PA 19348
(610)765-6791
colleen.hicks@exeloncorp.com

July 18, 2014

Anna Compton
Study Manager, Planning Division
Baltimore District, Corps of Engineers
10 South Howard Street
Baltimore, MD 21201

Re: Lower Susquehanna River Watershed Assessment DRAFT Report
Comments of Exelon Generation Company, LLC

Dear Anna:

Exelon Generation Company, LLC (Exelon) appreciates the opportunity to provide feedback and comments to the U.S. Army Corps of Engineers (Corps) Lower Susquehanna River Watershed Assessment (LSRWA) Draft Report distributed for review on June 23, 2014. The LSRWA Draft Report represents a tremendous amount of work by the project partners and represents an important step in understanding the Susquehanna River/Chesapeake Bay (the Bay) water quality interactions.

After extensive review of the main report and appendices, Exelon has developed detailed comments, which are contained in the accompanying table. Additionally, during our review a number of significant concerns were identified; these concerns are discussed in detail below. Exelon hopes that these comments will assist the Corps in developing the most technically sound and understandable document possible.

Study Findings

Exelon believes that the LSRWA Draft Report represents a significant contribution to the understanding of the overall positive benefit Conowingo Dam (Conowingo) provides for the health of the Bay. Specifically, the LSRWA Draft Report makes several well-supported conclusions, including the following: (1) the majority of the sediment that enters the Bay during storm events originates from the watershed rather than from scour from Conowingo Pond; (2) given the small contribution of sediment from Conowingo Pond, the primary impact to the Bay is from sediment and nutrients from the Susquehanna River and Chesapeake Bay watershed; and (3) implementation of Watershed Implementation Plans has the largest influence on the health of Chesapeake Bay.

In particular, Exelon notes that the LSRWA Draft Report concludes that, while Conowingo Pond is in dynamic equilibrium, the Pond will continue to trap sediments and associated nutrients into the future during depositional periods. The report states that from 1993-2012 the annual trapping efficiency of Conowingo Pond was 55-60%. This finding, which is consistent with the assumptions of the Chesapeake

Bay TMDL, highlights the day-to-day benefits that Conowingo provides to the Bay. Exelon believes that, to further strengthen these findings, it would be helpful for the next draft of the LSRWA to explicitly state the assumed trapping efficiencies for each modeling scenario.

The LSRWA Draft Report also includes discussion of nutrient loading and other contaminants in the sediment emanating from the river and in the Bay. The LSRWA Draft Report's finding that "nutrients, not sediment, have the greatest impact on Bay aquatic life" represents a valuable step forward in understanding how best to improve water quality in the Bay. As the LSRWA Draft Report acknowledges in several locations, however, nutrients came up late in the study process. Nonetheless, the report makes definitive statements regarding the effects of nutrients from scour on Bay water quality. As currently written, the LSRWA Draft Report gives the impression that sediment-bound nutrients scoured from Conowingo Pond are the main threat to Bay water quality. In contrast, the appendices (in particular Appendix C) indicate that all nutrients entering Chesapeake Bay threaten water quality, whether they are watershed-derived or bound to scoured sediments. The impact of sediment-bound nutrients on Bay water quality is not fully understood at this time. Indeed, a discussion of supporting nutrient data and quantitative nutrient model assumptions is conspicuous by its absence in the report. The next draft of the report should either provide the field and model data supporting these conclusions, with any appropriate qualifiers, or simply list nutrient interactions in the Susquehanna River and Chesapeake Bay as areas requiring additional study.

As currently drafted, the LSRWA Draft Report understates the significance of sediment and nutrient loading from sources upstream of Conowingo Pond. The main report specifically states that 70-80% of sediment that flows to the Bay during a major storm originates from the watershed upstream of Conowingo Pond. Yet rather than focus on those sources, the main report instead focuses primarily on Conowingo Pond scour. The fact that the terms "scour event" and "scour" are used interchangeably throughout the main report and appendices (especially Appendix D) only further confuses the impact of the runoff event with the impact of the scour itself.

Moreover, while the study goals state that the LSRWA was intended to examine the "loss of sediment and associated nutrient storage within the reservoirs of the lower Susquehanna River," the discussion and findings of the report (including sediment management strategies) focus almost exclusively on Conowingo Pond. This problem is further exacerbated by the fact that, in various places, the LSRWA Draft Report uses the terms "Conowingo Reservoir" and "the reservoirs of the Lower Susquehanna" almost interchangeably. As such, the report gives the impression that only Conowingo Pond scour has a potential impact on Bay health, when in fact all three reservoirs are in dynamic equilibrium and susceptible to episodic scour. In order for this study to be a true Lower Susquehanna River assessment, all three reservoirs (Lake Clarke, Lake Aldred, and Conowingo Pond) should be discussed proportionately.

Modeling

The findings of the LSRWA are based in part on a complex suite of mathematical models that were developed by the U.S. Environmental Protection Agency (USEPA), Corps, and U.S. Geological Survey (USGS). The output from various sub-models (HEC-RAS, AdH, etc.) were used as input parameters for the Chesapeake Bay Environmental Model Package (CBEMP). While the individual modeling efforts' methods, assumptions, inputs and outputs are well explained in their respective appendices (Appendix A, B and C), we believe it would be helpful for the reader to have a single point of reference within the main report to explain all of the interactions between the various LSRWA models (HEC-RAS, AdH, WSM, WQSTM, etc.). This will allow the reader to better understand how each of the models are "connected" in spite of the varying model timesteps (e.g., daily vs. hourly vs. 15-min), and output parameters (e.g., sediment loads, nutrient loads, nutrient components). While Figure 1-5 in the main report (identical to Figure 1-2 of Appendix C) explains the model interaction in a general sense, we envision an accompanying figure and narrative within the main report to more specifically define the interactions. We have included an example of what we believe an accompanying figure describing the model interactions could look like in Attachment 1.

It is also difficult to track the input conditions/assumptions (e.g., 1996 vs. 2011 sediment nutrient content, and trapping efficiency), water quality attainment analysis periods (e.g., 1993-1995 vs. 1996-1998) and attainment results (e.g., 2% nonattainment in CB4MH deep channel DO) for each of the LSRWA modeling scenarios. While page one in Appendix J-4 describes many of the model input datasets and assumptions, as well as the water quality attainment analysis period, this table only describes six out of the seventeen runs mentioned in Table 3-1 of Appendix C. To understand input conditions for the other eleven model scenarios not described in page one of Appendix J-4, one has to piece together information from the main report, Appendix C, D and J. Additionally, Appendix D only included "stoplight plot" analysis results for a handful of the scenarios described in Table 3-1 of Appendix C. In particular, there was some confusion regarding what each scenario assumed for trapping efficiencies. We suggest the Corps consider adopting a table similar in format to Attachment 2 to explain all of the LSRWA runs described in Appendix C, plus add a brief summary of any water quality nonattainment for each scenario (if possible). Even if the nonattainment assessment is limited to certain 'critical' model segments (e.g., deep channel DO in CB4MH, EASMH and CHSMH), this would provide the reader with an easy way to compare all of the runs in a single table. We have attempted to fill in the table with our understanding of the model runs so the table's intent is well understood. We also recommend including the "stoplight plot" analysis results into Appendix D for all of the scenarios described in Table 3-1 of Appendix C.

Finally, the limits of the individual models and the uncertainties associated with the model outputs are stated in the appendices and provided, in part, within the main report. However, the main report does not evaluate how the uncertainties inherent to each model constrain the conclusions ultimately reached by the LSWRA study. Thus, the reader is left with the impression that the quantitative outputs of these complex mathematical models are definitive and absolute which is not the case. For example, Appendix B on the AdH model states: "Because of these uncertainties the AdH model may potentially over-predict to some degree transport of scoured bed sediment through the dam." This is not reported in Chapter 4 of the main report when discussing AdH model uncertainties. While uncertainties of the CBEMP model are also discussed in Chapter 4, the quantitative consequences of over-prediction by the AdH model to the output of the CBEMP model are not. The ultimate effect of AdH over-prediction on LSRWA conclusions is not examined.

Sediment Management Options

Exelon believes that having a full understanding of the potential environmental impacts of each of the various sediment management strategies will help facilitate a balanced, well-rounded examination of the alternatives. The LSRWA Draft Report includes a conceptual-level screening of various sediment management strategies. This screening includes a brief description of each alternative including pros and cons and approximate cost. Although this screening includes some preliminary discussion of potential environmental impacts, in general these were not discussed in sufficient detail. While Exelon understands that a full environmental assessment was not within the scope of this report, the discussion of each alternative should acknowledge the environmental resources that would need to be investigated and to provide a qualitative description of the expected relative impact. Depending on the alternative, environmental resources that could be impacted include: aesthetics, air quality, soils, water quality, wetlands, groundwater, surface water, floodplains, biological resources, cultural resources, land use, recreation and tourism, utility and transportation infrastructure, and public health and safety. In many cases the environmental impact to these resources could be far greater than the benefit the sediment management alternative would provide.

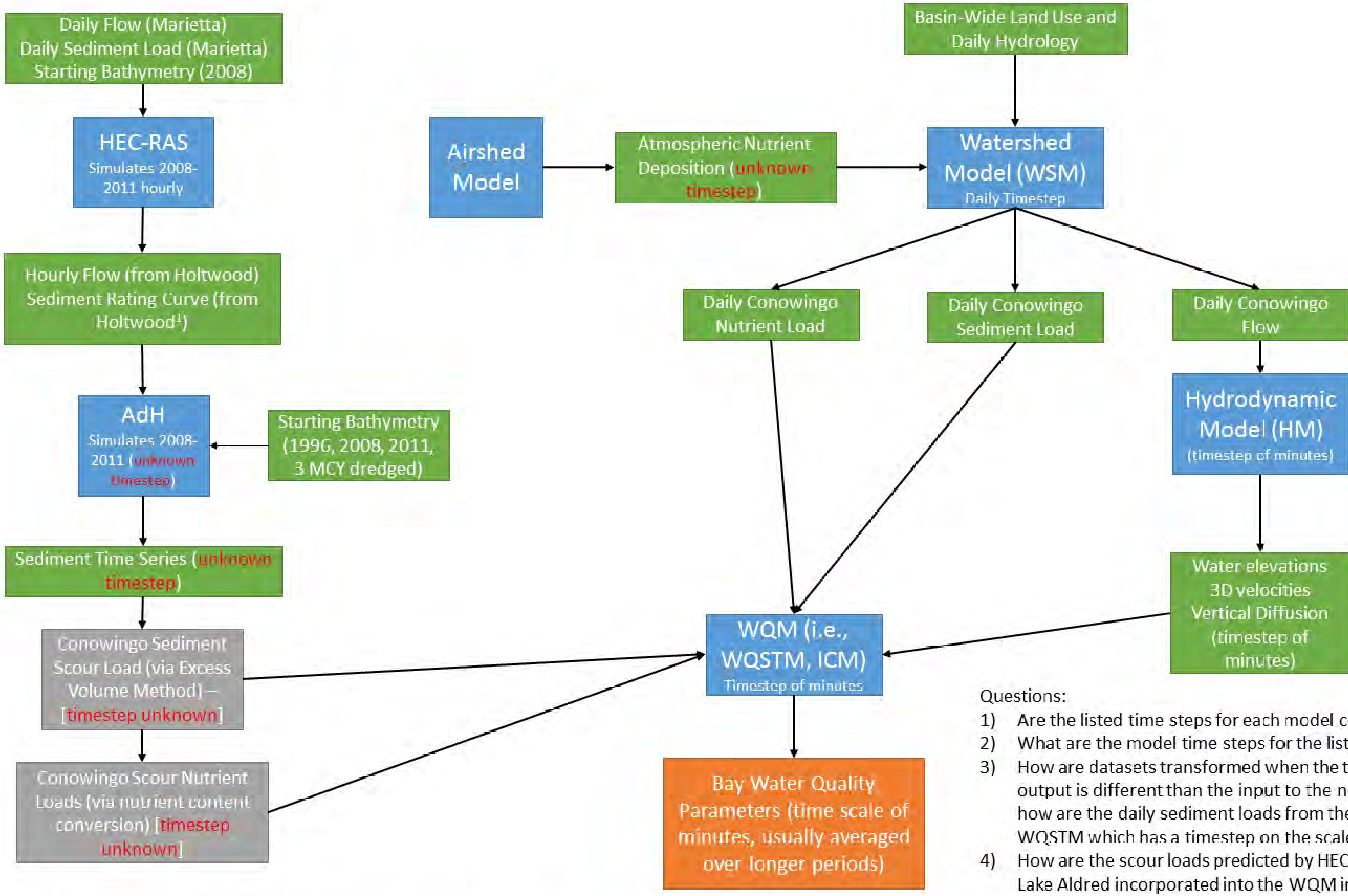
In addition, it should be reiterated here that, although the introduction to Chapter 6 discusses examining sediment management alternatives for the lower Susquehanna River reservoirs, the alternatives discussed throughout the rest of the chapter alternatively mention “the reservoirs” or “Conowingo Reservoir.” By interchanging these terms, it becomes unclear whether the sediment management alternatives are being proposed at all three lower Susquehanna River reservoirs or just Conowingo Pond. In many instances it appears the management alternative is targeting only Conowingo Pond, in which case sediment loads from Lake Clarke and Lake Aldred bed scour are implicitly not taken into consideration.

Detailed comments elaborating on the points discussed in this letter can be found in the accompanying table. Due to the short time frame provided for review, Exelon reserves the right to make additional comments in the future. We appreciate the opportunity to provide feedback and comments on the draft LSRWA and look forward to continuing to work with project partners in the future. Upon review of our comments if you have any questions please feel free to contact me at (610) 765-6791 or colleen.hicks@exeloncorp.com or Tom Sullivan at (603) 428-4960 or tsullivan@gomezandsullivan.com.

Respectfully submitted,

Colleen E. Hicks
Manager Regulatory and Licensing, Hydro
Exelon Power

Attachment 1: Description of WQSTM model interactions.



Questions:

1) Are the listed time steps for each model correct?
2) What are the model time steps for the listed unknowns (e.g., AdH)?
3) How are datasets transformed when the timestep of a model output is different than the input to the next model? For example, how are the daily sediment loads from the WSM translated into the WQSTM which has a timestep on the scale of minutes?
4) How are the scour loads predicted by HEC-RAS for Lake Clarke and Lake Aldred incorporated into the WQM inputs?

[1]The Holtwood sediment outflows were calculated from the HEC-RAS "scour" model, plus an additional 10% beyond the HEC-RAS predicted sediment load.

Attachment 2: Potential format for describing model inputs for each LSRWA scenario.
Footnotes are included to describe conditions common for all scenarios. Black text describes information taken from Appendix J-4. Blue text describes information taken from Appendix C.

Model Code	Description or Study Question	Models Used	Land Use (i.e., watershed sediment/nutrient loads)	HEC-RAS Model Run (scour or depositional)	Reservoir trapping efficiency	Reservoir Scour Load Method	Reservoir Sediment Nutrient Content	Time period analyzed for WQ Nonattainment	Deep Channel DO Nonattainment in CB4MH	Deep Channel DO Nonattainment in EASMH	Deep Channel DO Nonattainment in CHSMH
LSRWA-3	What is the system's condition when WIPS are in full effect and reservoirs have not all reached dynamic equilibrium?	CBEMP[1,2]	TMDL – WIPS in place	N/A	1991-2000 levels[3]	None	N/A	1993-1995	0%	0%	0%
LSRWA-4	What is the system's current (existing) condition?	CBEMP	2010 Land Use	N/A	1991-2000 levels	None	N/A	1993-1995	?	?	?
LSRWA-5	2010 land use with Conowingo reservoir removed from WSM. All sediments and nutrients pass through – no deposition or scour.	CBEMP	2010 Land Use	N/A	0%	N/A	N/A	Not analyzed?	?	?	?
LSRWA-6	TMDL land use with Conowingo reservoir removed from WSM. All sediments and nutrients pass through – no deposition or scour.	CBEMP	TMDL – WIPS in place	N/A	0%	N/A	N/A	Not analyzed?	?	?	?
LSRWA-20	2010 land use with sediment/nutrient from Conowingo scour added in.	HEC-RAS AdH CBEMP	2010 Land Use	?	Existing[4]	Excess volume method from AdH results (from 2011 bathymetry)	2011 Tropical Storm Lee	Not analyzed?	?	?	?
LSRWA-21	What is the system's condition when WIPS are in full effect, reservoirs have not all reached dynamic equilibrium and there is a winter scour event?	HEC-RAS[5] AdH[5] CBEMP	TMDL – WIPS in place	?	2011 levels	Excess volume method from AdH results (from 2011 bathymetry)	2011 Tropical Storm Lee	1996-1998	1%[6]	1%	1%
LSRWA-31	TMDL land use, sediment/nutrients from Conowingo scour added in.	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	1996 levels?	Excess volume method from AdH results (from 2011 bathymetry)	2011 Tropical Storm Lee	Not analyzed?	?	?	?
LSRWA-18	What is the system's condition when WIPS are not in effect, reservoirs have all reached dynamic equilibrium and there is a winter scour event?	HEC-RAS AdH CBEMP	2010 Land Use	?	"Conowingo Full" condition	Excess volume method from AdH results (from 2008 bathymetry)	2011 Tropical Storm Lee	1996-1998	?	?	?
LSRWA-30	What is the system's condition when WIPS are in full effect, the reservoirs have all reached dynamic equilibrium and there is a winter scour event?	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	"Conowingo Full" condition	Excess volume method from AdH results (from 2011 bathymetry)	2011 Tropical Storm Lee	1996-1998	?	?	?
LSRWA-22	TMDL land use, sediment/nutrients from Conowingo scour added in.	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	Existing	Excess volume method from AdH results (from 2008 bathymetry)	Jan 1996 flood event	Not analyzed?	?	?	?
LSRWA-23	TMDL land use, 1996 storm removed from hydrologic record and load record	? CBEMP	TMDL – WIPS in place	?	Existing	N/A?	N/A	Not analyzed?	?	?	?
LSRWA-24	What is the system's condition when WIPS are in full effect, reservoirs have not all reached dynamic equilibrium and there is a summer scour event?	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	2011 levels	Excess volume method from AdH results (from 2008 bathymetry)	2011 Tropical Storm Lee	1996-1998	?	?	?
LSRWA-25	What is the system's condition when WIPS are in full effect, reservoirs have not all reached dynamic equilibrium and there is a fall scour event?	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	2011 levels	Excess volume method from AdH results (from 2008 bathymetry)	2011 Tropical Storm Lee	1996-1998	?	?	?
LSRWA-26	TMDL land use, January 1996 storm moved to June 1996	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	Existing	Excess volume method from AdH results (from 2008 bathymetry)	Jan 1996 flood event	Not analyzed?	?	?	?

Model Code	Description or Study Question	Models Used	Land Use (i.e., watershed sediment/nutrient loads)	HEC-RAS Model Run (scour or depositional)	Reservoir trapping efficiency	Reservoir Scour Load Method	Reservoir Sediment Nutrient Content	Time period analyzed for WQ Nonattainment	Deep Channel DO Nonattainment in CB4MH	Deep Channel DO Nonattainment in EASMH	Deep Channel DO Nonattainment in CHSMH
LSRWA-27	TMDL land use, January 1996 storm moved to October 1996	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	Existing	Excess volume method from AdH results (from 2008 bathymetry)	Jan 1996 flood event	Not analyzed?	?	?	?
LSRWA-28	TMDL land use, sediment/nutrients from Conowingo scour added, 3 MCY dredged from Conowingo Pond.	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	Post dredging (3 MCY removed)	Excess volume method from AdH results (from 2008 bathymetry, dredged 3 MCY)	2011 Tropical Storm Lee	Not analyzed?	?	?	?
LSRWA-29	TMDL land use, sediment/nutrients from Conowingo scour added, 3 MCY removed from Conowingo Pond to represent bypassing, sediments/nutrients bypassed downstream from December-February every year.	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	Post dredging (3 MCY removed), bypassing during some months	Excess volume method from AdH results (from 2008 bathymetry, dredged 3 MCY)	2011 Tropical Storm Lee	Not analyzed?	?	?	?

[1]CBEMP is a suite of models used to assess Chesapeake Bay water quality conditions. Sub-models within CBEMP include the watershed model (WSM), a hydrodynamic model (HM) and a water quality/eutrophication model (WQM).

[2]CBEMP is always run for a hydrology period from 1991-2000.

[3]The specific trapping efficiency (e.g., 55%) used for the run should be listed in addition to the year range the trapping efficiency is associated with (e.g., 1991-2000).

[4]Appendix C lists “Existing” bathymetry for several runs, including LSRWA-3, LSRWA-4, LSRWA-20 and LSRWA-21). It is not clear if this is referring to trapping efficiencies or something else. Appendix J-4, pg. 1 lists LSRWA-4 and LSRWA-21 as having different trapping efficiencies, where LSRWA-4 has “1991-2000 levels”, and LSRWA-21 has “2011 levels.” It is not clear what 2011 levels means.

[5]AdH and HEC-RAS were always run using the four year 2008-2011 hydrology period (Jan 1, 2008 – Dec 31, 2011). The HEC-RAS outputs that were input into AdH were always the “scour” model results.

[6]We recommend that nonattainment calculations include one additional significant figure beyond the decimal point (e.g., 1.4% nonattainment instead of 1% nonattainment)

Questions/Comments:

1) Please verify that the data we have entered into this table are correct.
2) Please list specific trapping efficiencies (e.g., 55%) in addition to qualitative descriptors (e.g., 1991-2000 trapping levels).
3) What do “2011 levels” refer to as far as trapping efficiencies?
4) Please include an additional significant figure beyond the decimal point for nonattainment calculations (e.g., 1.4% nonattainment instead of 1% nonattainment).

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
1	Exelon	Main Report	General	To be consistent with reference citations contained in the Conowingo Final License Application please see the correct citations below for Exelon RSP 3.11, 3.12, and 3.15: • URS Corporation and Gomez and Sullivan Engineers (GSE). 2012a. Water level management study (RSP 3.12). Kennett Square, PA: Exelon Generation, LLC. • URS Corporation and Gomez and Sullivan Engineers (GSE). 2012b. Sediment introduction and transport study (RSP 3.15). Kennett Square, PA: Exelon Generation, LLC. • Gomez and Sullivan Engineers. 2012. Hydrologic Study of the Lower Susquehanna River (RSP 3.11). Kennett Square, PA: Exelon Generation, LLC. Additionally, references to 2011 bathymetric surveys as Gomez and Sullivan (2012) should be referenced as: • URS Corporation and Gomez and Sullivan Engineers. 2012. Sediment introduction and transport study (RSP 3.15) (Appendix F). Kennett Square, PA: Exelon Generation, LLC.	Compton	Changes made to reference list and citations in main report.	Yes.
2	Exelon	Main Report	General	Importance of nutrients over sediment recognized "late in the game" so report focus is still on sediment. Seems like a better understanding of nutrient/sediment interaction is needed.	Compton	Other comments will address this.	Yes.
3	Exelon	Main Report	General	Instead of presenting an equal focus on all three reservoirs, there are still points within the report that focus primarily on Conowingo. General sections of the report that present ideas or concepts not specific to Conowingo Pond by itself should reference the three reservoirs or reservoir complex.	Compton	Discussion in multiple sections about why Conowingo is emphasized. Also AdH modeling results are specific to Conowingo so data must be presented this way for accuracy. Mention of all three reservoirs and universal concepts are noted where appropriate.	No.
4	Exelon	Main Report	General	Many of the figures are 'fuzzy' and it is difficult to read the legend text (e.g., the cover page, figure 2-6, figure 2-8, figure 4-7).	Compton	All figures mentioned have been updated.	Yes.
5	Exelon	Main Report	General	The "full" condition estimation should be more clearly explained. Pieces of the explanation are given throughout the report (Page 112, Appendix A-3), but there is not enough detail given in any one location (or even collectively throughout the report and appendices) to understand or follow how the estimation was derived.	Langland	The full condition is a term used to describe the storage capacity of a given reservoir. A reservoirs is full when it can no longer effectively trap sediments and associated nutrients in the long term (decades). This language added to page 112. "Full" is better described as dynamic equilibrium which is described in detail on pages 109-110.) More detailed language has been added to Appendix A, Attachment A-3.	No.
6	Exelon	Main Report	General	The terminology "major scour event" is used throughout the report. Instead of referring to these events as major flood events, they are named major scour events. This predisposes the reader to assume major scouring is occurring when flows exceed 400,000 cfs, and while there is mass wasting occurring, that still doesn't mean the loads entering the bay are a higher percentage of scour than watershed-based sediments. For example, see page 81, paragraph 3.	Compton	Specific reference here was changed to "major flood event". In general throughout report, if discussion is on a storm event in the watershed "flood event" is stated if discussing impacts from the scour of reservoirs, then scour even, mass scour event is discussed, especially when differentiating impacts between watershed loads and scour loads.	Yes.
7	Exelon	Main Report	General	There are numerous instances throughout the main report where statements are not cited or where statements are cited but they do not reflect what was actually stated in the citation. This is misleading to the reader and should be reviewed.	Compton	Agree. However, need specific instances in order to address.	No.
8	Exelon	Main Report	ES-1/paragraph 6	I believe the word "is" in the 5^{th} line of this paragraph should be "are".	Compton	Change made.	Yes.
9	Exelon	Main Report	ES-2/paragraph 2	Paragraph focuses on sediments (no net trapping) with the potentially misleading implication that the same is necessarily true for nutrients. Nutrients, organic carbon, and other water quality aspects of sediments are reactive. If the residence times of nutrient-associated sediments are sufficient, labile materials may become refractory and non-reactive. Sediment transport is not necessarily equal to nutrient transport.	Cerco	We believe this paragraph is accurate and sufficient as written.	No.

Comment #	Agency	Main Report/ Appendix/A ttachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
10	Exelon	Main Report	ES-2/paragraph 3	"These additional loads due to the loss of sediment trapping capacity in the Conowingo Reservoir are causing adverse impacts to the Bay. These increased loads need to be managed or offset to restore the health of the Bay." This sentence contradicts the next section which states that the watershed is the principal source of sediment and leads the reader to believe that nutrients associated with sediment scoured from Conowingo Pond are the main problem in regard to Bay WQ.	Compton	No contradiction here. Both statements are presenting separate conclusions from modeling that (1) additional scour is causing impacts to Bay that are currently not being addressed and (2) in context, loads from watershed during these storms are more than loads from scour.	No.
11	Exelon	Main Report	ES-2/paragraph 3	Examples given are for sediment only. No information is given to determine if differences in flows are the cause of differences in sediment loads (W = Q C so if Q ↑, W ↑). No information is given to support the statement that reservoirs are trapping a smaller amount of nutrient loads from the upstream watersheds. No quantification of incoming or outgoing nutrient load.	Compton	Text altered to indicate that this conclusion is from a comparison of 1996 to 2011 bathymetry. Nutrients are discussed on ES-3. Also better quantification and reactivity of nutrients is identified as a recommendation of the study.	No.
12	Exelon	Main Report	ES-2/paragraph 3	"...upon analyzing the hydrology of the lower Susquehanna River from 2008-2011, this study estimated that the decrease in reservoir sediment trapping capacity from 1996-2011 (from Conowingo) resulted in a 10-percent increase in total sediment load to the Bay..., a 67-percent increase in bed scour..., and a 33-percent decrease in reservoir sedimentation..." Using a four year hydrology period is too short and contains an inordinate frequency of storms.	Scott	These data were the result of a comparison of the bathymetries, not a comparison of the 15 years between 1996 and 2011. Language updated to clarify this point.	Yes.
13	Exelon	Main Report	ES-2/paragraph 5(last)	Use of phrase "Conowingo Reservoir material" implies that the reservoir is the source of material rather than the reservoirs being a site where transient storage appears.	Compton	Text altered to indicate bed sediment stored behind Conowingo.	Yes.
14	Exelon	Main Report	ES-2/last paragraph	When stating that 20-30% of sediment entering the bay is from Conowingo Pond and the rest from the upper watershed it should be noted that all material in Conowingo Pond originated from the upper watershed.	Compton	Where sediment originally came from is mentioned several paragraphs before "Sediments and associated nutrients from the land, floodplain, and streams in the lower Susquehanna River have been transported and stored in the areas (reservoirs) behind the dams over the past century."	No.
15	Exelon	Main Report	ES-3/first paragraph	Under current (non-WIP) scenario, noncompliance in 3 of 92 segments. So material from Conowingo Pond changes from 20-30% to what?	Linker	Added "and achieves all dissolved oxygen levels required for healthy aquatic life." to improve clarity.	Yes.
16	Exelon	Main Report	ES-3/paragraph 3 (2nd full paragraph)	The sentence that states, "As a consequence, DO in the Bay's deep-water habitat is diminished by reservoir scour events" implies that there are no other influences in the Bay watershed that contribute to the health of deep-water habitat.	Linker	Disagree. The sentence, within the context of the paragraph, in no way implies that reservoir scour events are the only nutrient loads impacting Chesapeake hypoxia.	No.
17	Exelon	Main Report	ES-3/paragraph 3	Is this paragraph theoretical or based on actual data? If based on actual data a citation should be included. If theoretical, that should be stated.	Compton	This information is data from study, appendix C. Changed "This assessment " to "Modeling work for this assessment" at beginning of paragraph. Exec summary does not provide any citations.	Yes.
18	Exelon	Main Report	ES-3/paragraph 2-3	Paragraph 2 specifically discusses "...the sediment loads comprised of sand, silt, and clay particles from scouring of Conowingo Reservoir during storm events..." and concludes that these loads "are not the major threat to Chesapeake Bay water quality and aquatic life." Nonetheless, Paragraph 3 begins by stating that "...the nutrients associated with the sediments [from Conowingo Pond scour] were determined to be more harmful to Bay aquatic life than the sediment." Given the structure of these two paragraphs, it appears that the LSRWA Draft Report differentiates between nutrients associated with Conowingo scoured sediment and nutrients associated with sediment from upstream watershed sources (including the other two reservoirs). This differentiation is made throughout the entire report and leads the reader to believe that only those nutrients associated with sediment scoured from Conowingo Pond are harmful to Bay health.	Compton	Context of these two paragraphs is discussion of scour from Conowingo and they are conclusions of the study from modeling. ES-4, last paragraph discusses nutrients throughout the watershed and impacts, as well as more study is warranted on this issue.	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
19	Exelon	Main Report	ES-3/paragraph 3	This paragraph regarding nutrients is repeated throughout the report in various forms. This paragraph cites "reservoir scour events," however, the remainder of the report focuses almost exclusively on Conowingo scour events. This language leads the reader to believe that only nutrients associated with sediment scoured from the reservoirs (and in later portions of the report exclusively from Conowingo Pond) have the most impact to Bay health. While nutrients associated with scoured sediment may be important it is not isolated to only those nutrients from Conowingo Pond scour.	Compton	Text changed to Conowingo scour events. Context here is discussing specific loads from scour of Conowingo. Many places in report discuss loads from Conowingo vs. watershed (including upper 2 reservoirs) or Conowingo and upper two dams and watershed. In discussion of these loads, nutrients and sediment are indicated to come from all of these sources.	Yes.
20	Exelon	Main Report	ES-4/paragraph 6	"The conclusion that the primary impact to living resources in the Bay was from nutrients and not sediment, was not determined until late in the assessment process. Further study on this is warranted." The impacts of nutrients on Bay water quality need to be examined in greater detail (as stated in the report). Adequate scientific understanding of nutrient dynamics from Conowingo Pond, the other reservoirs, and upstream watershed sources does not currently exist. The report, however, speaks in absolute, definitive terms that lead the reader to believe the various nutrient findings have been thoroughly examined and understood.	Compton	Report lays out uncertainty and notes where further study is warranted in various places. Conclusions are laid out in context of what we are certain of now based on work done and what needs further understanding.	No.
21	Exelon	Main Report	ES-4/paragraph 6(last)	Important context is missing: what is the fraction of nutrients delivered to the Bay that originate from the watershed ("washload") versus the fraction that is in transient storage within Susquehanna River bed sediments ("bed material load")? This process needs to be clarified in the report.	Cerco	The fraction of the nutrient load delivered from the watershed vs. the fraction from bed scour varies depending on the scour event and on the duration of the averaging period. The fraction from scour will be relatively high during the event but much less when a period of years is considered. There is no single number which is applicable. Some insight into this effect is provided in Table 6-1 of Appendix C. In any event, the subject paragraph does not need revision based upon this comment.	No.
22	Exelon	Main Report	CH. 2/Paragraph 4	The Exelon study cited (RSP 3.12) does not state these locations. Peach Bottom Atomic Power station is not located along Muddy Creek. Peach Bottom Atomic Power station is located approximately 7 miles upstream of the Conowingo Dam. Muddy Creek does not flow into Conowingo Pond 7 miles upstream of Conowingo Dam.	Compton	Assume reference is to Section 1.3 paragraph 2. Text altered per correction here.	Yes.
23	Exelon	Main Report	CH. 1/P.6/Paragraph Arrow 3	CBPO is not on the list of acronyms.	Compton	Acronym added.	Yes.
24	Exelon	Main Report	CH. 1/P.8/Paragraph 1	First sentence needs to recognize that sediment delivery of sediment and nutrients was occurring prior to construction of any dams.	Compton	Sentence added at end of paragraph, summarized from Section 2. "Prior to construction of the dams on the lower Susquehanna River, sediment and associated nutrient transport occurred, however minimal sediment storage took place.	Yes.
25	Exelon	Main Report	CH. 1/P.8/Paragraph 2	SRBC 2001 is not listed in the References.	Compton	SRBC 2001 citation deleted from this text.	Yes.
26	Exelon	Main Report	CH. 1/P.8/Paragraph 3	Statement that "Generally, low flow increases deposition, while during higher flows, deposition is reduced and some of the sediment is resuspended, transported downstream, or conveyed out of the reservoir" is somewhat of an over-simplification. It would be more neutral to state that "some sediment may be resuspended…"	Compton	Changed "is resuspended" to "may be resuspended"	Yes.
27	Exelon	Main Report	CH. 1/P.8/Paragraph 4	Large events not only scour additional sediment from behind the dams but also bring high sediment inflows from the upper watershed.	Compton	Added "which increase inflow loads from the watershed"	Yes.
28	Exelon	Main Report	CH. 1/P.8/Paragraph 5	Statement that "there would be a 100- to 250-percent increase in sediment load; a 20- to 70-percent increase in phosphorus load and a 2- to 3-percent increase in nitrogen load (CBP STAC, 2000)" is not meaningful without stating the basis for what represents the "normal" load. Increase relative to what? [Page 9. implies that basis is mid-1990s…]	Compton	STAC report compares this increase to what was observed most recently (data through 1990's). Text added "had been observed in the 1990's" ".	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
29	Exelon	Main Report	CH. 1/P.10/Paragraph last (Sec 1.9) and Table 1-2	Assessment products include many overlapping, and not necessarily parsimonious, study elements. For example, the table states that HEC-RAS was used to compute sediment loads into Conowingo Pond. The Chesapeake Bay Watershed Model (CBWSM) also computes sediment loads to/though Conowingo Pond. How do they compare? SEDFLUME data were collected to determine erosion rates and erosion thresholds for sediment in Conowingo Pond. HEC-RAS, which was also used to calculate sediment transport, uses transport capacity relationships. How do the rates determined by the SEDFLUME work (and used in AdH) compared to calculations using HEC-RAS? Do they agree? The CBWSM also computes transport (because the reservoir is a node in the stream network) and uses an entirely different approach. How were differences handled? Which sediment load estimates were used to feed the CB water quality model (CE-QUAL-ICM) (Carl Cerco model)?	Langland/ Scott/ Cerco	HEC -RAS inputs of watershed loads compare well to CBWSM. USGS (HEC-RAS) annual average load for 1993 – 2012 is 1.5 million English tons/annum. This converts to 3.74 million kg/d. The WSM daily average load for 1991 – 2000 under 2010 Progress Run conditions is 3.06 million kg/d. The differences between the two estimates can be attributed to numerous factors including different summary intervals – 1993 – 2012 for USGS/HECRAS vs. 1991 – 2000 for the WSM. HECRAS also used some of the SEDflume data for estimation of several sediment model parameters.	No.
30	Exelon	Main Report	CH. 1/P.13/Section 1.10 and Table 1-5	Same issues as in Section 1.9. It is not clear how all tools/models were used. It is unclear how AdH was used to inform CE-QUAL-ICM. It looks like the CE-QUAL-ICM was fed estimates from the CBWSM.	Cerco	CE-QUAL-ICM is fed loads from the CBWSM. The CBWSM loads are augmented with Conowingo scour loads since the CBWSM does not compute scour. The scour loads are calculated based on ADH results. The text here will be revised to clarify this point: Under 3. CBPs Watershed Model ….. Add a sentence at the end of this paragraph "Watershed loads at the Conowingo outfall computed by the WSM were supplemented by bottom scour loads estimated through ADH and through data analysis."	Yes.
31	Exelon	Main Report	CH. 1/P.14/Figure 1-4	The orange area is supposed to indicate the CBP watershed model (WSM) extent. As indicated in the locus map, this means the 'watershed model' is really only the lower Susquehanna River watershed. Is this correct?	Cerco	This figure is simplified, highlighting the study area of the assessment. The watershed model covers the entire Chesapeake Bay watershed which lower Susquehanna is a part of. The WSM covers the entire Chesapeake Bay watershed including NY, PA, MD, WV, VA, and DC. The extent of the watershed and of the WSM is shown in gray in the inset. The orange highlights the lower Susquehanna River watershed. Footnote revised to clarify this.	Yes.
32	Exelon	Main Report	CH. 1/P.15/Figure 1-5	Why is a sediment rating curve used as input to Conowingo reservoir instead of a time series output? HEC-RAS is capable of providing a time series, and appendix A says providing a sediment load time series was the modeling objective.	Langland	We tried both the rating curve and HEC-RAS model output. There were problems with the HEC-RAS model as you point out later in comment #75.	No.
33	Exelon	Main Report	CH. 1/P.16/Figure 1-6	Figure does not clarify which model feeds sediment estimates to CE-QUAL-ICM and how differences between estimates from models in the suite (CBWSM, HEC-RAS, and AdH) are handled.	Cerco/ Compton	The information on CE-QUAL-ICM loading is provided in Figure 1-5. The differences in the model suite are not the subject of these flow charts. This flow chart is meant to provide a simplified, broad picture of the analytical approach of the study tailored for a wide-audience.	No.
34	Exelon	Main Report	CH. 1/P.16/Figure 1-6	Lake "Clarke" is misspelled in step 3 of the flow chart.	Compton	Change made.	Yes.
35	Exelon	Main Report	CH. 2/P.17/Paragraph 1	While the last portion of this paragraph describes why the discussion is focused on Conowingo it does not explain why there is no focus on the two upstream reservoirs. Why are these reservoirs not discussed at the same level of detail as Conowingo?	Spaur	Modify sentence "As such, it has potentially a large influence on the Chesapeake Bay during storm events due to scouring of nutrients and sediments stored behind this dam." to "Holtwood and Safe Harbor Dams were known to be at equilibrium at the start of this assessment. Because Conowingo was not believed to be in dynamic equilibrium and it reaching that condition could have a potentially large effect on the Bay, more attention is focused on Conowingo Dam than Holtwood or Safe Harbor Dams in this section."	Yes.
36	Exelon	Main Report	CH. 2/P. 17/Paragraph 1	This paragraph, and the third paragraph in particular, attempt to explain why Conowingo Pond is of particular importance; however, they do not quantify or adequately describe how much more important it is to Susquehanna River sediment loads versus Lake Clarke and Lake Aldred.	Spaur	Dealt with by response to #35.	Yes.
37	Exelon	Main Report	CH. 2/P. 18	It is difficult to differentiate between the "Major Basins" and "Main Segments" polygons in this figure.	Spaur	Concur, but figure originated from USEPA. Figure caption changed from Major Regions of the Chesapeake Bay" to "Figure 2-1. Major Regions of the Chesapeake Bay Mainstem" Also, removed "Chesapeake Main Segments"	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
38	Exelon	Main Report	CH. 2/P. 19/Paragraph 2	Last sentence says that the Flats are due to human influence, however, the delta area existed pre-European settlement and deltas are usually flat.	Spaur	Change sentence "The shallow character of the flats today is largely a result of anthropogenic sedimentation (Gottschalk, 1945)." to "Shallow waters of the Susquehanna River delta in the upper Bay expanded substantially in area following European settlement, and the expansive shallow flats that exist today largely derive from anthropogenic sedimentation (Gottschalk, 1945) (see Section 2.6.3)."	Yes.
39	Exelon	Main Report	CH. 2/P. 19/Paragraph 2	There are several references to various islands or other points of importance in this section – a location map of these landmarks would be useful.	Spaur	Figure 2-2 covers geographic names: Spesutie Island, Battery Island, Elk Neck, Havre de Grace, Susquehanna Flats. No figure revision needed.	No.
40	Exelon	Main Report	CH. 2/P. 21/Paragraph 4 (last part of Section 2.2)	The report identifies that climate change has resulted in recent years being wetter. In general, wetter years would mean increased watershed sediment delivery and transport through the reservoirs. This potentially conflicts with the conclusion that loads are increasing as a consequence of reduced trapping/dynamic equilibrium. It is unclear how earlier statements regarding decreases in trapping can be evaluated without first establishing how hydrologic (and land use) changes impact the watershed the river system.	Spaur	Added sentence to paragraph 2 on page 97, before "All of the Table 4-1 scenarios…" "However, there were no modeling runs formulated for forecasted climate change conditions; a general discussion of global climate change impacts can be found in Section 5.1.4. "	Yes.
41	Exelon	Main Report	CH. 2/P. 25/Paragraph 4	The watershed size is cited as 27,500 mi^2, but earlier it was noted as 27,510 mi^2. A consistent number should be used for significant figures.	Spaur	Change clause in 2nd sentence from "The basin drains more than 27,500 square miles, …" to "The drainage basin covers 27,510 square miles,…"	Yes.
42	Exelon	Main Report	CH. 2/P. 27/Paragraph 3	The Exelon study cited (RSP 3.12) does not mention contributions to vertical circulation in the reservoir.	Spaur	Citation corrected to "(Normandeau Associates and GSE, 2011)" -- see comment response #48 for citation details.	Yes.
43	Exelon	Main Report	CH. 2/P. 29/Paragraph 1	Sentence two could be read that the maximum salinity anywhere in the Bay is 18 ppt, but we believe this is trying to say that within Maryland waters the maximum salinity is approximately 18 ppt. Please clarify.	Spaur	Change "Bay surface waters range from fresh in headwaters of large tidal tributaries to a maximum of about 18 ppt in Maryland in the middle Bay along the Virginia border, as illustrated in Figure 2-6. " to "In Maryland, Bay surface waters range from fresh in headwaters of large tidal tributaries to a maximum of about 18 ppt in the middle Bay along the Virginia border, as illustrated in Figure 2-6. "	Yes.
44	Exelon	Main Report	CH. 2/P. 29/Paragraph 4	Second sentence states that each of the Bay's major tidal tributaries has an ETM. Susquehanna River does not have an ETM.	Spaur	After "Each of the Bay's major tidal tributary systems has an ETM zone near the upstream limit of saltwater intrusion, as shown in Figure 2-7. " add new sentence "The Susquehanna River ETM zone occurs in the upper Bay mainstem."	Yes.
45	Exelon	Main Report	CH. 2/P. 32/Paragraph 4	Statement that nutrients released from bottom sediments provide a substantial portion of the nutrients required by phytoplankton is perhaps a little simplified. First, as noted, vertical stratification limits the vertical exchange of dissolved oxygen between the surface and bottom waters (as pointed out on page 34 paragraph 4) and, therefore, the vertical exchange of bottom water nutrients to surface waters is also limited. In addition, as pointed out in paragraph 3 of page 33, nutrients are recycled and reused many times over as they move downstream in rivers towards the Bay. They are also recycled and re-used in the Bay as well. Bottom nutrients are likely to contribute to the production of surface phytoplankton, but it is not clear what the balance between surface recycling of nutrients and bottom release of nutrients is in determining algal productivity.	Spaur	Concur that complicated topic, so will further simplify/generalize. Change "Nutrients contained in Bay bottom sediments are re-released into the water column seasonally, and these regenerated nutrients provide a substantial portion of the nutrients required by phytoplankton in summer, particularly in the middle Bay. " to "Nutrients contained in Bay bottom sediments are re-released into the water column seasonally, and these regenerated nutrients provide a substantial portion of the nutrients required by phytoplankton, particularly in the middle Bay. "	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
46	Exelon	Main Report	CH. 2/P. 34/Paragraph 1 (at top)	"Monitoring of nutrients in the Susquehanna River has shown that the flow-adjusted annual concentrations of total nitrogen, total phosphorus, and suspended sediment delivered to the dams have been generally decreasing since the mid-1980s." It is unclear how much of any trends are due to increasing data density over time and reduced uncertainty. There may be some apples and oranges comparisons beneath everything. As stated in the Zhang et al. (2013) paper, there is interpolation and extrapolation in load estimates. The next statements that "This decrease is attributed to the success of environmental management measures. However, total nitrogen, total phosphorus, and suspended sediment loads from Conowingo Reservoir itself to the Chesapeake Bay have shown an increasing trend since the mid-1990s, indicating decreasing reservoir trapping capacity (Zhang et al., 2013)" need further evaluation. Changes in sediment export from the River could also include changing sediment delivery from the watershed. It is unclear how the data analysis on which these statements rely was performed	Spaur	Change middle sentence from "This decrease is attributed to the success of environmental management measures." to "Environmental management measures in the watershed contributed to this decrease." to be less precise over relative importance of management measures versus other causes.	Yes.
47	Exelon	Main Report	CH. 2/P. 34/Paragraph 1	Zhang et al (2013) refers specifically to the reservoir system (reservoirs plural) and loads from the Conowingo Dam outlet. To quote from their conclusions: "Flow-normalized loads of SS, PP, and PN at the outlet of the Conowingo Reservoir have been generally rising since the mid-1990s. The reservoirs' capacity to trap these materials has been diminishing, and the Conowingo Reservoir has neared its sediment storage capacity."	Spaur	Change last sentence in paragraph (already recently revised as per above) from "One study has indicated that loads of total nitrogen, total phosphorus, and suspended sediment from Conowingo Reservoir to the Chesapeake Bay are increasing and attributes this to decreasing reservoir trapping capacity (Zhang et al., 2013)." to "One study has indicated that loads of total nitrogen, total phosphorus, and suspended sediment from the reservoir system of the lower dams to the Chesapeake Bay are increasing and attributes this to decreasing trapping capacity of Conowingo Reservoir (Zhang et al., 2013)."	Yes.
48	Exelon	Main Report	CH. 2/P. 37/Paragraph 4	The citation to Exelon (2011) regarding DO in the reservoir is not the 2011 report in the References section. The 2011 Exelon study RSP 3.1 should be cited for this statement.	Spaur	Changed citation to (Normandeau Associates and GSE, 2011). Added reference but used the format that Exelon requested in comment #1. New reference = Normandeau Associates, Inc., and Gomez and Sullivan Engineers. 2011. *Seasonal and Diurnal Water Quality in Conowingo Pond and below Conowingo Dam* (RSP 3.1). Kennett Square, PA: Exelon Generation, LLC.	Yes.
49	Exelon	Main Report	CH. 2/P. 40/Figure 2-12	Over what timeframe does this assessment of erosion vs. deposition occur? How can an area be forever erosional?	Spaur	Change sentence "The Bay's erosional and depositional patterns are portrayed in Figure 2-12. " to "Figure 2-12 portrays regions of Bay bottom and whether erosional or depositional processes dominate. Processes producing these patterns occurred naturally over geologic time as the Bay evolved driven by rising sea level. Conversely, human activity has induced substantial deposition in headwater tributaries and in the Susquehanna Flats over the last few centuries (see Section 2.6.3)."	Yes.
50	Exelon	Main Report	CH. 2/P. 41/Paragraph 1	The report cites Hartwell and Hameedi (2007) for the proposition that "[t]idal portions of the Anacostia River, Baltimore Harbor, and the Elizabeth River are hotspot areas of contaminants." However, Hartwell and Hameedi (2007) does not mention the Anacostia River, and the figure with the sites of greatest contamination does not include the Anacostia.	Spaur	Change reference to instead be "CBP, 2013" (That these are the three "hottest" contaminated regions of Bay is widely reported and not dependent upon an individual report.)	Yes.
51	Exelon	Main Report	CH. 2/P. 44/Paragraph 2	"TP probably does not show a pattern of decrease with depth into the sediment." Personal communication with Langland is cited here but what is Langland's basis for this comment?	Spaur	Add clause "Because the phosphorus adsorbed to bottom sediments is minimally bioavailable and not being utilized by organisms nor reacting chemically," prior to beginning of sentence "TP probably does not show a pattern of decrease with depth into the sediment (Michael Langland, Hydrologist, U.S. Geological Survey, personal communication, 2014). Comment based on years of collected data observations.	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
52	Exelon	Main Report	CH. 2/P.44/Paragraph 2	Based on the estimates of bioavailable nitrogen and phosphorus quoted here, which could potentially be resuspended and transported into Chesapeake Bay, there is a serious mismatch between the bioavailable fractions of TN (96% typically of limited bioavailability) and TP (0.6-3.5% plant available) contained in the Conowingo Pond sediments and how they are incorporated in the CBEMP model, wherein they are assumed to be approximately 85% bioavailable, once they enter into the bay and are deposited back to the sediment bed in the Bay. Therefore, it is likely that the CBEMP is over-estimating the release of Conowingo nutrients from the sediment bed once they are deposited into the Bay sediments, and therefore the model is over-estimating the change in non-attainment of the DO water quality standard.	Spaur	The context here is IMMEDIATE bioavailability. Immediate added before bioavailability in this paragraph and this statement added: "The nutrients stored behind the dam that are not in immediately bioavailable forms might, however upon burial in the Bay bottom might be expected to gradually become bioavailable from microbial processes in the sediment (Michael Langland, Hydrologist, U.S. Geological Survey, personal communication, 2014). "	Yes.
53	Exelon	Main Report	CH. 2/P.44/Paragraph 3 (counting the partial at the top as 1)	The paragraph starting with "the sediment retained behind Conowingo Dam…" seems odd in that the focus is exclusively on Conowingo. Even if the measurements are from Conowingo Pond, it seems like the description would be applicable to all three reservoirs given that the sediments (and nutrients) are derived from the watershed. How do these measurements compare to the assumptions for labile and refractory carbon and nutrient distributions used to drive the Bay WQ model? Is/was this information used to update the bay WQ model?	Spaur	Statement at beginning of Section 2 informs reader why we focus on Conowingo. However, concur with need to provide additional information on sediments and nutrients of upper two dams. Please insert the following new paragraph covering this topic after paragraph 2 (p. 44, June 23 version): "TN and TP in bottom sediment samples collected in Lake Clarke considered vulnerable to scour ranged from 3.3 to 5.3 g/kg and 0.8 to 1.2 g/kg, respectively. TN and TP in bottom sediment samples collected in Lake Aldred considered vulnerable to scour ranged from 1.2 to 5.7 g/kg and 0.3 to 0.5 g/kg, respectively. Lake Clarke had higher clay content than Lake Aldred at these locations, likely accounting for greater TP content. Clay content of bottom sediments in downstream Lake Clarke remained consistent in comparison of findings of studies conducted in 1990 versus 1996. Conversely, clay content in bottom sediments in downstream portions of Lake Aldred decreased from 1990 to 1996 (Langland and Hainly, 1997)."	Yes.
54	Exelon	Main Report	CH. 2/P.44/Paragraph 5	The report does not appear to discuss the potential impacts that the particulate coal may have on collected data or model predictions, nor whether it is uncommon to have an 11-percent coal content.	Spaur	Unlikely that additional future coal to be transported into Bay from sediment behind the dams would have much effect on the Bay. The upper Bay already contains substantial coal as was stated in Section 2.6, and has for probably more than a century. Evaluating effects of additional coal input is one of many specific topics that were not evaluated in this assessment. An environmental impact statement covering any proposed project would be the appropriate place to specifically address this. However, we should change existing sentence on p. 38, 2nd paragraph in "Bay Bottom Materials and Processes" subsection from "Abundant coal occurs in Susquehanna Flats sediments (Robertson, 1998)." To "Abundant coal occurs in Susquehanna Flats sediments transported into the Bay from coal mining in the Susquehanna Basin (Robertson, 1998)." This would better clarify source and timing of coal deliveries to the Bay (coal mining having begun in earnest in Basin by early 1800s). (On side note, I skimmed MGS [1988] and Robertson [1998], but neither of these provides specific information on how much coal occurs in Bay's flats sediments, other than to state that it's abundant in certain strata near the surface.)	Yes.
55	Exelon	Main Report	CH. 2/P.44/Paragraph 5 & 6	Focus is only on Conowingo: what about the other reservoirs?	Spaur	See Comment #35.	No.
56	Exelon	Main Report	CH. 2/P.49/Paragraph 3	There appear to be many other substantial declines in total SAV acres that are not explained by storm events (figure 2-16 and figure 2-17). There is no narrative around this, leaving the reader with the impression that storm events are the primary reason for SAV abundance declining even though a close inspection of the graph doesn't necessarily prove this connection. In fact, Kemp et al (1983) examined potential reasons for the decline bay-wide and at the Flats from the mid-60s to 1983 and concluded that storms played a secondary role.	Spaur	Topic of SAV trends related to storms, eutrophication, and other stressors is covered adequately in last paragraph on bottom of p. 48. No change needed.	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
57	Exelon	Main Report	CH. 2/P.51/Figure 2-18	Difficult to read the legend and text on this figure and determine what point the author is trying to make by referring to this figure.	Spaur	Figure has been revised.	Yes.
58	Exelon	Main Report	CH. 2/P.52/Paragraph 1	The first sentence states that "no SAV beds were mapped immediately below Conowingo Dam in the non-tidal and tidal Susquehanna River over the period 1997-2012." Exelon RSP 3.17 mapped SAV at the mouth of Octoraro Creek and at the island complex at near the mouth of Deer Creek (Robert, Wood, and Spencer Islands) and at Steel Island along the opposite bank in 2010 surveys.	Spaur	Change paragraph "No SAV beds were mapped immediately below the Conowingo Dam in the non-tidal and tidal Susquehanna River over the period 1997-2012. However, SAV was frequently mapped in the non-tidal and tidal river downstream to the river mouth from the 1990s through 2010 (VIMS, 2013)." to "VIMS mapped no SAV beds immediately below the Conowingo Dam in the non-tidal and tidal Susquehanna River over the period 1997-2012. However, VIMS frequently mapped SAV in the non-tidal and tidal river downstream to the river mouth from the 1990s through 2010 (VIMS, 2013). SAV was found to occur in 2010 downstream of Conowingo Dam at creek mouths and islands between the dam and Port Deposit in shallow areas with fine-grained sediment and low water velocities (URS and GSE , 2011).	Yes.
59	Exelon	Main Report	CH. 2/P.52/Paragraph 4 First sentence	The statement that well-established SAV communities appear to be absent in bedrock dominate portions of the Susquehanna River above Conowingo Reservoir was not stated in the cited Exelon report. This statement should be changed to: "Well-established SAV communities were not observed in the bedrock-dominated reach of the reservoir above Hennery Island during 2006/2007 surveys."	Spaur	No change. Report makes general point that SAV is absent from bedrock (except in cracks with sediment), so I think statements are fair as written.	No.
60	Exelon	Main Report	CH. 2/P.54/Paragraph 3	Last sentence of this paragraph does not reflect what the cited Exelon report (RSP 3.12) concluded. Exelon RSP 3.12 concludes that vegetated habitat would be affected most by a reduction of water levels below 106 feet NGVD, and, given that pond levels are rarely below this elevation "impacts to vegetated littoral habitat from water level fluctuations are unlikely."	Spaur	Change sentence "Changes in water levels have the potential to decrease the extent of or dewater SAV beds" to "Changes in reservoir water level fluctuations in Conowingo Reservoir over the range at which they are typically managed have negligible effects on SAV there"	Yes.
61	Exelon	Main Report	CH. 2/P.59/Figure 2-20	What do the red areas represent in this figure? The legend does not define it.	Spaur	Add sentence at bottom of figure "Red area is Aberdeen Proving Ground, U.S Army materials testing site."	Yes.
62	Exelon	Main Report	CH. 2/P.65/Table 2-9	While the usable storage in the FERC allowable pool (101.2-109.2) may be closer to 75,000 acre feet, the storage from 104.7 feet to 109.2 feet is closer to 40,000 acre feet.	Spaur	Add additional footnote "3" after number "75,400" and then insert new footnote text: "3 Usable storage in FERC allowable pool (101.2-109.2). Storage from 104.7 feet to 109.2 feet is approximately 40,000 acre feet."	Yes.
63	Exelon	Main Report	CH. 2/P.66/Paragraph 3	Second sentence cites RSP 3.12 as saying Conowingo water levels are "primarily confined to elevations between 104 and 109 feet NGVD29." This is incorrect. Page 31 of RSP 3.12 states: "Analyses conducted over varying temporal scales of historic water level elevation data collected for Conowingo Pond indicate that water level fluctuations are primarily confined to water elevations between 107 feet and 109 feet, and rarely fall below 106 feet."	Spaur	Change sentence "However, water levels are primarily confined to elevations between 104 and 109 feet NGVD29, and periods at which elevations are lower than 106 feet NGVD29 are infrequent and brief (Exelon, 2011)." to "However, water levels are primarily confined to elevations between 107 and 109 feet NGVD29, and rarely fall below 106 feet NGVD29 (Exelon 2012a)	Yes.
64	Exelon	Main Report	CH. 2/P.66/Paragraph 4	The report correctly cites Conowingo Dam has having 50 stony-type crest gates and two (available) regulating gates (the third is currently used by the fish ladder). This contradicts Appendix A which incorrectly describes the dam as having 54 gates.	Spaur	Appendix A updated.	Yes.
65	Exelon	Main Report	CH.3/P.75/Paragraph 1 & 2	The report clearly states in Paragraph 2 (based on TMDL Appendix T) the actions that will need to be taken if the trapping capacity of Conowingo Pond is found to be reduced. This language is not consistently applied throughout the report and appendices (particularly Appendix D) when discussing the reduced trapping capacity of Conowingo Pond as related to the TMDL. In all cases the actual language from the TMDL Appendix T should be used.	Linker	The TMDL Appendix T has been correctly cited, referenced, and characterized throughout the main report and Appendix D. Charges are unwarranted.	No.
66	Exelon	Main Report	CH.3/P.75/Paragraph 1 & 2	Table 5-6 of the main report is consistent with TMDL Appendix T in stating that the reservoir trapping capacity of Conowingo has been 55-60% from 1993-2012. Please elaborate on what trapping capacities were used in the various WSM model runs.	Linker/ Cerco	The LSRWA scenarios are fully described and characterized in Appendix D along with the estimated Conowingo bathymetries used in each scenario. That is the correct place for the scenario information and not page 75. Changes are unwarranted.	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
67	Exelon	Main Report	CH.3/P.75/Paragraph 1 and 2	Appendix T of the 2010 Chesapeake Bay TMDL addresses the trapping capacity of all three dams of the Susquehanna River, including Safe Harbor (Lake Clarke) and Holtwood (Lake Aldred), but concludes that "Lake Clarke and Lake Aldred have no remaining sediment trapping capacity [and]…have been in long-term equilibrium for 50 years or more." Nonetheless, the LSRWA Draft Report shifts focus here from the three reservoirs/dams to only Conowingo Reservoir/Dam. We suggest adding language to clarify that, in addition to the assumptions regarding Conowingo Reservoir's trapping capacity, the TMDL assumes that Lake Aldred and Lake Clarke have no remaining sediment trapping capacity. The sediment and nutrient loads from Lake Clarke and Lake Aldred should be accounted for in the WQM input data.	Linker	Text revised too: The Chesapeake Bay TMDL assumed that the reservoirs above Conowingo, Lake Clarke (Safe Harbor Dam) and Lake Aldred (Holtwood Dam), have no remaining sediment trapping capacity and have been in long-term equilibrium for 50 years or more (USEPA, 2010b)."	Yes.
68	Exelon	Main Report	CH.3/P.77/Paragraph 4	PA DEP issues a 401 water quality certification for Muddy Run, not MDE.	Compton	Concur. MDE changed to PADEP.	Yes.
69	Exelon	Main Report	CH.3/P.77/Paragraph 4	The last two sentences of this paragraph need to be updated to reflect the current status of the relicensing process.	Balay	On June 3, 2014, PADEP issued a Section 401 Water Quality Certification (WQC) for the Muddy Run project. On July 30, 2014, FERC issued a draft Environmental Impact Statement (EIS) for the relicensing of the York Haven, Muddy Run, and Conowingo projects. At the writing of this report, a new FERC license for the Muddy Run project is pending.	Yes.
70	Exelon	Main Report	CH.3/P.78/Paragraph 2	The last two sentences of this paragraph need to be updated to reflect the current status of the relicensing process.	Balay	On July 30, 2014, FERC issued a draft EIS for the relicensing of the York Haven, Muddy Run, and Conowingo projects. At the writing of this report, Exelon still needs to acquire a 401 WQC from MDE, and a new FERC license for the Conowingo project is pending.	Yes.
71	Exelon	Main Report	CH. 4/P.81/Paragraph 2	Is Langland's 2009 report the correct citation for the previous 1D HEC model (i.e., HEC-6) used to study sediment transport in the lower Susquehanna River reservoir system? I believe this citation should be Hainley et al. (1995) titled "Deposition and Simulation of Sediment Transport in the Lower Susquehanna River Reservoir System".	Langland	Correct, please change this to Hainly and others, 1995.	Yes.
72	Exelon	Main Report	CH. 4/P.81/Paragraph 3, see Footnote #3	Footnote #3 indicates that HEC-RAS was used to simulate conditions in Conowingo Pond. HEC-RAS and AdH results for Conowingo Pond should be compared and contrasted. The simulated mass over Conowingo Dam in both models should be tabulated and compared. Any differences in outcomes reflect uncertainties in the assessment process that need to be identified and quantified. Also, given that HEC-RAS is used to drive the upstream boundary for the AdH model domain, it is reasonable to assume that similar sorts of differences would occur through each reservoir if AdH were used to simulate the upstream part of the system too. The upstream watershed (over Holtwood Dam) is the main source of sediment (and nutrients) entering Conowingo Pond. Uncertainties there propagate downstream.	Langland	It would be useful to show this comparison if the data existed. We gave Steve Scott (AdH modeler) the daily sediment load files which he used to help develop his sediment rating curve. I believe he found as we did that the HEC-RAS was not generating enough sediment to match measurements at Conowingo. It is unknown how HEC-RAS performed in the upper two reservoirs due to lack of calibration data, but chances are it also under predicted the load coming in to Conowingo. That is the reason Steve increased the sediment load for the 2008-2011 simulation period from 22 to 24 million tons. It also provided a range of conditions for Steve to make predictions.	No.
73	Exelon	Main Report	CH. 4/P.81/Paragraph 3	The statement "two major scour events (above 400,000 cfs)" is biased. This should be more factually stated as "two major flood events (above 400,000 cfs)."	Compton	Concur change made to two major flood events that included mass scour.	Yes.
74	Exelon	Main Report	CH. 4/P.81/Paragraph 3	The use of the term "major scour event" implies to the reader that scour is the major sediment transport process occurring in the lower Susquehanna River for these flow events, which contradicts what the study later concludes (only 20%-30% of the load is from scour). The wording on page 84, in the second paragraph, more accurately describes the events as "major high-flow events (above 400,000 cfs)".	Compton	Concur see change from comment #73.	

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
75	Exelon	Main Report	CH. 4/P.81/Paragraph 4	Use of HEC-RAS to simulate sediments with cohesive characteristics is problematic. The SEDFLUME results for Conowingo Pond provide a means to check on just how cohesive bedded sediments in the Lower Susquehanna are. SEDFLUME tests give information regarding the critical shear stress for erosion and erosion rate. If the critical erosion thresholds experimentally determined using the SEDFLUME differs substantially from the constraints that drive transport equations used in HEC-RAS, then HEC-RAS cannot be reasonably applied and cannot provide appropriate boundary conditions to drive AdH. The presumed occurrence of "dynamic equilibrium" in upstream reservoirs does not justify the use of HEC-RAS. As noted by the LSRWA, dynamic equilibrium does not imply that the sediment mass entering or leaving a reach of the stream will be equal on a day-to-day or month-to-month timeframe. It is not clear how the authors concluded that HEC-RAS provided understanding of physical processes in upstream reservoir if it does not represent the underlying physics of sediment transport.	Langland	Tying into comment number 32, that is why a rating curve was developed for AdH in Conowingo and the inflowing sediment from HEC-RAS was used as a backup.	No.
76	Exelon	Main Report	CH. 4/P.82/Figure 4-1	It appears the streams that were superimposed on this figure may be located slightly northwest of where they were intended to be.	Langland	Concur. Figure updated.	Yes.
77	Exelon	Main Report	CH. 4/P.83/Figure 4-2	The elevation datum used to construct this figure is not stated. The deepest elevations are +98 ft to -61 ft relative to what datum? The data used to represent sediment bed elevations should be verified to ensure it is consistent with the data used to determine water surface elevation boundary conditions in the model. Any differences could impact the inferred "scour threshold."	Scott	Added text box "(NGVD 88)" after "feet" in legend of Figure 4-2.	Yes.
78	Exelon	Main Report	CH. 4/P.84/Paragraph 3	The 'calculated "full" bathymetry' was not calculated, it was empirically estimated from bathymetric observations. The report should describe more thoroughly how the 'full' bathymetry was determined.	Langland	see number 116 below.	Yes.
79	Exelon	Main Report	Ch. 4/P. 85-86	The discussion of uncertainties in AdH results does not discuss the uncertainties pertaining to the upstream load. If there are 3 million tons/yr. entering Conowingo Pond and only 1 million tons/yr. leaving it, then transport processes must be dominated by upstream inputs. Errors in erosion estimates within the Pond can be compensated by corresponding errors in deposition estimates. Coupled with the LSRWA opinion that AdH results are uncertain because of the inability to represent flocculation (and therefore deposition fluxes) [flocculation in AdH only considered concentration but does not consider water column shear forces], the uncertainty of AdH results may be very high.	Scott	Uncertainties in total load entering Conowingo will indeed affect scour and deposition, and thus affect total load output to the bay. On page 86 (para 3) added "Uncertainties in the total sediment load entering Conowingo Reservoir will affect scour and deposition, and thus affect the total load output to the Bay. Consequently, " before "To provide more information..."	Yes.
80	Exelon	Main Report	CH. 4	The runs with the 1996 nutrients should be reported, not just the runs using the 2011 nutrient data.	Cerco	The runs with 1996 nutrient composition are presented in an appendix to the CBEMP (Appendix C) report. We can't present every scenario in the main report due to length considerations. Only the scenarios judged most important and most relevant are presented.	No.
81	Exelon	Main Report	CH. 4/P.86/Paragraph 2	Salinity will also impact fine sediment flocculation – probably only an issue in the Bay.	Scott	Agree, but not in Conowingo Reservoir	No.
82	Exelon	Main Report	CH. 4/P.86/Paragraph 3	The report needs to more clearly state the uncertainties surrounding AdH, and for that matter HEC-RAS, and how greatly those uncertainties could affect the models for which the results are used as input parameters. Given that the AdH model is based on the output from the HEC-RAS model, could not account for the dam, used water samples that were not representative of the entire river cross-section and were not collected over the entire hydrograph AdH result uncertainty may be very high.	Scott	Agree, but this is clearly stated in the report	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
83	Exelon	Main Report	CH. 4/P.86/Paragraph 3	"One source of uncertainty is the exact composition and bioavailability of nutrients associated with sediments scoured from the reservoir [Conowingo] bottom." Yet throughout the document nutrients are discussed in absolute terms using definitive statements.	Cerco	This paragraph acknowledges clearly and upfront the uncertainties in composition and bioavailability. There is no need to repeat this statement throughout the report.	No.
84	Exelon	Main Report	CH. 4/P.86/Last Paragraph	References for regular updates and calibration? Which constituents calibrated? What parameters adjusted?	Linker	The cited reference (Linker et al., 2013) has a complete description of the different phases and versions of the CBP models. Added "; Linker et al. (2013) provides a complete description of the different phases and versions of the Chesapeake Bay models. " to 3rd sentence in noted paragraph.	Yes.
85	Exelon	Main Report	CH. 4/P.87/Paragraph 2	The CBEMP has been calibrated multiple times; however, it was unclear how the model was calibrated once the scour load from the AdH model was added as an input parameter.	Linker/ Cerco	That's not the correct way to think about model calibration. The CBP models used in the LSRWA study are calibrated to observed data from 1985 to 2005. The model runs with the ADH model are "what if" scenarios. Models aren't calibrated to scenarios	No.
86	Exelon	Main Report	CH. 4/P.87/Paragraph 3 & 4	Why was the AdH model (unknown time step) output at 2 hours to then be computed in the WQSTM model at 15 min?	Scott/ Cerco	The ADH time step is short, on the order of seconds to minutes, compared to the daily loadings. ADH computations from each time step were summed into daily loads for use in the WQ model.	No.
87	Exelon	Main Report	CH. 4/P.89/Paragraph 1	How are the scoured sediment and nutrient loads from Lake Clarke and Lake Aldred accounted for? Is it similar to the process for which Conowingo-scoured sediments (and thus nutrients) are superimposed on the WSM nutrient loads input to the WQM?	Cerco	Sediment loads from Lake Clarke and Aldred are not specifically identified in the Chesapeake Bay loads. The Chesapeake Bay model only "sees" loads at the Conowingo outfall. Loads from Clarke and Aldred are combined with other loading sources at this outfall. The only material superimposed on the WSM loads is scour calculated in Conowingo Reservoir.	No.
88	Exelon	Main Report	CH. 4/P.89/Paragraph 1	The discord in the timeframes simulated by the model is noteworthy in that it likely affects model outcomes. The Bay WQ model period is 1991-2000. The HEC-RAS and AdH simulations were 2008-2010. Given the non-linearity of sediment transport and associated nutrient transport, it is unclear how results for one timeframe were "adjusted" to a different timeframe that may have different conditions (e.g., precipitation, different winds, different land uses, etc.).	Cerco	The only adjustment that was necessary was to adjust the amount of scour calculated for TS Lee downwards to a value appropriate for the January 1996 storm. This procedure is detailed in Appendix C and comparisons are provided of computed and observed solids concentration at the Conowingo outfall for January 1996.	No.
89	Exelon	Main Report	CH. 4/P.89/Paragraph 2	"Phase 5.3.2 of the CB WSM provided daily sediment and nutrient loads from the watershed for application in the LSRWA effort." How does this compare to the AdH time step for scour loads? From Cerco The ADH time step is short, on the order of seconds to minutes, compared to the daily loadings. ADH computations from each time step were summed into daily loads for use in the WQ model.	Cerco/ Scott	The AdH time step ranged from 1000 seconds for low flow conditions to 100 seconds for storms.	No.
90	Exelon	Main Report	CH. 4/P.89/Paragraph 3	Are sediment loads from un-simulated reaches somehow accounted for? It appears they may, in aggregate, make up a substantial drainage area.	Cerco	The loads from these small watersheds are accounted for. They go directly into the water quality model at the shoreline of the sub-watershed. The absence of a "reach" means they do not have a modeled river segment flowing through them.	No.
91	Exelon	Main Report	CH. 4/P. 89-95/Sections 4.3.2 to 4.3.8	A comparison between CB WSM, HEC-RAS, and AdH results at Conowingo Dam should be made. The WQSTM model (using the WSM as its input) has been calibrated numerous times, however, once the AdH results were used as an input the WQSTM model should have been re-calibrated. Did this occur? If not, how did the results of the CB WSM, HEC-RAS, and AdH outputs compare?	Cerco/ Scott	The CB WSM model used AdH scour loads for TS LEE as input. There is no need to re-calibrate because these are additional loads not accounted for by the CB WSM model. At the time of this study, the WSM was operable only through 2002 while the ADH model covered the period 2008 - 2011. Consequently, no direct comparison is possible. No results from HEC-RAS at Conowingo were utilized so comparisons between ADH and HEC-RAS are not necessary. The sole connection between ADH and the WQ model is that ADH was used to guide quantification of scour loads. The WQ model does not require recalibration when scour loads are implemented.	No.
92	Exelon	Main Report	CH. 4/P.91/Paragraph 3, 5	If the three reservoirs are a single node in the current version of the watershed model, as we have come to understand, then this should be explicitly mentioned. The current wording is unclear. Paragraph 5 makes it sound like Conowingo Pond is broken out explicitly in the watershed model.	Cerco	The three reservoirs are not a single node in the watershed model. Each, including Conowingo, is modeled individually.	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
93	Exelon	Main Report	CH. 4/P.91/Paragraph 5	What were the nutrients used for the AdH scour calculations? This appears to be explained on Page 92, Paragraph 1 but is still unclear. What about scour from upper two reservoirs?	Scott	No, nutrients were not in the AdH model	No.
94	Exelon	Main Report	CH. 4/P.91/Sections 4.3.3 & 4.3.4	If the WSM model does use only one node for all three reservoirs how can scour from just Conowingo Pond (AdH) then be added to determine the total outflow from the Pond that is used in the other models? What about scour from the upper two reservoirs?	Cerco	The three reservoirs are not a single node in the watershed model. Each, including Conowingo, is modeled individually. Scour from the upper two lakes is incorporated into the inputs to Conowingo. Only the scour from Conowingo is necessary to be added to the watershed model loads at Conowingo.	No.
95	Exelon	Main Report	CH. 4/P.92/Paragraph 2	Why are the nutrient loads from Conowingo Pond singled out in this paragraph when the larger watershed loads are not mentioned? No details are given on the nutrient content of watershed-derived sediment or Clarke/Aldred-derived sediment.	Cerco	This paragraph describes the process in which the nutrient fraction of sediment scoured from the bottom of Conowingo Reservoir was calculated. Nutrient composition of sediment entering Conowingo reservoir is considered by the WSM and was not altered or utilized directly in this study.	No.
96	Exelon	Main Report	CH. 4/P.92/Paragraph 3	Were these nutrient contents compared to Marietta samples to get an idea of what the 'watershed' makeup may have looked like?	Cerco	We did not find Marietta samples that provided relevant information for comparison with observations at Conowingo.	No.
97	Exelon	Main Report	CH. 4/P.92/Paragraph 2	The report should make explicit that the decision to use the 2011 data, in fact, results in a "worst case" scenario.	Cerco	The text revised to state this: After the sentence "For these reasons …. For LSWRA scenarios." Inserted a sentence "Use of the 2011 nutrient composition provides a worst-case analysis." In the next sentence, strike "Even so" and change to "Consequently".	Yes.
98	Exelon	Main Report	CH. 4/P. 95/Figure 4-9	What is the red CFD curve? This does not appear to be defined anywhere.	Linker	Language added to paragraph below figure to explain: for any modeled result where the exceedance in space and time (shown in Figure 4-9 as the area below the cumulative function distribution (CFD) reference curve, red line) exceeds the allowable exceedance (the area below the blue line that is shaded yellow), that segment is considered in nonattainment (U.S. EPA 2003a).	Yes.
99	Exelon	Main Report	CH. 4/P. 96	Based on the estimates of bioavailable nitrogen and phosphorus quoted here, which could potentially be resuspended and transported into Chesapeake Bay, there is a serious mismatch between the bioavailable fractions of TN and TP contained in the Conowingo Pond sediments and how they are incorporated in the CBEMP model wherein they are assumed to be approximately 85% bioavailable. Given this, it is likely that the CBEMP is over-estimating the release of Conowingo Pond nutrients from the sediment bed once they are deposited into the Bay sediments and therefore the model is over-estimating the change in non-attainment of the DO water quality standard	Cerco	The fractions assigned to G2 (slowly reactive) and G3 (inert) are based on long experience with the Bay model, as applied over the period 1985 – 2005. This interval includes multiple scour events so the assigned fractions are considered representative. Nevertheless, we acknowledge the reactivity of organic matter scoured from the reservoir bottom is an area of uncertainty. There are efforts underway to address this issue and this is a recommendation of the study.	No.
100	Exelon	Main Report	CH. 4/P.97/Paragraph 1	It is unclear how models were linked. It is also unclear what "desktop analyses" were used as model inputs (if any).	Compton	This section is an introduction and is to provide an overview. Details are provided later on in the section. Desktop analyses simply means that an actual model simulation was not run, instead calculations were made by one or more of the modelers. Text added ".... desktop analyses (calculations performed outside of the modeling tools)"	Yes.
101	Exelon	Main Report	CH. 5/P.105/Paragraph 2nd under 5.2.1	One could argue that, with a shallower depth, settling would be more rapid, since particles don't need to travel as far to reach the bottom. However, If you increase bottom shear stress because of increased velocities the likelihood of a particle settling to the bottom decreases.	Scott	Higher velocities in shallower depths will transport more sediment, these higher velocities also increase bed shear and erosion potential. The bulk of sediment passes to the bay during storms, thus scour potential is highest, along with transport of inflowing sediment through the dam. Subsections below indicate when desktop analyses were done, vs. a full model simulation.	No.
102	Exelon	Main Report	CH. 5/P.105/Paragraph 3rd under 5.2.1	The first sentence is not technically correct.	Scott	Transport of sediment size classes all depends on the flow regime, time consolidating, etc.; hence, exactly when scour occurs is unknown. First part of sentence "since the reservoir system is dynamic" was deleted.	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
103	Exelon	Main Report	CH. 5/P.105/Paragraph 3rd under 5.2.1	The first sentence oversimplifies the system processes. Additionally, it is not clear what the difference between being "transported" as silts are, and "suspended" as clays are.	Scott	Clays are generally considered washload, with silts interacting with the bed depending on the flow. Revised text for paragraph 3 in Section 5.2.1 (to replace first sentence). New sentences are: "Generally in a reservoir, sediment transport dynamics are dependent on flow. For lower to moderate flows, sand-sized sediments will tend to deposit, along with the larger, silt-sized fine sediments. Clays are generally considered wash load in that they have the potential to transport through the reservoir as suspended load without interacting with the bed. All sediment sizes have the potential to transport through the dam, provided flow, and resulting turbulence, is high enough to maintain the sediments in suspension."	Yes.
104	Exelon	Main Report	CH. 5/P.105/Paragraph Last	This sentence implies that coarser-grained material (i.e., sand) is not scoured during storms. Suspended sand is part of the storm load measured at Conowingo Dam and deposited in the upper Bay. From Appendix. B, page 26: "Generally, at low flows, clay is the dominant sediment that is scoured. However, the silt fraction increases with increasing flow, along with the sand fraction."	Scott	the thin mixing layer consists of fines that transport at lower flows. Sands do scour at higher flows. The samples collected below the dam reflect this. Low flows are almost all clay, as flow increases, silt and sand increases in the outflow. Added "while frequently" before "leaving behind the coarser, sand-size sediments."	Yes.
105	Exelon	Main Report	CH. 5/P.105/Paragraph 3-4 (Sec. 5.2.1)	There is a shift in focus from transport in general for all three reservoirs (paragraph 3) to just transport within Conowingo Reservoir (paragraph 4). The same condition would be expected in all three reservoirs, not just Conowingo Pond.	Scott	There most certainly is scour in the upper two reservoirs that supply Conowingo. However, without field data to quantify it, it is very uncertain how much of the scour enters Conowingo. More field data measurements are needed below the dams.	No.
106	Exelon	Main Report	CH. 5/P.106/Paragraph 4	Last sentence of paragraph starting with "A close inspection of the LSRWA…" should have the appropriate citation listed.	Scott	This evaluation was done by Steve Scott. Added "performed for this assessment" after "simulation results" --	Yes.
107	Exelon	Main Report	CH. 5/P.106/Paragraph 4	What does "trace" erosion mean? Is it resuspended sediment that is moved within the pond and does not pass the dam? Is it erosion of the thin unconsolidated layer?	Scott	erosion of the mixing layer in the reservoir. Very unconsolidated that mobilizes at low shear rates (.004 psf)	No.
108	Exelon	Main Report	CH. 5/P.106/Paragraph 4 & 5	It is not clear why the report is citing Hirsch, as the study was already assessing the hypotheses Hirsch presented (reservoir settling rates, higher flow velocities, change in scour potential). This section should be clearer about the differences in "scour" as a process and "net scour" throughout the reservoir, as there can be local scour within a reservoir without net scour occurring. Net scour is defined well in page 24 of Appendix C.	Scott	The reservoir can scour with deposition of the scour material occurring in the reservoir. Comparison of the 2008 and 2011 surveys indicate 5 million tons of bed scour, but a portion of that most likely re-deposited in the reservoir and did not transport through the dam. Added sentence to end of paragraph 5 -- "While a reservoir can scour with deposition of material occurring in the reservoir, for this assessment, the main concern was the net scour – that is, the material scoured from the bottom of Conowingo Reservoir and carried over the Conowingo outfall."	Yes.
109	Exelon	Main Report	CH. 5/P.106-107/Paragraph USGS Scour Eqn	The basis for this is unclear. Its reliability is even more unclear particularly because the USGS equation is an empirical representation and simplification of an outcome that is itself uncertain because of uncertainties in upstream loads and processes. However you look at it, another problem is one of potential spurious self-correlation. Bed scour computed in AdH is related to discharge; so discharge occurs as a factor in both "independent" variables in the relationship.	Langland	Agree somewhat with your assessment. This is just a simple relation between MEASURED sediment loads from 2 sites, upstream and downstream of the reservoirs. The difference is most likely due to scour. You did note the error bars around each prediction to account for some of the uncertainty.	No.
110	Exelon	Main Report	CH. 5/P. 106-107	"Calibration" is presented in Figure 5-1. Since the sediment scour load is a also a function of flow as well as solids, an interesting calibration skill comparison would be to compare the solids concentrations computed by AdH to the observed solids data – see figure 12 in Appendix B	Scott	Agree. The information tin Appendix B; that should suffice. Additional information would not add to the LSRWA analyses and conclusions.	No.
111	Exelon	Main Report	CH. 5/P.106&112&121/Last Paragraph & Table 5-4 & Table 5-8	The bathymetric study cited as Gomez and Sullivan (2012) is Appendix F of the Exelon (2012) study in the reference section.	Compton	Yes. Per comment #1 references updated where applicable. References updated as noted to URS and GSE, 2012b.	Yes.

Comment #	Agency	Main Report/ Appendix/A ttachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
112	Exelon	Main Report	CH. 5/P.111/Paragraph 2	This paragraph cites an 'active layer' depth of 2-3 feet. Specific study results that prove this statement should be provided or referenced. Appendix A of the LSRWA does not mention any 'thin unconsolidated mixing layer' as cited, and there is only a single reference to this in Appendix B which states that "[t]he top layer of Conowingo Reservoir sediments consists of a low density unconsolidated layer that may mobilize at lower flows."	Scott	The depth of sediments available for scour was assumed to be 2 - 3 feet in the model. Bed properties were measured in the SEDflume up to one foot of depth. The remaining 2 feet were estimated. Appendix B is the source of this info. Sentence in main report was changed from "The active layer has a depth …" to "For modeling purposes, the active layer is estimated to have a depth…"	Yes.
113	Exelon	Main Report	CH. 5/P.111/Paragraph 4	The USGS website cites the peak flow at Conowingo Dam during T.S. Lee as 778,000 cfs.	Scott	The mean daily flow was about 630,000 cfs. 778,000 is the peak instantaneous discharge. Text added to clarify this.	Yes.
114	Exelon	Main Report	CH. 5/P.111/Paragraph 5	How was the bed scour validation parameter derived? This should be described in the text or the appropriate section of Appendix B should be referenced.	Scott	The methodology for estimating the bed scour transport range for TS lee is well documented in the report (2 to 4 million tons). The change in survey calculations in the appendix indicates 5 million tons of bed scour, of which a percentage stays in the reservoir. For the 2 million-ton AdH estimate (the lower range), approximately 40 percent of the bed scour was estimated to leave the reservoir and 60 percent redepositing when referenced back to the change in survey calculations. For the upper range of AdH bed scour (4 million tons), approximately 80 percent of the bed scour was estimated to leave the reservoir, with 20 percent redepositing. On the average (3 million tons AdH transport), 60 percent of the bed scour leaves the reservoir, with 40 percent redepositing.	No.
115	Exelon	Main Report	CH. 5/P.112/Paragraph 2	It seems strange to jump immediately to describing the increase in scour (67%) between the 1996 and 2011 bathymetries rather than total pass-through increase (10%) that is described later. The 67% increase in scour load comes off as rather alarming until you realize that the 'scour load' is only 9-13% of the total sediment load entering the Bay. This point is not brought up until much later in the report (page 176).	Scott	Added sentence: "Although the scour load change is 67 percent, this scour load is a relatively small percentage (9 to 13 percent) of the total load delivered to the Bay. " as a second sentence to this paragraph; similar change as noted in comment #153.	Yes.
116	Exelon	Main Report	CH. 5/P.112/Table 5-4	The "full" condition bathymetry calculation is not well explained in the main report text. Upon investigation of Appendix A, it appears that the "full" estimation is based on assumption on how many acre-feet of sediment Conowingo Pond can store (146,000 acre-feet). The report does not provide any details regarding how this estimate of 146,000 acre-feet of sediment capacity was derived beyond general statements that recent bathymetry data were considered. Considering how frequently this "full" condition is cited throughout the report and Appendix A/B, more attention should be paid to how this value was arrived at, what assumptions were made and what methods were used to estimate this value.	Langland	The capacity of Conowingo is based upon original surveys from Conowingo Hydroelectric Company. The first estimation of the "full" capacity was made in Reed and Hoffman, 1996, USGS Report 96-4048. Some modifications have been made since that initial estimate based on more recent bathymetry. Additional details added to Appendix A. belong there. In response to comment #5, language was already added to para #1 on page 112.	Yes.
117	Exelon	Main Report	CH. 5/P.116/Paragraph 5	The statement that SAV species in the upper Bay were strongly affected by Hurricane Irene and Tropical Storm Lee is not cited. In addition, the graphs presented on pages 49 and 50 (figure 2-16 and figure 2-17) do not appear to support this statement.	Spaur	Add reference (Gurbisz and Kemp, 2013) to sentence on p. 116 covering this. Change sentence in Section 2.7.2 "Extent of the beds on the flats have varied notably in response to large storm events, with substantial declines occurring following Hurricane Ivan and Tropical Storm Lee (Gurbisz and Kemp, 2013)." to "Extent of the beds on the flats have varied in response to large storm events, with a minor decline occurring following Hurricane Ivan in 2004 but with substantial decline following Tropical Storm Lee in 2011 (Gurbisz and Kemp, 2013)."	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
118	Exelon	Main Report	CH.5/P.117/Figure 5-5	The second panel in this figure indicates that silt deposition buried oyster beds. It's not clear if this is a proven impact, as earlier in the report (page 57), evidence was cited that disproved the 'sediment burial theory' following Tropical Storm Lee and indicated that oyster mortality was likely due to excessive fresh water and low salinities for an extended duration. This is reiterated again on page 138.	Spaur	Second figure shows extent of sediment plume, not extent of substantial sediment deposition. Change sentence "As a result, sediment runoff from Tropical Storm Lee was quite extensive compared to that of Hurricane Sandy, as depicted in Figure 5-6. " to "As a result, sediment runoff from Tropical Storm Lee was quite extensive compared to that of Hurricane Sandy and produced a large sediment plume in Bay waters, as depicted in Figure 5-6. Where sediment transported into the Bay would be deposited is controlled by waves and currents, thus mainstem Bay deep waters and protected headwater tributary settings would likely retain sediment from this storm, whereas higher energy shallow waters of the mainstem Bay would be expected to show negligible deposition (see Section 2.6.1)."	Yes.
119	Exelon	Main Report	CH.5/P.118/Paragraph 1	It's not clear what "Average peak flow" means – is that the peak daily average flow (and if so at what location), or the average of the peak flows measured along the river? Also, the event says there was an ice dam breached "within the reservoir itself" but the specific reservoir (Clarke, Aldred, or Conowingo) was not described. It is our understanding that the ice jam breached in the Safe Harbor impoundment.	Langland	Correct, there is no average peak flow. Replaced "Average" with "The"; peak flow value changed to 908,000 cfs.	Yes.
120	Exelon	Main Report	CH.5/P.118/Paragraph 2	The 1996 event had a larger peak flow at the Conowingo USGS gage than Tropical Storm Lee did, as a result of the ice jam breach.	Langland	Correct, but for daily mean flow it was Lee. Inserted "(for daily mean flow)" after "the second largest recorded flood event"	Yes.
121	Exelon	Main Report	CH.5/P.119/Paragraph 2	Again Conowingo is specifically called out separately, while loads from Safe Harbor and Holtwood are just considered part of the "watershed" loads.	Langland	The design of the study was to model Conowingo since it was believed it had remaining capacity, was largest reservoir, and may have the greatest impact on the upper Bay	No.
122	Exelon	Main Report	CH.5/P.120/Table 5-7	Unclear language: what are scour load predictions are measured? How are these simulated values "measured"? Does this mean simulated values determined at the specified location?	Langland	Values are given flows, the specific location would be over Conowingo Dam. Modify title. Table 5-7 title to be "Scour and Load Predictions for Various Flows in Conowingo Reservoir	No.
123	Exelon	Main Report	CH.5/P.120/Table 5-7	Is there a reason that the AdH results were not used here instead?	Langland	The AdH model could not generate all the data included in Table 5-7.	No.
124	Exelon	Main Report	CH.5/P.122/Paragraph 5	What is the difference between trapping rates under the 2010 TMDL scenario and dynamic equilibrium conditions?	Cerco	We did not find in the text the topic addressed in this comment. There seems to be some confusion here. The 2010 TMDL scenario is a Watershed Model loading scenario. Trapping rates under dynamic equilibrium are computed by ADH. There is no comparison between these two different quantities.	No.
125	Exelon	Main Report	CH.5/P.125/Table 5-9	It would be more useful to the reader to list the absolute amount of nonattainment for each scenario, rather than a differential from other scenarios. It is difficult to 'back-calculate' the absolute nonattainment numbers from the differentials presented because of a lack of significant figures and because the 'baseline' scenario is different for several of the scenarios.	Linker	The critical period of the Chesapeake TMDL is 1993-95, but the year of the Big Melt high flow event on the Susquehanna was 1996, so a 1996-98 3-year period was used to capture the main scour event simulated in the LSRWA report. With the new 1996-98 period, the high flow event is simulated, but the scenario findings of the 1993-95 period are now lost. It is not a worthwhile exercise to compare the TMDL WIP or the 2010 scenarios on the 1996-98 period that is now disconnected to the 1993-95 hydrology and loads that the Chesapeake TMDL was based on. For this reason differential results are used.	No.
126	Exelon	Main Report	CH.5/P.131/Paragraph 3 and after	Further clarification should be provided in regard to how the Bay WQ model was calibrated once various input parameters were changed (i.e. AdH, sediment to nutrient analysis, etc.). In addition, assumptions about refractory vs. labile carbon forms and the reactivity of nutrient inputs should be clearly stated and discussed.	Cerco	The Bay model was not recalibrated for this study. The model framework and model parameters were not changed in any regard from the calibration conducted for the 2010 TMDL study. The model does not require recalibration to address changes in loads which were the only changes implemented for this study. The details on the partitioning of labile and refractory organic material are provided in the WQ model report.	No.
127	Exelon	Main Report	CH.5/P.133/Paragraph 4	Is this 'updated nutrient composition' from Tropical Storm Lee applied to all sediments (i.e., watershed sediments and bed scour sediments) or just bed sediments? If it is applied to just bed sediments, this same nutrient composition should be applied to the scour from Lake Clarke and Lake Aldred as well as Conowingo Pond.	Cerco	The TS Lee composition is applied only to scoured bed sediments. There is no need to apply any adjustment to lake Clarke and Aldred sediments. These loads are incorporated into the loading to Conowingo Reservoir.	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
128	Exelon	Main Report	CH.5	It should be noted (relative to the above comments) that the process parameters were also calibrated based on biochemical data as well (i.e., rates of primary production, community respiration, sediment oxygen demand, nutrient fluxes, etc.), so one would be a little concerned about the model being tuned to watershed loads "only" and how different the process parameterization would be given different loadings.	Cerco	The intent of this comment is not clear. As noted above, the Bay model was not recalibrated for this study. The model framework and model parameters were not changed in any regard from the calibration conducted for the 2010 TMDL study. The model does not require recalibration to address changes in loads which were the only changes implemented for this study.	No.
129	Exelon	Main Report	CH.5/P.137-138/Paragraph 4 (p. 137) and the next page	It is unclear how the LSRWA report reaches apparent conclusions about dynamic equilibrium in this paragraph (on 137).	Cerco	"Dynamic equilibrium" may be a poor choice of words here. Text revised: Change "caused by the dynamic equilibrium state" to "caused by the gradual filling"	Yes.
130	Exelon	Main Report	CH.5/P.139/Paragraph 4	Paragraph focuses on AdH results for Conowingo Pond and purported loss of storage despite prior (and subsequent) text suggesting that changes in sediment transport are not expected to have a big impact on Bay water quality.	Scott	The reservoir is currently in a dynamic equilibrium for which deposition and scour continually occurs without a net change in storage. Sediments will deposit during low flows and scour during periodic storms. The loads from TS Lee did not demonstrate a long-term adverse impact to water quality. There was a short-term impact as would be expected.	No.
131	Exelon	Main Report	CH. 6/P.142/Paragraph 1	Sediment being used as a surrogate for nutrients/water quality: Seems like a better understanding of interaction is needed	Compton/ Spaur	The concerns that served as impetus for study were the release into Bay of sediment and nutrients contained in the dam sediment. Study scope was developed accordingly. P is adsorbed to sediments, and management of P via managing sediments is one of the alternative P management measures that has been looked at for years by Bay Program and others. (This is less the case for N). Concur with the need for better consideration of bioavailability; this is discussed in Section 2.5.1 and is contained in Recommendation #1. Added sentences to first paragraph in Section 6.1: "The reason for this is that nutrients are contained within the dam sediments. A substantial portion of phosphorus delivered to the Bay is adsorbed to sediment. Some nitrogen is also delivered to the Bay with sediments. By virtue of their great volume, the dam sediments contain a great quantity of nutrients. Thus, by managing the dam sediments, one would also be managing the nutrients they contain." and deleted "; thus, in managing sediments, one is also managing nutrients"	Yes.
132	Exelon	Main Report	CH. 6/P.142/Paragraph 2	Goal of management not clearly stated. Stopping all sediment entering Bay is not possible or desirable.	Compton	Comment is vague. The referenced paragraph doesn't mention the word management or goal. There is no place the report that suggests stopping all sediment from entering the Bay. Goal/focus of the management strategies are adequately discussed in paragraphs 1 and 2.	No.
133	Exelon	Main Report	CH. 6/P.142/Paragraph 2	Equating reducing sediment with reducing nutrients. See prior comment.	Compton/ Spaur	See comment response to 131	Yes.
134	Exelon	Main Report	CH. 6/P.148/Paragraph 1	Isn't minimizing deposition (and increasing delivery to Bay) counter to goals?	Compton	Added "during non-storm periods, so as to reduce large influxes of sediment to the Bay" to the end of the first sentence in Section 6.3.	Yes.
135	Exelon	Main Report	CH. 6/P.149/Paragraph all	Post-construction addition of low level outlets is extremely expensive and not feasible.	Balay	Revised text "Furthermore, post-construction addition of low-level outlets would be extremely expensive, and thus, not cost-effective."	Yes.
136	Exelon	Main Report	CH. 6/P.149	Density currents often do not make it all the way to the face of the dam depending on reservoir geometry and distance.	Balay	Add sentence to end of Current Density Venting paragraph on page 149: "However, density currents may not make it all the way downstream to the face of the dam, depending on specific reservoir geometry and distance to the dam structure."	Yes.
137	Exelon	Main Report	CH. 6/P.150/Paragraph 5 (Sec 6.3.4)	Particle size for transport by agitation dredging is unclear. A particle diameter of 0.1 mm (100 um) would be a very fine sand, not fine silt or clay. However, the focus on sediment alone seems misplaced. Need to consider that the grain sizes most likely to be transported are those that are most likely to be enriched in nutrients.	Scott	the analysis used a fine sand size because sediment agitated from the bottom will not re-suspend as individual particles, but aggregates that can easily be larger than sand sized. It was a conservative calculation.	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
138	Exelon	Main Report	CH. 6/P.167-178	None of the evaluated dredging alternatives seem to consider sediment and nutrient (as well as other contaminant) releases during dredging. Such losses generally amount to several percent of all material handled	Compton/ Blama	Loss of sediment during mechanical dredging where material may fall from the bucket; regulations call this de minimis. When dredging is performed by hydraulic cutter head any contaminant attached to the sediment could be released due to the agitation of sediment. This can be calculated by running an elutriate test, however this test was not performed for the level analysis needed at the conceptual/watershed level. When dredging fines versus sand we lose more fines, so if we dredge more fines, we'd lose more material. Conversely, if we dredge more sand, we'd lose less. Language added to the report: When dredging is performed (hydraulically or mechanically) any contaminant attached to the sediment could be released during placement. To predict the release of contaminants elutriate tests can be performed. The standard elutriate test is used to predict the release of contaminants to the water column resulting from open water placement. The modified elutriate test is used to evaluate the release from a confined disposal facility. The results will vary depending on the grain size of the material being dredged. Since the LSRWA was a broad assessment of alternatives, elutriate tests were not performed on the potential dredged material. If specific dredging and placement sites are investigated in the future than it is recommended that	Yes.
139	Exelon	Main Report	CH. 6/P.177/Paragraph 2	Please check the units in this paragraph – it appears g/m^3 and mg/m^3 may be mixed up. Also, the 15% anoxia reduction is a little confusing – is this a reduction in time, space or in time/space as the % nonattainment is calculated?	Cerco	Chlorophyll is often reported as µg/L. This is equivalent to mg/m3. DO is often reported as mg/L. This is equivalent to g/m3. The reduction in anoxia is in a time-space integrated quantity reported as "volume-days." It is the time-space summary of water with DO concentration less than xx. See Appendix C for details.	No.
140	Exelon	Main Report	CH. 6/P.178/Paragraph 2	This paragraph cites reductions in sediment, bed scour, etc. after a 10-year period. What 10-year period is this referring to? Is this the estimate of how long it would take to dredge 31 MCY?	Scott	Yes, that assumes that 3 million tons per year are dredged (30 million tons total). However, you have to consider that 1.5 million tons are estimated to deposit annually, thus the net removal is less. Text revised at end of para 2, page 178 to: "...end of a 10-year period of long-term strategic dredging."	Yes.
141	Exelon	Main Report	CH. 6/P.178/Paragraph 4	The removal efficiency is described here, but this term is not defined.	Scott	Changed "efficiency" to "rate"	Yes.
142	Exelon	Main Report	CH. 6/P.178/Paragraph 7	The goals of the scenarios shouldn't be offhandedly mentioned in the middle of a section like this – they need to be clearly defined in the beginning of a chapter or section.	Compton	No report changes recommended. The text flows smoothly and is logical.	No.
143	Exelon	Main Report	CH. 6/P.182/Paragraph 1	How can one make the statement that nutrient-based mitigation options are more cost-effective when these are not presented or discussed in this report?	Linker	The main report text was modified to make the point more clear "could be more ….:"	Yes.
144	Exelon	Main Report	General Comment	Pertaining to all alternatives – not addressed are the potential environmental impacts as related to: aesthetics, air quality and greenhouse gases, soils, water quality, wetlands, groundwater, surface water, wetlands, floodplains, biological resources, cultural resources, land use, socioeconomic resources, recreation and tourism, utility and transportation infrastructure, public health and safety, and noise. In many cases the environmental impacts associated with a specific alternative may cause more harm than good.	Spaur/ Compton	This paragraph was inserted after last paragraph on page E-4 (before section titled "Future Needs of the Watershed") and after first paragraph on page 182 (before paragraph starting "Table 6-10 is a matrix….). "It should be noted that the LSRWA effort was a watershed assessment and not a detailed investigation of a specific project alternative(s) proposed for implementation. That latter would likely require preparation of a NEPA document. The evaluation of sediment management strategies in the assessment focused on water quality impacts, with some consideration of impacts to SAV. Other environmental and social impacts were only minimally evaluated or not evaluated at all. A full investigation of environmental impacts would be performed in any future, project-specific NEPA effort."	Yes.
145	Exelon	Main Report	CH. 7/P.186/Paragraph 6	The report states "a description of the meeting(s) will be placed here." Does that mean the final report will include a description of the public meeting?	Compton	Yes, it does mean that.	No.
146	Exelon	Main Report	CH. 8/P.187/Paragraph 2	"If a more detailed evaluation of the upper two reservoirs is required in the future, AdH would be the more appropriate model to apply." Given that this is used as the input to AdH to determine Conowingo Pond scour it would seem imperative to do this.	Scott	Detailed analysis of reservoir sediment transport is best performed with a 2D model. Although there was significant uncertainty in this application, improvements in the model through further research at ERDC will provide more capability with less uncertainty.	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
147	Exelon	Main Report	CH. 8/P.187/Paragraph 1-5 (all)	Recommendations for future use of HEC-RAS and AdH are unclear. A new 2-D version of HEC-RAS is now available. However, it is unclear if new sediment transport functionality (if any) would address the most basic limitations of the framework for using HEC-RAS. AdH also has limitations, some of which are beyond the limitation of the present flocculation approach.	Langland/ Scott	More capability is needed in AdH. The ability to simulate dam operations, particle flocculation dynamics and transport, and better sediment bed definition. Chapter 8 is not about future use of the model; it's about ideas for enhancements to those models. The new 2D HEC-RAS model does not have any specific additional sediment transport capability.	No
148	Exelon	Main Report	CH. 8/P.187/Paragraph 1	Agree that AdH may be better model to apply; however, using newer features in HEC-RAS (non-equilibrium transport, multiple channels) and better modeling techniques (using floc sizes instead of grain sizes) would make it more attractive.	Langland/ Scott	HECRAS is a very capable 1D model that is routinely used to determine sediment budgets in reservoirs. However, scour and deposition in reservoirs is a 2D process and should be evaluated in that context.	
149	Exelon	Main Report	CH. 8/P.188/Paragraph 4	Models are run for incongruent periods and hydrologic/sediment transport conditions. The appropriateness of substituting loads from models other than the Bay watershed model (e.g., HEC-RAS and AdH) as inputs to the Bay WQ model needs to be established.	Cerco	The only substitution of loads is to augment the watershed model results with estimated scour during the January 1996 storm. The estimate employs scour calculations from ADH during 2011. Appendix C clearly establishes that the calculated sediment concentration during January 1996 is vastly improved by addition of the scour loads. The Appendix also discusses and describes the result of various estimates of sediment composition on watershed model computed nutrient loads.	No.
150	Exelon	Main Report	CH. 8/P. 188	The CBEMP needs to take into account the reduced bioavailability of scoured Conowingo Pond sediments; present assumption used in CBEMP is that approximately 85% of the PON coming into the Bay over the Conowingo Dam go to G2 and the remaining fraction goes to G3. However, it is likely that the G2 in the Conowingo bed is the reverse approximately 85% G3 and 15% G2. This may have a significant impact on the scenario results and the non-attainment that results – particularly the portion that is ascribed to the Conowingo Pond scour.	Cerco	The fractions assigned to G2 (slowly reactive) and G3 (inert) are based on long experience with the Bay model, as applied over the period 1985 – 2005. This interval includes multiple scour events so the assigned fractions are considered representative. Nevertheless, we acknowledge the reactivity of organic matter scoured from the reservoir bottom is an area of uncertainty. This is a recommendation of the study that is currently being scoped by various agencies.	No.
151	Exelon	Main Report	CH. 9/P.189-190/Finding #1	The important point is to know if the trapping capacity assumed in the TMDL is the same as considered now. Based on reading Langland trapping efficiency data in Appendix T and this LSRWA report they are the same.	Langland	Good news. Thanks	No.
152	Exelon	Main Report	CH. 9/P.190/entire page	This test simply restates assertions made earlier in the report --> consequently, prior comments regarding the appropriateness of model use in the evaluation as well as underlying uncertainties need to be investigated and further considered before such definitive findings can be stated.	Compton	The team/has disclosed all sources of known uncertainties and recommendations to address these which are discussed in various places throughout report package. Findings/conclusions are made in this context and are valid.	No.
153	Exelon	Main Report	CH. 9/P.190/Paragraph 4	The point made on page 176 (that the scour load is only a small fraction of the total load entering the Bay) is not mentioned at all in this findings section – this should be made clear in this summary section.	Compton	Page 190, para 4, revised text: "It should be noted that although the scour load change is 67 percent, this scour load is a relatively small percentage (9 to 13 percent) of the total load delivered to the Bay." after calculation of 67 percent. Similar sentence was added in Chapter 5.	Yes.
154	Exelon	Main Report	CH. 9/P.191/Paragraph 2	Couldn't the amount of time for sediments to settle out increase if there is an increase in velocity due to decrease in depth? The statement may be too strong a statement since the time to settle is a unique combination of gravitational and fluid forces."	Langland/ Scott	No, because water is traveling faster, therefore, potentially, less time spent in reservoir.	No.
155	Exelon	Main Report	CH. 9/P.191/Paragraph 3	Re comparing with Hirsch findings: This is not consistent with the Hirsch report. Appendix B discusses scour that moves sediment around the reservoir and scour that passes the dam. P. 34 of Appendix. B states: "At 150,000 cfs, the maximum velocity in the reservoir is about 1.0 foot per second, with a bed shear less than the critical bed shear stress for erosion from the SEDflume studies (0.004 psf) over much of the reservoir." Also, on p. 34: "The 400,000 cfs event is considered the threshold for mass erosion of the reservoir bed."	Scott	Discharges in Conowingo Reservoir below 400,000 cfs can certainly scour and transport sediment from the surface unconsolidated layer (top centimeter of bed). Flows as low are 200,000 cfs can scour the bed and transport sediment. Mass erosion refers to scour in that penetrates the deeper layers, which occurs at higher flows with higher bed shear stresses (greater than 0.02 psu).	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/Section	Comment	LSRWA Lead	Response	Report Change?
156	Exelon	Main Report	CH. 9/P.191/Paragraph 4	More detail on this trace erosion should be presented in the report, and this statement should cite relevant sections or appendices. As stated in a previous comment, Appendix A did not mention any 'thin unconsolidated mixing layer', and there was only a single reference to this in Appendix B which stated "The top layer of Conowingo Reservoir sediments consists of a low density unconsolidated layer that may mobilize at lower flows."	Scott/ Langland	It occurs, but is not significant as compared to storm flows above 400,000 cfs and was not a focus of this assessment. Recommendations section outlines focus on understanding deposition and scour and flows below 400,000 cfs.	No.
157	Exelon	Main Report	CH. 9/P.191/Last Paragraph	Long term the sediment gradation will coarsen (more and more sand) and compact as less and less volume is scoured, and reservoir should reach more of a quasi-equilibrium	Scott/ Langland	Coarse sediments (sand) are deposited in the upper reaches of the reservoir. Storms move this sand load as either bed load or suspended load to lower reaches. Some of the finer sands pass through the dam, but coarse sands may deposit. As the reservoir fills, and becomes more shallow, fines will tend to transport due to higher velocities, with sands tending to stay within the reservoir.	No.
158	Exelon	Main Report	CH. 9/P.192/Finding #2	It seems strange that this finding is listed second, when finding #3 basically says that watershed sources are much more important than finding #2.	Compton	Findings are not presented in a particular order of importance.	No.
159	Exelon	Main Report	CH. 9/P.192/Finding #2	This finding seems to be misstated. Much of the LSRWA report documents that sediment transported from the river has relatively little impact on Bay water quality. Thus, this finding should be restated to focus on nutrients rather than sediment trapping. With respect to nutrients, most nitrogen is transported in a dissolved form so that trapping of particulates has no impact on nitrogen transport. With respect to phosphorus transport, there is a link between sediment transport, hydraulic conditions (particularly flow rate), and particle retention in the reservoirs. Increasing flow in recent years means that a greater load would be transported (and a smaller percentage trapped) regardless of conditions within the reservoirs. Given that the ultimate source of excess phosphorus is driven by fertilizer application on the land surface and the failure to control it before it enters the river, any finding that purports that infilling within the reservoir surface is the cause of impacts to the Bay appears to misstate the overall assessment. (i.e., the way Finding #2 is stated conflicts with Finding #3)	Compton	Disagree. It is clear from the text underneath the finding that nutrients are the issue see first "checkmark" note.	No.
160	Exelon	Main Report	CH. 9/P.195/Top of page	Key statement - Sediment will continue to the Bay with or without the dams, and contribution from pool scour should be less over time as beds coarsen and compact.	Compton	OK.	No.

LSRWA APPENDIX COMMENTS – JULY 2014

APPENDIX A – SEDIMENT RESERVOIR TRANSPORT SIMULATION OF THREE RESERVOIRS IN THE LOWER SUSQUEHANNA RIVER BASIN, PENNSYLVANIA USING HEC-RAS, 2008-2011

	Comment	Langland Response
GENERAL APPENDIX COMMENTS	To be consistent with the references in the Conowingo Final License Application, the reference to 2011 bathymetric surveys as Gomez and Sullivan (2012) should be referenced as: URS Corporation and Gomez and Sullivan Engineers. 2012. Sediment introduction and transport study (RSP 3.15) (Appendix F). Kennett Square, PA: Exelon Generation, LLC.	Reference updated.
	"Falling Velocity" is used throughout the report when the common scientific and industry term is "fall velocity".	Changed all occurrences of falling to fall
	The model depends on how upstream boundary conditions (BCs), sediment bed properties, and transport processes are represented in order to "calibrate" the model to reproduce measured downstream BCs. With respect to the sediment BC, USGS used a function where upstream TSS = 0.007 $Q^{0.9996}$. For all practical purposes, this is a linear relationship between TSS and Q. Although there is a lot of spread in the data, the maximum concentration reported at any Q is 700 mg/L (with a more general trend around 300 mg/L). Extrapolating the upstream BC function to the high flow of interest leads to TSS = 835 mg/L when Q = 1.2e6 cfs. This extrapolated TSS concentration is just ~15% more than the maximum reported value (and less than 3x more than the general trend value of ~300 mg/L). [If the upstream reservoirs are believed to in dynamic equilibrium (and Holtwood reservoir is very shallow), the increase in TSS concentration is modest given the factor of 2 extrapolation of flow beyond the limit of measurements.] In contrast, the downstream BC was represented using a parabolic function where downstream TSS = 4e-09 Q^2 – 0.0007 Q + 34.313. As before, there is a lot of scatter in the data but it is harder to see on the graph because the y-axis goes to such a high limit that typical values appear compressed. Nevertheless, typical values are on the order of 300 mg/L to ~1000 mg/L (at 600,000 cfs) with a maximum value of 3,000 mg/L (at 600,000 cfs). This may not be a reasonable representation of the downstream BC. Further, the form of this	Suspended-sediment concentration (SSC) was used not TSS, there is a bias difference in lab methods that generate an error when sand is present. The TSS method by using an aliquot taken at the middle of the sample potentially does not capture the heavier sands that have already settled. There are a lot of great discussion points here, linear vs quadratic relations, BC in and out of the reservoirs, maximum "measured" sediment concentrations, sediment recession, etc. It is important to note that the sediment concentrations shown in the sediment rating curves may NOT be the maximum concentrations. This is most likely the case at Marietta when the first (and highest at ~700 mg/L) measurement for the T.S.Lee event was 3 days after the peak. Most likely

	relationship presents a curious situation for several reasons: • the linear term, TSS = -0.0007 Q, is nearly identical in magnitude but opposite in direction to the upstream BC function • the quadratic term, TSS = 4e-09 Q^2, implies that concentration increase geometrically for a linear increase in flow • because the linear term is essentially equal to the upstream load (and opposite in sign), the mass represented quadratic term must be transported off the bed in the model in order for simulated TSS concentrations at the downstream boundary to equal measured values. When extrapolated, the relationship implies that TSS = ~5,000 mg/L when Q = 1.2e6 cfs. Not only is this concentration very high, it is 40% more than the maximum reported concentration of 3,000 mg/L (assuming that this 3,000 mg/L value is representative and not impacted by a sampling or measurement error), ~5x greater than other values measured at 600,000 cfs and ~10x higher than more typical values. There is no basis to determine if this downstream BC TSS relationship is reasonable or appropriate, particularly when extrapolated to 1.2e6 cfs. This situation is further exaggerated because the exponents in the sediment transport capacity/erosion relationships selected for HEC-RAS (1 for Parthenadies, 6/7 for Laursen) are much less than the value of 2 in the downstream BC relationship. This means that the model is forced to scour tremendous amounts of sediment from the reservoir bed to match downstream TSS levels. In short, with this downstream boundary, the model can only compute massive bed erosion and must be set-up so that erodible limits are sufficient to allow massive bed erosion.	this was well after the sediment peak and on the recession side of the sediment hydrograph. This monitoring location is just upstream of the reservoirs. The downstream site reflects the cumulative effect of the Susquehanna River and 3 reservoirs and therefore the sediment rating curve might be expected to be different than a rating curve outside of a reservoir system. The quadratic form of the equation suggests a different source of sediment than the linear upstream. as you mention, scoured bed sediments. This is reflected in the" measured" data at the Conowingo site. I'm not sure how you define "massive bed erosion". The conclusion of the model simulation was the model "UNDER ESTIMATED" the amount of sediment when compared to "measured data" at Conowingo.
	At a minimum, confidence intervals should be established for the upstream and downstream boundary conditions and alternative formulations should be explored for the functional relationships used for both BCs.	Selecting 2 different sediment transport functions for the model was the attempt to place some confidence interval in overall sediment transport from Conowingo.
	There is a link with the SEDFLUME data too (and the AdH report) for cohesive transport. As noted in the AdH report (Section 6.1 of Appendix B), the sampling tube could not penetrate the substrate indicating highly consolidated sediments. The AdH report notes that most of the cores were less than 1 foot in length. However, erodible depths in the HEC-RAS model	I did not collect the SEDFLUME data, but I am aware of some of the difficulties in the collection. Previous cores collected by USGS in 2000 and analyzed by University of

	ranged from 0 feet just downstream of each dam where the bed is composed of gravels, boulders, and bed rock to 20 feet in the deepest sediment accumulation areas. This seems a bit inconsistent.	Maryland, go down much deeper (average of 5 feet, deepest one 11.5 feet) and contain particle size information at incremental levels. In general, particle size becomes courser with depth, but there are many areas with erodible fines at depths greater than 5 feet. Just because the erodible depth is set to 20 feet, that does not mean the model is going to erode down that deep.

Chapter / Section	Page	Paragraph	Comment	Langland Response
Glossary	vi		"Shear" is misspelled as "Sheer" multiple times.	corrected
Glossary	vi		The two-dimensional modeling definition may be applicable to AdH but is not applicable to 2-D models in general.	
1.0 / Introduction	2	last	No references given as to Safe Harbor and Holtwood reaching their capacity to store sediment. Dynamic equilibrium term not used.	corrected
1.0 / Introduction	2	Last sentence	Conowingo should be described as in dynamic equilibrium not equilibrium.	OK
2.0 / Background	4	Bottom of middle one	Fall velocities do not change with water velocity, transport capacities and shear. Statement is incorrect.	Agree removed "due to"
3.0 / Purpose and Scope	5	First	HEC-RAS does not predict daily streamflow as stated. Streamflow is an input parameter to the model.	reworded
4.0 / Model	7	Second	The statement that all 20 particle size classes are required in the model is incorrect.	OK
4.0 / Model	8	First	First sentence states that transport can be computed using the selected sediment transport equation or Krone/Parthenaides. If the selected equation is used, it will extrapolate down to the smaller particle sizes which usually results in too much transport.	Maybe. We never had the problem of too much transport.
4.0 / Model	8	Table	The transport equation should read "Wilcock" not "Wilcox."	OK

4.1.2 / Sediment	11	Figure 6	Here and elsewhere (USGS regression equation) sediment transport curves are developed based on suspended sediment samples. Suspended samples do not capture bed load which is not estimated in the report. In addition there is always part of the water column on the bottom (usually with the highest concentrations) where the sampling device cannot collect data. I did not see any explanation of how the bed load or unmeasured loads were considered, if at all, in the analyses.	On page 24, under model limitations and uncertainty, this issue is addressed.
4.1.2 / Sediment	14	Table 3	The particle size classes <4 mm and <8 mm are not sand. 2 mm is the maximum size for sand.	Good catch
4.2 / Geometry &Hydraulic	17	Last	Gate ratings were developed and used to estimate gate openings. Were daily pool elevations not available so guessing at gage openings would not be necessary? Also, there are no HEC-RAS default values for Manning's n as stated.	The time step was run at less than daily intervals, the daily pool elevations would not provide the data needed for the simulation.
4.2 / Geometry &Hydraulic	17	1	Conowingo only has 53 gates.	OK, changed text.
5.0 / Calibration	18	Top of page	Only flows from two tributaries were included – any estimate of flow percentage missing from ungaged tributaries? Should be able to estimate by comparing outflow from Conowingo with sum of inflows from Marietta and gaged tributaries.	This was an additional exercise completed and included in attachment 1
5.0 / Calibration	18	2nd	N values of 0.3 are not within the range of normally accepted values.	I believe I mentioned the average is 0.034 and the range was to 0.3 for very rough bedrock and boulder. I did not mention anything about normal.
5.0 / Calibration	19	1st	USGS ESTIMATOR model is not described anywhere. It would be useful to include a description of the USGS ESTIMATOR model to eliminate the need to return to the reference.	Added a more descriptive sentence about the model.
5.0 / Calibration	20	1	Is the statement "Interaction, evaluation, and feedback of boundary-condition data provided by the USACE for the 2-D model also aided in model calibration" circular? Should they have been kept separate during calibrations?	They were independently developed then compared as to the magnitudes of results.

5.0 / Calibration	22	1st	The Appendix should recognize the significance of the fact that the model can only accept one non-varying series of cohesive sediment parameters even though the SEDflume data indicated a wide variability in these parameters.	I think all 8 limitations are all significant, not just 1 or 2.
6.0 / Model Uncertainty	23	2	The Appendix should recognize as significant that "project staff were not able to resolve these issues" (with critical shear for mass wasting).	I think all 8 limitations are all significant, not just 1 or 2.
6.0 / Model Uncertainty	24	4	Lots of problems were encountered with appropriate fall velocities for cohesive sediment. As recommended by HEC, the grain size distribution should reflect the flocs rather than discrete grains.	We did not have information about the floc size.
6.0 / Model Uncertainty	24	7	Statement is not exactly true. HEC-RAS solves sediment transport by size class.	With limited capacity
6.0 / Model Uncertainty	24		Missing a paragraph #9 which would point out that the hydrograph is being simulated by a series of steady flow pulses, and sediment transport is assumed at equilibrium for each flow pulse. This is different from true unsteady flow (non-equilibrium transport) models.	May be a little too technical to explain without adding more information on the difference (advantage, disadvantage) between steady and unsteady models
7.0 / Results	25	1	Why is there poor agreement with bathymetry?	Model performance and added "the estimated change"
7.0 / Results	25	Last	Model results are being compared to ESTIMATOR and scour equation results rather than directly to measured data. The model parameters were adjusted and a separate scour model with different parameters was created for the single Tropical Storm Lee event. This does not lend a lot of confidence to model results.	Agree, and one the important findings' of the study, that the HEC-RAS might not be the best choice of a model in this reservoir system
Appendix A-1	35	Table A1	It appears that the results were computed with Log-Pearson Type III distribution. The Appendix should note that this distribution is not always applicable for controlled systems.	I noted the difference might be due to flow regulation.

Attachment A-1	38	2	It is not clear how the Gomez and Sullivan (2012) bathymetry data were used in computing estimated scour loads from the lower Susquehanna River reservoirs for three reasons: 1) the 2011 survey described in Gomez and Sullivan (2012) was limited to Conowingo Reservoir (no bathymetry was collected in Lake Clarke or Lake Aldred); 2) the Gomez and Sullivan (2012) study compared bathymetry data from three years apart (2008-2011) and did not make an assessment of the 2011 flood event's specific contribution; and 3) the Gomez and Sullivan (2012) study calculated that there was net deposition from over the three year period from 2008-2011, not net scour.	Good points. 1 and 2. The GSE bathymetry was not the only data used to develop the equation. As the discussion indicates, the prediction equation is a tool, that allows a "quick" estimate of scour from the reservoir system, not just Conowingo. Based on the regression diagnostics, error bounds are plotted on figure A4. 3. Correct the study did indicate net deposition during the 2008-2011 interval, however that does not imply no scour during the short term T.S. Lee event.
Appendix A-1	38-39	Figure A4	Not clear how scour loads were computed and curve developed, important as used for model calibration. Also based on suspended load measurements only (no bedload).	Scour loads are defined as sediment capable of being lifted from the bed become "SUSPENDED" and transported through the dam. The bed is always moving to some degree, however, this study (and most of Chesapeake Bay Program is concerned with what exits the dam, not necessary how movable is the bed.

Attachment A-1	40	Table A2	Table A2 predicts the amount of scour exiting the Lower Susquehanna River reservoir system by using an equation fit to data from 1993-2011. Yet, 'scour' predictions are made for events as far back as 1936, when the reservoir system likely experienced much different sediment dynamics than it does in modern times. Additionally, it is not clear what criteria were used to estimate the scour load for these events, as the relationship between the two columns does not appear to fit a monotonic relationship.	Good point, I used the estimated trapping efficiency (table later in section) to estimate the scour load for storms previous to 1972.
Attachment A-1	41	Table A3	Do these numbers refer to just Conowingo Reservoir or all three reservoirs? If all three, caption to table should be modified accordingly.	Yes.
Attachment A-1	42	1	As velocity increases and bed shear increase, wouldn't the time for sediments to settle out also increase, not decrease?	NO, velocity increases, lessening the amount of time for sediment to settle out.
Attachment A-1	42	Table A4	There is no explanation given for how the estimated 146,000 acre-feet of sediment storage was calculated. Given that this number was then used to estimate the "full" bathymetry that was then carried throughout the assessment and ties into one of the study's major findings, this value needs to be more thoroughly explained.	Agree, and added some clarifying text.
Attachment A-1	43	Figure A-5	It should be clear that the Tropical Storm Agnes point (red dot) is an estimated point, and was not measured using bathymetric survey data. Also, there needs to be a more thorough explanation on how the other "estimated" points were derived.	Agree and added some clarifying text.

LSRWA APPENDIX COMMENTS – JULY 2014

APPENDIX B – SEDIMENT TRANSPORT CHARACTERISTICS OF CONOWINGO RESERVOIR

	Comment	Scott Response
GENERAL APPENDIX COMMENTS	This Appendix does a much better job of describing the uncertainties associated with the AdH results than the main report does. Specifically page 14, paragraph 2 which states that "Because of these uncertainties the AdH model may potentially over-predict to some degree transport of bed sediment through the dam." These points, for all models, need to be more clearly made and emphasized in the main report.	Main report will add this language.
	Caveat appears in several places that the results only describe sediment transport and do not imply a relationship exists between this and nutrient loads. This caveat should be included in the main report.	Main report will add this language.
	Lots of discussion about erosion threshold and SEDflume data but not much about deposition shear stress threshold. Are these set equal in the model?	Because of uncertainty in flocculation dynamics, there was no minimum depositional shear stress (based on particle fall velocity of individual particles
	The AdH model TSS upstream boundary condition is directly from the USGS HEC-RAS application. As noted in comments on Appendix A, USGS used a function where upstream TSS = 0.007 $Q^{0.9996}$. For all practical purposes, this is a linear relationship between TSS and Q. Although there is a lot of spread in the data, the maximum concentration reported at any Q is 700 mg/L (with a more general trend around 300 mg/L). It would be worth reviewing the basis and functional form for this upstream TSS BC. Uncertainty bounds and confidence limits for this relationship should also be established.	Agree. Perhaps the field data collection effort by Exelon and USGS can provide more data for such as effort.
	The AdH model TSS downstream boundary condition differs from the USGS HEC-RAS application. Whereas the USGS TSS downstream BC fit a parabolic function to the data and did not force the relationship to pass through the maximum point (TSS = 3,000 mg/L at Q = 600,000 cfs), the relationship used for AdH is forced through this maximum value. Consequently, at a flow of 600,000 cfs, AdH is calibrated to yield even more erosion than the USGS model. It would be worth reviewing the basis and functional form for this upstream TSS BC. Uncertainty bounds and confidence limits for this relationship should also be established.	The USGS did not use this linear function. They used actual data. The maximum value of their actual data set was more like 2700 mg/l. The AdH downstream output of TSS was based on both pass through sediment and bed scour contribution. The output of AdH was not forced through any curvefit. The actual measured values of concentration discharged through Conowingo were plotted as an exponential

		function that did pass through the maximum value.
	Boundary conditions should be reviewed to establish defensible ranges/relationships and quantify uncertainties.	Agree.
	SEDFLUME cores only penetrated to ~1 ft or less. In some cases the depth of scour identified in Figure 5 often exceeds 1 ft and can exceed 5-8 ft in several locations. Such model results are extrapolations beyond the range of measurements. Cores for the SEDFLUME could not penetrate sediment so it is likely that the erosion resistance of sediment at depth could be much more than at 1 ft below grade.	I agree. I increased the erosion threshold considerably for these deeper depths (greater than 1 ft) up to 5 – 6 pascals

Chapter / Section	Page	Paragraph	Comment	Scott Response
2 / Background	5	Bottom	"HEC-6 model did better when included coarser sediments." By using only suspended samples you are missing out on coarser particles that might transport as bedload	Agree.
3 / Approach and Goals	8-9		Goals stated more clearly here than in main report. This description should be incorporated into the main report.	Main report will be updated.
4 / Description of Modeling Uncertainties	All		This section does a much better job of describing the uncertainties associated with the AdH results than the main report does. Specifically page 14, paragraph 2 which states that "Because of these uncertainties the AdH model may potentially over-predict to some degree transport of bed sediment through the dam." These points, for all models, need to be more clearly made and emphasized in the main report.	Main report will be updated.
5.1 / Susquehanna River Flows	15	2	While 2008-2011 did have a range of flows, the frequency of the flows is not comparable to the long-term record.	Agree. TS Lee was 13 year return event.
5.2 / HEC-RAS output rating	16	1	USGS model input taken from inflowing suspended load not considering bedload – missing coarser materials?	Agree. Bedload not sampled
5.2 / HEC-RAS Output Rating Curve	16	2	It is not clear what exactly was input into AdH from HEC-RAS – was it an hourly time series of suspended sediment load, or was the flow time series simply correlated to a sediment rating curve that was constructed from data output by HEC-RAS?	HECRAS produced sediment loads for mean daily flows for different size classes. AdH used this for the inflowing sediment rating curve into Conowingo

5.2 / HEC-RAS output rating	17	1	Conservatively high inflowing sediment load assumed and used for all other simulations. This does not appear to have been stressed or explained well in the main report.	The USGS used measured suspended sediment concentration data to create a sediment rating curve into the uppermost reservoir. The output to the AdH model was based on HECRAS output to Conowingo.
5.2 / HEC-RAS output rating	17	1	What is the basis for increasing the HEC-RAS load 10%?	I believe HECRAS underestimated scour load from the upper two reservoirs
6 / Model Validation	22 & 23	2 & 2	One of the data sources used to validate the AdH model was the USGS data collected from the catwalks of Conowingo Dam. This data is not representative of the entire river cross-section. Moreover, if any of this data was collected during Tropical Storm Lee, the data may have been collected when the Station was shut down.	Agree
6 / Model Validation	23	3	What is the output time step of the AdH model?	Varied from 100 to 1000 seconds depending on the flow
6 / Model Validation	23	3	"The properties of the lower two feet were either approximated from the SEDflume results or determined from literature values." It would be useful to have a table of these properties.	I estimated increases in shear stress from literature.
7.1 / General flow and bed shear distribution in Conowingo Reservoir	34	1	Middle of paragraph, sentence starting with "This channel was not included…" and next sentence should include a citation.	Agree.
7.5 / Simulation full bathymetry	42	1	"The USGS provided the remaining storage volume…" Was this from Langland (2009) Figure 12?	No, the USGS estimated the remaining storage volume
7.6 / Discussion	44	1	Based on previous communication with Steve Scott it was indicated that the "consolidated" bulk density was wet bulk density. This is not clearly stated in the Appendix, please confirm.	Yes, it is the bulk (wet) density

7.6 / Discussion	46	2	What inflow load scenario was used where the relative load from Conowingo (versus the overall watershed) was up to 30% of the incoming load?	Inflow scenario was 24 million tons over the four years, 10 million tons from TS Lee
7.6 / Discussion	46	2	Last sentence of paragraph is speculative and goes to the uncertainty of using the HEC-RAS model as the input to the AdH model	Agree
9 / Impact of releases on flats	52	1	What is the age of the NOAA depth charts referenced?	35 edition 12/07 Number 12274
9 / Impact of releases on flats	52+	General	The description of this downstream model has much less detail and is shorter than the sections dealing with the upstream model.	Agree
9 / Impact of releases on flats	53-54	1, Fig. 34	What is the reference for the ratio of roughness with SAV?	The AdH users manual
9.2 / Sediment results	55	1	No description is given of the upstream or downstream boundary conditions. Assuming that the U/S BC is the outflow from the U/S AdH model, but which run? Or were measured SSCs used?	The upstream boundary was an arbitrary flow, not Specific conowingo outflow.
10.1 / Conclusions	57	1 & 3	Reinforces the importance of large less frequent events to sediment movement.	Agree
10.4 / Bypassing	59	1	Any guidance as to how these concentrations would impact wildlife?	Most the sediment released from Conowingo is fine sediments which passes below the flats. Not sure of the wildlife implications

11 / Recommendations to Improve Future Modeling Efforts	60	1	"…the model was not capable of passing sediment through the gates...this limitation impacted how sediment was spatially distributed in the lower reach of Conowingo Reservoir near the dam." How did it impact sediment? Further understanding on the exact impacts and uncertainty associated with this needs to be included in the Appendix and the main report.	Initially, we tried to input dam operations into the model (sequential opening and closing of gates as flood flows passed), however, the sediment transport component of the gate operation did not become operational during the conduct of the study. Opening the gates will affect the distribution of sediment from the powerhouse to the center of the channel, thus impacting sedimentation on the Eastern side of the dam (just upstream).
B-1, 6.0 Discussion & Conclusions	B-1		Using the provided graphs, the 86,000 cfs limit where all flows pass through the powerhouse accounts for about 30% of the annual sediment load. This should be mentioned.	Doesn't that depend on storm frequency? Not sure about that. Maybe "average" annual sediment load.

LSRWA APPENDIX COMMENTS – JULY 2014

APPENDIX C – APPLICATION OF THE CBEMP TO EXAMINE THE IMPACTS OF SEDIMENT SCOUR IN CONOWINGO RESERVOIR ON WATER QUALITY IN THE CHESAPEAKE BAY

GENERAL APPENDIX COMMENTS	Comment	Cerco Response
	The use of metric units when everything else is in English unnecessarily confuses the issue.	

Chapter / Section	Page	Paragraph	Comment	Cerco Response
Chapter 2	13	Table 2-1	How were the values of B and W determined for the analytical model?	The references cited indicate B varies from 500 to 10,000 g m^{-2} d^{-1} (0.006 to 0.12 g m^{-2} s^{-1}). The value employed, 0.019 g m^{-2} s^{-1}, was selected within the reported range so that C exceeds Cin when flow is 11,000 m^{3} s^{-2}, the threshold flow for erosion. Reported values of W range from 10^{0} to 10^{2} m d^{-1}. The value 10^{1} (geometric mean of reported range) was selected. This converts to 1.14 x 10-^{4} m s^{-1}.
Chapter 3	17	1	Although period examined has a range of flows, how representative is the flood frequency during this period with the long-term flood frequency?	The report indicates two erosion events (flow > 11,000 m^{3} s^{-1}) occurred during the ten-year simulation period. These events were in April 1993 and January 1996. Langland's report indicates flows in excess of 400,000 ft^{3} s^{-1} (11,000 m^{3} s^{-1}) have a recurrence interval of five years. Two events in ten years correspond well with the expected recurrence.

Chapter 3	18	2	How was the Conowingo Pond equilibrium condition determined?	The equilibrium bathymetry was determined by the team that modeled Conowingo Reservoir (Mike Langland, Steve Scott, and associates). This question must be answered by that team.
Chapter 3	18	2	The Main Report concludes Conowingo Pond is, at present, in a state of dynamic equilibrium. For example: • Page 10: "This assessment concludes that Conowingo Dam and Reservoir (along with upper two reservoirs) is currently in a dynamic equilibrium state." • Table 1-1: "Dynamic equilibrium reached in the mid-2000's, very limited capacity remaining." Appendix C (page 18) distinguishes between an "existing" bathymetry (2008) and an "equilibrium" bathymetry which "is the bathymetry projected to result when sediment loads in and out of the reservoir are in dynamic equilibrium and no net deposition occurs." However, Appendix D (page 21) says "the 2011 bathymetry is essentially the equilibrium bathymetry." The use of the term "dynamic equilibrium" and dynamic equilibrium conditions do not appear to be used in a consistent manner throughout the Main Report and the appendices.	We have endeavored to be consistent between reports as to the definition of "dynamic equilibrium." We believe the concept is clear despite the potential for differences in wording. Multiple bathymetry sets were employed in this report. The 2011 bathymetry was measured and provided to this study by Exelon. The "equilibrium" bathymetry was estimated by the sediment transport team. Application of the ADH model employing the 2011 and equilibrium bathymetry sets indicate little difference in calculated bottom erosion. Hence the statement "the 2011 bathymetry is essentially the equilibrium bathymetry." They are not literally the same but the calculated erosion from both sets is so close that they are the same for practical purposes.

Chapter 4	23	Entire Chapter	How are the scoured sediment and nutrient loads from Lake Clarke and Lake Aldred accounted for? Is it similar to the process for which Conowingo-scoured sediments (and thus nutrients) are superimposed on the WSM nutrient loads input to the WQM as described in Chapter 4 of Appendix C?	Sediment loads from Lake Clarke and Aldred are not specifically identified in the Chesapeake Bay loads. The Chesapeake Bay model only "sees" loads at the Conowingo outfall. Loads from Clarke and Aldred are combined with other loading sources at this outfall. The only material superimposed on the WSM loads is scour calculated in Conowingo Reservoir.
Chapter 4	23	1	"The loads at the head of the reservoir system are supplemented by inputs from the local watersheds immediately adjacent to the reservoirs." It would be useful if there were a figure depicting this either in the main report of this Appendix (or both).	A figure such as this one might be included in the main report. This doesn't appear to be a critical deficiency.
Chapter 4	26	3	Bullet 5 – "For key scenarios, an alternate set of nutrient loads was constructed based on 1996 observed nutrient fraction." These should be included and discussed in the main report.	The results from these scenarios are reported in the appendix to this report.
Chapter 4	32	Figure 4-1	Assuming that the Calculated eroded particulate nitrogen and phosphorus referenced are from AdH? Please confirm.	No, ADH does not calculate nutrients. The calculated eroded nutrients are based on ADH calculations of eroded sediment and on observed fractions of nutrients associated with sediments.

Chapter 6	48	last	How does this statement impact the LSRWA conclusions? Does it result in a greater modeled impact to the Bay from scour when applying the CBEMP? “The predominant role of net scour loads, reported here, is in contrast to the companion reports to this one (Scott and Sharp, 2013; Langland, 2013) in which scour is assigned a lesser fraction of the total storm loads.”	This report emphasizes the marginal impact of a scour event on Bay water quality. The marginal impact of a scour event depends on the magnitude of the scour event. The magnitudes of the scour events in 1996 and in TS Lee were similar. The ADH computation of scour during TS Lee is 2.64 million metric tons. The scour calculated for 1996 is 2.37 million metric tons. The marginal impact of the scour load is not affected by the watershed load.
Chapter 6	48	last	Why is there such a big difference between this study and the Scott and Sharp estimate of the % scoured sediment load?	The report is explicit on this point. The 1996 and 2011 storm events were fundamentally different. Tropical Storm Lee was a tropical storm event which passed over the lower portion of the Susquehanna Watershed. This portion of the entire watershed contains several sub-watersheds which produce notably high sediment loads. The 1996 flood was generated, in part, by snowmelt which is relatively “clean” with regard to sediment content. Therefore, we expect the ratio of watershed load to scour load to differ for these two events. Please see the report for additional information.

Chapter 6	52	Equilibrium Bathymetry Section	See comment for page 18, paragraph 2.	We believe this section provides an accurate description of model application and conclusions to be drawn from the application. In our response to the earlier comment, we indicated there was little practical difference in scour calculated with the 2011 bathymetry and with the “equilibrium” bathymetry. Here we are indicating there is little detectable difference in Bay response to erosion calculated for 2008 bathymetry and to erosion calculated for equilibrium bathymetry. The implication is that the reservoir was approaching equilibrium as early as 2008.
Chapter 6	53	1	The last sentence may also be interpreted as a quantification of the benefit of Conowingo Dam to the Bay when depositional.	During depositional periods, the retention of nutrients in Conowingo Reservoir is apparently of benefit to the Bay.
Chapter 6	81-82	Figs 6-21/6-22	Can additional figures be generated that show the percentage of additional flux represented by Figs 6-21 and 6-22?	During the first summer (June – August) after the scour event, NH4 release increases by 16.2%, PO4 release increases by 7.8%. At this time, no major addition and re-numbering of figures is possible. We will revise the figure captions to report these statistics.

Chapter7	119	1	"Model results can be reported with extensive precision, consistent with the precision of the computers on which the models are executed. Despite the precision, model results are inherently uncertain for a host of reasons including uncertain inputs, variance in model parameters, and approximations in model representations of prototype processes." This statement and the rest of this section do a much better job of clearly stating the uncertainties associated with models and model results than the main report does. While the main report does generally acknowledge some model limitations/uncertainties it does not do as good of a job as the Appendices in stating how uncertain some of these results may be.	The potential to alter the main report to reflect this section of Appendix C is left to the authors of the main report.
Chapter 7	120	2	While uncertainty due to bioavailability of the nutrients is acknowledged and while the "scoured" refractory nutrients are handled in the same fashion as the other boundary nutrients could an estimate be made of how the scoured nutrients might be different than the current assumption of 86% of refractory PON going to G2 and 14% of refractory PON going to G3 (based on Cerco and Noel, 2004)? We believe that SFM computed G2 and G3 is likely to be the other way around with G3 > G2 for organic matter that has been in the sediment bed for several years, as would be the case between scour events in Conowingo Pond.	The material on the bottom of Conowingo Reservoir has not all been there for several years. Material is deposited continuously, including fresh organic matter from phytoplankton in the reservoir. The fractions assigned to G2 and G3 are based on long experience with the Bay model, as applied over the period 1985 – 2005. This interval includes multiple scour events so the assigned fractions are considered representative. Nevertheless, we acknowledge the reactivity of organic matter scoured from the reservoir bottom is an area of uncertainty. Our understanding is that experiments are planned to address this issue.

Chapter 7	120	3	It is stated that the SEDflume studies reported in Appendix B "indicate erosion does not occur below 9,300 m^3s^{-1} (330,000 cfs)." Please clarify if the author is referring to the beginning of "mass bed erosion" as defined in Appendix B. If so, shouldn't the value be 400,000 cfs?	The commonly accepted threshold for mass erosion is 400,000 cfs. The text will be revised.

LSRWA APPENDIX COMMENTS – JULY 2014

APPENDIX D – ESTIMATED INFLUENCE OF CONOWINGO INFILL ON THE CHESAPEAKE BAY TMDL

Chapter / Section	Page	Paragraph	Comment	Linker Response
Introduction	3	3	The last portion of this paragraph starting with “During the 2017 Midpoint Assessment…” discusses decisions being made regarding any necessary adjustments to the CB TMDL. It should be clearly noted here that Appendix T of the TMDL discusses actions that will be taken in the event that the status of Conowingo Pond changes from previously understood conditions. The language used should be that contained in TMDL Appendix T.	Appendix T is correctly cited, referenced, and characterized in Appendix D. It’s clear from the text what’s directly quoted and what’s paraphrased. The citation and attribution is entirely correct and changes are unwarranted.
Results	11	LSRWA-3	It’s not clear to what magnitude the WSM-calculated Conowingo scour and the LSRWA/AdH-calculated Conowingo scour are “double-counting” the same effect (if at all), since the AdH-calculated scour is superimposed on the WSM sediment/nutrient outputs before being input into the WSM.	Added Text: “See Figure 4-2 of Cerco and Cole, Appendix D (this report) to see the observed and computed suspended solids at the Conowingo outfall during January 1996 for the WSM alone and for the WSM with additional erosion load.”
Results / DO Water Quality Standard Results	13	4	Last sentence of the paragraph starting with “The WIP Scenario…” lists LSRWA-4, we believe this should be LSRWA-3	Good catch. Corrected as suggested.
Results	20	Figure 5	While the differential values are useful, it is helpful for the reader to also list absolute nonattainment values rather than just relative values.	Listing the absolute values for Scenario LSRWA-21 and LSRWA-3 (and explaining why the 1996-1998 period is different from the 1993-1995 period and the reason they’re different , etc., etc. would add confusion, not clarity. Adding absolute nonattainment values is unwarranted.
Results / LSRWA Results: Non-Management Scenarios	21	3 & 4	Why were the points of comparison changed for the June and October events from the comparisons made earlier in the section?	In the seasonal scenarios the comparison is being made among the January, June, and October seasons (or months) and the No Storm Scenario of LSRWA-23 allowed the comparison of the three seasons to be made. In this case we’re looking at the relative difference among the different seasons and the use of LSRWA-23 is appropriate.
Results / LSRWA Results: Non-Management Scenarios	21	1	See comments on Appendix C (page 18) regarding existing bathymetry and equilibrium bathymetry. The use of the term “dynamic equilibrium” and dynamic equilibrium conditions do not appear to be used in a consistent manner throughout the Main Report and the appendices. The Main Report concludes Conowingo Pond is, at present, in a state of dynamic equilibrium. For example: • Page 10: “This assessment concludes that Conowingo Dam and Reservoir (along with upper two reservoirs) is currently in a dynamic equilibrium state.” • Table 1-1: “Dynamic equilibrium reached in the mid-2000s, very limited capacity remaining” Appendix C (page 18) distinguishes between an “existing” bathymetry (2008) and an “equilibrium” bathymetry which “is the bathymetry projected to result when sediment loads in and out of the reservoir are in dynamic equilibrium and no net deposition occurs.” However,	The exact date of the onset of dynamic equilibrium in the Conowingo Reservoir is unknown. But a definitive statement from the LSRWA report is that the Conowingo Reservoir is <u>now</u> in dynamic equilibrium. At some time prior to 2000 it was not. There is no contradiction.

Chapter / Section	Page	Paragraph	Comment	Linker Response
			Appendix D (page 21) says "the 2011 bathymetry is essentially the equilibrium bathymetry."	
Results / LSRWA Results: Non-Management Scenarios	21-22	June/Oct	It would be helpful if the stop-light tables 2a and 2b could be expanded to include the results from the various LSRWA scenarios. It is not clear at all as to whether the scenarios that are run with the nutrients collected with the 1996 scour event are significantly different that those using the 2011 water quality data. For example, for the June event, it is surprising that the non-attainment was reduced from 4% to 2% (a 50% reduction) for the Deep-Channel Attainment for Bay segment CB4MH comparing LSRWA26 vs. LSRWA-24, while no other changes in attainment were found.	Different simulation years (93-95) in table 2a and 2b from 1996-1998 period which contains the January 1996 Big Melt event.
Results / LSRWA Results: Non-Management Scenarios	23	Table 3	1) It would be useful to add a row for each of these columns specifically indicating which years are being analyzed for WQ attainment. 2) The nonattainment's should be listed with more significant figures (e.g., 1.4% nonattainment instead of 1% nonattainment) 3) The absolute nonattainment values (e.g., LSRWA-21 had 19% deep channel DO nonattainment in segment CBMH4) should be listed in addition to the relative nonattainment numbers (e.g., an increase of 1% nonattainment over the Base TMDL Scenario (LSRWA-3))	1) The text on (example page 18 paragraphs 2 and 3) provides sufficient information on when the 1996-1998 simulation period is used in order to simulate the January 1996 storm. 2) A single significant figure is sufficient and is consistent with the level of significance typically reported in the Chesapeake TMDL. 3) Listing both the absolute value and the base value along with the difference between the base scenario is from the base as suggested would be redundant, confusing, and unwieldy.
Results / LSRWA Results: Non-Management Scenarios	23-24	Tables 3-5	Why aren't LSRWA-22, 26, 27 discussed in these tables?	LSRWA-22, 26, and 27 are discussed in the text.
Conclusions	27	1	It is stated that the TMDL simulation period of 1991-2000 "was a condition prior to the current dynamic equilibrium state of sediment infill of the Conowingo Reservoir." However, an agreed timing of the onset of dynamic equilibrium is not clear in this report; nor is the relationship with changes in trapping efficiency. For example, Table 5-6 has the trapping efficiency of Conowingo Reservoir remaining at 55-60% for the time period 1993-2012. But Table 1-1 says dynamic equilibrium was first reached in the mid-2000s. Is this a contradiction?	The exact date of the onset of dynamic equilibrium in the Conowingo Reservoir is unknown. But a definitive statement from the LSRWA report is that the Conowingo Reservoir is now in dynamic equilibrium. At some time prior to 2000 it was not. There is no contradiction.
Conclusions	28	3	Second to last sentence of this paragraph references LSRWA-13. This scenario is not defined earlier in the Appendix.	Thank you for this correction. The text has been corrected to change LSRWA-13 to LSRWA-31.
Conclusions	29	1	"During episodic high flow scour events, large nutrient loads are delivered to Chesapeake Bay." The term "scour events" lead the reader to believe that the scour is responsible for all nutrient loads going to the Bay when in fact the vast majority of the loads originate from watershed sources upstream of Conowingo Pond and the Lower Susquehanna Reservoirs. This comment is true of any reference to "scour events" throughout the main report and appendices.	The scenarios referred to in the conclusion section separated the loads from the watershed and the scoured loads from the Conowingo by the difference between scenarios as described in the results section. The increase in nonattainment in Deep Water and Deep Channel DO (described in the results and discussed in the conclusions) were specifically because of the scoured nutrients from the Conowingo Reservoir.

Chapter / Section	Page	Paragraph	Comment	Linker Response
Conclusions	29	3	The last sentence of this paragraph discusses how the TMDL will account for changes in the trapping capacity of Conowingo Pond as per TMDL Appendix T. When discussing the TMDL and changes in Conowingo Pond trapping capacity throughout this Appendix, and the main report, it is important to always use consistent language from Appendix T in regard to how this will be handled.	Appendix T is correctly cited, referenced, and characterized in Appendix D. It's clear from the text what's directly quoted and what's paraphrased. The citation and attribution is entirely correct and changes are unwarranted.
LSRWA uncertainty			The CBEMP assumes that refractory organic nitrogen coming into the system and depositing to the sediment is 84% G2 and 16% G3 (Cerco and Noel, 2004). However, it is likely that scoured sediments from Conowingo Pond would have the reverse distribution G2 > G3. A model scenario should be constructed to evaluate this condition.	Agreed that the research now underway into the proportions of refectory and labile organics in Conowingo Reservoir sediments is needed in order to be definitive regarding the G2 and G3 fractions in the Conowingo bed.

LSRWA APPENDIX COMMENTS – JULY 2014

APPENDIX E – MGS SUSQUEHANNA FLATS SAMPLING RESULTS

	Comment	Ortt Response
GENERAL APPENDIX COMMENTS	The bathymetric map does not indicate the elevation datum for the contours.	Contour info added.
	The Introduction to the Appendix does not discuss Susquehanna Flats sediment sampling (it only discusses the need for bathymetry of the area) yet the first table in the Appendix is what appears to be a sediment core summary table. There is no information in the Appendix as to the scope of field efforts conducted in the Susquehanna Flats.	Text revised. MGS DID NOT perform any bathymetry for this project. USACE used NOAA for elevations.
	Nowhere in the Appendix is there a report summarizing field efforts (e.g., methodology, discussion, results, etc.) for either the sediment sampling or the bathymetry survey. Based on what is included in the Appendix, a reader would not know anything about how the data was collected, field conditions, etc.	Summary of field efforts (e.g., methodology, discussion, results, etc.) added.

LSRWA APPENDIX COMMENTS – JULY 2014

APPENDIX F – U.S. GEOLOGICAL SURVEY CONOWINGO OUTFLOW SUSPENDED SEDIMENT DATA REPORT

	Comment	Bloomquist Response
GENERAL APPENDIX COMMENTS	Cover letter states "samples were collected along a representative cross-section from the catwalk on Conowingo Dam…" Conowingo Dam catwalk sampling is not representative of the channel cross-section at the dam.	The data transmittal letter dated February 10, 2012, represents an accurate assessment of the relation between catwalk and cross-sectional variability, given the analysis of available historical USGS quality control data.
	A brief report to accompany the data would be useful (in addition to the cover letter provided). The report could highlight the sampling methods used, field conditions, hydrograph, sampling comments/notes, etc. In its current form, the Appendix does not provide the reader with very many details about the sampling event(s).	The data were collected using standard methods for the site as outlined in the QAPP on file with EPA CBPO. Streamflow records for the periods represented by these samples as well as the analytical results themselves are publically available at http://waterdata.usgs.gov. Limited time and funds availability precluded the preparation of a separate report detailing these data.

LSRWA APPENDIX COMMENTS – JULY 2014

APPENDIX G – 2011 EXELON CONOWINGO BATHYMETRY SURVEYS

	Comment
GENERAL APPENDIX COMMENTS	**No Comments**

LSRWA APPENDIX COMMENTS – JULY 2014

APPENDIX H – LITERATURE SEARCH FINDINGS REPORT

	Comment
GENERAL APPENDIX COMMENTS	No comments other than newspaper articles are not good references.

LSRWA APPENDIX COMMENTS – JULY 2014

APPENDIX I – STAKEHOLDER INVOLVEMENT

	Comment
GENERAL APPENDIX COMMENTS	No Comments

LSRWA APPENDIX COMMENTS – JULY 2014

APPENDIX J – PLAN FORMULATION

Chapter / Section	Page	Paragraph	Comment	Lead	Response
Introduction	N/A	1	The introduction does not clearly explain what the reader is viewing in any of the attachments. The introduction should explain how each attachment is used in the LSWRA and the main report.	Compton	Intro's expanded for each attachment.
Attachment J-1	2	2	The implication that sediment plumes as represented by TS Lee in Figure 3 are due to scour from Conowingo Reservoir is incorrect. As noted in the main report, these plumes are predominantly comprised of sediment from the watershed upstream of Conowingo Reservoir.	Michael	Page 2, paragraph 2 – change the last sentence to "The massive plume of sediment that occurred following Tropical Storm Lee extended from the Conowingo Dam past the mouth of the Patuxent River (Figure 3) and originated both from the watershed and from scour behind the dam.", with the majority of the sediment coming from the watershed.
Attachment J-1	4	3	In the text and references (p. 8-9) the affiliations of the personal communications are not clear.	Michael	Page 4, paragraph 3 – change "(Kevin DeBell, Ph.D., personal communication)" to "(Kevin DeBell, Ph.D., U.S. Environmental Protection Agency, Chesapeake Bay Program, personal communication)".
Attachment J-1	4	4	What model run is being referred to in the second sentence?	Michael	Page 4, paragraph 4 – change "The model run" to "Output from the Phase 5.3.2 Watershed Model".
Attachment J-1	5	2	In the text and references (p. 8-9) the affiliations of the personal communications	Michael	Page 5, paragraph 2 – change "(Greg Busch, personal communication)" to

			are not clear.		"(Greg Busch, Maryland Department of the Environment, personal communication)". Change "(John Rhoderick, personal communication)" to (John Rhoderick, Maryland Department of Agriculture, personal communication)". Page 8 – change "Blomquist, J. D. (24 October 2013)" to "Blomquist, J. D., United States Geological Survey (24 October 2013)". Change "Busch, G. C. (26 August 2013)" to "Busch, G. C., Maryland Department of the Environment (24 October 2013)". Change "DeBell, K. M. (9 September 2013) to "DeBell, K. M., United States Environmental Protection Agency, Chesapeake Bay Program (9 September 2013)". Change "Rhoderick, J. (13 September 2013)" to "Rhoderick, J., Maryland Department of Agriculture (13 September 2013)". Page 9 – change "Sweeney, J. D. (31 October 2013)" to "Sweeney, J. D., United States Environmental Protection Agency, Chesapeake Bay Program (31 October 2013)".
Attachment J-2	3 tables		Pertaining to all alternatives – not addressed are the potential environmental impacts associated with each alternative.	Compton	LSRWA effort was a watershed assessment and not a detailed investigation of a specific project

			Environmental resources that could be impacted could include: aesthetics, air quality and greenhouse gases, soils, water quality, wetlands, groundwater, surface water, wetlands, floodplains, biological resources, cultural resources, land use, socioeconomic resources, recreation and tourism, utility and transportation infrastructure, public health and safety, and noise.		alternative(s) proposed for implementation. That latter would require preparation of a NEPA document. The evaluation of sediment management strategies in the assessment focused on water quality impacts, with some consideration of impacts to SAV. Other environmental and social impacts were only minimally evaluated or not evaluated at all. A full investigation of environmental impacts would be performed in any future, project-specific NEPA effort.
Attachment J-4	1	Table	It is not clear what reservoir bathymetry/trapping efficiency means. If it is simply referring to trapping efficiency, then it should be stated as such. The actual trapping efficiencies should be listed as well (e.g., 55%) rather than just a level associated with a time period.	Compton	For scenarios 2-6 the input parameter is actual reservoir bathymetry per AdH. The exception is Scenario 1, which did not use AdH but was the TMDL/WSM only run which considered trapping rates/efficiency of the 1990s (which was around 55%). What is most important is what era is represented in the simulation which is depicted.
Attachment J-4	1,7	Table	It's not clear how nonattainment differentials are be compared between LSRWA-30 and LSRWA-3 (on page 7), since page 1 of this report says that the nonattainment's were calculated for different time periods for the two runs (1993-1995 for LSRWA-3, 1996-1998 for LSRWA-30). Similar comment for LSRWA-4 and LSRWA-18.	Compton	The CBEMP utilizes the 1991-2000 hydrologic period. For the criteria assessment procedure, a 3-year critical period (1993-95) was used as the period for assessing attainment of the water quality standards for several LSRWA model scenarios. The 1993–1995 critical period was chosen based on key environmental factors, principally rainfall and streamflow,

					which influenced attainment of the DO water quality standards for the deep-water and deep-channel habitats (USEPA, 2010a). Since the January 1996 high flow event was outside the 1993-95 critical period, the 1996-98 hydrologic period was used as the assessment period for LSRWA modeling scenarios that included an evaluation of a storm event.
Attachment J-4	1,7,8	Table	The DO nonattainment's should be listed by segment (similar to pieces from the stoplight plots), and must be listed as absolute numbers as opposed to differentials from other runs, as it becomes confusing for the reader to follow which runs are being compared to other runs. Also, the nonattainment's should carry an additional significant figure (e.g., 1.4% instead of 1%).	Compton/Linker	Organizing nonattainment by segment does not work in the format of the table. As comment states Appendix D stoplight plots organizes by segment if reader wants to view it this way. Listing the absolute nonattainment values is unwarranted. Significant figures will remain as we received comments earlier on that that amount of precision was not conducive.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
1	MES	Main Report	ES-2	last sentence of first paragraph. ".....to the Chesapeake Bay due to reservoir deposition within that increased capacity."	Original wording is ok, but I think that with the addition it makes clearer where the deposition is occurring. My addition in red	Compton	Concur. Change made.	Yes.
2	MES	Main Report	ES-2	Third Paragraph, second sentence: Change "from Conowingo" to "within Conowingo"		Compton	Concur. Change made.	Yes.
3	MES	Main Report	ES-2	4th paragraph, (first in Section "Watershed is the principal source of Sediment"); Last sentence, change "Consequently, this percentage of" to "Consequently, the relative proportion of"	A percentage number has not actually been calculated or identified.	Compton	Concur. Change made.	Yes.
4	MES	Main Report	ES-3	3rd complete paragraph; second one in the Section "Nutrients, not Sediment.....: In the sentence "As a consequence, DO in the Bay's deep-water habitat is diminished by reservoir scour events." change "by reservoir scour" to "following reservoir scour."	There is a time lag associated with nutrient delivery, utilization and regeneration, not immediately caused by simple delivery.	Compton	Concur. Change made.	Yes.
5	MES	Main Report	ES-5	Consider putting numbers 1 through 3 on the first three paragraphs.	Clearer relationship to the 3 strategies identified in the last paragraph of the previous page.	Compton	Instead of numbering paragraphs, descriptors from sediment management strategies 1-3 were added in parenthesis to each paragraph to make this clearer.	Yes.
6	MES	Main Report	ES-5	5th paragraph. I'll admit that I didn't check through the main report section for this, but it is not clear to me if the cost range in the first sentence ($5 to $90) is entirely related to physical removal of sediments, or if it also includes cost estimates for reduction of sediment delivery from the watershed. If the latter, the end of the first sentence can simply be changed from ".....yard of sediment removed." to "....yard of sediment reduced or removed."		Compton	Added a new sentence at the end of this paragraph. "Costs for reductions in sediment yield from the watershed were on the order of a one time cost of $1.5-$3.5 billion dollars which is estimated to manage approximately 117,000 cubic yards of sediment annually. "	Yes.
7	MES	Main Report, Chapter 1	8	last sentence 5th paragraph. Change "..chemical contaminants attached to them." to "associated with them."	contaminants may be attached or sorbed to the surface, or chemically attached, or simply present in the pore waters of fine grained sediments. Attached implies that they physically move with the sediments under changing geochemical states.	Compton	Concur. Change made.	Yes.
8	MES	Main Report, Chapter 1	10	last sentence of first paragraph. Change from "This assessment…." to "That assessment…"	This assessment would refer to this ACOE report, while I think you are still referring to the Hirsch effort.	Compton	Referring here to LSRWA effort. "LSRWA" added.	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
9	MES	Main Report, Chapter 2	41	3rd paragraph which begins "However, erosional areas do occur…" should be changed to "However, historic data indicates that long-term erosional areas can occur…."	The MDNR report identified used historic data and there is no actual indication that the erosion or non deposition is occurring in the same areas at the present time. You might also consider adding the sentence "Erosion may or may not be dominant in these areas at the present time."	Compton	Concur. Change made.	Yes.
10	MES	Main Report, Chapter 2	49	Figure 2-16: Title should be …..1984-2013.	data extends beyond 2010	Compton	Concur. Change made.	Yes.
11	MES	Main Report, Chapter 4	95	Figure 4-9. Somewhere in the text there should be an explanation of "CFD", for the curve shown		Compton	Concur language revised in paragraph below figure 4-9. CFD is cumulative distribution function. For any modeled result where the exceedance in space and time (shown in Figure 4-9 as the area below the CFD reference curve, red line) exceeds the allowable exceedance (the area below the blue line that is shaded yellow), that segment is considered in nonattainment (U.S. EPA 2003a). The amount of nonattainment is shown in the figure as the area in white between the red line and the blue line and is displayed in model results as percent of nonattainment for that segment. The amount of nonattainment is reported as a whole number percentage. The CFD reference curve is based on observations of healthy ecosystem habitats for the assessed criterion where those observations exist with a default reference curve used in other areas (See Appendix D for more detail).	Yes.
12	MES	Main Report, Chapter 9	196	4th paragraph, first sentence: "Dredging limited quantities….Conowingo Reservoir cause a…" should be changed to "Dredging limited quantities….reservoir result in…"		Compton	Concur. Change made.	Yes.
13	MES	Main Report, Chapter 9	196	Second to last paragraph which begins "Strategic dredging had…" change the end of the last sentence from "….resulting from Tropical Storm Lee." to "….resulting from a storm with the same flow magnitude of a Tropical Storm Lee."		Compton	Concur. Change made.	Yes.
14	USACE-EN	Executive Summary	ES-1	Last paragraph, 2nd to last sentence, "The evaluations carried out through this assessment demonstrate that Conowingo Dam and Reservoir, as well as upstream Safe Harbor and Holtwood dams and their reservoirs, is no longer trapping sediment and the associated nutrients over the long term." should have the word 'is' changed to the word 'are'!	Grammar	Compton	Concur. Change made.	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
15	USACE-EN	Executive Summary	ES-3	Last sentence has the first mention of dissolved oxygen, suggested adding the abbreviation (DO) after this first mention in the document.	Ease of reading	Compton	Concur. Change made.	Yes.
16	USACE-EN	Executive Summary	ES-5	Bullet 1. what are the Changed conditions we speak of here? Either briefly summarize here the changed conditions or have a callout to a specific section in the documentation.	Reader comprehension	Compton	No change to report made. Exec summary is a brief level. The changed conditions are discussed under the sub heading "Loss of Long-Term Sediment and Associated Nutrient Trapping Capacity" in the exec summary.	No.
17	USACE-EN	Main Report	Page 147	In the last paragraph on this page before table 6-2 why are we only looking at 192 acres in Maryland and over +100,000 acres in other states?		Compton	only a small portion of the Lower Susquehanna river watershed is in Maryland.	No.
18	USACE-EN	Main Report	Page 150	In section 6.3.4… Would agitation dredging negatively affect impellors on the turbines? Should we mention this?		Compton/ Balay	Possibly. But this method has been implemented elsewhere with success. Added following sentence to end of first paragraph on page 151: "Release of sediment through the turbines, in excess of what is transported normally during generation operations at higher streamflows, could cause significant damage."	Yes.
19	USACE-EN	Main Report	Page 151	Is Three Mile Island considered lower or middle?		Compton	Three-Mile Island is in the lower Susquehanna River watershed. It is located about 10 miles south of Harrisburg, PA. This site is in the LSRWA study area and the lower Susquehanna River sub-basin, as defined by USGS, NOAA, and others.	No.
20	USACE-EN	Main Report	Page 167	2nd paragraph, last sentence. The smaller BMPs will also need to be cleaned out and will not continue to reduce/remove sediment indefinitely.		Compton/ Michael	Language added at the end in "(although smaller BMPs will need to be cleaned out and maintained to continue to be effective).	Yes.
21	USACE-EN	Main Report	Page 181	3rd paragraph, talking about smaller BMP's. While it is a slow process in adding BMP's it could be done at a relatively cost effective rate and maintenance cost for the smaller facilities could be borne by local HOA's and not Federal/State interests.		Compton	OK. No language changed in report.	No.
22	USACE-EN			General thought. Right now we are going through the WV project and one of the things we state is that 4 of the top 10 events since 1865 have occurred in the last 20 years. May want to discuss climate change and the potential increase of the frequency of larger storms?	General Comment	Compton	Concur. This concept is discussed. Climate change is discussed in Section 2.2, 5.4, and Chapter 6.	No.
23	LS Riverkeeper	Main	ES-2	10% increase in load? Is this normalized to account for TS Lee, or does it include this?	Saying that there is a loss of trapping capacity because of the anomaly of two scouring events occurring in 2011 seems presumptuous.	Compton/ Scott	This range includes all flows during 2008-2011, which includes extreme events like Tropical Storm Lee as well as lower and moderate flows.	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
24	LS Riverkeeper	Main	ES-3	Sediment settles out before the growth period for SAV?	Wouldn't this depend on the timing of the scour event?	Compton/ Cerco	Seasonality does play a role, which is why text indicates for most conditions examined. The report states accurately the results of the work conducted. We could perform more investigations, including moving the storm around to additional periods of the year. The additional investigations are not feasible at this time. Consequently, the report is limited to accurately stating the results of the investigations performed. Revised language indicates that if a storm events occurs during the SAV growing season some burial and light attenuation impacts could occur causing damage to SAV.	Yes.
25	LS Riverkeeper	Main	ES-5	As most decision-makers will not read this report, do we want to include a list of requested studies for information not obtained from LSRWA in the Executive Summary?	Including additional studies of physical effects of deposition on crabs, spawning areas, and SAV; nutrient cycling;4 effects of larger scouring events at 800,000, 900,000, and 1,000,000 cfs.	Compton	Recommended studies/information needs are laid out in section 9.1 and are not so easy to list out in a simple bulleted form, at least comprehensively. To keep the Exec summary concise we will keep the (4) overall summary statements of recommendations included currently.	No.
26	LS Riverkeeper	Main	P-19	The Susquehanna Flats are a natural feature, similar to any river delta, and that delta has existed for millions of years. Does everyone agree with the sentence- "The shallow character of the flats today is largely a result of anthropogenic sedimentation (Gottschalk, 1945). " ? Wouldn't it be better to be a little more precise by saying "The addition of 5-7 feet of sediment (or whatever number is accurate), giving the flats their shallow character today, is largely a result of anthropogenic sedimentation."?	It would seem that at best it would be a combination of natural and more recent (past 300 years) of anthropogenic impacts.	Spaur	Text changed too "Shallow waters of the Susquehanna River delta in the upper Bay expanded substantially in area following European settlement, and the expansive shallow flats that exist today largely derive from anthropogenic sedimentation (Gottschalk, 1945) (see Section 2.6.3)." Text in report does not get into total thickness or total age of delta - both more complicated topics dealing with Bay evolution and multiple bays over geologic time as sea-level has risen/fallen hundreds of feet).	Yes.
27	LS Riverkeeper	Main	P-34	1st Paragraph- Add the quantities of reductions in N, P, and sediment for context. How much has been reduced. This would also be good to emphasize total reductions from NY and PA's efforts.		Spaur	Add new sentence "With corrections to account for year to year variation in river flows, over the 20 year period from 1990 to 2010 TN loads delivered to the Bay from the Susquehanna River declined by 26%, while TP loads declined by 7%, and sediment loads declined by 17% (Langland et al., 2012)." Also add new reference: "Langland, M., J. Blomquist, D. Moyer, and K. Hyer. 2012. Nutrient and Suspended-Sediment Trends, Loads, and Yields and Development of an Indicator of Streamwater Quality at Nontidal Sites in the Chesapeake Bay Watershed, 1985–2010. U.S. Geological Survey. Scientific Investigations Report 2012–5093. 26 pages."	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
28	LS Riverkeeper	Main	P-55	Is Smith, et al., 2003 referring to the upper bay oyster habitat or is this a generalization? Is the Susquehanna currently experiencing "pre-European settlement conditions"? If so, is that on average? Does that take into account scouring events? During what period were the measurements done to quantify current "pre-European settlement conditions"? Was this a period that included a major scouring event?		Spaur	Smith and others (2003) sentence is a general statement on oysters' capability to survive sedimentation anywhere, it doesn't imply that it's specific to upper Bay. Sentence in earlier paragraph on page notes that oysters are most abundant elsewhere in Bay and nearest bed is ~20 miles from river mouth. In Bay where oysters occur, sedimentation today is occurring at about rate it did prior to pre-European settlement, as was covered in Section 2.6.3. Prior to European settlement, there was no major accumulation of sediment behind dams so nothing comparable to a scouring event of a major storm of today would likely have been produced. However, the nutrient and sediment loads from the watershed delivered during a major storm prior to European settlement would also likely have been vastly less than today. (Interestingly, nutrient loads from storms may have had positive impacts to SAV as indicated by Brush and others studies). So, I don't know that there's any value in attempting to speculate about this. Note that impacts of scouring from storms today is covered later in Section 2.7.4 on pages 56 and 57.	No.
29	LS Riverkeeper	Main	P-58	Improving passage of migratory fish through the dams is a topic of ongoing concern in reservoir relicensing." Should this be hydro-power project relicensing. I have never heard anyone refer to the reservoirs being relicensed.	End of 3rd paragraph	Spaur	Revise last sentence in paragraph 3 as suggested to "Improving passage of migratory fish through the dams is a topic of ongoing concern in relicensing of the Conowingo Dam hydropower project (CBP, 2013)."	Yes.
30	LS Riverkeeper	Main	P-63	Connectiv/ York Energy Center is a natural gas power plant at Peach Bottom, York County utilizing Conowingo Pool as their water source	http://www.keystoneedge.com/innovationnews/yorkenergycenter0616.aspx	Spaur	Add new row entry in last two columns of Conowingo Reservoir in Table 2-8 covering this. Entity: "York Energy Center." Usage: "water source."	Yes.
31	LS Riverkeeper	Main	P-70	Why does the chart say that Conowingo's license in 1980 was an "initial license"?		Compton	Instead of "Initial" chart should say "existing". On August 30, 2012, Exelon filed with FERC an application for a new license for its 573-MW Conowingo Hydroelectric Project, FERC Project No. 405 (Exelon, 2012). The existing license for the project was issued by FERC to Susquehanna Power Company and Philadelphia Electric Power Company on August 14, 1980, for a term ending August 31, 2014.	Yes.
32	LS Riverkeeper	Main	P-70	At, 2025, stating that the TMDL is met seems optimistic for a scientific document. Wouldn't "deadline for meeting TMDL requirements" be more appropriate?		Compton/ Linker	See your point, but will leave as is. Per EPA, the TMDL is mandatory, and is designed to ensure that pollution control measures needed to fully restore the Bay and its tidal rivers are in place by 2025. EPA report is cited.	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
33	LS Riverkeeper	Main	P-75	EPA has specifically refused to state that these changes would apply only to the Susquehanna. They have instead maintained a broad view that it would apply to NY, PA, and MD. If they have changed their position, I would like to see this in writing. Otherwise, this should not be stated this way in the document.	" In practical terms, this means that nutrient and sediment loads from the Pennsylvania, Maryland, and New York portions of the Susquehanna River basin would have to be further reduced to offset the increase in sediment and associated nutrient loads in order to achieve the established TMDL allocations and achieve the states' Chesapeake Bay water quality standards."	Linker/ Batiuk	The discussion of Appendix T (2010) on page 75 is entirely correct and changes are unwarranted.	No.
34	LS Riverkeeper	Main	P-77	I believe Muddy Run is in PA and requires a 401 certification from PADEP, which I believe they already received.		Balay	Last two sentences of final paragraph revised to: On June 3, 2014, PADEP issued a Section 401 Water Quality Certificate (WQC) for the Muddy Run project. On July 30, 2014, FERC issued a draft Environmental Impact Statement (EIS) for the relicensing of the York Haven, Muddy Run, and Conowingo projects. At the writing of this report, a new FERC license for the Muddy Run project is pending."	Yes.
35	LS Riverkeeper	Main	P-91	What is the explanation for why the WSM showed no scouring during the Jan 1996 storm?	"During the course of this LSRWA effort, it was determined that little or no scouring of reservoir bed material was calculated during the January 1996 flood event by the Chesapeake Bay WSM. As a consequence, computed solids concentrations, and potentially particulate nutrient concentrations, were less than observed. "	Cerco	Response added as a footnote: The WSM calculates deposition and scour. These processes are parameterized to improve agreement between computed and observed concentrations at the Conowingo outfall. However, there are no independent observations of deposition and scour. All that can really be calculated is the net difference between the two. The problem of correctly evaluating deposition and scour is acute during the rare erosion events that take place during the WSM application period (through 2002 at initiation of this study). The WSM can perform well for the majority of events but still miss rare and unusual events like the January 1996 storm. Apparently, the calculated scour during this event simply was not adequate.	Yes.
36	LS Riverkeeper	Main	P-96	Further explanation of this would be helpful. How does shifting the date reduce the uncertainty? This is not obvious to the reader and a sentence of explanation would be helpful.	"An additional source of uncertainty was that the January 1996 flow event was a very atypical storm event caused by a unique combination of snow melt and ice jams. This uncertainty was reduced by moving the storm's flows and sediment and associated nutrient loads to different seasons (June, October) to compare the storm's effects on Chesapeake Bay water and habitat quality."	Cerco	Some uncertainty in computed storm effects on Chesapeake Bay would result from considering solely a January storm. Bay response to storms in other seasons might vary. To reduce this uncertainty, the January storm was moved to June and to October. The June storm coincides with the occurrence of the notorious Tropical Storm Agnes, which resulted in the worst recorded incidence of storm damage to the Bay. The October storm corresponds to the occurrence of Tropical Storm Lee and is in the typical period of tropical storm events. This paragraph was added to report.	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
37	LS Riverkeeper	Main	P-105	At what depth of the core sample, and average of over what length of the core sample? For example, 20% in the first 3 feet of the core sample, representing the last 10 years.	"For example, in the lower portion of Conowingo Reservoir in 1990, particle size analysis from sediment cores indicated the area had about 5 percent sand; in 2012, it had 20 percent sand."	Langland	The percentage of sand in the cores is based on the top 2 feet of sediment. The results for 2012 are PROJECTED based on all previous cores. Changed sentence to: "For example, in the lower portion of Conowingo Reservoir in 1990, particle size analysis from 2-foot-deep sediment cores indicated the area had about 5 percent sand; in 2012, it was projected to have 20 percent sand based on all previous cores."	Yes.
38	LS Riverkeeper	Main	P-112	Eventual actual Dynamic Equilibrium must be met at some point, a point where the net deposition is zero, or at least approaches much closer to zero. It is illogical to say that the reservoir will always be at a state of 1 million ton per year deposition rate.	The net deposition for 2011 remains at 1 million tons per year. It is the same for "Full" condition.	Compton/ Scott	Net deposition is what sediment remained in Conowingo Reservoir during the 4-year simulation period as indicated in this chart. With a "full" bathymetry this 4-year simulation showed that on average 1 million tons deposited on average, a year. In dynamic equilibrium, long-term net deposition will be zero however deposition will still occur, until a scour event occurs.	No.
39	LS Riverkeeper	Main	P-113	Why were the increased sediment loads for 500,000 and 600,000 not included? These are important benchmarks.	Table 5-5	Scott	The purpose of this modeling simulation was - 1) there was a need to define the potential increase in scour after equilibrium, 2) 400,000 is the flow at which mass reservoir bed erosion occurs , and 700,000 was the highest flow in the 2008-2011 simulation, and 3) there was also a need to examine impact of scour at "full" condition for flows under 400,000 to see if the model could detect increased loads at flows lower than 400,000 cfs.	No.
40	LS Riverkeeper	Main	P-115	It would be good to include the date of the storm for comparison- October 2012	Hurricane Sandy	Compton	Added months to Sandy, Lee, and Agnes: "They are Hurricane Sandy (October 2012), Tropical Storm Lee (September 2011), the January 1996 "Big Melt," and Tropical Storm Agnes (June 1972). "	Yes.
41	LS Riverkeeper	Main	P-115-118	It would be helpful to include peak average flows in the text for all 4 storms for comparison, as was done for the 1996 storm. Figure 5-7 is helpful, but doesn't come in until after reading the narratives of each storm.		Langland	Peak instantaneous flows added for each event: Page 116, para 1, last sentence: "In addition, its peak discharge over Conowingo Dam in late October 2012 was only 155,000 cfs." Page 116, para 3, after 2nd sentence: "The peak Conowingo discharge during Lee was measured at 778,000 cfs. " Page 118, para 1, 2nd sentence, changed "Average peak flow for this event was 630,000 cfs." to "The instantaneous peak flow for this event was 908,000 cfs." Page 118, para 2, after 4th sentence added: "During the Agnes event, the flow over Conowingo Dam peaked at 1,098,000 cfs. "	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
42	LS Riverkeeper	Main	p-120	What is more important, peak flow or daily mean average, or some combination of the two? An explanation at this point could be helpful to readers.	"This methodology allowed the team to have a more detailed look at one scour event that was recent (Tropical Storm Lee) under various bathymetries (1996, 2008, 2011, and "full"). The AdH model estimated the impact of Tropical Storm Lee (approximately a 700,000-cfs event at peak discharge, with a 630,000-cfs mean daily flow) on the total load passing through the Conowingo Dam."	Scott/ Langland	See Comment 41.	No.
43	LS Riverkeeper	Main	P-121	So what were the scour loads from the upper two dams? When discussing the impacts of scour, are we only talking about Conowingo? It is addressed in the next paragraph, but without giving a total of scour impact. Adding the 4 million tons from the upper 2 reservoirs to the 3 million from Conowingo gives us just under 50% load caused by scouring.	"Regarding the contribution of Conowingo Reservoir bed scour to the total load to the Chesapeake Bay during a storm event, under 2011 bathymetry conditions, the sediment scour load (from the reservoir behind Conowingo Dam) during Tropical Storm Lee comprises about 20 percent of the Tropical Storm Lee total sediment load (about 3.0 million tons of the 14.5 million tons). This includes scour from the upper two reservoirs and loads from the rest of the Susquehanna River watershed."	Langland/ Scott	The first paragraph discuses just Tropical Storm Lee scour and total load, while the second paragraph disuses the entire 2008-2011 modeling scenario time period. The 3 million was increased during the Lee storm period (7 days) to 4 million. They are not additive. So in reality, instead of 3+4 it was 3+1. Last sentence in 2nd paragraph revised to say "....inflowing sediment rating curve for the AdH simulations <u>was increased</u> to ~~assumed~~ a maximum scour potential for the upper two reservoirs during Tropical Storm Lee of approximately 4 million tons.	Yes.
44	LS Riverkeeper	Main	P-121	Does this mean that as we improve watershed sediment control through BMPs and WIP implementation that the water (now carrying less sediment) will have a greater ability to scour reservoir sediment?	"The transport capacity of Conowingo Reservoir during a large flow event is strongly influenced by the sediment load entering into the system. Generally, the higher the inflowing sediment load, the lower the transport capacity and subsequent bed erosion in the reservoir."	Langland	While this statement follows logical concepts, I'm not sure it holds true in the 3 reservoir system. The transport capacity could be maximized in the upper reservoir, drop in the 2nd and regained in Conowingo. Text revised to say "The transport capacity of Conowingo Reservoir during a large flow event is strongly influenced by the sediment load entering into the system which could impact the transport capacity and bed scour and subsequent sediment transport through the reservoirs to the upper Chesapeake Bay.	Yes.
45	LS Riverkeeper	Main	P-122	This sentence makes no sense to me. Long-term storage has maximized. The ability to store more material has been minimized. Does this sentence mean, or should it be replaced with: "The ability to trap additional sediment in the reservoir system is much reduced compared to historical trapping."?	Sediment Transport, Storm Effects, and Scour Summary "Long-term sediment storage in the reservoir system is much reduced compared to historical trapping."	Compton	Yes change made. The dams are not trapping (and storing) as much as they were historically. "Sediment storage" has been replaced with "sediment trapping". This is discussed in numerous places in report but is not discussed explicitly in this summary section.	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
46	LS Riverkeeper	Main	P-133	Could this be explained better? How do the numbers given here as a "first order estimate" compare with the numbers that we are using in state WIP's. For instance, PA needs to reduce TN by over 30 million pounds from the Susquehanna. Where does 4.4 million come from?	"EPA provided a first order estimate of the degree of Susquehanna River watershed nutrient pollutant load reduction needed to avoid estimated increases in DO nonattainment of 1 percent in the deep-water and deep-channel areas; this analysis is described further in Appendix D. A rough estimate of the load reduction needed Bay-wide is about 2,200 tons of TN (4.4 million pounds) and 205 tons of TP (0.41 million pounds) to offset the DO nonattainment in the deep channel and deep water areas. Estimates of the nitrogen and phosphorus pollutant load reductions from the Susquehanna River watershed needed to offset the 1-percent increase in DO nonattainment are about 1,200 tons of nitrogen (2.4 million pounds) and 135 tons of phosphorus (0.27 million pounds)."	Linker	As pointed out in the text, Appendix D provides details on the how the estimates were developed.	No.
47	LS Riverkeeper	Main	P-137	*"For most conditions examined"- I am concerned about this statement, and how it can be used to diminish the actual potential impacts. This research has only addressed January, June, and October. What are the effects of a March, April, May, July, and August storm? According to page 134, light attenuation can last for 90 days. Apply this to the eco-calendar on p. 117, Figure 5-5. What effects can we expect for each of the above monthly scenarios?	CBEMP modeling estimates showed that the sediment load (not including the nutrients that they contain) from Conowingo Reservoir scour events are not the major threat to Bay water quality. For most conditions examined,* sediments from bottom scour settle out of the Bay water column before the period of the year during which light attenuation is critical.	Cerco	The January storm is based on an actual occurrence. The October storm characterizes a storm during the usual tropical storm period. The June event characterizes the highly unusual tropical storm event Agnes. These runs establish principles. Winter storms pass without much effect. Late summer storms are not damaging because most of the SAV growing season is past. Late spring/early summer storms are potentially the worst. We could run an infinite number of occurrences. Each month. Early and late in each month. Each week in each month. The detailed results will change. The general principles won't change.	No.
48	LS Riverkeeper	Main	P-138	Is this a good place to emphasize the actual quantity or load of nitrogen added by scour, instead of using a percent comparison?	"The magnitude of nitrogen scour load has not been emphasized in preceding studies."	Cerco	The exact amount of scoured nitrogen load for numerous conditions is reported in Appendix C. Repeating those numbers is not necessary in a chapter entitled "problem Identification."	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
49	LS Riverkeeper	Main	P-151	While a statement regarding the cost of losing power production with little benefit to the environment is appropriate, the statement of purpose of the dams is irrelevant and improper. The operations of the dam are contingent on making every reasonable effort to reduce environmental impacts. This is equivalent to saying that there is no need to alter operations for fish passage because that is not the primary purpose of the dams. The first two sentences of this paragraph can be removed without impacting the meaning.	"Ultimately, the primary purpose for each of the lower Susquehanna River dams is to provide hydropower."	Compton/ Balay	Concur. Sentences removed.	Yes.
50	LS Riverkeeper	Main	P-161	HarborRock- "Material must be dried" listed twice?		Compton	Concur. Change made. Second mention, deleted.	Yes.
51	LS Riverkeeper	Main	P-171-174	Are the effects related in the table associated with the January 1996 storm occurring in January (Scenario's 8, 12,and 13 specifically)? What are the effects if this storm occurs in June?		Cerco	The scenarios were run for the January storm only. The order of magnitude for the response of DO and chlorophyll to dredging will likely not change for storms in other seasons.	No.
52	LS Riverkeeper	Main	P-180	This is a dangerous argument. The load per acre ratio is high. We have 3 dam reservoirs, an area of approximately 30 square miles delivering/ If you look at Table 6-9 on page 177, TS Lee was 65% of a 4-year load, and scouring was 21% of that. So for the 4 year period 3 facilities, with a 30 square mile footprint, contributed 13.65% of the total 4-year load of a 27,000 square mile watershed. This is a relatively LARGE load, and I believe that is the highest total load and percentage contribution of any facility/facilities in the Bay Watershed. Why is this a dangerous argument? Any BMP that requires annual implementation, taken individually, has little impact on the total load to the Bay. Why plant cover crops on a farm? One season's crop on one farm has little impact. Why spend money annually to manage manure? An argument or comparison of cost effectiveness per ton of sediment or pound of nutrient is valid, just like with all other BMP's. A blanket statement about the percent contribution toward reducing the total load is of definite concern and could be used against WIP implementation.	"Strategic dredging reduces bed sediment scour load. However, it is a relatively small contribution to the overall total sediment load dominated by watershed and upstream dam sources. Dredging limited quantities from depositional areas in the reservoir has a minimal impact on total sediment load transported to the Bay. Large periodic flood flows dominate sediment transport dynamics in Conowingo Reservoir. The amount of sediment passed through the dam during high flows, is significantly higher than the estimated bed scour load; thus, small reductions in bed sediment scour due to dredging operations provide minimal benefits in terms of sediment load reduction to the Bay over time. Strategic dredging had little effect on estimated water quality conditions in the Chesapeake Bay."	Scott/ Langland	The conclusions as stated are valid. Strategic dredging did not show a significant improvement to water quality. Removal of 1MCY while a large amount of material to remove, which is also high expense, is not a large amount in comparison to the total load entering the Bay during storms. Text here is not stating that the scour load is insignificant. It is stating that the amount dredged ends up being insignificant when it comes to improving water quality to the Bay. Carrying this argument further even when dredging/removing a more significant amount (back to 1996 bathymetry) at an even higher expense water quality conditions were still not improved significantly. This feeds into conclusions that the nutrients are the major water quality contributor, while removing, even large volumes of sediment, does not impact or meet water quality goals. What we really need is a comparison of the cost-effectiveness per ton of nutrient removal (phosphorus or nitrogen or both). Which is a recommendation, to develop nutrient focused measures. If we had that, we could assess the value of the BMPs versus direct sediment removal (dredging).	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
53	LS Riverkeeper	Main	P-190	Where did these numbers come from? I can find no significant reductions in phosphorus, let alone 55%. And dissolved inorganic phosphate has increased. See Marietta gauge at http://cbrim.er.usgs.gov/cgi-bin/loads12.p?STAID=1576000+--+SUSQUEHANNA+RIVER+AT+MARIETTA%2C+PA&PCODE=ALL&YEAR=ALL	"Over the past 30 years, due to widespread implementation of regulatory and voluntary nutrient and sediment reduction strategies, nutrient and sediment loads to the lower Susquehanna River are significantly lower than what was delivered in the mid 1980s. Total nitrogen (TN), total phosphorus (TP), and sediment have been reduced by 19, 55, and 37 percent, respectively (http://cbrim.er.usgs.gov/)."	Bryer/Langland	Text revised based on website review. "Flow adjusted contentraions of total nitrogen, total phosphorus, and suspended sediment concentration declined by 30, 40, and 45 percent, respectively, between 1985 and 2012 at Marietta, PA (see (http://cbrim.er.usgs.gov/).	Yes.
54	LS Riverkeeper	Main	P-192	I continue to be concerned about the fact that only June was analyzed for SAV effects, but then broad statements are made as if extensive evaluation was done. Specifically, only one month of the SAV growing season was analyzed, when the season can run from April to September, already in major decline by October. To analyze January, June and October, and then say, "For most conditions examined, sediments from bottom scour settle out of the Bay water column before the period of the year during which light attenuation is critical." is improper. Most conditions examined are 1 during the growing season and two not in the growing season. Of course "most conditions examined", being 2 out of 3 NOT during the growing season, will show little effect. I don't feel this is enough information to completely discount the effect of sediment in Finding #2. I would continue to include sediment in this finding. "Sediment and 'Nutrients associated with sediment scoured from the Conowingo Reservoir cause impacts to the upper Chesapeake Bay ecosystem'." It's OK to continue on that the nutrients are currently of bigger concern.	Finding #2- "Nutrients associated with sediment scoured from the Conowingo Reservoir cause impacts to the upper Chesapeake Bay ecosystem.	Cerco	The report accurately states the results of the investigations conducted. Additional model runs are not feasible at this time, nor are they necessary. The work conducted establishes principles. Winter storms pass without much effect. Late summer storms are not damaging because most of the SAV growing season is past. Late spring/early summer storms are potentially the most damaging. Detailed results from additional runs may differ from those conducted but the established principles will not..	No.
55	LS Riverkeeper	Main	P-193	Should this say "not suitable"?	"Modeling done for this assessment estimated that under current conditions (no WIP implementation), more than half of the deep channel habitat in the Chesapeake Bay is frequently not unsuitable for healthy aquatic life."	Compton	Concur. Yes change made.	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
56	LS Riverkeeper	Main	P-194	This may be what the model says, but continuous scour and deposition, occurring at more frequent intervals and at lower flows, make this unlikely, if not impossible. If this were the case then there would be no scouring of the upper two dam reservoirs.	"So at some point, the bed will either not erode"	Compton/ Scott	This text is specifically talking about scouring at higher flows. There will come a point a high flow event where scouring will no longer occur due: "transport capacity and the ability of the reservoir bed to erode."	No.
57	LS Riverkeeper	Main	P-194	Again, are we only studying Conowingo? When you add the other two dams, scour is nearly 50% of the total load.	"These results imply that the Susquehanna River watershed located above the Conowingo Dam (including the two upstream reservoirs) provided 80 percent of the load during Tropical Storm Lee, with the remaining 20 percent from scoured bed sediment trapped in Conowingo Reservoir behind the dam."	Scott/ Langland	See Response to #43.	No.
58	LS Riverkeeper	Main	P-196	Again, this is a judgment for policy makers. A better approach would be to place the costs on a continuum of costs for BMPs. If it is too expensive, this will show it without making a judgment call. Urban reductions are also expensive. If we go too far with this argument it may be quoted against us in future efforts to gain urban WIP implementation.	"Increasing reservoir sediment storage volume yields minimal, short-lived benefits at high costs. Evaluation of a range of dredging alternatives did not yield any management strategies that could approach fully offsetting sediment and associated nutrient loads from the Conowingo reservoir due to scour events and provide meaningful, long-term Chesapeake Bay water quality benefits. Increasing or recovering sediment storage volume of the reservoirs via dredging or other methods is possible, and in some cases can effectively reduce sediment and associated nutrient scour. But analyses in the study indicate Upper Chesapeake Bay water quality benefits are minimal and short-lived, and the costs are high (Appendices C and J)."	Compton	We do lay out results of costs and impacts/effectiveness in report. However it is beneficial (and expected) for the team to draw conclusions based on the numbers that we see. Conclusions as stated here are supported by numbers presented. This is professional judgment of the team however implementation and meeting goals is ultimately an EPA/State matter.	No.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
59	LS Riverkeeper	Main	P-198	Add-a fourth area to build upon existing knowledge-Run models for storm flows of 800,000, 900,000, and 1,000,000 cfs.	Recommendation #1	Compton/ all modelers	Team has given this quite a bit of thought. We developed a brief paper on running an Agnes sized event. At this time we won't be recommending this. The simple answer is the LSRWA team would have made this run (along with other runs mentioned here) if data was available and existing modeling tools covered this period. However it is believed the reoccurrence of an event like Agnes (size and time of year) would cause severe impacts to the Bay from which it would take decades to recover. Accordingly, it was not believed that modeling to further clarify catastrophic effects would aid in decision-making, and thus it was determined that it was unnecessary to make the additional effort for synthesizing data and/or modifying modeling tools. Based on LSRWA results there is no amount of dredging/in-reservoir management that would reduce the impacts of an Agnes event in any meaningful way. For example during TS Lee modeling showed that the watershed load overwhelms the scour load so that mitigating the lesser scour load does not improve water quality. The case is the same for Agnes as well. Both the watershed and the scour are so immense that removal of sediment in reservoir is high cost and would not improve water quality conditions. In summary, though it would be an interesting exercise the expense needed to construct a model or simulation of Agnes is not	No.
60	LS Riverkeeper	Main	P-198	Add a fifth area to build upon existing knowledge-Determine effects on SAV during flow events applied to all growing season months - March through September.	Recommendation #1	Cerco	There's a large body of literature on this subject. For example Moore et al (1997) "Seasonal pulses of turbidity and their relations to eelgrass survival..." and Gurbisz and Kemp (2014) "Unexpected resurgence of a large submersed plant bed in Chesapeake Bay ..." It's not a priority to add to this body of knowledge. Also, the ability to address effects of flow events with a model are limited. For example, burial and destruction from flood flows are not subject to mass-balance model approaches. It's not worth adding a fifth area to the recommended future investigations. One of the sub-recommendations already mentioned will cover this at least in general terms: "Determine impacts on shallow water habitats from reduced light availability and physical burial in the upper Chesapeake Bay due to delivery of scoured sediment from flood events. "	No.
61	LS Riverkeeper	Main	P-201	First paragraph should say "managers", not mangers.	"The importance of this long term monitoring is that it allows mangers to track and ensure effectiveness of implemented management strategies;"	Compton	Concur. Change made.	Yes.

Comment #	Agency	Main Report/ Appendix/Attachment	Page Number/ Section	Comment	Basis for Comment (if applicable)	Lead	Response	Report Change?
62	LS Riverkeeper	Main	P-201	Recommendation 4-1. A monitoring point at the state border would be advantageous, and may be necessary, to determine load allocations at the 2017 TMDL Mid-Point Assessment.		Langland	The state border is the middle of Conowingo Pond, not very conducive for flow and water-quality sampling. USGS has agreed to a short-term project where water-quality sampling and flow is being measures at Marietta, and Holtwood and Conowingo Dams.	No.

LSRWA-An Agnes sized event modeling scenario.
August 2014

This paper was developed with input from Carl Cerco (ERDC), Steve Scott (ERDC), Mike Langland (USGS), and Lewis Linker (EPA-CBP).

A. Background

For the LSRWA effort the team did not conduct a modeling scenario evaluating a Tropical Storm Agnes sized event. It was briefly discussed during scoping of the LSRWA effort but dismissed due to high cost, study time frame and lack of available data for a run like this.

Agnes occurred in June 1972 and has the highest recorded flows, highest scouring loads and is considered to have had the worst observed environmental impacts of all storms in Chesapeake Bay.

The LSRWA has received the comment that we should have conducted a modeling run of an Agnes sized event and impacts. The underlying concern is that this is really the worst case scenario and that we should know what this means to the Bay/reservoir system in its current state.

The simple answer is the LSRWA team would have made this run if data was available and existing modeling tools covered this period. However it is believed the reoccurrence of an event like Agnes (size and time of year) would cause severe impacts to the Bay from which it would take decades to recover. Accordingly, it was not believed that modeling to further clarify catastrophic effects would aid in decision-making, and thus it was determined that it was unnecessary to make the additional effort for synthesizing data and/or modifying modeling tools.

Based on LSRWA results there is no amount of dredging/in-reservoir management that would reduce the impacts of an Agnes event in any meaningful way. For example during TS Lee modeling showed that the watershed load overwhelms the scour load so that mitigating the lesser scour load does not improve water quality. The case is the same for Agnes as well. Both the watershed and the scour are so immense that removal of sediment in reservoir is high cost and would not improve water quality conditions.

In summary, though it would be an interesting exercise the expense needed to construct a model or simulation of Agnes is not conducive, since the simulations would still have high uncertainty and it would not provide additional management insight.

Below is a discussion on additional effort and various options to conduct an Agnes sized modeling scenario.

B. Agnes- sized event critical data gaps.

1. Reservoir bathymetry data is critical as data input for the 2D AdH model.

Reservoir bathymetry data for all three reservoirs both before and after Agnes does not exist in digital form to be readily used by existing computer models. Hand drawn maps may exist but this would require further investigation to confirm. USGS started collecting bathymetry data in 1990 in a digitized form (since 1990 there were four bathymetries conducted by USGS in all three reservoirs). Exelon would need to be contacted (Philadelphia Electric Company was the owner back in the1970's) and see if they have any records. Best case is that they would have hand drawn maps.

2. Data on flow and sediment entering and exiting the Reservoir system during a storm is critical as data input into HEC-RAS and 2D AdH models.

During Agnes there was no sampling at Conowingo Dam or Marietta (coordinated network water-quality monitoring really did not begin until the late 1970’s). Only Harrisburg has some record. Estimates of total load (30 M tons) and scour (20 M tons) were made by estimates of sediment thickness in the Upper Bay by Johns Hopkins University. There were supposed to be follow up studies, but these have not been located. The estimates were vague at best and based upon a previous study that reported yields based on land use types in the Susquehanna basin. The John’s Hopkins University estimate took sediment yields and multiplied by drainage area which was then compared to loads from the Susquehanna River Basin.

Also there was a conflict between the sediment load estimates based on yields and those based on limited cores in the Bay. The 20 M tons scour estimate is likely not reasonable for two reasons. First, at some point the river will reach sediment transport capacity and lose the ability to scour and second, bed and critical shear thresholds would limit the depth (and therefore the amount that can be scoured).

3. They hydrology of the time period that Agnes occurred in would need to be constructed for modeling.

The Chesapeake Bay Environmental Modeling Package (CBEMP) is based on a 1991-2000 hydrologic period which is not the time period that Agnes occurred. CBEMP was utilized to evaluate impacts to Chesapeake Bay from loads from the watershed and scour. This data would need to be built into the model and as discussed in #2 watershed loads and scour loads from this time period is lacking.

To make an appropriate simulation the CBEMP model require hourly rainfall though-out the Chesapeake Watershed in June 1972 to get the precipitation amount, intensity, and timing as well as land use. In reality we will never simulate anything close to Agnes, as this data is not available. All that can be done is to scale the Big Melt (1996 event) in the CH3D & Bay Model to Agnes like flows and estimate Agnes like loads. This alternate approach is discussed in Section D.

C. Agnes sized event scope (similar to LSRWA modeling scenarios).

1. A 2D AdH modeling grid for this simulation would need to be developed. As discussed earlier we don't know what the bathymetry was for this storm, so an estimate would need to be generated, and then mapped to the current modeling mesh.

2. All available sediment samples (concentrations and particle size) would need to be collected from this period.

3. Estimates could be made of the river transport (rating curves, land use yields, etc). It would be difficult to provide the data in a way that could be utilized by CBEMP.

4. Erosion characteristics with depth would be required which would require 6 ft vibracores in numerous locations. The SedFlume work alone for this is estimated to be 200k.

5. The total incoming load into Conowingo would need to be estimated.

6. Dam operations would need to be included in the model also, along with better methods for estimating particle flocculation.

The current AdH model does lack full dam operations capability and needs a more sophisticated method of accounting for particle flocculation. We would expect a more significant scour depth with the higher flows associated with an Agnes sized event, thus the 6 ft vibracores depths. Twice the amount of sediment could be potentially entering Conowingo, thus understanding the flocculation and fate of sediment would be a higher priority than for lower flow events like TS Lee. Although the current modeling has limitations, these limitations would be even more magnified for an Agnes event.

The field work, model development, boundary condition development, and model improvement, testing, and validation would probably have a cost of perhaps $400k. This would be for AdH/HEC-RAS component and does not include CBEMP component.

If this could be done, it would represent the most severe environmental effects (based on time and year and magnitude of flow, sediments, and associated nutrients). It has the potential for providing a range of conditions, but would be highly subjective based on the uncertainty of the input data.

D. Alternate-Agnes sized event scope

An alternate estimate approach would be to scale an existing storm to the Agnes level of flow and loads. For example in the LSRWA effort we moved the January 1996 event to June and October. There is potential to scale a recent event to an Agnes level storm. It would be a very first cut estimate. But as discussed previously the amount of data we have does not really support a very specific representation of Agnes.

For this alternate approach new field work and additional AdH simulations would not be required. A good rough estimate for an Agnes simulation would be our best estimate of total load leaving Conowingo which would be a combination of scour from the reservoir plus pass through load from upstream.

Below is one example of a calculation for estimating total loads and scour load for an Agnes event.

Estimate of Total load to the Bay from Conowingo Reservoir over a four year period that includes an Agnes Event.

1. The difference in recent Conowingo bathymetry surveys (2008 – 2011) indicated after the four years (and the Lee event) 8.8 million tons were deposited and 5.6 million tons were scoured (The TS Lee event data were taken from the comparison of surveys which is Appendix B of LSRWA report).

2. Assume 30 percent of bed scour stays in the reservoir, so scour load that leaves is 5.6 - (.3 * 5.6) = 3.9 million tons.

3. For the TS Lee event, assume 14 million tons (upper range) enter Conowingo. Load out = 14 + 3.9 - 8.8 = 9.1 million tons. 65% of total load passes to Bay.

4. For the TS Lee event, assume 10 million tons (lower range) enters Conowingo. Load out = 10 + 3.9 - 8.8 = 5.1 million tons. 51% of total load passes to Bay.

Estimate of Scour load to the Bay from Conowingo Reservoir during the Hurricane Agnes Event

1. Agnes has an estimated bed scour of 13.5 million tons (this estimate is based on USGS scour estimates and literature estimates which implies that this is the bed scour load that passes to the bay). Assume the total inflowing load during event is 20 million tons (lower range). Now the estimated total deposition is scaled by a factor of 2 (20 / 10), and is now 8.8 *2 or 17.6 million tons. Total Load out to Bay= 20+13.5-17.6 = 15.9 or 80 percent of total the load entering Conowingo during Agnes.

2. Now assume a total inflow load of 25 million tons (upper range), with total deposition scaled by 25/14 which is a scaling factor of 1.78. The mass balance is now 25 + 13.5 – 15.6 = 22.9 or 91 percent of the load inflowing load.

In summary, if you know the sediment load coming into Conowingo for the Agnes event, approximately 85 percent of it can be considered to be the total load passes to the bay. This would include both watershed load and bed scour. For example, if someone were to estimate the total load coming into Conowingo during Agnes to be 22 million tons, the load expected to pass through Conowingo would be 0.85 *22 million or 18.7 million tons. This is approximately twice the load that TS Lee passed considering the upper range of inflowing load (14 million tons).

Based on this total amount, a sediment rating curve can be developed using the hydrograph for Agnes, and the USGS data on sediment concentration measurements up to 700,000 cfs (TS Lee). This hydrograph can then be passed to CBEMP.

This method is a very rough approximating based on assumptions that the deposition will linearly increase from the Tropical Storm Lee event to the Agnes Event, and the estimation of scour for the Agnes event. The higher velocities and associated bed shear from Agnes may decrease sedimentation, thus increasing the load passed to the bay (greater than 85%). Additionally, a more accurate estimation of total load entering Conowingo for the Agnes event will potentially change the percentage of load discharged to the bay.

A CBEMP (CH3D) run and a couple of water quality runs with various hypothetical sediment management activities could be conducted. A rough estimate for this run would be $100K.

Attachment I-8:
Public Comments and Responses

Attachment I-8: Public Comments and Responses
Table of Contents

Explanation of Public Comments and Response Organization

This attachment contains public comments that were received on the Lower Susquehanna River Watershed Assessment, October 2014 draft. The public comment period ran from November 13, 2014, to January 9, 2015. Each comment was input into a comment-response matrix. Responses to every comment that was received are provided in the comment-response matrix. Also in this attachment, following the comment-response matrix, are copies of the original comments as submitted by individuals or organizations.

The table below shows the coding system used for the comments. Codes were necessary to identify the commenter without compromising the privacy of individual members of the public, during the compilation of the responses. The text in parentheses in the "commenter code" column shows the location in the October 2014 draft referenced by the comment. Some comments are general comments, while others refer to the main document text or text within the appendices. For example, comment Ex-1 and DR-1 are comments on the main report, whereas comment Ex-A-1 or comment A-1 are comments on Appendix A. If there is any confusion over the location referenced by the comment in the comment response matrix, please see the original copy of the comment at the end of this attachment.

Comment Codes: LSRWA Public Comments

Commenter	Format Received	Commenter Code (comment location in report)
Public Individuals		
Public (from 12/9/14 public meeting)	Comment card at public meeting	P.1-P.38 (general)
Public (from 12/9/14 public meeting	Web question at public meeting	W.1-W.9 (general)
Individual	Email	E.7 (general)
Individual	Email	E.1 (general)
Individual	Email	E.2 (general)
Individual	Email	E.4 (general)
Individual	Email	E.5.# (general)
Organizations		
Chesapeake Bay Foundation	Email	E.6.# (general)
Soil and Water Conservation Society	Email	E.8.# (general)
State Water Quality Advisory Committee	Email	E.10 (general)
Support Conowingo Dam	Hand delivered petition (11,500+ signatures)	E.3 (general)

Commenter	Format Received	Commenter Code (comment location in report)
U.S. Fish and Wildlife Service	Mail	E.11 (general)
Clean Chesapeake Coalition	Email	CCC-L-# (general, from transmittal letter text) CCC-# (general, from enclosure introduction) DR-# (main report) A-# (Appendix A) B-# (Appendix B) C-# (Appendix C) D-# (Appendix D) E-# (Appendix E) F-# (Appendix F) G-# (Appendix G) H-# (Appendix H) I-6-# (Appendix I, Attachment I-6) I-7-# (Appendix I, Attachment I-7) J# (Appendix J and attachments) K# (Appendix K) Mtg-# (Public Meeting 12/9/14)
Exelon Corporation	Email	Ex-# (main report) Ex-A-# (Appendix A) Ex-B-# (Appendix B) Ex-C-# (Appendix C) Ex-D-# (Appendix D) Ex-E-# (Appendix E) Ex-F-# (Appendix F) Ex-I-# (Appendix I) Ex-J-# (Appendix J) Ex-K-# (Appendix K)

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
P.1	The report asserts the nutrients associated with sediments have more of an adverse impact than the sediments themselves and that there may be more cost effective means than restoring the Conowingo storage volume to prevent these nutrients from reaching the Bay. Did the study quantify the nutrient offsets required and identify options and costs for achieving these offsets?	The assessment did not specifically quantify nutrient offsets. The assessment recommends additional modeling, monitoring, and evaluation of management options to determine nutrient offsets. It is recommended that this information be integrated into analyses for the 2017 TMDL midpoint assessment.
P.2	Once the WIPs are in place and fully effective, now many tons per year of nitrogen and phosphorus associated with the sediments are needed to offset the dynamic equilibrium state?	The assessment did not specifically quantify nutrient offsets. The assessment recommends additional modeling, monitoring, and evaluation of management options to determine nutrient offsets. It is recommended that this information be integrated into analyses for the 2017 TMDL midpoint assessment.
P.3	Besides evaluating the impact of sedimentation on the indicators of dissolved oxygen, light attenuation and chlorophyll concentrations, did the study identify the environmental and cost benefits that a reduced sedimentation rate would have on other parameters such as dredging the shipping channels, restoring the oyster population, and sustaining recreational activities?	No. A direct relationship between material that passes the dam versus what ends up in the channels has not been determined. The material that deposits in the channel is mostly from the Bay bottom nearby, but it is obvious that storms generate sediment. It should be noted that maintenance dredging the channels is much more economical than dredging the reservoirs. Impacts of sedimentation on oysters or recreation from chronic or ongoing sedimentation are not specifically accounted for in the models used during this study.
P.4	What are the panel's thoughts that the draft report is already influencing some Maryland politicians and policy makes to make the case of why should their jurisdictions be required to control nonpoint source sediments and nutrients since they won't be controlled beyond the WIPs in place form the very large areas of New York and Pennsylvania?	The panel concurred that the best available science should be used to determine where and how much nutrients and sediments should be addressed by the states/jurisdictions. The assessment produced numerous products that are now available to assist in future watershed planning efforts. Furthermore, the LSRWA identified critical data needs that resulted in additional monitoring efforts to fill data gaps and better inform this decision-making. The report recommends that U.S. EPA and their seven Chesapeake Bay watershed jurisdictional partners integrate these into their ongoing analyses and development of their Phase 3 watershed implementation plans as part of the Chesapeake Bay TMDL 2017 midpoint assessment.
P.5	The Susquehanna River Basin Commission has studied the sediments from the floor of the Conowingo Pond and reported to MDE (the Maryland Department of the Environment) that such sediments contain PCBs (polychlorinated biphenlys), pesticides and herbicides, phosphorus and nitrogen, and acid mine drainage (AMD) that contained sulfides. Does the Draft LSRWA take into account the impact of such components of scored sediments on the aquatic life in the Bay? If so, how does the report account for the impact of such components on the aquatic life in the Bay? If not, why were such impacts not considered? Does the Draft LKSRWA take into account the impact of such components of scored sediments on the SAV (submerged aquatic vegetation) in the Bay? If so, how does the report account for the impact of such components on the SAV in the Bay? If not, why were such impacts not considered?	Studies do indicate that contaminants other than nutrients may be attached to sediments behind the dams. However, the assessment focused on the nutrients associated with sediments and did not evaluate other potential contaminants. Chapter 5.4.3 briefly discusses heavy metals found in sediment cores with regards to the beneficial reuse of dredged sediments. Additional study is needed on other potential contaminants and on the biologic availability of these contaminants, including nutrients, as they are released from sediments.

Comment Code	Comment	Comment Response
P.6	USGS reports that a flow event greater than or equal to 800 cfs (cubic feet per second) will occur once every 25 years and the last time such a flow event occurred was in 2011 (Tropical Storm Lee). Appendix A at page 41; Draft LSRWA Report page 71. USGS estimates that the scour from the floor of the Conowingo Pond during such a flow event is between 4 and 20 million tons of sediment. Exelon has requested a 46 year permit from FERC (the Federal Energy Regulatory Commission), so such a storm event is predicted to occur twice during the life of the renewal period. Why does the Draft LSRWA not take into account the scour that will occur during such a storm event? What accounts for the large range or predicted scour? What impact will such a scour event have on fisheries habitat and which fisheries would be impacted? What impact will such a scour event have on SAV habitat and how was such impact determined?	The models did evaluate scour from high flow events, including modeling scenarios for Tropical Storm Lee and the January 1996 high flow event. Appendix C discusses these model simulations in detail, including the impacts of scour events on water quality (light attenuation, chlorophyll and dissolved oxygen) and aquatic life. Impacts to aquatic life, including SAV, are also discussed in Chapter 4. Chapters 4.2.1, 4.2.2, and Table 4-7 discuss the range of scour for different flow events. Appendices A-1 and B detail the computations for predicted scour and sediment load. The ranges in scour and estimates of total loads transported out the reservoir system allow for differences in season, total volume of potential scour flow, and errors in the estimates.
P.7	USGS reports that a flow event greater than or equal to 1 million cfs (cubic feet per second) will occur once every 60 years and the last time such a flow event occurred was in 1972 (Hurricane Agnes). Appendix A at page 41. USGS estimates that the scour from the floor of the Conowingo Pond during such a flow event is between 10 and 31 million tons of sediment. Exelon has requested a 46 year permit from FERC (the Federal Energy Regulatory Commission), so such a storm event is predicted to occur during the life of the renewal period. Why does the Draft LSRWA not take into account the scour that will occur during such a storm event? What accounts for the large range or predicted scour? What impact will such a scour event have on fisheries habitat and which fisheries would be impacted? What impact will such a scour event have on SAV habitat and how was such impact determined?	See response to comments W.1 and P.6. See response to comment CCC-L-7 for a description of the effects of Tropical Storm Lee on SAV in the upper Bay.
P.8	Does the Draft LSRWA account for sediments that are scoured from the floor of Lake Aldred and Lake Clark during storm events and already are in suspension in the river when it flows into the Conowingo Pond? If so, how does the Draft LSRWA account for such scoured sediments and what appendix references the data used to determine the quantity of such scour and how such scour varies with the rate of flow across those lakes during storm events?	Yes, the assessment does account for sediment scoured from the floors of Lake Aldred and Lake Clarke which are in suspension when the flow reaches Conowingo Pond. Appendix A discusses the 1-D USGS model used to simulate transport through these three reservoirs. Streamflow and sediment boundary-condition data were developed using this model. This information was used to develop a 2-D model (described in Appendix B) to predict scour and deposition zones, sediment transport, and scenario development for the Conowingo Reservoir and upper Chesapeake Bay.
P.9	How if at all do the models used in the Draft LSRWA predict scour from the floors of the Conowingo Pond, Lake Aldred, and Lake Clark and account for scour that occurs from the circular flow and agitation that occurs when storm surges hit the Conowingo, Holtwood and Safe Harbor Dams and are turned back. How many cfs (cubic feet per second) can flow through the sluiceway at each dam? How many cfs can flow through each gate at each dam? How many gates are at each dam? During what storm events has water flowed over each dam?	See response to comment P.8. The 2D models account for motion in the vertical and horizontal direction and for the physics of the reservoir bed; therefore, circular flow and agitation are considered. Erosion rates of bottom sediments from Conowingo Reservoir were also evaluated using sediment cores eroded in a flume (Appendix B-2). Some information on Conowingo Dam is provided in Table 1-1. Specific information on the dam can be found on Exelon's website: http://www.exeloncorp.com/PowerPlants/conowingo/relicensing/background.aspx

Comment Code	Comment	Comment Response
P.10	EPA studies show that phosphorus that is bound to sediments in a fresh water river estuary and is therefore not available to spawn algae blooms is released into the water and is available to spawn algae blooms when such sediments are transported into a slightly saline, warmer and more acidic bay or delta estuary. Does the LSRWA account for the impact of the release of phosphorus bound to sediments that are scoured from the floor of the Conowingo Pond and if so what percentage or quantity of phosphorus is attributed to phosphorus bound to sediments prior to passing through or over the Conowingo Dam and being release in the Bay estuary.	The assessment did not specifically evaluate the release of phosphorus from sediments scoured from Conowingo Pond. It is estimated that the Susquehanna River contributes about 40 percent of the total phosphorus inputs to the Bay; however, the percentage attributed to scoured sediments is not known. The enhanced monitoring and modeling will better evaluate the impacts of nutrients on water-quality and habitat in the Bay.
P.11	Is a Hurricane Agnes (with excessive delivery of sediment that buries subaquatic vegetation) now more likely to occur or not? And if so what are we going to do about it, if anything?	Following the occurrence of Agnes, the storm was calculated to be a 500-year event, but each time the hydrologic record is updated, that number declines. Climate change simulations for the Chesapeake Bay watershed out to the year 2100 predict increased precipitation amounts in the winter and spring, as well as increased intensities of precipitation, tropical storms, and northeasters (although their frequency may decrease). The impacts of these events will need to be considered when planning for climate changes.
P.12	A lifetime ago, when the dam was built, what historically, if indeed anything, was said about sediment or other environmental impacts, their costs, how they would be dealt with or the like? Is this the missing discussion we now need to have?	The build-up of sediment behind the dam does not impact the generation of electricity; therefore, there was no past motivation to address the impacts. Furthermore, the dam was built before the federal Clean Water Act and other environmental laws curbing sediment impacts. The report makes recommendations (Chapter 8.1) for a commitment to enhanced long-term monitoring and analyses of sediment and nutrient processes in the lower Susquehanna River and upper Chesapeake Bay. For the relicensing process, Exelon has agreed to fund studies to address the Maryland Department of the Environment's questions/concerns regarding water quality impacts from the Conowingo Hydroelectric Project. Other environmental impacts to fisheries and recreation must also be addressed during relicensing.
P.13	If one percent of the value of the electricity produced by the dam since it was built was spent on preventing sediment scouring or fish kills, what would that number of dollars be? How much to date for that sort of thing has been spent?	The assessment did not evaluate these costs. The build-up of sediment behind the dams does not impact the generation of electricity; therefore there was no past motivation to address this. To date, substantial investment has been made to address concerns for sediment storage in the lower Susquehanna River reservoirs (see Chapter 2.2, Sediment Management Investigations). The report makes recommendations (Chapter 8.1) for a commitment to enhanced long-term monitoring and analyses of sediment and nutrient processes in the lower Susquehanna River and upper Chesapeake Bay to promote adaptive management into the future.
P.14	If Conowingo Dam was not there would it make a difference in the amount of sediment in the Bay? Has an extensive study been done assessing the storms that pass down from NY and PA? How much sediment?	The assessment shows that between 2008 and 2011, about 13 percent of the Susquehanna River's sediment load came from the reservoir behind the Conowingo Dam. The remaining 87 percent originated from the 27,510-square mile Susquehanna River watershed. During lower flow periods, the three reservoirs act as sediment traps and aid in the health of the Bay until the next high-flow event or storm occurs. Without the dam, the river would carry all the sediment to the Bay from throughout the watershed. Subsequently, the dam is affecting the timing and delivery of sediments to Chesapeake Bay as well as holding back some of the coarser sediments (i.e., sand, gravel) from reaching the bay since they are more resistant to scouring.

Comment Code	Comment	Comment Response
P.15	All of the discussion has focused on Conowingo Dam. What about Holtwood Dam and Safe Harbor Dam? It seems that the study recommendations are equally applicable to those dams as well.	The focus of the assessment was on the Conowingo Dam and mathematically defining the quantity of sediment coming from behind the Conowingo Dam. However, the other two dams were considered in the analyses (see response to comment P.8). The models show that all three reservoirs are active with respect to scour and deposition even at the dynamic equilibrium storage capacity, as is the case in the upper two reservoirs. The findings of the study are applicable to the upper two reservoirs, but not to same degree.
P.16	What are the costs for achieving/implementing enough BMPs in the watershed to make a difference? Is this even feasible?	Discussion of concept-level BMP costs is included in Section 5.2 and Appendix J-1. Note that Appendix J-1 describes costs associated with the "E3" scenario, which involves the theoretical maximum implementation of BMPs throughout the watershed (E3 = Everything, Everywhere, by Everyone). It would not be feasible to implement the E3 scenario (it was a "what-if" modeling exercise) and the relatively small reduction in sediment over the WIPs would not justify the cost.
P.17	How does this report impact the dam relicensing?	In addition to the Federal Energy Regulatory Commission requirements, a license for continued operation of Conowingo Dam cannot be granted to Exelon without a Section 401 water quality certification from the Maryland Department of the Environment (MDE). Issuance of a certification is contingent upon the applicant demonstrating to MDE that the proposed project will comply with state water quality standards. The current findings of the assessment were considered MDE's decision-making process for the water quality certification. In December 2014, Exelon withdrew its application for Section 401 water quality certification and agreed to fund studies to address MDE's questions/concerns regarding water quality impacts.
P.18	Is non-renewal of operating license being considered as a possible measure to be taken?	The Federal Energy Regulatory Commission has jurisdiction over hydroelectric licensing; therefore, the team cannot comment on their considerations with regards to relicensing the Conowingo Hydroelectric Project. Also see responses to comments W.7 and P.17.
P.19	I am an avid fisherman, boater and wildlife photographer. I fully support relicensing the Conowingo Dam and its form of renewable green energy. (The dam is not a source.) What can I do as a Maryland resident to support the restriction on sources of nutrient and sediment into the Chesapeake Bay watershed?	Attending and providing comment at the public meeting for this assessment is a good step toward voicing your support for sediment and nutrient restrictions. Continue to provide input to organizations and governments in your watershed and do your part to implement best management practices at home.
P.20	Do we know what sources of nutrients are largest contributors?	The main sources of nutrients in the Susquehanna River watershed include agricultural runoff, wastewater treatment plants, septic systems, stormwater runoff, and atmospheric deposition.
P.21	We seem to have a handle on the nutrient load that is impacting the Chesapeake. Given the reforestation recommendation in particular as it contributes to best practices, do we have an estimate for the approximate acreage that would need to be reforested? How achievable would that be?	The assessment did not quantify acreage needed to support achievement of TMDLs.
P.22	Recommendation: In the Executive summary (page ES-4) sediment is quantified as cubic yards. Elsewhere in the report, those sections describing TMDL, sediment is quantified as tons. Recommend that any cubic yard figures be also shown as tons.	**Editorial Comment** In the executive summary, cubic yards will also be identified as tons (final report pages ES-5 and ES-6).
P.23	Has there been any analysis or data collection into the impact of the Vulcan Materials Quarry in Harve de Grace on upper Bay water quality?	The report did not look specifically at impacts from the Vulcan Materials Quarry.

Comment Code	Comment	Comment Response
P.24	All dams have a lifespan, what happens to the sediment behind the dam when the dam reaches the end of its useful life? Who pays for it?	This question was not part of the assessment since the Conowingo Dam is expected to operate into the foreseeable future.
P.25	The assessment concludes that it is not cost effective to dredge the sediment. It shifts the solution and the costs upstream. In doing so, it shifts the burden from a few big players, Feds, States, etc. to small jurisdictions. Will sufficient funding be made available to the townships in PA and similar jurisdictions in NY to get the job done?	Comment noted. The team cannot speak to the funding that will be provided to support achievement of water quality milestones.
P.26	How are TMDLs enforced? What will it take to strengthen them - i.e. what is the approval process?	The Chesapeake Bay TMDL is discussed Chapter 2, Management Activities in the Watershed. Under Section 303(d) of the Clean Water Act, states and authorized tribes are required to list and develop TMDLs for impaired surface waters not meeting water quality standards. Federal actions to enforce TMDLs are described in Section 2.1.2 of the assessment. Further details about the TMDL approval process can be found on the EPA website: http://water.epa.gov/lawsregs/lawsguidance/cwa/tmdl/dec4.cfm
P.27	There's a great deal of talk about sediment with Conowingo Dam. Are there other ecological impacts associated with the dam that we should be concerned about? If so, what can be done to reduce those impacts?	The dams do trap course-grained sediments, which provide downstream aquatic habitat and help SAV and wetlands proliferate. The enhanced monitoring recommended by the assessment will evaluate the biologic availability of nutrients and other ecological impacts. The dam also impacts the movement of migratory fishes, impeding access to spawning grounds. The dam relicensing process will help ensure this impacts are addressed. Chapters 5.4.3 and 5.4.5 discuss the beneficial reuse of dredged sediment for the purpose of habitat restoration and wetland creation. Chapter 2.6 describes the Susquehanna River Basin Ecological Flow Management Study, which sought to establish the volume and timing of flows to support aquatic species and ecosystems. Chapter 4.2 discusses river and reservoir conditions and implications to the Bay.
P.28	Bruce Michael (DNR) stated that Appendix T of the 2010 TMDLs in the 2010 TMDL anticipated the source trapped behind the Dam. Isn't it true that Appendix T actually showed a sink or trapping of TMDLs? And not a source?	The text for Appendix T of the Chesapeake Bay TMDL can be found on U.S. EPA's website: http://www.epa.gov/chesapeakebaytmdl/ The Conowingo Dam has long served as an effective trap for a portion of the pollution from the Susquehanna River. Should those sediments be released from the dam through scour or dam removal, those sediments would act as a source of pollutants.

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
P.29	For Mike Langland (USGS) – The HEC-RAS model is one dimensional. How is this model different from the HEC-6 model, also one dimensional? How is scour accounted for in these one dimensional models? Do you feel comfortable with the scour estimates from those models?	It is true that one-dimensional models have more limitations than two- or three-dimensional models; however, the team has confidence in the estimates provided by each of the models as all the models have been used extensively in the past, including for TMDL development, and have been vetted by the scientific community. Additionally, the models were calibrated with real observations. Additional data from the recommended enhanced monitoring will be used to further refine the models. HEC-RAS is essentially HEC-6 converted from a DOS to a graphical interface. The HEC-RAS graphical interface provides the user with the capability to perform sediment transport and analysis, and display the results. There are some additional changes in some of the algorithms which can produce different computations when compared to HEC-6. Information on the actual "functionality" of the HEC-RAS model is presented in Appendix A.
P.30	What would conditions be like if the Dam had never been built? How would impacts change if the Dam were removed?	If the dam had never been built, the river would carry all the sediments from throughout the watershed to the Bay, including beneficial coarse-grained sediment and any pollutants potentially associated with the sediments. If the dams were breeched or removed, there would be less trapping of nutrients and sediment during lower flows, and scour of the legacy sediments and associated nutrients during the higher flows would continue to occur until the sediments and nutrients had been removed. This would take many years. The river would continue to carry sediment to the Bay from throughout the watershed. Without the dams, fish passage would not be an issue, allowing migratory fish (American shad, river herring and American eels) to swim upstream and spawn.
P.31	A recent scientific editorial in *NY Times* advocated for removing Conowingo Dam and replacing it with smaller hydroelectric and other green energy systems. Dam removal is gaining ground in the US. The ecological benefits to the Susquehanna River and especially Chesapeake Bay would be transformative. Thoughts?	Dam removal was not considered as part of the assessment. One of the main reasons is because the reservoir created by the dam is critical in providing cooling water to the nuclear power plant as well as a providing a supplemental drinking water intake for Baltimore City.
P.32	Is the 2 year period of enhanced monitoring of sufficient duration to provide meaningful input to the 2017 model adjustment?	It is important to note that recommended enhanced monitoring will supplement long-term comprehensive monitoring that has been done over the past several decades. Therefore, the team believes the new data collected will enhance our understanding of the system to allow meaningful input to the 2017 Chesapeake Bay TMDL midpoint assessment.
P.33	In the Executive Summary it seems that “management strategies for reducing sediment from the Susquehanna watershed beyond the WIPs” are not given much consideration, but in the analysis of sources of sediment, the watershed contributions are assessed to be the source of the majority of the sediment load. Doesn’t it make sense to target reductions to the main source, rather than secondary sources?	Yes. The assessment suggests that strategies focused on reducing nutrient pollutant loads from the upstream watershed are likely more effective for improving the health of the Bay than reducing sediment from behind the dams. Additional upstream watershed practices to address Conowingo sediments and nutrients, if necessary and appropriate, will be considered during EPA’s analyses for the Chesapeake Bay TMDL midpoint assessment in 2017. Please see the response to comment P.16. The "E3" scenario, which implements BMPs beyond the WIPs, would not result in enough sediment reduction to justify the cost.

Comment Code	Comment	Comment Response
P.34	We have been doing BMP's "at the source" for decades, yet your graph shows phosphorus levels continue to rise. What makes you think additional BMPs will help cut down that 87% sediment load?	Chapter 2 discusses management activities in the watershed, including Chesapeake Bay agreements and TMDLs. Chapter 5.2 evaluates sediment management strategies that reduce sediment yield from the upstream watershed. Initial agreements to reduce nutrients were non-binding and did not include all the watershed states. However, nutrient and sediment loads to the lower Susquehanna River are significantly lower than what was delivered in the mid-1980s, due to widespread implementation of regulatory and voluntary nutrient and sediment reduction strategies in the Susquehanna River watershed over the past 30 years. The 2010 Chesapeake Bay TMDL allocations for each of the seven watershed jurisdictions were derived by modeling nutrient and sediment pollutant loads that result in achievement of water quality standards. These allocations will be re-evaluated for the 2017 TMDL midpoint assessment.
P.35	We are increasing TMDLs based on information found in this study and the volume of sediments found behind the Dam. Will we increase TMDLs in other systems with large dams or series of smaller dams?	The assessment focuses specifically on sediment storage behind the Safe Harbor, Holtwood, and Conowingo Dams. Conclusions regarding the trapping capacities of other dams will require site-specific studies. As part of the Chesapeake Bay Program Partnership's Chesapeake Bay TMDL 2017 midpoint assessment, the partners are working to factor in hundreds of new dams into the input data for the partnership's Phase 6 Chesapeake Bay Watershed Model. The effects of these dams on the movement of nutrients and sediments through the watershed will be factored into the partnership's decision on the target nitrogen, phosphorus and sediment loads for the watershed jurisdictions' Phase III watershed implementation plans in the 2017 timeframe.
P.36	I'm wondering if you can help put the slide on "estimated sediment load" (the pie chart with 87% - 13% split between Susquehanna watershed and Conowingo reservoir) into perspective. Am I correct that Conowingo's 13% contribution is 13% of Susquehanna load, not 13% of total load flowing into the Bay from all sources? How significant is Conowingo's sediment/nutrient contributing seen from the perspective of total loads into the Bay?	The slide indicates that 13 percent of the sediment load in the Susquehanna River comes from the reservoir behind the Conowingo Dam. The remaining 87 percent originates from the 27,510-square mile Susquehanna River watershed. Sediments and nutrients also enter the Bay from other tributaries. The Susquehanna River contributes about 50 percent of the total freshwater flow to the Bay, which includes about 40 percent of the annual phosphorus load, 25 percent of the suspended sediment load, and 66 percent of the nitrogen load entering the Bay.
P.37	To what extent has Maryland reached its goals for TMDL? Is there anything we citizens can do politically to help move us toward our goals?	Maryland met the 2012-2013 pollution reduction milestones — in large part due to conservation practices such as record cover crops planted, wastewater treatment plant upgrades completed on schedule, and implementation of the Fertilizer Use Act of 2011 — and is on target for meeting the 2014-2015 2-year milestones. The public can help to achieve water quality goals by voicing to governments and organizations in your watershed that you support these goals, and by implementing best management practices at home.
P.38	Is sediment the only carrier of nutrients? If not, why is sediment only mentioned in the report?	Sediments are not the only carrier of nutrients. For example, nutrients may be dissolved in water or carried in the air. Sediments were the focus of the assessment, as the purpose of the assessment was to analyze the movement of sediment and associated nutrients within the lower Susquehanna River watershed through the dams and to the upper Chesapeake Bay.

Comment Code	Comment	Comment Response
W.1	I believe the concern regarding the Conowingo Dam is whether or not the loss of sediment storage capacity will contribute to the recurrence of Hurricane Agnes type ecological impacts on the Lower Susquehanna Watershed. The base weather period you used in your study did not include years and time periods of extreme weather, such as Hurricane Agnes. The TMDL and the model that is used to develop the TMDL, looks at broad average, longer-term impacts, not those from very short-term extreme events. So the question remains: Is a Hurricane Agnes, with excessive delivery of sediment that essentially buries subaquatic vegetation, now more likely to occur or not and, if so, what are we going to do about it, if anything?	The comment is correct that the models did not incorporate the hydrologic period during which Agnes occurred, but they did include other high flow events such as Tropical Storm Lee and the January 1996 high flow event. Chapter 3.3 and Appendix C discuss these model simulations in detail. During scoping, the team did discuss conducting a modeling scenario evaluating an Agnes-sized event; however, this was determined to not be feasible due to high cost, study time frame, and lack of available data for model calibration. The reoccurrence of an event like Agnes (size and time of year) would likely cause severe impacts to the Bay, from which it may take decades to recover. Accordingly, it was not believed that modeling to further clarify the effects would aid in decision-making, and thus it was determined that it was impractical to make the additional effort for synthesizing and/or modifying the modeling tools. Additionally, there is no amount of dredging/in-reservoir management that would reduce the impacts of an Agnes-sized event in any meaningful way. With the current available data, simulations of Agnes would have high uncertainty and would not provide additional management insight. Appendix I-7 contains a discussion of what would be needed to conduct a modeling scenario for an Agnes-sized event. Following the occurrence of Agnes, the storm was calculated to be a 500-year event. However, there is general agreement that the 500-year frequency was overstated. There may have been isolated areas in the Susquehanna River watershed where this was true. But by the 1990's, the return interval was dropped to 200 and 100 years for most parts of the watershed. The lower Susquehanna reservoirs were not designed to be flood storage dams. The reservoirs have a very limited capacity to store water. During high flow events, the Susquehanna River delivers such large volumes of water that are beyond the control of reservoir regulation. In addition, climate change simulations for the Chesapeake Bay watershed out to the year 2100 predict increased precipitation amounts in the winter and spring, as well as increased intensities of precipitation, tropical storms, and northeasters (although their frequency may decrease). The impacts of these events will need to be considered when planning for climate changes.
W.2	Isn't the lower Chesapeake Bay starved for coarse grain sediment as a consequence in part of the dams on the rivers? If so, isn't there a benefit that should be considered of transporting some of this coarse grain sediment to where it is needed for ecological restoration or rehabilitation?	Chapter 5.4.3 of the assessment discusses the beneficial reuse of dredged sediments, including for habitat restoration. Sediment cores taken from behind the Conowingo Dam were composed of 80 percent sand in the upper reservoir, but only 20 percent sand in the lower reservoir. It would not be practical nor cost-effective to sort the coarse grains in the Susquehanna River for reuse in the lower Bay. Additionally, the sediment profile in the lower Chesapeake Bay is typically fed by flows from lower Bay tributaries, and not the Susquehanna River. Section 5.4.4 also discusses the time-of-year limitations for sediment bypassing (there are very limited ecologically bening times when sediments could be placed).
W.3	Will in-situ technology for denitrification be evaluated for managing the increases in nitrogen loadings to the Bay?	The assessment did not evaluate specific technologies for managing nitrogen inputs to the Bay. The Chesapeake Bay Program partnership will continue to consider crediting in-situ technologies for reducing nutrient pollutant loadings as part its "Protocol for the Development, Review, and Approval of Loading and Effectiveness Estimates for Nutrient and Sediment Controls in the Chesapeake Bay Watershed Model."

Comment Code	Comment	Comment Response
W.4	If the runoff from my driveway makes a big difference, what plans are in effect to control runoff from business lots and our highways?	Chapter 2, Management Activities in the Watershed, describes planned and ongoing actions to limit inputs of pollutants in the watershed. Implementations of these actions vary by jurisdiction, but could include storm water remediation fees and/or best management practices to reduce sediment and nutrient runoff. In Maryland specifically, the current stormwater remediation fund (often referred to as the "rain tax") being implemented by certain jurisdictions assesses fees based upon the size of impervious surfaces (i.e., driveways, parking lots, rooftops, etc.).
W.5	Did the cost analysis for sediment removal consider the ongoing cost for sediment removal in the navigation channels downstream?	No. A direct relationship between material that passes the dam versus what ends up in the channels has not been determined. The material that deposits in the channel is mostly from the Bay bottom nearby, but it is obvious that storms generate sediment. It should be noted that maintenance dredging the channels is much more economical than dredging the reservoirs.
W.6	Will the economic benefit to the use of dredged sediments to replace wetlands being lost as a result of sea level rise?	Chapters 5.4.3 and 5.4.5 discuss the beneficial reuse of dredged sediment for the purpose of habitat restoration and wetland restoration. A qualitative assessment of these options is included in Table 5-5 and some costs are included in Appendix J-2.
W.7	What specifically is the reason for not granting the license to Exelon today? I understood their license ended in September.	Chapter 2.3 of the assessment summarizes Federal Energy Regulatory Commission (FERC) activities with regards to licenses for operations on the Susquehanna River. Exelon's current license from FERC for the operation of the Conowingo Hydroelectric Project was issued on August 14, 1980 and expired in September 2014. Exelon is now operating the dam on a temporary annual license. A license for continued operation of Conowingo cannot be granted to Exelon without a Section 401 water quality certification from the Maryland Department of the Environment (MDE). Issuance of a certification is contingent upon the applicant demonstrating to MDE that the proposed project will comply with state water quality standards. In December 2014, Exelon withdrew its application for Section 401 water quality certification and agreed to fund studies to address MDE's questions/concerns regarding water quality impacts.
W.8	Someone stated that whether or not sediment from scour is good or bad depends upon when the scoring event occurs. Lee was late in the year. Agnes early. Have you examined the possibility of controlled, intentional scours at times of the year when adverse impacts are less likely to occur?	The timing of storm events and sediment scour do make a difference to how these events impact the Bay. Storm events and timing are discussed in Chapters 4.2.2, 4.2.3, and shown in Figure 4-5. Observations and model computations indicate that an autumn event, such as Lee, has the least detrimental impact on Bay water quality. A late spring storm has the greatest impact due to high biologic activity and the height of the SAV growing season (see Table 4-9, Scenario 6) for seasonal impact differences). This assessment did evaluate intentional scour/dredging and bypassing sediment at times of the year that would be least impactful to aquatic life. Chapters 5.3, 5.4, 5.6, and Table 5-7 discuss management strategies for routing sediment or increasing storage behind the dams at different times of the year.
W.9	When Exelon was initially granted the original license were they required to do silt removal? If not, what changed to even discuss the issue with them rather than requiring those up river to be responsible parties and leave Exelon to generate power.	Questions regarding the specifics of Exelon's license to operate the Conowingo Hydroelectric Project should be addressed to the Federal Energy Regulatory Commission. However, it is unlikely at the time the license was granted in 1980 that sediment was considered an issue that would require action by the licensee. In addition, at that time, the reservoir behind the dam was not near full and had ample capacity to store sediments. The assessment indicates that some sediment is scoured from behind the dam, but a large portion of sediment is from the watershed. Future studies as recommended by the assessment will provide better indications of specific quantities from individual sources.

Comment Code	Comment	Comment Response
E.1	Is it true that most of the sediment behind the Dam has already blown through the Shoot-Gates every time they are OPENED during Flooding??? Is there not very much Sediment in BACK of the DAM now??? How about behind the other UPSTREAM Dams??? Do we need another DAM built down-stream of Conowingo...prior to the BAY??? HELP Save the BAY.	Comment noted. The assessment indicates that the reservoirs behind the Holtwood, Safe Harbor, and Conowingo Dams no longer have the long-term ability to store sediment and associated nutrients: a state of dynamic equilibrium now exists. As a result, large periodic storm events that occur on average every 4 to 5 years wash away sediment from behind the dams, increasing associated nutrient loads to the Bay. This creates a short-term increase in storage volume in the reservoirs for trapping sediment and nutrients.
E.2	One of the main findings of the report was that the nutrients associated with the sediments were more harmful to the Bay than the sediment itself. However, the report is unclear as to the effectiveness of dredging on reducing the sediment load to the Bay. There are numerous locations that discuss returning the bathymetry to 1996 levels etc. (for example Table 4-4) but it is not made clear just exactly how much sediment is estimated to be prevented from entering the Bay for each ton of sediment removed from the reservoir. This analysis should include taking the levels back to 1996 and beyond. It should also incorporate the value of strategic dredging to address high deposition areas and targeting removal of the fines (more likely transported). My company, HarborRock, is able to use the fines to make its product and leave the sand fraction in place – a benefit to lowering the scour rate. Reuse is the only option that is sustainable but the report does not clearly articulate or evaluate the long-term value of long-term dredging. We believe the information is within the various appendices etc. but is not being presented with enough transparency to make an informed decision on the value (nutrient reduction) obtained by dredging.	Comment noted. The assessment shows that sediment removal yields minimal, short-lived water quality improvements due to the constant deposition of sediment and associated nutrients that come from the watershed. Long-term, large volumes of sediment are depositing annually. Therefore, the net removal of sediments from the reservoirs via dredging only serves to keep up with deposition. Additionally, water quality improvements from dredging are minimal as the majority of sediment loads come from the watershed during high-flow events. Results of this study suggest that management opportunities in the watershed that reduce nutrient delivery to the Bay, as opposed to sediment only, are likely more effective at reducing impacts to water quality and aquatic life from high-flow events.
E.3	General Comment (see Appendix I-x for complete Petition Language): The Conowingo Dam has played a key role in providing clean reliable electricity to the region for more than 85 years. I am submitting a petition that endorses the work of the U.S. Army Corps of Engineers, numerous Maryland state agencies and many other stakeholders for a science-based approach to developing a course of regional action in improving the water quality in the Chesapeake Bay. On behalf of the more than 11,500 signers of this petition we thank the Corp and those involved for the work already completed on this issue and look forward to the continued work on addressing this regional issue.	Comment noted.

Comment Code	Comment	Comment Response
E.4	Thank you for providing an opportunity to comment on this important report. I attended the December 9 public meeting and have reviewed the LSRWA Draft Report. I believe that the relicensing of the Conowingo Dam Hydroelectric Generating Station presents a unique opportunity to improve the health of Chesapeake Bay. The legacy sediments behind Conowingo Dam contain nutrients and toxins that otherwise would have entered Chesapeake Bay. What needs to happen now is to remove them. This will reduce scour of the legacy sediments into the Bay during storm events and restore capacity to trap new sediments behind the dam. Removal of legacy sediments upstream is an important strategy for protecting and improving the water quality of Chesapeake Bay. This effort should be undertaken not solely by the state of Maryland but with support from all of the states in the Susquehanna River watershed. Maryland governor-elect Larry Hogan explained the importance of this approach during his campaign and I believe this strategy should be incorporated into the relicensing of Conowingo Dam.	Comment noted. The assessment shows that sediment removal yields minimal, short-lived water quality improvements due to the constant deposition of sediment and associated nutrients that come from the watershed. Long-term, large volumes of sediment are depositing annually. Therefore, the net removal of sediments from the reservoirs via dredging only serves to keep up with deposition. Additionally, water quality improvements from dredging are minimal as the majority of sediment loads come from the watershed during high-flow events. Results of this study suggest that management opportunities in the watershed that reduce nutrient delivery to the Bay, as opposed to sediment only, are likely more effective at reducing impacts to water quality and aquatic life from high-flow events.
E.5.1	The report asserts the nutrients associated with sediments have more of an adverse impact than the sediments themselves and that there may be more cost effective means than restoring the Conowingo storage volume to prevent these nutrients from reaching the Bay. It is suggested that in updating the draft study that it be made clear that the study did not quantify the nutrient offsets required nor recommend options and costs for achieving the offsets. It is also suggested that it be made clear that the study does not rule out dredging from behind the dam as an option in future studies. The draft study indicates with the WIPs in full effect (Table 4-9, page 82, Scenario 2) the nutrient load associated with the sediments will be 50.8 tons per day of nitrogen and 4.2 tons per day of phosphorus. These are very large loads. To put them in perspective, if we looked to the 173 wastewater treatment plants in Pennsylvania that are in the watershed to contribute to the nitrogen offset, the most they could provide would be 5 million pounds per year, or 6.85 tons per day. The Phase II WIP already counts on these treatment plants removing nitrogen to achieve effluent concentrations of 6 mg/L to achieve their annual nitrogen wasteload allocation of approximately 10 million pounds. Upgrading these wastewater treatment plants to the limit of technology to achieve 3 mg/L will provide 5 million pounds per year offset. Treating to the limit of technology is a strategy being employed at Maryland's major wastewater treatment plants to achieve a comparable amount of nitrogen removal and the capital costs are in excess of $1 billion. Thus, a very considerable expenditure would be required to remove only 6.85 tons per day using this strategy. It may be that increasing the storage volume is found to be the most cost effective option after all.	Comment noted. The assessment did not quantify nutrient offsets, although this has been included as a recommendation by the report. The assessment presents management options and recommendations. This does not preclude evaluation or implementation of these options in the future.

Comment Code	Comment	Comment Response
E.5.2	In evaluating the impact of sedimentation on the indicators of dissolved oxygen, light attenuation and chlorophyll concentration, the study did not identify the environmental and cost benefits that a reduced sedimentation rate would have on other parameters such as dredging the shipping channels, restoring the oyster population and recreational activities. While the Chesapeake is a national resource, we as Marylanders at the downstream end of the watershed have the most at stake in having a healthy Bay, because it largely defines who we are. It's not the correct question to ask: Is it cost effective to remove the sediment from behind the Conowingo dam? The correct question to ask is: Do we want to restore the Conowingo dam to beneficially serve as a sediment trap as it had for the past 70 to 80 years, or do we want to give up that benefit and essentially allow all sediment to pass through it? It would be a big mistake to accept a well publicized interpretation of the draft Study's findings that there is little benefit to dredging. For example, see Karl Blankensip's *Bay Journal* article dated November 13, 2014 which stated in part: *"The $1.4 million study, released by the Army Corps of Engineers and the Maryland Department of the Environment, also concluded that dredging built-up sediment from behind the 100-foot-high Susquehanna River dam would have huge costs and provide little benefit."* We shouldn't be satisfied to have a sediment-laden, degraded, unhealthy Bay define us. Instead we need to focus our efforts on restoring the dam as a sediment trap. We need to determine the most cost-effective and environmentally responsible means of removing the sediments and to identify the most beneficial re-use for them.	Comment noted. The assessment shows that sediment removal yields minimal, short-lived water quality improvements due to the constant deposition of sediment and associated nutrients that come from the watershed. Long-term, large volumes of sediment are depositing annually. Therefore, the net removal of sediments from the reservoirs via dredging only serves to keep up with deposition. Additionally, water quality improvements from dredging are minimal as the majority of sediment loads come from the watershed during high-flow events. Results of this study suggest that management opportunities in the watershed that reduce nutrient delivery to the Bay, as opposed to sediment only, are likely more effective at reducing impacts to water quality and aquatic life from high-flow events.

Comment Code	Comment	Comment Response
E.5.3	It appears that the draft report is already influencing some Maryland politicians and policy-makers to make the case of why should their jurisdictions be required to control non-point source sediments and nutrients since they won't be further controlled from the very large areas of New York and Pennsylvania? Regardless of what is done to control sediments and nutrients from the Susquehanna, we should not reduce our own activities in Maryland to control non-point source sediments and nutrients, nor reduce our efforts to improve nutrient removal at our wastewater treatment plants. My main concern with draft Study is it may influence policy makers to do nothing about sediments from the Susquehanna and it also may be influencing policy makers to cut back on environmental measures that are already being implemented in Maryland. We must reduce the sediments and nutrients from the Susquehanna in addition to what we are already doing and for funds to be available for each initiative. The Chesapeake is a national resource influenced by several states. As such, it is very reasonable to expect funding to be fairly shared among the federal government, New York, Pennsylvania and Maryland to mitigate the Susquehanna's impacts on the Bay. For this to happen, consideration needs to be given as to what New York and Pennsylvania will receive in return.	Comment noted. The assessment suggests that strategies focused on reducing nutrient pollutant loads from the upstream watershed are likely more effective for improving the health of the Bay than reducing sediment behind the dams. All of the Bay watershed states are required under the Chesapeake Bay TMDL to meet their targeted nutrient and sediment load allocation by the year 2025.
E.6.1	Overall, CBF believes the report's conclusions and recommendations are well supported and grounded in the best available science. The results clearly show that nutrients scoured from the behind the Conowingo Dam during high flow events are contributing to the violation of downstream water quality standards for dissolved oxygen. Results also suggest, however, that implementation of the state Watershed Implementation Plans (WIPs) which complement the Chesapeake Bay TMDL, have a far larger influence on the health of Chesapeake Bay in comparison to scouring of the lower Susquehanna River reservoirs. In addition, results also show that while impacts to the Chesapeake Bay ecosystem from all three dams and reservoirs are important, the majority of the sediment load from the lower Susquehanna River entering Chesapeake Bay during storm events, originates from the watershed rather than from scour from behind the Conowingo reservoir.	Comment noted.
E.6.2	The study also makes recommendations for future research and monitoring needed to address key data gaps. We firmly support these recommendations, particularly those related to enhancing the understanding of the nature, availability, and fate of nutrients scoured from the Conowingo Reservoir. These findings and the additional research are critical to the development of the Section 401 Water Quality Certification by the state of Maryland during the relicensing process and will also serve to inform the 2017 Midpoint Evaluation for the Chesapeake Bay TMDL.	Comment noted.

Comment Code	Comment	Comment Response
E.6.3	We do, however, believe the report would benefit by bolstering the qualitative discussion regarding potential impacts of storms and scouring on submerged aquatic vegetation (SAV) and oysters. We recognize that all LSRWA modeling scenarios listed in Table 4-9 resulted in estimates of full attainment of the SAV and water clarity water quality standards for all Chesapeake Bay segments. And furthermore, that the SAV and water clarity water quality standards were not the drivers behind the TMDL allocations like the DO deep-channel and deep-water water quality standards were. That said, we also know that big storms like Tropical Storms Agnes and Lee do affect underwater grasses. In addition, when the January 1996 "Big Melt" event storm was moved to the June time period, light attenuation was estimated to be greater than 2/m for 10 days, a level of light attenuation that does not support long-term SAV growth and survival (1.5/m is required).	There are some GIS and aerial photography evidence that suggest scour of SAV beds in the Susquehanna Fats occurred during Tropical Storm Lee, but the estimates of scour were unquantified and to date, citations on the SAV scour phenomena from Tropical Storm Lee or other large Susquehanna storms are unavailable in the peer review or grey literature. Additional information on water quality implications for SAV (in general) have been added to the report, as well as a quantification of nutrients associated with the sediments for storm events.
E.6.4	On page 71 there is a brief discussion about effects of storm events on underwater grasses and then the statement that "Appendix K provides further discussion on SAV trends and impacts from storms in Chesapeake Bay." Appendix K, though containing a section on underwater grasses, is more devoted to general background information on the Bay and associated habitats. We suggest this Appendix include more discussion of the findings of Gurbisz and Kemp (2013), Wang and Linker (2005) and any more recent work on this topic including, if possible, a consideration of the relative effects of scouring versus watershed loads, if only in a qualitative sense.	Text has been added to the main report in Chapter 4.2.2 to bolster the discussion of the effects of storm events on SAV. Information from Wang and Linker (2005) and Gurbisz and Kemp (2013) has been included.
E.6.5	Similarly, we suggest a more in depth discussion on oyster impacts. Currently, the report references a post Tropical Storm Lee study indicating the oyster mortality in the northern Bay was due to salinity decreases, not to sedimentation. We are not disputing this finding, but would encourage the study authors to include additional studies and information that support this contention. In addition, we also recommend including a discussion of why some oyster bars are susceptible to sedimentation that may not be, in any way, related to storm events. Questions about effects of scouring from behind Conowingo Dam on SAV and oysters continue to be raised in the public domain. To the extent that they can be addressed more comprehensively in the report, may help to assuage some lingering concerns.	Additional information about oyster impacts has been added to Chapters 4.2.2 and 4.2.3.

Comment Code	Comment	Comment Response
E.7	As you know, an interesting project is evolving as to the Conowingo Dam and the release of sediment laden contaminants (primarily Phosphorous and Nitrogen), from the Susquehanna River into the Chesapeake Bay. Of particular interest to various parties invested in this project, is the approximately 200m cubic yards of sediment behind the dam and the reduced "trapping" capacity of the dam itself. While there are conflicting tactics as to the sort of solution to the sediment/nutrient discharge, The Chesapeake remains in limbo regarding the "best of solutions". This is a seminal project requiring a provocative technological approach tied to cost effective disposal solutions. I am here to report that the dewatering component of the project can be done at a small fraction of traditional costs. Production of tens of thousands of cubic yards per day is achievable. Return water is clean and clear (<20 mg. per ltr.,t.s.s.), with virtually all phosphorous (99%), and most nitrogen removed. Obviously, all organics and clay are captured and dewatered. I have a "dog in this hunt". I am the founder of a company (Genesis Water) that holds recent patents on very high-speed dewatering capabilities. Any eutrophic waterway can be restored as quickly as the dredge can pump. I hope we have the opportunity to discuss the core issues of this unusual project.	Comment noted.
E.8.1	We find that the report, though it summarizes well the science related to issue of management of the Conowingo Dam reservoir for the protection of the water quality of Chesapeake Bay, fails in its argument that the loss of sediment storage capacity in the dam reservoir lacks critical importance to the health of the Bay ecosystem. The critical findings of the studies that underlie the report suggest the opposite. Also not convincing is its assertion that the current approach to water resource management through the Chesapeake Bay Total Maximum Daily Load (TMDL) water quality management process alone will adequately safeguard the resilience of the Bay ecosystem from the impacts of extreme weather events. Though a policy and its implementation process—the TMDL--is conceived and designed to achieve a longer term goal of water quality, this does not in itself argue that the individual steps and components in this highly complicated venture will necessarily succeed. There is uncertainty in any approach and consideration of this uncertainty should be apparent in the study. As the report states--though this admission is buried deep in the body of the report--, the nature of the problem of legacy nutrients in the hydrologic system makes verification of effectiveness of measures implemented as part of the TMDL implementation plans nearly impossible in the short while. The report also fails to identify and examine what the unique opportunities are for changing the management of a key component of the water system presented by this once-in-a-lifetime relicensing of the operation of the dam. This latter should be the focus of this study and should be answered in the report.	Comment noted. Finding #2 of the assessment (Chapter 8) states, "The loss of long-term sediment trapping capacity is causing impacts to the health of the Chesapeake Bay ecosystem." However, the modeling conducted for this assessment indicates that it is the nutrients associated with the enhanced sediment load, and not the sediments themselves, that have the most harmful impact on water quality and aquatic life. Furthermore, between 2008 and 2011, just 13 percent of the Susquehanna River's sediment load came from the reservoir behind the Conowingo Dam, while 87 percent originated from the 27,510-square mile watershed. Therefore, options for managing sediment behind the dam will be less effective than strategies focused on nutrient reductions throughout the watershed. It is recommended that the findings of this report be considered and incorporated into the analyses for the Chesapeake Bay TMDL 2017 midpoint assessment, and that management options that offset Bay impacts from increased sediment-associated nutrient loads be implemented.

Comment Code	Comment	Comment Response
E.8.2	We suggest strongly that a revised report discuss measures to reduce the volume of water, and hence the nutrients and sediment contained within, associated with the kind of extreme weather events that normally occur within the timeframe of the dam electrical plant operating permit and those that become more likely to occur as a consequence of a rapidly changing climate. As the report states, though this too is hidden deep in the body, a Conowingo dam at dynamic equilibrium leads to faster flowing water that carries with it more sediment and nutrients. Hence, expanding the amount of stormwater that can be temporarily stored on the land adjacent or immediately connected to the Susquehanna and its tributaries and otherwise slowing the runoff from these lands should be a major focus of the options for addressing the consequence of Conowingo dynamic equilibrium. Instead the reader is presented with the tautological argument that a policy designed to achieve a policy goal will by definition do so. It does not reconcile this assertion with the admission that the current TMDL and its measures are already out of date and must be revised as a consequence of increasing nutrient and sediment loads from a Conowingo dam that is already at dynamic equilibrium.	Comment noted. The focus of the assessment was to analyze the movement of sediment and associated nutrient loads within the lower Susquehanna River watershed, including the reservoir at Conowingo Dam and the capacity of the dam to trap sediment. As such, the assessment did not evaluate strategies to reduce the volume of water passing the dam, although watershed strategies to reduce sediment will likely also help reduce stormwater flows to Chesapeake Bay. The assessment updated our understanding of the system and produced numerous products that are now available to assist in future watershed planning and management efforts, including informing the Chesapeake Bay TMDL 2017 midpoint assessment.
E.8.3	The finding of a current TMDL already out of date belies the conclusion of the report that the dam and its accumulated sediments are inconsequential to the health of the Bay and the implicit suggestion that a change in the conditions for relicensing of the operation of the dam—whether or not the onus is placed directly on the operator of the dam--are not necessary. Rather than a "[f]uture needs and opportunities in the watershed," as the report suggests, development of management options that offset impacts to the upper Chesapeake should instead be examined in this report in order to take advantage of the relicensing opportunity that is available for only a short period of time.	Comment noted. See response to comment E.8.1. It is also important to note that enhanced monitoring and modeling is recommended for the lower Susquehanna River. This includes studies that Exelon has agreed to fund to address the Maryland Department of the Environment's concerns regarding water-quality impacts from operation of the Conowingo Hydroelectric Project. Information from these studies will feed into decisions regarding relicensing of the dam.

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
E.8.4	An assessment was indeed conducted as part of the study but the act of assessing is itself NOT a clear articulation of what the assessment is conducted for. The Executive Summary nor the introductory chapters to the report makes clear what the core questions were that the assessment was to provide information to answer. These should be stated at the outset so that the reader can better evaluate the science and the arguments that underlie the conclusions relating to key public policy choices that pertain to the relicensing decision. Our examination of the body of the report suggests that the major conclusions as stated in the Executive Summary are not well supported by the methods and results. The reader has literally to dig deep into the report to identify the scientific questions that were posed and to discover the scientific findings. Often one set of findings, such as related to extreme weather events, i.e. greater than five years recurrence intervals, and reservoir bed scouring were not sufficiently incorporated into the analyses in another section. What was the perceived problem for which the study was to provide the information to answer? It appears that an answer to this question is provided only later in the press release, not in the introduction or body of the report—what is the importance of loss of sediment storage capacity in the dam reservoir relative to implementation of the Chesapeake Bay TMDL and the environmental problem that it—the TMDL-- is designed to address. It is unclear how the findings and conclusions of the LSRWA will or can be used in the relicensing decision. We hope that the final report will contain a serious examination of conditions and options that should be considered in the relicensing decision.	Comment noted. See response to Comments E.8.2 and E.8.3. Substantial text was added to the executive summary, Chapter 1, and Chapter 4 to clarify the problem.

Comment Code	Comment	Comment Response
E.8.5	We learn elsewhere in the body of the report that the loss of sediment storage capacity behind the dam in the next few years will increase the threat to the ecosystem health from extreme weather events (ever more likely with a rapidly changing climate, such as occurred with Hurricane Agnes just some forty years ago). Also, inconsistent with the conclusions that are presented in the Executive Summary, we learn that the dam and its reservoir are already at dynamic equilibrium and that the TMDL, which the report argues is the answer to water quality concerns, will no longer achieve its intended goals as a consequence of the dam at dynamic equilibrium. Nor do we have an answer as to how at this juncture with the pending relicensing of the Conowingo Dam for electric power use, the management of the dam and its reservoir could or should be changed to ensure that the ecologic damage from a future Hurricane Agnes does not recur. Also disturbing is the absence of a discussion of the value of the sediment that increasingly fills up the reservoir to the ecosystem health of the larger Bay system, particularly in lower sections of the Bay. Here the problem is land disappearing in part because of sediment starvation. Sediment that restores and enriches the land-water interface is instead captured behind the dam. The answer at the public hearing by representatives of the study that "we all agree that we should study the issue more" is, to be blunt, an acknowledgement that this report does not address the prevailing public policy concerns. Calling for another study to do what this study should do does not instill confidence in how this larger issue of protection of ecosystem resilience, as we have articulated it here, will ever be addressed. We are not persuaded by the report's statement that a Conowingo Dam reservoir at dynamic equilibrium with regard to sediment matters little to ecosystem health. There is no discussion in the analytical section of the report of how the dam at dynamic equilibrium may adversely affect ecosystem resilience and the ability of the ecosystem to withstand infrequent, but highly severe insults, such as 40 year or more recurrent interval storms. Should we not be managing components of the system, such as the dam and its reservoir, for resilience? If so, then the study should have examined the ability of the system, with the reservoir at dynamic equilibrium, to withstand infrequent recurrence interval storm events and used these results as the measure against which to compare alternative management strategies. Since the Conowingo Dam license renewal is for some fifty years, fifty years, at least, would seem to be the proper recurrent interval number to be used, not five or ten-year storms.	Comment noted. The executive summary clearly states that the reservoirs are in a state of dynamic equilibrium. See response to comments E.8.2 and E.8.3 regarding dam licensing and TMDL evaluations. The dams do trap course-grained sediments, which provide downstream aquatic habitat and help SAV and wetlands proliferate. Chapters 5.4.3 and 5.4.5 discuss the beneficial reuse of dredged sediment for the purpose of habitat restoration and wetland creation. See response to comment E.8.1 regarding the relative importance of the sediment behind the dam to ecosystem health. See response to comment W.1 with regards to modeling larger, less-frequent storm events (e.g., Agnes).

Comment Code	Comment	Comment Response
E.8.6	The study appears designed to give the answer that implementing regulatory requirements under the Clean Water Act for the Chesapeake Bay to meet the Total Maximum Daily Load (TMDL) goal will address any current and future problem of sediments and nutrients. The implementation plan under the Chesapeake Bay TMDL may or may not eventually result in significant improvements in the ecosystem health of the Bay and its environs. Time will tell. However, choosing to examine only that period of time in the analytical part of the report that compares options that coincides with the current phase of the TMDL and that incorporates only relatively minor storm events of low recurrence intervals that are not of the kind that can be expected to occur during the much longer time period (some fifty years) of the Conowingo Dam relicensing period leads not surprisingly to results supportive of the major conclusions regarding importance of storm-related scour events. Certainly the inclusion of forty or fifty year recurrence interval storm scour events would have been called for and may have likely led to different conclusions regarding the appropriateness of management strategies.	Comment noted. See response to comment W.1 regarding modeling larger, less frequent storm events (e.g., Agnes).

Comment Code	Comment	Comment Response
E.8.7	The assumption in this study that the TMDL implementation occurs flawlessly and on time despite the thousands of required practices conducted by different public and private entities necessary to achieve predicted levels of performance defies logic and almost fifty years of Clean Water Act experience. That this assumption regarding success on the agricultural portion of the TMDL is highly questionable and that it should be bracketed within a large uncertainty range is supported by hundreds of studies conducted under the auspices of the United States Department of Agriculture's Conservation Effects Assessment Project (CEAP)2. Over more than ten years, the top government and academic researchers under the auspices of CEAP examined the effectiveness of agricultural nutrient reduction practices and strategies in watersheds throughout the country and over many decades. The conclusions are that most nutrient reduction practices on agricultural lands, for a variety of reasons that are often location-specific, have not been successful. More effective interventions needed to be implemented as part of a comprehensive management system that is tailored to site-specific conditions with constant reassessment regarding the effectiveness. How this must occur is still the subject of scientific and policy debate. The reason stems in part from the fact that no farm or section of land is the same, nor is any the management of any two farms or sections of land likely to be the same. The problem is one for which there are no certain answers at the moment and that requires more research to resolve. Compounding the problem is the legacy of how the land was managed in previous decades and its impact on nutrient loss from these lands. This is an issue of cutting edge science and policy that has been reduced to almost cartoon simplicity in this report. In any case, the uncertainty regarding TMDL implementation success and effectiveness should be factored into any comparison of alternative options for managing sediment and nutrients to and from the Conowingo Dam. We suggest only that alternative and parallel strategies of managing sediment, such as through dredging or controlled flushing, and actions to expand temporary stormwater storage upland from the dam can potentially be far more certain since sediment management at the dam can be relatively easily implemented and monitored and increased upland water storage quantified using today's new technologies. And, of course, there is a significant cost for all strategies.	Comment noted. The assessment provides an update to our understanding of the Lower Susquehanna River system and makes recommendations regarding future monitoring and management options; however, decisions regarding the most effective strategies for nutrient reductions will need to be made by EPA and their seven Chesapeake Bay watershed jurisdictional partners. Having said this, it is also clear that the agricultural community will have to be key partners in restoring the Bay because agricultural sources are significant contributors and are often the most cost-effective solution.

Comment Code	Comment	Comment Response
E.8.8	For unknown reasons, only the cost of dredging was estimated in detail. The cost of implementing the TMDL was assumed to be a one-time cost that appears lower than the ongoing Net Present Value (NPV) of a stream of costs associated with dredging. How farm management practices to reduce nutrients and sediment can be assumed to be one-time costs is not credible and runs counter to hundreds of economic studies and case studies that argue significant ongoing costs. Moreover, unpublished data generated as part of US Environmental Protection Agency's Chesapeake Bay TMDL cost-benefit analysis suggest that TMDL implementation, if and when fully implemented in the upper sections of the Chesapeake Bay watershed, will also likely cost billions of dollars per year. Clearly, a large range of benefits can be expected to accrue from successful implementation of the TMDL which can justify this costs. But the public policy issue is not either the TMDL or another intervention at the locus of the dam, but rather whether or not an action linked to the dam relicensing and operation can be justified by its costs and benefits.	Comment noted. Chapters 5.3 and 5.6 present the E3 scenario and Scenario 14 for implementing additional BMPs in the watershed to meet TMDLs. The costs provided are concept-level costs and include a range for each BMP, given the uncertainty of site-specific implementation considerations. The E3 Scenario and Scenario 14 were presented as a quick comparison to sediment management strategies. Since the assessment was designed to study the issue of sediment movement and delivery to the Bay, the management strategies evaluated in detail were primarily targeted at sediment removal and bypass.

Comment Code	Comment	Comment Response
E.8.9	The question that should have been the driver for the analysis is instead the caboose in this report in that it finally appears in the "Future Needs and Opportunities.." section of the Executive Summary. The recommendation, i.e. "[d]evelop and implement management options that offset impacts to the upper Chesapeake," should actually be restated as the core question that the study should address. What do you do with the loss of sediment capturing capacity over time since the implication is that the currently required practices under the TMDL are or will no longer be enough to reduce significant increases in nutrient and sediment loads to the Bay? Can there be beneficial uses to the sediment, if dredged or otherwise removed from the reservoir? The town hall meeting that occurred in December 2014, acknowledged these questions. One-time costs assumed by this study become ongoing costs as new requirements on urban communities and on farmers get imposed to offset this loss. It appears that alternative strategies to or along with the TMDL to address the consequence of rising nutrient and sediment loads as a result of the loss of storage capacity behind the dam are treated in a biased manner. The discussion of intentional scouring, for example, was given short shrift and deserves a more unbiased and serious examination. The issue of timing and its relationship to unintended downstream consequences was totally neglected. That these other options are not viable has not been well demonstrated by the analyses presented in this report. The sediment management options were limited to engineering and technological options. Why were no economic options examined? Options for addressing the problem of stormwater flow volume and rate of through the system at times of extreme weather events were not examined. Doing so would consider means for expanding floodwater storage on lands adjacent to the river, such as on agricultural lands. There are likely to be options on temporarily storing water on non-agricultural lands, such as through the management of road culverts, rehabilitation of wetland and of wet lands and forested lands, as well New digital elevation map data could be extremely helpful in identifying these lands for increased storage. Contingent contracting would serve to make these lands available when needed [See the references below.] Another example of an economic approaches is a policy to convert negative economic value of "pollutants" (i.e., sediment and nutrients) to tradeable commodities with positive economic value. This is can be done through labeling and a combination of regulatory and economic measures.	Comment noted. The focus of the assessment was to analyze the movement of sediment and associated nutrient loads within the lower Susquehanna River watershed, including the reservoir at Conowingo Dam and the capacity of the dam to trap sediment. The question going into the study was not as stated in the comment (i.e., to develop and implement management solutions to offset impacts to the Bay). Initially, the current capacity of the reservoirs behind the dam had to be assessed, followed by an evaluation of the associated environmental implications and whether this could be addressed through sediment management. With respect to the sediment management strategies, the assessment conducted a screening level analysis of fairly traditional alternatives. As such, this analysis has its limitations and many potential options were not explored. In general, however, these traditional sediment management alternatives were found to be either cost-prohibitive or technically infeasible due to multiple competing uses of reservoir storage. The issue of timing was discussed separately in Section 4.2.2 on "Storm Effects and Implications" (see Figure 4-5). The assessment did not evaluate strategies to reduce the volume of water passing the dam or the economic approaches identified in the comment. It is recommended that the findings of the assessment be integrated into the ongoing analyses and development of Phase 3 watershed implementation plans as part of the Chesapeake Bay TMDL 2017 midpoint assessment. In reality, a mix of strategies will likely be needed to affect sediment and nutrient reductions.

Comment Code	Comment	Comment Response
E.8.10	No economic cost was assigned to the uncertainty regarding the implementation and effectiveness of TMDL measures as opposed to measures, such as dredging for which the effectiveness and be more quantitatively ascertained. For example, the cost estimates for TMDL measures lack credibility. The report should have made clear that then values were largely drawn from scattered studies of unclear relevance to where they could be implemented in the watershed, along with no credible assessment of the variability of their effectiveness given the myriad site-specific factors that affect performance.	Comment noted. The concept-level costs for the BMPs used in the modeling scenario were obtained from the Chesapeake Bay Program, Maryland Department of the Environment, and/or Maryland Department of Agriculture (see Chapter 5.2.1). Cost and effectiveness of BMPs will be site specific. Given site specific factors for implementation of BMPS, a range of costs is provided for each BMP in Table 5-2. Table 5-3 shows a range of costs for implementing the E3 scenario. It is correct that there is some uncertainty in these costs and that future technologies will also play a role in driving costs that cannot be adequately estimated.
E.8.11	The discussion of the TMDL and its implementation measures uses tautological arguments that are not convincing. The argument repeatedly presented is that, because the TMDL is designed to achieve success and meet water quality goals, implementation of the implementation plans and associated practices must by definition lead to the water quality goals. This is further assured, we are told, because of periodic monitoring that leads to readjustments in implementation plans over time. However, not until chapter four do we learn that this is not possible—in other words, verifiability is not possible--because the nature of the nitrogen and phosphorous pollution problem itself and its legacy effects with the hydrologic system. This same tautological argument can be constructed for every option that one can conceive to address water quality problems in the Bay.	See response to comment E.8.1.
E.8.12	The report, Table 4-1 presents practices that are not defined and hence cannot be independently evaluated as to their likely effectiveness. For example, what does "improved nitrogen management" mean in practice. And if it is so improved, why is the practice not already adopted since nutrients are a cost to a farmer? Similarly, what does "improved conservation practices" mean? Again, if they really are improved, then there should be some discussion as to why they have not been adopted by a rational person.	Table 4-1 represents a very general summary of strategies incorporated into different states' WIPs. For further information on the specifics of the strategies for each state, please see the links (in Chapter 4.1) to the Phase II WIPs for each state.
E.8.13	The report contradicts itself repeatedly. It makes the argument that a Conowingo at dynamic equilibrium is not important but then states a Conowingo at dynamic equilibrium necessitates revision of the TMDL in order to achieve water quality. If a revision to the TMDL is already needed (page 97), then clearly it is important and the conclusions are wrong. Which is it? The science presented in the report suggests that the conclusion is unsupported and thus just plain wrong.	See response to comment E.8.1.
E.8.14	The report fails to acknowledge the unique opportunity to change the management of a key component in the ecosystem of the Bay—i.e., the node at a critical juncture point represented by the Conowingo Dam. Instead of presenting and examining innovative options for how to use this opportunity for improvements in the protection of the resilience of the system, it recycles old tautological arguments for staying the course and just focusing on implementation of the Chesapeake Bay TMDL. In doing so, it sheds no new light on what the path forward should be.	See response to comments E.8.1, E.8.2, and E.8.3.

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
E.8.15	For example, there could and should be discussion of options for reducing the volume of stormwater laden with sediment and nutrients that surge through the system at times of extreme weather events. Such options could include arrangements or contracts with farmers and landowners on lands adjacent or directly connected to the river to allow for temporary water storage at times of anticipated high flow. Thus temporary storage could serve to reduce the volume of water at key high flow times through the reservoir and the dam and to slow down and allow for settling out of sediment and associated nutrients in areas upstream from the reservoir. Examining a broader array of options than what the Corps of Engineers traditionally identifies is in fact now since December 2015 a requirement [See http://www.whitehouse.gov/administration/eop/ceq/initiatives/PandG/] For a discussion of how more storage capacity can be effected, please see http://www.jswconline.org/content/55/3/285.short. See also http://www.rff.org/Publications/WPC/Pages/Options-Contracts-for-Contingent-Takings.aspx and On Risk and Disaster: Learning from Hurricane Katrina by Ronald Daniels, Donald Kettl, and Howard Kunreuther.]	Comment noted. The focus of the assessment was to analyze the movement of sediment and associated nutrient loads within the lower Susquehanna River watershed, including the reservoir at Conowingo Dam and the capacity of the dam to trap sediment. As such, the assessment did not evaluate strategies to reduce the volume of water passing the dam, although watershed strategies to reduce sediment will likely also help reduce stormwater flows to Chesapeake Bay.
E.8.16	In conclusion, the report, as it is currently written, does not adequately address public and interested party concern regarding the loss of sediment storage capacity behind the dam nor does it illuminate options for managing the dam for future protection of the Bay ecosystem. We recommend engaging a broader set of stakeholders, such as the National Capital Chapter of the Soil and Water Conservation Society and other professional organizations that deal with the conservation of soil and water resources, in reviewing and drawing new conclusions from the data that exist that pertain to the issue.	Comment noted. Appendix I-1 and I-2 outline public outreach activities. Through press releases, distributed emails, presentations to stakeholder groups, the public meeting, and the public comment period, the study process attempted to engage as many interested stakeholders as possible.

Comment Code	Comment	Comment Response
E.10	The SWQAC commends the U.S. Army Corps of Engineers, Baltimore District (USACE), and the Maryland Department of the Environment (MDE) and multiple partners, on the objective science and research performed and summarized in this document. The report provides much needed information for management decisions to ensure water quality is protected and improved. The SWQAC supports the four specific recommendations outlined on ES-5 and section 8.1 'Future Needs and Opportunities in the Watershed'. Furthermore, the SQWAC recommends that reliable and sustainable sources of funding, staffing and commitments should be secured to ensure the recommendations are fully implemented. In addition, we support the continued efforts of WIPs in recognition that 89 of the 92 Bay segments might achieve water quality goals by 2025, given the Lower Susquehanna is just one of multiple stressors on the Bay. We also recommend that the findings from the Report and any new information on the impacts of Conowingo Dam reaching "dynamic equilibrium" be used to inform the Chesapeake Bay TMDL 2017 Mid-Point Assessment.	Comment noted.
E.11	We appreciate the opportunity to comment on the Lower Susquehanna River Watershed Assessment and want to extend the U.S. Fish and Wildlife Service's support of the findings in accordance with the provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). We agree with the Future Needs and Opportunities in the Watershed and look forward to the reporting of those outcomes. It is critical that we understand how sediment and nutrients impact Chesapeake Bay water quality and health. The Chesapeake Bay is a national treasure and we support any findings to help clean up and restore the health of the Bay and enhance fish and wildlife resources. Again thank you for the opportunity to review and comment on the assessment.	Comment noted.
CCC-L-1	The Maryland counties that have combined their efforts and resources in order to address concerns relative to the improvement of the water quality of the Chesapeake Bay in a meaningful and cost effective manner known as the Clean Chesapeake Coalition ("Coalition") 1 provide their comments and concerns with the Draft Lower Susquehanna River Watershed Assessment ("DLSRWA") 2 collectively instead of separately and individually. The Coalition appreciates this opportunity to provide comments.	The study partners appreciate the coalition's comments on the LSRWA.

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
CCC-L-2	The Coalition counties and their representatives have been precluded from participating in the scoping of the study underpinning the DLSRWA report and the quarterly progress meetings reviewing the progress of such studies and the report. At the quarterly progress meetings, critical decisions have been made about the scope and direction of the study, the information to be considered during the study, the underlying assumptions on which the modelling and study efforts have been predicated and the conclusions to be determined and reported based on the study and modelling results. Coalition members have requested to have meaningful input into this process and have been denied that opportunity by U.S. Army Corps of Engineers ("USACE") and the Federal and State agencies and private persons (includ ng Exelon and Exelon's representatives) that are undertaking the Lower Susquehanna River Watershed Assessment ("LSRWA"). Indeed, handpicked "stakeholders" such as Exelon and The Nature Conservancy were afforded several months to review the draft report and appendices before its release while local government officials of the Coalition counties, along with the general public, got their first look in mid-November 2014 and have been pressed to review and analyze the roughly 1,500 pages that comprise the DLSRWA to meet today's public comment deadline.	The study began in September 2011 with the execution of a cost-sharing agreement between USACE and MDE, and the first quarterly team meeting for the study was held in November 2011. The team was first contacted by the Clean Chesapeake Coalition in February 2013. The study process was open to the public. All quarterly team meetings were open to the public and all meeting agendas, materials, and minutes were posted on the study website as soon as available. It appears that through a misunderstanding with one of the study partners, CCC feels that they were denied access to the meeting; however, CCC was not prohibited nor prevented from attending the quarterly meetings. As soon as the coalition's interest was known, CCC was included on the mailing list for email distribution of study notices. The team conducted many stakeholder briefings and presentations regarding the study, its progress, and findings, and attempted to involve stakeholders and the public as much as possible, including through this public comment process. Therefore, there was substantial opportunity to provide input to the study process.
CCC-L-3	Coalition counties have been mandated by the Maryland Department of the Environment and the Maryland General Assembly with planning, funding and implementing nutrient and sediment load allocation reductions in order to enable Maryland to meet the objectives of the U.S. Environmental Protection Agency 's ("EPA") 2010 Chesapeake Bay TMDL ("2010 Bay TMDL"). Given the necessary role of Maryland local governments in the Bay restoration program *(i.e.,* watershed implementation plans), the concerns of the Coalition counties with the DLSRWA must not be ignored. Otherwise, we will continue spending billions of dollars to earn D+ "State of the Bay" report cards from the Chesapeake Bay Foundation for years to come. [3]	Statement noted; no response required.
CCC-L-4	The human environment *(e. g.,* the economic, social and cultural, and natural environments) of the Coalition counties has been and will continue to be directly impacted by the conclusions and results of the LSRWA. Such conclusions and results are being used to direct the Environmental Impact Statement being prepared in the Federal Energy Regulatory Commission's pending relicensing of the Conowingo Hydroelectric Project and the relicensing of other power projects in the lower Susquehanna River, and will inform the EPA's 2017 recalibration of load allocations under the 2010 Bay TMDL.	Concur. The Chesapeake Bay Program partners have publicly committed to factoring in the findings from the Lower Susquehanna River Watershed Assessment within the Chesapeake Bay TMDL 2017 midpoint assessment to inform the collaborative decision-making process.

Comment Code	Comment	Comment Response
CCC-L-5	The USACE and the other Federal and State agencies who have conducted the LSRWA have failed to coordinate with the Coalition member counties in the preparation of the LSRWA and have deprived them of their rights under the National Environmental Policy Act ("NEPA") and the Federal Advisory Committee Act ("FACA") as well violating a number of U.S. Presidential Executive Orders in the manner in which the study and report processes has been conducted to date. The Coalition counties urge USACE and the participating Federal and State agencies to revise their approach as they move forward with the LSRWA.	The activities of the various study committees for this effort are statutorily exempt from FACA, either quite explicitly, or as confirmed by a number of federal court cases. Representatives of the Clean Chesapeake Coalition attended at least some of the public meetings of the main committee, whose minutes were posted promptly on a widely distributed project website (http://mddnr.chesapeakebay.net/LSRWA/index.cfm). The LSRWA does not qualify as a "federal action" for the purposes of NEPA; no official policy is being adopted; no formal plans or programs are being adopted; and no specific projects are being recommended, let alone approved. See Title 40, Code of Federal Regulations, §1508.18.
CCC-L-6	The Coalition counties observe with interest the report detailing the concerns of the Scientific and Technical Advisory Committee (STAC) of EPA's Chesapeake Bay Program with respect to the DLSRWA and generally concur with all of the STAC's comments and concerns, which have yet to be adequately addressed.4 It is disingenuous for any person familiar with the STAC report to suggest that the DLSRWA has been favorably peer reviewed or has been endorsed by the scientific community.	We have checked and ensured that all STAC comments have been addressed and incorporated as necessary into the final report. Please see the Chesapeake Bay Program Partnership's Management Board's formal response back to STAC on how the partnership addressed each comment. We do believe that review by the scientific community has been favorable based on comments submitted by other agencies and organizations. The study partners also realize that there is uncertainty associated with the report findings and that additional monitoring and modeling efforts will be necessary to fully quantify the Conowingo impacts. This information will be reassessed during the 2017 midpoint assessment process to determine any additional steps necessary for reaching full Chesapeake Bay water quality standards attainment by 2025.

Comment Code	Comment	Comment Response
CCC-L-7	We take issue, however, with one observation made by the STAC and with one issue overlooked by the STAC. The STAC suggests that the harm caused by an increased loading of sediments due to scour from the floors of the reservoirs behind the hydroelectric dams in the lower Susquehanna River will not be as harmful as the nutrients bound to the sediments, particularly phosphorus, to the Bay estuary. In their 2012 Native Oyster Restoration Master Plan USACE has documented the harmful impact of sediments to the habitat necessary to allow bivalves (oysters, clams and mussels) to reproduce in the Bay.[5] The watermen working out of the Coalition counties on the Bay will testify about the harmful impact of the massive quantities of sediments entering the Bay during significant storm events such as the storms events of 2011 and how such events have devastated the habitat for bivalve breeding and have suffocated hibernating crabs and destroyed the SAV necessary to protect young of years crabs from predators. We observe that while the scientific credentials of the 11 member STAC team that reviewed the DLSRWA are not disclosed, none appear to have any, or an extensive, background in the marine science of bivalves or blue crabs. The National Oceanic and Atmospheric Administration and the U.S. Fish & Wildlife Service should be consulted before making such sweeping generalizations.	The STAC review does point out that sediment is a problem as well as nutrients, but that suspended sediment is a localized and episodic problem. Whereas, the water quality problems from scoured nutrients are more long-term, persistent, and widespread, i.e., lasting an entire summer hypoxia season and covering the contiguous region of deep-water and deep-channel designated uses in the Chesapeake. Information on the background and affiliation of the STAC team can be found on pg. 5 of their report in Appendix I-7. Coordination was performed with aquatic resource agencies, including NOAA (National Oceanic and Atmospheric Administration), Pennsylvania Fish and Boat Commission, U.S. Fish and Wildlife Service, and Maryland Department of Natural Resources (MDNR). With regard to submerged aquatic vegetation (SAV), after exceeding the goals for submerged aquatic vegetation in the northern Chesapeake Bay (segment CB1TF) for 2008-2010 and reaching a peak of 436.58 hectares in 2009, Bay grass acreage decreased to 342.34 hectares in 2010, to 201.09 hectares in 2011, and to 186.51 hectares in 2012. Since then, SAV area in CB1TF increased to 229.81 hectares in 2013, and preliminary data indicate that 2014 will have more than 2013. Thus, while SAV coverage in CB1TF decreased following Tropical Storm Lee, SAV was not "destroyed" and coverage now appears to be increasing. In addition, while there are occasional storm events that generate large plumes of sediment and deposition in the upper Bay, long-term (1985-2013) and short-term (2003-2013) trends in total suspended sediment measured at the USGS (U.S. Geological Survey) stream gage at Conowingo Dam are not statistically significant. The University of Maryland Center for Environmental Science (UMCES) did conduct an analysis of the sediment distribution from Tropical Storm Lee in the upper Chesapeake Bay. This report indicated that the majority of the sediment deposition was in the upper Bay, directly below the Susquehanna Flats. In general, less than 1.5 cm of sediment was deposited downstream of this area. The UMCES report can be found at Palinkas, C.M., et al., Sediment deposition from tropical storms in the upper Chesapeake Bay: Field observations and model simulations. Continental Shelf Research (2013), http://dx.doi.org/10.1016/j.csr.2013.09.012i . The MDNR assessment was based on observations of live fouling organisms, including barnacles, mussels, and bryozoans, that were found attached to the oysters and shells on oyster bars in the northern Bay. Had the oysters been smothered by sediment, these organisms would not have been able to attach to the oyster shells and would not have survived.
CCC-L-8	Neither the STAC nor the persons conducting the LSRWA have given any consideration to the toxic pollutants that are documented (*see* Susquehanna River Basin Commission reports to the Maryland Department of the Environment) as being in the sediments impounded in the reservoirs behind the hydroelectric power dams: herbicides; pesticides; sulfur and acid mine drainage; coal; PCBs; and other aromatic hydrocarbons and heavy metals, in addition to the nitrogen and phosphorus bound in such sediments. Such toxic pollutants must be accounted for in determining the impact of scour and in undertaking a benefit cost analysis of dredging above the dams in the lower Susquehanna River.	This is not entirely correct. In evaluating whether sediments behind the lower Susquehanna River dams could be used for beneficial reuse, the LSRWA study partners looked at sediment chemical analyses (mostly metals) data. In general, however, the assessment focused on the nutrients associated with sediments and did not evaluate other potential contaminants. Chapter 5.4.3 briefly discusses heavy metals found in sediment cores with regards to the beneficial reuse of dredged sediments. Additional study is needed on other potential contaminants and on the biologic activity of these contaminants, including nutrients, as they are released from sediments. It is expected that sampling over the next 2 years will detail this information.

Comment Code	Comment	Comment Response
CCC-L-9	The initial pages of the attached comments and concerns provide a slightly more comprehensive overview of the comments and concerns of the local government members of the Coalition. The latter pages contain more detailed questions, comments and concerns focused on the individual portions of the DLSRWA and the attached appendices. The Coalition members expect that the comments presented in each section of the attached review will be considered and addressed.	All coalition comments have been considered and addressed.
CCC-L-10	Given the predictive failure of the HEC-RAS and AdH models, upon which the major findings and conclusion of the DLSRWA are predicated and the reported fact that the underlying goals and objectives of the LSRWA were changed in midstream, the DLSRWA undisputedly is a mishmash of information rapidly cobbled together in a report and appendices in order to fulfill a political agenda. The DLSRWA is not scientifically sound and does not achiever valid objectives and outcomes. The Coalition urges the USACE and the other Federal and State agencies utilizing the report in conjunction with relicensing and regulatory objectives to restart the process and to proceed in legal compliance with NEPA, FACA, the regulations of the Council of Environmental Equality implementing NEPA, and the applicable Executive Orders.	All scientific studies contain some uncertainty and the predictive ability of models is heavily dependent upon empirical data. However, the modeling tools used in the assessment are considered by experts to be some of the best available. The question of scientific soundness raised is a matter of opinion made without any substantive evidence to support that opinion. Given that the LSRWA report was independently peer reviewed as to its scientific soundness, the commenters would have to provide more evidence to support their conclusion. As to the study goals, the LSRWA adapted to study findings as they were revealed. Specifically, the finding that the nutrients were more of a water quality issue than the associated sediments influenced both the study direction and overall recommendations. The criteria for the LSRWA were established by § 729 the Water Resources Development Act of 1986, as amended (33 U.S.C. 2267a; 114 Stat. 2587–2588; 100 Stat. 4164, Public Law 99-662). As such, no executive orders were violated in order to execute the terms of the statute. Please see our response to comment CCC-L-5 above. Also, please note that the National Environmental Policy Act of 1969 established the President's Council on Environmental Quality, not the Council of Environmental Equality.
CCC-L-11	There is no denying that the hydroelectric power dams in the lower Susquehanna River have profoundly altered the lower Susquehanna River estuary and the Chesapeake Bay estuary. If the ongoing impact of the dams and the other power projects in the lower Susquehanna River are not addressed, the downstream efforts and expenditures undertaken by Marylanders will not achieve meaningful and lasting improvement to the upper Bay or overall Bay water quality.	Comment noted; this is one of the reasons that the LSRWA was initiated. However, it was found that most of the sediment comes from the watershed, not from scour behind the dams.
CCC-L-12	The Coalition counties have suggestions about how a natural oyster bed cultivation and seeded shell relocation program could serve as a viable and cost effective alternative to full-scale dredging behind the dams. Again, if a proper NEPA process is instituted, such alternatives could be preliminarily scoped and given due consideration. The failure to adhere to such legal mandates will be more expensive and cause greater delay and expense for all involved in the long run.	Comment noted and any suggestions offered by the coalition will be considered. Regarding the NEPA process, please see response to comment CCC-L-5. Note that any "natural oyster bed cultivation and seeded shell relocation program" would have to be located well south of the upper Bay, because oyster growth and reproduction are limited or non-existent in the low salinities areas of the Bay.

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
CCC-1	The Lower Susquehanna River Watershed Assessment ("LSRWA") was originally undertaken in 2011, before a number of Maryland counties coalesced to form the Clean Chesapeake Coalition (the "Coalition") in last quarter of 2012 and began to shine the spotlight on the problem of scour from the floors of the reservoirs behind the three major hydroelectric power dams in the lower Susquehanna River: the Safe Harbor Dam (Lake Clarke is the reservoir behind that dam); the Holtwood Dam (Lake Aldred is the reservoir behind that dam) and the Conowingo Dam (the Conowingo Pond is the reservoir behind that dam).1 The Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment, Dec. 29, 2010 ("2010 Bay TMDL") was published in December 2010 and concluded that Lake Clarke and Lake Aldred already had reached dynamic equilibrium,2 but that the Conowingo Pond would not reach dynamic equilibrium until sometime between 2025 and 2030. The United States Environmental Protection Agency ("USEPA"), therefore, erroneously concluded in the 2010 Bay TMDL that 50% of the sediments flowing down the Susquehanna River would continue to be trapped in the Conowingo Pond. The LSRWA study originally was undertaken by the United States Army Corps of Engineers ("USACE") and the Maryland Department of the Environment ("MDE") to begin to consider the impact that the sediments accumulating in the three reservoirs would have once the Conowingo Pond reached dynamic equilibrium some 15 to 20 years down the road. There was no urgency to the study and there was very little in funding procured for the study.	Comment noted.

Comment Code	Comment	Comment Response
CCC-2	The issue of what would happen when dynamic equilibrium was reached was always "the elephant in the room'' that the regulatory agencies and NGOs have avoided addressing, because it was too complicated and there is no existing legal framework that empowers the Federal or State regulators to directly address the problems that will result from such eventuality. Today, there is no commitment, plan, responsible party or budget to specifically address the devastating amounts of nutrients, sediment and other contaminants that are scoured into the Chesapeake Bay during storm events and in equally harmful proportions now on a regular basis.	Agencies at all levels have been aware of and discussing the issue of sediment behind the dams for decades. Furthermore, the Chesapeake Bay TMDL and associated watershed implementation plans form the regulatorily binding plans to make sure these sediments and associated nutrients are addressed. The 2010 Bay TMDL also includes an appendix (Appendix T) that specifically identified the issues associated with Conowingo infill, and the 2017 midpoint assessment process will include a refined Bay model and additional monitoring data to address Conowingo Dam impacts. The states, through their Clean Water Act permitting authority, have the necessary mechanisms to make sure that point sources are appropriately addressed by responsible parties. The states' non-point source programs use non-regulatory mechanisms such as funding, cooperative partnerships, and management plans to address those sources. Chapter 2 of the draft LSRWA report described many of these items in detail. Even though the dams have reached dynamic equilibrium, they will act as sinks most of the time and as sources at other times during major storm events. The annual average total suspended sediment loads based on monitoring data from USGS for 1987 through 2012 for the Susquehanna River load monitoring sites at Marietta, PA (USGS gage number 01576000) and Conowingo, MD (USGS gage number 01578310) indicate that loads at Conowingo exceeded Marietta in only two years, 2004 (Hurricane Ivan) and 2011 (Tropical Storm Lee). This is despite an increase in the watershed area, from 25,990 mi^2 at Marietta, PA to 27,100 mi^2 at Conowingo, MD. These data show that in 24 of the last 26 years, sediment loads, on average, decrease from Marietta to Conowingo, which implies that sediment was stored behind the dams unless there was a storm of such magnitude that it results in sediment being scoured from behind the dams. It is estimated that even under the condition of dynamic equilibrium, scour represents 30 percent of the sediment load. Storms large enough to generate large amounts of scour are estimated to have a recurrence interval of 5 years, which is not "now on a regular basis." We recommend that the coalition counties review the complete public record, which shows a 20-year history of the resource agencies addressing this issue. Important documents include, but are not limited to, a 1995 USGS / SRBC report, the SRBC Sediment Task Force Recommendations of 2002, a 2009 USGS report, and the FERC relicensing documents. All of this scientific data and information, including the LSRWA report, will be used to inform the TMDL 2017 midpoint assessment.

Comment Code	Comment	Comment Response
CCC-3	In 2008, the Chesapeake Bay Foundation, in a friendly lawsuit, sued USEPA to make it use its authority under the Clean Water Act to promulgate a total maximum daily load ("TMDL") for the Chesapeake Bay, in order to take control of the agenda for the clean-up of the Bay. In settlement of the lawsuit, USEPA generated the 2010 Bay TMDL and assigned to each Chesapeake Bay watershed state load allocations for the amount of nitrogen, phosphorus and sediments that each state would have to remove from the amount of such pollution currently being discharged to Bay tributaries. After the State of Maryland received its load allocation under the 2010 Bay TMDL, it determined that in excess of $14.5 billion dollars would have to be spent to meet its load allocation obligations. The State was unwilling to redirect its spending and/or to pass the additional taxes and fees necessary to fund this unprecedented obligation. The State, therefore, required each Maryland county to prepare a watershed implementation plan ("WIP") for meeting the 2010 Bay TMDL load allocation assessed against Maryland by USEPA and, among other mandates, passed legislation requiring the largest counties to adopt stormwater management fees (aka "rain tax") to raise the money necessary to implement the WIPs.	The commentors are correct that the stormwater management fee legislation was a key initiative that the state used to assist local jurisdictions in meeting their stormwater permit requirements to restore the Chesapeake Bay. In addition to this fee, Maryland has many other existing fund sources to provide for Bay restoration such as the Chesapeake and Atlantic Coastal Bays Trust Fund, the Chesapeake Bay Trust, and the Section 319 program to address non-point sources of pollution. Also, the Maryland Agricultural Water Quality Cost-Share Program provides farmers with grants to cover up to 87.5 percent of the cost to install best management practices on their farms to prevent soil erosion, manage nutrients, and safeguard water quality in streams, rivers and the Chesapeake Bay. For point sources, the Bay Restoration Fund fee is used to upgrade major wastewater treatment plants and address septic system pollution. The Watershed Assistance Collaborative helps local partners leverage all of these existing fund sources for watershed restoration activities. Other initiatives, such as nutrient trading, are also being pursued to help create market-based mechanisms to fund Bay restoration projects. The combination of funding and market-based approaches are anticipated to fully fund Bay restoration.
CCC-4	As counties undertook the WIP process and began examining what MDE and the Maryland Department of Natural. Resources (MDNR) were doing and requiring counties to do in order to address Maryland's load allocation under the 2010 Bay TMDL, they recognized how useless the regulatory initiatives would be in making any meaningful improvement to the water quality of the Bay and how expensive, unproductive and inequitable Maryland's regulatory initiatives have been and would continue to be. They also recognized that the largest problems contributing to the pollution of the Bay were being ignored.	The Maryland Departments of Environment and Natural Resources do not agree that regulatory programs are useless. On the contrary much of the progress in meeting Maryland's restoration goals are coming through wastewater sector regulation and funding. Water quality data collected and analyzed by MDNR clearly document improvements to water quality following upgrades to wastewater treatment plants to secondary treatment, BNR, and now ENR. Banning phosphate in detergents also played a major role in helping to reduce phosphorus loads to the Bay's tributaries. The data that document these improvements in nitrogen and phosphorus are available on the Chesapeake Bay Program website and CCC is encouraged to review these data. There is only so much that can be done by improving wastewater treatment, which is why it is important to control nutrients and sediment from non-point sources throughout the watershed.
CCC-5	One of the largest problems being ignored was the impact of scour from the floors of the reservoirs behind the three hydroelectric power dams in the lower Susquehanna River during storm events. During storm events, suspended solids that were trapped behind the dams during low flow and normal flow conditions are agitated, become re-suspended in the river and flow into the Bay. Over the course of a 2 - 8 day storm event, including the high flows that are generated by runoff from the storm, as much as one-half-year to 12+ years of the average loading of suspended solids from the Susquehanna River are scoured and dumped in the upper Bay *(i.e .,* the Maryland portion of the Bay) over such 2 - 8 day period. Such massive loading over such a short period of time has a devastating impact, and a much greater impact than if such solids flowed into the Bay when they originally became suspended in the river.	Comment noted. As mentioned in the LSRWA findings, the nutrients associated with the Conowingo sediments have a greater impact on Chesapeake Bay water quality. Based on monitoring data from USGS, the 1981-2012 average annual load measured at Conowingo Dam is 1,886,875 tons per year and the load for 12 years would be 22,642,500 tons, so the 12+ years of average loading must be referring to Hurricane Agnes, which was quite devastating, but also an unusual event (return period of 60 years).

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
CCC-6	Reports studying the impact of Hurricane Agnes on the Bay published by the Johns Hopkins University Press in 1978 concluded that 56% of the sediments flushed into the Bay during the hurricane were scoured from the floors of the reservoirs behind the hydroelectric power dams in the lower Susquehanna River- 20 million tons of sediments out of the 32 million tons of sediments flushed into the upper Bay from the Susquehanna River by the hurricane.	Comment noted. See response to comment CCC-5 above.
CCC-7	In August 2012, Robert M. Hirsch of the Department of Interior's U.S. Geological Survey ("USGS") published a report concluding that the Conowingo Pond had virtually reached dynamic equilibrium.[3] In presenting the report, Mr. Hirsch discussed the scour phenomena but advised that the bathymetric data *(i.e.,* raw data of the depth from surface to floor of the reservoirs before and after storm events) did not exist. The bathymetric data necessary to determine the amount of scour during different storm events still does not exist and has never been generated. Exelon, in the pending Federal Energy Regulatory Commission ("FERC") relicensing proceeding for the Conowingo Hydroelectric Project, has requested a year-to-year extension of its current license while it collects the bathymetric data after storm events necessary to engage in meaningful modeling and prediction.[4]	Comment noted. The agencies agree that bathymetric information immediately before and after storms would be useful. Pre and post-storm bathymetry surveys have been incorporated into a multi-agency monitoring program to fill the data gaps/uncertainties. This additional monitoring is currently underway.
CCC-8	Different persons are reporting that the LSRWA Draft Report ("DLSRWA") concludes that scour from the floor of the reservoir of the Conowingo Pond is not a significant source of pollution to the Bay. Such a conclusion, as discussed more fully below, is devoid of any scientific validation and support. The raw data necessary to make such a determination is nonexistent. There is no bathymetric data sufficient to enable a scientifically valid determination of the amount of scour from the floors of the reservoirs behind the hydroelectric power dams in the lower Susquehanna River. There is no scientific data on which to predicate a determination of the volume of nutrients bound to sediments in the Susquehanna River or what percentage of such bound nutrients become bioavailable when such scoured sediments are flushed into the Bay.	This is not entirely correct. The LSRWA collected sediment cores and determined associated shear stresses in order to predict Conowingo scour using the AdH model. The study concludes that reservoir scour does contribute a sizable amount of sediment to the Bay in addition to what is already entering the system from the watersheds. That contribution varies depending on the flow. See response to comment CCC-19. The assessment's modeling efforts estimated that during a major storm event, approximately 20 to 30 percent of the sediment that flows into Chesapeake Bay from the Susquehanna River is from scour of bed material stored behind Conowingo Reservoir. We concur that additional study is needed on the bioavailability of nutrients attached to scoured sediments.
CCC-9	When the LSRWA was undertaken, the impact of scour on the Bay was not an issue. That issue became a hot topic because it was raised in the FERC relicensing proceeding for Conowingo Dam by the Coalition and because the Coalition has focused public attention on the issue.	The LSRWA was undertaken at the request of the project partners, not FERC. While the assessment analyses began in fall 2011, coordination on the sediment scouring issue dates back to the SRBC's Sediment Task Force in 1999, and was identified by the resource agencies early (2009) in the FERC relicensing process as a significant issue that needed to be addressed.
CCC-10	(A) Instead of dredging sediments from behind the dams from the Bay after they have been flushed into and dispersed throughout the upper Bay causing damage to the marine environment and fisheries of the Bay, such sediments should be dredged from above the dams (thus ensuring that such pollution never reaches the Maryland portion of the Bay).	Comment noted. The assessment evaluated strategies for managing sediment behind the dams. Findings are provided in Chapter 8.

Comment Code	Comment	Comment Response
CCC-11	(B) Before Marylanders spend billions of dollars to implement clean-up programs that can be rendered completely useless by scour from a significant storm event and pollution above the dams, the harm caused by above the dam sediments and pollution needs to be addressed. It is a fool's errand to spend money on band-aids to cover superficial cuts before stopping the bleeding from the artery; and that is precisely what is happening when billions of tax dollars are spent on *de minimus* issues downstream while nothing meaningful is done to abate the harm above the dams.	See response to CCC-2. The findings of the LSRWA indicate that high flow events, such as Tropical Storm Lee, can have an impact on water quality (see Chapter 8); however, these impacts were short-lived and confined to locations mostly within the upper Bay. The findings do not support the notion that high flow events from the Susquehanna will render other clean-up programs useless. The Susquehanna River is just one of many tributaries to the Bay that provide sediment and nutrient loading. Although Tropical Storm Lee did result in the release of a significant amount of sediment from behind the dams and from the watershed, it was an unusual event. Flow at Conowingo Dam during Tropical Strom Lee was the "second largest annual maximum daily discharge recorded for water years 1968-2011" as reported in USGS's Scientific Investigations Report 2012-5185. Also note that Marylanders are not the only people being asked to spend considerable amounts of money to clean up the Bay and to imply otherwise is false. In addition, it is estimated that on average the Susquehanna River contributed 27 percent of the sediment load to the Chesapeake Bay during 1991-2000 as reported in USGS's Scientific Investigations Report 2012-5185. That leaves 73 percent coming from other sources which is hardly "de minimus."
CCC-12	Years worth of the average annual loading of sediments and nutrients have been discharged from the Susquehanna River into the Bay in the matter of days during recent storm events. If the sediments and nutrients are not from scour, they are from upstream (above the dams) sources. None of the other states in the Chesapeake Bay watershed have adopted wastewater treatment discharge limits that are close to as stringent as those imposed on Maryland by MDE. None of the other states in the Chesapeake Bay watershed have stormwater management requirements that are as demanding and expensive to meet as those in Maryland. No other state in the Chesapeake Bay watershed has a "phosphorus management tool" that is as stringent and as costly to comply with as that mandated by the recently re-promulgated Maryland regulations. No other state in the Chesapeake Bay watershed has individual septic requirements that are as stringent and costly to comply with as Maryland. The above has been true for several decades, yet the additional expenditures paid by Marylanders have not resulted in any meaningful overall improvement to the water quality of the Bay. Instead, such regulations and expenditures have driven businesses and residents out of Maryland and caused fatigue among those being taxed to "save the Bay."	See response to CCC-11 and CCC-4. The Chesapeake Bay is comprised of a 64,000-square mile watershed covering six states and the District of Columbia. As a result, the actions by a single state will not result in overall Bay restoration and the collective actions of all states, even if implemented today, have ecological lag times before resulting in improved water quality. Maryland believes that the other states in the Bay watershed will ultimately have to mirror Maryland's programs, and likely go further, to meet the Bay TMDL requirements. However, water quality in Maryland's local streams and rivers will have more immediate responses to actions taken in Maryland. In the Patuxent River, for example, long-term sediment, nutrient and phosphorus levels are decreasing (see USGS studies at http://cbrim.er.usgs.gov/trendandyieldhighlights.html), demonstrating that Maryland's water quality programs are working. The continued success of these programs in Maryland supports local economies, the commercial fishery, and tourism sectors, as well as make Maryland a desirable place to work, live and recreate. Citizens of the headwater states are being asked to do their share to clean up the Bay, even though they do not receive the recreational and economic benefits that Maryland does, so perhaps Maryland should take the lead on implementing stringent regulations to protect their resource. In addition, a pound of sediment or nutrients released from a headwater state does not have the same impact as a pound being released from a Maryland tributary. There are physical and biological processes that mitigate the impact over the miles it takes for sediment and nutrients to reach the Bay from the headwaters.

Comment Code	Comment	Comment Response
CCC-13	The DLSRWA attempts to minimize the significance of scour to the Bay without adequate scientific underpinning. Regulatory agencies and environmental organizations are stating that the DLSRWA concludes that the problems at the Conowingo Dam are not as bad as scientists thought. The statement is almost laughable because the problem had been completely ignored until it was raised by the Coalition. No thought was given to the problem, and now the problem is recognized as real such that MDE has required Exelon to engage in additional data compilation and studies before MDE will even begin its consideration of the Section 401 Clean Water Act water quality certification needed by Exelon in the FERC relicensing process for Conowingo Dam. What is disconcerting for the reasons explained more fully below is that the DLSRWA discusses predicted minimum impacts instead of discussing the full range of impacts discussed in the projections underpinning the report.	See response to comment CCC-9. Also, the findings of the assessment (see Chapter 8) indicate that the loss of long-term sediment trapping capacity is causing impacts to the health of the Chesapeake Bay ecosystem, but that these impacts are due primarily to nutrients associated with scoured sediments. To understand the full range of impacts to the bay, additional monitoring and study is needed as outlined in Chapter 8.1 Recommendations.
CCC-14	The work underpinning the DLSRWA is a misguided exercise in modelling. Considerable time and effort has been spent discussing and manipulating models to generate meaningless results instead of gathering and modeling meaningful information.[5] At least nine (9) different models were used to generate data for use in other models and for making predictions and estimations: (1) The Chesapeake Bay Environmental Model Package (CBEMP) is used to project the water quality of the Chesapeake Bay. That model is predicated on a suite of models consisting of: (a) A watershed model (WSM); (b) A hydrodynamic model (HM); (c) A water quality eutrophication model (WQM); (2) A computational hydrodynamics in a three-dimensions model (CH3D); (3) A USACE integrated compartment water quality model (CR-QUAL-ICM), which model is predicated on a suite of models consisting of: (a) An ICM model; (b) A WQM model; and (c) A WQSTM model;[6] (4) An adaptive hydrodynamics model (ADH), which was used for estimating sediment erosion in the Conowingo Pond based on projected data derived from other models; and (5) A hydrodynamic engineering center river analysis system model (HEC-RAS), which was used to generate a rating curve for use in the ADH.[7]	Yes, these models were used in the assessment analyses. While all models have limitations, the team has confidence in the estimates provided by each of the models as all the models have been used extensively in the past, including for TMDL development, and are vetted by the scientific community. Additionally, the models were calibrated with real observations. Additional data from the recommended enhanced monitoring will be used to further refine the models. All models are limited by both the simplifications inherent in the model development, and the uncertainties associated with parameterization of unknowns, and initial and boundary conditions. This assessment used models to gain insight into the governing processes associated with the Conowingo Reservoir, with full recognition of the limitations of this or any modeling effort. Models provide insight; they do not predict the future. Although more data are always of benefit, the primary conclusions reached by this study are corroborated by multiple modeling efforts and data analyses, and are therefore robust.

Comment Code	Comment	Comment Response
CCC-15	What little raw data was used in the CBEMP model was generated from raw data collected in the period from 1991 - 2000.[8] This outdated data as well as data generated by other models not designed to determine scour was used to run applications under the ADH for 2008 - 2011 timeframe. The ADH was run to project the amount of scour from the floors of the Conowingo Pond and Lakes Aldred and Clarke that serve as the reservoirs behind the three major hydroelectric power dams in the lower Susquehanna River: the Conowingo Dam, the Holtwood Dam and the Safe Harbor Dam.	There are data collected over a wide range of dates, some as recently as 2012, used in this analysis. AdH is only used to analyze scour in the Conowingo Reservoir.
CCC-16	Peter Moskos, a Harvard educated criminologist, author and professor, made a comment that appropriately captures the deficiency of the modelling exercises underpinning the DLSRWA: "And if you have bad data, it doesn't matter what fancy quantitative methods you use. It's putting lipstick on the damn pig of correlation." In short, a modelling conclusion is only as good as the data underpinning the modelling effort. When the data needed to generate a predictive model does not exist, the predictive conclusions generated from a cluster of other models used to generate data for use in the predictive model are meaningless.	The best available models and data were used to develop the LSRWA findings and will be further improved with the current ongoing research for the Conowingo Reservoir.
CCC-17	Nowhere does the DLSRWA concisely list the raw data underpinning the reported results of the ADH modelling efforts. Nowhere does the DLSRWA clearly describe what actual data was used in what manner to generate the data on which particular modelling exercises were run. To provide such data would expose how the findings and conclusions of the DLSRWA are superficial.	Each modeling effort is described in detailed in the individual appendices (A to D) assigned to each model, including the sources of input data. Appendix A describes the HEC-RAS modeling; Appendix B describes the AdH modeling; Appendix C describes the CBEMP modeling (including the WSM, CH3D-WES and CE-QUAL-ICM); and Appendix D describes the TMDL modeling.
CCC-18	The raw data necessary to determine the impact of scour from the ponds/lakes/reservoir in the lower Susquehanna River on the Bay during storm events simply does not exist.	See response to CCC-8. There are data collected by USGS used to estimate scour in the reservoir by comparing sediment concentrations upstream and downstream of the reservoir. There are also sequential bathymetric surveys, where net bed change can be measured. Both of these are referenced extensively in the LSRWA report.
CCC-19	No bathymetry has been run before and after a major storm event in the Conowingo Pond, Lake Aldred or Lake Clark. Such bathymetry runs would show the elevation of the floor of such lakes and pond before and after a storm. From the difference in depth, the volume of scour could be determined and the amount of scour from a storm event with a peak flow measured in cubic feet per second through each dam could be determined. There is, therefore, no raw data from which to determine the volume of sediments scoured from the floors of such reservoirs during a storm event with a known flow rate.	This comment is correct in that no "direct" before and after bathymetry has been completed in the reservoir system. Several reasons explain the complications in the timing and analysis of the bathymetry data. First, it is difficult to predict when flows are going (guaranteed?) to be excessive and produce "mass scour." Second, subtle changes (even to the tenth of a foot) are difficult to document due to averaging in any currently available volume/capacity program. Third, the available analysis tools (HYPACK and mean capacity change) have reporting limitations. To compensate for these complications, collection of bathymetry data was proposed in the past by USGS to be collected on a shorter time scale, but was never funded. So, the only choice is to document changes from previous bathymetries in combination with analysis of sediment loads upstream and downstream of the reservoirs in a mass-balance approach.

Comment Code	Comment	Comment Response
CCC-20	Measuring bathymetry is not complicated. Sonar technology in conjunction with global positioning system (GPS) technology is relatively inexpensive and widely available. Such technology could be installed on any small and transportable boat and used to rapidly and efficiently chart the bathymetry of the lakes and pond before and after storm events. NOAA has published how its vessels equipped with such technology can record the topography/ bathymetry of floor of the Bay so accurately that NOAA employees can detect if oysters have been illegally harvested from a harvest restricted area of the Bay.[9]	Agree. Sonar technology would be ideal not only to document the depth to bottom more accurately over the entire reservoir, but it could also provide a "picture" of the bottom sediment grain size. The drawback is that it is very expensive technology to purchase. MDNR and NOAA have such equipment and MDNR had conducted a survey in Conowingo last fall (2014).
CCC-21	Further evincing the complete void of data necessary to determine scour from the floor of the Conowingo Pond during storm events and the impact of such scour on the Bay is the December 22, 2014 1etter from Jay Ryan on behalf of Exelon to John B. Smith, Chief of the Mid- Atlantic Branch of the Division of Hydropower Licensing of FERC re: Conowingo Hydroelectric Project, FERC Project No. 405, Response to Letter from Office of Energy Project Regarding Withdrawal of Section 401 Water Quality Certification Application. In the letter, Exelon's representative explains to the FERC why it withdrew its application for a Clean Water Act 401 water quality certification from MDE, why Exelon will keep re-filing and withdrawing the application over the next several years while it accumulates the raw data before and after storm events necessary to meaningful prepare an analysis of the impact of sediment scoured from the floor of the Conowingo Dam during storm events on the Bay, and whyn addition, it is estimated that on average the Susquehanna River contributed 27 percent of the sediment load to the Chesapeake Bay during 1991-2000 as reported in USGS's Scientific Investigations Report 2012-5185. That leaves 73 percent coming from other sources which is hardly “de minimus.” implement the WIPs.er the impact that the sediments accumulating in the three reservoirs would have once the Conowingo Pond reached dynamic equilibrium some 15 to 20 years down the road. There was no urgency to the study and there was very little in funding procured for the study.ion in the upper Bay, long-term (1985-2013) and short-term (2003-2013) trends in total suspended sediment measured at the USGS (U.S. Geological Survey) stream gage at Conowingo Dam are not statistically significant. The Uni	Comment noted. Just because Exelon is conducting a more definitive study of the amount of scour released from the dams during storm events does not mean there is a “complete void of data.” It is the nature of science and scientists to want additional data to confirm or refute hypotheses and gain a better understanding of how systems function. Storage capacity and changes in bathymetry have been studied by the USGS for decades. In fact, USGS has conducted five extensive bathymetric and sediment coring studies since 1990. A recent report indicated that 70 percent of the sediment load comes from the watershed, 30 percent comes from scour, and that more benefit would be derived from implementing best management practices above the dams than dredging sediment from behind the dams. Please see USGS Open File Report 2014-1235.
CCC-22	For the DLSRWA, scour has been guesstimated by comparing samples of total suspended solids (TSS) taken at various points above and below the Conowingo Dam and guesstimating the portion of such suspended solids attributable to storm water runoff versus the portion attributed to scour from the floor of the Conowingo Pond, Lake Aldred and Lake Clark.	USGS collects and analyzes suspended sediment, not total suspended solids (TSS). USGS has several reports out explaining the difference in TSS and suspended-sediment analysis. They are not the same. Changes in bottom-surface profiles are discussed in the response for comment CCC-19.
CCC-23	There is no analysis or even any discussion from a statistical science perspective of the confidence level of any data generated by any of the models or any conclusions or determinations made based on any of the modelling analysis. Undoubtedly that is because any such discussion would acknowledge that there is insufficient raw data to generate any meaningful modelling data or to draw any meaningful conclusions to a reasonable degree of scientific certainty.	The Lower Susquehanna River Watershed Assessment applied the same models and assessment procedures as was used in the Chesapeake TMDL. The uncertainty of the models and procedures are discussed in the Chesapeake Bay TMDL documentation (2010).

Comment Code	Comment	Comment Response
CCC-24	Michael Langland, one of the USGS scientists, has admitted that there was insufficient data to calibrate the ADH model for river flows greater than 600,000 cfs. The table of predicted scour during storm events generating different flow rates in the lower Susquehanna River evidences the wide range of scour estimates based on the available data and modelling efforts.[10] The existing data and modelling efforts predict that between one-half million (500,000) tons and 1.5 million tons will be scoured from the floors of the lakes and pond during a one-in-five-year storm event (between 21% and 44% of the total sediment load during such a storm event). Thus, a single 1 - 3 day storm event will generate flows sufficient to scour from the floor of the Conowingo Pond and Lakes Aldred and Clarke one-half to 1 year-worth of the average annual sediment loading from the Susquehanna River and deposit such amount in the upper Bay in such 3-day period. The existing data and modelling efforts predict that between I 0.5 million tons and 15.5 million tons will be scoured from the floor of the lakes and pond during a one-in-sixty-year storm event (between 39% and 50% of the total predicted sediment load during such a storm event).[11] Thus, one such 4 - 8 day storm event will scour and deposit from the floor of the Conowingo Ponds and Lakes Aldred and Clarke between 8 - 12 years-worth of average annual sediment loading from the Susquehanna River and deposit such amount in the upper Bay over the course of eight days. The Safe Harbor Dam, the Holtwood Dam and the Conowingo Dam have so altered the flow of the Susquehanna River and sediments in the Susquehanna River that one to twelve years or more of the average annual sediment loading from the Susquehanna River can be delivered over the course of a week or less to the upper Bay.	The peak daily flow through the Conowingo Dam in the AdH 2008-2011 simulation period was 709,000 cfs on September 9, 2011 during TS Lee. The mean flow was 629,000 cfs. The highest suspended sediment sample collected during the storm was 2,950 mg/L at an instantaneous flow of 617,000 cfs on September 8, 2011.
CCC-25	The last 60 year storm event occurred in 1972 *(i.e.,* Hurricane Agnes). The next 60-year storm event will occur during the term of the 40+ year license requested by Exelon from FERC for the continued operation of the Conowingo Hydroelectric Power Project. This means that during the next 20 years, we can expect that scour from the floor of reservoirs behind the three dams in the lower Susquehanna River will completely annihilate the marine habitat in the upper Chesapeake Bay if no action is taken to reduce the volume of sediments in those reservoirs.	This comment is based on a lack of understanding of a return period. Please see Dunne and Leopold, 1978 (Water in Environmental Planning) or http://en.wikipedia.org/wiki/Return_period. Just because an event has a 60-year return period does not mean that it will happen every 60 years, or even within 60 years. A 60-year event could occur several times within the predicted return period, or not at all. Even for an event of that magnitude, a recent paper estimated that the percent scour to total load for Conowingo Reservoir ranges from 39 to 49 percent (USGS Open-File Report 2014-1235), so most of the sediment load would still come from the watershed. Also, what is the scientific basis for "completely annihilate the marine habitat"? Living resources did return to the upper Bay following Hurricane Agnes.
CCC-26	The persons who drafted and edited the DLSRWA inexplicably chose the lowest levels of predicted scour to report in the DLSRWA and upon which to predicate the findings and conclusions made in the draft report without providing any explanation of why the lowest values, as opposed to the highest values or the middle values were selected. What agenda is served and whose interests are benefitted by downplaying the impacts of sediment scour?	This is incorrect. The degree of estimated scour applied was the central tendency of the estimates and avoided the extremes.

Comment Code	Comment	Comment Response
CCC-27	USACE does not want to dredge above Conowingo Dam because it will have to deal with the hazardous and toxic pollutants that are in those accumulated sediments. Currently, when USACE dredges sediments from the navigable channels of the Bay, it does not have to give significant concern to the hazardous and toxic substances found in the sediments in looking for a place to safely deposit such sediments. Such sediments historically have been deposited in impoundments in the Bay such as Poplar Island and other islands composed of dredged sediments in the Bay. Attention will be focused on the hazardous and toxic sediments that are dredged above the dams in the lower Susquehanna River in determining how and what to do with such sediments. The cost, therefore, in properly disposing of such sediments will be magnified, because instead of allowing such hazardous and toxic pollutants to discharge into the Bay and then largely ignoring them when determining where to deposit sediments dredged from the navigable channels, such hazardous and toxic pollutants will have to be addressed up front.	Navigation channels are tested for contaminants during the design stage. Sediments determined to be contaminated or legally designated as such (Patapsco River sediments), are placed in upland containment sites to minimize harm that could be caused by these materials. The use of an upland containment site would increase costs. In making the determination as to a final disposal site, the NEPA process would be followed.
CCC-28	Exelon does not want to dredge sediments from behind the dams because in so doing it will exercise control over such sediments and in so doing will become responsible for disposing of such sediments in a manner that the hazardous and toxic pollutants in such sediments do not leach into the environment. Dredging sediments under the current legal framework will confer liability on Exelon for such hazardous and toxic substances. In fairness to Exelon, much of the hazardous and toxic pollutants in the accumulated sediments were not generated by Exelon or the power companies acquired by Exelon, so Exelon will fight hard not to dredge.	It is beyond the scope of this assessment to ascertain Exelon's intentions regarding dredging.

Comment Code	Comment	Comment Response
CCC-29	The DLSRWA is devoid of any analysis or meaningful discussion of the nutrients and pollutants that are bound to the sediments resting on the floor of the lakes and pond behind the three dams in the lower Susquehanna River. Studies conducted by the Susquehanna River Basin Commission ("SRBC") for MDE have determined that that the following nutrients and pollutants are bound to such sediments: (1) Herbicides; (ii) Pesticides; (iii) Sulfur and acid mine drainage; (iv) Coal; (v) Polychlorinated Bi-phenyls (PCBs); (vi) Nitrogen; and (vii) Phosphorus. The presence of such hazardous and toxic pollutants comes as no surprise given the extensive agricultural, mining and power generation activities that have historically been conducted in the Susquehanna River watershed.	Studies do indicate that contaminants other than nutrients may be attached to sediments behind the dams. However, the assessment focused on the nutrients associated with sediments and did not evaluate other potential contaminants. Chapter 5.4.3 briefly discusses heavy metals found in sediment cores with regards to the beneficial reuse of dredged sediments. Additional study is needed on other potential contaminants and on the biologic activity of these contaminants, including nutrients, as they are released from sediments.
CCC-30	During the December 9, 2014 presentation on the DLSRWA made at the Harford County · Community College, Dan Bierly of the USACE, with acquiescence from the other panelists (i.e., Bruce Michael from MDNR, Mark Bryer from The Nature Conservancy, Rich Batiuk from USEPA Reg. III, Matthew Rowe from MDE and Michael J. Langland from USGS) acknowledged that such nutrients and toxic and hazardous pollutants were bound to the sediments deposited on the floors of the pond and lakes in the lower Susquehanna River.	Comment noted. See response to comment CCC-29.

Comment Code	Comment	Comment Response
CCC-31	No study has been conducted to determine what nutrients that are bound to the sediments in the lower Susquehanna River estuary are · released into the water of the Bay in the less oxygenated, more saline, more acidic, and warmer Bay estuary. Assumptions, for example, that none of the phosphorus that is bound to such sediments above the Conowingo Dam were released into the Bay estuary when such sediments were transported over or through the dam and into the Bay simply are unfounded. There are 4 - 8 ppm of salt in the Bay waters as far north as Tolchester and phosphorus and nitrogen that are bound to such sediments while they were in the Susquehanna River undoubtedly are released into the water in the Bay once such sediments are scoured and flushed into the Bay. Likewise, the coal, herbicides, pesticides, sulfur and acid mine drainage, and other toxic substances bound to such sediments above the dam probably are released into the Bay when such sediments are flushed through or over the dam. Again, during the December 9, 2014 presentation on the DLSRWA made at the Harford County Community College, Messrs. Bierly and Rowe acknowledged that no such analysis was made and there currently is no scientific basis for determining the impact of the release of nutrients bound to the sediments scoured from the floor of the lakes and te pond behind the dams in the lower Susquehanna River. Mr. Bierly further expounded on the limited scope of the LSRWA, the limited funding for the study and the limited sampling conducted in conjunction with the study.	Comment noted. As identified in Chapter 8.1 Recommendations, additional study is needed on the bioavailability and impacts of nutrients on aquatic ecosystems. This will not change the fact that most of the sediment comes from the watershed and not from scour, even during high flow events.

Comment Code	Comment	Comment Response
CCC-32	Mr. Bierly stated some of the problems with dredging, *e.g.,* there are hundreds of millions of tons of sediments in the pond and lakes behind the three dams that have accumulated over the last 80 ± years and very limited places to deposit such sediments in close proximity to such ponds and lakes. The following concerns were not spoken, but undoubtedly influence the decision making process: (a) USACE only has to dredge the navigable channels in the Bay. Sediments scoured and flushed into the Bay during storm events settle out all over the shallows and non-dredged tributaries in the upper Bay, and so a lesser percentage of such sediments that enter the Bay from above the dams probably need to be dredged by USACE, although no study ever has been conducted to make such a determination. (b) Sediments dredged from the Bay historically have been deposited on manmade islands and containment areas in the' Bay with little to no thought given to the leaching of nutrients and toxic and hazardous pollutants from such islands and containment areas. This historical course of dealing has generally allowed USACE to ignore the impacts of such nutrients and toxic and hazardous pollutants. Withdrawal of sediments above the dams will entail the analysis of such nutrients and pollutants and regulators will not allow the disposal of above the dam sediments until there has been an accounting of how such nutrients and toxic and hazardous substances will be neutralized or responsibly addressed. (c) No one has been willing to answer the question of whether Exelon will assume liability for the nutrients and toxic and hazardous pollutants in above-dam sediments if it undertakes dredging operations. In fairness to Exelon, the dams impact the timing of the release of such nutrient and toxic and hazardous pollutant laden sediments into the Bay and the devastating shock of the massive releases over a short period of time due to the trapping and scour phenomena caused by the dams. With the exceptions of the PCBs and chemicals associated with keeping power company water intakes and discharge lines free and clear of biological life and growth, such nutrients and pollutants were not generated by the power companies, so it is not fair to saddle them with liability for such nutrients and toxic and hazardous pollutants in conjunction with remedial action undertaken to ameliorate the impact from trapping and scour.	(a) True. If Congress authorized USACE to do so, USACE would be able to dredge in an area other than a Federal channel. (b) See response to comment CCC-27. The material would be tested and a NEPA document and the process would be followed. Example: Hart Miller Island was designed to handle contaminated material and the State of Maryland regulates associated discharges under a Clean Water Act permit. (c) The ownership of liability of said sediment was not part of this study.

Comment Code	Comment	Comment Response
CCC-33	Exelon has directly and indirectly contributed millions of dollars to Federal and State campaigns and has made undisclosed contributions, probably in the millions of dollars, to the environmental organizations that were allowed to participate in the decision making process underpinning the preparation of the DLSRWA. Exelon funded a large portion of the study underpinning the DLSRWA. Exelon's consultants, Gomez & Sullivan, had a voice in and directly participated in the decisions made about how to conduct the study, what assumptions to make, what data to use, and what conclusions to report. Exelon undoubtedly expects and demands a return on this investment. Exelon undoubtedly has influenced the politics underpinning the decision making processes that have led to the findings and conclusions reported in the DLSRWA.[12]	Over the course of the assessment, Exelon representatives and its consultants attended the quarterly meetings, along with other members of the public. Neither Exelon nor Gomez and Sullivan were involved in any decisions regarding the conduct of the assessment or its conclusions. See also response to CCC-34.
CCC-34	The studies underpinning the DLSRWA and the preparation of the DLSRWA were not undertaken in compliance with the National Environmental Policy Act (NEPA), the Federal Advisory Committee Act (FACA), the NEPA-implementing regulations of the President's Counsel of Environmental Quality (CEQ), or applicable Presidential Executive Orders. Select special interest groups including Exelon and environmental organizations that probably have been the recipients of significant monetary and non-monetary contributions from Exelon, Exelon executives and officials and non-profits funded by Exelon were granted a seat and voice at the study table. Exelon, directly and indirectly, was given considerable influence over the reported outcomes and there has been no opportunity for persons with countervailing perspectives to influence the decisional process and the reported outcomes. NEPA, FACA and the CEQ regulations were promulgated to preclude exactly what has happened in generating the DLSRWA. The report legally is not entitled to be given any deference in any governmental decision making process.	Please see our response to Comment CCC-L-5 regarding NEPA and FACA. Exelon, as we understand it, did supply information and funds to support the study efforts of the non-Federal sponsor, the State of Maryland, in the event that the federal cash contributions fell short and direct cash contributions were needed instead of Maryland's in-kind services. As Exelon operates the dam for the principal reservoir being studied, it, quite naturally, is a stakeholder, with a right to attend public meetings, receive emails, and make comments like the Clean Chesapeake Coalition or any other member of the general public. It was given no greater access than has been available to any other member of the public who wished to avail themselves of the information being disseminated about the study. The LSRWA report is intended to present general study findings and recommendations about the impact of sediments found in the Lower Susquehanna River reservoirs; any use made of it, if any, let alone deference given to it, is entirely up to the decision-makers involved in any other project or process for the Susquehanna River or the Chesapeake Bay.
CCC-35	Unfortunately, Federal and State environmental and natural resources agencies have conveniently chosen to ignore the impact to the Bay estuary of the hydroelectric power dams in the lower Susquehanna River for over eight (8) decades. USEPA conveniently and quite erroneously predicted in the 2010 Bay TMDL that the Conowingo Pond would not reach dynamic equilibrium and discontinue acting as a net trap of sediments until 2025 or 2030. 13 The same suite of models used to support that erroneous assumption in the 2010 Bay TMDL were used in the "studies" underpinning the DLSRWA.	Previous estimates were for the dynamic equilibrium infill of the Conowingo Reservoir to occur later in the 21st century, with estimates of Conowingo dynamic infill occurring around 2020 to 2030. The previous estimates were incorrect, and it's now known that the Conowingo infill condition of dynamic equilibrium is currently occurring.

Comment Code	Comment	Comment Response
CCC-36	Mr. Batiuk of USEPA Region III, during the December 9, 2014 presentation at Harford 'County Community college, as well as the other presenters (Messrs. Bierly and Michael), admitted that the Conowingo Pond is now in a state of dynamic equilibrium- i.e., the Conowingo Pond no longer acts as a net trap of sediments and pollutants washing down the Susquehanna River to the Bay. They acknowledge that EPA's 2010 Bay TMDL prediction based on the CBEMP was off by 12-17 years.	As documented on pages 10-7 and 10-8 in the December 2010 "Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment" report as well as in the supporting Appendix T, the sediment trapping capacity of the Conowingo Dam and Reservoir was based on the latest available data and findings reported by the USGS (see Langland 2009a, 2009b citations in Appendix T) at the time that the Chesapeake Bay TMDL was under development by EPA and its seven watershed jurisdictional partners. Even though the dam system has reached a state of dynamic equilibrium, to quote Langland (Open-File Report 2014-1235) "The percent scour to total load, based on frequency of streamflow events, ranges from 20 percent to 37 percent (average 30 percent) for streamflows of 400,000-800,000 ft^3/s." Thus, during high flow events, when most sediment is transported, most of the sediment that enters the upper Bay comes from the watershed and not from scour. Also note that on average, the Susquehanna River contributed 27 percent of the sediment load to the Chesapeake Bay during 1991-2000 (SIR 2012-5185), which emphasizes the need to control sediment that comes from other sources and the Susquehanna River.
CCC-37	MDNR and MDE completely ignored the impact of sediment scour from the floors of Lake Aldred, Lake Clarke and the Conowingo Pond in the 20I0 Bay TMDL process and the FERC relicensing process until the Coalition made it an issue that those agencies could no longer ignore. Maryland's WIP makes no mention whatsoever of Conowingo Dam or sediment scour due to storm events. Shamelessly, Bruce Michael of MDNR explained during the December 9, 2014 informational meeting how MDNR and the other regulatory agencies have been aware of the problem for decades, and indeed they have been. Studies prepared and disseminated by the SRBC have documented the problem of sediment scour from the lower Susquehanna River for several decades. Unfortunately, the warnings sounded by such reports have been ignored throughout that period of time.	This issue has not been ignored by MDNR and MDE. The coalition counties have been encouraged to review the FERC record associated with relicensing and specifically the proposed study plans of 2009. MDNR and MDE requested further study of this issue on the public record. The 2010 TMDL stated that Conowingo would be considered in the 2017 midpoint assessment if data suggested the trapping efficiency has been diminished. The authors of the 2010 Bay TMDL were well aware that the Conowingo was reaching full capacity and would potentially have an impact on our ability to meet water quality standards. Therefore, the 2010 TMDL includes provisions under Appendix T that require the Bay Partnership to address the impacts of Conowingo Dam reaching full capacity as part of the 2017 midpoint assessment. The 2017 midpoint assessment allows for the most up-to-date water quality monitoring and modeling information to be incorporated into the TMDL revisions.
CCC-38	The LSRWA has been integrally linked with the FERC relicensing process for Conowingo Dam. The Draft Environmental Impact Statement prepared by FERC repeatedly references the LSRWA and what will be learned and divulged by that report.	Concur. MDNR and MDE have filed public comments with the FERC arguing that the LSRWA should not be used as a surrogate for the sediment study required of Exelon, but the State of Maryland does not have jurisdiction over the FERC process.
CCC-39	At the December 9, 2014 public presentation, Mr. Batiuk of USEPA Region Ill stated that because of the findings of the DLSRWA, USEPA was in the process of recalibrating the 2010 Bay TMDL to recognize that the Conowingo Dam no longer acted as a net trap and, therefore, all waste load allocations would have to recalculated and revised.	The statement at the December 9, 2014 public meeting was that the Chesapeake Bay Program Partnership, as part of its Chesapeake Bay TMDL 2017 midpoint assessment, was enhancing its suite of Chesapeake Bay watershed and tidal water quality models and other decision support tools to reflect the latest understanding and data regarding Conowingo Dam and Reservoir's sediment and associated nutrient trapping capacity. Those enhanced partnership models and tools would be applied in carrying out the stated objectives of the 2017 midpoint assessment.

Comment Code	Comment	Comment Response
CCC-40	By letter dated December 22, 2014 Exelon, in the FERC relicensing proceeding, requested FERC to issue temporary 1-year license renewals while it participated in the LSRWA with MDE in order to determine the impact of its operation on the water quality of the Bay.[14]	Statement noted; no response required.
CCC-41	In short, the LSRWA is the linchpin for two major federal actions that will have significant and far reaching environmental impacts: (1) the FERC long-term relicensing of the Conowingo Hydroelectric Power Project and (2) the USEPA 2017 Chesapeake Bay TMDL recalibration. Given that this study will inform such major Federal actions, it should be conducted in compliance with NEPA, FACA, the CEQ regulations implementing NEPA, and the applicable Executive Orders issued by Presidents of the United States.	"Linchpin" is too strong a word, given the independence of, and the prior work performed for, the two federal actions you mention. The U.S. Army Corps of Engineers has no direct role in either action; USACE's indirect role is limited solely to the information provided by this study effort. See the responses to CCC-L-5, CCC-L-10, and CCC-34, respectively above, regarding NEPA, FACA, executive orders, and the use to be made of this study report.
CCC-42	The Clean Chesapeake Coalition counties are stakeholders in both of the foregoing Federal actions and in myriad efforts to improve the water quality of the Chesapeake Bay. MDE and the Maryland General Assembly have empowered and tasked the counties with developing, funding and implementing WIPs and to implement and fund other local legislative and regulatory programs to improve the water quality of the Bay. The ability of the counties to implement such programs is directly impacted by the TMDL and the FERC relicensing of the Conowingo Dam. Economic development in the counties and the ability of the counties to retain existing businesses (including but not limited to agricultural and fishery dependent businesses) and to attract new businesses and residents is directly dependent on expenditures and programs associated with the WIPs, the 2010 Bay TMDL and the health of the Bay.	Statement noted; no response required.
CCC-43	The members of the Clean Chesapeake Coalition request USACE, FERC and USEPA to set aside the DLSRWA and to reinstitute the study process in full compliance with NEPA, FACA, the NEPA implementing regulations promulgated by the President's CEQ, and a number of Presidential Executive Orders.	Please see the response to comment CCC-L-5 regarding NEPA and FACA, and the response above to comment CCC-L-10 regarding executive orders.
CCC-44	As discussed, the DLSRWA and appendices contain a host of information that was not well organized or concisely and clearly presented as required by NEPA and the NEPA implementing CEQ regulations. What follows, in no particular order, are additional concerns, questions and observations relative to the DLSR WA. The attached "Summary and Comments on Lower Susquehanna River Watershed Assessment Draft Report and Appendices" are by no means meant to be comprehensive or all inclusive; but are expected to be considered and addressed.	Comment noted. See the responses to comments CCC-L-5, CCC-L-10, and CCC-34, respectively above, regarding NEPA, FACA, executive orders, and the use to be made of this study report.

Comment Code	Comment	Comment Response
DR-1	• According to the Draft LSRWA Report ("Draft Report"), an HEC-RAS model was designed primarily for non-cohesive sediment transport (sands and coarse silts) with additional, but limited, capability to simulate processes of cohesive sediment transport (generally medium silts to fine clays). Thus this model may not be suitable for all reservoir simulations, especially in areas of highly variable bed shear stress (the force of water required to move bed sediment) and active scour and deposition. Limitations of the model most likely resulted in less than expected deposition for the 2008 – 2011 simulation and less than expected erosion (scour) for the Tropical Storm Lee seven day event simulation, when compared to other approaches and estimates. (Pg. 33). **Comment DR-1:** A one dimensional model cannot account for scour since there is no lateral variable to account for sediment load on the river basin. This was Langland's (*i.e.* , USGS') same concern regarding Exelon's use of the HEC6 model in their Sediment Transport Study.	The HEC-RAS model can simulate scour by examining the change in load exported out of the reservoir versus the input loads. Any increase or decrease in bed volume would be due to a mass change from the bed.
DR-2	**Comment DR-2:** USACE's two dimensional AdH model computed detailed hydrodynamics and sediment transport in and out of Conowingo Reservoir, and the response of the reservoir and flats area to various sediment management scenarios and flows. According to the Draft Report the AdH simulates hydrodynamics and sediment transport. However, this may not the case given the following limitations: • A one dimensional model, HEC-RAS, was used to provide data for the AdH model; the two dimensional AdH model utilized the HEC-RAS model results (sediment load and flow) from Holtwood Dam as the inflowing sediment load boundary condition. (Pg. 66).	The use of the one-dimensional model as an inflow just means that the inflowing load is uniformly distributed across the cross-section. As the flow proceeds though the two-dimensional domain, it will redistribute laterally according to the modeled physics in the AdH model, and redistribute vertically according to the analytic quasi-3D physics in the AdH model. Since the inflow location is relatively narrow and well-mixed (from turbulence downstream of the Holtwood Dam), the assumption of a uniform distribution of load at the boundary is acceptable,
DR-3	• Through a validation process, the application of the AdH two dimensional model to the Conowingo Reservoir and Susquehanna Flats system was determined to be adequate for simulating general reservoir sediment scour and deposition modelling scenarios for the LSRWA. However, there is some uncertainty that remains with the estimates provided by the AdH model. (Pg. 37). **Comment DR-3:** What was the validation process? Was it consensus at the meeting? By whom?	Model validation for the AdH model is described in Appendix B, Chapter 6. It was the consensus of the assessment team that the AdH model would be sufficient for simulation of hydrodynamics and sediment transport from the Conowingo Reservoir to the Susquehanna Flats.

Comment Code	Comment	Comment Response
DR-4	• The AdH sediment model (a two dimensional model) required bed sediment data. Only 8 bed core samples were taken from Conowingo Reservoir to a maximum depth of only one foot. Core samples were required to determine the inception of erosion (critical shear stress for erosion) and the erosion rate used to develop six material zones. (Pg. 19). The sediment bed in the AdH Model was approx. 3 feet deep. The properties of the lower 2 feet were either approximated from the SEDFlume data results (which is the one foot data) or determined from literature values. **Comment DR-4:** How old is the SEDFlume data? If the age of the data is different than model runs how is this an accurate portrayal? What literature values were used?	The SEDFlume data was collected in spring 2012. The goal of the data collection was to determine the characteristics of how sediment that settles in the reservoir tends to consolidate, and how the erosional properties vary spatially. The exact rates of erosion at a given time would require many more observations. Although having these data would be of great benefit, they would not be any more accurate for determining long-term trends (i.e., whether or not and at what rate the reservoir is approaching dynamic equilibrium), since they would only be strictly valid for the date they were collected. The source for the corrections applied to the critical shear is cited in the text (Whitehouse, 2000).

Comment Code	Comment	Comment Response
DR-5	• The hydrologic period used for these scenarios was 2008-11. This 4-year time period was utilized because it included low (less than 30,000 cfs.) moderate (30,000 to 150,000 cfs.) and high (greater than 150,000 cfs.) flows as well as two major flood events (above 400,000 cfs.). Each HECRAS simulation provided a range of probable conditions and also provided a range of uncertainty in the boundary condition flows. (*See* Appendix A for more details on the HECRAS analyses and model.) (Pg. 33). • The second modelling tool utilized for this LSRWA effort was the AdH model. The AdH model was developed at the USACE's ERDC, located in Vicksburg, MS, and has been applied in riverine systems around the country and world. For this assessment, the AdH model was constructed and applied from Conowingo Reservoir to the Susquehanna Flats just below the Conowingo Dam, as shown in Figure 3- 2. Modelling scenarios were run by ERDC team members. (Pg. 34). Additional details about the AdH model and analyses are available in Appendix B. The AdH model was selected for the LSRWA effort and for use in the Conowingo Reservoir/Susquehanna Flats area (vs. HECRAS) because of the higher uncertainty of conditions and processes in this area, particularly in comparison to the upper two reservoirs which were understood to be in dynamic equilibrium for several decades. (Pg. 35). All AdH simulations that were run for the LSRWA effort were conducted with the same Susquehanna River flow and inflowing sediment boundary conditions. Using the HECRAS input, the 4-year flow period from 2008 - 2011 was simulated in the model. As noted earlier, this time period was utilized because it included low, moderate and high flows as well as two major high-flow events (above 400,000 cfs.). (Pg. 36). The AdH model was also utilized to estimate the effectiveness of selected sediment management strategies to reduce sediment loadstransported through Conowingo Reservoir and Susquehanna Flats. Ultimately, the AdH model output was sediment transport, scouring loads or erosion from the reservoirs which were utilized in Chesapeake Bay Environmental Model Package (CBEMP) to compute the impact of the sediment management strategies on water quality in Chesapeake Bay. (Pg. 37). **Comment DR-5:** AdH output data put into a model that has incorrect data based on 2010 TMDL with incorrect estimates? How can a two dimensional model rely on data generated from a one dimensional model?	See response to comment DR-2.

Comment Code	Comment	Comment Response
DR-6	• Through a validation process, the application of the AdH two dimensional model to the Conowingo Reservoir and Susquehanna Flats system was determined to be adequate for simulating general reservoir sediment scour and deposition modelling scenarios for the LSRWA. However, there is some uncertainty that remains with the estimates provided by the AdH model that were considered in results, as described below. One source of uncertainty was that the AdH model was not capable of simulating sediment passing through the flood gates of Conowingo Dam. Therefore, dam operations are not simulated in detail in the model; these include flood gate operation and Peach Bottom Atomic Power Station sequences. (Appendix K provides a description of dam operations.) For this study Conowingo Dam was modeled as an open boundary with downstream control represented by the water surface elevation at the dam. This limitation impacted how sediment was spatially distributed in the lower reach of Conowingo Reservoir near the dam. To minimize this uncertainty more sophisticated methods would need to be developed to incorporate dam operations in Conowingo Reservoir. (Pg. 37). **Comment DR-6:** How can the two dimensional model (AdH model) provide accurate results with an open boundary approach? This approach is very limited given the cyclical movement of water (kicking up more sediment scour) as it is resisted by the dam.	See response to comment DR-2. It is true that the dam operations are not included. Hence, the influence of dam operations on the distribution and storage conditions of sediments in the lowermost reaches of the reservoir (especially sandy sediments) must be considered an additional source of uncertainty in the results. However, the model was calibrated against scour load data, and against sediment type data (sand, silt, clay) measured below the dam. Hence, the general relationship between discharge and scour from the reservoir is well-represented.
DR-7	**Comment DR-7:** According to Chesapeake Bay Program's (CBP) Scientific and Technical Advisory Committee (STAC): "The AdH application in this study has been developed to the point that scour and deposition is consistent with what is already known from survey and sampling observations. However, the AdH model application does not refine that empirical understanding. The uncalibrated and weakly constrained model application provides an essentially heuristic basis for scenario evaluation and the AdH model has not, as yet, added substantial new understanding of the sediment dynamics of the reservoir. The modelling does not strongly reinforce the existence of a scour threshold at 300,000 and 400,000 cfs. At best, it can be said that an uncalibrated model was found that produces results that are consistent with that particular threshold." (Pg. 22, Attachment I-7). How is the sediment dynamic of the reservoir evaluated and taken into account? Especially during episodic events?	This assessment of the capability of the AdH model application is somewhat too conservative with respect to what can be learned from the modeling. The analysis of the various bathymetries, including the projected bathymetry, is additional information that provides insight into the degree to which dynamic equilibrium exists in the reservoir, and the anticipated changes to the rate of scour over time, including the rate of scour for a large event. These results are consistent with observed trends, but also provide insights that cannot be ascertained from observations alone.

Comment Code	Comment	Comment Response
DR-8	• Another source of uncertainty concerned fine sediment flocculation and consolidation. Sediment transport models in general do not have a sophisticated approach to simulating fine sediment flocculation. Suspended fine sediment can either exist as primary silt and clay particles or in low energy systems such as reservoirs form larger particles in the water column due to flocculation. Particles that flocculate are larger and have higher settling velocities, thus their fate in the reservoir can be quite different than the lighter primary particles (Ziegler, 1995). When fine sediment particles deposit on the reservoir bed they compact and consolidate over time. As they consolidate the yields stress increases, meaning that the resistance to erosion becomes greater. Higher flows and subsequent bed shear stresses are required to scour the consolidated bed. Laboratory results show that sediment that erodes from consolidated beds may have larger diameters than the primary or flocculated particles (Banasiak, 2006). Scour may result in resuspension of large aggregates that re-deposit in the reservoir and do not pass through the dam. To add to the complexity of this phenomenon, the large aggregate particles scoured from the bottom during a high flow event can break down to smaller particles in highly turbulent conditions. Thus the fate of inflowing sediment particles in the reservoir is highly variable and difficult to capture with current modelling techniques. The AdH model has the capability to relate flocculation to concentration but not to other variables such as shear stress which determines flock particle size and the overall fate of the sediment. The ability to predict flocculation dynamics is important to track the fate of sediment in a reservoir. To quantify this uncertainty numerous model simulations were conducted to determine a potential range of values. To reduce uncertainty more sophisticated methods would need to be developed to predict the flocculation dynamics. (Pg. 38). **Comment DR-8**: How many numerous models were used? What is the margin of error pertaining to these models?	Note that text indicates that numerous model simulations were conducted, not that numerous models were used. The margin of error is difficult to quantify, since there are not sufficient observations against which to meaningfully measure the error. Because of this inherent uncertainty, the results being gleaned from the modeling are focused on robust, qualitative trends, and model-to-model comparisons, not on specific quantitative measures.
DR-9	• The last major source of uncertainty was the limited data of suspended loads during storms and bed sediment erosion characteristics. Currently, the suspended sediment samples are collected from one location in Conowingo Reservoir. Because of the danger of sampling during large storms samples are not currently collected at the peak of the largest storms. To verify the estimations of bed scour during large storms improved field methods are required for sampling storm concentrations or turbidity over the entire storm hydrograph. Additionally, more samples of the reservoir bed would provide more data on the erosional characteristics of the sediment which would reduce uncertainty. (Pg.38). **Comment DR-9:** Please explain those improvements to field measurements or methods?	The text notes that it is dangerous to sample during large storms. It is out of the scope of this assessment to speculate on how improvements could be made in the field. With respect to the core samples in the Conowingo Reservoir, they could be used in sediment flume studies to better understand the erosional characteristics of the entire core with depth, and thereby, improve the field measurements.

Comment Code	Comment	Comment Response
DR-10	• CBEMP. The final modelling tool utilized for this LSRWA effort was CBEMP. CBEMP is an umbrella term used to describe a series of models that are applied to the Chesapeake Bay and its watershed. CBEMP was developed by CBP, the state-federal partnership responsible for coordinating the Chesapeake Bay and watershed restoration efforts. CBEMP has had almost three decades of management applications supporting collaborative, shared decision-making among the partners (USEPA, 2010b). This suite of environmental models has an unrivaled capacity to translate loadings in the watershed to Clean Chesapeake Coalition Summary and Comments on DLSRWA and Appendices Page 5 of 53 5 water quality in the Chesapeake Bay (Linker et al., 2013). CBEMP includes the same models and was applied using the same scenario development and simulation methods for this LSRWA effort as were used in the development of the 2010 Chesapeake Bay TMDL (USEPA, 2010a, Appendix D). (Pg. 39). In addition, the full suite of Chesapeake Bay models has been regularly updated and calibrated based on the most recently available monitoring data, about every 5 to 7 years over the past three decades. Linker et al. (2013) provides a complete description of the different phases and versions of the Chesapeake Bay models. Used properly, CBEMP provides the best estimates of water quality and habitat quality responses of the Chesapeake Bay ecosystem to future changes in the loads of nutrient and sediment pollutants. For this LSRWA effort, CBEMP had two major applications. The first application was a series of modelling runs conducted by USACE ERDC documented within Appendix C. These CBEMP application scenarios were utilized to estimate water quality impacts of selected watershed and land use conditions, reservoir bathymetries, a major storm (scour) event (January 1996) at different times of year, and selected sediment management strategies. Sediment erosion or scour from the bed of Conowingo Reservoir estimated from AdH was utilized as input for selected CBEMP scenarios. The second CBEMP application was a series of modelling runs conducted by CBP, as described, *infra* , in more detail in Appendix D. • Chesapeake Bay WSM Model. The Chesapeake Bay WSM simulates the 21-year period (1985 - 2005) on a 1-hour time step (USEPA, 2010b). Nutrient inputs from manure, fertilizers and atmospheric deposition are based on an annual time series using a mass balance of U.S. Census of Agriculture animal populations and crops, records of fertilizer sales and other data sources. Best management practices (BMPs) are incorporated on an annual time step; nutrient and sediment reduction efficiencies are varied by the size of storms. Municipal and industrial wastewater treatment and discharging facilities and onsite wastewater treatment systems' nitrogen, phosphorus and sediment contributions are also included in the Chesapeake Bay WSM. (Pg. 39). **Comment DR-10:** How is this model run protective of scour entering Maryland's waters?	The question is difficult to understand. Model runs in and of themselves are insufficient to be protective of water quality. It's the decisions that managers make with the model runs that have the potential to be protective of water quality.

Comment Code	Comment	Comment Response
DR-11	• Chesapeake Bay Estuarine Models. The hydrodynamic model computes intra-tidal transport using a three dimensional grid framework of 57,000 cells (Cerco et al., 2010). The hydrodynamic transport model computes continuous three dimensional velocities, surface elevation, vertical viscosity, and diffusivity, temperature, salinity, and density using time increments of 5 minutes. The hydrodynamic model was calibrated for the period 1991 – 2000 and verified against the large amount of observed tidal elevations, currents, and densities available for the Chesapeake Bay. Computed flows and surface elevations from the hydrodynamic model were output at 2-hour intervals for use in the water quality model. Boundary conditions were specified at all river inflows, lateral flows and at the mouth of the Chesapeake Bay. • The eutrophication model, referred to as the Chesapeake Bay Water Quality/Sediment Transport Model 6, computes algal biomass, nutrient cycling and DO, as well as Clean Chesapeake Coalition Summary and Comments on DLSRWA and Appendices Page 6 of 53 6 numerous additional constituents and processes using a 15-minute time step (Cerco and Cole, 1993; Cerco, 2000; Cerco et al., 2002; Cerco and Noel, 2004). In addition, the Chesapeake Bay Water Quality/Sediment Transport Model incorporates a predictive sediment diagenesis component, which simulates the chemical and biological processes which take place at the bottom sediment-water interface after sediment is deposited (Di Toro, 2001; Cerco and Cole, 1994). (Pg. 40). • The Chesapeake Bay Water Quality/Sediment Transport Model simulates water quality, sediment, and living resources in three dimensional in 57,000 discrete cells, which extend from the mouth of the Bay to the heads of tide of the Bay and its tidal tributaries and embayments, as depicted in Figure 3-5. The primary application period for the combined hydrodynamic model and eutrophication model covers the decade from 1991 - 2000. For LSRWA applications the 1991 - 2000 hydrologic record was retained as this is the hydrologic period that CBEMP is based upon. Additionally, this is the same hydrologic period employed by the CBP partners in development of the 2010 TMDL (USEPA, 2010a). • 1996 January High-Flow Event Scenario. The January high-flow event in 1996 was selected as the event to observe water quality impacts for LSRWA scenarios requiring a storm event because it is the highest observed flow within CBEMP's 1991 – 2000 hydrologic period. High flow events wash in loads (sediment and nutrients) from the watershed; if there is high enough flow these events scour additional loads from the reservoir beds behind the three dams on the lower Susquehanna River. (Pg. 44). • A one-dimensional HEC-RAS model computed hydraulic conditions and sediment transport in the reservoir system and sediment loads to Conowingo Reservoir for use in the two- dimensional model the Adaptive Hydraulics (AdH) model.	Comment noted.

Comment Code	Comment	Comment Response
	Comment DR-11: MDE admitted that this data was limited in terms of the number of core samples and the depth taken at the DLSRWA Public Hearing Meeting in December 2014 at Harford Community College.	
DR-12	• Model was not capable of passing sediment through the gates, therefore, for this study the dam was modeled as an open boundary with downstream control represented by the water surface elevation. (Pgs. 38 and 149). • Flow rates capped at approximately at 620,000 cfs. - 640,000 cfs. for Tropical Storm Lee. (Pg. 62; *see* Figure 4.1). Table 4.3- Pg. 63 shows an event of 798,000 cfs. having an occurrence of 1 in 25 years. • Each reservoir bed consists of a number of layers. The lowermost layer is considered an inactive layer that will rarely, if ever, scour to any degree. Above that, there is an "active" scour and depositional zone. The surface of the active layer consists of a relatively thin mixing layer that is unconsolidated and may have a high potential for scour Clean Chesapeake Coalition Summary and Comments on DLSRWA and Appendices Page 7 of 53 7 at flows less than the scour threshold. For modelling purposes, the active layer is estimated to have a depth of approximately of 2 to 3 feet; however, it is spatially variable due to bed composition and consolidation. (Pg. 65). **Comment DR-12:** How do 8 core samples with a depth of 1 foot delineate the reservoir bed in a 14 mile reservoir?	See response to comment DR-4. The study team believes the data were sufficient for the modeling effort, with respect to the goals of the study. While, more cores would provide greater insight into the existing spatial variability of the reservoir, they would not provide significantly more insight into historical or projected conditions of the reservoir. So although more cores would always be of benefit, eight cores are adequate to determine the erosional characteristics of the Conowingo reservoir.
DR-13	• Sediment transport is directly related to particle size. (Pg. 60). Storms can potentially scour the silts and clays, which are easier to transport, while frequently leaving behind the coarser, sand-sized sediment. For example, in the lower portion of Conowingo Reservoir in 1990, particle size analysis from 2-foot deep sediment cores indicated the area had about 5 percent sand; in 2012, it was projected to have 20 percent sand based on all previous cores. The reservoir sediment data collected show that generally there is more sand in the bed upstream and silts and clays are more prevalent closer to the dam for all three reservoirs. Silt is the dominate particle size transported from the reservoir system with little sand (less than 5 percent) transported to the upper Chesapeake Bay (*see* Appendix A for further discussion). (Pg. 60). **Comment DR-13:** Was this 20 year old data used to address the inadequacies of the 8 core samples?	The eight SEDflume cores were used to characterize the bed. The only parameter that was corrected was the critical shear stress, which was corrected according to literature values (Whitehouse, 2000, reference in report).

Comment Code	Comment	Comment Response
DR-14	**Comment DR-14:** Core samples used in model runs from Conowingo Pond are inadequate given discussion later in the DLSRWA on Pg. 60. Generating data from a one dimensional model to be used in a two dimensional model is uncomforting and frightening. In addition, the following statements quoted below from the DLSRWA shows the lack of data in the models as it relates to scour. Such statements attempt to justify insufficient data in the model runs: • "…more samples of the reservoir bed would provide more data on the erosional characteristics of the sediment which would reduce uncertainty." (Pg. 38). • "Uncertainties in the total sediment load entering Conowingo Reservoir will affect scour and deposition, and thus affect the total load output to the Bay. Consequently, to provide more information on reservoir mass balance, future sampling program should extend both upstream and downstream of Conowingo Dam. To quantify the uncertainty of the limited data available to the LSRWA effort numerous model simulations were conducted to determine a potential range of values." (Pg. 38).	See response to comments DR-2 and DR-4.
DR-15	• "In summary, of all the modelling uncertainties that exist, three are most critical for interpreting the Conowingo Reservoir modelling results. These include the potential for flocculation of sediment flowing into the reservoir, the potential for large sediment aggregates to erode from cohesive beds and dam operations. Because of these uncertainties the AdH model may potentially over-predict to some degree the transport of scoured bed sediment through the dam to the Chesapeake Bay. Appendix B provides further detail on the uncertainty associated with AdH, as well as documentation of the model inputs, outputs and calculations." (Pg. 39). **Comment DR-15:** Over-predict? The Corps is saying that the lack of data is somehow portraying the problem in a negative light to undermine the severity of this problem. How could there be an over-prediction of the transport of scour bed sediment when model runs are capped at 600,000 - 640,000 cfs. instead of running the models at the more appropriate level of 900,000 cfs.?	The assertion that the model may over-predict scour is because each of the uncertainties listed has a tendency to result in the increased retention of sediment in the reservoir, relative to the modeled condition (i.e., relative to the modeled approximation of that uncertainty). According to USGS observations, a discharge of 900,000 cfs is on the order of a 50-year event, whereas the discharge associated with Tropical Storm Lee is on the order of a 20-year event. Hence, although the load for a given event would be higher for 900,000 cfs, the resulting impact to the Bay would have a lower probability of occurrence. Figures 4 and 5 in Appendix B-1 integrate the frequency together with the load. These figures demonstrate that, on an annually averaged basis, the 900,000-cfs event does not have a significantly greater impact than an event on the order of 600,000 to 700,000 cfs.

Comment Code	Comment	Comment Response
DR-16	• Chesapeake Bay Environmental Model Package ("CBEMP" – Chapter 3 of the DLSRWA). This model is used to determine dredging effectiveness. (Pgs. 136-140). Developed by CBP and based on computed loads from the watershed at key locations in the reservoir system including the Conowingo inflow and outflow. Watershed loads at the Conowingo outfall computed by the Watershed Model ("WSM") were supplemented by bottom scour loads estimated through AdH and through data analysis. The WSM is considered part of the CBEMP. • CBEMP includes the same models used in the development of the 2010 Chesapeake Bay TMDL, and is based on land use, management practices, wastewater treatment facility loads, and atmospheric deposition from the year 2010. (Pg. 39). This run is considered to represent existing conditions to provide assistance with projected land use, management practices, waste loads, and atmospheric deposition upon which the 2010 Chesapeake Bay TMDL was based. (Pg. 45). • CBEMP produces estimates, not perfect forecasts. Hence, it reduces, but does not eliminate, uncertainty in environmental decision-making. There are several sources of uncertainty summarized and discussed in more detail in Appendix C. (Pg. 49). • One source of uncertainty is the exact composition of nutrients associated with sediment scoured from the reservoir bed. Two alternative sets of observations are presented in Appendix C, one based on observations at the Conowingo Dam outfall in January 1996 and one based on observations collected at Conowingo Dam during Tropical Storm Lee in September 2011. The nutrients associated with suspended solids differ in the two events with 1996 being lower. In fact, both data sets represent a mixture of solids from the watershed and solids scoured from the bottom so that neither exactly represents the composition of scoured material alone. The 2011 observations are consistent with samples collected in the reservoir bed (Appendix C, Attachment C-1), are more recent and represent a typical tropical storm event rather than the anomalous circumstances of January 1996. For this reason nutrient composition observed at Conowingo Dam in 2011 is preferred and was utilized to characterize the future and is emphasized in the DLSRWA. Several key scenarios were repeated with the 1996 composition, however, to quantify the uncertainty inherent in the composition of solids scoured from the reservoir bottom. (Pg. 50).	Comment noted. The statement that "the 2010 TMDL needs to be revised" is incorrect.

Comment Code	Comment	Comment Response
	• Another source of uncertainty is the availability (*i.e.* , bioavailability) and reactivity of the nutrients scoured from the reservoir bottom. The majority of analyses of collected data at the Conowingo Dam outfall and from within the reservoir bed sediment quantify particulate nitrogen and particulate phosphorus without further defining the nature of the nitrogen or phosphorus. For the LSRWA effort, modelers opted to maintain the accepted, consistent particle composition that has been employed throughout the application of CBEMP. Uncertainty in the particle composition, and consequently, the processes by which particulate nutrients are transformed into biologically available forms still exists. (Pg. 50). • Some uncertainty in computed storm effects on Chesapeake Bay would result from considering solely a January storm. Bay response to storms in other seasons might vary. To reduce this uncertainty the January storm was moved to June and to October. The June storm coincides with the occurrence of the notorious Tropical Storm Agnes, which resulted in the worst recorded incidence of storm damage to the Bay. The October storm corresponds to the occurrence of Tropical Storm Lee and is in the typical period of tropical storm events. (Pg. 50). • CBEMP evaluated water quality impacts from a single large flow event (January 1996). Lower flow, more frequent events may also have a cumulative impact over time in the future. Future modelling work could investigate the potential effects of smaller more frequent events to reduce uncertainty and expand understanding of how various flows influence Chesapeake Bay water quality. (Pg. 50). **Comment DR-16:** This study has a schizophrenic analyses and discussion considering that the 2010 TMDLs need to be revised and yet the models that established those numbers are acknowledged and used to determine the effectiveness of dredging in the DLSRWA.	

Comment Code	Comment	Comment Response
DR-17	• Chesapeake Bay Estuarine Models – used to compute the impacts of sediment and nutrient loads to the estuary on light attenuation, SAV, chlorophyll, and DO concentrations in Chesapeake Bay tidal waters. (Pgs. 39-40). • The eutrophication model, referred to as the Chesapeake Bay Water Quality/Sediment Transport Model6, computes algal biomass, nutrient cycling, and DO, as well as numerous additional constituents and processes using a 15-minute time step. (Pg. 40). • In addition, the Chesapeake Bay Water Quality/Sediment Transport Model incorporates a predictive sediment diagenesis component, which simulates the chemical and biological processes which take place at the bottom sediment-water interface after sediment is deposited (Di Toro, 2001; Cerco and Cole, 1994). (Pg. 40). • The primary application period for the combined hydrodynamic model and eutrophication model covers the decade from 1991 - 2000. For LSRWA applications the 1991 - 2000 hydrologic record was retained as this is the hydrologic period that CBEMP is based upon. Additionally this is the same hydrologic period employed by the CBP partners in development of the 2010 TMDL (USEPA, 2010a). **Comment DR-17:** More predictions and scientific buzz words in establishing variables and definitely less science. Why not used data from the same years or timeframe as the other model runs? The eutrophication model does not include Tropical Storm Lee given the timeframe of 1991 - 2000.	The LSRWA report is clear on the application of the January 1996 "Big Melt" high-flow event on the Susquehanna River, which is an event consistent with the same time period of calibration and application (1991-2000) of the Chesapeake Bay Program models. Other large storm events are also discussed.
DR-18	• In order to compute water quality impacts with CBEMP, nutrient loads associated with sediment (in particular, nutrient loads carried over Conowingo Dam as a result of sediment scour from the reservoir bottom) were calculated by assigning a fractional nitrogen and phosphorus composition to the scoured sediment (solids). The initial fractions assigned for nitrogen and phosphorus were based on analyses of sediment cores removed from the reservoir (Appendix C, Attachment C-1). However, further analysis was done to ensure the most appropriate nutrient composition of loads was being utilized. (Pg. 46). **Comment DR-18:** Are these the same core samples that were limited to 1 foot? If not, from where were these sediment core samples taken? And why weren't these samples used in the AdH Model run?	The sediment cores described in the text of the draft LSRWA report were used to characterize the nutrient content of reservoir bottom sediments for use in the CBEMP. These were not the same cores collected for the SEDflume analyses and utilized in the AdH application. The locations of the cores used in the CBEMP can be found in Appendix C-1 and references therein. The cores analyzed for nutrient content were collected in studies which preceded this one and were neither available nor suited for use in the SEDflume.

Comment Code	Comment	Comment Response
DR-19	• "SAV species in the upper Bay were strongly affected by Hurricane Irene and Tropical Storm Lee which increased river flow and sediment loads in this region for almost two months (Gurbisz and Kemp, 2013). However, the dense SAV bed on the Susquehanna Flats persisted through the storms demonstrating how resilient SAV beds can be to water quality disturbances (CBP, 2013)." (Pg. 71). • Regarding oysters, Maryland's 2011 oyster survey conducted after Tropical Storm Lee indicated that those high freshwater flows from heavy rains in the spring and two tropical storms in late summer impacted oysters in the upper Bay, although ultimately representing a relatively small proportion of the total oyster population. The lower salinities proved to be beneficial to the majority of oysters in Maryland by reducing disease impacts to allow the yearling oysters to thrive (MDNR, 2012). (Pgs. 71-72). **Comment DR-19:** How was sediment scour ruled out given that this analysis seems to be based on observations? Who at DNR made these observations? Do DNR field notes exist that make such an observation?	Please see the referenced report or contact MDNR for more information on this topic. With regard to SAV, after exceeding the goals for submerged aquatic vegetation (SAV) in the northern Chesapeake Bay (segment CB1TF) for 2008-2010 and reaching a peak of 436.58 hectares in 2009, Bay grass acreage decreased to 342.34 hectares in 2010, to 201.09 hectares in 2011, and to 186.51 hectares in 2012. Since then, SAV area in CB1TF increased to 229.81 hectares in 2013 and preliminary data indicate that 2014 will have more than 2013. Thus, it appears that SAV beds in the upper Bay are resilient to disturbances in water quality. Please see http://www.vims.edu/research/topics/sav/ for annual SAV monitoring reports. Sediment scour was ruled out due to the fact that other upper Bay benthic organisms survived after TS Lee. The DNR assessment was based on observations of live fouling organisms, including barnacles, mussels, and bryozoans, that were found attached to the oysters and shells on oyster bars in the northern Bay. Had the oysters been smothered by sediment, these organisms would not have been able to attach to the oyster shells and would not have survived.
DR-20	• "The "Big Melt" event occurred in January 1996. The instantaneous peak flow for this event was 908,000 cfs. (Pgs. 73-74). • Hurricane Agnes was the largest flood in the Susquehanna River basin since 1896, when recording of flow began at Harrisburg, PA. During the Agnes event the flow over Conowingo Dam peaked at 1,098,000 cfs. • "As discussed in Chapter 3, the LSRWA modelling efforts included Tropical Storm Lee and the January 1996 high-flow event because these storms were included in the hydrologic period of the modelling tools utilized for this effort and because there was existing collected data available for these storms." (Pg. 74). • Attachment 4 of Appendix J includes detailed information on "Septic Systems." (Pgs. 29-33). **Comment DR-20:** Septic systems are not discussed at all in the corresponding tables for the cost analysis in Attachments 2 and 3. Why not?	Septic systems are estimated to contribute about 5 percent of the nitrogen load to the tidal Chesapeake on an average annual basis and have no phosphorus or sediment contributions whatsoever. In the high-flow events described in the LSRWA report, the septic loads are negligible. The focus of the BMP assessment was sediments, not nutrients. The discussion regarding septic systems was included in Appendix J by mistake and has been deleted.
DR-21	**Comment DR-21:** However, the flow rate for model runs was set at approx. 620,000 cfs. – so how does the LSRWA modelling account for these storms? Figure 4.7 seems to undermine the "1996 Big Melt" by capping the flow rate at 600,000 cfs.	See response to comment DR-15.

Comment Code	Comment	Comment Response
DR-22	• "On average, flows above 800,000 cfs. produced a scour load that comprised about 30 to 50 percent of the total load entering the Bay. Flows of this magnitude are rare with a recurrence interval of 40 years or more." (Pg. 76). Keep in mind, that Pg. 63 shows an event of 798,000 cfs. having an occurrence 1 in 25 years. The assumptions and conclusions regarding the potential number of storm events in a given interval are inconsistent and result in minimizing the adverse impacts on the Bay. • SAV, Chlorophyll and light attenuation relied on three model storms: January, June and October. (Charts on Pgs. 80-83). • The June scour event had an estimated increase in deep-channel DO water quality standard nonattainment (negative impact) of 1 percent, 4 percent, 8 percent, and 3 percent in segments. (Pg. 93). • The severity of the DO hypoxia response estimated by the degree of nonattainment of the deep channel and deep-water DO standards was greatest in the June storm scenario, followed by the January and October storm scenarios. The seasonal differences in water quality response, despite the same magnitude of nutrient and sediment loads in the June storm, October storm, and January storm scenarios, is thought to be because of the fate and transport of nutrients in the different seasons. (Pg. 94). • CBEMP does not model direct storm wave damage to aboveground or belowground SAV tissue, nor direct impacts of excess storm bottom erosion and deposition upon SAV. Accordingly, to consider these other effects of major storms on SAV, it was appropriate to consider the CBEMP model outputs as well as other recent and historical information in this study. Effects of storms can differ based on SAV bed health, size, and density. (Pg. 95). Admission. **Comment DR-22:** To investigate the effect of the storm season, scenarios were completed with the January 1996 Susquehanna storm flows and loads moved to June and October 1996. (Scenario 6 from Table 4-9, with three CBEMP model runs). Only one model run occurred during the growing season. Effects are discussed in terms of light attenuation, chlorophyll and DO. (Pg. 91). The models do not account for direct storm wave damage to above ground or below ground SAV. (Pg. 95).	Correct. The WQSTM does not simulate wave damage to SAV.

<table>
<tr><th>Comment Code</th><th>Comment</th><th>Comment Response</th></tr>
<tr><td>DR-23</td><td>

• "Nitrogen loads associated with the scoured sediment exceed the phosphorus loads, as noted in Table 4-9. The excess of nitrogen over phosphorus in Conowingo Reservoir bed sediment indicates that the scoured nitrogen load will exceed the scoured phosphorus load any time bottom material is scoured (eroded), regardless of the quantity of bottom material." (Pg. 96).

<u>Sediment Management Strategy</u>

• "Storms will continue to occur and will vary in track, timing and duration. Due to global climate change it is predicted that there will be increased intensity of precipitation in spring and winter potentially causing more frequent scour events." (Pg. 99).

• "Watershed loads of sediment, nitrogen and phosphorus will continue to decrease compared to today due to the continued implementation of Pennsylvania, New York and Maryland WIPs to meet the 2010 Chesapeake Bay TMDL allocations. Predicted higher temperatures and continued warming of Chesapeake Bay's tidal waters could have negative implications on DO causing intense hypoxia to occur substantially earlier or end substantially later in the year making it more difficult to meet Chesapeake Bay water quality standards, potentially increasing costs to achieve the Bay TMDL." (Pg. 99).

• "In reducing the amount of sediment available for a scour event, water quality could be improved and impacts to aquatic life could be reduced." (Pg. 100).

Comment DR-23: According to the Draft Report: "It is important to note that if suspended sediment was passively transported (*e.g.* , via modification of reservoir operations, flushing, sluicing, or agitation) as discussed in this section, a permit may not be required. However, if sediment transport were done actively through dredging or a pipeline, a permit would be required (Elder Ghigiarelli, MDE, Deputy Program Administrator, Wetlands and Waterways Program, Water Management Administration, personal communication, 2013). (Pg. 107) Does the Study group still believe that a permit would not be required under a new Maryland Gubernatorial Administration?

</td><td>Correct. The Maryland Department of the Environment believes that the change in administration will not change existing permitting requirements.</td></tr>
<tr><td>DR-24</td><td>

• "There are hundreds of combinations of ways to dredge, manage and place material. However, there are two main types of dredging – hydraulic dredging and mechanical dredging". (Pg. 110).

Comment DR-24: What type of dredging did the Draft Study focus on in their cost estimates?

</td><td>Both forms of dredging (hydraulic and mechanical) were investigated as shown in Table 5-6 on page 129.</td></tr>
</table>

Comment Code	Comment	Comment Response
DR-25	• Quarries appear to be the best option for material placement due to: (1) they can accept wet or dry material; (2) large volumes could be placed; and (3) there are several quarries nearby that can have material pumped in directly from Conowingo Reservoir without the need for costly re-handling or trucking. (Pg. 120). • Additional analyses characterizing sediment to be dredged including grain size, plasticity and percent moisture, metals, non-metals, pesticides, PCB's and PAH's, paint filter, and elutriate tests. (Pg. 120). • Must meet state regulations (PADEP for PA and MDE for MD). Transport containers must be watertight. Long transport distance. Water may need to be decanted, requiring another pipeline to return the effluent to the Susquehanna River. Mine owners contacted had no interest in sediment because of limitations on their mining permits. (Pg. 124). <u>Dredging Effectiveness</u> • It was assumed that 3 mcy (2.4 million tons) were removed by dredging from an area above the Conowingo Dam on the eastern side of the reservoir approximately 1 to 1.5 miles north of the dam. This dredging area was selected because large amounts of sediment still naturally deposit at this location. Although changing the dredging area location will likely influence results, removing such a relatively small quantity of sediment will have a minimal impact on total load delivered to the Bay when large flood events occur. (Pg. 136). The estimated scouring of sediment and nutrients was reduced by 32 percent in comparison to scour with a 2011 bathymetry (with all other parameters remaining the same). Dredging had little effect on model simulated water quality conditions in the Chesapeake Bay. (Pg. 136). • CBEMP estimated a decrease (a positive improvement) of 0.2 percent nonattainment in the deep channel DO water quality standard for segments. (Pg. 137). • The results imply that if 31 mcy (25 million tons) of sediment were removed, there would be a 9 percent decrease in total load to the Bay (from 22.3 to 20.3 million tons), a 40 percent decrease in bed scour (from 3.0 to 1.8 million tons) and a 50 percent increase in reservoir sedimentation or deposition (from 4.0 to 6.0 million tons). (Pg. 139). **Comment DR-25:** Please provide the data and models used for this analysis.	The models used in the watershed assessment are summarized in Chapter 3 of the main report. Extensive details about each model, including the input data, are provided in Appendices A through D.

Comment Code	Comment	Comment Response
DR-26	• "However, these calculations do not take into account that the storage capacity would be increasing and thus more incoming sediment could be depositing." (Pg. 139). • It was assumed that the average Susquehanna River flow during the winter months was 60,000 cfs., approximately twice that of the median flow of about 30,000 cfs. At 60,000 cfs., the average suspended sediment measurement below the dam was assumed to be about 12 mg/L, which equates to a daily load of about 1,940 tons of sediment passing through the dam. (Pg. 140). **Comment DR-26:** CBEMP model is being used to determine dredging effectiveness. How could this be the case given that the CBEMP model has many uncertainties? (*See* Pgs. 3-4 of this outline). Moreover, calculations do not take into account that storage capacity is increasing in the reservoir behind the dam.	The comment states "CBEMP model is being used to examine dredging effectiveness." This statement is incorrect. Page 139 of the draft LSRWA report, under the heading 5.6.3 Long-Term Strategic Dredging states "For this analysis, no models were used instead it was a desktop analysis using information from other modeling runs." Moreover, the other modeling runs referenced for this analysis were conducted using the AdH sediment transport model of Conowingo Reservoir. The CBEMP was not utilized in this analysis at all.
DR-27	Findings • "Sediment bypassing results in increased suspended solids computed in the Bay during the bypassing period. The bypassed sediment settles quickly after bypassing stops." (Pg. 141). • "CBEMP estimated that deep-channel DO and deep-water DO water quality standards were seriously degraded as a result of nutrients associated with the bypassed sediment." (Pg. 141). • "Bypassing costs are still high but not as high as dredging. Bypassing is just as effective as dredging at increasing sediment deposition and reducing available sediment for scour events. However, this method increases total sediment loads to the Bay. The environmental costs (diminished DO, increased chlorophyll) are roughly 10 times greater than the benefits gained from reducing bed sediment scour in Conowingo reservoir." (Pg. 142). **Comment DR-27:** NEPA is required for these investigations. "It should be noted that the LSRWA effort was a watershed assessment and not a detailed investigation of a specific project alternative(s) proposed for implementation. That latter would likely require preparation of a NEPA document. The evaluation of sediment management strategies in the assessment focused on water quality impacts, with some consideration of impacts to SAV. Other environmental and social impacts were only minimally evaluated or not evaluated at all. A full investigation of environmental impacts would be performed in any future, project-specific NEPA effort." (Pg. 143).	Please see the response to Comment CCC-L-5 regarding NEPA. Additional text regarding impacts to SAV and oysters has been added to Section 4.2.3. Text to further address environmental implications has also been added throughout the document.

Comment Code	Comment	Comment Response
DR-28	Public Participation Concerns • "The team sent out study coordination letters to various federal and state resource agencies in February 2012 to inform agencies of the initiation of the study and to request Clean Chesapeake Coalition Summary and Comments on DLSRWA and Appendices Page 15 of 53 15 the level of involvement each agency would like to have with the study. Two response letters were received requesting involvement in the study as well as various emails from agencies confirming their willingness to participate in study. A study initiation notice was distributed via email in February 2012 as well." (Pg. 147). • "The team held quarterly meetings to discuss, coordinate, and review technical components of the assessment, as well as management activities. These meetings were open to all stakeholders to attend. Agendas and handouts were provided to stakeholders via email prior to the meeting and the meeting summary with items presented at quarterly meetings was posted to the public website after quarterly meetings. A total of 10 quarterly meetings were held from November 2011 to January 2014, with attendance ranging from 30 to 50 participants. These participants represented 19 different stakeholder groups." (Pg. 147). • "Throughout the duration of the assessment, the LSRWA team coordinated with other pertinent Chesapeake Bay groups, so as to be included on their agendas to provide updates and get feedback on the LSRWA. Feedback received from these other Chesapeake Bay groups was reported back to the rest of the LSRWA team and was incorporated into this LSRWA report." (Pg 147). • "Throughout the duration of the assessment, email updates were sent out periodically to interested stakeholders on study progress and news. This email distribution list was started by the original Sediment Task Force (included interested stakeholders) that Susquehanna River Basin Commission led in 1999 and 2000. The team has been updating this list since 2009 with people interested in this effort." (Pg. 147). • "Prior to public release the draft LSRWA report was reviewed by the agencies involved in quarterly meetings. Additionally, the STAC sponsored an independent scientific peer review of the draft LSRWA report in June - August of 2014. STAC provides scientific and technical guidance to the Chesapeake Bay Program on measures to restore and protect the Chesapeake Bay. More information about STAC is located here: www.chesapeake.org/stac. Appendix I, Attachment I-7 contains the comments and LSRWA team responses to the LSRWA quarterly group's reviews and the STAC sponsored independent scientific peer review." (Pg. 147). • At least one public meeting is expected to be held later in 2014. Once that meeting is held, a description of the meeting(s) will be placed here and will include a location, date, participants, and feedback received. All comments will become part of Appendix I, Attachment I-7. (Pg. 147).	Neither NEPA nor FACA applied to this study; please see our response to comment CCC-L-5 for more information. The public participation element of the assessment is described in Chapter 6 of the main report, as well as Appendix I.

Comment Code	Comment	Comment Response
	Comment DR-28: Please explain how this study group involved public participation. How does the LSRWA's approach address NEPA public participation requirements and those required by the Federal Advisory committee Act (FACA)?	
DR-29	• Recommendation – U.S. EPA and Bay watershed jurisdictional partners should integrate findings from the LSRWA into their ongoing analyses and development of the seven watershed jurisdictions' Phase III WIPs as part of Chesapeake Bay TMDL 2017 midpoint assessment. (Pg. 160). **Comment DR-29:** Having such findings integrate with 7 watershed jurisdictions requires a FACA approach. Was FACA ever discussed? If not, why not? If so, how was FACA addressed?	EPA and its seven watershed jurisdictional partners have already publicly committed to integrating the findings from the LSRWA into the partnership's Chesapeake Bay TMDL 2017 midpoint assessment in numerous public forums and publicly accessible documents. Please also see the response to comment CCC-L-5 regarding FACA.

Comment Code	Comment	Comment Response
DR-30	Finding #1: Conditions in the Lower Susquehanna reservoir system are different than previously understood. (Pg. 151). • Conowingo Reservoir is essentially at full capacity; a state of dynamic equilibrium now exists. Previously, it was thought that Conowingo still had long-term net trapping capacity for decades to come. • Storm event based scour of Conowingo Reservoir has increased. Previously, it was not fully understood how scouring was changing as the reservoirs filled. (Pg. 152). • The LSRWA modelling efforts indicate that the scour threshold for the current Conowingo Reservoir condition ranges from about 300,000 cfs. to 400,000 cfs. (Pg. 152). • Modelling simulations comparing current conditions of the Conowingo Reservoir to the mid-1990s indicate that a higher volume of sediment is scoured currently at flows above 150,000 cfs. in comparison to the mid-1990s, with the threshold for mass scouring occurring at about 400,000 cfs. (Pg. 152). • Sediment transport is related to particle size. Storms can potentially scour the silts and clays (easier to transport) leaving behind the coarser sand-sized sediment. (Pg. 152). Finding #2: The loss of long-term sediment trapping capacity is causing impacts to the health of the Chesapeake Bay ecosystem. (Pg. 153). • The assessment indicates that the ecosystem impacts to the Chesapeake Bay result from the changed conditions and are due primarily to extra nutrients associated with the scoured sediment as opposed to the sediment itself. **Comment DR-30:** Modelling estimates showed that the sediment loads (not including nutrients they contain) from Conowingo Reservoir scour events are not the major threat to Bay water quality. The models do not account for the sediment smothering that is occurring. Low DO was estimated to persist in the deeper waters of northern Chesapeake Bay for multiple seasons due to nutrient storage in the Bay's bed sediment and recycling between the bed sediment and overlying water column. (Pg. 153). This needs to be reviewed and there needs to be concern with the bed sediments and smothering.	Concur with the commenter's summation that nutrients are the primary concern with Conowingo infill. In addition, studies now underway will improve the assessment of the water quality influences of Conowingo infill. However, "SAV smothering" was unobserved in measurements following Tropical Storm Lee.
DR-31	• Full WIP implementation won't fully restore the Chesapeake Bay given changes to the Conowingo Reservoir sediment and associated nutrient trapping capacity. (Pg. 154). • The Susquehanna River watershed, not the Conowingo Dam and its Reservoir, is the principal source of adverse pollutant impacts on upper Chesapeake Bay water quality and aquatic life. (Pg. 154). **Comment DR-31:** So why has the U.S. EPA not declared the Susquehanna River (in Pennsylvania) impaired?	The Pennsylvania Department of Environmental Protection has been delegated the authority to assess the quality of the commonwealth's waters and make determination, consistent with the federal Clean Water Act, as to whether specific stream and river segments are supporting their designated uses as defined within Pennsylvania's water quality standards regulations. EPA does review and approve Pennsylvania's list of impaired waters on a biennial basis. EPA is currently working with Pennsylvania Department of Environmental Protection on enhanced monitoring and assessment of the Susquehanna River in support of Pennsylvania's future assessments of the quality of the Susquehanna River's waters.

Comment Code	Comment	Comment Response
DR-32	• On average flows above 800,000 cfs. produced scour load that comprised about 30 to 50 percent of the total load entering the Bay; however, an event of this magnitude is extremely rare with a recurrence interval of 40 years or more. (Pg. 155). **Comment DR-32:** *See* Figure 4.1. (Pg. 62). Table 4.3 shows an event of 798,000 cfs. having an occurrence of 1 in 25 years. (Pg. 63). Exelon's relicensing application with FERC is for a 46 year license. So how is such an occurrence of flows above 800,000 cfs. a rarity? Why weren't the model runs conducted with a flow rate of at least 798,000 cfs., having an occurrence of 1 in 25 years?	Text has been clarified. Paragraph 2 on page 155 (October 2014 version, now on page 162) has been changed. Line 4 now indicates "...recurrence interval of less than 40 years at the Marietta, PA gage).... Line 8 has been changed to " flows above 800,000 cfs at the Marietta, PA gage produced scour...." Line 10 has been changed to "... an event of this magnitude has a recurrence interval ....).
A-1	**Comment A-1:** Two one dimensional models were used instead of more and current data and considering a three dimensional model. Statements Regarding the Use and Limitations of Models in the DLSRWA • Due to data limitations two one dimensional model simulations were produced: one for the modelling period 2008 - 2011 (representing net deposition) and a second for a high streamflow event using Tropical Storm Lee to represent net scour. (Pg. 1). • Each simulation used the same model data inputs but model parameters were changed. The depositional model resulted in a net deposition of 2.1 million tons while the scour model resulted in a net loss of 1.5 million tons of sediments. (Pg. 1). • Dynamic equilibrium results in increased loads that may have a greater impact on sediment and phosphorus that tend to transport in the particles phase and have less of an impact on nitrogen which tends to transport in a dissolved phase. (Pg. 4). • It is implied that increasing concentrations and loads are due to the loss of storage capacity from a decrease in the scour threshold. These increases are not certain but likely involve changes in particle fall velocities, increased water velocity, transport capacities, and bed shear. (Pg. 4). • The HEC-RAS one dimensional model simulates the capability of a stream to transport sediment, both bed and suspended flow, based on yield from upstream sources and current composition of bed. The HEC-RAS transport equations are designed mainly for sand and coarser particles. (Pg. 13).	There was only one HEC-RAS model (one-dimensional) used for this study, but two simulations based on the same input and calibration data. The AdH model, also used in this study, is a two-dimensional model.
A-2	**Comment A-2:** How does the HEC-RAS model account for clay sediments? • Sediment loads entering and leaving a reservoir can be determined from a sediment (*i.e.* , transport) curve or from actual concentration data from upstream and/or downstream sites(s). (Pg. 11).	There is detailed information on the particle size" groupings" and on the particle size parameters used in calibrating the model in Appendix A.
A-3	**Comment A-3:** Figure 6 (Pg. 1) portrays the discharge flow rate capped at 425,000 cfs., which triggers data manipulation concerns. Figure 7 portrays flow rate at approximately 625,000 cfs. The core samples utilized for the Conowingo Reservoir were limited to 8 samples of less than 12'' in depth. *See* Figures 7 and 8.	See responses to comments DR-4 and DR-15.

Comment Code	Comment	Comment Response
A-4	• At the time that this assessment began, there was concern about the issue of the reservoirs and their reduced trapping capacity because of the implications to sediment and the associated nutrient loads to the Chesapeake Bay and management of those loads. More specifically, there were significant implications to the then ongoing development of the Chesapeake Bay TMDL by EPA working collaboratively with the six watershed states and the District of Columbia. In the 2010 Chesapeake Bay TMDL report, EPA and its seven partner watershed jurisdictions documented their assumption that the Chesapeake Bay TMDL allocations were based on the Conowingo Dam and Reservoir's sediment and associated nutrient trapping capacity in the mid-1990s, the midpoint of the 10 years of hydrology (1991-2000) used in the underlying model scenarios (USEPA, 2010a). EPA documented within its 2010 Chesapeake Bay TMDL main report and supporting technical appendix that if future monitoring shows the trapping capacity of the dam were reduced, then EPA would consider adjusting the Pennsylvania, Maryland, and New York sediment and associated nutrient load reduction obligations based on the new delivered loads to ensure that they were offsetting any new loads of sediment and associated nutrients being delivered to Chesapeake Bay (USEPA, 2010a). (Pg. 9). **Comment A-4:** Admission. It is interesting that they don't discuss this assumption in terms of its impact on the models.	It is unclear what the commenter means by this statement. Since the Bay TMDL was developed using the 1991-2000 hydrologic period as well as with a critical period of 1993-1995 for water quality standards attainment, it is a given that the bathymetry, sediment storage capacity, and transport from Conowingo Reservoir during that period is what is established in the TMDL. As those conditions change with the reservoir reaching dynamic equilibrium, the models must be revisited using newer data to accurately reflect the changed conditions. This iterative adaptive process is built into the Chesapeake Bay TMDL through the 2017 midpoint assessment. Also, the additional data collected in 2015 and 2016 with the new and enhanced monitoring will ensure that there are additional empirical data to calibrate/validate the updated Chesapeake Bay watershed and estuarine water quality models. The trapping efficiency was incorporated in the HEC-RAS model by use of the sediment duration curve and actual estimated loads, both of which inherently contain a gain or loss of sediment due to trapping.
A-5	• According to the DLSRWA the 52 flood gates that span the dam begin to open at a flow rate greater than 86,000 cfs. Each flood gate generally has the capability to pass up to about 15,000 cfs. (Pg. 14). • During a large flood that requires the majority of the gate to be open, the spatial distribution of discharge shifts from the western side of the dam where the power plant resides, to the center of the channel. This shift in flow distribution and subsequent sediment load causes the sediment load on the eastern side of the reservoir t increase resulting in a high deposition rate in the area. (Page 14). "Thus depending on the reservoir inflows the spatial and quantitative fate of sediment in Conowingo Reservoir can be quite variable and difficult to stimulate with current modelling methods." **Comment A-5:** Concerns expressed in the DLSRWA that the Conowingo Reservoir is quite variable and difficult to simulate. So how is the simulations conducted?	See response to comment DR-6.

Comment Code	Comment	Comment Response
A-6	• A report prepared for the LSRWA study discusses modelling uncertainties in Attachment B-1. (Pg. 14). • Susquehanna River Inflows- the AdH (2 dimensional) simulations used flow rates from 2008-2011- all but one - **Question:** what was the one's flow rate? (Pg. 15). • Tropical Storm Lee (September 2011) with a peak discharge of 700,000 cfs. (Pg. 15) - 776,000 cfs. (Pg. 66). **Comment A-6:** Peak flow rate is marginalized at 776,000 cfs. This rate seems to change throughout the report as a way to run the models with marginalized flow rates. The bathymetric discussion on Pg. 67 makes no sense.	See the responses for comments CCC-24 or B-9 for full explanation of flows, and the response for comment DR-15 about the frequency relationship.
A-7	• The HEC-RAS one dimensional model sediment rating curve produced two sediment inflow scenarios: scenario one no scour from upper reservoirs and scenario 2 with 1.8 million tons of scour from the upper two reservoirs for a total inflow load of 24 million tons. (Pg. 16). **Comment A-7:** How are these numbers derived given the statement on Pg. 14 that stated the Conowingo Reservoir is quite variable and difficult to simulate?	The numbers are derived from HEC-RAS modeled results. They were adjusted somewhat for the AdH input, to ensure a conservative estimate of the total load coming into the Conowingo Reservoir (i.e., they were increased by 10 percent: this is conservative with respect to making sure the load was not underpredicted by the HEC-RAS model). It is recognized that this is a source of uncertainty in the results.
A-8	• The one dimensional model HEC-RAS was used to provide data for the AdH model (two dimensional model). (Pg. 17). Figure 6 shows a sediment rating curve with this data at a flow rate slightly above 600,000 cfs. (Pg. 17). What does this purport to represent? • In addition, the AdH sediment model requires bed sediments. This data was also manipulated as only 8 bed core samples were taken from the Conowingo Reservoir to a maximum depth of only 1 foot. Core samples were required to determine the inception of erosion (critical shear stress for erosion) and the erosion rate (Pg. 18) used to develop six material zones (Pg. 19). According to the DLSRWA the sediment bed in the AdH Model was approximately 3 feet. (Pg. 23). The properties of the lower 2 feet were either approximated from the SEDFlume data results (which is the one foot data) or determined from literature values. (Pg. 23). **Comment A-8:** A general trend was established with this tenuous data which is used to account for sediment size and critical shear stress. Figure 11 is a not based on core samples but rather approximations. (Pg. 26). Figure 12's presentation of suspended sediment concentrations undermined Tropical storm Lee to 600,000 cfs. given that it relied on approximations from Figure 11.	The sediment data happened to be taken at slightly higher than 600,000 cfs (the sample was taken on September 8, 2011 at an instantaneous flow of 617,000 cfs); this does not mean that 600,000 was the highest flow that occurred, or the highest that was modeled. The actual flows for the event were modeled in the LSRWA analyses.
A-9	**Comment A-9:** Because of the uncertainty of measured model boundary conditions the AdH two dimensional model was validated by comparing model output to the total suspended sample measurements below the Conowingo Dam. (Pg. 23). Where is this data from? How could these flow rates above the dam correlate with flow rates below the dam?	The sediment data were taken below the dam. The flow above the dam must equal the flow below the dam (with a short time-lag factored in), unless the dam is storing water (i.e., the stage/elevation in the dam is changing). The model is computing this according to its internal physics.

Comment Code	Comment	Comment Response
A-10	• "The hydrodynamics were successfully implemented in the AdH; however, the model was not capable of passing sediment through the gates, therefore, for this study the dam was modeled as an open boundary with downstream control represented by the water surface elevation at the dam. This limitation impacted how sediment was spatially distributed in the lower reach of the Conowingo Reservoir near the dam." (Pg. 60). **Comment A-10:** This is an important factor to consider in the two dimensional AdH Model, yet the dam is somehow removed for the model run and flow rates above the dam are compared to flow rates below the dam. How does this account for scour from behind the dam and the circular river flow motion against the dam?	See response to comment DR-6.
B-1	**Comment B-1:** "Conowingo Reservoir currently is approaching a dynamic equilibrium state and continues to store inflowing sediments from non-flood periods." (Pg. 2) This discussion is not consistent or current throughout the DLSRWA as the Dam has indeed reached a state of dynamic equilibrium.	The first comment relates to what was known previously from observations alone; the second comment (that the reservoir has effectively reached dynamic equilibrium) relates to what was learned from this study.
B-2	• "The USGS estimates that the average inflow of sediment is about 3.2 million tons per year into the Conowingo reservoir, with deposition ranging from 1.0 to 2.0 million tons per year." (Pg. 5). HEC-6 model one dimensional mode under-predicted the trap efficiency. (Pg. 5). **Comment B-2:** Exelon's report is cited as a good summary, which is concerning given that Exelon revised the USGS HEC-6 model and conducted a series of simulations to evaluate scour potential of the three reservoirs. (Pg. 5-6). Please keep in mind this is the same model (Exelon's HEC-6 model) that Langland criticized in his notes and review of the FERC required Exelon Sediment Transport Study.	On page 6, the usage of the word "summary" is not meant to say the report provided "a good summary", but rather "a good summary of the report" is provided. Report had been changed to "A summary of…"
B-3	• Models: Two dimensional model: AdH and HEC-RAS. (Pg. 7). • Data: "The USGS provided reservoir surveys from 1996 and 2008 with Exelon Corporation providing the most recent 2011 survey. The survey was modified by USGS to represent a sediment capacity condition." (Pg. 7-8). "The 4-year flow period from Clean Chesapeake Coalition Summary and Comments on DLSRWA and Appendices Page 22 of 53 22 2008 - 2011 was simulated in the model. The flow and sediment entering the upstream model boundary (the channel below the dam of Lake Aldred) were provided by USGS from HEC-RAS (one dimensional model simulations of the 4 year period)." (Pg. 8). **Comment B-3:** Not only is Exelon providing the model data to establish a full sediment capacity condition but the 1996 - 2008 reservoir data is being used with 2008 - 2011 flow data. The one dimensional model is not taking into account the impact of scour no matter what data manipulation is being considered. Why not use the USACE's bathymetric changes from 2008 - 2011 data (see Pg. 1) instead of Exelon's data? Wasn't there USGS data to consider?	Several different bathymetries were used together with the same set of boundary conditions to ascertain to what degree the system is approaching dynamic equilibrium. The USGS modified the 2011 data provided by Exelon to approximate a full reservoir conditions; hence, USGS generated the full reservoir bathymetry,

Comment Code	Comment	Comment Response
B-4	• A report was prepared for the DLSRWA effort discussing modelling uncertainties. (Pg. 14). **Comment B-4:** Where is this report?	As noted on page 14 of Appendix B, the report is located in Attachment B-1.
B-5	• One dimensional models are typically utilized when depth and laterally average conditions can provide adequate results to a problem. Two dimensional models are appropriate when lateral sediment transport conditions need to be resolved. Model results are depth averaged with model results available throughout the domain area. Two dimensional models can be used to stimulate sediment transport over years or decades for long term simulations. Three dimensional models are the most complex and provide problem resolution in all three dimensions (*i.e.* , depth, lateral and longitudinal). However, three dimensional models are computationally intensive and require long periods of simulation time to rum relatively short problem durations. If the goal of a study is to better understand reservoir stratification in low flow, low turbulence conditions than a three dimensional model is required to differentiate vertical properties. • "During a large flood that requires the majority of the gates to open, the spatial distribution of discharge shifts from the westerns side of the dam where the power plant resides, to the center of the channel. This shift in flow distribution and subsequent sediment load causes the sediment load on the eastern side of the reservoir to increase resulting in a high deposition rate in this area." (Pg. 14). According to Exelon: a flow rate greater than 86,000 cfs. the 52 flood gates that span the dam begin to open. Each flood gate generally has the capability to pass up to about 15,000 cfs." (Pg. 14). **Comment B-5:** Having all gates operating at full capacity the flow rate would allow for 780,000 cfs. In addition two dimensional models are limited in the short term and are using data obtained from a one dimensional model.	The capacity of the gate does not indicate the actual flow that passes the gate for a given event; it merely indicates how much flow the gate is capable of passing. Also, see response to comment DR-2.

Comment Code	Comment	Comment Response
B-6	<u>Model Flow and Sediment Boundary Conditions</u> 2008-2011 Time Period • First two years had relatively low flows of approximately 300,000 cfs. The last two years had flows that reached or surpassed the scour threshold of 400,000 cfs. Tropical Storm Lee occurred in September 2011 with a peak discharge of approximately 700,000 cfs. (Pg. 15). o HECRAS Output Sediment 1st scenario indicated no scour from the upper two reservoirs and inflow of sediment into Conowingo of 22 million tons. o HECRAS Output Sediment 2nd Scenario indicated approximately 1.8 million tons of scour from the upper two reservoirs with inflow of sediment estimated at 24 million tons. **Comment B-6:** According to the DLSRWA Tropical Storm Lee had a peak discharge of 776,000 cfs. (Page 66). The approximation marginalizes this storm by lowering the peak discharge to 700,000 cfs. Keep in mind that models aren't even running the flow rate at 700,000 cfs., but rather the 620,000 cfs. (Page 22).	For clarification, the text in the main report on page 66 (October 2014 version; now page 68) has been changed to include the daily peak flow value of 709,000 cfs for Tropical Storm Lee, along with the instantaneous peak value of 778,000 cfs. The text on page 15 of Appendix B refers to the daily peak flow value of 709,000 cfs which is approximately 700,000 cfs.
B-7	• The scour load from the upper two reservoirs is needed because the maximum load may influence transport capacity in Conowingo and thus impact bed scour potential. Therefore, the 24 million ton HECRAS load was increased by 10 percent to reflect a potential maximum scour load from the upper reservoirs." (Pg. 17). **Comment B-7:** What is the model or science behind this 10% increase?	See response to comment A-7.
B-8	• "Figures 6 and 7 show loads increasing exponentially after the 400,000 cfs. Scour threshold…" (Pg. 17). **Comment B-8:** Figure 6 shows that the AdH model is only considering a 600,000 cfs. flow rate and not a 700,000 cfs. that was initially discussed. (Pg. 17). Keeping in mind that as this is increasing exponentially these lower marginalized numbers significantly lower the scoured sediment amounts. How did these number associated with Tropical Storm Lee get to 600,000 cfs.? Again the actual numbers regarding Tropical Storm Lee (*i.e.* , the USGS number for Tropical Storm Lee is 709,000 cfs. (*see* Pg. 2 of Hirsch 2012 Report)) are being marginalized.	Figure 6 describes the data used to create the sediment rating curve. The sediment sample was taken at roughly 600,000 cfs (the sample was taken on September 8, 2011 at an instantaneous flow of 617,000 cfs), but this was not the largest value of discharge modeled. Figure 5 indicates that the peak flow of 709,000 cfs was indeed modeled. The sediment rating curve is an exponential equation fitted to the data in Figure 6, so the load associated with 709,000 cfs (that was indeed applied in the model) is much greater than the load seen for 600,000 cfs.

Comment Code	Comment	Comment Response
B-9	Model Validation • SEDflume analysis of bed sediments. The AdH sediment model requires bed sediment properties for each layer in the bed. Eight bed core samples were taken from Conowingo. "The bed was sampled to a maximum depth of only one foot because the resistance of the more consolidated sediments at deeper depths." (Pg. 18). **Comment B-9:** Figure 12 states 630,000 cfs. as the mean daily flow for Tropical Storm Lee. These numbers are being downplayed. The USGS number for Tropical Storm Lee is 709,000 cfs. (*See* Hirsch 2012 Report, Pg. 2). (Pg. 25). When simulated in the so-called Hydrodynamic Model" Tropical Storm Lee's flow velocity near the peak event was now 600,000 cfs. (Pg. 54). This data was used to address the sediment releases on the Susquehanna Flats SAV. One foot core sample limit makes no sense when other reports included much deeper samples.	For Tropical Storm Lee, the peak mean daily discharge at the Marietta, PA gage was 629,000 cfs, while at Conowingo the peak daily discharge was 709,000. Both numbers are correct; in the assessment analyses, the Marietta flow is for the starting (inflow) and the Conowingo flow represents the ending (outflow) point. Flow values in Section 4.2 have been revised and the accompanying text clarified to show that the noted values are for peak daily values at the Conowingo gage. A very specific coring method is used for SEDFLUME analyses, to ensure that the sample is undisturbed and retains as closely as possible the in situ erosional characteristics. This method requires that the depth of penetration obtainable by the gravity coring method (self weight core penetration) is the limit of sampling that one can employ.
B-10	• "A relatively small number of bed samples were taken from Conowingo Reservoir. Eight samples were used to represent the entire domain. Analysis of these samples revealed how the sediment size distribution coarsened with distance from the dam, and the subsequent variation of the critical shear stress and erosion rate. With such a small data set it was necessary to conduct a parametric model study in which variables were varied or adjusted to reflect the potential variation in bed properties." **Comment B-10:** The meeting notes reveal that the core sample number was originally set at 16 instead of 8 and was reduced only due to cost concerns. (Pg. 28). Keep in mind that the HECRAS model was one dimensional and that the AdH model was used for a two dimensional approach to address lateral sediment transport conditions. Two dimensional model results are depth averaged throughout the domain area (which was stated earlier on Pg. 12) and are inadequate during well-mixed turbulent conditions. Not only is this model inadequate in predicting scour in high flow rate conditions but the data needed for the depth averaged in the domain area relied on only 8 samples of 1 foot depth. Due to the inadequate amount of samples, data had to be obtained from another model and assumptions had to be made. Given the foregoing what are the margins of error? This is a very serious concern given the limitations of both one dimensional and two dimensional models when considering sediment transport during turbulent conditions. (Pg. 12). The explanations associated with data and models have not shown model validation but rather the reverse.	The commenter's reference to 16 core samples being reduced by cost could not be found in the meeting notes. There is a mention of 16 samples of sand/silt/clay samples (and 391 samples of sand/fines), but that refers to a different data collection effort. See also response to comment DR-2. The AdH model is depth-averaged, but includes several quasi-3D parameterizations of sediment concentration variability in the vertical, which are appropriate for quasi-steady flow conditions. The turbulence question raised by the comment is presumably associated with the inability to model resuspension due to turbulence at the dam, but the general agreement between the modeled and observed grain fractions downstream of the reservoir (Figures 14 and 15, Appendix B) and the scour load (Figure 16) indicate that the model is transporting sediment through the reservoir in a manner similar to what has been observed.

Comment Code	Comment	Comment Response
B-11	<u>Model Simulations – Impact of Temporal Change in Sediment Storage Capacity</u> • The scour load during Tropical Storm Lee comprised of 20% of Tropical Storm Lee's total load (*i.e.* , about 3 million tons of the 14.5 million tons). (Pg. 45). The reservoir will have more capacity as a result of this scouring. The large periodic storms like Tropical Storm Lee will continue to transport large quantities of sediment to the Bay which are much higher than the reduced scour loads resulting from sediment removal operations. (Pg. 45). **Comment B-11:** The August 2012 USGS Hirsch Report determined sediment loads of 4 million tons from scour and 19 million tons of suspended solids. Why is this data different and why are these numbers being marginalized?	In late September 2011, the USGS said 3.5 million tons was scoured, based on a regression equation. The error bars were 2.5 to 4.1 million tons. The estimate of about 3 million tons of scour from the total sediment load of 14.5 million tons during Tropical Storm Lee (AdH results from this report) is comparable to what Bob Hirsch estimated (WRTDS method) in his 2012 report (4 million tons of scour from the total sediment load of 19 million tons) when you consider the differences in the period of record being analyzed in this study compared to the Hirsch study and the fact that there are no confidence intervals in the WRTDS results. In 2015, the USGS should be able to provide confidence intervals on WRTDS results.
B-12	<u>Simulation of Sediment Management Alternatives</u> • "Impact of Sediment Removal - assumed the removal of 2.4 million tons of sediments above the dam. Total outflow load to bay was reduced by about 1.4% from 22.3 to 22 million tons, scour load decreased by 10 % (from 3.0 to 2.7) and the net reservoir sedimentation increased by about 5.0% (4.1 to 4.3 million tons). For this simulation, the Clean Chesapeake Coalition scour load decreased approx. 3.3 percent for every million cubic yards removed." (Pg.47). • "Although changing the dredging area location will likely influence model results, removing such a relatively small quantity of sediment will have a minimal impact on total load delivered to the Bay when large flood events occur." (Pg. 47). **Comment B-12:** Simulation was run on inadequate data. *See* discussion, *infra* , in Section 6.	The LSRWA team disagrees that the data or models were inadequate. However, models do have uncertainties and limitations. Chapter 4 of Appendix B-1 describes modeling uncertainties for the AdH model.
B-13	<u>Conclusions</u> • "A number of conclusions can be drawn from the modelling study. Although the uncertainty of the modelling is high due to the uncertainty of sediment boundary conditions and model limitations, the existing versus alternate approach to simulations reveals change in sediment transport based on the alternate condition scenario." (Pg. 57). **Comment B-13:** What is the meaning of this statement? That modelling uncertainty is high?	It means that, although the uncertainty is high, the reliance on model-to-model-comparisons (rather than absolute predictions) cancels some of the effects of these uncertainties, and allows us to draw conclusions about how the system will respond to certain changes (such as the continued infilling of the reservoir).
B-14	• The AdH sediment transport model results only estimated the transport and fate of sediments that enter the reservoir and scour from the bed. The model does not predict nutrient transport and does not imply any predictive relationship between nutrients and sediment transport. (Pg. 59). **Comment B-14:** Nutrient transport is model limited and there is no relationship between nutrients and sediments.	The referenced text on pg. 59 correctly characterizes the model results.

Comment Code	Comment	Comment Response
B-15	Recommendations to Improve Future Modelling Efforts • The AdH model was not capable of passing sediment through the gates, therefore, for the study the dam was modeled as an open boundary with downstream control represented by water surface elevation. (Pg. 60). This limitation impacted how sediment was spatially distributed in the lower reach of the Conowingo Reservoir near the dam. **Comment B-15:** In this statement the DLSRWA admits its severe limitations. The model's limitations impacted how sediments were spatially distributed in the lower reach of the Conowingo Reservoir near the dam.	Comment noted.
B-16	• Sediment transport models in general do not have a sophisticated approach to simulate fine sediment flocculation. The AdH model has the capability to relate flocculation to concentration, but not to other variables such as shear stress which determine flock particle size and overall fate. The ability to predict flocculation dynamics is critical to track the fate of sediment in a reservoir system. (Pg. 60). **Comment B-16:** This is an admission by the DLSRWA regarding the inadequate modeling scheme utilized.	The LSRWA team disagrees that the data or models were inadequate. However, models do have uncertainties and limitations. Chapter 4 of Appendix B-1 describes modeling uncertainties for the AdH model.
B-17	• Field data collection needs to continue both upstream and downstream of the Conowingo Dam to provide more information on reservoir balance. Currently, the suspended sediment samples are collected from one location near the power plant. (Pg. 60). **Comment B-17:** This is an admission by the DLSRWA regarding the inadequate data.	The referenced statement provides a recommendation on how to improve future modeling efforts.

Comment Code	Comment	Comment Response
B-17 (2)	<u>Attachment B1 – Evaluation of Uncertainties in Conowingo Reservoir Sediment Transport Modelling, October 2012, Baltimore District Corps of Engineers, Stephen Scott</u> The Impact of Conowingo Dam on Hydraulics and Sediment Transport: • “The Presence of the dam creates a backwater effect, reducing the energy slope, thus reducing velocities and encouraging sedimentation. In the area adjacent to Conowingo Dam, circulation of water and sediment is directly impacted by both the Dam face and how water is discharged through the Dam. • “There are 52 flood gates with a crest elevation of 89.2 feet NGVD 29. For flows exceeding 86,000 cfs., both the power plant and flood gates pass flow up to 400,000 cfs. At higher flows the power plant is shut down with all flow passing through the gates.” Significance of Low Flow Sediment Transport: • “Wind and wave action may impact how sediment moves through reservoir system.” • Suspended sediment transport is an inherently three dimensional process. Correction factor was used in the two dimensional model (AdH model) to account for three dimensional stratification by simulating three dimensional suspended sediment transport. **Comment B-17:** How was this correction factor obtained? Does the correction factor also address the open boundaries once the dam was removed in the model run?	The correction factor is based on an equation developed from analytic and semi-analytic principles. It is a non-equilibrium form of the Rouse equation , which is a very well-established approximation of the vertical sediment profile. The reference for this equation is given here http://dx.doi.org/10.1061/(ASCE)0733-9429(2008)134:7(1010)

Comment Code	Comment	Comment Response
C-1	• "Application of the Chesapeake Bay environmental Model Package to examine the Impacts of Sediment Scour in Conowingo Reservoir on Water Quality in Chesapeake Bay," Report of the US Army Corps of Engineers. • This report examines the impact of reservoir filling on water quality in the Chesapeake Bay with emphasis placed on chlorophyll, water clarity and DO. • Models: numerous, predictive environmental models and transfer of information between the models. (Pg. 2). • CBEMP consist of three independent modes: (1) Watershed Model (WSM 5.3.2); (2) Hydrodynamic model; and (3) WQM- Water Quality or Eutrophication Model. • Analytical Model: Steady state – Reservoir volumetric inflow must equal volumetric outflow and sediment sources must equal sediment sink. Bottom shear stress is the product of shear velocity and fluid density. (Pg. 9). • Results from Analytical Model: When volumetric flow is below the erosion threshold the solids concentration in the reservoir is independent of depth. (Pg. 10). As reservoir depth decreases the flow required to initiate erosion diminishes. (*Id*). When the erosion threshold is exceeded, the sediment concentration in the outflow is inversely proportional to depth. (Pg. 11). One significant insight is that the reservoir is never completely filled. Solids accumulate continuously until an erosion event occurs. As the reservoir fills, however, the flow threshold to initiate an erosion event diminishes. Erosion events become more frequent and severe. Equilibrium implies a balance between suspended solids inflows and outflows over a time period defined by erosion events. The conventional threshold for erosion of ≈ 11,000 m3 s-1 has a recurrence interval of five years (Langland, 2013) implying the equilibrium exists over roughly that period. If we believe the threshold for erosion is below 11,000 m3 s-1, when volumetric flow is below the threshold, the solids concentration in the reservoir is independent of depth. (Pg. 10). As reservoir depth decreases, the flow required to initiate erosion diminishes **Comment C-1:** The use of existing models and practices that the LSRWA points out as being advantageous to the DLSRWA since these tools could not be developed within the time and budget limitations of the LSRWA. The individual models within Chesapeake Bay Environmental Model Package (Watershed Model, Hydrodynamic Model, and Water Quality Model) are documented, reviewed and used. CBEMP relies on the flawed TMDL model.	The Chesapeake Bay TMDL relied on the application of WQSTM, not the other way around as suggested by the commenter.

Comment Code	Comment	Comment Response
C-2	• "The resources necessary to acquire raw observations, create model input decks, execute and validate the individual models within the CBEMP for the years 2008 - 2011 was beyond the scope of the LSRWA." (Pg. 17). • Data limitations: "…[M]eans were required to transfer information from the 2008 – 2011 AdH application to the 1991 - 2000 CBEMP." (Pg. 17). **Comment C-2:** What kinds of means were required?	A method was required to compute sediment scour for the January 1996 event, represented in the CBEMP, from two 2011 events represented in AdH. The method is described on page 24 of Appendix C. "A procedure to apply ADH calculations to the 1996 storm was developed based on the volumetric flow in excess of the threshold for scour, ≈ 11,000 m^3 s-1. The year 2011 contained two erosion events, an un-named event in March and Tropical Storm Lee, in late August. The excess volume for each event was computed by integrating flow over time for the period during which flow exceeded 11,000 m^3 s-1. The amount of solids eroded during each event was taken as the difference between computed loads entering and leaving Conowingo Reservoir. Solids loads leaving the reservoir in excess of loads entering were taken as evidence of net erosion from the bottom. Net erosion for January 1996 was calculated by linear interpolation of the two 2011 events, using excess volume as the basis for the interpolation."
C-3	• "The crucial transfer involved combining scour computed by AdH for Tropical Storm Lee with watershed loads computed by the WSM model for a January 1996 flood and scour event represented by the CBEMP. (Pg. 17). "The WSM provides computations of volumetric flow and associated sediment and nutrient loads throughout the watershed and at the entry points to Chesapeake Bay. Flow computations are based on precipitation, evapotranspiration, snow melt, and other processes. Loads are the result of land use, management practices, point-source wasteloads, and additional factors. The loads computed for 1991 - 2000 are no longer current and are not the loads utilized in the TMDL computation. To emphasize current conditions, a synthetic set of loads was created from the WSM based on 1991 - 2000 flows but 2010 land use and management practices. The set of loads is designated the "2010 Progress Run." The TMDL loads are a second set of synthetic loads created with the WSM. In this case, the 1991 - 2000 flows are paired with land uses and management practices sufficient to meet the TMDL limitations." (Page 17). **Comment C-3:** Limited observations of sediment associated nutrients are available at the Conowingo outfall during the 1996 flood event.	Concur.
C-4	• Major storm events occur at different times of the year. In order to examine the effect of seasonality of storm loads on Chesapeake Bay, the January 1996 storm was moved, within the model framework, to June and to October. The loads were moved directly from January to the other months. No adjustment was made for the potential effects of seasonal alterations in land uses. New Chesapeake Bay hydrodynamic model runs were completed based on the revised flows, to account for alterations in flow regime and stratification within the Bay. (Pg. 18). **Comment C-4:** Limitations on the impact on growing cycles. Table 3-1 needs to reference the flow rate used in model runs. (Pgs. 20-21) What were the flow rates?	The commenter requests the flow rates for the January 1996 storm and suggests they should be included in Table 3-1. The peak flow rates for the storm are given in the two paragraphs which immediately follow the paragraph cited by the commenter. On page 18, the report states "The January 1996 event included the second highest daily flow observed at Conowingo since the inception of the modern management era in 1985, 17,600 m3 s-1" and "Peak instantaneous flow was 25,000 m3 s-1." The daily flows observed at Conowingo for January 1996 are presented in Figure 3-2. Watershed Model flows for the interval are summarized in Table 4-1. In view of the material already in the report, no revision of Table 3-1 is necessary.

Comment Code	Comment	Comment Response
C-5	• Loads from the watershed are calculated by the CBP WSM for two configurations: existing conditions (2010 Progress Run) and total maximum daily load (TMDL). (Pg. 21). • Nutrient loads associated with bottom erosion were calculated by assigning a fractional nitrogen and phosphorus composition to the eroded solids. The initial fractions assigned, 0.3% nitrogen and 0.1% phosphorus, were based on analyses of sediment cores removed from the reservoir (Cerco, 2012). (Pgs. 24-25). **Comment C-5:** Sediment core samples from the reservoir were limited to 8 samples at less than 1 foot deep.	Concur.
C-6	• Dilemma discussed in Appendix C (Pg. 25): Employment of the 1996 nutrient composition to characterize the nutrients associated with sediment eroded in 1996 results in reasonable agreement between observed and computed nutrients at the Conowingo outfall (Figures 4-5, 4-6) but presents a dilemma. Which nutrient fractions should be used in subsequent scenario analysis? The 1996 composition, which accompanied the 1996 event and was observed during the 1991 - 2000 scenario period? Or the 2011 composition which is more recent and characterizes a typical tropical storm event? In view of the dilemma, several key scenarios have been run with alternate composition, presenting a range of potential outcomes. • The ADH model was run for several bathymetry sets including: existing (2008) bathymetry; equilibrium bathymetry; bathymetry following 1996 storm; and bathymetry resulting from dredging 2.3 x 106 m3 (3 million cubic yards). • In all cases, the procedure for determining the scour load followed the same steps: Solids loads into and out of Conowingo Reservoir using the hydrologic record for the period 2008 to 2011were provided by the ADH model; Solids scour for two events in 2011 was determined by the excess of outflowing solids loads over inflowing solids loads; Scour for the 1996 hydrologic record was estimated by interpolation based on excess volume; Nutrient composition was assigned to the scoured solids based on 2011 observations; and For key scenarios, an alternate set of nutrient loads was constructed based on 1996 observed nutrient fractions. **Comment C-6:** Mixing 1996 data for the ADH model that used the hydrogeological record for 2008 - 2011. When reviewing the tables in report please keep in mind that 1 cubic meter per second = 35.3146667 cfs. Table 4-3 (Pg. 29) sets the highest flow rate at 17,479 cubic meters per second multiplied by 35.3 result in 617,009 cubic feet per second, which is well below Tropical Storm Lee's flow rate. Table 4.4 (Pg. 30) is not much better at 621,986 cubic feet per second.	The Big Melt event's peak daily flow value for the Conowingo gage was 622,000 cfs while Tropical Storm Lee's peak daily Conowingo flow value was 709,000 cfs, according to the published USGS gage data (USGS water data site, http://waterdata.usgs.gov). Table 4-3 is titled "Particle Composition Observed at Conowingo Outfall 2010 to 2011." On September 8, 2011, the flow rate at <u>the time</u> of sample collection was 17,749 m3 s-1, according to data provided by USGS. This value does not correspond to the peak daily flow value for the event (709,000 cfs) which occurred a day later on September 9, 2011. Table 4-4 is titled "Observed and Derived Concentration at Conowingo Outfall, January 1996." On January 21, 1996, the reported flow rate was 17,620 m3 s-1 (621,986 ft3 s-1). This value matches the recorded peak daily flow value of 622,000 cfs for the January 1996 event.

Comment Code	Comment	Comment Response
D-1	• The Susquehanna River delivers about 41 percent of the nitrogen loads, 25 percent of the phosphorus loads, and 27 Percent of the suspended solids on an annual basis (CBOP 1991 - 2000 simulation period). **Comment D-1:** The simulation period is flawed. Why was that simulation period, which doesn't take into account episodic event, such as Tropical Storm Lee, considered? As for the Phase 5.3.2 Watershed Model this relies on 2010 TMDLs. Doesn't the 5.3.2 model also have a problem with nutrient load estimations?	Tropical Storm Lee of 2011 was outside the simulation period of the CBP models which run from 1985 to 2005. Updates to the CBP models for use in the Conowingo decisions for 2017 TMDL midpoint assessment will expand the CBP model simulation period from 1985 to 2013 and will include the simulation of Tropical Storm Lee.
D-2	• The mid-point assessment of the Chesapeake TMDL is planned for 2017 to account for Conowingo Dam infill and to offset any additional sediment and associated nutrient loads to the Bay. (Pg. 3). **Comment D-2:** Although the TMDL model is admittedly flawed for nutrient and sediment load, why is it still being used by the LSRWA team to estimate influence of the Conowingo reservoir infill on the Bay's water quality? Modelling for the Chesapeake Bay TMDL consisted of an assessment of the entire hydrologic period of 1991 - 2000, which only takes into account one high flow rate of the big ice melt in 1996. Why isn't flow rate ever discussed in terms of magnitude and velocity in the model? (Pg. 8).	The CBP TMDL models have been thoroughly reviewed and vetted; these models are fully capable of estimating sediment and nutrient loads. Measurements of flow are thoroughly discussed and documented in the report.
E-1	• May, 2, 2012 – Maryland Geological Survey (MGS) conducted 16 sediment grab samples (surficial grab samples) taken in the Susquehanna Flats area of the upper Chesapeake (Figure 1). (Pg. 2). • Sample locations were determined through consultation with USACE based on existing sediment sample data available. (Pg. 2) Two samples sites located in the Susquehanna were not sampled because of concerns regarding bedrock. • Sediment grab samples were analyzed for water content, bulk density and grain size. Two homogenous splits of each sample were processed with one for bulk property analyses and the other for gain-size characterization. (Pg. 4). **Comment E-1:** How deep or what was the depth of these samples?	Depths of samples are annotated in the fourth column of Table 3, page 8 of Appendix E.
E-2	• Shephard's (1954) classification of sediment types presented in Figure 2. (Pg. 7). **Comment E-2:** What is "1954 classification data"? Haven't the characteristics of sediments changed in the last 60 years?	The system used to classify sediment characteristics has not changed. Certainly, sediments change, but the structure to classify them remains consistent making for valid, comparable datasets over the last half a century. The defining document for sediment classification was written in 1954 by Shepard. The reference to that document is in the reference section of Appendix E.
E-3	• Table 3 – Results shows the field data of grain size based on the grab samples. **Comment E-3:** The table emphasized the fact that samples were too shallow or very difficult to get. How were these limitations addressed?	Sample sites #1 and #2 were eliminated because they were rock. There were no sediments present. The lack of sediment is data. The suggested location for Site #6 was in extremely shallow water (< 0.5 feet) and not navigable waters. Site #6 was collected as close as possible in what would be a sedimentary area in 0.5 feet of water depth (400 meters from office-chosen location). The collected coordinates for site #6 are documented. Site #12 was moved due to an emerged point bar at the office-chosen location. Site #12 was collected as close as possible to the intended location (approximately 700 meters east of office-chosen location).

Comment Code	Comment	Comment Response
F-1	• Need for updated chemical and physical measurements of suspended sediment flowing through Conowingo Dam. • During four storm flow events in water year 2010 (October 1, 2010 - September 30, 2011) large volume samples were collected to support analysis of detailed suspended sediment with six fractions and physical and chemical measurements of sediments. **Comment F-1:** What model runs used the USGS data described above?	These are used in the suspended grain size and total load calibration efforts for the AdH model.
F-2	• Ten samples were taken during four high flow events during water year 2011. The U.S. Department of Interior (MD-DE-DC Water Science Center, Baltimore, MD). **Comment F-2:** At which high flow events were the ten samples taken during water year 2011?	Samples were collected for high-flow events on 10/3/2010, 12/3/2010, 3/8/2011, 3/12/2011, 4/18/2011, 4/30/2012 9/8/2011, 9/10/2011, and 9/12/2011. These samples were collected at streamflows ranging from 233,000 to 617,000 cubic feet per second.
F-3	• Table 4. Elements in suspended-sediment samples collected at the Susquehanna River at Conowingo, Maryland (USGS 01578310) were determined by cold vapor atomic absorption spectrophotometry. **Comment F-3:** Were hazardous constituents such as PCBS also monitored in the ten samples? If not, why not?	No measurements of hazardous organic compounds were made on the suspended sediment samples. That sort of analysis was well outside of the scope and budget limits of the program.
G-1	• October 2011, Gomez and Sullivan Engineers conducted bathymetric surveys of the Conowingo Reservoir. These 2011 bathymetry survey data and methods were evaluated and approved by the USGS for the LSRWA's effort. Their efforts included: measured depth data combined with water surface elevation (WSE); the unit measured bottom depths several times per second, recorded averages. To account for the WSE difference, the WSE gradient between Conowingo Dam and Peach Bottom was used to determine the WSE throughout Conowingo Pond. (Pg. 3). **Comment G-1:** How are the influences by Holtwood and the Muddy Run operations accounted for in this analysis? How were depth measurement points calculated between the two measurement areas?	The bathymetric surveys that were performed by Gomez and Sullivan were solely of the Conowingo Reservoir area. Bathymetric surveys are simply a survey of the elevation of the reservoir bottom using depth data and water surface elevation. The Holtwood and Muddy Run facilities are upstream of Peach Bottom, and thus would not affect the analyses. The methodology for the bathymetric surveys is detailed on pages 2-4 of Appendix G.
G-2	• Sediment volume change for each cross section was calculated using the weighted and unweighted water volume methodologies. (Pg. 5). **Comment G-2:** This study relied on a comparison of 2008 and 2011 data to get some insight into the sediment transport process focusing in the Conowingo Pond.	For the LSRWA effort, the AdH model was utilized to estimate the system's sediment transport response to a wide range of flows for four different reservoir bathymetries (1996, 2008, 2011, and calculated "full," in which the system no longer has sediment storage available). The years 1996, 2008, and 2011 were selected for bathymetry input, because in these years, bathymetric surveys had been conducted and data were available.
G-3	**Comment G-3:** Although these samples were taken in a short period of time they cannot really provide what the sediment transport rate would be with one major episodic event.	As noted in previous responses, there are some limitations to data used in this analysis.
G-4	**Comment G-4:** Gomez and Sullivan stated that the 2011 cross-section data may serve as a reference point for future surveys. (Pg. 7). What additional surveys would be recommended by Gomez and Sullivan if these surveys were used as a reference point?	This question should be directed to Gomez and Sullivan.

Comment Code	Comment	Comment Response
G-5	**Comment G-5:** According to Gomez and Sullivan's findings and conclusions, it appears that the zone of dynamic equilibrium has expanded farther downstream that in previous surveys, extending to about 3.7 miles upstream of the Conowingo Dam. (Pg. 8). Did any of the model runs account for this recent observation and conclusion? If not, how will this impact the model runs? Will scour amounts be adjusted to address this recent observation?	The model runs determined that, even if the reservoir fills (effectively) completely, the scour load does not change significantly. That is, the reservoir has approached dynamic equilibrium. Hence, this observation does not significantly alter the findings.
H-1	• A question that was not addressed in the DLSRWA is related to the various techniques for sediment management explored in the literature review of Appendix H. While different kinds of dredging are mentioned in the Appendix and in the body of the report, a technique known as hydro-suction dredging is mentioned several times in the Appendix but not mentioned explicitly in the DLSRWA. This technique would be especially useful for sediment bypassing because it makes use of the huge natural head difference between the reservoir and the river below the dam to maintain flow through a dredging pipe or bypass tunnel. (Pg. 35, Appendix 1-7). **Comment H-1:** Was this technique considered in figuring the relatively low cost of bypassing, or not? Would it make a difference?	This specific technique was not considered. However, this is a subset technique of sediment bypassing. Detailed cost analyses were not performed for the sediment bypassing because there are limited times of the year that are not critical to some species (fish, SAV, etc.). As such, it was considered an nonviable alternative. Similar ideas were also mentioned in the same appendix with the cost estimates.
H-2	• The literature review in Appendix H ignored nutrients." (Pg. 35, Appendix 1-7). • A literature search was conducted on managing watershed/reservoir sedimentation in Appendix H. Findings and lessons learned from the literature search were incorporated into refining sediment management strategies for this Assessment. Results of this literature search are presented in Appendix H. **Comment H-2:** How could findings and lessons learned from case studies in which there is no consistency in the data presented for each LSRWA? For example, many of these case studies have no data for cost/funding or amount of sediment removed.	The intent of the literature search was to investigate how other regions and countries had historically and recently approached watershed and reservoir sedimentation management, with an eye to potential use in the lower Susquehanna River watershed. The compilation of case studies was simply a presentation of the information from the documented efforts. It was not intended to be an exhaustive design and cost review.
H-3	**Comment H-3:** Please explain why the case studies in Appendix H actually include the Susquehanna River Dams (*see* Pg. 26, No. 19). Oddly, the information contained for the Susquehanna River Dams is based on 1990 data. Why wasn't this information updated? How is old information and data useful and or important for the DLSRWA? If the Susquehanna River Dam information is outdated, how can the Study group ensure that case studies in Appendix H contain current and accurate information? Is this just a data dump that includes dams and reservoirs or was most of this information used for the DLSRWA? If it was used for the DLSRWA, how was it used?	The intent of the literature search was to investigate how the Chesapeake region, other regions, and other countries had historically and recently approached watershed and reservoir sedimentation management, with an eye to potential use in the lower Susquehanna River watershed. The compilation of case studies was simply a presentation of the information from the documented efforts. Pertinent strategies were then further evaluated as discussed in Chapter 5.

Comment Code	Comment	Comment Response
H-4	• From the research found, especially overseas, warping technique was found to be often used where river water with high sediment loads is diverted onto agricultural land. The sediment deposition on the land enhances its agricultural value. (Pg. 52). **Comment H-4:** Doesn't the warping technique increase the potential for erosion and greater sediment and nutrient runoff?	The warping technique was determined to be nonviable for the lower Susquehanna River. A detailed evaluation of the warping technique is outside the scope of this assessment.
H-5	**Comment H-5:** Why does Appendix H include overseas sites located in China, Switzerland, Pakistan, etc.? Where is the value regarding such information?	The assessment team wanted to include as many examples as possible, including opportunities to learn from international projects.
H-6	• Minimizing Sediment Deposition includes a description of alternatives such as selectively diverting water. (Pg. 51). **Comment H-6:** When these potential alternatives were identified, was there consideration given to the multiple uses of the Susquehanna reservoirs? For example the Peach Bottom Nuclear Plant relies on reservoir water for cooling, which begs the question: do these alternatives impact the industrial use of the Susquehanna River?	The assessment team was very much aware of the multi-purpose nature of the lower Susquehanna reservoirs. The sediment management strategies that were investigated for concept-level plans and costs, as detailed in Chapter 5 of the main report, are not expected to impact the industrial uses of the water. Prior to implementation of any strategy, the impacts on the other users of the reservoirs would be considered during the NEPA process.
H-7	**Comment H-7:** One case study that was not listed in Appendix H is the Plainwell Impoundment located on the Kalamazoo River, Plainwell, Michigan. The dredged sediments associated with the Plainfield Impoundment contained levels of PCBs. Please keep in mind that recently EPA expressed this concern regarding the Conowingo sediments. This Plainwell Impoundment provided detailed cost data that could be very useful in the event that detectable levels of PCBs are present in the Conowingo sediments. Why was the Plainfield Impoundment overlooked? More information regarding the Plainfield Impoundment can be obtained from the following EPA Region V URL site: http://www.epaosc.org/site/site_profile.aspx?site_id=2815.	The assessment team was unaware of the Plainwell Impoundment action. A review of the noted website indicates that the Plainwell Impoundment action involved dredging/excavation operations and simple dam removal. Both of these actions were already considered in the evaluation of sediment management strategies. The Plainwell Impoundment (13 feet high, 123 acres) is much smaller than the Conowingo Reservoir (94 feet high, 8,625 acres), so the cost information is difficult to scale up to the Conowingo situation.

Comment Code	Comment	Comment Response
I-6-1	• The LSRWA revisited the goals that were developed for the study early on in the scoping process of the LSRWA in order to refine these goals. The purpose of the goals are to create bounds and focus for the team on what will be accomplished with the LSRWA and to communicate to stakeholders what the LSRWA will accomplish. Such goals included evaluating sediment management, and to determine the effects to the Chesapeake Bay from the sediment and nutrient storage located behind the dam. (Pg. 5). • Exelon, the owner and operator of the dam, must undertake a variety of studies as requested by state and federal resource agencies to get an understanding of impacts of the dam. Several of the requested studies deal with sediment transport and accumulation in the dam system which relates to LSWRA efforts. At this time, most of the relicensing studies dealing with sediment transport and accumulation undertaken by Exelon are simply a compilation of existing literature and data. Their study findings were that 400,000 cfs. (cubic feet per second) is not the threshold where sediments are scoured from behind the Conowingo Dam and that overall Tropical Storm Agnes did not scour sediments but ended up depositing more sediment behind Conowingo Dam. Mike said that this latter finding is not supported by USGS at this time. (Pg. 5). **Comment I-6-1:** Knowing that Exelon was responsible for studies dealing with sediment transport and accumulation behind the Dams as part of the license requirement, why did the LSRWA workgroup deicide to take on this task? Why would tax payer funds be used to perform these tasks when the burden was clearly on Exelon?	It is a matter of public record that the state agencies discussed the issues with the FERC re-licensing. Due to the issue being raised during the FERC re-licensing processs, there was an assertion made that more detailed sediment analyses may be helpful to the process. Because USACE has unique technical abilities and tools to conduct these analyses at this scale, the LSRWA was conducted. The Maryland agencies also suggested that FERC require Exelon to complete all aspects of the study, but subsequent FERC filings suggested that the LSRWA would be used in their EIS. Now that the regulatory burden has been put on the State of Maryland, additional information is needed before a Section 401 water quality certification can be approved. Exelon has agreed to fund the additional study, so no public funds are being used for this expanded effort. Since the study findings could influence Maryland's TMDL requirements and associated responsibilities, the state felt that it was critically important to take leadership on this effort. Furthermore, the study was a bigger picture analysis that included the dams above Conowingo, contributions from the lower Susquehanna River watershed, as well as an analysis of management actions to address sediments and associated nutrients.
I-6-2	• Mike Langland noted in the past, USGS utilized a one dimensional HEC-6 model to assess sediment deposition and transport in the entire reservoir system including sediments from the watersheds. Mike noted that there were shortcomings to this model. As part of his LSRWA efforts, Mike will construct and calibrate an updated one dimensional HEC-RAS model that will route inflowing sediment through the reservoirs, accounting for both sediment deposition and erosion in the upper reservoirs. The output of this model will provide boundary conditions for the two dimensional model simulations that Steve will be conducting as part of his scope in the Conowingo Reservoir. **Comment I-6-2:** STAC commented on limitations of the HEC-RAS and AdH models. These limitations were not made sufficiently clear in the DLSRWA. The HEC-RAS modelling effort was largely unsuccessful and the HEC-RAS simulation was largely abandoned as an integral part of the DLSRWA. (Pgs. 8-9, Appendix I-7). What were the limitations associated with the HECRAS model? Was USGS able to obtain a level of comfort with this model?	The limitations of the HEC-RAS model are presented in detail in Appendix A. By identifying the limitations, the USGS was able to gain a better understanding of where the model was misrepresenting the simulations. While USGS recognized that the model was not able to calibrate to the "total" mass of sediment transport, the model did perform well for particle size distribution and flow simulations. .

Comment Code	Comment	Comment Response
I-6-3	• Bruce Michael noted that there was minimal scouring during the spring 2011 high flow events. However, this was the worst year on record for hypoxia and second highest flow on record. (Pg. 8). **Comment I-6-3:** Please provide the data that Bruce Michael based his observation on in the spring of 2011.	There was a 2011 spring scour event as flows at Conowingo Dam were greater that 400,000 cfs. Although this was a significant flow event, it was less than the TS Lee event in September 2011 of over greater than 700,000 cfs. Sediment load data are available on a USGS website (http://cbrim.er.usgs.gov/). Mean monthly loads for the spring of 2011 indicate that sediment loads at Conowingo, MD exceeded those at Marietta, PA by an average of 22,000,000 lbs/day in March and by an average of 8,500,000 lbs/day in April. Some of the difference would be accounted for by the increase in watershed size between the two locations and some represents scour. It should be noted that sediment deposition occurred at the dams during eight months in 2011 and ranged from an average of 950,000 lbs/day in February to an average of 20,800,000 lbs/day in May. Although the first June and second July 2011 cruises indicated record bad dissolved oxygen volumes below 2 mg/L for 1985 through 2011, for the dissolved oxygen reporting season of June through September, the volume of dissolved oxygen below 2 mg/L was the fifth worst year on record. Dissolved oxygen data for the Bay are available on the EPA's Chesapeake Bay Program web site (http://www.chesapeakebay.net/).
I-6-4	• Jeff noted that scouring occurred during Tropical Storm Lee from behind the Conowingo Dam. These sediments appeared to bypass the upper Bay and accumulated more in the middle Bay. The approach channels to the C&D Canal were scoured according to Philadelphia District and there did not appear to be significant burial of organisms since sediment was widely dispersed. (Pg. 8). **Comment I-6-4:** Please provide the data source for Jeff's comments.	See response for comment I-6-1.
I-6-5	• Discussion ensued about the status of federal funding for this study. The study received funding for FY12 by mid-February. [Update: $300,000 received in February 2012.] The FY13 budget will be coming out in a few weeks and then it will be determined if funding is available for next FY. [Update: This project is not in the president's FY13 budget.] (Pg. 3 – January 23, 2012 Meeting at MDE). **Comment I-6-5:** Again please explain why taxpayer money being used when the study should have been conducted by Exelon as part of the FERC relicensing application.	See response for comment I-6-1.
I-6-6	• Dave added that it is important as we finalize the watershed assessment that we make sure to refer back to the public outreach plan and follow what we have laid out to engage the public in the LSRWA. (Pg. 5). **Comment I-6-6:** Why weren't the public involvement procedures established by the Federal Advisory Committee Act (FACA) followed and adhered to? What is this public outreach plan that is discussed above? Please provide a copy of this plan.	Please see the response to comment CCC-L-5 regarding FACA. A copy of the public outreach plan may be found in Appendix I, Attachment I-1. Chapter 6 has since been updated to include more information on stakeholder involvement.

Comment Code	Comment	Comment Response
I-6-7	• Shawn Seaman will contact Michael Helfrich to notify him of quarterly meetings to see if he can attend. (Pg. 2). **Comment I-6-7:** Is this how the public outreach plan works? There seems to be exclusivity involving who can participate.	When specific individuals interested in the assessment were identified to the team, the LSRWA team did try to reach out to them individually. In addition, numerous state and federal agencies, local governments, non-governmental organizations, and business groups were included by providing regular updates of the assessment's progress. These groups were identified through prior communication and the team's knowledge of appropriate groups, or by request from the group. A project website was created to try to reach as many stakeholders as possible. Presentations/briefings were provided to interested groups, as requested. The process and study products have been made fully available to the public.
I-6-8	• Herb mentioned that he, Secretary Summers (MDE) and Paul Swartz (Executive Director, SRBC) met with the Maryland delegation from the Eastern Shore. He noted that feedback from these meetings was that there is a lot of interest in water quality in the Bay; farmers feel like they are being picked on (it will be important to engage agriculture groups in study); and the costs of the implementation of the TMDL and the proposed "flush tax" to cover the cost of implementation of TMDL. (Pg. 5 – 2/16/2012). **Comment I-6-8:** How were agriculture groups engaged in the DLSRWA? If not, why not?	The study team tried to engage as broad a group of stakeholders as possible. Emails were sent to all interested stakeholders and presentations were given whenever possible if requested (e.g., to soil conservation districts).
I-6-9	• The Conowingo Dam has been undergoing the 5-year FERC relicensing process. Out of this relicensing process Exelon (owner and operator of Conowingo Dam) was required to conduct several studies that relate to sediment accumulation and transport. Year 2 study reports are due by January 23, 2012. Several contractors of Exelon attended the quarterly meeting and provided results of these studies to the LSRWA team. Marjie from URS explained that the objective of the sediment transport and accumulation study they conducted was to provide data that will be useful in the future development of an overall sediment management strategy for the Susquehanna River and Chesapeake Bay. **Comment I-6-9:** Was Exelon's sediment transport and accumulation study relied upon or used in the overall sediment management study? Why didn't any workgroup member state that Exelon should be responsible for the LSRWA study given Exelon's contractor's (*i.e.* , URS) comment?	See response for comment I-6-1.
I-6-10	• Anna will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, nongovernment organization (NGO), and state and counties representatives) notifying the group of LSRWA kick-off meeting and study start and will periodically update this group as the LSRWA progresses. (Action Items from November Meeting.) **Comment I-6-10:** Was this update distributed? Did this update include future dates for meetings for all to attend? If so, why didn't the Clean Chesapeake Coalition receive this notice?	Yes, the update was distributed. Following each quarterly meeting, the USACE study manager (Anna Compton) emailed the large email distribution list with notification about the meeting minutes. The minutes were posted on the project website for public access.

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
I-6-11	• Shawn will notify the team when the most recent Exelon study reports are released. Status – Recent report was sent out to the team; ongoing action. Shawn was not in attendance so Tom let the group know that the Exelon application for the Conowingo Dam license will be filed with FERC at the end of August [2012] and all required studies will be completed by the end of September with the exception of two fish studies. (Pg. 3 – 8/16/2012). **Comment I-6-11:** Did LSRWA workgroup members review Exelon's required studies? If so, were deficiencies identified and discussed with Exelon and or its consultants?	Yes, the LSRWA workgroup members were provided the report for review. Also, see response to comment I-6-1.
I-6-12	• The LSRWA identified their mission as: "To comprehensively forecast and evaluate sediment and associated nutrient loads into and from the system of hydroelectric dams located on the Lower Susquehanna River above the Chesapeake Bay and consider structural and non-structural strategies to manage these loads to protect water quality and aquatic life in the Chesapeake Bay." (Pg. 4 – 8/16/2012). **Comment I-6-12**: Did anyone on the LSRWA team question this mission, given that this was Exelon's obligation in the FERC relicensing application? How many scientists in the LSRWA were involved in this comprehensive study? Please provide their names and degrees. Did the LSRWA consist of any hydro engineers?	Yes, the team critically evaluated the study's mission relative to Exelon's obligations and decided that since the study findings could influence Maryland's TMDL requirements and associated responsibilities, it was critically important for Maryland to take leadership through the study agreement with USACE on this effort. Furthermore, the study was a bigger picture analysis that included the dams above Conowingo, contributions from the Lower Susquehanna River watershed, as well as an analysis of management actions to address sediments and associated nutrients, since Exelon's obligation was to study the Conowingo Pond only. The original intent of the LSRWA was to look at the issue from a regional perspective, including Lake Clarke and Lake Aldred, and to provide an unbiased report to support the public record. The primary members of the study team and their technical function are listed on page 185 of the main report. Additional modeling staff are listed within the modeling appendices.
I-6-13	• Matt Rowe will compare the results from the analysis of sediment cores taken from behind the Conowingo dam in 2006 to the decision framework criteria laid out in the 2007 IRC report to help the team better understand the suitability of the sediments in the lower Susquehanna river watershed for innovative reuse options. (Pg. 2 – 12/26/2012). **Comment I-6-13:** How does comparing 2006 data help in the decision making process? Doesn't Tropical Storm Lee in 2011 have a significant impact on this data?	This task of comparing the 2006 data was intended serve as an exploratory analysis. The objective of this effort was to compare the data compiled in the 2006 SRBC report to the 2007 IRC decision framework with the goal of evaluating innovative reuse options. The analysis showed that innovative reuse could not be ruled out as a possible sediment management strategy; therefore that option was discussed in the final report. To our knowledge, it is unknown if any high flow events, such as Tropical Storm Lee, have altered the chemical composition of the Conowingo reservoir sediment. However, any permitted use of the sediment would be subjected to other state and federal requirements and demand further environmental analysis, regardless of any additional sediment scoured or deposited in the reservoir.

Comment Code	Comment	Comment Response
I-6-14	• Currently the law firm Funk and Bolton is proposing and accepting money from counties for a study to be conducted by this law firm on the Bay TMDL. (Pg. 3 – 12/26/2012). Michael added that there has been concern raised by this coalition that MD has county WIPs while PA does not. Pat Buckley noted that PA has "WIP planning targets" in lieu of "County WIPs". **Comment I-6-14:** Is there a reason why the Clean Chesapeake Coalition wasn't invited to attend this meeting? How does the Clean Chesapeake Coalition's attendance interfere with the LSRWA's mission to comprehensively forecast and evaluate sediment and associated nutrient loads into and from the system of hydroelectric dams located on the Lower Susquehanna River above the Chesapeake Bay and consider structural and non-structural strategies to manage these loads to protect water quality and aquatic life in the Chesapeake Bay? How is Funk & Bolton even relevant to this study?	This comment references a quarterly team meeting held on November 19, 2012. Clearly, from the comment, the assessment team did not have advance knowledge of the coalition or their interests in order to extend an invitation to the meeting, as the coalition had just been formed. All quarterly team meetings were open to the public, and all meeting agendas, materials, and minutes were posted on the study website, and the coalition was added to the study mailing list as soon as its interest was known (see response to comment CCC-L-2). The study partners value all stakeholder input, including that of the coalition. That said, it is unlikely that the coalition's particular thoughts related to TMDLs (as referenced in the comment) would have influenced the direction of the study, given that TMDLs were, at best, indirectly related to the study's purpose. Had these inputs been raised at the meeting, the coalition would undoubtedly been referred to EPA and its state TMDL partners for a separate conversation on that topic.
I-6-15	• Carl noted that his previous efforts involved running modelling scenarios that removed Conowingo from the system to understand what it would look like with all sediments flowing into the bay and no longer being trapped by Conowingo. With this latest simulation, Carl looked at what the system would look like (*i.e.,* impacts on water quality) if there were a scouring event. More specifically, he took the system's current condition (Conowingo still trapping) with WIPs in place, using bathymetry from after the 1996 scour event. (Pg. 5 – 03/22/2013). **Comment I-6-15:** How is a scoring event measured if the dam is removed in the model runs? How is the circular flow hitting the dam and scoring sediments adjusted in such a model run?	This comment is based on minutes of a March 22, 2013, project meeting. Carl Cerco stated that the phase of his work involved with scenarios which removed Conowingo from the system was completed. He was moving into a new project phase involving simulation of scour events. The scour events were simulated with Conowingo Dam in place. No simulations of scour events with the dam removed were conducted.
I-6-16	• Lew Linker noted that the results may not represent effects on SAV; a period of reduced light could really impact SAV. Carl noted that for the final report these final outputs need to be remedied. (Pg. 8 – 06/07/2013) **Comment I-6-16:** Were these final outputs ever obtained? If so, please provide a copy of this study.	As described in Wang and Linker (2005), the duration of high light attenuation after extreme storms is an important influence on SAV biomass. The study described the extreme event (Hurricane Juan) caused a light attenuation to exceed 4 m^{-1} for a period of weeks after the storm. The estimated influence on SAV biomass from the extreme event in different seasons was fully documented in Wang and Linker (2005). Follow-up reports which will incorporate the current Conowingo research and monitoring program into the CBP modeling work will more fully document the period of extreme event high light attenuation and its influence on SAV. <u>Source</u>: Wang, P. and L. Linker, 2005. "Effect of Timing on Extreme Storms on Chesapeake Bay Submerged Aquatic Vegetation" in K.A. Selner (ed.), 2005. Hurricane Isabel in Perspective. Chesapeake Research Consortium, CRC Publication 05-160 Edgewater, MD.

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
I-6-17	• Michael Helfrich noted that Carl's modelling is using the 4th biggest event we have on record to show storm scouring (the 1996 winter storm event). What about the storms that have occurred on record that were larger than this event? Also the loads (nutrient and solids) shown in condition 6 (scour event in summer, fall, and winter) are less than loads in Conditions 3 - 5, which all included a simulation of the same storm event. Why is this? (Pg. 9 – 06/07/2013). **Comment I-6-17:** Please provide an answer to Michael Helfrich's statement	As noted in the meeting minutes following this statement, "Carl explained that Condition 6 used HSPF and CBP WSM model (which can take into account sediments from the watershed as well) while Conditions 3-5 used the ADH model, so results vary and should not be compared directly. Condition 6 sheds light on impact of the timing of event while Conditions 2-5 show impacts of a full reservoir, WIPs in place, and a storm event."
I-6-18	• "The group determined that data on nutrient (and sediment) in water outflows from Conowingo Pond was inadequate, and collecting data to fill gaps was scoped into the study. It was recognized that it would be useful to have additional information on Conowingo Pond bottom sediment biogeochemistry, particularly with regard to phosphorus. However, it was determined that existing information/data was adequate for study modelling purposes, and it was decided to not undertake such investigations in light of need to control study costs." (Pg. 3 – 09/24/2013). **Comment I-6-18:** How does the use of old data to fill in the gaps effect the LSRWA's mission to comprehensively forecast and evaluate sediment and associated nutrient loads into and from the system of hydroelectric dams located on the Lower Susquehanna River above the Chesapeake Bay and consider structural and non-structural strategies to manage these loads to protect water quality and aquatic life in the Chesapeake Bay?	Collection of new data is not always needed. Using existing data is an efficient, economical, and reasonable way to conduct studies. Virtually every scientific or engineering study employs "old" data to some extent. Data evaluation for a study involves reviewing available data, obtaining critical new data, and identifying data gaps. This study followed that process. Available data on pond outflows and bottom composition was assembled (e.g., Attachment C-1). Critical new data was obtained (e.g., cores for analysis in the SEDflume Attachment B-2). In the course of the study, gaps in our understanding were identified (e.g., reactivity and biological availability of scoured sediments, Appendix C, chapter 7). A field and laboratory study is underway and aimed, in part, at filling some of the data gaps identified during this study.
I-6-19	• With regard to (P) phosphorus biogeochemistry, Carl had identified Jordan and others (2008) as presenting a concept applicable to utilize for our situation. P is generally bound to iron in fine-grained sediments in oxygenated freshwater and of limited bioavailability. Under anoxic/hypoxic conditions iron is reduced and P can become more bioavailable. Prebinds to iron in sediments if oxygen is again present. P adsorbed to Conowingo Pond bottom sediments would remain bound to those sediments in the freshwater uppermost Bay. In saltwater, biogeochemical conditions change. Jordan and others (2008) indicate that as salinities increase above about 3-4 ppt/psu (parts per thousand/practical salinity units, P is increasingly released from sediments and becomes mobile and bioavailable to living resources, which is likely due to increased sulfate concentrations in marine water (*e.g.* , Caraco, N., J. Cole, and G. Likens, 1989. Evidence for Sulphate-controlled Phosphorus Release from Sediments of Aquatic Systems. (Pg. 3 – 09/24/2013). **Comment I-6-19:** More recent studies show phosphorus is released and no longer bound to sediments in the presence of higher salinity in water. Why weren't these more recent studies evaluated?	The comment repeats the statement recorded in the minutes. Both the minutes and the comment agree that phosphorus is likely more mobile in saltwater. The minutes cite Caraco et al. (1989), one of the fundamental references on this subject. The minutes also cite a more recent publication by Jordan et al. (2008). The modelers are aware of additional recent publications on this topic (e.g., Hartzell et al. (2010) Estuaries and Coasts 33:92-106; Hartzell and Jordan (2012) Biogeochemistry 107:489-500) and have considered them in their work. These and other publications are simply not cited in meeting minutes.

Comment Code	Comment	Comment Response
I-7-1	• The charge from STAC to the review team was: "You should focus your comments on the following [questions], but you are encouraged to provide additional comment that would improve the analyses, report or its recommendations." (Pg. 6). **Comment I-7-1:** How were the questions developed that the review team focused on?	For the STAC peer review of the LSRWA report, STAC requested that the LSRWA team provide questions to focus their review. The LSRWA team worked together to determine these questions so that they would provide the most useful information for the LSWRA efforts+C116.
I-7-2	• "The science associated with assessing the evolving condition of the Lower Susquehanna River and its effects on the Chesapeake Bay is exceptionally challenging. As far as the reviewers are aware the Conowingo situation is truly unique. A major reservoir that had been an effective trap for fine sediment and associated nutrients has largely transitioned to one that no longer has an ability to perform this long-term function." (Pg. 6). **Comment I-7-2:** If this were the case, how could the science associated with the LSRWA continuously flip flop back and forth on whether the reservoir still has trapping capacity or whether reservoirs are in dynamic equilibrium?	Comment noted. The assessment indicates that the reservoirs behind the Holtwood, Safe Harbor, and Conowingo Dams no longer have the long-term ability to store sediment and associated nutrients: a state of dynamic equilibrium now exists. As a result, large periodic storm events that occur on average every 4 to 5 years wash away sediment from behind the dams, increasing associated nutrient loads to the Bay. This creates a short-term increase in storage volume in the reservoirs for trapping sediment and nutrients.
I-7-3	• "The goals stated in the main report (which stress both sediment and nutrient management) are inconsistent with the methodological approach taken by LSRWA (which mainly emphasized sediment) and appear not to be the study's original goals. This review recommends that the original goals of the study (*i.e.* , sediment management to extend the life of Conowingo Dam more than nutrient management to protect Chesapeake Bay water quality) be presented in the introduction followed by a fuller explanation of how and why the focus of the study evolved in time." (Pg. 7). **Comment I-7-3:** If that is the case how adequately does the draft report stress both sediment and nutrient management?	See response to the referenced STAC comment provided in Appendix I-7, on p. 2 of the STAC comment responses.

Comment Code	Comment	Comment Response
I-7-4	• "It must also be stressed early and repeatedly that the dollar costs associated with alternative sediment management approaches specifically focus on the cost of reducing the amount of total sediment behind the dam, not on the cost of managing the impact of associated nutrients on the Chesapeake Bay. Further analysis would be required to appropriately rank the alternative strategies based on a more environmentally relevant total cost in terms of dollars per pound of nitrogen and/or phosphorus reduction." (Pg. 8). **Comment I-7-4:** Such an analysis is extremely important and lost in the DLSRWA. If conducted, will the relevant total cost in terms of dollars per pound of nitrogen and/or phosphorus reduction be compared to all the BMPs and activities discussed in the DLSRA?	See response to the referenced STAC comment provided in Appendix I-7, on p. 3 of the STAC comment responses. This assessment included a survey-level screening of management strategies to address the additional loads to Chesapeake Bay from the reservoirs' bed sediment scour. The costs presented were not calculated for strategies focused on nutrient removal/reduction. More analysis is warranted on nutrient-specific reductions and costs. This is included as a recommendation in the report. No further cost information will be added to the report.
I-7-5	• "Although the report lists and discusses sources of uncertainty, it expresses the expected confidence intervals on its model predictions less often. Although there is no single accepted procedure for reporting uncertainty in the context of scenario modelling, a part of the report should more explicitly explain why confidence intervals on predictions are generally not provided." (Pg. 8). **Comment I-7-5:** Why isn't there any reporting of uncertainty in the context of scenario modelling? Are the uncertainties that significant in terms of considering a margin of error analyses?	See response to the referenced STAC comment provided in Appendix I-7, on p. 4 of the STAC comment responses. A full discussion of the assessment's uncertainty was provided in the LSRWA documentation.

Comment Code	Comment	Comment Response
I-7-6	• "Key areas of concern which are expanded upon in response to Questions 3 and 4 include: (1) Stated sediment discharges from the Conowingo Dam are inconsistent with the literature. The report authors should either correct their numbers or present a clear explanation that reconciles why their estimates are significantly different from other estimates that are based on analysis of observed data. (2) Reduced deposition associated with reservoir infilling has been neglected. The fundamental issue motivating the LSRWA study is that the net trapping efficiency of Conowingo Reservoir has decreased dramatically over the past 15 to 20 years. Net trapping efficiency is the sum of increases in average annual scour and decreases in average annual deposition. However, the simulations and calculations in the study only considered the increase in scour. (3) Grain size effects within and exiting the reservoir were not sufficiently considered. The combination of two grain size effects – (i) changing grain size in time in the reservoir and (ii) the greater effects of fine sediment in transporting nutrients - mean that the effects of the reservoir on water quality have not reached a full dynamic equilibrium. However, the report did not address whether reservoirs were in dynamic equilibrium with respect to nutrients other than by assuming that if sediment was at equilibrium, then nutrients were also. (4) Limitations of the HEC-RAS and AdH models were not made sufficiently clear in the main report. The HEC-RAS modelling effort was largely unsuccessful, and the HEC-RAS simulation was largely abandoned as an integral part of the main report. Although consistent with four observed, integrated sediment-related properties of the system, the AdH model was not fully validated, and the AdH model was forced by boundary conditions outside the range of observed values. This means that the AdH model alone was not reliably predictive, and until the AdH model has been improved, observations should instead be emphasized to support the most important conclusions of the LSRWA study." (Pgs. 8-9). **Comment I-7-6:** These are serious concerns and misinformation, how will this comment be addressed in the DLSRWA? The inconsistencies in data that pertains to sediment discharge, low rates, trapping capacity, dynamic equilibrium, grain size has a significant impact on model runs. How will this be addressed? How can Models be analyzed and compared with such inconsistencies? The DLSRWA authors should correct the fact that the Conowingo Dam is no longer trapping.	See responses to the individual parts of the referenced STAC comment provided in Appendix I-7, starting on pg. 4 of the STAC comment responses.
I-7-7	**Comment I-7-7:** If the AdH model alone was not reliably predictive, and needs substantial improvement, how can observations instead be emphasized to support the important conclusions of the study that relied heavily on the AdH two dimensional model? Does this statement mean that observations trump scientific data? Or does the statement mean that scientific data is not required?	The observations support the trends observed in the AdH model. Further observations over time can be compared back to these results, to confirm or cast doubt on their veracity. It is not clear what is meant by observations trumping scientific data; observations are scientific data. If modeling is what is meant, then no, modeling does not trump data, but it can provide insight that can help to interpret data.

Comment Code	Comment	Comment Response
I-7-8	• "Many of recommendations for future work and modelling tool enhancement are very good and are consistent with the views of this review." (Pg. 9). **Comment I-7-8:** How could this statement be made given the statements above and the data inconsistencies and that the AdH model alone was not reliably predictive?	The Chesapeake Bay Program's Scientific and Technical Advisory Committee made the subject statement. As such, it is the opinion of that committee.
I-7-9	• "…[T]he HEC-RAS modelling effort was ultimately unsuccessful, and results of the HEC-RAS simulation did not form an integral part of the main report, and (ii) the existing application of the AdH model, although generally consistent with the validation data used, was not reliably predictive beyond constraints provided by a few integrated observations of sediment-related properties of the system." **Comment I-7-9:** How can STAC say that these models did not provide an integral part of the report? If these models were not integral, why were they discussed and used? Why were these models used to identify concerns and also used to discuss the financial value of sediment management strategies if they were ultimately unsuccessful?	The Chesapeake Bay Program's Scientific and Technical Advisory Committee made the subject statement. As such, it is the opinion of that committee. The assessment team considered the models to be an integral part of the watershed assessment, and important to the overall conclusions of the watershed assessment.
I-7-10	• The purpose of this assessment was to analyze the movement of sediment and associated nutrient loads within the lower Susquehanna watershed through the series of hydroelectric dams (Safe Harbor, Holtwood, and Conowingo) located on the lower Susquehanna River to the upper Chesapeake Bay. This included analyzing hydrodynamic and sedimentation processes and interactions within the lower Susquehanna River watershed, considering strategies for sediment management, and assessing cumulative impacts of future conditions and sediment management strategies on the upper Chesapeake Bay." A similar "purpose" statement appears in the Introduction. (Pgs. 5-6). Note that the word "nutrient" appears only once in the above statement, and the purpose of the study was mainly to address "sediment management". **Comment I-7-10:** How was that purpose conducted through the use of unsuccessful modelling?	While all models have limitations, the team has confidence in the estimates provided by each of the models as all the models have been used extensively in the past, including for TMDL development, and are vetted by the scientific community. Additionally, the models were calibrated with real observations.
I-7-11	• "The report only briefly states that during the course of the study it became clear that nutrients were more important than sediment. More background is needed in the introduction regarding how and why this judgment was made and how the course of the study then evolved." (Pgs. 11-12). **Comment I-7-11:** Once again the Report relies on assumptions. Is there any scientific background to this concern?	The Chesapeake Bay Program's Scientific and Technical Advisory Committee made the subject statement. As such, it is the opinion of that committee.

Comment Code	Comment	Comment Response
I-7-12	• "Although it is not specifically described as such in the draft report, the overall economic analysis in the LSRWA is in essence a cost-effectiveness analysis (CEA). In contrast to cost-benefit analysis in which the positive and negative impacts of alternatives are expressed and directly compared in monetary terms, CEA expresses some key impacts in non-monetary but still quantitative terms." (Pg. 14). **Comment I-7-12:** Will a cost-benefit analysis be performed on this DLSRWA in terms of BMPs and sediment management strategies?	This assessment included a survey-level screening of management strategies to address the additional loads to Chesapeake Bay from the reservoirs' bed sediment scour. No further cost-benefit analyses will be performed.
I-7-13	• "The report should also emphasize that further analysis would be required to appropriately rank the alternative strategies based on a more environmentally relevant total cost in terms of dollars per pound of nitrogen and/or phosphorus reduction." (Pg. 15). **Comment I-7-13:** The Clean Chesapeake Coalition agrees with this comment. Will the final DLSRWA include alternative strategies based on environmental relevance with total cost in terms of dollars per pound of nitrogen and phosphorus reduction?	The LSRWA team agrees that costs in the report focus on sediment management removal/reduction. Nutrient reduction specific strategies and associated costs warrant further analysis. The premise for sediment management strategy development was: "The focus was on managing and evaluating sediment loads with the understanding that there are nutrients associated with those sediment loads; thus, in managing sediments, one is also managing nutrients. However, it must be noted that the relatively low importance of sediment from the dam as a stressor to Chesapeake Bay water quality and aquatic life versus nutrients was not known until late in the study process. For that reason, management measures focused primarily or solely on nutrients were not considered in this assessment." Therefore, the costs of nitrogen and phosphorus reduction will not be included in the final report.
I-7-14	• "Although there is no single accepted procedure for reporting uncertainty in the context of scenario modelling, a part of the report should more explicitly explain why confidence intervals on predictions are generally not provided." (Pg. 16). • "In many of the modeled scenarios, the changes in attainment of water quality criteria with fairly large management actions would appear to a non-technical reader to be very small. For instance, p. 135 states: "…estimated…nonattainment…of 1 percent, 4 percent, 8, percent, 3 percent…" One should ask if such estimates are statistically significant. Similarly, in appendix A, p. 25, the net deposition model indicated that ~2.1 million tons net deposition in the reservoirs occurred in 2008-11. This is the difference of two order-of-magnitude larger numbers (22.3M tons entered the reservoir, 20.2M tons entered the Bay). There is a rule-of-thumb in sedimentology: ±10% in concentration or transport is 'within error'." (Pg. 16). **Comment I-7-14:** Does the precision of the computed difference fall within the margin of error in these metrics?	The problem of uncertainty in this context is incorrectly stated. The "rule-of-thumb in sedimentology [that a] ±10 percent in concentration or transport is within error" refers to the measurements of sediment in rivers. However, the LSRWA scenarios were done by difference with a base scenario in order to examine only the aspect of scour for the Conowingo and its influence on Chesapeake water quality. In this case the same uncertainty is in the scenarios with Conowingo scour and without Conowingo scour and essentially cancel out.

Comment Code	Comment	Comment Response
I-7-15	• On p. 113 the report states, "A close inspection of the model simulation results indicate that trace erosion does occur at lower flows (150,000 to 300,000 cfs.), which is a 1- to 2- year flow event. This finding is consistent with prior findings reported by Hirsch (2012)." The Hirsch (2012) findings are different from what is expressed here. The relevant statement from Hirsch (2012) is: "The discharge at which the increase [i.e., the increase in suspended sediment concentrations at the dam] occurs is impossible to identify with precision, though it lies in the range of about 175,000 to 300,000 cfs. Furthermore, the relative roles of the two processes that likely are occurring – decreased deposition and increased scour – cannot be determined from this analysis." **Comment I-7-15:** Does the DLSRWA and the model runs account for such a discrepancy? If so, how? If not, why not?	This discussion of trace erosion is specific to sediment particle size. The difference between the low end of 150,000 cfs and 175,000 cfs is minimal in light of what Bob Hirsch indicates "the discharge at which the increase in sediment concentrations is IMPOSSIPLE to identify with precision...".
I-7-16	• "Also on p. 190, the report indicates that, "The total sediment outflow load through the dam… increased by about 10 percent from 1996 to 2011…" These results are so strongly at odds with other published numbers on this subject that some explanation and discussion is certainly required. Hirsch (2012) reports an increase in flow-normalized flux over the period 1996-2011 of 97 percent (*see* Table 3 of Hirsch). Also, Langland and Hainly (1997) published an estimate of change in average flux from about 1997 to the time the reservoir is full of 250%. Reporting a 0% increase in light of these two other findings appears erroneous." **Comment I-7-16:** Why weren't Hirsch's and Langland's numbers used instead of 10%?	The last sentence in the last paragraph on page 154 has been revised to: "The total sediment outflow load through the dam, which consists of the Conowingo Reservoir bed sediment scour load, the bed sediment scour load of the upper two reservoirs, and the pass-through Susquehanna River watershed load, increased by about 10 percent from the 1996 bathymetry to the 2011 bathymetry for the 4-year simulation (2008-2011)". So for the same boundary conditions, there was a 10-percent increase im sediment outflow using the two different bathymetries. The modeled results were used because they were consistent with USGS observations of long-term reservoir trends, suspended sediment concentrations, and net reservoir storage determined from sequential bathymetric surveys.
I-7-17	• From STAC: "p. 138 Paragraph 2: Oysters are discussed here within a section that otherwise discussed the modelling and simulation activities. Is there a description of how model analysis was used in this report to determine flow and management effects on oysters? Whatever the case, it should be clearly stated where the oyster effects fit into this report and whether or not model simulations were used to understand effects on oysters." • LSRWA Response: No specific modelling simulations were run to quantify oyster impacts. However this resource is of high interest so this qualitative language was added. This paragraph was deleted from this section since the context here is specific LSRWA simulation results (*i.e.* , quantified results). Section 2.7.4 discusses oysters and impacts from storm events summarizing a DNR report on effects from Tropical Storm Lee. **Comment I-7-17:** Were model runs conducted by DNR to determine impact on oysters or was it based on observations? If based on observation were sediment levels that blanketed the oysters considered as an impact?	Model runs were not conducted by MDNR, but the University of Maryland Center for Environmental Science did conduct an analysis of the sediment distribution from TS Lee in the upper Chesapeake Bay. This report indicated that the majority of the sediment deposition was in the upper Bay, directly below the Susquehanna Flats. In general, less than 1.5 cm of sediment was deposited downstream of this area. The UMCES report can be found at Palinkas, C.M., et al., Sediment deposition from tropical storms in the upper Chesapeake Bay: Field observations and model simulations. Continental Shelf Research (2013), http://dx.doi.org/10.1016/j.csr.2013.09.012i. The MDNR assessment was based on observations of live fouling organisms, including barnacles, mussels, and bryozoans, that were found attached to the oysters and shells on oyster bars in the northern Bay. Had the oysters been smothered by sediment, these organisms would not have been able to attach to the oyster shells and would not have survived.

Comment Code	Comment	Comment Response
I-7-18	• "As described in Section 5.2, "the LSRWA team relied heavily on the Bay TMDL work done by CBP and state partners to develop the watershed management strategies. As such, the LSRWA team adopted the CBP methodology and unit costs as the representative alternative for a watershed management strategy; additional cost and design analyses were not undertaken." Citations are included where appropriate (e.g. U.S. Environmental Protection Agency (U.S. EPA). 2010), however, personal communication by LSRWA was required to ensure that LSRWA interpretations of CBP work on watershed BMPs/strategies were accurate." (Pg. 35). **Comment I-7-18:** Throughout the report, statements are made that the Bay TMDL work needs to be reevaluated given that the Conowingo Dam no longer has the trapping capacity that was once considered. Given that the DLSRWA adopted the outdated CBP methodology, how could the team ignore additional cost and design alternatives?	The most recent information and cost estimates available at the time of report development were used in the analyses, with an understanding that these were just estimates. All estimates and methodologies can be updated after completion of the Chesapeake Bay TMDL 2017 midpoint assessment, providing more accurate evaluation of the most cost-effective and efficient management alternatives.
I-7-19	• Attachment I-7 includes a letter from Exelon to the Army Corps of Engineers (dated July 18, 2014) thanking the Corps of Engineers for the opportunity to review and comment on the Draft LSRWA Study. (No Page number provided). **Comment I-7-19:** Please explain why Exelon received the DLSRWA several months earlier to perform an extensive review of the main report and appendices. Why weren't other commenters, such as the Clean Chesapeake Coalition given that opportunity? Are we to expect that Exelon will assist the LSRWA study group in addressing our comments?	The purpose of the public review was to allow all interested parties to submit comments. This comment period ran from November 13, 2014 to January 9, 2015. Exelon and their contractors did not assist the assessment team in addressing the public comments, nor did they influence the findings of the report. Exelon's bathymetric data (collected in 2011 by Gomez and Sullivan Engineers) represented the most current condition of sediment within the reservoir. These data were used in the modeling efforts for this study; therefore, Exelon was able to review the report during the team review.

Comment Code	Comment	Comment Response
J-2	*It is quite evident that the data and studies used in the Watershed Strategy Section are outdated and incorrect. Appendix J relies on the following incorrect statements: • "Sediment deposition to Chesapeake Bay from the Susquehanna River is mitigated by the presence of three consecutive hydroelectric dams (Safe Harbor Dam, Holtwood Dam, and Conowingo Dam). These three dams form a reservoir system in the lower part of the River that These three dams form a reservoir system in the lower part of the River that has been trapping sediment behind the dams since they were constructed in 1910 (Holtwood Dam), 1928 (Conowingo Dam) and 1931 (Safe Harbor Dam). The uppermost two dams, Safe Harbor Dam and Holtwood Dam, have already reached their capacity to store sediment and sediment-related nutrients. Conowingo Reservoir, which is formed by Conowingo Dam, the lowermost and largest dam, has not reached storage capacity and is still capable of trapping." (Pgs. 1-2). **Comment J-2:** Appendix J begins with incorrect information by expressing the remaining storage capacity of the Conowingo Dam. (Pg. 2). Given that this Appendix is used to develop a watershed strategy, a major concern and comment is how could this be accomplished if the current status of the Conowingo Dam is not properly delineated or understood?	The watershed study evaluated the cost of the E3 scenario (Everything, Everywhere, by Everyone), which is a theoretical highest BMP implementation scenario that would largely be impossible to implement. Regardless of the storage capacity of the dams, the conclusion of the watershed study remains that implementing the E3 scenario would not be cost-effective and would not provide an adequate return on investment over implementing the watershed implementation plans (WIPs) in reducing sediment from the watershed, because the additional sediment removed in the E3 scenario is small relative to the total load. The watershed strategy has nothing to do with the sediment-trapping capacity in the lower Susquehanna River reservoir system. It evaluated the cost of implementing a theoretical scenario to achieve the maximum possible reduction of sediment. Appendix J did not evaluate the cost of implementing the WIPs as a sediment control strategy. The latest information from USGS indicates that there remains 8 percent of sediment storage capacity at Conowingo Dam, that 30 percent of sediment comes from scour and 70 percent comes from the watershed. Appendix J has been updated to reflect the latest information on storage and the high contribution of sediment from the watershed relative to scour from the dams. Note that even though the system has reached dynamic equilibrium, there will be years when sediment is stored followed by events that result in scour that in effect allow for new periods of storage.
J-3	*The Appendix discusses further the importance of the TMDLs and the CBP 5.3.2 Watershed model run established in 2010. • The Chesapeake Bay Program developed the E3 scenario from a list of approved agriculture and urban/suburban BMPs using output from the Phase 5.3.2 Watershed Model, which is also used for tracking towards the TMDL. "The BMPs that are fully implemented in the E3 scenario were estimated to produce greater reductions than alternative practices that could be applied to the same land base (Jeff Sweeney, personal communication)." **Comment J-3:** Is personal communication is now the new standard in determining scientific merit? What science is Jeff Sweeney using to make such an evaluation of BMPs and to make such a statement?	As described in Section 5.3, "the LSRWA team relied on the Bay TMDL work done by CBP and state partners to develop the watershed management strategies. As such, the LSRWA team adopted the CBP methodology…" Journal and report citations are included where appropriate; however, personal communication by the LSRWA team was required to ensure that LSRWA interpretations of the Chesapeake Bay Program work were accurate. C110

Comment Code	Comment	Comment Response
J-4	• The Chesapeake Bay Program also developed unit costs for the approved BMPs. Most, though not all, of the BMPs used in the E3 scenario have associated unit costs in either acres or feet. The primary source of the unit costs was the Bay Program approved list; however, in order to have as complete a cost estimate as possible, in the absence of unit costs from the Bay Program, costs from the Maryland Department of the Environment (MDE) (Greg Busch, MDE, personal communication), and costs from the Maryland Department of Agriculture (MDA) (John Rhoderick, MDA, personal communication) were used. (Pg. 5). **Comment J-4:** Is there a cost benefit analysis associated with these expected costs on local governments? If so, is it based on science and data or someone's personal communication?	As described in Section 5.3, "the LSRWA team relied on the Bay TMDL work done by CBP and state partners to develop the watershed management strategies. As such, the LSRWA team adopted the CBP methodology and unit costs as the representative alternative for a watershed management strategy; additional cost and design analyses were not undertaken." Citations are included where appropriate; however, personal communication by LSRWA team was required to ensure that LSRWA interpretations of the Chesapeake Bay Program work were accurate. The purpose of Appendix J was to develop a range in costs to implement the E3 scenario and achieve the theoretical maximum amount of sediment reduction in the watershed. The LSRWA team is not aware of a cost-benefit analysis that evaluates the costs to local governments of implementing the WIPs relative to the benefits associated with having the Bay and its tributaries meet their designated uses.
J-5	• Agriculture unit costs ranged from $2 per acre to develop conservation management plans to $1,948 per acre for "loafing lot management" (stabilizing areas frequently and intensively used by animals, people, or equipment). **Comment J-5:** Where is the source of this data? Is it from the unit cost estimates from the Bay Program and other sources used to develop a range in the cost of achieving the theoretical maximum amount of sediment reduction to the Conowingo Reservoir (discussed on Pg. 6)? If so, where is this data and what are the other sources?	The unit costs came from a series of spreadsheets that were prepared by the Chesapeake Bay Program and had references on which the costs were based. Please contact the Chesapeake Bay Program directly for the unit costs and the references.
J-6	• "The maximum available load of sediment per year that could be reduced by additional BMP implementation above and beyond the WIPs throughout the Susquehanna River watershed is approximately 95,000 tons (equivalent to 190,000,000 lbs of sediment per year; or 117,284 cubic yards per year) 2,000 lbs is equivalent to approximately 1 ton; 190,000,000 lbs divided by 2,000 equals 95,000 tons per year; approximately 81 tons are in 1 cubic yard; or 1600 kilograms/cubic meter; 95,000 divided by .81 equals 117,284 cubic yards per year) at a cost of 1.5 to 3.6 Billion dollars. The amount of 95,000 tons is an order of magnitude less of what is estimated to flow over Conowingo Dam into Chesapeake Bay on an average annual basis, which is approximately, 1.8 million tons (1993-2012 hydrology)." (Pgs. 5-6). **Comment J-6:** This no longer seems to be the case given that the Conowingo Reservoir was considered a trap and not a source of sediments and nutrients in these calculations.	Please see the response to Comment J-2.
J-7	**Comment J-7:** Attachments 2 and 3 (Pgs. 11-12) of Appendix J state the following: "Cost estimates are provided for planning purposes only, and are based on generalized costs of implementation. Project specific design and cost estimates would be required prior to actual implementation of any of these alternatives." What are the generalized costs of implementation? How do these attachments provide anyone with a true understanding of costs if design and cost estimates are not considered in the total cost analyses?	Cost estimates were identified for a number of in-reservoir sediment management alternatives as documented in Attachment J-2. These costs evaluated both one-time investment costs and yearly operation and maintenance costs. The cost components included real estate, specialty services, design, booster pump construction, permanent pipeline construction, transfer site and dike construction, dredging and dewatering plant, and reuse manufacturing plant. In addition, the operation costs evaluated tipping fees, dredging and transportation costs, manufacturing processing costs, and construction design and management.

Comment Code	Comment	Comment Response
J-8	• "EPA uses unit costs for agricultural sediment or nutrient controls identified in the WIPs from USDA's Environmental Quality Incentive Program (EQIP), where available, and WIPs and prior studies where EQIP estimates are not available. In selecting relevant studies, EPA excludes those prior to 2000, and relies on EQIP and WIP estimates where feasible because these costs likely represent the most recent and best estimates of actual implementation costs." **Comment J-8:** The U.S. Department of Agriculture's Environmental Quality Incentive Program (EQIP) is currently an interim rule open for comment. In addition, Executive Order 12866 and 13563 "Improving Regulation and Regulatory Review," directs agencies to assess all costs and benefits of available regulatory alternatives and, if regulation is necessary, to select regulatory approaches that maximize net benefits (including potential economic, environmental, public health and safety effects, distributive impacts, and equity). Executive Order 13563 emphasizes the importance of quantifying both costs and benefits, of reducing costs, of harmonizing rules, and of promoting flexibility. The Clean Chesapeake Coalition would appreciate an assessment of all costs and benefits of available regulatory alternatives, in particular analyses of how the unit costs were derived for the DLSRWA.	The two noted executive orders (12866 and 13563) are directed at the promulgation of regulations and regulatory actions. The Lower Susquehanna River Watershed Assessment was a science-based planning effort, not a regulatory action or review. No regulation actions are proposed for adoption or consideration. As such, executive orders 12866 and 13563 are not applicable to the LSRWA effort. The E3 maximum watershed action scenario, which is included in the LSRWA report as a potential sediment management strategy, was developed from a list of approved agriculture, urban, and suburban best management practices using output from the Phase 5.3.2 Chesapeake Bay Watershed Model. The E3 scenario and the development of its cost is summarized in Attachment J-1 (Appendix J) of the LSRWA report, but full documentation can be found in Appendix J of *Chesapeake Bay Total Maximum Daily Load for Nitrogen Phosphorus and Sediment: Technical Appendices* , published in 2010 by EPA's Chesapeake Bay Program Office. Any questions regarding the impacts of the noted executive orders on the sediment or nutrient controls identified in the E3 scenario or the WIPs should be addressed to EPA.
J-9	**Comment J-9:** Throughout the Document it is stated that: "EPA annualizes capital costs over the specified life of the BMP." How does EPA annualize capital costs?	The Chesapeake Bay Program annualized capital costs by dividing the capital costs over the useful life of the BMP. Please see Attachment 4 of Appendix J for the years over which capital costs were annualized for any specific project alternative.
J-10	• Forest buffers are linear wooded areas along rivers, stream, and shorelines. The recommended buffer width for riparian forest buffers (agriculture) is 100 feet, with a 35-foot minimum width required. Upfront installation costs associated with forest buffers typically include site preparation, tree planting and replacement planting, tree shelters, initial grass buffer for immediate soil protection, mowing (during the first 3 years), and herbicide application (during the first three years). **Comment J-10:** Forrest Buffers are listed as a BMP. Has anyone evaluated Sapropel concerns from decaying leaves and their ability to seriously decrease deep water oxygen and increase Hydrogen sulfide deposits?	The oxygen demand of tannins is negligible in the Susquehanna River at Conowingo, and in any case the organic nitrogen and phosphorus are calibrated state variables in the Watershed and Water Quality and Sediment Transport models.

Comment Code	Comment	Comment Response
J-11	• Estimates pertaining to unit cost in association with frequent maintenance and pumping of septic systems is expected to reduce nitrogen loadings. (Pg. 29). **Comment J-11:** What is the origin of these estimates? Where is the financial cost data associated with these estimates?	The focus of the BMP assessment was sediments, not nutrients. The discussion regarding septic systems was included in Appendix J by mistake and has been deleted.
Appendix J-2 J-12	• The Costs associated with the Charts presented in Attachment J2 are "concept-level costs for planning purposes only. Detailed design and cost estimate would be required for any future studies investigation implementation of any of these alternatives. All alternatives assume the dredging of a location in Conowingo Reservoir which currently has the highest amounts of deposition in the entire lower Susquehanna reservoir system; similar costs could be developed for the other lower Susquehanna reservoirs." **Comment J-12:** Given the assumption above, will the design and cost estimates be the same if the purpose of the DLSRWA were to comprehensively forecast and evaluate sediment and associated nutrient loads into and from the system of hydroelectric dams located on the Lower Susquehanna River above the Chesapeake Bay and consider structural and non-structural strategies to manage these loads to protect water quality and aquatic life in the Chesapeake Bay? (Pg. 4 – 08/16/2012, Attachment I- 6).	The elements within the design and cost estimates provided in Attachment J-2 would be the same; however, placement sites, movement of material, amount of material, etc. would all change with location and what is available at the other dam locations, thereby, changing specific cost.
J-13	**Comment J-13:** Screening level estimates are included in charts that evaluate available capacity. Does the available capacity evaluation consider that the Conowingo Reservoir is still trapping? In addition, estimates are based on assumptions in the screening level cost estimates. How are the financial benefit analyses achieved with assumptions being made for estimates? Is there a margin of error available for these estimates? What is the source for the cost estimates related to temporary dewatering sediment?	The table in Attachment J-2 refers to available capacity of the disposal site, not Conowingo Reservoir. As such, the trapping status of Conowingo Reservoir does not come into play. The cost estimates are presented in the format of low and high values to show the range of costs that would be expected. Information for the temporary dewatering plant costs for the innovative reuse alternative was provided by Jeff Otto of Harbor Rock.
J-14	• This analysis is based on planning level sediment management concepts. To fully understand and evaluate effects of any of these concepts detailed designs would be required. Fatal Flaw-Determined by team that strategy should be dropped from consideration. **Comment J-14:** What is the basis for these management concepts? What scientific studies and/or data were considered in developing such concepts? According to the summary "…because of amount of variables, representative alternatives were developed to cover ranges of costs each one of these variables could impact." What are those variables and alternatives developed?	The development of the sediment strategies and management concepts are detailed in Chapter 5 of the main report, beginning on page 100.

Comment Code	Comment	Comment Response
J-15	• Attachments 2 and 3 on Pgs. 12-13 in Appendix J show the costs by practice across the three states. However, the current information does not make it possible to assess the variation in cost effectiveness of the various urban and agricultural BMPs in meaningful terms, such as the dollars per cubic yard of sediment removal. Importantly, the cost effectiveness between practice types typically varies by one or two orders of magnitude. Hence, the current analysis aggregates all practices types and reports an overall cost estimate at $3.5 billion in Table 3 (or Table 6-3). Then the report provides an overall average cost effectiveness of $256-$597 per cubic yard in Table 6-6, and seems to imply that this watershed BMP approach is supposedly the most expensive. But this assessment that aggregates all practice types may overlook the high degree of heterogeneity in costs between practice types. (Pg. 35, Appendix 1-7). **Comment J-15:** Please explain how such an analysis is beneficial to the DLSRWA.	The intent of these analyses was to provide a concept level evaluation of a suite of alternatives for sediment management. See also response to referenced STAC comment in Appendix I-7.
J-16	• Attachment 4 of Appendix J on pp. 29-33 includes detailed information on "Septic Systems". However, septic systems are not discussed at all in the corresponding tables for the cost analysis in Attachments 2 and 3. **Comment J-16:** Please provide the cost analyses by different States.	The focus of the BMP assessment was sediments, not nutrients. The discussion regarding septic systems was included in Appendix J by mistake and has been deleted.
K-1	• Climate trends in the last two decades have shown wetter conditions on average, than in previous decades. Increased precipitation has produced higher annual minimum flows and slightly higher median flows during summer and fall (Najjar et al., 2010). (Pg. 5). **Comment K-1:** Why aren't climate change or climate trends considered in the draft model runs? If there were indeed considered why are the model runs capped at a flow rate slightly above 620,000 cfs.?	Specific climate-change flow scenarios were not considered in the LSRWA modeling analyses, due to the wide range of uncertainty associated with these forecasts. The LSRWA modeling runs focused on known historic flow events.
K-2	• As of 2003, 23 percent of the Chesapeake Bay watershed is used for agriculture and almost 12 percent has been developed. (Pg. 5). • Water circulation in the Bay is primarily driven by the downstream movement of fresh water in from rivers and upstream movement of salt water from the ocean. Less dense, fresher surface water layers are seasonally separated from saltier and denser water below by a zone of rapid vertical change in salinity known as the pycnocline (CBP, 2013). The pycnocline plays an important role in Bay water quality acting to prevent deeper water from being reoxygenated from above (Kemp et al., 1999). Pycnocline depth varies in the Bay as a function of several factors. It shows general long-term geographic patterns as summarized in Table K-4, but varies over shorter time periods as a function of precipitation and winds. (Page 8) During warm weather months it promotes stronger stratification that can last for extended periods during a year. Conversely, sustained winds in a single direction for several days can cause the pycnocline to tilt, bringing deeper water up into shallows on the margins of the Bay. **Comment K-2:** How do any of the models account for this water circulation or wave	The CH3D hydrodynamic model described in the LSRWA report accounts for estuarine circulation and waves with a time step of minutes.

Comment Code	Comment	Comment Response
	• Because of this partial seasonal separation into layers, or strata, the Bay is classified as a partially stratified estuary. Division of surface from deeper waters varies depending on the season, temperature, precipitation, and winds. In late winter and early spring, melting snow and high streamflow increase the amount of fresh water flowing into the Bay, initiating stratification for the calendar year. During spring and summer, the Bay's surface waters warm more quickly than deep waters, and a pronounced temperature difference forms between surface and bottom waters, strengthening stratification. In autumn, fresher surface waters cool faster than deeper waters and freshwater runoff is at its minimum. The cooler surface water layer sinks and the two layers mix rapidly, aided by winds. During the winter, relatively constant water temperature and salinity occurs from the surface to the bottom (CBP, 2013). (Pg. 9). • USACE and SRBC recognize the Susquehanna River basin as one of the most floodprone basins in the United States from a human impacts perspective. Flow conditions can vary substantially from month to month; floods and droughts sometimes occur in the same year. Floods can scour large volumes from the river bed and banks, and convey large quantities of nutrients and sediment downstream. (Pg. 11). • Salinity is an important factor controlling the distribution of Bay plants and animals. Salinity is the concentration of dissolved solids in water and is often discussed in terms of parts per thousand (ppt). In Maryland, Bay surface waters range from fresh in headwaters of large tidal tributaries to a maximum of about 18 parts per thousand (ppt) in the middle Bay along the Virginia border. Salinity varies during the year, with highest salinities occurring in summer and fall and lowest salinity in winter and spring. (Pg. 13). • The ETM zone is an area of high concentrations of suspended sediment and reduced light penetration into the water column. Each of the Bay's major tidal tributary systems has an ETM zone near the upstream limit of saltwater intrusion. The Susquehanna River ETM zone occurs in the upper Bay main stem. The position of the ETMs changes seasonally and with large freshwater flow events from storms. The ETMs extend further downstream into the Bay during times of year when lower salinities occur and following major storm events, and further upstream when seasonally higher salinities occur. The ETM zone is produced by a complex interaction of physical and biological processes, including freshwater inflow, tidal and wave-driven currents, gravitational circulation, particle flocculation, sediment deposition and resuspension, and biogeochemical reactions. (Pg. 13).	Both the Watershed Model (WSM) and the Water Quality and Sediment Transport Model (WQSTM) simulate phosphorus bound to sediment.

Comment Code	Comment	Comment Response
K-3	• Tidal resuspension and transport are primarily responsible for the maintenance of the ETM zone at approximately the limit of saltwater intrusion. Generally, fine-grained riverborne sediment in the ETM zones is exported further downstream into the main Bay only during extreme hydrologic events. The mainstem Bay ETM zone occurs in the upper Bay; in this region, most of the fine-grained particulate matter from the Susquehanna River is trapped, deposited, and sometimes resuspended and redeposited. • The mainstem ETM zone acts as a barrier under normal conditions for southward sediment transport of material introduced into the Bay from the Susquehanna River (USGS, 2003). Eutrophication • Anthropogenic nitrogen and phosphorus nutrient pollution delivered to the Bay exceeds the Bay ecosystem's capability to process it without ill effect. The Bay's physical character and circulation patterns tend to retain water-borne materials, thus exacerbating the effect of anthropogenic pollution. The Bay's natural capability to buffer the incoming nutrient loads are governed by seasonal stratification and limited tidal mixing rate (Bever et al., 2013). Anthropogenic nutrient pollution to the Bay derives from agricultural runoff and discharges, wastewater treatment plant discharges, urban and suburban runoff, septic tank discharges, and atmospheric deposition of exhaust (CBP, 2013). Water bodies possess a range of nutrient availability conditions. Water bodies possessing ample or excessive nutrients whether from natural or human sources are said to be eutrophic. The Bay became eutrophic because of inputs of large quantities of anthropogenic nutrients. Excess nutrients in the water column from human sources fuel the growth of excess phytoplankton. Zooplankton, oysters, menhaden, and other filter feeders eat a portion of the excess algae, but much of it does not end up being consumed by these organisms. The leftover algae die and sink to the Bay's bottom, where bacteria decompose it, releasing nutrients back into the water, fueling further algal growth. During this process in warm weather months, bacteria consume DO until there is little or none left in deeper bottom waters (CBP, 2013). Within the Bay, nitrogen is the principal limiting-nutrient regulating phytoplankton. The limiting nutrient is that nutrient available in lowest supply in proportion to biological demand. However, phosphorus is the limiting nutrient for phytoplankton growth in low salinity Bay waters in spring. Phosphorus is typically the limiting nutrient in freshwater ecosystems. (Pg. 16). • Nitrogen and phosphorus actually occur in a number of different forms in the environment that differ in their biological availability and effects on water quality. (Pg. 17). Total nitrogen (TN) includes nitrate, nitrite, ammonia, and organic nitrogen. (Pg. 17).	

Comment Code	Comment	Comment Response
	• Ammonia is the dominant dissolved nitrogen form in deeper waters during warm months. Nitrite is generally unstable in surface water and contributes little to TN for most times and places. Organic nitrogen (mostly from plant material, but also including organic contaminants) occurs in both particulate and dissolved forms, and can constitute a substantial portion of the TN in surface waters. However, it is typically of limited bioavailability, and often of minimal importance with regard to water quality. Conversely, nitrate and ammonia are biologically available and their concentration is very important. • Total phosphorus (TP) includes phosphates, organic phosphorus (mostly from plant material), and other phosphorus forms. Phosphates and organic phosphorus are the main components of TP. Phosphates tend to attach to soil and sediment where their bioavailability varies as a function of environmental conditions. Dissolved phosphate is readily bioavailable to aquatic plant life, and consequently promotes eutrophication (USGS, 1999). Phosphorus binds to river sediments and is delivered to the Bay with sediment. (Pg. 17). **Comment K-3:** What model is used to address how phosphorus is bound to sediments? How are phosphorus levels and its impact addressed in the DLSRWA?	
K-4	• Nutrient transport in rivers is usually considered in two fractions – that portion conveyed in dissolved form and that portion carried as particulates. Particulates include mineral sediments and plant debris. During downstream transport, bacteria and other stream organisms take up dissolved nutrients and convert them to organic form. When organisms containing these nutrients die, the nutrients return to the water in inorganic form, only to be taken up yet again by other organisms. This cycle is referred to as nutrient spiraling. • Nutrient pollutants delivered to the Bay vary year to year as a function of amount and timing of precipitation. Wet years deliver greater nutrient pollution to the Bay than dry years. For example, the amounts of nitrogen and phosphorus transported during Tropical Storm Lee (a September 2011 high-flow event) were very large compared to long-term averages for the Susquehanna River over the past 34 years. However, this difference is less pronounced for nitrogen than it is for phosphorus, because on average, a large part of the nitrogen flux is delivered in dissolved form. Specifically, the amounts transported during the Tropical Storm Lee event were estimated to be 42,000 tons of nitrogen and 10,600 tons of phosphorus. For comparison, the estimates of the averages for the entire period from 1978 to 2011 were 71,000 tons per year for nitrogen and 3,300 tons per year for phosphorus (Hirsch, 2012). (Pg. 17). **Comment K-4:** How were the phosphorus levels, namely 10,600 tons, generated for Tropical Storm Lee? Did the 10,600 tons number take into account phosphorus bound to sediments?	The phosphorus load from Tropical Storm Lee was calculated by Robert Hirsch of USGS. He used a method called "Weighted Regressions on Time, Discharge, and Season." Details of his methods are found in the publication referenced below and in citations therein. "Total Phosphorus" is reported; this parameter includes phosphorus bound to sediments. Text was added to Chapter 4.2.3 to discuss phosphorus bound to sediments. Hirsch, R. 2012. "Flux of nitrogen, phosphorus, and suspended sediment from the Susquehanna River basin to the Chesapeake Bay during Tropical Storm Lee, September 2011, as an indicator of the effects of reservoir sedimentation on water quality," Scientific Investigations Report 2012-5185, US Geological Survey, Reston VA.

Comment Code	Comment	Comment Response
K-5	• Phosphorus is conveyed in rivers as phosphate adsorbed to sediment particles. It is also conveyed bound to calcium, and as organic particles. The processes by which phosphorus is released from sediments is complicated and affected by biological as well as physical chemical processes. In oxygenated fresh water, phosphorus adsorbed to fine grained sediments remains bound and has limited bioavailability. Under anoxic or hypoxic freshwater conditions, phosphorus becomes more bioavailable, but phosphorus rebinds to sediments if oxygen is again present. In the Bay's saltwater environment, biogeochemical conditions change causing phosphorus bioavailability to differ from in freshwater. As salinities increase above about 3 to 4 ppt, phosphorus bound to sediments is increasingly released and becomes mobile and bioavailable to living resources (Jordan et al., 2008; Hartzell and Jordan, 2012). The uppermost Bay remains generally below salinities of 3 ppt all year, which tends to favor phosphorus immobilization in sediments, but otherwise the Bay is salty enough to allow phosphorus release from sediments (CBP, 2013). (Pg. 19). • Conowingo Reservoir water temperatures range from about 59°F to 91°F during the period of April through October. The reservoir remains relatively constant in temperature vertically for much of the year, but reservoir water can be up to several degrees cooler at the bottom than at the surface for brief periods. DO in Conowingo Reservoir becomes depleted in waters of the reservoir greater than 25-foot depth under conditions of low river inflow (less than 20,000 cfs.) and warm water temperatures (greater than 75°F). Reservoir DO levels occasionally drop below 2 mg/L (Normandeau Associates and GSE, 2011). USGS collected and analyzed water samples of Conowingo Reservoir outflow during high-flow events during water year 2011 (which ran from October 1, 2010 to September 30, 2011) for this assessment. (Pg. 22). **Comment K-5:** How did the models take into account reservoir water temperature? What type of model analysis was used to account for DO levels? • The Susquehanna River transports large volumes of sediment to the Chesapeake Bay. Two flood events, associated with Hurricanes Agnes (1972) and Eloise (1975), contributed approximately 44 million tons of sediment to the Bay. Recent estimates calculate that the Susquehanna River transports 3.1 million tons annually, depositing 1.9 million tons behind Conowingo Dam with the remaining 1.2 million tons deposited in the Chesapeake Bay (1996-2008 evaluation periods) (Langland, 2009). In the upper Bay, the Susquehanna River is the dominant source of sediment influx, supplying over 80 percent of the total sediment load in the area (SRBC Sediment Task Force, 2001). (Pg. 27).	The representation of Chesapeake Bay has its upstream limit at Conowingo Dam. The reservoir upstream of the dam is not represented. The temperature and dissolved oxygen concentration of water flowing over the dam are based on the observational record. The AdH model did not model water temperature or dissolved oxygen.

Comment Code	Comment	Comment Response
Mtg-1	**Comment Public Meeting:** The three individuals at the December 9, 2014 meeting at Harford Community College that presented the DLSRWA (Messrs. Bierly, Michael and Bier) suggested that the report will be used to determine who should have responsibility for addressing harm to the Bay caused by sediment scour. The discussion overlooked the decades of harm from scour that already has occurred and the fundamental evolution of the surface solids that now settle in the reservoirs. When the dams were new and the reservoirs behind the dams were deep, clays and silts in addition to the larger grained sands settled in the reservoirs behind the dams. The clays are the easiest sediments to scour as they are the finest grained and lightest solids to settle out of suspension and become more easily resuspended. The clays also probably bond the most phosphorus and other pollutants and nutrients. Silts lie somewhere in the middle and the sands are the heaviest and probably bond the least amount of sediments and nutrients. For decades, the dams have deprived the upper Bay of sands and have allowed the less desirable and more harmful clays and silts to be scoured and flushed into the Bay in deathly quantities during storm events. Such clays and silts also are more likely to become resuspended during turbulent weather in the Bay than the sands. Now, much of the material remaining on the floor of the reservoirs consists of sand, as the clays and silts have been flushed into the Bay for the last 80 years, while the sand, due to particle size and weight, has settled to the bottom and has less frequently been scoured into the Bay. There are studies that confirm these phenomena. Any consideration of responsibility for scour should take into account how the dams already have materially altered and damaged the Bay estuary by depriving it of the more beneficial sand while flushing in the more harmful clays and silts, until the present, when most of what remains to be scoured consists primarily of sand.	Comment noted.

Comment Code	Comment	Comment Response
Mtg-2	**Comment Public Meeting:** The three individuals at the December 9, 2014 meeting at Harford Community College that presented the DLSRWA (Messrs. Bierly, Michael and Bier) suggested that the report had received favorable peer review. Peer review can take on several formats but it most commonly is understood as review by qualified scientists of written scientific reports to test and to assess the methodology used to reach findings and conclusions and to access the confidence level in/validity of the findings made and the conclusions drawn in the report. It is hard to imagine that the DLSRWA was peer reviewed because the report does not begin to explain the methodology used to derive any findings or conclusions. Only upon reading thousands of pages of appendices can one begin to assess what work was performed, and even then only in the most cursory of manners. For example, the flow chart used to diagram the models used to generate data is cursory. Nowhere is the raw data underpinning different modelling efforts set forth, let alone being adequately explained. If there was any meaningful peer review of the DLSRWA, any report or appendix attached to the report, or any of the findings and conclusions in the report, please identify by name and qualifications the each person who conducted any peer review and attach any written findings conclusions, and input made by each such individual or group of individuals. There should be a peer review document. Please identify and provide a link to such document.	The document review process included many different reviews from within the team member's respective agencies and from outside organizations. Of significance, the Chesapeake Bay Program's Scientific and Technical Advisory Committee (STAC) sponsored an independent review. The STAC review committee consisted of 11 professionals in the fields of economics, and watershed, riverine, and estuarine processes. Chapter 6 of the report describes stakeholder involvement and the review process. Appendix I-7 describes STAC and identifies the committee and their affiliations. All peer review comments are included in Appendix I-7. Additional clarification regarding the inputs and links between model is included in the revised report as Figure 1-5 and Attachment J-5.
Ex-1 General	Regarding citation of Study 3.17 – currently the LSRWA report cites the 2011 Initial report. The Final report should be cited as: URS Corporation and Gomez and Sullivan Engineers (GSE). 2012c. Downstream EAV/SAV study. (RSP 3.17). Kennett Square, PA: Exelon Generation, LLC.	The citation was changed in the list of references; no references to a 2011 URS/GSE report were found in the main report.
Ex-3 General	**<u>Original Comment:</u>** The "full" condition estimation should be more clearly explained. Pieces of the explanation are given throughout the report (Page 112, Appendix A-3), but there is not enough detail given in any one location (or even collectively throughout the report and appendices) to understand or follow how the estimation was derived. **<u>Additional Comment:</u>** Exelon is trying to more thoroughly understand what specific methods were used to estimate the 'full' bathymetry. It is not clear how this was done, or how the assumptions made as part of this process may ultimately influence the ADH model results.	**<u>Original Response:</u>** The full condition is a term used to describe the storage capacity of a given reservoir. A reservoir is full when it can no longer effectively trap sediments and associated nutrients in the long term (decades). This language added to page 112. "Full" is better described as dynamic equilibrium which is described in detail on pages 109-110.) More detailed language has been added to Appendix A, Attachment A-3. **<u>Additional Response:</u>** A reference and some text regarding the estimation of the "full condition" has been added to Appendix A, page 52, in step 2 of the procedure; see response for Ex-C-3.

Comment Code	Comment	Comment Response
Ex-6 ES-2/ paragraph 3	**Original Comment:** Examples given are for sediment only. No information is given to determine if differences in flows are the cause of differences in sediment loads (W = Q C so if Q ↑, W ↑). No information is given to support the statement that reservoirs are trapping a smaller amount of nutrient loads from the upstream watersheds. No quantification of incoming or outgoing nutrient load. **Additional Comment:** The revised text states that bathymetric data were the basis for estimates of changing sediment loads; there is no quantification of incoming or outgoing nutrient loads. For example, if nutrients are preferentially present on the finest fraction of sediment particles (e.g., clays), then the relative change in trapping may be small (i.e., trapping of clays may never have been high). Thus, there is still a disconnect between trapping of sediment in general and trapping of sediment fractions that carry the most nutrients.	**Original Response:** Text altered to indicate that this conclusion is from a comparison of 1996 to 2011 bathymetry. Nutrients are discussed on ES-3. Also better quantification and reactivity of nutrients is identified as a recommendation of the study. **Additional Response:** The data to perform a nutrient budget for the reservoir based on nutrients associated with sediment size fractions does not exist. Certainly, the reservoir traps nutrients, as evidenced by the observations of nutrients attached to bottom sediments. Two scientific studies have determined that nutrient trapping is declining in concert with declining sediment trapping. Hirsch (2012) reported a 55-percent increase in total phosphorus and a 97-percent increase in suspended sediment in the Susquehanna River at Conowingo during 1996--2011. Zhang et al. (2013) reported “upward trends of SS and particulate-associated N and P were generally observed below the Conowingo Reservoir since the mid-1990s. The reservoir’s capacity to trap these materials has been diminishing over the past two or three decades.” See comment-response for K-4 for the full Hirsch reference. The Zhang et al. (2013) reference is Zhang, Q., Brady, D., and Ball, W. 2013. “Long-term seasonal trends of nitrogen, phosphorus, and suspended sediment load from the non-tidal Susquehanna River to Chesapeake Bay,” Science of the total Environment 452-453: 208-221.
Ex-8 ES-3/ paragraph 2 (full)	**Original Comment:** Use of phrase “Conowingo Reservoir material” implies that the reservoir is the source of material rather than the reservoirs being a site where transient storage appears. **Additional Comment:** The phrases “Conowingo Reservoir material” to “bed sediment stored behind Conowingo Dam” mean the same thing. The point of the comment is that the assessment is predisposed to assume that all “excess” sediment generated during high flow is coming from Conowingo Pond. However, the uncertainties involved preclude such a definitive statement.	**Original Response:** Text altered to indicate bed sediment stored behind Conowingo. **Additional Response:** The noted statement is based on the findings of the modeling analyses; that is, approximately 20 to 30 percent of the sediment flowing in during a major storm event comes from the Conowingo Reservoir sediments. The report does not refer to this as "excess" sediment. No changes to the report are required.
Ex-10 Chapter 1 – page 8 – 1st paragraph	The 2nd sentence is new and the reference cited, Pazzaglia and Gardner 1993, is inappropriate. This reference examines the state of the lower Susquehanna River in recent geologic time (≈ 10,000 – 20 million years ago), not historic time. This new sentence seems to refer to historic time prior to construction of the dams. If referring to historic time, a different citation should be used. If Pazzaglia and Gardner 1993 reference meant to be cited, add that this publication explores geologic conditions, not historic.	Concur. The referenced has been removed and text has been changed to include an appropriately referenced statement.

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
Ex-11 Page 10 - para. 2	Is the reference given as Gomez & Sullivan (2012) (RSP 3.11) [twice in this paragraph] really meant to be URS and Gomez & Sullivan (2012b)?	Yes, the references have been changed on page 10.
Ex-12 CH. 1/P.11/Paragraph last(Sec 1.9) and Table	**<u>Original Comment:</u>** Assessment products include many overlapping, and not necessarily parsimonious, study elements. For example, the table states that HEC-RAS was used to compute sediment loads into Conowingo Pond. The Chesapeake Bay Watershed Model (CBWSM) also computes sediment loads to/though Conowingo Pond. How do they compare? SEDFLUME data were collected to determine erosion rates and erosion thresholds for sediment in Conowingo Pond. HEC-RAS, which was also used to calculate sediment transport, uses transport capacity relationships. How do the rates determined by the SEDFLUME work (and used in AdH) compared to calculations using HEC-RAS? Do they agree? The CBWSM also computes transport (because the reservoir is a node in the stream network) and uses an entirely different approach. How were differences handled? Which sediment load estimates were used to feed the CB water quality model (CE-QUAL-ICM) (Carl Cerco model)? **<u>Additional Comment:</u>** This comment is not meaningfully addressed without a change to the report to include this information and discuss the uncertainty. There are three different load estimates at Conowingo and each implies a different balance of transport processes: (1) Bay watershed model, (2) HEC-RAS, and (3) AdH. An attempt to identify or reconcile these differences in a quantitative way or recognize uncertainties does not appear to be made in the report. If AdH results differ from HEC-RAS results for Conowingo, is it appropriate to consider HEC-RAS results for upstream reservoirs to be reasonable?	**<u>Original Response:</u>** HEC -RAS inputs of watershed loads compare well to CBWSM. USGS (HEC-RAS) annual average load for 1993 – 2012 is 1.5 million English tons/annum. This converts to 3.74 million kg/d. The WSM daily average load for 1991 – 2000 under 2010 Progress Run conditions is 3.06 million kg/d. The differences between the two estimates can be attributed to numerous factors including different summary intervals – 1993 – 2012 for USGS/HECRAS vs. 1991 – 2000 for the WSM. HECRAS also used some of the SEDflume data for estimation of several sediment model parameters. **<u>Additional Response:</u>** First, the HEC-RAS data was only from 2008 to 2011, not 1993-2011. Neither the daily loads from HEC-RAS (underestimated) nor AdH were used; the WSM daily inputs were used because the data was available for the time period for simulating effects on water quality in the Chesapeake Bay. Its use allowed comparisons to the TMDL evaluations and water quality attainment criteria. A longer time period than provided by HEC-RAS and AdH was needed.
Ex-14 CH. 1/ P.18/ Figure 1-6	**<u>Original Comment:</u>** Figure does not clarify which model feeds sediment estimates to CE-QUAL-ICM and how differences between estimates from models in the suite (CBWSM, HEC-RAS, and AdH) are handled. **<u>Additional Comment:</u>** No further comment at this time. Please see comments in cover letter regarding Exelon's proposed Attachment 1 and 2.	**<u>Original Response:</u>** The information on CE-QUAL-ICM loading is provided in Figure 1-5. The differences in the model suite are not the subject of these flow charts. This flow chart is meant to provide a simplified, broad picture of the analytical approach of the study tailored for a wide-audience. **<u>Additional Response:</u>** Attachments 1 and 2 have been reviewed, and incorporated into the document within Figure 1-5 and Attachment J-5, with some changes for accuracy and clarity.

Comment Code	Comment	Comment Response
Ex-15 CH.2/P.26/ Paragraph 1	**Original Comment:** Table 5-6 of the main report is consistent with TMDL Appendix T in stating that the reservoir trapping capacity of Conowingo has been 55-60% from 1993-2012. Please elaborate on what trapping capacities were used in the various WSM model runs. **Additional Comment:** We disagree that Appendix D adequately describes the input parameters for each run. It is important to understand the conditions of the scenario runs within the context of trapping capacity/efficiency as discussed in TMDL Appendix T.	**Original Response:** The LSRWA scenarios are fully described and characterized in Appendix D along with the estimated Conowingo bathymetries used in each scenario. That is the correct place for the scenario information and not page 75. Changes are unwarranted. **Additional Response:** There will be a refined assessment of Conowingo infill and its influence on Chesapeake water quality done in 2017 based on extensive research and monitoring supported by Exelon and appropriate changes made to the Watershed Model (WSM) and the Water Quality Sediment Transport Model (WQSTM). This assessment will better reflect the improved understanding of sediment and associated nutrient scour and mobilization from the Conowingo. The refined assessment of the Conowingo based on the best monitoring, research, and modeling available will allow a better understanding of the Conowingo trapping capacity/efficiency as it relates to the Chesapeake TMDL.
Ex-18	A good test of the AdH model would have been to start with the 2008 bathy and perform a continuous run of the model thru the date of the 2011 bathy and see how well the model reproduces the observed 2011 bathy	This was done, and is reported in the validation section. But it was only compared in a bulk sense (i.e., in terms of a total volume change); it was not compared spatially.
Ex-25 CH. 3/P.45/ Paragraph last (onto P.46)	**Original Comment:** Were these nutrient contents compared to Marietta samples to get an idea of what the 'watershed' makeup may have looked like? **Additional Comment:** Relevant data may be available from the Susquehanna River Basin Commission's Nutrient Assessment Program (SNAP)	**Original Response:** We did not find Marietta samples that provided relevant information for comparison with observations at Conowingo. **Additional Response:** SRBC's Sediment and Nutrient Assessment Program (SNAP) provides relevant data as it utilizes equivalent sampling and analysis methodology as compared to the USGS sampling effort at Conowingo, Md. The existing dataset extends from 1987 to the present with sampling occurring twice per month (roughly every two weeks) and during storm events for total nitrogen, total nitrate/nitrite, total ammonia, dissolved nitrogen, dissolved nitrate/nitrite, dissolved ammonia, total phosphorus, dissolved phosphorus, dissolved inorganic phosphorus, total organic carbon, total suspended solids (Aug 2000-present), and suspended sediment concentration. Samples were collected during both referenced high flow events, 1996 (including SSC) and 2011 (including TSS and SSC). Additionally, the dataset was used to compute nutrient and sediment loads at Marietta using the USGS estimator model.

Comment Code	Comment	Comment Response
Ex-26 CH. 3/P. 49-50	**Original Comment:** Based on the estimates of bioavailable nitrogen and phosphorus quoted here, which could potentially be resuspended and transported into Chesapeake Bay, there is a serious mismatch between the bioavailable fractions of TN and TP contained in the Conowingo Pond sediments and how they are incorporated in the CBEMP model wherein they are assumed to be approximately 85% bioavailable. Given this, it is likely that the CBEMP is over-estimating the release of Conowingo Pond nutrients from the sediment bed once they are deposited into the Bay sediments and therefore the model is over- estimating the change in non-attainment of the DO water quality standard. **Additional Comment:** The comment was not meant to describe the G2 and G3 fractions in the SFM bed, but rather to point out that the current particulate organic matter coming in from the boundary is assumed to be all refractory. However, it may be possible that during a large scour event a major portion of the scoured particulate organic matter may be largely G3 and therefore putting this into the refractory pool (G2) may over-estimate the bioavailability of the combined watershed and scoured POM pool coming into the Bay. However, we acknowledge that a proposed study effort will be undertaken to address this issue.	**Original Response:** The fractions assigned to G2 (slowly reactive) and G3 (inert) are based on long experience with the Bay model, as applied over the period 1985 – 2005. This interval includes multiple scour events so the assigned fractions are considered representative. Nevertheless, we acknowledge the reactivity of organic matter scoured from the reservoir bottom is an area of uncertainty. There are efforts underway to address this issue and this is a recommendation of the study. **Additional Response:** The comment expresses some misunderstanding about the nature of refractory matter in the water quality model (WQM) and how material deposited on the bottom is mapped to variables in the sediment model (SFM). The misunderstanding originates in a "disconnect" between the variable suite in the water quality and sediment models. As noted in the comment, "all particulate organic matter coming in from the boundary is assumed to be refractory." The refractory variables in the WQM combine the G2 and G3 fractions represented in the sediment model. When refractory organic material settles from the water column into the sediments, it is split into G2 and G3 fractions for subsequent treatment in the sediment model. At present, refractory material settling from the water column is assumed to be 80% G2 and 20% G3. So the transport of G3 material across the boundary is not ignored.
Ex-27 CH. 4/ P.59-60/ Paragraph 3-4 (Sec. 4.2.1)	**Original Comment:** There is a shift in focus from transport in general for all three reservoirs (paragraph 3) to just transport within Conowingo Reservoir (paragraph 4). The same condition would be expected in all three reservoirs, not just Conowingo Pond. **Additional Comment:** True, but still an important issue that warrants a statement in the report that is similar, if not the same, as Scott's response.	**Original Response:** There most certainly is scour in the upper two reservoirs that supply Conowingo. However, without field data to quantify it, it is very uncertain how much of the scour enters Conowingo. More field data measurements are needed below the dams. **Additional Response:** The following paragraph was added after the first partial paragraph on page 61 (October 2014 version, now page 63): "While the focus for many of the LSRWA analyses is the Conowingo Reservoir, there most certainly is scour in the upper two reservoirs that supply Conowingo. However, without field data to quantify this scour, it is very uncertain how much of the scour enters Conowingo. More field data measurements would be needed below the two dams (Safe Harbor and Holtwood Dams) for this level of detail."

Comment Code	Comment	Comment Response
Ex-28 CH. 4/P.106/ Paragraph 4 (full paragraphs) (term appears on pg. 60)	**Original Comment:** What does "trace" erosion mean? Is it resuspended sediment that is moved within the pond and does not pass the dam? Is it erosion of the thin unconsolidated layer? **Additional Comment:** The qualitative term "trace erosion" is used several times in text. Since this response indicates it refers to a quantitative condition, the use of this term should be defined when used in the text. Ditto for the term "mass erosion."	**Original Response:** Erosion of the mixing layer in the reservoir. Very unconsolidated that mobilizes at low shear rates (.004 psf) **Additional Response:** Term occurs on pg. 60. Definition for "trace erosion" has been added to text on page 60 (October 2014 version, now page 63) and to the glossary as: "Erosion of the unconsolidated material of the mixing layer in the reservoir, which occurs at low shear rates"; also, the mass erosion definition has been added on page 43 and in the glossary: "Scour which penetrates the deeper layers and occurs at higher flows with higher bed shear stresses (greater than 0.02 pounds per square inch). "
Ex-30 CH. 4/P.65/ Paragraph	**Original Comment:** This paragraph cites an 'active layer' depth of 2-3 feet. Specific study results that prove this statement should be provided or referenced. Appendix A of the LSRWA does not mention any 'thin unconsolidated mixing layer' as cited, and there is only a single reference to this in Appendix B which states that "[t]he top layer of Conowingo Reservoir sediments consists of a low density unconsolidated layer that may mobilize at lower flows." **Additional Comment:** We were not clear in our first comment – our primary concern was the evidence behind the statement of a 'thin unconsolidated mixing layer', which we cannot find a satisfactory description of within the main report. Our concern is that the main report appears to step beyond what is stated in Appendix B.	**Original Response:** The depth of sediments available for scour was assumed to be 2 - 3 feet in the model. Bed properties were measured in the SEDflume up to one foot of depth. The remaining 2 feet were estimated. Appendix B is the source of this info. Sentence in main report was changed from "The active layer has a depth …" to "For modeling purposes, the active layer is estimated to have a depth…" **Additional Response:** This mixing layer is a real phenomenon, but is modeled as an "active layer" -- a very thin layer at the surface where sediment sorting takes place. The text at the top of page 68 was changed to include this new language: "....; this very thin layer at the surface where sediment sorting takes place was modeled as part of the active layer." This definition of the mixing layer has been added to the glossary.
Ex-32 Page 66, end of last paragraph	Two new sentences were added to the bottom of <u>Bathymetry Comparisons</u> section explaining what "full" condition means – unfortunately they do not clarify the definition of dynamic equilibrium given elsewhere.	The last sentence of that section (page 69, para 3) was changed to: "In this state, the reservoir will experience a periodic "cycle" with an increase in sediment and associated nutrient loads to the Bay from scour also resulting in an increase in storage volume (capacity) behind the dam, followed by reduced sediment and associated nutrient loads transported to the Chesapeake Bay due to reservoir deposition within that increased capacity."
Ex-33 Page 69, end of last paragraph	The phrase "Hurricane Agnes in 1972" appears to have been inadvertently deleted from the last sentence after the word "excluding."	"Excluding" was removed from the text. The value presented in this sentence is for the past 30 years which does not include the Hurricane Agnes event.

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
Ex-34 CH.4/P.73/ Figure 4-5	**Original Comment:** The second panel in this figure indicates that silt deposition buried oyster beds. It's not clear if this is a proven impact, as earlier in the report (page 57), evidence was cited that disproved the 'sediment burial theory' following Tropical Storm Lee and indicated that oyster mortality was likely due to excessive fresh water and low salinities for an extended duration. This is reiterated again on page 138. **Additional Comment:** Response appears to reference the second figure not the second panel (Tropical Storm Agnes June, 1972 – "silt deposition buried oyster beds.")	**Original Response:** Second figure shows extent of sediment plume, not extent of substantial sediment deposition. Change sentence "As a result, sediment runoff from Tropical Storm Lee was quite extensive compared to that of Hurricane Sandy, as depicted in Figure 5-6. " to "As a result, sediment runoff from Tropical Storm Lee was quite extensive compared to that of Hurricane Sandy and produced a large sediment plume in Bay waters, as depicted in Figure 5-6. Where sediment transported into the Bay would be deposited is controlled by waves and currents, thus mainstem Bay deep waters and protected headwater tributary settings would likely retain sediment from this storm, whereas higher energy shallow waters of the mainstem Bay would be expected to show negligible deposition (see Section 2.6.1)." **Additional Response:** Additional text covering SAV and oyster impact concerns has been added to Section 4.2.3.
Ex-35 Chapter 4 (pp. 74-75)	Langland's response to the Riverkeeper comment (# 41) in Appendix I (page 7) indicates both the average peak flow for the Jan 1996 storm (630,000 cfs) and the instantaneous peak flow (908,000 cfs) are to be added to the text to match what is now figure 4-7. However, the text only mentions the 908,000 cfs value and the figure illustrates a 630,000 cfs value (but it shows up more as a transposed 603,000 cfs). The mean daily flow for the 24-hr period centered on the 908,000 cfs peak is reported in Langland and Hainly (1997) as 530,000 cfs. These discrepancies should be resolved.	The instantaneous peak flow for the January 1996 "Big Melt" event was 908,000 cfs. The peak mean daily flow value was 622,000 cfs which is what is plotted in Figure 4-7. Figure 4-7 has been revised to indicate daily peak flow values for the Y-axis. Text has been added to page 75, last para, to show that 622,000 cfs was the daily peak flow value for the Big Melt. The 1997 Langland and Hainly report value of 530,000 cfs was as noted in the comment, a calculated 24-hour value centered on the instantaneous peak. As such, it is not the instantaneous peak nor the peak daily value which were 908,000 cfs and 622,000 cfs, respectively. It has no meaning or use in the context of the LSRWA.
Ex-36 CH.4/P.74/ Paragraph 1	**Original Comment:** It's not clear what "Average peak flow" means – is that the peak daily average flow (and if so at what location), or the average of the peak flows measured along the river? Also, the event says there was an ice dam breached "within the reservoir itself" but the specific reservoir (Clarke, Aldred, or Conowingo) was not described. It is our understanding that the ice jam breached in the Safe Harbor impoundment. **Additional Comment:** The first portion of this comment was adequately addressed, however, clarification was not provided in regard to the specific reservoir where the ice jam breached.	**Original Response:** Correct, there is no average peak flow. Replaced "Average" with "The"; peak flow value changed to 908,000 cfs. **Additional Response:** The peak flow is for Susquehanna River at Conowingo, MD; the ice dam breach was in the uppermost reservoir behind Safe Harbor Dam. The first paragraph on page 74 (October 2014 version, now page 75, last paragraph) has been changed to read "The event was further exacerbated by the breaching of an ice dam in Lake Clarke behind Safe Harbor Dam ..."

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
Ex-37 CH.4/ P.75/ Paragraph last (onto P. 76)	**Original Comment:** Again Conowingo is specifically called out separately, while loads from Safe Harbor and Holtwood are just considered part of the "watershed" loads. **Additional Comment:** We would like to see a breakdown of the model results for each reservoir similar to what is shown for Conowingo Pond, recognizing that there are little to no measured data available to assess accuracy. Additional information should be added to the report.	**Original Response:** The design of the study was to model Conowingo since it was believed it had remaining capacity, was largest reservoir, and may have the greatest impact on the upper Bay **Additional Response:** A breakdown of the model results for each reservoir cannot be done because there is no monitoring data between the upstream dams. However, scour estimates include all three reservoirs.
Ex-38 CH.4/P.76/ Table 4-7	**Original Comment:** Is there a reason that the AdH results were not used here instead? **Additional Comment:** It is unclear why the AdH model could not be used to estimate scour loads at various sized flood events.	**Original Response:** The AdH model could not generate all the data included in Table 5-7. **Additional Response:** The model is likely not validated sufficiently to predict absolute values of scour loads. It is better served to examine model-to-model comparisons, i.e., if something is changed in the model (such as bathymetry) what is the relative change in the modeled result.
Ex-39 Page 78 (Nov), 5th Paragraph	In the first sentence, recommend changing "versus scour from the Conowingo Reservoir" to "versus scour of watershed sediments stored in the Conowingo Reservoir"	Text has been changed as noted.
Ex-40 CH.4/ P.80/ Table 4-9	**Original Comment:** It would be more useful to the reader to list the absolute amount of nonattainment for each scenario, rather than a differential from other scenarios. It is difficult to 'back-calculate' the absolute nonattainment numbers from the differentials presented because of a lack of significant figures and because the 'baseline' scenario is different for several of the scenarios. **Additional Comment:** Our original comment still stands. We disagree that this would not be a worthwhile exercise.	**Original Response:** The critical period of the Chesapeake TMDL is 1993-95, but the year of the Big Melt high flow event on the Susquehanna was 1996, so a 1996-98 3-year period was used to capture the main scour event simulated in the LSRWA report. With the new 1996-98 period, the high flow event is simulated, but the scenario findings of the 1993-95 period are now lost. It is not a worthwhile exercise to compare the TMDL WIP or the 2010 scenarios on the 1996-98 period that is now disconnected to the 1993-95 hydrology and loads that the Chesapeake TMDL was based on. For this reason differential results are used. **Additional Response:** Appendix J4 already has the relevant information. A typical excerpt is as follows, "Generally, a June high flow storm event has the most detrimental influence on Deep Channel DO followed by a storm of the same magnitude in January and then October. A 'no large storm" condition has the highest level of Deep Channel DO attainment. The June high flow event scenario (LSRWA -24) had an estimated increase in Deep –Channel nonattainment of 1%, 4%, 8% and 3% in segments CB3MH, CB4MH, CHSMH and EASMH when compared to the No Storm Scenario." Note the values are given for each of the CB segments as requested. The reason the individual absolute values for each CB segment for each scenario are not given is because the relevant information only comes from the scenario comes from the difference with a base scenario. The absolute scenario values are meaningless in and of themselves.

Comment Code	Comment	Comment Response
Ex-42 CH.4/P.97/ Paragraph 3 (full paragraphs)	**Original Comment:** Paragraph focuses on AdH results for Conowingo Pond and purported loss of storage despite prior (and subsequent) text suggesting that changes in sediment transport are not expected to have a big impact on Bay water quality. **Additional Comment:** Given uncertainties in upstream loads to Conowingo reservoir and loads passing the Dam, what is the uncertainty associated with the mass estimates ascribed to erosion and deposition within Conowingo Pond?	**Original Response:** The reservoir is currently in a dynamic equilibrium for which deposition and scour continually occurs without a net change in storage. Sediments will deposit during low flows and scour during periodic storms. The loads from TS Lee did not demonstrate a long-term adverse impact to water quality. There was a short-term impact as would be expected. **Additional Response:** The uncertainties are difficult to quantify, but they are on the order of the uncertainties associated with the incoming load. The most significant point, however, is that the reservoir is effectively at dynamic equilibrium, which means that future loads, whatever they may be, are unlikely to exhibit an increasing trend attributable to additional losses of capacity in the reservoir.
Ex-43 CH. 5/P.100/ Paragraph 2	**Original Comment:** Goal of management not clearly stated. Stopping all sediment entering Bay is not possible or desirable. **Additional Comment:** The nature of our comment is that the goal appears to be to reduce sediment loading to the Bay; however, this is not stated clearly in the report.	**Original Response:** Comment is vague. The referenced paragraph doesn't mention the word management or goal. There is no place the report that suggests stopping all sediment from entering the Bay. Goal/focus of the management strategies are adequately discussed in paragraphs 1 and 2. **Additional Response:** The previous paragraph (first) on page 100 clearly states that the strategies were "to address the additional loads to Chesapeake Bay from the reservoirs' bed sediment scour." No change to the report is required.
Ex-44 CH.5/P.102)Figure 5-2	Morris (1998) is not in the list references. This figure is not from Morris & Fan (1998). Believe the correct citation should be: Morris, G.L., (2014). Sediment management and sustainable use of reservoirs. In: Modern Water Resources Engineering (L.K. Wang and C.T. Yang, eds.). Humana Press. NY. Chapter 5. Pp. 279-338.	Reference has been corrected to Morris, 2014, both in the text and the list of references.
Ex-46 General	**Original Comment:** Pertaining to all alternatives – not addressed are the potential environmental impacts as related to: aesthetics, air quality and greenhouse gases, soils, water quality, wetlands, groundwater, surface water, wetlands, floodplains, biological resources, cultural resources, land use, socioeconomic resources, recreation and tourism, utility and transportation infrastructure, public health and safety, and noise. In many cases the environmental impacts associated with a specific alternative may cause more harm than good. **Additional Comment:** While a NEPA level review of potential environmental impacts is well beyond the scope of such as assessment, it is not unreasonable for a watershed assessment to discuss the relative environmental impact of alternatives and to list specific resources to be considered for future analysis.	**Original Response:** This paragraph was inserted after last paragraph on page E-4 (before section titled "Future Needs of the Watershed") and after first paragraph on page 182 (before paragraph starting "Table 6-10 is a matrix....). "It should be noted that the LSRWA effort was a watershed assessment and not a detailed investigation of a specific project alternative(s) proposed for implementation. That latter would likely require preparation of a NEPA document. The evaluation of sediment management strategies in the assessment focused on water quality impacts, with some consideration of impacts to SAV. Other environmental and social impacts were only minimally evaluated or not evaluated at all. A full investigation of environmental impacts would be performed in any future, project-specific NEPA effort." **Additional Response:** Disagree. The environmental impacts are identified to the degree needed for the purposes of the assessment, including as pro/cons in Table 5-5. Additional environmental information has also been added in response to internal comments.

Comment Code	Comment	Comment Response
Ex-50 CH. 8/ P.150-151/ Finding #1	**Original Comment:** The important point is to know if the trapping capacity assumed in the TMDL is the same as considered now. Based on reading Langland trapping efficiency data in Appendix T and this LSRWA report they are the same. **Additional Comment:** To clarify the original comment, is the trapping capacity assumed in the TMDL the same as is considered now? It appears based on this report and Langland trapping efficiency data in TMDL Appendix T that they are. Please confirm.	**Original Response:** Good news. Thanks **Additional Response:** The 2010 TMDL documentation of Appendix T clearly stated that the Conowingo was assumed to be effectively trapping particles. The LSRWA report clearly states that the Conowingo is in dynamic equilibrium and is no longer effectively trapping particles.
Ex-52 CH. 8/P.152/ Paragraph 2	**Original Comment:** Couldn't the amount of time for sediments to settle out increase if there is an increase in velocity due to decrease in depth? The statement may be too strong a statement since the time to settle is a unique combination of gravitational and fluid forces." **Additional Comment:** Based on the response of this comment, recommend revising the paragraph in question as shown below in red: "As the lower Susquehanna River reservoirs have filled, water depths have decreased and water velocity has increased. This has led to increasing the bed shear (which can result in more scour) and to decreasing the amount of time ~~for~~ sediments spend in the reservoir ~~to settle out of the water column~~, which thereby, reduces sediment deposition within the reservoir (Appendix A)."	**Original Response:** No, because water is traveling faster, therefore, potentially, less time spent in reservoir. **Additional Response:** Text has been changed as suggested.
Ex-54 CH. 8/ P.154/2nd Full Paragraph	Recommended revision to wording at the end of Finding #2: "To achieve the required water quality conditions under the Chesapeake Bay TDML, full attainment of the states' Chesapeake Bay water quality standards, the extra nutrient loads associated with sediment scoured from the three reservoirs ~~Conowingo Reservoir~~ must be offset by equivalent nutrient load reductions."	Yes, the 2010 Bay TMDL was based on the understanding and the supporting monitoring data that the upper two dam/reservoir systems were in long-term equilibrium. Text has been changed from "Conowingo Reservoir" to "the three lower Susquehanna reservoirs"

Comment Code	Comment	Comment Response
	Original Comment: The model depends on how upstream boundary conditions (BCs), sediment bed properties, and transport processes are represented in order to "calibrate" the model to reproduce measured downstream BCs. With respect to the sediment BC, USGS used a function where upstream TSS = 0.007 Q $^{0.9996}$. For all practical purposes, this is a linear relationship between TSS and Q. Although there is a lot of spread in the data, the maximum concentration reported at any Q is 700 mg/L (with a more general trend around 300 mg/L). Extrapolating the upstream BC function to the high flow of interest leads to TSS = 835 mg/L when Q = 1.2e6 cfs. This extrapolated TSS concentration is just ~15% more than the maximum reported value (and less than 3x more than the general trend value of ~300 mg/L). [If the upstream reservoirs are believed to in dynamic equilibrium (and Holtwood reservoir is very shallow), the increase in TSS concentration is modest given the factor of 2 extrapolation of flow beyond the limit of measurements.] In contrast, the downstream BC was represented using a parabolic function where downstream TSS = 4e-09 Q ^{2} – 0.0007 Q + 34.313. As before, there is a lot of scatter in the data but it is harder to see on the graph because the y-axis goes to such a high limit that typical values appear compressed. Nevertheless, typical values are on the order of 300 mg/L to ~1000 mg/L (at 600,000 cfs) with a maximum value of 3,000 mg/L (at 600,000 cfs). This may not be a reasonable representation of the downstream BC. Further, the form of this relationship presents a curious situation for several reasons: • the linear term, TSS = -0.0007 Q, is nearly identical in magnitude but opposite in direction to the upstream BC function • the quadratic term, TSS = 4e-09 Q ^{2}, implies that concentration increase geometrically for a linear increase in flow • because the linear term is essentially equal to the upstream load (and opposite in sign), the mass represented quadratic term must be transported off the bed in the model in order for simulated TSS concentrations at the downstream boundary to equal measured values. When extrapolated, the relationship implies that TSS = ~5,000 mg/L when Q = 1.2e6 cfs. Not only is this concentration very high, it is 40% more than the maximum reported concentration of 3,000 mg/L (assuming that this 3,000 mg/L value is representative and not impacted by a sampling or measurement error), ~5x greater than other values measured at 600,000 cfs and ~10x higher than more typical values. There is no basis to determine if this downstream BC TSS relationship is reasonable or appropriate, particularly when extrapolated to 1.2e6 cfs.	**Original Response:** Suspended-sediment concentration (SSC) was used, not TSS; there is a bias difference in lab methods that generate an error when sand is present. The TSS method by using an aliquot taken at the middle of the sample potentially does not capture the heavier sands that have already settled. There are a lot of great discussion points here, linear vs. quadratic relations, BC in and out of the reservoirs, maximum "measured" sediment concentrations, sediment recession, etc. It is important to note that the sediment concentrations shown in the sediment rating curves may NOT be the maximum concentrations. This is most likely the case at Marietta when the first (and highest at ~700 mg/L) measurement for the T.S. Lee event was 3 days after the peak. Most likely this was well after the sediment peak and on the recession side of the sediment hydrograph. This monitoring location is just upstream of the reservoirs. The downstream site reflects the cumulative effect of the Susquehanna River and 3 reservoirs and therefore the sediment rating curve might be expected to be different than a rating curve outside of a reservoir system. The quadratic form of the equation suggests a different source of sediment than the linear upstream. as you mention, scoured bed sediments. This is reflected in the" measured" data at the Conowingo site. I'm not sure how you define "massive bed erosion". The conclusion of the model simulation was the model "UNDER ESTIMATED" the amount of sediment when compared to "measured data" at Conowingo.

Comment Code	Comment	Comment Response
Ex-A-1 Appendix A, General	This situation is further exaggerated because the exponents in the sediment transport capacity/erosion relationships selected for HEC-RAS (1 for Parthenadies, 6/7 for Laursen) are much less than the value of 2 in the downstream BC relationship. This means that the model is forced to scour tremendous amounts of sediment from the reservoir bed to match downstream TSS levels. In short, with this downstream boundary, the model can only compute massive bed erosion and must be set-up so that erodible limits are sufficient to allow massive bed erosion.	
	Additional Comment: No revisions in the report appear to relate to this comment. Uncertainty bounds for both the upstream and downstream load estimates from measurements should be evaluated. There are no means to determine how much overlap may exist in these estimates. Understanding overlap in estimates is important because the difference between the downstream load and the sum of the upstream loads and tributary inputs empirically defines the amount of bed scour. All load estimates are extrapolated to high flow to represent high flow events. The functional form of load estimation equations can have a pronounced impact on inferences of bed scour.	**Additional Response:** Additional efforts were completed for just this reason. Error bounds were estimated and presented for regression scour estimates and the sediment flux estimates at Marietta and Conowingo. It is important to note that the sediment concentrations shown in the sediment rating curves may NOT be the maximum concentrations that occurred because only a small percentage of a storm event is sampled. This is most likely the case at Marietta when the first (and highest at ~700 mg/L) measurement for the T.S. Lee event was 3 days after the peak. Most likely this was well after the sediment peak and on the recession side of the sediment hydrograph. This monitoring location is just upstream of the reservoirs. The downstream site reflects the cumulative effect of the Susquehanna River and three reservoirs, and therefore, the sediment rating curve might be expected to be different than a rating curve outside of a reservoir system.
	If 2 points in the downstream load estimate data set were treated as outliers (TSS = ~1,200 mg/L at Q = ~390,000 cfs; and TSS = ~3,000 mg/L at Q = 610,000 cfs), the implied curvature where TSS rapidly increases with Q at high flow in the downstream boundary load estimate would be reduced (or eliminated).	Suspended-sediment concentration (SSC) were used not TSS, since there is a bias difference in lab methods that generate an error when sand is present. The TSS method uses an aliquot taken at the middle of the sample that potentially does not capture the heavier sands that have already settled. SSC used the entire sample and captures all the sediment. Concur with your point, but excluding data and treating as outliers would also bias the curvature, perhaps in the opposite way. The USGS has deployed continuous monitoring sondes for turbidity to help with improving the Q-C relation at high flows. The "outliers" were removed to determine the effect on the regression equations. For Marietta, the linear change was from 0.0007 to 0.0008 with exponent change from 0.9996 to 0.9957. For Conowingo, the change was 4e09 to 3e09 in the quadratic and from (-0.0007) to (-0.0003) in the linear. The curvature for the Conowingo Q-C is still very evident but obviously dampened a little.
	Thus the quadratic term speaks more to a likely error in model boundary conditions rather than a different source of sediment. Moreover, correlation does not imply causation; cause cannot be inferred; particularly because the USGS analysis appears that it does not account for the time of travel between Marietta and Conowingo.	The quadratic form of the equation suggests a different source of sediment than the linear upstream. And, as you mention below, scoured bed sediments. This is also reflected in the" measured" data at the Conowingo site.
	The fact that the model was judged to underestimate the empirical TSS load passing Conowingo Dam speaks to errors in representing erosion and deposition processes in the reservoir.	This is likely so. The underestimation was related to lack of scour due to the model algorithms, not misspecification of the sediment rating curve.
	Table 2 (p. 12) of the revised report indicates a high clay fraction in the sediment bed. The inference is that the sediment is substantially cohesive. The transport formulations selected are not applicable to such sediment.	Concur, and that is one of the limitations of HEC-RAS in a reservoir simulation. Once in suspension, the model parameters settings control cohesive transport.

Comment Code	Comment	Comment Response
	The model is largely set to operate on a transport capacity limited basis (with infinite supply down to erodible limits). In contrast, reality may be more of a case where, due to sediment cohesion, the system is supply limited. Ultimately, the USGS' assessment that the model underestimates the TSS load leaving Conowingo is more a reflection of the method used to estimate upstream and downstream loads rather than an assessment of the model. Underestimation of loads at Conowingo could be the result of errors or uncertainties in any of the following: (1) (overestimating) the empirical load at Conowingo, (2) the upstream load, (3) watershed loads, and (4) scour from the bed. The report does not adequately deal with these issues and instead advances a priori conclusion that scour within Conowingo reservoir is the source of sediments.	Concur, this is most likely the case, but not for sediment cohesion but for sediment compaction. Errors contribute to the estimation of sediment loads entering and leaving the system. However, other issues with the model were determined to have a greater effect on underestimation. These are presented in the report in Appendix A. Based upon the HEC-RAS model, there was difficulty simulating to the calibration data. This was related to model, not data, limitations. There are other lines of evidence that scour does occur. Bathymetric surveys provided a good indication of bottom change. Increasing loads using a mass balance approach combined with a color change in the sediments also provide evidence of scour.
Ex-A-2 Appendix A, General	**Original Comment:** At a minimum, confidence intervals should be established for the upstream and downstream boundary conditions and alternative formulations should be explored for the functional relationships used for both BCs. **Additional Comment:** Use of alternative sediment transport functions (which are themselves not applicable to the types of sediment being modeled) does not establish confidence intervals. This is a question of statistics; given the TSS and flow values used in the regressions shown in Figures 6 and 7, what are the confidence limits? Do the confidence limits of the upstream and downstream load estimates overlap? This is unrelated to sediment transport functions.	**Original Response:** Selecting 2 different sediment transport functions for the model was the attempt to place some confidence interval in overall sediment transport from Conowingo. **Additional Response:** The transport function selected was chosen because it performs best with the dominant bed material and suspended material transport in and through the reservoirs (silt). Use of the transport function does allow for a range of simulations under two different conditions. Nowhere in the report is it stated that these were "confidence limits." The original response was in error. Computing the confidence limits for Figures 6 and 7 would be misleading due to the water regulation of dams and the trapping of sediment. For flows up about 400.000 cfs, the concentrations are nearly always greater at Marietta than Conowingo. There is overlap in the concentration data, but loads are more important when evaluating reservoir dynamics because the loads can be related to flow. In Table A3 in Appendix A, error (confidence) ranges are presented.

Comment Code	Comment	Comment Response
Ex-A-3 Appendix A, General	**Original Comment:** There is a link with the SEDFLUME data too (and the AdH report) for cohesive transport. As noted in the AdH report (Section 6.1 of Appendix B), the sampling tube could not penetrate the substrate indicating highly consolidated sediments. The AdH report notes that most of the cores were less than 1 foot in length. However, erodible depths in the HEC-RAS model ranged from 0 feet just downstream of each dam where the bed is composed of gravels, boulders, and bed rock to 20 feet in the deepest sediment accumulation areas. This seems a bit inconsistent. **Additional Comment:** Did the HEC-RAS model show erosion depths greater than the depths to successful SEDflume collection? The maximum depth of erosion in the HEC-RAS model should be compared to the physical information implied by difficulty collecting SEDflume core deeper than 1 ft.	**Original Response:** I did not collect the SEDFLUME data, but I am aware of some of the difficulties in the collection. Previous cores collected by USGS in 2000 and analyzed by University of Maryland, go down much deeper (average of 5 feet, deepest one 11.5 feet) and contain particle size information at incremental levels. In general, particle size becomes courser with depth, but there are many areas with erodible fines at depths greater than 5 feet. Just because the erodible depth is set to 20 feet, that does not mean the model is going to erode down that deep. Just because the erodible depth is set to 20 feet, that does not mean the model is going to erode down that deep. **Additional Response:** No, it did not, but the model did erode in areas were the critical shear stress was higher than the bed shear, again pointing to issues with the HEC-RAS model. In addition, SEDflume results were not the only means used to estimate potential for "erosion." SEDflume erosion data indicated an eight-fold "erosion" variability in Conowingo Reservoir. HEC-RAS only has the ability to enter one non-changing set of erosion parameters.
Ex-A-4 Appendix A, General	Starting with the second sentence on page 4, in the citation for the URS and Gomez & Sullivan publication, "USR" is used in multiple locations.	Typographical errors have been corrected.
Ex-A-5 Appendix A, P. 4, middle paragraph	**Original Comment:** Fall velocities do not change with water velocity, transport capacities and shear. Statement is incorrect. **Additional Comment:** The response to the original comment is satisfactory; however, the last two sentences of this paragraph are somewhat unclear: "The report implies increasing concentrations and loads are due to the loss of storage capacity from a decrease in the scour threshold. Reasons for this increase are not certain but likely involve changes in particle fall velocities, increased water velocity, transport capacities, and bed shear." Please provide further clarification.	**Original Response:** Agree removed "due to" **Additional Response:** See response to comment Ex-A-20; also added "and from a possible decrease" in paragraph 2, penultimate sentence, page 4.
Ex-A-6 Appendix A, P. 5, Figure	This figure indicates that sediment transport by means of density currents is an important process in reservoirs. What evidence is there that this is occurring in Conowingo Pond?	This is an "idealized" schematic, not necessary representative of Conowingo. The figure was not meant to imply that this is exactly what happens in Conowingo but is representative of reservoirs in general. The fact that the particle size is sandier at the top of the reservoir and finer near the dam combined with changes in bed-surface elevations, indicate the bottom sediments are mobile.

Comment Code	Comment	Comment Response
Ex-A-7 Appendix A, P. 11, Figure 6	**Original Comment:** Here and elsewhere (USGS regression equation) sediment transport curves are developed based on suspended sediment samples. Suspended samples do not capture bed load which is not estimated in the report. In addition there is always part of the water column on the bottom (usually with the highest concentrations) where the sampling device cannot collect data. I did not see any explanation of how the bed load or unmeasured loads were considered, if at all, in the analyses. **Additional Comment:** Other than "initial conditions or boundary conditions in a model may not be well known" (page 22) there appeared to be no discussion about the uncertainty in the inflowing load based on our review of the cited section. Not including bedload or unmeasured load at the upstream boundary does not appear to be addressed.	**Original Response:** On page 24, under model limitations and uncertainty, this issue is addressed. **Additional Response:** Correct, bedload is separate from "wash" or suspended load. Data analysis indicates that sand (primarily deprived from bedload) is less than 10 percent of the total washload. Bedload movement and resuspension could account for large quantities of sediment transport, but this study was focused on what was in the suspended load, and therefore available for transport over the dam and into the Bay.
Ex-A-8 Appendix A, P. 18, top of page	**Original Comment:** Only flows from two tributaries were included – any estimate of flow percentage missing from ungaged tributaries? Should be able to estimate by comparing outflow from Conowingo with sum of inflows from Marietta and gaged tributaries. **Additional Comment:** Is the reference to Attachment A-1 of the report or to a different one? Did not see anything about this in A-1.	**Original Response:** This was an additional exercise completed and included in attachment 1 **Additional Response:** No, there is not a long enough streamflow record at the gaged sites to do this type of analysis.
Ex-A-9 Appendix A, P. 24, para 4	**Original Comment:** Lots of problems were encountered with appropriate fall velocities for cohesive sediment. As recommended by HEC, the grain size distribution should reflect the flocs rather than discrete grains. **Additional Comment:** This should be identified as a limitation or uncertainty.	**Original Response:** We did not have information about the floc size. **Additional Response:** Agree. Text in Appendix A has been updated to include limitations; change can be found on page 24, first line, in limitation #4.
Ex-A-10 Appendix A, P. 24, para 7	**Original Comment:** Statement is not exactly true. HEC-RAS solves sediment transport by size class. **Additional Comment:** Original comment still stands. Item #7 is still incorrect in that sediment load is determined by size class using whatever transport formula was chosen (some are bed load only, some are total load) and the capacity limiters mentioned in the response.	**Original Response:** With limited capacity **Additional Response:** Concur, HEC-RAS does determine sediment load by size class. But the issue is that the HEC-RAS model, while partitioning the sediment load and transport by particle size, has limited capacity to simulate the suspended load, which is critical in reservoir transport.

Comment Code	Comment	Comment Response
Ex-A-11 Appendix A, P. 24	**Original Comment:** Missing a paragraph #9 which would point out that the hydrograph is being simulated by a series of steady flow pulses, and sediment transport is assumed at equilibrium for each flow pulse. This is different from true unsteady flow (non-equilibrium transport) models. **Additional Comment:** Should be listed as a limitation. Can put something simple without further explanation required, e.g., "the model simulates flow hydrographs via a series of steady flow pulses."	**Original Response:** May be a little too technical to explain without adding more information on the difference (advantage, disadvantage) between steady and unsteady models **Additional Response:** This is presented on page 7 of Appendix A.
Ex-A-12 Appendix A, P. 25, para 1	**Original Comment:** Why is there poor agreement with bathymetry? **Additional Comment:** The report should have an explanation for the poor agreement.	**Original Response:** Model performance and added "the estimated change" **Additional Response:** Text has been revised to include "due to model limitations" on page 25 of Appendix A.
Ex-A-13 Appendix A, P. 25, last para	The Duan et al. reference is not very pertinent as her work on the Rillito Wash was for an ephemeral sand bed riverine system as opposed to a perennial silt dominated reservoir environment.	This suggests the model should have been better at predicting the transport, because many of the transport functions are for sand. While not in the identical situational use, it is interesting that the results are similar.
Ex-A-15 Appendix A, P. 29, para 1	The first sentence that models were calibrated to samples is misleading in that there was no comparison of computed versus measured (based on concentration) sediment load but rather of percentages of sand/silt/clay	Agree; text has been modified on page 29, including Table 7, to indicate that the particle size data was compared to the model output.
Ex-A-16 Appendix A, P. 35, Table A1	**Original Comment:** It appears that the results were computed with Log-Pearson Type III distribution. The Appendix should note that this distribution is not always applicable for controlled systems. **Additional Comment:** Noting that the difference between the in and out curves may be due to flow regulation is not the same as recognizing that the assumed distribution itself may not be appropriate for regulated systems.	**Original Response:** I noted the difference might be due to flow regulation. **Additional Response:** According to "Water Committee on Water Information" http://acwi.gov/hydrology/Frequency/B17bFAQ.html, the issue with regulated flows is the effect on natural peaks. If the reservoir is effective at regulating floods, then the difference will be noticeable in the upper middle range with the regulated flow below the natural river flow, then converging again near the upper end. This is not the case when comparing the two stream gages. At the higher ends, the reservoirs do not have the ability to "hold" much water (i.e., the reservoirs are overwhelmed by higher flows) helping to negate this effect. This does not mean that there is zero effect, and it is noted that flow regulation may have some effect.

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
Ex-A-18 Appendix A, P. 38-39, Figure A4	**Original Comment:** Not clear how scour loads were computed and curve developed, important as used for model calibration. Also based on suspended load measurements only (no bedload). **Additional Comment:** The original question remains. How were scour loads computed and curves developed? Also, it appears the regression equation in the Figure has changed since the last draft even though the data appears to be the same. Not sure what happened here?	**Original Response:** Scour loads are defined as sediment capable of being lifted from the bed become "SUSPENDED" and transported through the dam. The bed is always moving to some degree, however, this study (and most of Chesapeake Bay Program is concerned with what exits the dam, not necessary how movable is the bed. **Additional Response:** The estimated loads from upstream of the reservoirs plus the tributary input is subtracted from the estimated loads from Conowingo. The scour estimates are used in a total mass balance approach and checked against estimated changes in bathymetry. Estimated data may change depending on the load model and time period chosen. In general, the closer the data is to the center of an estimation time period, the more accurate the estimate becomes. Newer estimates (results) are reflected in regression equations.
Ex-A-20 Appendix A, P. 42, para 1	**Original Comment:** As velocity increases and bed shear increase, wouldn't the time for sediments to settle out also increase, not decrease? **Additional Comment:** It seems the authors are referring to the <u>time available to settle out in the reservoir</u> and not the time it takes to settle. The text and author's response here are not clear. The sentence in question is: "As the reservoir fills with sediment, the velocity increases, perhaps increasing the bed shear (can result in more scour) and decreasing the amount of time for sediments to settle out of the water column thereby reducing deposition." Under the scenario of increased flow velocity and bottom shear, a particle in suspension will remain in suspension longer. That is, it will take longer to settle out of the water column. If the author means to communicate that there is less time available for the particle to settle out of the water column in the reservoir because it is being transported out of that system faster, this should be clearly stated.	**Original Response:** NO, velocity increases, lessening the amount of time for sediment to settle out. **Additional Response:** The word "residence" is added in front of time in the noted sentence (line 7, para 1, page 42).
Ex-B-1 Appendix B, General	**Original Comment:** Lots of discussion about erosion threshold and SEDflume data but not much about deposition shear stress threshold. Are these set equal in the model? **Additional Comment:** Floccing is given importance and described on page 13, it is identified as one of three most critical model uncertainties on page 14, it is presented as a needed improvement to the AdH model on page 60, and it is identified as a source of uncertainty in the main report (2nd paragraph of page 38 in November version). However, I did not see this uncertainty described in Attachment B-1.	**Original Response:** Because of uncertainty in flocculation dynamics, there was no minimum depositional shear stress (based on particle fall velocity of individual particles **Additional Response:** The title of Attachment B-1 has been changed to reflect the fact that it is really a discussion of AdH model simplifications, not uncertainties. The uncertainty discussions are located in Chapter 4 of Appendix B.

Comment Code	Comment	Comment Response
Ex-B-2 Appendix B, General	**Original Comment:** The AdH model TSS upstream boundary condition is directly from the USGS HEC-RAS application. As noted in comments on Appendix A, USGS used a function where upstream TSS = 0.007 $Q^{0.9996}$. For all practical purposes, this is a linear relationship between TSS and Q. Although there is a lot of spread in the data, the maximum concentration reported at any Q is 700 mg/L (with a more general trend around 300 mg/L). It would be worth reviewing the basis and functional form for this upstream TSS BC. Uncertainty bounds and confidence limits for this relationship should also be established. **Additional Comment:** This comment does not appear to have been addressed by a revision to the report.	**Original Response:** Agree. Perhaps the field data collection effort by Exelon and USGS can provide more data for such as effort. **Additional Response:** Please see response to comment Ex-A-1. No changes to the report are warranted. Please note that a linear TSS relationship represents a quadratic load relationship, since the load is TSS times Q.
Ex-B-3 Appendix B, General	**Original Comment:** The AdH model TSS downstream boundary condition differs from the USGS HEC-RAS application. Whereas the USGS TSS downstream BC fit a parabolic function to the data and did not force the relationship to pass through the maximum point (TSS = 3,000 mg/L at Q = 600,000 cfs), the relationship used for AdH is forced through this maximum value. Consequently, at a flow of 600,000 cfs, AdH is calibrated to yield even more erosion than the USGS model. It would be worth reviewing the basis and functional form for this upstream TSS BC. Uncertainty bounds and confidence limits for this relationship should also be established. **Additional Comment:** AdH simulations attempt to approximate the load implied by the product of flow and concentration (Q times C) at Conowingo Dam. The load implied by the data reflects uncertainties in measurements and the timing of those measurements relative to flow conditions (i.e., rising limb, versus falling limb, etc.). The issue is whether the handful of high concentrations measured at Conowingo Dam, or not measured upstream, are accurate and reflective of the true load. The original comment was intended to express these concerns rather than to imply that AdH was curve fit. What effort was put into screening and evaluating the data?	**Original Response:** The USGS did not use this linear function. They used actual data. The maximum value of their actual data set was more like 2700 mg/l. The AdH downstream output of TSS was based on both pass through sediment and bed scour contribution. The output of AdH was not forced through any curve fit. The actual measured values of concentration discharged through Conowingo were plotted as an exponential function that did pass through the maximum value. **Additional Response:** The paucity of available data, especially at high flows, make quantitative assessments of these uncertainties difficult. This is one reason why the AdH model is validated by comparison to several bulk-measured properties, the load being just one. It is true that these unquantified uncertainties render such comparisons somewhat subjective, and could even result in an overly pessimistic perception of the model (if the model is validated to within the known uncertainty of the data, that is as good as it is possible to know). But there is just not enough data to do this analysis.
Ex-B-4 Appendix B, General	**Original Comment:** Boundary conditions should be reviewed to establish defensible ranges/relationships and quantify uncertainties. **Additional Comment:** It is unclear if any action was taken based on this comment.	**Original Response:** Agree. **Additional Response:** The reliance on model-to-model comparisons makes the uncertainties in boundary conditions far less significant with respect to model results, as the impacts of boundary condition uncertainties largely subtract out of the results for model-to-model comparisons. Also, it is not clear that sufficient data exist to perform meaningful uncertainty analyses on boundary conditions. No further action is warranted.

Comment Code	Comment	Comment Response
Ex-B-5 Appendix B, General	**Original Comment:** SEDFLUME cores only penetrated to ~1 ft or less. In some cases the depth of scour identified in Figure 5 often exceeds 1 ft and can exceed 5-8 ft in several locations. Such model results are extrapolations beyond the range of measurements. Cores for the SEDFLUME could not penetrate sediment so it is likely that the erosion resistance of sediment at depth could be much more than at 1 ft below grade. **Additional Comment:** This comment does not appear to have been addressed by a revision to the report.	**Original Response:** I agree. I increased the erosion threshold considerably for these deeper depths (greater than 1 ft) up to 5 – 6 pascals **Additional Response:** Table 1 of Appendix B is correct. For simulation #3, 1 lb/foot^2 is equal to 5 Pascals which is what the modeler used in the run.
Ex-B-6 Appendix B, General	Appendix B-1 mentions transport by density currents several times as a process of sediment transport in reservoirs. What evidence is there that this is occurring in Conowingo Pond?	It typically occurs in reservoirs during low flow, or perhaps with sediment-laden water. But it is not generally of great significance during high flow events.
Ex-B-7 Appendix B, P. ii, para 1	Recommend deleting the 1st paragraph of abstract. As currently written, it comes off largely as the opinion of others (i.e. USGS). Besides, it is not needed given content of rest of abstract.	The paragraph provides historical context for the problem, and is of use to anyone reading the abstract without knowledge of the system. Therefore, the abstract will not be changed.
Ex-B-8 App. B, P. 1-2, para 3/1	How is enforcement of a TMDL standard related to perception of steady-state sedimentation in a reservoir?	It addresses the question of whether the TMDL is likely to increase over time or not.
Ex-B-9 Appendix B, P. 2, para 1	Statement that "[i]n the absence of large flow events, the majority of sediments that enter the two upstream reservoirs transport to the lowermost Conowingo Reservoir" has no clear basis. The AdH report only covers the Conowingo Reservoir; it does not extend to consider reservoirs upstream. This statement should either have a citation, reflecting the work/opinion of others, or it should be deleted.	This statement is based on the discussion of studies of the other reservoirs (referenced in the report), indicating that these reservoirs are in a state of dynamic equilibrium.
Ex-B-10 Appendix B, P. 4-5, entire sect.	This section seems as if it is a summary of work by others; however, there are relatively few direct citations. Recommend updating to include the appropriate citations.	This section is based on a general discussion of studies of the other reservoirs (already referenced in the report), indicating that these reservoirs are in a state of dynamic equilibrium. All citations are present, but a repeat of the USGS citation in the next paragraph has been added, to make it clear that these data being cited are also from that report.
Ex-B-11 Appendix B, P. 5, bottom of page	**Original Comment:** "HEC-6 model did better when included coarser sediments." By using only suspended samples you are missing out on coarser particles that might transport as bedload **Additional Comment:** To state this as a question, is the potential lack of coarser material at the upstream boundary considered in the uncertainty analysis?	**Original Response:** Agree. **Additional Response:** The potential lack of coarser material is not specifically considered in the uncertainty analysis; concur that it is a potential source of error.

Comment Code	Comment	Comment Response
Ex-B-12 Appendix B, P. 8-9	**Original Comment:** Goals stated more clearly here than in main report. This description should be incorporated into the main report. **Additional Comment:** This comment does not appear to have been addressed by a revision to the report.	**Original Response:** Main report will be updated. **Additional Response:** The Appendix B study goals for the AdH model have been added into the main report in Section 3.2. It should be noted that the AdH study goals should not be confused with the overall goals of the LSRWA study.
Ex-B-13 Appendix B, Chapter 4	**Original Comment:** This section does a much better job of describing the uncertainties associated with the AdH results than the main report does. Specifically page 14, paragraph 2 which states that "Because of these uncertainties the AdH model may potentially over-predict to some degree transport of bed sediment through the dam." These points, for all models, need to be more clearly made and emphasized in the main report. **Additional Comment:** This comment does not appear to have been addressed by a revision to the report.	**Original Response:** Main report will be updated. **Additional Response:** The suggested text was previously added to Chapter 3.2, page 39. Text on uncertainty was also added as suggested by comment Ex-C-11.
Ex-B-15 Appendix B, P. 16, para 1	**Original Comment:** USGS model input taken from inflowing suspended load not considering bedload – missing coarser materials? **Additional Comment:** See response 4 rows up. [EX-B-11] To state this as a question, is the potential lack of coarser material at the upstream boundary considered in the uncertainty analysis?	**Original Response:** Agree. Bedload not sampled **Additional Response:** The potential lack of coarser material is not specifically considered in the uncertainty analysis; concur that it is a potential source of error.
Ex-B-17 Appendix B, P. 17, para 1	**Original Comment:** Conservatively high inflowing sediment load assumed and used for all other simulations. This does not appear to have been stressed or explained well in the main report. **Additional Comment:** To confirm, we understand that the HEC-RAS sediment load was increased by 10% to account for the under prediction of sediment loads.	**Original Response:** The USGS used measured suspended sediment concentration data to create a sediment rating curve into the uppermost reservoir. The output to the AdH model was based on HECRAS output to Conowingo. **Additional Response:** Yes, it was increased by 10 percent to account for the under-prediction of sediment loads and to err on the side of conservatism with respect to estimating scour potential in the Conowingo Reservoir -- the more sand that enters the reservoir during lower flows, the more potential for erosion of material from the sediment bed during high flow events.

Comment Code	Comment	Comment Response
Ex-B-19 Appendix B, P. 22-32, entire section	In the absence of data that were considered sufficient for calibration, please explain how parameterizing AdH to reproduce results from USGS studies independently validates AdH results: 1. If USGS results are driven by empirical load estimates (or regression equations) that assume different functional relationships for upstream and downstream locations, and scour is imputed by the difference between downstream and upstream estimates, do AdH simulations parameterized to reproduce USGS results provide an independent confirmation of those results? 2. If AdH is constrained by SEDflume core measurements, what are upper and lower bound limits of AdH solids concentrations given upper and lower bound parameterizations based on SEDflume core data (without limiting the erodible depth of sediment as described to 1 ft)?	In the absence of sufficient data for calibration, boundary conditions, and model parameterization, AdH was subjected to a "validation exercise." The results were compared against several bulk parameters: the USGS scour load estimates, the grain size distribution of the outflow, and the net change in volume of the reservoir, computed from bathymetric differences. Since the model compared well to these three semi-independent sources of data, it was determined that the model was representing the basic sediment dynamics of the reservoir with sufficient fidelity to conduct model-to-model comparisons and observe modeled trends.
Ex-B-21 Appendix B, P. 23, para 3	**Original Comment:** "The properties of the lower two feet were either approximated from the SEDflume results or determined from literature values." It would be useful to have a table of these properties. **Additional Comment:** This comment does not appear to have been addressed by a revision to the report.	**Original Response:** I estimated increases in shear stress from literature. **Additional Response:** Concur. Noted sentence has been revised to reflect source of shear stress values from literature only.
Ex-B-22 Appendix B, P. 34, para 1	**Original Comment:** Middle of paragraph, sentence starting with "This channel was not included…" and next sentence should include a citation. **Additional Comment:** This comment does not appear to have been addressed by a revision to the report.	**Original Response:** Agree. **Additional Response:** Concur. The noted paragraph in Appendix B has been revised to include references to the USGS and Exelon surveys. The source of the bathymetric data that described the general channel shape and slope is believed to be LIDAR data from USGS. However, this cannot be confirmed since the original AdH modeler has retired from federal service.
Ex-B-24 Appendix B, P. 46, para 2	**Original Comment:** Last sentence of paragraph is speculative and goes to the uncertainty of using the HEC-RAS model as the input to the AdH model **Additional Comment:** This comment does not appear to have been addressed by a revision to the report.	**Original Response:** Agree. **Additional Response:** This comment was addressed by the inclusion of the word "potentially" in the noted paragraph. No further text change is warranted.

Comment Code	Comment	Comment Response
Ex-B-25 Appendix B, P. 52+, General	**<u>Original Comment:</u>** The description of this downstream model has much less detail and is shorter than the sections dealing with the upstream model. **<u>Additional Comment:</u>** This comment does not appear to have been addressed by a revision to the report.	**<u>Original Response:</u>** Agree. **<u>Additional Response:</u>** While the description is shorter, it contains sufficient information to characterize the modeling effort.
Ex-B-26 Appendix B, P. 53-54, para 1, Figure 34	**<u>Original Comment:</u>** What is the reference for the ratio of roughness with SAV? **<u>Additional Comment:</u>** Add reference to Berger et al. to text and/or figure.	**<u>Original Response:</u>** The AdH user's manual **<u>Additional Response:</u>** Change has been made to Appendix B.
Ex-B-27 Appendix B, P. 55, para 1	**<u>Original Comment:</u>** No description is given of the upstream or downstream boundary conditions. Assuming that the U/S BC is the outflow from the U/S AdH model, but which run? Or were measured SSCs used? **<u>Additional Comment:</u>** Does not answer the question of what was used in the modeling exercise that produced the figures and led to conclusions.	**<u>Original Response:</u>** The upstream boundary was an arbitrary flow, not Specific Conowingo outflow. **<u>Additional Response:</u>** The text in Appendix B has been altered to reflect that this is a synthetic event that is simulated, not actual observed or modeled boundary conditions.
Ex-B-30 Appendix B, P. B-1	**<u>Original Comment:</u>** Using the provided graphs, the 86,000 cfs limit where all flows pass through the powerhouse accounts for about 30% of the annual sediment load. This should be mentioned. **<u>Additional Comment:</u>** Original comment was based on Figure 5. Maybe the ordinate (y-axis) should be labeled average annual load? It is notable that 70% of the average annual load does NOT go through the powerhouse (usually due to larger events).	**<u>Original Response:</u>** Doesn't that depend on storm frequency? Not sure about that. Maybe "average" annual sediment load. **<u>Additional Response:</u>** This cannot be meaningfully quantified without some integration of storm frequency into the calculations.
Ex-C-1 Appendix C, General	The use of metric units when everything else is in English unnecessarily confuses the issue.	The investigation reported in Appendix C was conducted using SI units. These are the international standard in science and engineering. Unfortunately, federal planning studies meant for public consumption in the United States report English (non-metric) units, so as to not confuse non-scientist Americans.

Comment Code	Comment	Comment Response
Ex-C-2 Appendix C, P. 18, para 3	**Original Comment:** Although period examined has a range of flows, how representative is the flood frequency during this period with the long-term flood frequency? **Additional Comment:** Does the use of the 1996 storm event combined with the high nutrients observed in 2011 make for either a worst case, or at least very conservative, estimate of Bay impacts?	**Original Response:** The report indicates two erosion events (flow > 11,000 m3 s-1) occurred during the ten-year simulation period. These events were in April 1993 and January 1996. Langland's report indicates flows in excess of 400,000 ft3 s-1 (11,000 m3 s-1) have a recurrence interval of five years. Two events in ten years correspond well with the expected recurrence. **Additional Response:** The model application did not combine the 1996 storm event with high nutrients observed in 2011. The model characterized the nutrient composition of scoured material based on multiple surveys of bottom sediments in Conowingo Reservoir. The characteristic nutrient concentrations were combined with estimates of the mass of sediment scoured during the 1996 storm. The characteristic bottom sediment nutrient content exceeded the observed nutrient content of material flowing over the dam in January 1996. Consequently, model results tend towards the "worst case." They are not the absolute worst case but the effects on the Bay are more severe than if the nutrient fractions observed in 1996 were employed.
Ex-C-3 Appendix C, P. 19, para 3	**Original Comment:** How was the Conowingo Pond equilibrium condition determined? **Additional Comment:** Original comment still stands. Please address as appropriate following the next round of LSRWA comment review.	**Original Response:** The equilibrium bathymetry was determined by the team that modeled Conowingo Reservoir (Mike Langland, Steve Scott, and associates). This question must be answered by that team. **Additional Response:** The sediment storage capacity (i.e., equilibrium) was determined by USGS in Reed and Hoffman, 1996, based on conveyance equations.
Ex-C-4 Appendix C, P. 23, entire chapter 4	**Original Comment:** How are the scoured sediment and nutrient loads from Lake Clarke and Lake Aldred accounted for? Is it similar to the process for which Conowingo-scoured sediments (and thus nutrients) are superimposed on the WSM nutrient loads input to the WQM as described in Chapter 4 of Appendix C? **Additional Comment:** While author's response is correct, it still does not address the upper reservoir issue directly.	**Original Response:** Sediment loads from Lake Clarke and Aldred are not specifically identified in the Chesapeake Bay loads. The Chesapeake Bay model only "sees" loads at the Conowingo outfall. Loads from Clarke and Aldred are combined with other loading sources at this outfall. The only material superimposed on the WSM loads is scour calculated in Conowingo Reservoir. **Additional Response:** These are considered lumped into the sediment inflow into Conowingo Reservoir, as they are taken from HEC-RAS models of the upper reservoirs, which would include these scour loads.
Ex-C-5 Appendix C, P. 23, para 1	**Original Comment:** "The loads at the head of the reservoir system are supplemented by inputs from the local watersheds immediately adjacent to the reservoirs." It would be useful if there were a figure depicting this either in the main report of this Appendix (or both). **Additional Comment:** It would be useful to the reader to have such a figure.	**Original Response:** A figure such as this one might be included in the main report. This doesn't appear to be a critical deficiency. **Additional Response:** Comment noted. The addition of the figure is not considered critical to the reader's understanding of the modeling effort.

Comment Code	Comment	Comment Response
Ex-C-6 Appendix C, P. 26, para 3	**Original Comment:** Bullet 5 – "For key scenarios, an alternate set of nutrient loads was constructed based on 1996 observed nutrient fraction." These should be included and discussed in the main report. **Additional Comment:** Given the uncertainty of the exact composition of the nutrients, the main report should include discussion about the results from the scenarios which used the alternate nutrient loads.	**Original Response:** The results from these scenarios are reported in the appendix to this report. **Additional Response:** Basic time-series plots were produced for the scenario conducted with loads based on the 1996 sediment nutrient fraction. As noted previously, these are available from the Baltimore District Corps of Engineers. Since this scenario was based on anomalous conditions and was not employed in the study, no further analysis was conducted on this scenario.
Ex-C-10 Appendix C, P. 53, last para	Last paragraph at bottom of page 53 in public draft report, makes a strong case that the Conowingo Dam is still providing WQ benefits. Similar argument at bottom of page 55 in public draft report.	At times, the dam in its present state provides water quality benefits to the bay. In basic terms, the reservoir slowly accumulates organic matter and nutrients that come down the Susquehanna River. The accumulated material is suddenly released during scour events. During intervals of accumulation, the Chesapeake Bay benefits because organic matter and nutrients are retained in the reservoir rather than pouring into the Bay. The benefits are "repaid" however, when the accumulated material is scoured and deposited in the Bay.
Ex-C-11 Appendix C, P. 119, para 1	**Original Comment:** "Model results can be reported with extensive precision, consistent with the precision of the computers on which the models are executed. Despite the precision, model results are inherently uncertain for a host of reasons including uncertain inputs, variance in model parameters, and approximations in model representations of prototype processes." This statement and the rest of this section do a much better job of clearly stating the uncertainties associated with models and model results than the main report does. While the main report does generally acknowledge some model limitations/uncertainties it does not do as good of a job as the Appendices in stating how uncertain some of these results may be. **Additional Comment:** The main report should state as clearly as the Appendix does how uncertain some of these results may be.	**Original Response:** The potential to alter the main report to reflect this section of Appendix C is left to the authors of the main report. **Additional Response:** In the draft report for public review, the suggested text change had been made to Chapter 3, paragraph 2., prior to being released for public review.
Ex-C-13 Appendix C, P. 119-120	The new report should acknowledge that another area of uncertainty is how much of the nutrient load coming from the three reservoir system is due to the Conowingo Pond alone versus a combination of all three reservoirs, since they are all likely to be in some form of dynamic equilibrium. Needs to be addressed with a more refined model of the three reservoirs.	Our study emphasizes the effect of additional material released to the Bay due to the gradual filling of Conowingo Reservoir. Evidence suggests that the reservoir has arrived at or is approaching dynamic equilibrium, and that material that previously accumulated on the bottom is now released to the Bay. In addition, less sediment is able to deposit due to increased velocities resulting from reduced storage capacity. The study also examines potential remediation measures in Conowingo Reservoir. In the long-term, no additional material enters the Bay from the two upper reservoirs. They arrived at dynamic equilibrium decades ago and the influence of these reservoirs is already incorporated into monitoring, modeling and management actions. No remediation measures been proposed or examined for the two upper reservoirs. Consequently, the loads from these reservoirs do not require mention as a source of model uncertainty in Appendix C.

Comment Code	Comment	Comment Response
Ex-D-1 Appendix D, P. 3, paragraph 3	**Original Comment:** The last portion of this paragraph starting with "During the 2017 Midpoint Assessment…" discusses decisions being made regarding any necessary adjustments to the CB TMDL. It should be clearly noted here that Appendix T of the TMDL discusses actions that will be taken in the event that the status of Conowingo Pond changes from previously understood conditions. The language used should be that contained in TMDL Appendix T. **Additional Comment:** To clarify, Appendix T of the TMDL already takes into consideration actions that should be taken if it is found that Conowingo Pond has reached dynamic equilibrium. The TMDL specifically states, "…if future monitoring shows the trapping capacity of the dam is reduced, then EPA would consider adjusting Pennsylvania, Maryland, and New York 2-year milestones loads based on the new delivered loads."	**Original Response:** Appendix T is correctly cited, referenced, and characterized in Appendix D. It's clear from the text what's directly quoted and what's paraphrased. The citation and attribution is entirely correct and changes are unwarranted. **Additional Response:** Appendix T outlines some strategies that could be taken to address sediment build up behind the dam. The referenced text in the comment from Appendix T of the 2010 TMDL documentation is correctly quoted and cited in Appendix D and further text will not be added.
Ex-D-2 Appendix D, P. 21, Figure 5	**Original Comment:** While the differential values are useful, it is helpful for the reader to also list absolute nonattainment values rather than just relative values. **Additional Comment:** We disagree; having absolute nonattainment values is the only way to compare various loading scenarios and time periods. We understand the goal of reducing confusion and improving clarity, but we feel these data need to be provided somewhere for the public to digest. We cannot fully evaluate the modeling scenarios without this critical piece.	**Original Response:** Listing the absolute values for Scenario LSRWA-21 and LSRWA-3 (and explaining why the 1996-1998 period is different from the 1993-1995 period and the reason they're different , etc., etc. would add confusion, not clarity. Adding absolute nonattainment values is unwarranted. **Additional Response:** See response to comment Ex-40.
Ex-D-5 Appendix D, P. 25, Table 3	**Original Comment:** 1) It would be useful to add a row for each of these columns specifically indicating which years are being analyzed for WQ attainment. 2) The nonattainment's should be listed with more significant figures (e.g., 1.4% nonattainment instead of 1% nonattainment) 3) The absolute nonattainment values (e.g., LSRWA-21 had 19% deep channel DO nonattainment in segment CBMH4) should be listed in addition to the relative nonattainment numbers (e.g., an increase of 1% nonattainment over the Base TMDL Scenario (LSRWA-3)) **Additional Comment:** Please see our previous comment (2nd comment, page D-1) [EX-D-2]. We believe it is crucial that absolute nonattainment values are provided somewhere in order for the reader to comprehensively evaluate the model results.	**Original Response:** 1) The text on (example page 18 paragraphs 2 and 3) provides sufficient information on when the 1996-1998 simulation period is used in order to simulate the January 1996 storm. 2) A single significant figure is sufficient and is consistent with the level of significance typically reported in the Chesapeake TMDL. 3) Listing both the absolute value and the base value along with the difference between the base scenario is from the base as suggested would be redundant, confusing, and unwieldy. **Additional Response:** See response to comment Ex-40.

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
Ex-D-6 Appendix D, P. 25-26, Tables 3-5	**Original Comment:** Why aren't LSRWA-22, 26, 27 discussed in these tables? **Additional Comment:** Important to note that only the worst case scenarios are presented in the tables.	**Original Response:** LSRWA-22, 26, and 27 are discussed in the text. **Additional Response:** All relevant findings were presented in the reports text, tables, and figures.
Ex-D-8 Appendix D, P. 31, para 1	**Original Comment:** "During episodic high flow scour events, large nutrient loads are delivered to Chesapeake Bay." The term "scour events" lead the reader to believe that the scour is responsible for all nutrient loads going to the Bay when in fact the vast majority of the loads originate from watershed sources upstream of Conowingo Pond and the Lower Susquehanna Reservoirs. This comment is true of any reference to "scour events" throughout the main report and appendices. **Additional Comment:** As stated in the updated text and pointed out by STAC in their review, DO water quality standards are greatly affected by seasonality; that is, the summer hypoxic period is the season of concern and "a small difference in DO during this period makes a big difference to living resources…" As stated in the Appendix, deep-water and deep-channel DO water quality standards are on a "knife-edge of attainment". STAC went on to say that, "it strikes the reviewers that changes in chlorophyll and dissolved oxygen associated with "normal" inter-annual variability in climate and nutrient loading are much higher than those associated with additional Conowingo Dam-derived nutrients as simulated here."	**Original Response:** The scenarios referred to in the conclusion section separated the loads from the watershed and the scoured loads from the Conowingo by the difference between scenarios as described in the results section. The increase in nonattainment in Deep Water and Deep Channel DO (described in the results and discussed in the conclusions) were specifically because of the scoured nutrients from the Conowingo Reservoir. **Additional Response:** As described previously, the relevant scenario of the watershed implementation plans (WIPs) that are applied to attain Chesapeake water quality standards is done by a difference of the same WIP scenario with Conowingo scour of sediments and nutrients simulated, and the same scenario with Conowingo scour of sediments and nutrients not simulated. The difference between the two scenarios is the estimated water quality nonattainment that is solely attributed to the Conowingo scour.
Ex-D-9 Appendix D, P. 31, para 3	**Original Comment:** The last sentence of this paragraph discusses how the TMDL will account for changes in the trapping capacity of Conowingo Pond as per TMDL Appendix T. When discussing the TMDL and changes in Conowingo Pond trapping capacity throughout this Appendix, and the main report, it is important to always use consistent language from Appendix T in regard to how this will be handled. **Additional Comment:** See first response at beginning of table --- [To clarify, Appendix T of the TMDL already takes into consideration actions that should be taken if it is found that Conowingo Pond has reached dynamic equilibrium. The TMDL specifically states, "…if future monitoring shows the trapping capacity of the dam is reduced, then EPA would consider adjusting Pennsylvania, Maryland, and New York 2-year milestones loads based on the new delivered loads."]	**Original Response:** Appendix T is correctly cited, referenced, and characterized in Appendix D. It's clear from the text what's directly quoted and what's paraphrased. The citation and attribution is entirely correct and changes are unwarranted. **Additional Response:** Text in this paragraph has been changed to exactly quote Appendix T of the TMDL, specifically text in Appendix D, para 3, on p. 31 now reads: ..."then the Chesapeake Bay Program partners will need to consider adjusting the Pennsylvania, Maryland, and New York 2-year milestone loads based on the new delivered loads to ensure that all are meeting their target load obligations."
Ex-E-1 Appendix E, General	**Original Comment:** The bathymetric map does not indicate the elevation datum for the contours. **Additional Comment:** The location map of the first draft (Figure 1) has been replaced with a NOAA bathymetric map. Contours, however, are not legible.	**Original Response:** Contour info added. **Additional Response:** The bathymetric contours are not critical for showing the location of the sample sites. For depth information at the specific sample sites, please consult Table 3, page 8, in Appendix E.

Public Review Comments and Response – October 2014 Draft
Review Period: November 13, 2014 – January 9, 2015

Comment Code	Comment	Comment Response
Ex-E-2 Appendix E, P.2, para 1	The Susquehanna River drainage does not include six states; it includes three states.	In this context, the reference is to the drainage of the Chesapeake Bay which includes six states. No report change is required.
Ex-E-3 Appendix E, P.2, para 1	What is meant by 'increasing' in the sentence: "In addition to an increasing amount of sediments being deposited behind Conowingo Dam in the Conowingo Reservoir, there is an increasing quantity of sediment that is delivered to the Chesapeake Bay by bypassing the dam."? Increasing relative to what?	Replaced 2nd and 3rd sentences in paragraph with "Historically, these dams functioned as sediment traps, reducing the amount of sediments and associated nutrients reaching the Chesapeake Bay. Over time, the trapping efficiency of these dams has diminished as the volume of sediment trapped behind the dams approached storage capacity. As a result, increasingly more sediments bypass the dams and enter into the Chesapeake Bay. There is growing concern that, if not properly managed, the increase in sediment delivery to the Chesapeake Bay will have deleterious effects on the Bay's ecosystem."
Ex-E-4 Appendix E, P.2, para 4	Where were samples #1 and #2 to be located in the Susquehanna River?	Samples 1 and 2 were located in the lower Susquehanna River proper where hard rock was exposed along the river channel. A note indicating that these locations were not actually sampled was added to the Figure 1 caption.
Ex-E-5 Appendix E, P.4, para 3	Please indicate that the Bennett and Lambert method provides wet bulk density values.	"Wet" has been inserted before "Bulk" in first sentence of noted paragraph.
Ex-E-6 Appendix E, P.4, para 4	Remove comma after Kerhin and others.	Comma has been removed from noted location.
Ex-E-7 Appendix E, P.5, para 1, Figures 2-3	Correct citations are Shepard (1954) and Folk (1974), not Shepard's (1954) or Folk's (1974). Remove apostrophe.	Text has been corrected.
Ex-E-8 Appendix E, P.6,last para	Insert period at end of sentence.	Text has been corrected.
Ex-E-9 Appendix E, P. 7,Figure 2	Caption should indicate that the classification is based on percent of sediment size classes in sample. Otherwise the numbers on the tertiary diagram are not explained.	"Sediment type classification is based on relative percentages of each size component (sand, silt and clay)." has been added to Figure 2 caption.
Ex-E-10 Appendix E, P. 7,Figure 3	The sediment type codes in the tertiary diagram should be explained, as per Table 7.	"Sediment type classification is based on relative percentages of each size component (gravel, sand, and mud (i.e., silt plus clay)." has been added to the Figure 3 caption.
Ex-E-11 Appendix E, P. 8, Table 3	The columns labeled #alive and #dead appear to refer to clams. Please note this on table. The footers (#6, #12, #17) are not lined up nor are they clear as to meaning. Please clarify.	Text has been corrected.
Ex-E-12 Appendix E, P. 8, Table 4	Please note that color notations (e.g., 5 YR 3/4) are in accordance with the Munsell color system. "Asian" for sample 7 should be capitalized	"Colors and color codes (e.g. 5 YR 3/4) from the Rock-Color Chart (Rock-Color Chart Committee, 1984)." has been added to the Table 4 caption.

Comment Code	Comment	Comment Response
Ex-E-13 Appendix E, P. 11, Fig. 4	This is a very important graph. It may show up better if printed in landscape view. To help the reader understand this graph, interpretive footnotes may be useful, e.g., the steeper the slope the better the sorting; the 50% mark is the median grain size; etc.	This graph was presented in landscape view in the original file submitted. Minor explanations have been added. Depending on the audience's experience with this type of data, further detailed explanations could be rather lengthy.
Ex-E-14 Appendix E, P. 14, Tab. 7	Please note that bulk density is wet bulk density.	Text has been corrected.
Ex-F-1 Appendix F, General	**Original Comment:** Cover letter states "samples were collected along a representative cross-section from the catwalk on Conowingo Dam…" Conowingo Dam catwalk sampling is not representative of the channel cross-section at the dam. **Additional Comment:** The reader of this letter may take the originally commented upon statement as meaning the data collected are representative of the river at the dam. In a published document prepared by USGS it is noted these data are only representative of the river in front of the turbines. That is, in the USGS Quality-Assurance Project Plan (QAPP) for the Maryland River Input Monitoring Program and Nontidal Network Stations for the period July 1, 2013 to June 30, 2014 (Updated July 2013) available at: http://www.chesapeakebay.net/documents/MD_RIM_QAPP_2013_2014.pdf it is written: "Previous testing at Conowingo Dam has shown that this approach provides a representative sample for flows confined to the turbines. However, sampling from the turbines can be unrepresentative of spillway discharges since the flows originate from different locations in the reservoir's vertical profile." The Introduction of this Appendix should include the same language.	**Original Response:** The data transmittal letter dated February 10, 2012, represents an accurate assessment of the relation between catwalk and cross- sectional variability, given the analysis of available historical USGS quality control **Additional Response:** The sample-collection methods are an assessment of representativeness based on historical analyses. The QAPP notes that the turbines can be unrepresentative. However, these differences were not observed in a previous study comparing catwalk and spillway samples.
Ex-F-2 Appendix F, General	**Original Comment:** A brief report to accompany the data would be useful (in addition to the cover letter provided). The report could highlight the sampling methods used, field conditions, hydrograph, sampling comments/notes, etc. In its current form, the Appendix does not provide the reader with very many details about the sampling event(s). **Additional Comment:** While it is understood that a brief report goes beyond the time and funding constraints of this effort, a more detailed Introduction providing a general overview of the sampling methods, field conditions, hydrograph, sampling notes/comments, etc. would be helpful to the reader to put the data collected into context.	**Original Response:** The data were collected using standard methods for the site as outlined in the QAPP on file with EPA CBPO. Streamflow records for the periods represented by these samples as well as the analytical results themselves are publically available at http://waterdata.usgs.gov. Limited time and funds availability precluded the preparation of a separate report detailing these data. **Additional Response:** The most important piece of information for context of the sediment data provided is Instantaneous discharge presented in Table 6. In 2010 and 2011, these analyses were performed on samples collected at streamflows ranging from 233,000 to 617,000 cubic feet per second.
Ex-F-3 Appendix F, General	The sampling does not appear to take into account the travel time of the water and sediment through the reservoir system during a storm event. It would be useful if the author could provide comment on what effects this may have on the use of the data and any subsequent results/conclusions.	The sampling was conducted to measure the Susquehanna River at the Conowingo Dam. No consideration was given to reservoir travel time in determining when to sample.

Comment Code	Comment	Comment Response
Ex-I-1 Appendix I-7, General	In response to STAC comments pertaining to the AdH model, there are multiple references to “Response under development by ERDC AdH modeler” yet no response is actually provided. Please provide a response for each of these instances.	Responses have now been finalized and will be included in the final document.
Ex-I-2 Appendix I-7, P. 17	The graph in Appendix A (Figure 7) does not appear to have been updated as indicated.	Figure 7 is the sediment-transport curve for Conowingo, no "updates" were ever needed on this graph.
Ex-I-3 Appendix I-7, P. 28	The notes to Figure 1-6 (Main Report) do not appear to have been changed as indicated.	In the October 2014 public draft report (Figure 1-6, page 18), the third note which contained the commented language was removed from the text.
Ex-I-4 Appendix I-7, P. 29	The definition of saprolite does not appear to have been added as indicated.	In the October 2014 public draft report (Appendix K, page 11), a definition of saprolite was provided in parentheses at the appropriate location in Appendix K. The term "saprolite" does not appear in the October 2014 main report. Definition of saprolite has been changed slightly. Parenthetical expression on page 12, paragraph 2, 1st sentence (May 2015 version), was changed to "(decomposed rock that has weathered in place)".
Ex-I-5 Appendix I-7, P. 29	The deletion of ‘river’ does not appear to have been made as indicated (now in Appendix K).	The commenter is correct. Change was made to Appendix K on page 11, line 5 ("natural variations ....").
Ex-J-1 Appendix J, Attachment J-1, Page 2, para 2	**Original Comment:** The implication that sediment plumes as represented by TS Lee in Figure 3 are due to scour from Conowingo Reservoir is incorrect. As noted in the main report, these plumes are predominantly comprised of sediment from the watershed upstream of Conowingo Reservoir. **Additional Comment:** Please make “dam” plural. That is, change to: “…from scour behind the dams.”	**Original Response:** Page 2, paragraph 2 – change the last sentence to “The massive plume of sediment that occurred following Tropical Storm Lee extended from the Conowingo Dam past the mouth of the Patuxent River (Figure 3) and originated both from the watershed and from scour behind the dam.”, with the majority of the sediment coming from the watershed. **Additional Response:** Text has been changed as noted.
Ex-J-3 Appendix J, Attachment J-4, Page 1, Table	**Original Comment:** It is not clear what reservoir bathymetry/trapping efficiency means. If it is simply referring to trapping efficiency, then it should be stated as such. The actual trapping efficiencies should be listed as well (e.g., 55%) rather than just a level associated with a time period. **Additional Comment:** It would be useful to the reader to have the trapping efficiency explicitly listed for each scenario. Please see our example matrix provided as an attachment to our cover letter.	**Original Response:** For scenarios 2-6 the input parameter is actual reservoir bathymetry per AdH. The exception is Scenario 1, which did not use AdH but was the TMDL/WSM only run which considered trapping rates/efficiency of the 1990s (which was around 55%). What is most important is what era is represented in the simulation which is depicted. **Additional Response:** Comment noted; however, we believe the information is available in the main document (e.g. Table 4-6) and the appendices, so no change will be made to the text.

Comment Code	Comment	Comment Response
Ex-J-5 Appendix J, Attachment J-4, P. 1/7/8, Table	**Original Comment:** The DO nonattainment's should be listed by segment (similar to pieces from the stoplight plots), and must be listed as absolute numbers as opposed to differentials from other runs, as it becomes confusing for the reader to follow which runs are being compared to other runs. Also, the nonattainment's should carry an additional significant figure (e.g., 1.4% instead of 1%). **Additional Comment:** As noted in some Appendix D comments, we believe listing absolute nonattainment values by segment would be useful. We also understand that providing the data in this report may be difficult. We are interested in the absolute nonattainment values if there is another way for them to be provided.	**Original Response:** Organizing nonattainment by segment does not work in the format of the table. As comment states Appendix D stoplight plots organizes by segment if reader wants to view it this way. Listing the absolute nonattainment values is unwarranted. Significant figures will remain as we received comments earlier on that that amount of precision was not conducive. **Additional Response:** See response to comment Ex-40.
Ex-K-1 Appendix K, P. 1, para 1	**Original Comment:** While the last portion of this paragraph describes why the discussion is focused on Conowingo it does not explain why there is no focus on the two upstream reservoirs. Why are these reservoirs not discussed at the same level of detail as Conowingo? **Additional Comment:** To be consistent, the report should acknowledge that Holtwood and Safe Harbor are in "dynamic equilibrium" The revised text still does not quantify or adequately describe how much more important Conowingo Pond loads are to Susquehanna River sediment loads versus loads from Lake Clarke or Lake Aldred. In general, throughout the report and appendices a satisfactory reason has not been given as to why so much more importance has been placed on Conowingo Pond scour as opposed to scour from Lake Clarke and Lake Aldred.	**Original Response:** Modify sentence "As such, it has potentially a large influence on the Chesapeake Bay during storm events due to scouring of nutrients and sediments stored behind this dam." to "Holtwood and Safe Harbor Dams were known to be at equilibrium at the start of this assessment. Because Conowingo was not believed to be in dynamic equilibrium and it reaching that condition could have a potentially large effect on the Bay, more attention is focused on Conowingo Dam than Holtwood or Safe Harbor Dams in this section." **Additional Response:** Concur with consistently using term "dynamic equilibrium." Noted sentence in the original response has been revised with the insertion of the word "dynamic" before "equilibrium". While it would ideally have been useful in retrospect to have also included detailed consideration of processes occurring in dynamic state in upper reservoirs, that was not the context of concern that propelled study and was effectively beyond study scope. It is likely that having done so would not change findings of the study, although it could provide additional detailed consideration of processes occurring within those reservoirs while in dynamic equilibrium condition.
Ex-K-2 Appendix K, P. 1, para 1	**Original Comment:** This paragraph, and the third paragraph in particular, attempt to explain why Conowingo Pond is of particular importance; however, they do not quantify or adequately describe how much more important it is to Susquehanna River sediment loads versus Lake Clarke and Lake Aldred. **Additional Comment:** It is hard to follow why believing Lake Clarke and Lake Aldred are in dynamic equilibrium means that they are not capable of having an equally important impact on Bay health. We understand that the initial focus was on Conowingo because it appeared to be fundamentally different (larger in size, trapping more) than the other two reservoirs, but now that we understand that all three reservoirs have reached dynamic equilibrium, we feel that future efforts should be more evenhanded between all three impoundments.	**Original Response:** Dealt with by response to #35. **Additional Response:** The LSRWA report has no recommendations for any management measures in Conowingo Reservoir. Because dynamic equilibrium processes would presumably be comparable in upstream reservoirs, it is unlikely that any management measures would have been recommended for implementation had they been studied.

Comment Code	Comment	Comment Response
Ex-K-3 Appendix K, P. 5, para 4	**Original Comment:** The report identifies that climate change has resulted in recent years being wetter. In general, wetter years would mean increased watershed sediment delivery and transport through the reservoirs. This potentially conflicts with the conclusion that loads are increasing as a consequence of reduced trapping/dynamic equilibrium. It is unclear how earlier statements regarding decreases in trapping can be evaluated without first establishing how hydrologic (and land use) changes impact the watershed the river system. **Additional Comment:** The original comment is still valid. The revision does not address the fact that conclusions are made that focus on sediment transport within Conowingo Reservoir without also noting that watershed changes and responses to climate also contribute to changes in sediment and nutrient delivery to the Bay.	**Original Response:** Added sentence to paragraph 2 on page 97, before "All of the Table 4-1 scenarios…" "However, there were no modeling runs formulated for forecasted climate change conditions; a general discussion of global climate change impacts can be found in Section 5.1.4." **Additional Response:** Text has been changed in Section 4.1.4 of the main report and now addresses implications for changes in sediment and nutrient transport. No change has been made to Appendix K as the paragraph in Appendix K references Chapter 4.1.4 of the main report.
Ex-K-4 Appendix K, P. 11, para 3	**Original Comment:** The Exelon study cited (RSP 3.12) does not mention contributions to vertical circulation in the reservoir. **Additional Comment:** The corrected citation should be for the final report which is 2012, not 2011. A similar citation change was made at the end of the 2nd preceding paragraph (page 11). That change was incorrect. At the end of the first paragraph on page 11 of Appendix K the citation should be URS and Gomez & Sullivan (2012a).	**Original Response:** Citation corrected to "(Normandeau Associates and GSE, 2011)" -- see comment response #48 for citation details. **Additional Response:** Citations have been corrected.
Ex-K-5 Appendix K, P. 16, para 4	**Original Comment:** Statement that nutrients released from bottom sediments provide a substantial portion of the nutrients required by phytoplankton is perhaps a little simplified. First, as noted, vertical stratification limits the vertical exchange of dissolved oxygen between the surface and bottom waters (as pointed out on page 34 paragraph 4) and, therefore, the vertical exchange of bottom water nutrients to surface waters is also limited. In addition, as pointed out in paragraph 3 of page 33, nutrients are recycled and reused many times over as they move downstream in rivers towards the Bay. They are also recycled and re-used in the Bay as well. Bottom nutrients are likely to contribute to the production of surface phytoplankton, but it is not clear what the balance between surface recycling of nutrients and bottom release of nutrients is in determining algal productivity. **Additional Comment:** Suggest adding "could" as shown in red " Nutrients contained in Bay bottom sediments are re-released into the water column seasonally, and these regenerated nutrients could provide a substantial portion of the nutrients required by phytoplankton, particularly in the middle Bay. "	**Original Response:** Concur that complicated topic, so will further simplify/generalize. Change "Nutrients contained in Bay bottom sediments are re-released into the water column seasonally, and these regenerated nutrients provide a substantial portion of the nutrients required by phytoplankton in summer, particularly in the middle Bay. " to "Nutrients contained in Bay bottom sediments are re-released into the water column seasonally, and these regenerated nutrients provide a substantial portion of the nutrients required by phytoplankton, particularly in the middle Bay. " **Additional Response:** Text has been changed as suggested, with the addition of "could."

Comment Code	Comment	Comment Response
Ex-K-6 Appendix K, P. 18, para 3	**Original Comment:** “Monitoring of nutrients in the Susquehanna River has shown that the flow-adjusted annual concentrations of total nitrogen, total phosphorus, and suspended sediment delivered to the dams have been generally decreasing since the mid-1980s.” It is unclear how much of any trends are due to increasing data density over time and reduced uncertainty. There may be some apples and oranges comparisons beneath everything. As stated in the Zhang et al. (2013) paper, there is interpolation and extrapolation in load estimates. The next statements that “This decrease is attributed to the success of environmental management measures. However, total nitrogen, total phosphorus, and suspended sediment loads from Conowingo Reservoir itself to the Chesapeake Bay have shown an increasing trend since the mid-1990s, indicating decreasing reservoir trapping capacity (Zhang et al., 2013)” need further evaluation. Changes in sediment export from the River could also include changing sediment delivery from the watershed. It is unclear how the data analysis on which these statements rely was performed **Additional Comment:** Original comment is still valid.	**Original Response:** Change middle sentence from "This decrease is attributed to the success of environmental management measures." to "Environmental management measures in the watershed contributed to this decrease." to be less precise over relative importance of management measures versus other causes. **Additional Response:** Original sentence stating that monitoring has shown decreases includes word "generally" to imply that there are bumps/uncertainties. While nutrient and sediment loads from the river channels versus the watershed should be elucidated to determine appropriate BMPs, that difference is subtle compared to the overarching concern that incentivized the study, that is, the Conowingo Reservoir filling to capacity and potential management measures in the reservoir itself.
Ex-K-7 Appendix K, P. 18, para 3	**Original Comment:** Zhang et al (2013) refers specifically to the reservoir system (reservoirs plural) and loads from the Conowingo Dam outlet. To quote from their conclusions: “Flow-normalized loads of SS, PP, and PN at the outlet of the Conowingo Reservoir have been generally rising since the mid-1990s. The reservoirs' capacity to trap these materials has been diminishing, and the Conowingo Reservoir has neared its sediment storage capacity.” **Additional Comment:** The revised statement still does not reflect the cited Zhang et al 2013 appropriately. Suggested edits are shown in red (page 18 of Appendix K): "One study has indicated that loads of total particulate nitrogen, total particulate phosphorus, and suspended sediment from the reservoir system of the lower dams to the Chesapeake Bay are increasing and attributes this, in part, to decreasing trapping capacity of Conowingo Reservoir (Zhang et al., 2013)." Furthermore, the actual statement from Zhang is “Flow-normalized loads of SS, PP, and PN at the outlet of the Conowingo Reservoir have been generally rising since the mid-1990s. The reservoirs' capacity to trap these materials has been diminishing, and the Conowingo Reservoir has neared its sediment storage capacity.” Zhang says reservoirs (plural).	**Original Response:** Change last sentence in paragraph (already recently revised as per above) from "One study has indicated that loads of total nitrogen, total phosphorus, and suspended sediment from Conowingo Reservoir to the Chesapeake Bay are increasing and attributes this to decreasing reservoir trapping capacity (Zhang et al., 2013)." to "One study has indicated that loads of total nitrogen, total phosphorus, and suspended sediment from the reservoir system of the lower dams to the Chesapeake Bay are increasing and attributes this to decreasing trapping capacity of Conowingo Reservoir (Zhang et al., 2013)." **Additional Response:** While Zhang may state plural reservoirs at the end of the sentence, the paradigm in place at the start of the study was that upper reservoirs were in dynamic equilibrium for decades, thus they are part of the trend condition already in place. Conversely, changes in Conowingo Reservoir are recent/ongoing and are of concern as they could produce greatest changes in Bay. The study findings from Zhang and others' (2013) are not universally accepted yet. The text in Appendix K has been revised to: "One study has indicated that loads of total particulate nitrogen, total particulate phosphorus, and suspended sediment from the reservoir system of the lower dams to the Chesapeake Bay are increasing and attributes this, in part, to decreasing trapping capacity of Conowingo Reservoir (Zhang et al., 2013)."

Comment Code	Comment	Comment Response
Ex-K-8 Appendix K, P. 22, para 4	**Original Comment:** The citation to Exelon (2011) regarding DO in the reservoir is not the 2011 report in the References section. The 2011 Exelon study RSP 3.1 should be cited for this statement. **Additional Comment:** Please cite the final report which is 2012, not 2011.	**Original Response:** Changed citation to (Normandeau Associates and GSE, 2011). Added reference but used the format that Exelon requested in comment #1. New reference = Normandeau Associates, Inc., and Gomez and Sullivan Engineers. 2011. *Seasonal and Diurnal Water Quality in Conowingo Pond and below Conowingo Dam* (RSP 3.1). Kennett Square, PA: Exelon Generation, LLC. **Additional Response:** Citation has been changed as noted.
Ex-K-9 Appendix K, P. 26, para 1	**Original Comment:** The report cites Hartwell and Hameedi (2007) for the proposition that "[t]idal portions of the Anacostia River, Baltimore Harbor, and the Elizabeth River are hotspot areas of contaminants." However, Hartwell and Hameedi (2007) does not mention the Anacostia River, and the figure with the sites of greatest contamination does not include the Anacostia. **Additional Comment:** Hartwell and Hameedi (2007) needs to be removed from the reference section in the main report.	**Original Response:** Change reference to instead be "CBP, 2013" (That these are the three "hottest" contaminated regions of Bay is widely reported and not dependent upon an individual report.) **Additional Response:** The Hartwell and Hameedi (2007) reference has been removed from the list of references in the main report.
Ex-K-13 Appendix K, P. 29, para 7	**Original Comment:** The report does not appear to discuss the potential impacts that the particulate coal may have on collected data or model predictions, nor whether it is uncommon to have an 11-percent coal content. **Additional Comment:** The importance of coal content is not the effect of future transport to the Bay, but how its presence may influence chemical measurements of sediments.	**Original Response:** Unlikely that additional future coal to be transported into Bay from sediment behind the dams would have much effect on the Bay. The upper Bay already contains substantial coal as was stated in Section 2.6, and has for probably more than a century. Evaluating effects of additional coal input is one of many specific topics that were not evaluated in this assessment. An environmental impact statement covering any proposed project would be the appropriate place to specifically address this. However, we should change existing sentence on p. 38, 2nd paragraph in "Bay Bottom Materials and Processes" subsection from "Abundant coal occurs in Susquehanna Flats sediments (Robertson, 1998)." To "Abundant coal occurs in Susquehanna Flats sediments transported into the Bay from coal mining in the Susquehanna Basin (Robertson, 1998)." This would better clarify source and timing of coal deliveries to the Bay (coal mining having begun in earnest in Basin by early 1800s). (On side note, I skimmed MGS [1988] and Robertson [1998], but neither of these provides specific information on how much coal occurs in Bay's flats sediments, other than to state that it's abundant in certain strata near the surface.) **Additional Response:** The presence of coal and its impact on chemical analyses of the sediment are unimportant in light of the report's no recommended action. In the future, if dredging or other action is recommended, further investigation of coal in sediment may be appropriate.
Ex-K-14 Appendix K, P. 29/30, para 7/1	**Original Comment:** Focus is only on Conowingo: what about the other reservoirs? **Additional Comment:** See Exelon comment to first two rows of this table on page 1 [Ex-K-1 and Ex-K-2]	**Original Response:** See Comment #35. **Additional Response:** Some limited attention to sediment behind upper two reservoirs is provided on p. 28. In the context of this assessment, it was appropriate to focus more attention on Conowingo Reservoir than the upper two reservoirs.

Comment Code	Comment	Comment Response
Ex-K-16 Appendix K, P. 38, para 1	**Original Comment:** The first sentence states that "no SAV beds were mapped immediately below Conowingo Dam in the non-tidal and tidal Susquehanna River over the period 1997-2012." Exelon RSP 3.17 mapped SAV at the mouth of Octoraro Creek and at the island complex at near the mouth of Deer Creek (Robert, Wood, and Spencer Islands) and at Steel Island along the opposite bank in 2010 surveys. **Additional Comment:** SAV was found to occur in 2010 downstream of Conowingo Dam at creek mouths and islands between the dam and Port Deposit in shallow areas with coarser-grained sediment (sand and cobble) near sources of sediment supply and reduced flow velocities (tributary mouths and a protected island complex) (URS and GSE , 2012c). Study 3.17 should be cited with the final report year (2012). Thus, in the references section it should become 2012c.	**Original Response:** Change paragraph "No SAV beds were mapped immediately below the Conowingo Dam in the non-tidal and tidal Susquehanna River over the period 1997-2012. However, SAV was frequently mapped in the non-tidal and tidal river downstream to the river mouth from the 1990s through 2010 (VIMS, 2013)." to "VIMS mapped no SAV beds immediately below the Conowingo Dam in the non- tidal and tidal Susquehanna River over the period 1997-2012. However, VIMS frequently mapped SAV in the non-tidal and tidal river downstream to the river mouth from the 1990s through 2010 (VIMS, 2013). SAV was found to occur in 2010 downstream of Conowingo Dam at creek mouths and islands between the dam and Port Deposit in shallow areas with fine-grained sediment and low water velocities (URS and GSE , 2011). **Additional Response:** Last sentence of paragraph 1, page 38 (October 2014 version, now page K-34, 4th paragraph), has been revised as suggested. Reference was changed as noted in the response to comment Ex-1.

Lower Susquehanna River Watershed Assessment
Public Meeting * December 9, 2014
Questions/Comments

Questions received via Webcast:

1. I believe the concern regarding the Conowingo Dam is whether or not the loss of sediment storage capacity will contribute to the recurrence of Hurricane Agnes type ecological impacts on the Lower Susquehanna Watershed. The base weather period you used in your study did not include years and time periods of extreme weather, such as Hurricane Agnes. The TMDL and the model that is used to develop the TMDL, looks at broad average, longer-term impacts, not those from very short-term extreme events. So the question remains: Is a Hurricane Agnes, with excessive delivery of sediment that essentially buries subaquatic vegetation, now more likely to occur or not and, if so, what are we going to do about it, if anything?

2. Isn't the lower Chesapeake Bay starved for coarse grain sediment as a consequence in part of the dams on the rivers? If so, isn't there a benefit that should be considered of transporting some of this coarse grain sediment to where it is needed for ecological restoration or rehabilitation?

3. Will in-situ technology for denitrification be evaluated for managing the increases in nitrogen loadings to the Bay?

4. If the runoff from my driveway makes a big difference, what plans are in effect to control runoff from business lots and our highways?

5. Did the cost analysis for sediment removal consider the ongoing cost for sediment removal in the navigation channels downstream?

6. Will the economic benefit to the use of dredged sediments to replace wetlands being lost as a result of sea level rise?

7. What specifically is the reason for not granting the license to Exelon today? I understood their license ended in September.

8. Someone stated that whether or not sediment from scour is good or bad depends upon when the scoring event occurs. Lee was late in the year. Agnes early. Have you examined the possibility of controlled, intentional scours at times of the year when adverse impacts are less likely to occur?

9. When Exelon was initially granted the original license were they required to do silt removal? If not, what changed to even discuss the issue with them rather than requiring those up river to be responsible parties and leave Exelon to generate power.

Questions received in-person:

1. The report asserts the nutrients associated with sediments have more of an adverse impact than the sediments themselves and that there may be more cost effective means than restoring the Conowingo storage volume to prevent these nutrients from reaching the Bay. Did the study quantify the nutrient offsets required and identify options and costs for achieving these offsets?

2. Once the WIPs are in place and fully effective, now many tons per year of nitrogen and phosphorus associated with the sediments are needed to offset the dynamic equilibrium state?

3. Besides evaluating the impact of sedimentation on the indicators of dissolved oxygen, light attenuation and chlorophyll concentrations, did the study identify the environmental and cost benefits that a reduced sedimentation rate would have on other parameters such as dredging the shipping channels, restoring the oyster population, and sustaining recreational activities?

4. What are the panel's thoughts that the draft report is already influencing some Maryland politicians and policy makes to make the case of why should their jurisdictions be required to control nonpoint source sediments and nutrients since they won't be controlled beyond the WIPs in place form the very large areas of New York and Pennsylvania?

5. The Susquehanna River Basin Commission has studied the sediments from the floor of the Conowingo Pond and reported to MDE (the Maryland Department of the Environment) that such sediments contain PCBs (polychlorinated biphenlys), pesticides and herbicides, phosphorus and nitrogen, and acid mine drainage (AMD) that contained sulfides. Does the Draft LSRWA take into account the impact of such components of scored sediments on the aquatic life in the Bay? If so, how does the report account for the impact of such components on the aquatic life in the Bay? If not, why were such impacts not considered? Does the Draft LKSRWA take into account the impact of such components of scored sediments on the SAV (submerged aquatic vegetation) in the Bay? If so, how does the report account for the impact of such components on the SAV in the Bay? If not, why were such impacts not considered?

6. USGS reports that a flow event greater than or equal to 800 cfs (cubic feet per second) will occur once every 25 years and the last time such a flow event occurred was in 2011 (Tropical Storm Lee). Appendix A at page 41; Draft LSRWA Report page 71. USGS estimates that the scour from the floor of the Conowingo Pond during such a flow event is between 4 and 20 million tons of sediment. Exelon has requested a 46 year permit from FERC (the Federal Energy Regulatory Commission), so such a storm event is predicted to occur twice during the life of the renewal period. Why does the Draft LSRWA not take into account the scour that will occur during such a storm event? What accounts for the large range or predicted scour? What impact will such a scour event have on fisheries habitat and which fisheries would be impacted? What impact will such a scour event have on SAV habitat and how was such impact determined?

7. USGS reports that a flow event greater than or equal to 1 million cfs (cubic feet per second) will occur once every 60 years and the last time such a flow event occurred was in 1972 (Hurricane Agnes). Appendix A at page 41. USGS estimates that the scour from the floor of the Conowingo Pond during such a flow event is between 10 and 31 million tons of sediment. Exelon has requested a 46 year permit from FERC (the Federal Energy Regulatory Commission), so such a storm event is predicted to occur during the life of the renewal period. Why does the Draft

LSRWA not take into account the scour that will occur during such a storm event? What accounts for the large range or predicted scour? What impact will such a scour event have on fisheries habitat and which fisheries would be impacted? What impact will such a scour event have on SAV habitat and how was such impact determined?

8. Does the Draft LSRWA account for sediments that are scoured from the floor of Lake Aldred and Lake Clark during storm events and already are in suspension in the river when it flows into the Conowingo Pond? If so, how does the Draft LSRWA account for such scoured sediments and what appendix references the data used to determine the quantity of such scour and how such scour varies with the rate of flow across those lakes during storm events?

9. How if at all do the models used in the Draft LSRWA predict scour from the floors of the Conowingo Pond, Lake Aldred, and Lake Clark and account for scour that occurs from the circular flow and agitation that occurs when storm surges hit the Conowingo, Holtwood and Safe Harbor Dams and are turned back. How many cfs (cubic feet per second) can flow through the sluiceway at each dam? How many cfs can flow through each gate at each dam? How many gates are at each dam? During what storm events has water flowed over each dam?

10. EPA studies show that phosphorus that is bound to sediments in a fresh water river estuary and is therefore not available to spawn algae blooms is released into the water and is available to spawn algae blooms when such sediments are transported into a slightly saline, warmer and more acidic bay or delta estuary. Does the LSRWA account for the impact of the release of phosphorus bound to sediments that are scoured from the floor of the Conowingo Pond and if so what percentage or quantity of phosphorus is attributed to phosphorus bound to sediments prior to passing through or over the Conowingo Dam and being release in the Bay estuary.

11. Is a Hurricane Agnes (with excessive delivery of sediment that buries subaquatic vegetation) now more likely to occur or not? And if so what are we going to do about it, if anything?

12. A lifetime ago, when the dam was built, what historically, if indeed anything, was said about sediment or other environmental impacts, their costs, how they would be dealt with or the like? Is this the missing discussion we now need to have?

13. If one percent of the value of the electricity produced by the dam since it was built was spent on preventing sediment scouring or fish kills, what would that number of dollars be? How much to date for that sort of thing has been spent?

14. If Conowingo Dam was not there would it make a difference in the amount of sediment in the Bay? Has an extensive study been done assessing the storms that pass down from NY and PA? How much sediment?

15. All of the discussion has focused on Conowingo Dam. What about Holtwood Dam and Safe Harbor Dam? It seems that the study recommendations are equally applicable to those dams as well.

16. What are the costs for achieving/implementing enough BMPs in the watershed to make a difference? Is this even feasible?

17. How does this report impact the dam relicensing?

18. Is non-renewal of operating license being considered as a possible measure to be taken?

19. I am an avid fisherman, boater and wildlife photographer. I fully support relicensing the Conowingo Dam and its form of renewable green energy. (The dam is not a source.) What can I do as a Maryland resident to support the restriction on sources of nutrient and sediment into the Chesapeake Bay watershed?

20. Do we know what sources of nutrients are largest contributors?

21. We seem to have a handle on the nutrient load that is impacting the Chesapeake. Given the reforestation recommendation in particular as it contributes to best practices, do we have an estimate for the approximate acreage that would need to be reforested? How achievable would that be?

22. Recommendation: In the Executive summary (page ES-4) sediment is quantified as cubic yards. Elsewhere in the report, those sections describing TMDL, sediment is quantified as tons. Recommend that any cubic yard figures be also shown as tons.

23. Has there been any analysis or data collection into the impact of the Vulcan Materials Quarry in Harve de Grace on upper Bay water quality?

24. All dams have a lifespan, what happens to the sediment behind the dam when the dam reaches the end of its useful life? Who pays for it?

25. The Assessment concludes that it is not cost effective to dredge the sediment. It shifts the solution and the costs upstream. In doing so, it shifts the burden from a few big players, Feds, States, etc. to small jurisdictions. Will sufficient funding be made available to the townships in PA and similar jurisdictions in NY to get the job done?

26. How are TMDLs enforced? What will it take to strengthen them - i.e. what is the approval process?

27. There's a great deal of talk about sediment with Conowingo Dam. Are there other ecological impacts associated with the dam that we should be concerned about? If so, what can be done to reduce those impacts?

28. Bruce Michael (DNR) stated that Appendix T of the 2010 TMDLs in the 2010 TMDL anticipated the source trapped behind the Dam. Isn't it true that Appendix T actually showed a sink or trapping of TMDLs? And not a source?

29. For Mike Langland (USGS) – The HEC-RAS model is one dimensional. How is this model different from the HEC-6 model, also one dimensional? How is scour accounted for in these one dimensional models? Do you feel comfortable with the scour estimates from those models?

30. What would conditions be like if the Dam had never been built? How would impacts change if the Dam were removed?

31. A recent scientific editorial in *NY Times* advocated for removing Conowingo Dam and replacing it with smaller hydroelectric and other green energy systems. Dam removal is gaining ground in the US. The ecological benefits to the Susquehanna River and especially Chesapeake Bay would be transformative. Thoughts?

32. Is the 2 year period of enhanced monitoring of sufficient duration to provide meaningful input to the 2017 model adjustment?

33. In the Executive Summary it seems that “management strategies for reducing sediment from the Susquehanna watershed beyond the WIPs” are not given much consideration, but in the analysis of sources of sediment, the watershed contributions are assessed to be the source of the majority of the sediment load. Doesn’t it make sense to target reductions to the main source, rather than secondary sources?

34. We have been doing BMP’s “at the source” for decades, yet your graph shows phosphorus levels continue to rise. What makes you think additional BMPs will help cut down that 87% sediment load?

35. We are increasing TMDLs based on information found in this study and the volume of sediments found behind the Dam. Will we increase TMDLs in other systems with large dams or series of smaller dams?

36. I’m wondering if you can help put the slide on “estimated sediment load” (the pie chart with 87% - 13% split between Susquehanna watershed and Conowingo reservoir) into perspective. Am I correct that Conowingo’s 13% contribution is 13% of Susquehanna load, not 13% of total load flowing into the Bay from all sources? How significant is Conowingo’s sediment/nutrient contributing seen from the perspective of total loads into the Bay?

37. To what extent has Maryland reached its goals for TMDL? Is there anything we citizens can do politically to help move us toward our goals?

38. Is sediment the only carrier of nutrients? If not, why is sediment only mentioned in the report?

Comments: General Public (5 Individuals, Received via email)

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Commenter Code E.4

Thank you for providing an opportunity to comment on this important report. I attended the December 9 public meeting and have reviewed the LSRWA Draft Report. I believe that the relicensing of the Conowingo Dam Hydroelectric Generating Station presents a unique opportunity to improve the health of Chesapeake Bay.

The legacy sediments behind Conowingo Dam contain nutrients and toxins that otherwise would have entered Chesapeake Bay. What needs to happen now is to remove them. This will reduce scour of the legacy sediments into the Bay during storm events and restore capacity to trap new sediments behind the dam.

Removal of legacy sediments upstream is an important strategy for protecting and improving the water quality of Chesapeake Bay. This effort should be undertaken not solely by the state of Maryland but with support from all of the states in the Susquehanna River watershed. Maryland governor-elect Larry Hogan explained the importance of this approach during his campaign and I believe this strategy should be incorporated into the relicensing of Conowingo Dam.

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Commenter Code E.2

One of the main findings of the report was that the nutrients associated with the sediments were more harmful to the Bay than the sediment itself. However, the report is unclear as to the effectiveness of dredging on reducing the sediment load to the Bay.

There are numerous locations that discuss returning the bathymetry to 1996 levels etc. (for example Table 4-4) but it is not made clear just exactly how much sediment is estimated to be prevented from entering the Bay for each ton of sediment removed from the reservoir. This analysis should include taking the levels back to 1996 and beyond. It should also incorporate the value of strategic dredging to address high deposition areas and targeting removal of the fines (more likely transported).

My company, HarborRock, is able to use the fines to make its product and leave the sand fraction in place – a benefit to lowering the scour rate. Reuse is the only option that is sustainable but the report does not clearly articulate or evaluate the long-term value of long-term dredging. We believe the information is within the various appendices etc. but is not being presented with enough transparency to make an informed decision on the value (nutrient reduction) obtained by dredging.

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Commenter Code E.1

Is it true that most of the sediment behind the Dam has already blown through the Shoot-Gates every time they are OPENED during Flooding??? Is there not very much Sediment in BACK of the DAM now?? ? How about behind the other UPSTREAM Dams??? Do we need another DAM built down-stream of Conowingo...prior to the BAY??? HELP Save the BAY.

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Commenter Code E.5.1 to E.5.3

Comment #1

The report asserts the nutrients associated with sediments have more of an adverse impact than the sediments themselves and that there may be more cost effective means than restoring the Conowingo storage volume to prevent these nutrients from reaching the Bay. It is suggested that in updating the draft study that it be made clear that the study did not quantify the nutrient offsets required nor recommend options and costs for achieving the offsets. It is also suggested that it be made clear that the study does not rule out dredging from behind the dam as an option in future studies.

The draft study indicates with the WIPs in full effect (Table 4-9, page 82, Scenario 2) the nutrient load associated with the sediments will be 50.8 tons per day of nitrogen and 4.2 tons per day of phosphorus. These are very large loads. To put them in perspective, if we looked to the 173 wastewater treatment plants in Pennsylvania that are in the watershed to contribute to the nitrogen offset, the most they could provide would be 5 million pounds per year, or 6.85 tons per day. The Phase II WIP already counts on these treatment plants removing nitrogen to achieve effluent concentrations of 6 mg/L to achieve their annual nitrogen wasteload allocation of approximately 10 million pounds. Upgrading these wastewater treatment plants to the limit of technology to achieve 3 mg/L will provide 5 million pounds per year offset. Treating to the limit of technology is a strategy being employed at Maryland’s major wastewater treatment plants to achieve a comparable amount of nitrogen removal and the capital costs are in excess of $1 billion. Thus, a very considerable expenditure would be required to remove only 6.85 tons per day using this strategy. It may be that increasing the storage volume is found to be the most cost effective option after all.

Comment #2

In evaluating the impact of sedimentation on the indicators of dissolved oxygen, light attenuation and chlorophyll concentration, the study did not identify the environmental and cost benefits that a reduced sedimentation rate would have on other parameters such as dredging the shipping channels, restoring the oyster population and recreational activities.

While the Chesapeake is a national resource, we as Marylanders at the downstream end of the watershed have the most at stake in having a healthy Bay, because it largely defines who we are. It's not the correct question to ask: Is it cost effective to remove the sediment from behind the Conowingo dam? The correct question to ask is: Do we want to restore the Conowingo dam to beneficially serve as a sediment trap as it had for the past 70 to 80 years, or do we want to give up that benefit and essentially allow all sediment to pass through it? It would be a big mistake to accept a well publicized interpretation of the draft Study's findings that there is little benefit to dredging. For example, see Karl Blankensip's *Bay Journal* article dated November 13, 2014 which stated in part:

“The $1.4 million study, released by the Army Corps of Engineers and the Maryland Department of the Environment, also concluded that dredging built-up sediment from behind the 100-foot-high Susquehanna River dam would have huge costs and provide little benefit.”

We shouldn't be satisfied to have a sediment-laden, degraded, unhealthy Bay define us. Instead we need to focus our efforts on restoring the dam as a sediment trap. We need to determine the most cost-effective and environmentally responsible means of removing the sediments and to identify the most beneficial re-use for them.

Comment #3

It appears that the draft report is already influencing some Maryland politicians and policy-makers to make the case of why should their jurisdictions be required to control non-point source sediments and nutrients since they won't be further controlled from the very large areas of New York and Pennsylvania?

Regardless of what is done to control sediments and nutrients from the Susquehanna, we should not reduce our own activities in Maryland to control non-point source sediments and nutrients, nor reduce our efforts to improve nutrient removal at our wastewater treatment plants. My main concern with draft Study is it may influence policy makers to do nothing about sediments from the Susquehanna and it also may be influencing policy makers to cut back on environmental measures that are already being implemented in Maryland.

We must reduce the sediments and nutrients from the Susquehanna in addition to what we are already doing and for funds to be available for each initiative. The Chesapeake is a national resource influenced by several states. As such, it is very reasonable to expect funding to be fairly shared among the federal government, New York, Pennsylvania and Maryland to mitigate the Susquehanna's impacts on the Bay.

For this to happen, consideration needs to be given as to what New York and Pennsylvania will receive in return.

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Commenter Code E.7

As you know, an interesting project is evolving as to the Conowingo Dam and the release of sediment laden contaminants (primarily Phosphorous and Nitrogen), from the Susquehanna River into the Chesapeake Bay. Of particular interest to various parties invested in this project, is the approximately 200m cubic yards of sediment behind the dam and the reduced "trapping" capacity of the dam itself.

While there are conflicting tactics as to the sort of solution to the sediment/nutrient discharge, The Chesapeake remains in limbo regarding the "best of solutions". This is a seminal project requiring a provocative technological approach tied to cost effective disposal solutions.

I am here to report that the dewatering component of the project can be done at a small fraction of traditional costs. Production of tens of thousands of cubic yards per day is achievable. Return water is clean and clear (<20 mg. per ltr.,t.s.s.), with virtually all phosphorous (99%), and most nitrogen removed. Obviously, all organics and clay are captured and dewatered. I have a "dog in this hunt". I am the founder of a company that holds recent patents on very high-speed dewatering capabilities. Any eutrophic waterway can be restored as quickly as the dredge can pump. I hope we have the opportunity to discuss the core issues of this unusual project.

January 9, 2015

U.S. Army Corps of Engineers, Baltimore District
Attn: Anna Compton
P.O. Box 1715
Baltimore, MD 21203

Via Email: LSRWAcomments@usace.army.mil

The Chesapeake Bay Foundation has reviewed the October 2014 draft of the Lower Susquehanna River Watershed Assessment (LSRWA), Maryland and Pennsylvania Phase I report. The following comments are provided for your consideration.

The Chesapeake Bay Foundation (CBF) is a non-profit environmental education and advocacy organization dedicated to the restoration and protection of the Chesapeake Bay. With over 200,000 members, CBF works to ensure that changes in policy, regulation, and legislation are protective of the water quality of the Chesapeake Bay and its watershed. In this regard, we have a keen interest in the results of the LSRWA study as it pertains to the achievement of the Chesapeake Bay's water quality goals and the Total Maximum Daily Loads for nitrogen, phosphorus, and sediment (TMDLs) established to achieve those goals.[1]

First, we would like to sincerely commend and thank the staff at the Army Corps of Engineers and the other participating agencies and organizations for their efforts. This study addressed a number of extremely challenging scientific issues, requiring the integration of complex models, observational data, and the coordination of multiple participants. In the end, the study has dramatically increased and changed our collective understanding of the processes and impacts of the Susquehanna River and scouring from behind the Conowingo Dam on downstream habitats and water quality.

Overall, CBF believes the report's conclusions and recommendations are well supported and grounded in the best available science. The results clearly show that nutrients scoured from the behind the Conowingo Dam during high flow events are contributing to the violation of downstream water quality standards for dissolved oxygen. Results also suggest, however, that implementation of the state Watershed Implementation Plans (WIPs) which complement the Chesapeake Bay TMDL, have a far larger influence on the health of Chesapeake Bay in comparison to scouring of the lower Susquehanna River reservoirs. In addition, results also show that while impacts to the Chesapeake Bay ecosystem from all three dams and reservoirs are important, the majority of the sediment load from the lower Susquehanna River entering Chesapeake Bay during storm events, originates from the watershed rather than from scour from behind the Conowingo reservoir.

[1] 76 Fed. Reg. 419, 549 (Jan. 5, 2011)

The study also makes recommendations for future research and monitoring needed to address key data gaps. We firmly support these recommendations, particularly those related to enhancing the understanding of the nature, availability, and fate of nutrients scoured from the Conowingo Reservoir. These findings and the additional research are critical to the development of the Section 401 Water Quality Certification by the state of Maryland during the relicensing process and will also serve to inform the 2017 Midpoint Evaluation for the Chesapeake Bay TMDL.

We do, however, believe the report would benefit by bolstering the qualitative discussion regarding potential impacts of storms and scouring on submerged aquatic vegetation (SAV) and oysters. We recognize that all LSRWA modeling scenarios listed in Table 4-9 resulted in estimates of full attainment of the SAV and water clarity water quality standards for all Chesapeake Bay segments. And furthermore, that the SAV and water clarity water quality standards were not the drivers behind the TMDL allocations like the DO deep-channel and deep-water water quality standards were. That said, we also know that big storms like Tropical Storms Agnes and Lee do affect underwater grasses. In addition, when the January 1996 "Big Melt" event storm was moved to the June time period, light attenuation was estimated to be greater than 2/m for 10 days, a level of light attenuation that does not support long-term SAV growth and survival (1.5/m is required).

On page 71 there is a brief discussion about effects of storm events on underwater grasses and then the statement that "Appendix K provides further discussion on SAV trends and impacts from storms in Chesapeake Bay." Appendix K, though containing a section on underwater grasses, is more devoted to general background information on the Bay and associated habitats. We suggest this Appendix include more discussion of the findings of Gurbisz and Kemp (2013), Wang and Linker (2005) and any more recent work on this topic including, if possible, a consideration of the relative effects of scouring versus watershed loads, if only in a qualitative sense.

Similarly, we suggest a more in depth discussion on oyster impacts. Currently, the report references a post Tropical Storm Lee study indicating the oyster mortality in the northern Bay was due to salinity decreases, not to sedimentation. We are not disputing this finding, but would encourage the study authors to include additional studies and information that support this contention. In addition, we also recommend including a discussion of why some oyster bars are susceptible to sedimentation that may not be, in any way, related to storm events. Questions about effects of scouring from behind Conowingo Dam on SAV and oysters continue to be raised in the public domain. To the extent that they can be addressed more comprehensively in the report, may help to assuage some lingering concerns.

Thank you for the opportunity to provide comments and once again for your collective efforts on drafting this report.

Sincerely,

Beth McGee

Beth L. McGee, Ph.D.
Senior Water Quality Scientist

cc: Jon Mueller, CBF
Alison Prost, CBF
Doug Myers, CBF

Comments of the Soil and Water Conservation Society, National Capital Chapter

Andrew Manale, President

The National Capital Chapter appreciates this opportunity to comment on a report on a scientific and policy subject which has received insufficient attention—management of a legacy dam and its associated accumulated sediments and nutrients at critical node in the water-land ecosystem. The Soil and Water Conservation Society (SWCS) is a nonprofit scientific and educational organization -- founded in 1943 -- that serves as an advocate for conservation professionals and for science-based conservation practice, programs, and policy. SWCS has over 4,000 members around the world. They include researchers, administrators, planners, policymakers, technical advisors, teachers, students, farmers, and ranchers. Our members come from nearly every academic discipline and many different public, private, and nonprofit institutions. The National Capital Chapter represents members who live and work in the greater Washington, DC area.

General comments

We find that the report, though it summarizes well the science related to issue of management of the Conowingo Dam reservoir for the protection of the water quality of Chesapeake Bay, fails in its argument that the loss of sediment storage capacity in the dam reservoir lacks critical importance to the health of the Bay ecosystem. The critical findings of the studies that underlie the report suggest the opposite. Also not convincing is its assertion that the current approach to water resource management through the Chesapeake Bay Total Maximum Daily Load (TMDL) water quality management process <u>alone</u> will adequately safeguard the resilience of the Bay ecosystem from the impacts of extreme weather events. Though a policy and its implementation process—the TMDL--is conceived and designed to achieve a longer term goal of water quality, this does not in itself argue that the individual steps and components in this highly complicated venture will necessarily succeed. There is uncertainty in any approach and consideration of this uncertainty should be apparent in the study. As the report states--though this admission is buried deep in the body of the report--, the nature of the problem of legacy nutrients in the hydrologic system makes verification of effectiveness of measures implemented as part of the TMDL implementation plans nearly impossible in the short while. The report also fails to identify and examine what the unique opportunities are for changing the management of a key component of the water system presented by this once-in-a-lifetime relicensing of the operation of the dam. This latter should be the focus of this study and should be answered in the report.

We suggest strongly that a revised report discuss measures to reduce the volume of water, and hence the nutrients and sediment contained within, associated with the kind of extreme weather events that normally occur within the timeframe of the dam electrical plant operating permit and those that become more likely to occur as a consequence of a rapidly changing climate. As the report states, though this too is hidden deep in the body, a Conowingo dam at dynamic equilibrium leads to faster flowing water that carries with it more sediment and nutrients. Hence, expanding the amount of stormwater that can be temporarily stored on the land adjacent or immediately connected to the Susquehanna and its tributaries and otherwise slowing the runoff from these lands should be a major focus of the options for addressing the consequence of Conowingo dynamic equilibrium. Instead the reader is presented with the tautological argument that a policy designed to achieve a policy goal will by definition do so. It does not reconcile this assertion with the admission that the current TMDL and its measures are already out of date and must be revised as a consequence of increasing nutrient and sediment loads from a Conowingo dam that is already at dynamic equilibrium.

The finding of a current TMDL already out of date belies the conclusion of the report that the dam and its accumulated sediments are inconsequential to the health of the Bay and the implicit suggestion that a change in the conditions for relicensing of the operation of the dam—whether or not the onus is placed directly on the operator of the dam--are not necessary. Rather than a "[f]uture needs and opportunities in the watershed," as the report suggests, development of management options that offset impacts to the upper Chesapeake should instead be examined in this report in order to take advantage of the relicensing opportunity that is available for only a short period of time.

Management of water volume, particularly as it relates to agricultural land, is not specifically covered by TMDL measures. The Soil and Water Conservation Society National Capital Chapter is eager to demonstrate how, for its part, agricultural land can be managed for temporary water storage and for retarding the rate of flow of water into the river system and thus effectively reduce water volume to reduce scour. Moreover we can also help identify and explain the policies that can feasibly and cost-effectively be implemented, taking advantage of this once-in-a-lifetime relicensing opportunity.

Specific comments

The relicensing of Conowingo Dam for hydropower generation presents a unique opportunity for the Federal Government to ensure that the operation of the dam minimizes unintended environmental consequences and supports the provision of the suite of ecosystem services that benefit everyone who lives, works, and recreates in the Chesapeake Bay watershed. Under the new Federal Principles, Requirements, and Guidelines[1], the relicensing of the Conowingo Dam represents a project that falls under the provisions of the new rules, i.e. " 3. [e]xisting assets that may not result in a change in water quality or quantity by themselves, but without which unintended changes to water resources may occur. These situations may occur when an existing infrastructure may fail or degrade in the absence of additional Federal investment, resulting in a change in quality or quantity of the water resources, or the level of service provided. and 4. Activities where the Federal government is responsible for implementation of an action, or when another party is responsible for implementation using Federal funds." As a consequence of the applicability of Conowingo to these new rules, we expect that the analytical studies that support the relicensing decisions meet the new principles, in particular, the use of healthy and resilient ecosystems as a measure of performance.

According to the Executive Summary of the LSRWA report, " [t]he purpose of this assessment was to analyze the movement of sediment and associated nutrient loads within the lower Susquehanna watershed through the series of hydroelectric dams (SafeH arbor, Holtwood, and Conowingo) located on the lower Susquehanna River to the upper Chesapeake Bay. This included analyzing hydrodynamic and

[1] http://www.whitehouse.gov/sites/default/files/docs/prg_interagency_guidelines_12_2014.pdf

sedimentation processes and interactions within the lower Susquehanna River watershed, considering strategies for sediment management, and assessing cumulative impacts of future conditions and sediment management strategies on the upper Chesapeake Bay. The need for this assessment is to understand how to better protect water quality, habitat and aquatic life in the lower Susquehanna River and Chesapeake Bay. "

An assessment was indeed conducted as part of the study but the act of assessing is itself NOT a clear articulation of what the assessment is conducted for. The Executive Summary nor the introductory chapters to the report makes clear what the core questions were that the assessment was to provide information to answer. These should be stated at the outset so that the reader can better evaluate the science and the arguments that underlie the conclusions relating to key public policy choices that pertain to the relicensing decision. Our examination of the body of the report suggests that the major conclusions as stated in the Executive Summary are not well supported by the methods and results. The reader has literally to dig deep into the report to identify the scientific questions that were posed and to discover the scientific findings. Often one set of findings, such as related to extreme weather events, i.e. greater than five years recurrence intervals, and reservoir bed scouring were not sufficiently incorporated into the analyses in another section.

What was the perceived problem for which the study was to provide the information to answer? It appears that an answer to this question is provided only later in the press release, not in the introduction or body of the report—what is the importance of loss of sediment storage capacity in the dam reservoir relative to implementation of the Chesapeake Bay TMDL and the environmental problem that it—the TMDL-- is designed to address. It is unclear how the findings and conclusions of the LSRWA will or can be used in the relicensing decision. We hope that the final report will contain a serious examination of conditions and options that should be considered in the relicensing decision.

We learn elsewhere in the body of the report that the loss of sediment storage capacity behind the dam in the next few years will increase the threat to the ecosystem health from extreme weather events (ever more likely with a rapidly changing climate, such as occurred with Hurricane Agnes just some forty years ago). Also, inconsistent with the conclusions that are presented in the Executive Summary, we learn that the dam and its reservoir are already at dynamic equilibrium and that the TMDL, which the report argues is the answer to water quality concerns, will no longer achieve its intended goals as a consequence of the dam at dynamic equilibrium. Nor do we have an answer as to how at this juncture with the pending relicensing of the Conowingo Dam for electric power use, the management of the dam and its reservoir could or should be changed to ensure that the ecologic damage from a future Hurricane Agnes does not recur. Also disturbing is the absence of a discussion of the value of the sediment that increasingly fills up the reservoir to the ecosystem health of the larger Bay system, particularly in lower sections of the Bay. Here the problem is land disappearing in part because of sediment starvation. Sediment that restores and enriches the land-water interface is instead captured behind the dam. The answer at the public hearing by representatives of the study that "we all agree that we should study the issue more" is, to be blunt, an acknowledgement that this report does not address the prevailing public policy concerns. Calling for another study to do what this study should do does not instill confidence in how this larger issue of protection of ecosystem resilience, as we have articulated it here, will ever be addressed.

We are not persuaded by the report's statement that a Conowingo Dam reservoir at dynamic equilibrium with regard to sediment matters little to ecosystem health. There is no discussion in the analytical section of the report of how the dam at dynamic equilibrium may adversely affect ecosystem resilience and the ability of the ecosystem to withstand infrequent, but highly severe insults, such as 40 year or more recurrent interval storms. Should we not be managing components of the system, such as the dam and its reservoir, for resilience? If so, then the study should have examined the ability of the system, with the reservoir at dynamic equilibrium, to withstand infrequent recurrence interval storm events and used these results as the measure against which to compare alternative management strategies. Since the Conowingo Dam license renewal is for some fifty years, fifty years, at least, would seem to be the proper recurrent interval number to be used, not five or ten-year storms.

The study appears designed to give the answer that implementing regulatory requirements under the Clean Water Act for the Chesapeake Bay to meet the Total Maximum Daily Load (TMDL) goal will address any current and future problem of sediments and nutrients. The implementation plan under the Chesapeake Bay TMDL may or may not eventually result in significant improvements in the ecosystem health of the Bay and its environs. Time will tell. However, choosing to examine only that period of time in the analytical part of the report that compares options that coincides with the current phase of the TMDL and that incorporates only relatively minor storm events of low recurrence intervals that are not of the kind that can be expected to occur during the much longer time period (some fifty years) of the Conowingo Dam relicensing period leads not surprisingly to results supportive of the major conclusions regarding importance of storm-related scour events. Certainly the inclusion of forty or fifty year recurrence interval storm scour events would have been called for and may have likely led to different conclusions regarding the appropriateness of management strategies.

The assumption in this study that the TMDL implementation occurs flawlessly and on time despite the thousands of required practices conducted by different public and private entities necessary to achieve predicted levels of performance defies logic and almost fifty years of Clean Water Act experience. That this assumption regarding success on the agricultural portion of the TMDL is highly questionable and that it should be bracketed within a large uncertainty range is supported by hundreds of studies conducted under the auspices of the United States Department of Agriculture's Conservation Effects Assessment Project (CEAP)[2].

Over more than ten years, the top government and academic researchers under the auspices of CEAP examined the effectiveness of agricultural nutrient reduction practices and strategies in watersheds throughout the country and over many decades. The conclusions are that most nutrient reduction practices on agricultural lands, for a variety of reasons that are often location-specific, have not been successful. More effective interventions needed to be implemented as part of a comprehensive management system that is tailored to site-specific conditions with constant

[2] See CEAP, http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/technical/nra/ceap/.

reassessment regarding the effectiveness. How this must occur is still the subject of scientific and policy debate. The reason stems in part from the fact that no farm or section of land is the same, nor is any the management of any two farms or sections of land likely to be the same. The problem is one for which there are no certain answers at the moment and that requires more research to resolve. Compounding the problem is the legacy of how the land was managed in previous decades and its impact on nutrient loss from these lands. This is an issue of cutting edge science and policy that has been reduced to almost cartoon simplicity in this report.

In any case, the uncertainty regarding TMDL implementation success and effectiveness should be factored into any comparison of alternative options for managing sediment and nutrients to and from the Conowingo Dam. We suggest only that alternative and parallel strategies of managing sediment, such as through dredging or controlled flushing, and actions to expand temporary stormwater storage upland from the dam can potentially be far more certain since sediment management at the dam can be relatively easily implemented and monitored and increased upland water storage quantified using today's new technologies. And, of course, there is a significant cost for all strategies.

For unknown reasons, only the cost of dredging was estimated in detail. The cost of implementing the TMDL was assumed to be a one-time cost that appears lower than the ongoing Net Present Value (NPV) of a stream of costs associated with dredging. How farm management practices to reduce nutrients and sediment can be assumed to be one-time costs is not credible and runs counter to hundreds of economic studies and case studies that argue significant ongoing costs. Moreover, unpublished data generated as part of US Environmental Protection Agency's Chesapeake Bay TMDL cost-benefit analysis suggest that TMDL implementation, if and when fully implemented in the upper sections of the Chesapeake Bay watershed, will also likely cost billions of dollars per year. Clearly, a large range of benefits can be expected to accrue from successful implementation of the TMDL which can justify this costs. But the public policy issue is not either the TMDL or another intervention at the locus of the dam, but rather whether or not an action linked to the dam relicensing and operation can be justified by its costs and benefits.

The question that should have been the driver for the analysis is instead the caboose in this report in that it finally appears in the "Future Needs and Opportunities.." section of the Executive Summary. The recommendation, i.e. "[d]evelop and implement management options that offset impacts to the upper Chesapeake," should actually be restated as the core question that the study should address. What do you do with the loss of sediment capturing capacity over time since the implication is that the currently required practices under the TMDL are or will no longer be enough to reduce significant increases in nutrient and sediment loads to the Bay? Can there be beneficial uses to the sediment, if dredged or otherwise removed from the reservoir? The town hall meeting that occurred in December 2014, acknowledged these questions. One-time costs assumed by this study become ongoing costs as new requirements on urban communities and on farmers get imposed to offset this loss.

It appears that alternative strategies to or along with the TMDL to address the consequence of rising nutrient and sediment loads as a result of the loss of storage capacity behind the dam are treated in a biased manner. The discussion of intentional scouring, for example, was given short shrift and deserves a more unbiased and serious examination. The issue of timing and its relationship to unintended downstream consequences was totally neglected. That these other options are not viable has not been well demonstrated by the analyses presented in this report.

The sediment management options were limited to engineering and technological options. Why were no economic options examined? Options for addressing the problem of stormwater flow volume and rate of through the system at times of extreme weather events were not examined. Doing so would consider means for expanding floodwater storage on lands adjacent to the river, such as on agricultural lands. There are likely to be options on temporarily storing water on non-agricultural lands, such as through the management of road culverts, rehabilitation of wetland and of wet lands and forested lands, as well New digital elevation map data could be extremely helpful in identifying these lands for increased storage. Contingent contracting would serve to make these lands available when needed [See the references below.] Another example of an economic approaches is a policy to convert negative economic value of “pollutants” (i.e., sediment and nutrients) to tradeable commodities with positive economic value. This is can be done through labeling and a combination of regulatory and economic measures.

No economic cost was assigned to the uncertainty regarding the implementation and effectiveness of TMDL measures as opposed to measures, such as dredging for which the effectiveness and be more quantitatively ascertained. For example, the cost estimates for TMDL measures lack credibility. The report should have made clear that then values were largely drawn from scattered studies of unclear relevance to where they could be implemented in the watershed, along with no credible assessment of the variability of their effectiveness given the myriad site-specific factors that affect performance.

The discussion of the TMDL and its implementation measures uses tautological arguments that are not convincing. The argument repeatedly presented is that, because the TMDL is designed to achieve success and meet water quality goals, implementation of the implementation plans and associated practices must by definition lead to the water quality goals. This is further assured, we are told, because of periodic monitoring that leads to readjustments in implementation plans over time. However, not until chapter four do we learn that this is not possible—in other words, verifiability is not possible--because the nature of the nitrogen and phosphorous pollution problem itself and its legacy effects with the hydrologic system. This same tautological argument can be constructed for every option that one can conceive to address water quality problems in the Bay.

The report, Table 4-1 presents practices that are not defined and hence cannot be independently evaluated as to their likely effectiveness. For example, what does “improved nitrogen management” mean in practice. And if it is so improved, why is the practice not already adopted since nutrients are a cost to a farmer? Similarly, what does “improved conservation practices” mean? Again, if they really are improved, then there should be some discussion as to why they have not been adopted by a rational person.

The report contradicts itself repeatedly. It makes the argument that a Conowingo at dynamic equilibrium is not important but then states a Conowingo at dynamic equilibrium necessitates revision of the TMDL in order to achieve water quality. If a revision to the TMDL is already needed (page 97), then clearly it is important and the conclusions are wrong. Which is it? The science presented in the report suggests that the conclusion is unsupported and thus just plain wrong.

The report fails to acknowledge the unique opportunity to change the management of a key component in the ecosystem of the Bay—i.e., the node at a critical juncture point represented by the Conowingo Dam. Instead of presenting and examining innovative options for how to use this opportunity for improvements in the protection of the resilience of the system, it recycles old tautological arguments for staying the course and just focusing on implementation of the Chesapeake Bay TMDL. In doing so, it sheds no new light on what the path forward should be.

For example, there could and should be discussion of options for reducing the volume of stormwater laden with sediment and nutrients that surge through the system at times of extreme weather events. Such options could include arrangements or contracts with farmers and landowners on lands adjacent or directly connected to the river to allow for temporary water storage at times of anticipated high flow. Thus temporary storage could serve to reduce the volume of water at key high flow times through the reservoir and the dam and to slow down and allow for settling out of sediment and associated nutrients in areas upstream from the reservoir. Examining a broader array of options than what the Corps of Engineers traditionally identifies is in fact now since December 2015 a requirement [See http://www.whitehouse.gov/administration/eop/ceq/initiatives/PandG/] For a discussion of how more storage capacity can be effected, please see http://www.jswconline.org/content/55/3/285.short. See also http://www.rff.org/Publications/WPC/Pages/Options-Contracts-for-Contingent-Takings.aspx and On Risk and Disaster: Learning from Hurricane Katrina by Ronald Daniels, Donald Kettl, and Howard Kunreuther.]

Conclusion and recommendation

In conclusion, the report, as it is currently written, does not adequately address public and interested party concern regarding the loss of sediment storage capacity behind the dam nor does it illuminate options for managing the dam for future protection of the Bay ecosystem. We recommend engaging a broader set of stakeholders, such as the National Capital Chapter of the Soil and Water Conservation Society and other professional organizations that deal with the conservation of soil and water resources, in reviewing and drawing new conclusions from the data that exist that pertain to the issue.

STATE WATER QUALITY ADVISORY COMMITTEE

Julie Pippel
Chair

Fred Jacobs, Ph.D.
1st Vice Chair

Sarah Taylor Rogers, Ph.D.
2nd Vice Chair

January 9, 2015

Anna Compton
U.S. Army Corps of Engineers, Baltimore District
P.O. Box 1715
Baltimore, MD 21203

RE: Lower Susquehanna River Watershed Assessment (LSRWA) Draft Report

Via Email: LSRWAcomments@usace.army.mil

Dear Ms. Compton:

As a balanced advisory committee comprised of 32 members representing private citizens, public officials, economic interests and public interest organizations from different geographic areas of the State, the Maryland State Water Quality Advisory Committee (SWQAC) offers comments on the Lower Susquehanna River Watershed Assessment (LSRWA) Draft Report as invited during the public comment period.

The SWQAC commends the U.S. Army Corps of Engineers, Baltimore District (USACE), and the Maryland Department of the Environment (MDE) and multiple partners, on the objective science and research performed and summarized in this document. The report provides much needed information for management decisions to ensure water quality is protected and improved.

The SWQAC supports the four specific recommendations outlined on ES-5 and section 8.1 'Future Needs and Opportunities in the Watershed'. Furthermore, the SQWAC recommends that reliable and sustainable sources of funding, staffing and commitments should be secured to ensure the recommendations are fully implemented.

In addition, we support the continued efforts of WIPs in recognition that 89 of the 92 Bay segments might achieve water quality goals by 2025, given the Lower Susquehanna is just one of multiple stressors on the Bay. We also recommend that the findings from the Report and any new information on the impacts of Conowingo Dam reaching "dynamic equilibrium" be used to inform the Chesapeake Bay TMDL 2017 Mid-Point Assessment.

Thank you for the opportunity to provide comments on this document. We look forward to reviewing future updates, and providing additional thoughts and perspectives on infill, redevelopment, and revitalization.

Sincerely,
Julie Pippel, Chair

Cc: MDE, DNR Sec and EPA Region III,

"Advisors to the State of Maryland on Water Quality Issues"

c/o Christine Thomas ♦ MDE/WMA ♦ 1800 Washington Boulevard ♦ Baltimore MD 21230
410-537-3524 or tollfree 1-800-633-6101 ♦ FAX 410-537-3553 ♦ Website: www.marylandwaterquality.org

SUPPORT
CONOWINGO
DAM

January 8, 2015

To whom it may concern:

The Conowingo Dam has played a key role in providing clean reliable electricity to the region for more than 85 years. I am submitting a petition that endorses the work of the U.S. Army Corp of Engineers, numerous Maryland state agencies and the many other stakeholders for a science-based approach to developing a course of regional action in improving the water quality in the Chesapeake Bay.

On behalf of the more than 11,500 signers of this petition we thank the Corp and those involved for the work already completed on this issue and look forward to the continued work on addressing this regional issue.

Sincerely,
Jan Nethen

Petition Language:

For more than 80 years, the Conowingo Dam has been a source of clean, carbon-free, reliable energy for thousands of residents and businesses in the Chesapeake Bay region. It is also an economic powerhouse for the region, generating $273 million in economic benefits for our state. The dam also supports 265 full-time jobs and pays about $10 million in state and local taxes annually, including $3.8 million in property taxes.

The Conowingo Dam also offers a wealth of recreational opportunities like boating, hiking, fishing and bird watching. As a result, it is an incredibly popular destination in northeastern Maryland, drawing an estimated 250,000 visitors each year.

In addition to providing recreational opportunities for the community, the Conowingo Dam protects the Chesapeake Bay by trapping more than 2 million tons of sediment each year – sediment that would have otherwise flowed into the bay.

The Conowingo Dam has never created one ounce of sediment and although the dam is not responsible for sediment in the Chesapeake Bay, the bay's health is an important issue that requires all of our attention and action. While others are pointing fingers and playing politics, we believe that the best way to reduce sedimentation and protect the Chesapeake Bay is to let the science lead.

The U.S. Army Corps of Engineers is currently conducting a study to evaluate and provide recommendations on the most effective ways to improve the bay's health. This study will be instrumental in determining what steps should be undertaken to address the long-term health of the Chesapeake Bay.

The Conowingo Dam's relicensing should be led by science, not politics. That's why Maryland, its neighboring states, and the federal government need to adopt a regional approach that includes all of us doing our part in reducing pollution in the Chesapeake Bay.

The Conowingo Dam helps protect the Chesapeake Bay, powers the Maryland economy, is the state's largest source of renewable energy and is a cherished recreational resource for the state. Please support Conowingo Dam and preserve the many benefits it provides to our region.

More information about Conowingo Dam is available at www.SupportConowingoDam.com.

A full list of all petition signatures follows.

United States Department of the Interior

FISH AND WILDLIFE SERVICE

Chesapeake Bay Field Office
177 Admiral Cochrane Drive
Annapolis, Maryland 21401
http://www.fws.gov/chesapeakebay

January 8, 2015

Anna Compton
U.S. Army Corps of Engineers
Baltimore District
P.O. Box 1715
Baltimore, MD 21203-1715

Re: Lower Susquehanna River Watershed Assessment Draft Report

Dear Ms. Compton:

We appreciate the opportunity to comment on the Lower Susquehanna River Watershed Assessment and want to extend the U.S. Fish and Wildlife Service's support of the findings in accordance with provisions of the Fish and Wildlife Coordination Act (48 Stat. 401, as amended; 16 U.S.C. 661 et seq.). We agree with the Future Needs and Opportunities in the Watershed and look forward to the reporting of those outcomes. It is critical that we understand how sediment and nutrients impact Chesapeake Bay water quality and health. The Chesapeake Bay is a national treasure and we support any findings to help clean up and restore the health of the Bay and enhance fish and wildlife resources. Again thank you for the opportunity to review and comment on the assessment.

If there are any questions please contact Robbie Callahan of my staff at 410-573-4524.

Sincerely,

Genevieve LaRouche
Supervisor

210 S. CROSS STREET, SUITE 101
CHESTERTOWN, MARYLAND 21620
PHONE: (410) 810-1381
FAX: (410) 810-1383
WWW.CLEANCHESAPEAKECOALITION.COM

January 9, 2015

VIA Electronic Mail
U.S. Army Corps of Engineers
Baltimore District
Attn: Anna Compton
P.O. Box 1715
Baltimore, MD 21203
LSRWAcomments@usace.army.mil

Re: Clean Chesapeake Coalition – LSRWA Draft Report Comments

Dear U.S. Army Corps of Engineers:

The Maryland counties that have combined their efforts and resources in order to address concerns relative to the improvement of the water quality of the Chesapeake Bay in a meaningful and cost effective manner known as the Clean Chesapeake Coalition ("Coalition")[1] provide their comments and concerns with the Draft Lower Susquehanna River Watershed Assessment ("DLSRWA") [2] collectively instead of separately and individually. The Coalition appreciates this opportunity to provide comments.

The Coalition counties and their representatives have been precluded from participating in the scoping of the study underpinning the DLSRWA report and the quarterly progress meetings reviewing the progress of such studies and the report. At the quarterly progress meetings, critical decisions have been made about the scope and direction of the study, the information to be considered during the study, the underlying assumptions on which the modelling and study efforts have been predicated and the conclusions to be determined and reported based on the study and modelling results. Coalition members have requested to have meaningful input into this process and have been denied that opportunity by U.S. Army Corps of Engineers ("USACE") and the Federal and State agencies and private persons (including Exelon and Exelon's representatives) that are undertaking the Lower Susquehanna River Watershed Assessment ("LSRWA"). Indeed, handpicked "stakeholders" such as Exelon and The Nature Conservancy were afforded several months to review the draft report and appendices before its release while local government officials of the Coalition counties, along with the general public, got their first look in mid-November 2014 and have been pressed to review and analyze the roughly 1,500 pages that comprise the DLSRWA to meet today's public comment deadline.

[1] Coalition counties include Allegany, Caroline, Carroll, Cecil, Dorchester, Frederick, Harford, Kent, Queen Anne's and Wicomico.
[2] Dated October 2014. *See* link: http://mddnr.chesapeakebay.net/LSRWA/report.cfm.

Coalition counties have been mandated by the Maryland Department of the Environment and the Maryland General Assembly with planning, funding and implementing nutrient and sediment load allocation reductions in order to enable Maryland to meet the objectives of the U.S. Environmental Protection Agency's ("EPA") 2010 Chesapeake Bay TMDL ("2010 Bay TMDL"). Given the necessary role of Maryland local governments in the Bay restoration program (*i.e.*, watershed implementation plans), the concerns of the Coalition counties with the DLSRWA must not be ignored. Otherwise, we will continue spending billions of dollars to earn D+ "State of the Bay" report cards from the Chesapeake Bay Foundation for years to come.[3]

The human environment (*e.g.*, the economic, social and cultural, and natural environments) of the Coalition counties has been and will continue to be directly impacted by the conclusions and results of the LSRWA. Such conclusions and results are being used to direct the Environmental Impact Statement being prepared in the Federal Energy Regulatory Commission's pending relicensing of the Conowingo Hydroelectric Project and the relicensing of other power projects in the lower Susquehanna River, and will inform the EPA's 2017 recalibration of load allocations under the 2010 Bay TMDL.

The USACE and the other Federal and State agencies who have conducted the LSRWA have failed to coordinate with the Coalition member counties in the preparation of the LSRWA and have deprived them of their rights under the National Environmental Policy Act ("NEPA") and the Federal Advisory Committee Act ("FACA") as well violating a number of U.S. Presidential Executive Orders in the manner in which the study and report processes has been conducted to date. The Coalition counties urge USACE and the participating Federal and State agencies to revise their approach as they move forward with the LSRWA.

The Coalition counties observe with interest the report detailing the concerns of the Scientific and Technical Advisory Committee (STAC) of EPA's Chesapeake Bay Program with respect to the DLSRWA and generally concur with all of the STAC's comments and concerns, which have yet to be adequately addressed.[4] It is disingenuous for any person familiar with the STAC report to suggest that the DLSRWA has been favorably peer reviewed or has been endorsed by the scientific community.

We take issue, however, with one observation made by the STAC and with one issue overlooked by the STAC. The STAC suggests that the harm caused by an increased loading of sediments due to scour from the floors of the reservoirs behind the hydroelectric dams in the lower Susquehanna River will not be as harmful as the nutrients bound to the sediments, particularly phosphorus, to the Bay estuary. In their 2012 Native Oyster Restoration Master Plan USACE has documented the harmful impact of sediments to the habitat necessary to allow

[3] CBF 2014 State of the Bay Report. *See* link: http://www.cbf.org/about-the-bay/state-of-the-bay-report-2014.
[4] Freidrichs, C., T. Dillaha, J. Gray, R. Hirsch, A. Miller, D. Newburn, J. Pizzuto, L. Sanford, J. Testa, G. Van Houtven, and P. Wilcock, *Review of Lower Susquehanna River Watershed Assessment*, Publication No. 14-006 of the Chesapeake Bay Scientific and Technical Advisory Committee (Aug. 2014).

bivalves (oysters, clams and mussels) to reproduce in the Bay.[5] The watermen working out of the Coalition counties on the Bay will testify about the harmful impact of the massive quantities of sediments entering the Bay during significant storm events such as the storms events of 2011 and how such events have devastated the habitat for bivalve breeding and have suffocated hibernating crabs and destroyed the SAV necessary to protect young of year crabs from predators. We observe that while the scientific credentials of the 11 member STAC team that reviewed the DLSRWA are not disclosed, none appear to have any, or an extensive, background in the marine science of bivalves or blue crabs. The National Oceanic and Atmospheric Administration and the U.S. Fish & Wildlife Service should be consulted before making such sweeping generalizations.

Neither the STAC nor the persons conducting the LSRWA have given any consideration to the toxic pollutants that are documented (*see* Susquehanna River Basin Commission reports to the Maryland Department of the Environment) as being in the sediments impounded in the reservoirs behind the hydroelectric power dams: herbicides; pesticides; sulfur and acid mine drainage; coal; PCBs; and other aromatic hydrocarbons and heavy metals, in addition to the nitrogen and phosphorus bound in such sediments. Such toxic pollutants must be accounted for in determining the impact of scour and in undertaking a benefit cost analysis of dredging above the dams in the lower Susquehanna River.

The initial pages of the attached comments and concerns provide a slightly more comprehensive overview of the comments and concerns of the local government members of the Coalition. The latter pages contain more detailed questions, comments and concerns focused on individual portions of the DLSRWA and the attached appendices. The Coalition members expect that the comments presented in each section of the attached review will be considered and addressed.

Given the predictive failure of the HEC-RAS and AdH models, upon which the major findings and conclusions of the DLSRWA are predicated and the reported fact that the underlying goals and objectives of the LSRWA were changed in midstream, the DLSRWA undisputedly is a mishmash of information rapidly cobbled together in a report and appendices in order to fulfill a political agenda. The DLSRWA is not scientifically sound and does not achieve valid objectives and outcomes. The Coalition urges the USACE and the other Federal and State agencies utilizing the report in conjunction with relicensing and regulatory objectives to restart

[5] The sediments deposited in the Bay during and in the aftermath of Hurricane Agnes in 1972 destroyed the oyster beds north of the Bay Bridge. (2012 MP § 4.6.3 at 83-84.) Sediments smother and kill oysters and prevent oyster spat from seeding because spat require hard clean shell on which to attach in order to grow new oysters. (2009 EA § 3.3.1 at 13 (sediments now cover most historic oyster beds and planted shell becomes covered in an average of 5.5 years); Chesapeake Bay Oyster Recovery: Native Oyster Restoration Master Plan, Maryland and Virginia dated September 2012 (2012 MP) § 2.1.1 at 17 ("Shell is being lost due to burial by sediments. Larval oysters require hard substrate on which to settle to grow."), § 4.1.1 at 49 (sediments eliminate oyster habitat), § 4.1.1.4 at 56 (sediment smothers oysters), § 5.5.4.5 at 150 (oyster growth must exceed sedimentation rates in order for oysters to survive).)

the process and to proceed in legal compliance with NEPA, FACA, the regulations of the Council of Environmental Equality implementing NEPA, and the applicable Executive Orders.

There is no denying that the hydroelectric power dams in the lower Susquehanna River have profoundly altered the lower Susquehanna River estuary and the Chesapeake Bay estuary. If the ongoing impact of the dams and the other power projects in the lower Susquehanna River are not addressed, the downstream efforts and expenditures undertaken by Marylanders will not achieve meaningful and lasting improvement to the upper Bay or overall Bay water quality.

The Coalition counties have suggestions about how a natural oyster bed cultivation and seeded shell relocation program could serve as a viable and cost effective alternative to full-scale dredging behind the dams. Again, if a proper NEPA process is instituted, such alternatives could be preliminarily scoped and given due consideration. The failure to adhere to such legal mandates will be more expensive and cause greater delay and expense for all involved in the long run.

Any questions about the Coalition's comments concerning the DLSRWA may be directed to Jeff Blomquist (jblomquist@fblaw.com or 410-659-4982), Michael Forlini (mforlini@fblaw.com or 410-659-7769) or Chip MacLeod (cmacleod@fblaw.com or 410-810-1381).

Very truly yours,

Ronald H. Fithian

Enclosures

cc: United States Environmental Protection Agency
United States Geological Survey
Maryland Department of the Environment
Maryland Department of Natural Resources
Maryland Geological Survey
Susquehanna River Basin Commission
The Nature Conservancy
Clean Chesapeake Coalition

Clean Chesapeake Coalition

Comments, Questions & Observations

Draft Lower Susquehanna River Watershed Assessment Report

January 9, 2015

Background

The Lower Susquehanna River Watershed Assessment ("LSRWA") was originally undertaken in 2011, before a number of Maryland counties coalesced to form the Clean Chesapeake Coalition (the "Coalition") in last quarter of 2012 and began to shine the spotlight on the problem of scour from the floors of the reservoirs behind the three major hydroelectric power dams in the lower Susquehanna River: the Safe Harbor Dam (Lake Clarke is the reservoir behind that dam); the Holtwood Dam (Lake Aldred is the reservoir behind that dam) and the Conowingo Dam (the Conowingo Pond is the reservoir behind that dam).[1] The Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment, Dec. 29, 2010 ("2010 Bay TMDL") was published in December 2010 and concluded that Lake Clarke and Lake Aldred already had reached dynamic equilibrium,[2] but that the Conowingo Pond would not reach dynamic equilibrium until sometime between 2025 and 2030. The United States Environmental Protection Agency ("USEPA"), therefore, erroneously concluded in the 2010 Bay TMDL that 50% of the sediments flowing down the Susquehanna River would continue to be trapped in the Conowingo Pond. The LSRWA study originally was undertaken by the United States Army Corps of Engineers ("USACE") and the Maryland Department of the Environment ("MDE") to begin to consider the impact that the sediments accumulating in the three reservoirs would have once the Conowingo Pond reached dynamic equilibrium some 15 to 20 years down the road. There was no urgency to the study and there was very little in funding procured for the study.

[1] Shawn A. Seaman, in the comments submitted by the Maryland Department of Natural Resources to FERC in Project No. P-405-106 on January 31, 2014 at 2, stated: "[T]he [LSRWA] was never intended to be part of FERC's licensing process." MDE and MDNR have repeatedly taken the position that Exelon must be required "to conduct appropriate sediment and nutrient studies to determine the Project's impacts on water quality and living resources of the Lower Susquehanna River and the Chesapeake Bay." (Footnote omitted.) (*Id.*) Nevertheless, USEPA, by letter dated December 29, 2014 from John R. Pompomo, the Director of Environmental Assessment and Innovation Division of USEPA, to FERC Secretary Kimberly Bose, requested FERC to include and consider the DLSRWA in the EIS being prepared by FERC for the Conowingo Hydroelectric Power Project. The LSRWA has morphed into something it never was intended to be.

[2] "Dynamic equilibrium" is the term used to indicate that the amount of sediments (suspended solids) in the water above the dam would be equivalent to the amount of suspended solids in the water below the dam. Before any of the hydroelectric dams were built in the Susquehanna River, it was a narrow, rapidly flowing river with whitewater rapids and falls. Most of the suspended solids in the river flowed into the Chesapeake Bay. When the hydroelectric dams were constructed, they were built well above the natural top of the river in order to build up and trap a large reservoir of water behind the dams that could be used to steadily turn (*i.e.*, power) the turbine electric power generators installed along the sluce gates in the bottom of the dams so that even during drought conditions there would be sufficient water with enough head space to power the generators. These dams acted as stormwater management ponds. They significantly slowed the flow of the water in the Susquehanna River and significantly deepened the river. As soon as the water deepened and slowed, suspended solids that used to flow down the river into the Bay began to settle out in the reservoirs behind the dams.

The issue of what would happen when dynamic equilibrium was reached was always "the elephant in the room" that the regulatory agencies and NGOs have avoided addressing, because it was too complicated and there is no existing legal framework that empowers the Federal or State regulators to directly address the problems that will result from such eventuality. Today, there is no commitment, plan, responsible party or budget to specifically address the devastating amounts of nutrients, sediment and other contaminants that are scoured into the Chesapeake Bay during storm events and in equally harmful proportions now on a regular basis.

Total Maximum Daily Loads

In 2008, the Chesapeake Bay Foundation, in a friendly lawsuit, sued USEPA to make it use its authority under the Clean Water Act to promulgate a total maximum daily load ("TMDL") for the Chesapeake Bay, in order to take control of the agenda for the clean-up of the Bay. In settlement of the lawsuit, USEPA generated the 2010 Bay TMDL and assigned to each Chesapeake Bay watershed state load allocations for the amount of nitrogen, phosphorus and sediments that each state would have to remove from the amount of such pollution currently being discharged to Bay tributaries. After the State of Maryland received its load allocation under the 2010 Bay TMDL, it determined that in excess of $14.5 billion dollars would have to be spent to meet its load allocation obligations. The State was unwilling to redirect its spending and/or to pass the additional taxes and fees necessary to fund this unprecedented obligation. The State, therefore, required each Maryland county to prepare a watershed implementation plan ("WIP") for meeting the 2010 Bay TMDL load allocation assessed against Maryland by USEPA and, among other mandates, passed legislation requiring the largest counties to adopt stormwater management fees (aka "rain tax") to raise the money necessary to implement the WIPs.

As counties undertook the WIP process and began examining what MDE and the Maryland Department of Natural Resources (MDNR) were doing and requiring counties to do in order to address Maryland's load allocation under the 2010 Bay TMDL, they recognized how useless the regulatory initiatives would be in making any meaningful improvement to the water quality of the Bay and how expensive, unproductive and inequitable Maryland's regulatory initiatives have been and would continue to be. They also recognized that the largest problems contributing to the pollution of the Bay were being ignored.

Major Sole Source of Sediment and Nutrient Loading

One of the largest problems being ignored was the impact of scour from the floors of the reservoirs behind the three hydroelectric power dams in the lower Susquehanna River during storm events. During storm events, suspended solids that were trapped behind the dams during low flow and normal flow conditions are agitated, become re-suspended in the river and flow into the Bay. Over the course of a 2 - 8 day storm event, including the high flows that are generated by runoff from the storm, as much as one-half-year to 12+ years of the average loading of suspended solids from the Susquehanna River are scoured and dumped in the upper Bay (*i.e.*, the Maryland portion of the Bay) over such 2 - 8 day period. Such massive loading over such a short period of time has a devastating impact, and a much greater impact than if such solids flowed into the Bay when they originally became suspended in the river.

Reports studying the impact of Hurricane Agnes on the Bay published by the Johns Hopkins University Press in 1978 concluded that 56% of the sediments flushed into the Bay during the hurricane were scoured from the floors of the reservoirs behind the hydroelectric power dams in the lower Susquehanna River - 20 million tons of sediments out of the 32 million tons of sediments flushed into the upper Bay from the Susquehanna River by the hurricane.

In August 2012, Robert M. Hirsch of the Department of Interior's U.S. Geological Survey ("USGS") published a report concluding that the Conowingo Pond had virtually reached dynamic equilibrium.[3] In presenting the report, Mr. Hirsch discussed the scour phenomena but advised that the bathymetric data (*i.e.*, raw data of the depth from surface to floor of the reservoirs before and after storm events) did not exist. The bathymetric data necessary to determine the amount of scour during different storm events still does not exist and has never been generated. Exelon, in the pending Federal Energy Regulatory Commission ("FERC") relicensing proceeding for the Conowingo Hydroelectric Project, has requested a year-to-year extension of its current license while it collects the bathymetric data after storm events necessary to engage in meaningful modelling and prediction.[4]

<u>Mistaken Conclusions</u>

Different persons are reporting that the LSRWA Draft Report ("DLSRWA") concludes that scour from the floor of the reservoir of the Conowingo Pond is not a significant source of pollution to the Bay. Such a conclusion, as discussed more fully below, is devoid of any scientific validation and support. The raw data necessary to make such a determination is nonexistent. There is no bathymetric data sufficient to enable a scientifically valid determination of the amount of scour from the floors of the reservoirs behind the hydroelectric power dams in the lower Susquehanna River. There is no scientific data on which to predicate a determination of the volume of nutrients bound to sediments in the Susquehanna River or what percentage of such bound nutrients become bioavailable when such scoured sediments are flushed into the Bay.

When the LSRWA was undertaken, the impact of scour on the Bay was not an issue. That issue became a hot topic because it was raised in the FERC relicensing proceeding for Conowingo Dam by the Coalition and because the Coalition has focused public attention on the issue.

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[3] Robert M. Hirsch, USGS, Scientific Investigations Report 2012-5185, *Flux of Nitrogen, Phosphorus, and Suspended Sediment from Susquehanna River Basin to Chesapeake Bay during Tropical Storm Lee, September 2011, as an Indicator of the Effects of Reservoir Sedimentation on Water Quality* at 4, 13 (August 30, 2012) (observing, when the Conowingo Reservoir is full and no longer has any trapping capacity, even at normal flows, there will be a 2% increase in total annual nitrogen loading from the Susquehanna River, a 70% increase in total annual phosphorus loading, and a 250% increase in annual sediment loading).

[4] Letter dated December 22, 2014 from Jay Ryan on behalf of Exelon to John B. Smith, Chief of the Mid-Atlantic Branch of the Division of Hydropower Licensing of FERC re: Conowingo Hydroelectric Project, FERC Project No. 405, Response to Letter from Office of Energy Project Regarding Withdrawal of Section 401 Water Quality Certification Application.

Several truths are inescapable:

(A) Instead of dredging sediments from behind the dams from the Bay after they have been flushed into and dispersed throughout the upper Bay causing damage to the marine environment and fisheries of the Bay, such sediments should be dredged from above the dams (thus ensuring that such pollution never reaches the Maryland portion of the Bay).

(B) Before Marylanders spend billions of dollars to implement clean-up programs that can be rendered completely useless by scour from a significant storm event and pollution above the dams, the harm caused by above the dam sediments and pollution needs to be addressed. It is a fool's errand to spend money on band-aids to cover superficial cuts before stopping the bleeding from the artery; and that is precisely what is happening when billions of tax dollars are spent on *de minimus* issues downstream while nothing meaningful is done to abate the harm above the dams.

(C) Years worth of the average annual loading of sediments and nutrients have been discharged from the Susquehanna River into the Bay in the matter of days during recent storm events. If the sediments and nutrients are not from scour, they are from upstream (above the dams) sources. None of the other states in the Chesapeake Bay watershed have adopted wastewater treatment discharge limits that are close to as stringent as those imposed on Maryland by MDE. None of the other states in the Chesapeake Bay watershed have stormwater management requirements that are as demanding and expensive to meet as those in Maryland. No other state in the Chesapeake Bay watershed has a "phosphorus management tool" that is as stringent and as costly to comply with as that mandated by the recently re-promulgated Maryland regulations. No other state in the Chesapeake Bay watershed has individual septic requirements that are as stringent and costly to comply with as Maryland. The above has been true for several decades, yet the additional expenditures paid by Marylanders have not resulted in any meaningful overall improvement to the water quality of the Bay. Instead, such regulations and expenditures have driven businesses and residents out of Maryland and caused fatigue among those being taxed to "save the Bay."

The foregoing inconvenient truths are ignored because such truths cause the public to question the actions being advocated by such agencies and organizations.

The DLSRWA attempts to minimize the significance of scour to the Bay without adequate scientific underpinning. Regulatory agencies and environmental organizations are stating that the DLSRWA concludes that the problems at the Conowingo Dam are not as bad as scientists thought. The statement is almost laughable because the problem had been completely ignored until it was raised by the Coalition. No thought was given to the problem, and now the problem is recognized as real such that MDE has required Exelon to engage in additional data compilation and studies before MDE will even begin its consideration of the Section 401 Clean Water Act water quality certification needed by Exelon in the FERC relicensing process for

Conowingo Dam. What is disconcerting for the reasons explained more fully below is that the DLSRWA discusses predicted minimum impacts instead of discussing the full range of impacts discussed in the projections underpinning the report.

DLSRWA Modelling Concerns

The work underpinning the DLSRWA is a misguided exercise in modelling. Considerable time and effort has been spent discussing and manipulating models to generate meaningless results instead of gathering and modeling meaningful information.[5] At least nine (9) different models were used to generate data for use in other models and for making predictions and estimations:

(1) The Chesapeake Bay Environmental Model Package (CBEMP) is used to project the water quality of the Chesapeake Bay. That model is predicated on a suite of models consisting of:

 (a) A watershed model (WSM);

 (b) A hydrodynamic model (HM);

 (c) A water quality eutrophication model (WQM);

(2) A computational hydrodynamics in a three-dimensions model (CH3D);

(3) A USACE integrated compartment water quality model (CR-QUAL-ICM), which model is predicated on a suite of models consisting of:

 (a) An ICM model;

 (b) A WQM model; and

 (c) A WQSTM model;[6]

(4) An adaptive hydrodynamics model (ADH), which was used for estimating sediment erosion in the Conowingo Pond based on projected data derived from other models; and

(5) A hydrodynamic engineering center river analysis system model (HEC-RAS), which was used to generate a rating curve for use in the ADH.[7]

[5] "The [DLSRWA] investigation involves the use of numerous predictive environmental models and the transfer of information between the models." Carl F. Cerco & Mark R. Noel, *Application of the Chesapeake Bay Environmental Model Package to Examine the Impacts of Sediment Scour in Conowingo Reservoir on Water Quality in the Chesapeake Bay, A Report to the U.S. Army Corps of Engineers, Baltimore District, September 2014 Final Report* at 2.
[6] *Id.* at Fig. 1-2.
[7] *Id.* at 3.

DLSRWA Data Concerns

What little raw data was used in the CBEMP model was generated from raw data collected in the period from 1991 - 2000.[8] This outdated data as well as data generated by other models not designed to determine scour was used to run applications under the ADH for 2008 - 2011 timeframe. The ADH was run to project the amount of scour from the floors of the Conowingo Pond and Lakes Aldred and Clarke that serve as the reservoirs behind the three major hydroelectric power dams in the lower Susquehanna River: the Conowingo Dam, the Holtwood Dam and the Safe Harbor Dam.

Peter Moskos, a Harvard educated criminologist, author and professor, made a comment that appropriately captures the deficiency of the modelling exercises underpinning the DLSRWA: "And if you have bad data, it doesn't matter what fancy quantitative methods you use. It's putting lipstick on the damn pig of correlation." In short, a modelling conclusion is only as good as the data underpinning the modelling effort. When the data needed to generate a predictive model does not exist, the predictive conclusions generated from a cluster of other models used to generate data for use in the predictive model are meaningless.

Nowhere does the DLSRWA concisely list the raw data underpinning the reported results of the ADH modelling efforts. Nowhere does the DLSRWA clearly describe what actual data was used in what manner to generate the data on which particular modelling exercises were run. To provide such data would expose how the findings and conclusions of the DLSRWA are superficial.

The raw data necessary to determine the impact of scour from the ponds/lakes/reservoirs in the lower Susquehanna River on the Bay during storm events simply does not exist.

No bathymetry has been run before and after a major storm event in the Conowingo Pond, Lake Aldred or Lake Clark. Such bathymetry runs would show the elevation of the floor of such lakes and pond before and after a storm. From the difference in depth, the volume of scour could be determined and the amount of scour from a storm event with a peak flow measured in cubic feet per second through each dam could be determined. There is, therefore, no raw data from which to determine the volume of sediments scoured from the floors of such reservoirs during a storm event with a known flow rate.

Measuring bathymetry is not complicated. Sonar technology in conjunction with global positioning system (GPS) technology is relatively inexpensive and widely available. Such technology could be installed on any small and transportable boat and used to rapidly and efficiently chart the bathymetry of the lakes and pond before and after storm events. NOAA has published how its vessels equipped with such technology can record the topography/bathymetry of floor of the Bay so accurately that NOAA employees can detect if oysters have been illegally harvested from a harvest restricted area of the Bay.[9]

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[8] *Id.*

[9] *See* link: http://www.stardem.com/news/environment/article_f6f9782b-fbef-50de-890a-c99d918d2210.html, NOAA *analyzing oyster habitat, restoration* (Sept. 16, 2014). The National Oceanic and Atmospheric

Further evincing the complete void of data necessary to determine scour from the floor of the Conowingo Pond during storm events and the impact of such scour on the Bay is the December 22, 2014 letter from Jay Ryan on behalf of Exelon to John B. Smith, Chief of the Mid-Atlantic Branch of the Division of Hydropower Licensing of FERC re: Conowingo Hydroelectric Project, FERC Project No. 405, Response to Letter from Office of Energy Project Regarding Withdrawal of Section 401 Water Quality Certification Application. In the letter, Exelon's representative explains to the FERC why it withdrew its application for a Clean Water Act 401 water quality certification from MDE, why Exelon will keep re-filing and withdrawing the application over the next several years while it accumulates the raw data before and after storm events necessary to meaningful prepare an analysis of the impact of sediment scoured from the floor of the Conowingo Dam during storm events on the Bay, and why it would like FERC to issue one year renewal licenses for as many years as it takes to obtain the raw data necessary to meaningfully analyze the amount of scour and the impact of scour from the floor of the Conowingo Pond during storm events. If the data to conduct a meaningful analysis already existed, it would have been completely unnecessary for Exelon to make this request and for MDE to demand that additional raw data being gathered and analyzed before MDE is willing to consider Exelon's Clean Water Act 401 water quality certification application. The actions of MDE and Exelon constitute an admission that the raw data necessary to determine the amount of scour during storm events and the impact of such scour on the Bay simply does not exist.

DLSRWA Guesstimates and Assumptions

For the DLSRWA, scour has been guesstimated by comparing samples of total suspended solids (TSS) taken at various points above and below the Conowingo Dam and guesstimating the portion of such suspended solids attributable to stormwater runoff versus the portion attributed to scour from the floor of the Conowingo Pond, Lake Aldred and Lake Clark.

There is no analysis or even any discussion from a statistical science perspective of the confidence level of any data generated by any of the models or any conclusions or determinations made based on any of the modelling analysis. Undoubtedly that is because any such discussion would acknowledge that there is insufficient raw data to generate any meaningful modelling data or to draw any meaningful conclusions to a reasonable degree of scientific certainty.

Michael Langland, one of the USGS scientists, has admitted that there was insufficient data to calibrate the ADH model for river flows greater than 600,000 cfs. The table of predicted scour during storm events generating different flow rates in the lower Susquehanna River evidences the wide range of scour estimates based on the available data and modelling efforts.[10] The existing data and modelling efforts predict that between one-half million (500,000) tons and

Administration has a boat with a multibeam – a surveying technology outfitted with 256 laser beams to get a data driven view of the bottom by bouncing sonar and laser beams off the bottom and collecting the data through a system on the boat – such surveys can be resolved both horizontally and vertically to within a few centimeters.

[10] *See* Michael J. Langland & Edward H. Koerkle, *Calibration of One Dimensional Hydraulic Model HEC-RAS for Simulating Sediment Transport through Three Reservoirs, Lower Susquehanna River Basin, 2008 - 2011*, USGS, Attachment A-1: Additional Information for Susquehanna River at Marietta, Pa. and Conowingo, Md. and Conowingo Reservoir at 41, Table A3.

1.5 million tons will be scoured from the floors of the lakes and pond during a one-in-five-year storm event (between 21% and 44% of the total sediment load during such a storm event). Thus, a single 1 - 3 day storm event will generate flows sufficient to scour from the floor of the Conowingo Pond and Lakes Aldred and Clarke one-half to 1 year-worth of the average annual sediment loading from the Susquehanna River and deposit such amount in the upper Bay in such 3-day period. The existing data and modelling efforts predict that between 10.5 million tons and 15.5 million tons will be scoured from the floor of the lakes and pond during a one-in-sixty-year storm event (between 39% and 50% of the total predicted sediment load during such a storm event).[11] Thus, one such 4 - 8 day storm event will scour and deposit from the floor of the Conowingo Ponds and Lakes Aldred and Clarke between 8 - 12 years-worth of average annual sediment loading from the Susquehanna River and deposit such amount in the upper Bay over the course of eight days. The Safe Harbor Dam, the Holtwood Dam and the Conowingo Dam have so altered the flow of the Susquehanna River and sediments in the Susquehanna River that one to twelve years or more of the average annual sediment loading from the Susquehanna River can be delivered over the course of a week or less to the upper Bay.

Marginalizing Storm Events

The last 60 year storm event occurred in 1972 (*i.e.*, Hurricane Agnes). The next 60-year storm event will occur during the term of the 40+ year license requested by Exelon from FERC for the continued operation of the Conowingo Hydroelectric Power Project. This means that during the next 20 years, we can expect that scour from the floor of reservoirs behind the three dams in the lower Susquehanna River will completely annihilate the marine habitat in the upper Chesapeake Bay if no action is taken to reduce the volume of sediments in those reservoirs.

The persons who drafted and edited the DLSRWA inexplicably chose the lowest levels of predicted scour to report in the DLSRWA and upon which to predicate the findings and conclusions made in the draft report without providing any explanation of why the lowest values, as opposed to the highest values or the middle values were selected. What agenda is served and whose interests are benefitted by downplaying the impacts of sediment scour?

Toxic Pollutants and Dredging

USACE does not want to dredge above Conowingo Dam because it will have to deal with the hazardous and toxic pollutants that are in those accumulated sediments. Currently, when USACE dredges sediments from the navigable channels of the Bay, it does not have to give significant concern to the hazardous and toxic substances found in the sediments in looking for a place to safely deposit such sediments. Such sediments historically have been deposited in impoundments in the Bay such as Poplar Island and other islands composed of dredged sediments in the Bay. Attention will be focused on the hazardous and toxic sediments that are dredged above the dams in the lower Susquehanna River in determining how and what to do with such sediments. The cost, therefore, in properly disposing of such sediments will be magnified, because instead of allowing such hazardous and toxic pollutants to discharge into the Bay and

[11] *Id.*

then largely ignoring them when determining where to deposit sediments dredged from the navigable channels, such hazardous and toxic pollutants will have to be addressed up front.

Exelon does not want to dredge sediments from behind the dams because in so doing it will exercise control over such sediments and in so doing will become responsible for disposing of such sediments in a manner that the hazardous and toxic pollutants in such sediments do not leach into the environment. Dredging sediments under the current legal framework will confer liability on Exelon for such hazardous and toxic substances. In fairness to Exelon, much of the hazardous and toxic pollutants in the accumulated sediments were not generated by Exelon or the power companies acquired by Exelon, so Exelon will fight hard not to dredge.

The DLSRWA is devoid of any analysis or meaningful discussion of the nutrients and pollutants that are bound to the sediments resting on the floor of the lakes and pond behind the three dams in the lower Susquehanna River. Studies conducted by the Susquehanna River Basin Commission ("SRBC") for MDE have determined that that the following nutrients and pollutants are bound to such sediments:

(i) Herbicides;

(ii) Pesticides;

(iii) Sulfur and acid mine drainage;

(iv) Coal;

(v) Polychlorinated Bi-phenyls (PCBs);

(vi) Nitrogen; and

(vii) Phosphorus.

The presence of such hazardous and toxic pollutants comes as no surprise given the extensive agricultural, mining and power generation activities that have historically been conducted in the Susquehanna River watershed.

During the December 9, 2014 presentation on the DLSRWA made at the Harford County Community College, Dan Bierly of the USACE, with acquiescence from the other panelists (*i.e.*, Bruce Michael from MDNR, Mark Bryer from The Nature Conservancy, Rich Batiuk from USEPA Reg. III, Matthew Rowe from MDE and Michael J. Langland from USGS) acknowledged that such nutrients and toxic and hazardous pollutants were bound to the sediments deposited on the floors of the pond and lakes in the lower Susquehanna River.

No study has been conducted to determine what nutrients that are bound to the sediments in the lower Susquehanna River estuary are released into the water of the Bay in the less oxygenated, more saline, more acidic, and warmer Bay estuary. Assumptions, for example, that none of the phosphorus that is bound to such sediments above the Conowingo Dam were released into the Bay estuary when such sediments were transported over or through the dam and into the Bay simply are unfounded. There are 4 - 8 ppm of salt in the Bay waters as far north as Tolchester and phosphorus and nitrogen that are bound to such sediments while they were in the Susquehanna River undoubtedly are released into the water in the Bay once such sediments are scoured and flushed into the Bay. Likewise, the coal, herbicides, pesticides, sulfur and acid mine drainage, and other toxic substances bound to such sediments above the dam probably are released into the Bay when such sediments are flushed through or over the dam. Again, during the December 9, 2014 presentation on the DLSRWA made at the Harford County Community College, Messrs. Bierly and Rowe acknowledged that no such analysis was made and there currently is no scientific basis for determining the impact of the release of nutrients bound to the sediments scoured from the floor of the lakes and the pond behind the dams in the lower Susquehanna River. Mr. Bierly further expounded on the limited scope of the LSRWA, the limited funding for the study and the limited sampling conducted in conjunction with the study.

Mr. Bierly stated some of the problems with dredging, *e.g.*, there are hundreds of millions of tons of sediments in the pond and lakes behind the three dams that have accumulated over the last 80 ± years and very limited places to deposit such sediments in close proximity to such ponds and lakes. The following concerns were not spoken, but undoubtedly influence the decision making process:

(a) USACE only has to dredge the navigable channels in the Bay. Sediments scoured and flushed into the Bay during storm events settle out all over the shallows and non-dredged tributaries in the upper Bay, and so a lesser percentage of such sediments that enter the Bay from above the dams probably need to be dredged by USACE, although no study ever has been conducted to make such a determination.

(b) Sediments dredged from the Bay historically have been deposited on manmade islands and containment areas in the Bay with little to no thought given to the leaching of nutrients and toxic and hazardous pollutants from such islands and containment areas. This historical course of dealing has generally allowed USACE to ignore the impacts of such nutrients and toxic and hazardous pollutants. Withdrawal of sediments above the dams will entail the analysis of such nutrients and pollutants and regulators will not allow the disposal of above the dam sediments until there has been an accounting of how such nutrients and toxic and hazardous substances will be neutralized or responsibly addressed.

(c) No one has been willing to answer the question of whether Exelon will assume liability for the nutrients and toxic and hazardous pollutants in above-dam sediments if it undertakes dredging operations. In fairness to Exelon, the dams impact the timing of the release of such nutrient and toxic and hazardous pollutant laden sediments into the Bay and the devastating shock of the massive releases over a short period of time due to the trapping and scour phenomena caused by the dams. With the exceptions of the PCBs and chemicals associated with keeping power company water intakes and discharge lines free and clear of biological life and growth, such nutrients and pollutants were not generated by the power companies, so it is not fair to saddle them with liability for such nutrients and toxic and hazardous pollutants in conjunction with remedial action undertaken to ameliorate the impact from trapping and scour.

Exelon's Involvement

Exelon has directly and indirectly contributed millions of dollars to Federal and State campaigns and has made undisclosed contributions, probably in the millions of dollars, to the environmental organizations that were allowed to participate in the decision making process underpinning the preparation of the DLSRWA. Exelon funded a large portion of the study underpinning the DLSRWA. Exelon's consultants, Gomez & Sullivan, had a voice in and directly participated in the decisions made about how to conduct the study, what assumptions to make, what data to use, and what conclusions to report. Exelon undoubtedly expects and demands a return on this investment. Exelon undoubtedly has influenced the politics underpinning the decision making processes that have led to the findings and conclusions reported in the DLSRWA.[12]

Non-Compliance With Federal Law

The studies underpinning the DLSRWA and the preparation of the DLSRWA were not undertaken in compliance with the National Environmental Policy Act (NEPA), the Federal Advisory Committee Act (FACA), the NEPA-implementing regulations of the President's Counsel of Environmental Quality (CEQ), or applicable Presidential Executive Orders. Select special interest groups including Exelon and environmental organizations that probably have been the recipients of significant monetary and non-monetary contributions from Exelon, Exelon executives and officials and non-profits funded by Exelon were granted a seat and voice at the study table. Exelon, directly and indirectly, was given considerable influence over the reported outcomes and there has been no opportunity for persons with countervailing perspectives to influence the decisional process and the reported outcomes. NEPA, FACA and the CEQ regulations were promulgated to preclude exactly what has happened in generating the DLSRWA. The report legally is not entitled to be given any deference in any governmental decision making process.

[12] The Coalition repeatedly was denied a right to participate in quarterly meetings where decisions relative to the data to obtain and to utilize and the assumptions to be made and utilized in generating the modelling efforts and reported the conclusions underpinning the DLSRWA were made. The process was and is not open and has wholly failed to comply with the requirements of NEPA, FACA, the regulations of the President's CEQ, and Presidential Executive Orders. The process is not open and has not been transparent.

The Elephant In The Room

Unfortunately, Federal and State environmental and natural resources agencies have conveniently chosen to ignore the impact to the Bay estuary of the hydroelectric power dams in the lower Susquehanna River for over eight (8) decades. USEPA conveniently and quite erroneously predicted in the 2010 Bay TMDL that the Conowingo Pond would not reach dynamic equilibrium and discontinue acting as a net trap of sediments until 2025 or 2030.[13] The same suite of models used to support that erroneous assumption in the 2010 Bay TMDL were used in the "studies" underpinning the DLSRWA.

Mr. Batiuk of USEPA Region III, during the December 9, 2014 presentation at Harford County Community college, as well as the other presenters (Messrs. Bierly and Michael), admitted that the Conowingo Pond is now in a state of dynamic equilibrium- *i.e.*, the Conowingo Pond no longer acts as a net trap of sediments and pollutants washing down the Susquehanna River to the Bay. They acknowledge that EPA's 2010 Bay TMDL prediction based on the CBEMP was off by 12-17 years.

MDNR and MDE completely ignored the impact of sediment scour from the floors of Lake Aldred, Lake Clarke and the Conowingo Pond in the 2010 Bay TMDL process and the FERC relicensing process until the Coalition made it an issue that those agencies could no longer ignore. Maryland's WIP makes no mention whatsoever of Conowingo Dam or sediment scour due to storm events. Shamelessly, Bruce Michael of MDNR explained during the December 9, 2014 informational meeting how MDNR and the other regulatory agencies have been aware of the problem for decades, and indeed they have been. Studies prepared and disseminated by the SRBC have documented the problem of sediment scour from the lower Susquehanna River for several decades. Unfortunately, the warnings sounded by such reports have been ignored throughout that period of time.

Conclusion

The LSRWA has been integrally linked with the FERC relicensing process for Conowingo Dam. The Draft Environmental Impact Statement prepared by FERC repeatedly references the LSRWA and what will be learned and divulged by that report.

At the December 9, 2014 public presentation, Mr. Batiuk of USEPA Region III stated that because of the findings of the DLSRWA, USEPA was in the process of recalibrating the 2010 Bay TMDL to recognize that the Conowingo Dam no longer acted as a net trap and, therefore, all waste load allocations would have to recalculated and revised.

By letter dated December 22, 2014 Exelon, in the FERC relicensing proceeding, requested FERC to issue temporary 1-year license renewals while it participated in the LSRWA with MDE in order to determine the impact of its operation on the water quality of the Bay.[14]

[13] 2010 TMDL, Apx. T at T-2.
[14] *See*, *supra*, FN4.

In short, the LSRWA is the linchpin for two major federal actions that will have significant and far reaching environmental impacts: (1) the FERC long-term relicensing of the Conowingo Hydroelectric Power Project and (2) the USEPA 2017 Chesapeake Bay TMDL recalibration. Given that this study will inform such major Federal actions, it should be conducted in compliance with NEPA, FACA, the CEQ regulations implementing NEPA, and the applicable Executive Orders issued by Presidents of the United States.

The Clean Chesapeake Coalition counties are stakeholders in both of the foregoing Federal actions and in myriad efforts to improve the water quality of the Chesapeake Bay. MDE and the Maryland General Assembly have empowered and tasked the counties with developing, funding and implementing WIPs and to implement and fund other local legislative and regulatory programs to improve the water quality of the Bay. The ability of the counties to implement such programs is directly impacted by the TMDL and the FERC relicensing of the Conowingo Dam. Economic development in the counties and the ability of the counties to retain existing businesses (including but not limited to agricultural and fishery dependent businesses) and to attract new businesses and residents is directly dependent on expenditures and programs associated with the WIPs, the 2010 Bay TMDL and the health of the Bay.

The members of the Clean Chesapeake Coalition request USACE, FERC and USEPA to set aside the DLSRWA and to reinstitute the study process in full compliance with NEPA, FACA, the NEPA implementing regulations promulgated by the President's CEQ, and a number of Presidential Executive Orders.

As discussed, the DLSRWA and appendices contain a host of information that was not well organized or concisely and clearly presented as required by NEPA and the NEPA implementing CEQ regulations. What follows, in no particular order, are additional concerns, questions and observations relative to the DLSRWA. The attached "Summary and Comments on Lower Susquehanna River Watershed Assessment Draft Report and Appendices" are by no means meant to be comprehensive or all inclusive; but are expected to be considered and addressed.

Any questions about the Coalition's comments concerning the DLSRWA may be directed to Jeff Blomquist (jblomquist@fblaw.com or 410-659-4982), Michael Forlini (mforlini@fblaw.com or 410-659-7769) or Chip MacLeod (cmacleod@fblaw.com or 410-810-1381).

Summary and Comments on Lower Susquehanna River Watershed Assessment Draft Report and Appendices

The following outline contains statements made in the Draft Lower Susquehanna River Watershed Assessment report and the Clean Chesapeake Coalition's (Coalition) comments regarding the Draft Report and its Appendices. Page numbers are included to provide reference to those statements made within the Draft Report.

DRAFT REPORT

Statements Regarding the Use and Limitations of Models in the Draft Study:

- According to the Draft LSRWA Report ("Draft Report"), an HEC-RAS model was designed primarily for non-cohesive sediment transport (sands and coarse silts) with additional, but limited, capability to simulate processes of cohesive sediment transport (generally medium silts to fine clays). Thus this model may not be suitable for all reservoir simulations, especially in areas of highly variable bed shear stress (the force of water required to move bed sediment) and active scour and deposition. Limitations of the model most likely resulted in less than expected deposition for the 2008 - 2011 simulation and less than expected erosion (scour) for the Tropical Storm Lee seven day event simulation, when compared to other approaches and estimates. (Pg. 33).

Comment DR-1: A one dimensional model cannot account for scour since there is no lateral variable to account for sediment load on the river basin. This was Langland's (*i.e.*, USGS') same concern regarding Exelon's use of the HEC6 model in their Sediment Transport Study.

- Produced two sediment inflow scenarios: Scenario 1 which included no scour from upper reservoirs and Scenario 2 which attempted to account for scour by estimating that 1.8 million tons of scour from the upper two reservoirs for a total inflow load of 24 million tons.

Comment DR-2: USACE's two dimensional AdH model computed detailed hydrodynamics and sediment transport in and out of Conowingo Reservoir, and the response of the reservoir and flats area to various sediment management scenarios and flows. According to the Draft Report the AdH simulates hydrodynamics and sediment transport. However, this may not the case given the following limitations:

- A one dimensional model, HEC-RAS, was used to provide data for the AdH model; the two dimensional AdH model utilized the HEC-RAS model results (sediment load and flow) from Holtwood Dam as the inflowing sediment load boundary condition. (Pg. 66).

- Through a validation process, the application of the AdH two dimensional model to the Conowingo Reservoir and Susquehanna Flats system was determined to be adequate for simulating general reservoir sediment scour and deposition modelling scenarios for the LSRWA. However, there is some uncertainty that remains with the estimates provided by the AdH model. (Pg. 37).

Comment DR-3: What was the validation process? Was it consensus at the meeting? By whom?

- The AdH sediment model (a two dimensional model) required bed sediment data. Only 8 bed core samples were taken from Conowingo Reservoir to a maximum depth of only one foot. Core samples were required to determine the inception of erosion (critical shear stress for erosion) and the erosion rate used to develop six material zones. (Pg. 19). The sediment bed in the AdH Model was approx. 3 feet deep. The properties of the lower 2 feet were either approximated from the SEDFlume data results (which is the one foot data) or determined from literature values.

Comment DR-4: How old is the SEDFlume data? If the age of the data is different than model runs how is this an accurate portrayal? What literature values were used?

- The hydrologic period used for these scenarios was 2008-11. This 4-year time period was utilized because it included low (less than 30,000 cfs.) moderate (30,000 to 150,000 cfs.) and high (greater than 150,000 cfs.) flows as well as two major flood events (above 400,000 cfs.). Each HECRAS simulation provided a range of probable conditions and also provided a range of uncertainty in the boundary condition flows. (*See* Appendix A for more details on the HECRAS analyses and model.) (Pg. 33).

- The second modelling tool utilized for this LSRWA effort was the AdH model. The AdH model was developed at the USACE's ERDC, located in Vicksburg, MS, and has been applied in riverine systems around the country and world. For this assessment, the AdH model was constructed and applied from Conowingo Reservoir to the Susquehanna Flats just below the Conowingo Dam, as shown in Figure 3- 2. Modelling scenarios were run by ERDC team members. (Pg. 34). Additional details about the AdH model and analyses are available in Appendix B. The AdH model was selected for the LSRWA effort and for use in the Conowingo Reservoir/Susquehanna Flats area (vs. HECRAS) because of the higher uncertainty of conditions and processes in this area, particularly in comparison to the upper two reservoirs which were understood to be in dynamic equilibrium for several decades. (Pg. 35). All AdH simulations that were run for the LSRWA effort were conducted with the same Susquehanna River flow and inflowing sediment boundary conditions. Using the HECRAS input, the 4-year flow period from 2008 - 2011 was simulated in the model. As noted earlier, this time period was utilized because it included low, moderate and high flows as well as two major high-flow events (above 400,000 cfs.). (Pg. 36). The AdH model was also utilized to estimate the effectiveness of selected sediment management strategies to reduce sediment loads transported through Conowingo Reservoir and Susquehanna Flats. Ultimately, the AdH model output was sediment transport, scouring loads or erosion from the reservoirs which were utilized in Chesapeake Bay Environmental Model Package (CBEMP) to compute the impact of the sediment management strategies on water quality in Chesapeake Bay. (Pg. 37).

Comment DR-5: AdH output data put into a model that has incorrect data based on 2010 TMDL with incorrect estimates? How can a two dimensional model rely on data generated from a one dimensional model?

- Through a validation process, the application of the AdH two dimensional model to the Conowingo Reservoir and Susquehanna Flats system was determined to be adequate for simulating general reservoir sediment scour and deposition modelling scenarios for the LSRWA. However, there is some uncertainty that remains with the estimates provided by the AdH model that were considered in results, as described below. One source of uncertainty was that the AdH model was not capable of simulating sediment passing through the flood gates of Conowingo Dam. Therefore, dam operations are not simulated in detail in the model; these include flood gate operation and Peach Bottom Atomic Power Station sequences. (Appendix K provides a description of dam operations.) For this study Conowingo Dam was modeled as an open boundary with downstream control represented by the water surface elevation at the dam. This limitation impacted how sediment was spatially distributed in the lower reach of Conowingo Reservoir near the dam. To minimize this uncertainty more sophisticated methods would need to be developed to incorporate dam operations in Conowingo Reservoir. (Pg. 37).

Comment DR-6: How can the two dimensional model (AdH model) provide accurate results with an open boundary approach? This approach is very limited given the cyclical movement of water (kicking up more sediment scour) as it is resisted by the dam.

Comment DR-7: According to Chesapeake Bay Program's (CBP) Scientific and Technical Advisory Committee (STAC): "The AdH application in this study has been developed to the point that scour and deposition is consistent with what is already known from survey and sampling observations. However, the AdH model application does not refine that empirical understanding. The uncalibrated and weakly constrained model application provides an essentially heuristic basis for scenario evaluation and the AdH model has not, as yet, added substantial new understanding of the sediment dynamics of the reservoir. The modelling does not strongly reinforce the existence of a scour threshold at 300,000 and 400,000 cfs. At best, it can be said that an uncalibrated model was found that produces results that are consistent with that particular threshold." (Pg. 22, Attachment I-7). How is the sediment dynamic of the reservoir evaluated and taken into account? Especially during episodic events?

- Another source of uncertainty concerned fine sediment flocculation and consolidation. Sediment transport models in general do not have a sophisticated approach to simulating fine sediment flocculation. Suspended fine sediment can either exist as primary silt and clay particles or in low energy systems such as reservoirs form larger particles in the water column due to flocculation. Particles that flocculate are larger and have higher settling velocities, thus their fate in the reservoir can be quite different than the lighter primary particles (Ziegler, 1995). When fine sediment particles deposit on the reservoir bed they compact and consolidate over time. As they consolidate the yields stress increases, meaning that the resistance to erosion becomes greater. Higher flows and subsequent bed shear stresses are required to scour the consolidated bed. Laboratory results show that sediment that erodes from consolidated beds may have larger diameters than the primary or flocculated particles (Banasiak, 2006). Scour may result in re-suspension of large aggregates that re-deposit in the reservoir and do not pass through the dam. To add to the complexity of this phenomenon, the large aggregate particles scoured from the bottom during a high flow event can break down to smaller particles in highly turbulent conditions. Thus the fate of inflowing sediment particles in the reservoir is highly variable and difficult to capture with current modelling techniques. The AdH model has the capability to relate flocculation to concentration but not to other variables such as shear stress which determines flock particle size and the overall fate of the sediment. The ability to predict flocculation dynamics is important to track the fate of sediment in a reservoir. To quantify this uncertainty numerous model simulations were conducted to determine a potential range of values. To reduce uncertainty more sophisticated methods would need to be developed to predict the flocculation dynamics. (Pg. 38).

Comment DR-8: How many numerous models were used? What is the margin of error pertaining to these models?

- The last major source of uncertainty was the limited data of suspended loads during storms and bed sediment erosion characteristics. Currently, the suspended sediment samples are collected from one location in Conowingo Reservoir. Because of the danger of sampling during large storms samples are not currently collected at the peak of the largest storms. To verify the estimations of bed scour during large storms improved field methods are required for sampling storm concentrations or turbidity over the entire storm hydrograph. Additionally, more samples of the reservoir bed would provide more data on the erosional characteristics of the sediment which would reduce uncertainty. (Pg. 38).

Comment DR-9: Please explain those improvements to field measurements or methods?

- CBEMP. The final modelling tool utilized for this LSRWA effort was CBEMP. CBEMP is an umbrella term used to describe a series of models that are applied to the Chesapeake Bay and its watershed. CBEMP was developed by CBP, the state-federal partnership responsible for coordinating the Chesapeake Bay and watershed restoration efforts. CBEMP has had almost three decades of management applications supporting collaborative, shared decision-making among the partners (USEPA, 2010b). This suite of environmental models has an unrivaled capacity to translate loadings in the watershed to water quality in the Chesapeake Bay (Linker et al., 2013). CBEMP includes the same models and was applied using the same scenario development and simulation methods for this LSRWA effort as were used in the development of the 2010 Chesapeake Bay TMDL (USEPA, 2010a, Appendix D). (Pg. 39). In addition, the full suite of Chesapeake Bay models has been regularly updated and calibrated based on the most recently available monitoring data, about every 5 to 7 years over the past three decades. Linker et al. (2013) provides a complete description of the different phases and versions of the Chesapeake Bay models. Used properly, CBEMP provides the best estimates of water quality and habitat quality responses of the Chesapeake Bay ecosystem to future changes in the loads of nutrient and sediment pollutants. For this LSRWA effort, CBEMP had two major applications. The first application was a series of modelling runs conducted by USACE ERDC documented within Appendix C. These CBEMP application scenarios were utilized to estimate water quality impacts of selected watershed and land use conditions, reservoir bathymetries, a major storm (scour) event (January 1996) at different times of year, and selected sediment management strategies. Sediment erosion or scour from the bed of Conowingo Reservoir estimated from AdH was utilized as input for selected CBEMP scenarios. The second CBEMP application was a series of modelling runs conducted by CBP, as described, *infra*, in more detail in Appendix D.

- Chesapeake Bay WSM Model. The Chesapeake Bay WSM simulates the 21-year period (1985 - 2005) on a 1-hour time step (USEPA, 2010b). Nutrient inputs from manure, fertilizers and atmospheric deposition are based on an annual time series using a mass balance of U.S. Census of Agriculture animal populations and crops, records of fertilizer sales and other data sources. Best management practices (BMPs) are incorporated on an annual time step; nutrient and sediment reduction efficiencies are varied by the size of storms. Municipal and industrial wastewater treatment and discharging facilities and on-site wastewater treatment systems' nitrogen, phosphorus and sediment contributions are also included in the Chesapeake Bay WSM. (Pg. 39).

Comment DR-10: How is this model run protective of scour entering Maryland's waters?

- Chesapeake Bay Estuarine Models. The hydrodynamic model computes intra-tidal transport using a three dimensional grid framework of 57,000 cells (Cerco et al., 2010). The hydrodynamic transport model computes continuous three dimensional velocities, surface elevation, vertical viscosity, and diffusivity, temperature, salinity, and density using time increments of 5 minutes. The hydrodynamic model was calibrated for the period 1991 - 2000 and verified against the large amount of observed tidal elevations, currents, and densities available for the Chesapeake Bay. Computed flows and surface elevations from the hydrodynamic model were output at 2-hour intervals for use in the water quality model. Boundary conditions were specified at all river inflows, lateral flows and at the mouth of the Chesapeake Bay.

- The eutrophication model, referred to as the Chesapeake Bay Water Quality/Sediment Transport Model 6, computes algal biomass, nutrient cycling and DO, as well as numerous additional constituents and processes using a 15-minute time step (Cerco and Cole, 1993; Cerco, 2000; Cerco et al., 2002; Cerco and Noel, 2004). In addition, the Chesapeake Bay Water Quality/Sediment Transport Model incorporates a predictive sediment diagenesis component, which simulates the chemical and biological processes which take place at the bottom sediment-water interface after sediment is deposited (Di Toro, 2001; Cerco and Cole, 1994). (Pg. 40).

- The Chesapeake Bay Water Quality/Sediment Transport Model simulates water quality, sediment, and living resources in three dimensional in 57,000 discrete cells, which extend from the mouth of the Bay to the heads of tide of the Bay and its tidal tributaries and embayments, as depicted in Figure 3-5. The primary application period for the combined hydrodynamic model and eutrophication model covers the decade from 1991 - 2000. For LSRWA applications the 1991 - 2000 hydrologic record was retained as this is the hydrologic period that CBEMP is based upon. Additionally, this is the same hydrologic period employed by the CBP partners in development of the 2010 TMDL (USEPA, 2010a).

- 1996 January High-Flow Event Scenario. The January high-flow event in 1996 was selected as the event to observe water quality impacts for LSRWA scenarios requiring a storm event because it is the highest observed flow within CBEMP's 1991 - 2000 hydrologic period. High-flow events wash in loads (sediment and nutrients) from the watershed; if there is high enough flow these events scour additional loads from the reservoir beds behind the three dams on the lower Susquehanna River. (Pg. 44).

- A one-dimensional HEC-RAS model computed hydraulic conditions and sediment transport in the reservoir system and sediment loads to Conowingo Reservoir for use in the two-dimensional model the Adaptive Hydraulics (AdH) model.

Comment DR-11: MDE admitted that this data was limited in terms of the number of core samples and the depth taken at the DLSRWA Public Hearing Meeting in December 2014 at Harford Community College.

- Model was not capable of passing sediment through the gates, therefore, for this study the dam was modeled as an open boundary with downstream control represented by the water surface elevation. (Pgs. 38 and 149).

- Flow rates capped at approximately at 620,000 cfs. - 640,000 cfs. for Tropical Storm Lee. (Pg. 62; *see* Figure 4.1). Table 4.3- Pg. 63 shows an event of 798,000 cfs. having an occurrence of 1 in 25 years.

- Each reservoir bed consists of a number of layers. The lowermost layer is considered an inactive layer that will rarely, if ever, scour to any degree. Above that, there is an "active" scour and depositional zone. The surface of the active layer consists of a relatively thin mixing layer that is unconsolidated and may have a high potential for scour at flows less than the scour threshold. For modelling purposes, the active layer is estimated to have a depth of approximately of 2 to 3 feet; however, it is spatially variable due to bed composition and consolidation. (Pg. 65).

Comment DR-12: How do 8 core samples with a depth of 1 foot delineate the reservoir bed in a 14 mile reservoir?

- Sediment transport is directly related to particle size. (Pg. 60). Storms can potentially scour the silts and clays, which are easier to transport, while frequently leaving behind the coarser, sand-sized sediment. For example, in the lower portion of Conowingo Reservoir in 1990, particle size analysis from 2-foot deep sediment cores indicated the area had about 5 percent sand; in 2012, it was projected to have 20 percent sand based on all previous cores. The reservoir sediment data collected show that generally there is more sand in the bed upstream and silts and clays are more prevalent closer to the dam for all three reservoirs. Silt is the dominate particle size transported from the reservoir system with little sand (less than 5 percent) transported to the upper Chesapeake Bay (*see* Appendix A for further discussion). (Pg. 60).

Comment DR-13: Was this 20 year old data used to address the inadequacies of the 8 core samples?

Comment DR-14: Core samples used in model runs from Conowingo Pond are inadequate given discussion later in the DLSRWA on Pg. 60. Generating data from a one dimensional model to be used in a two dimensional model is uncomforting and frightening. In addition, the following statements quoted below from the DLSRWA shows the lack of data in the models as it relates to scour. Such statements attempt to justify insufficient data in the model runs:

- "…more samples of the reservoir bed would provide more data on the erosional characteristics of the sediment which would reduce uncertainty." (Pg. 38).

- "Uncertainties in the total sediment load entering Conowingo Reservoir will affect scour and deposition, and thus affect the total load output to the Bay. Consequently, to provide more information on reservoir mass balance, future sampling program should extend both upstream and downstream of Conowingo Dam. To quantify the uncertainty of the limited data available to the LSRWA effort numerous model simulations were conducted to determine a potential range of values." (Pg. 38).

- "In summary, of all the modelling uncertainties that exist, three are most critical for interpreting the Conowingo Reservoir modelling results. These include the potential for flocculation of sediment flowing into the reservoir, the potential for large sediment aggregates to erode from cohesive beds and dam operations. Because of these uncertainties the AdH model may potentially over-predict to some degree the transport of scoured bed sediment through the dam to the Chesapeake Bay. Appendix B provides further detail on the uncertainty associated with AdH, as well as documentation of the model inputs, outputs and calculations." (Pg. 39).

Comment DR-15: Over-predict? The Corps is saying that the lack of data is somehow portraying the problem in a negative light to undermine the severity of this problem. How could there be an over-prediction of the transport of scour bed sediment when model runs are capped at 600,000 - 640,000 cfs. instead of running the models at the more appropriate level of 900,000 cfs.?

- Chesapeake Bay Environmental Model Package ("CBEMP" – Chapter 3 of the DLSRWA). This model is used to determine dredging effectiveness. (Pgs. 136-140). Developed by CBP and based on computed loads from the watershed at key locations in the reservoir system including the Conowingo inflow and outflow. Watershed loads at the Conowingo outfall computed by the Watershed Model ("WSM") were supplemented by bottom scour loads estimated through AdH and through data analysis. The WSM is considered part of the CBEMP.

- CBEMP includes the same models used in the development of the 2010 Chesapeake Bay TMDL, and is based on land use, management practices, wastewater treatment facility loads, and atmospheric deposition from the year 2010. (Pg. 39). This run is considered to represent existing conditions to provide assistance with projected land use, management practices, waste loads, and atmospheric deposition upon which the 2010 Chesapeake Bay TMDL was based. (Pg. 45).

- CBEMP produces estimates, not perfect forecasts. Hence, it reduces, but does not eliminate, uncertainty in environmental decision-making. There are several sources of uncertainty summarized and discussed in more detail in Appendix C. (Pg. 49).

- One source of uncertainty is the exact composition of nutrients associated with sediment scoured from the reservoir bed. Two alternative sets of observations are presented in Appendix C, one based on observations at the Conowingo Dam outfall in January 1996 and one based on observations collected at Conowingo Dam during Tropical Storm Lee in September 2011. The nutrients associated with suspended solids differ in the two events with 1996 being lower. In fact, both data sets represent a mixture of solids from the watershed and solids scoured from the bottom so that neither exactly represents the composition of scoured material alone. The 2011 observations are consistent with samples collected in the reservoir bed (Appendix C, Attachment C-1), are more recent and represent a typical tropical storm event rather than the anomalous circumstances of January 1996. For this reason nutrient composition observed at Conowingo Dam in 2011 is preferred and was utilized to characterize the future and is emphasized in the DLSRWA. Several key scenarios were repeated with the 1996 composition, however, to quantify the uncertainty inherent in the composition of solids scoured from the reservoir bottom. (Pg. 50).

- Another source of uncertainty is the availability (*i.e.*, bioavailability) and reactivity of the nutrients scoured from the reservoir bottom. The majority of analyses of collected data at the Conowingo Dam outfall and from within the reservoir bed sediment quantify particulate nitrogen and particulate phosphorus without further defining the nature of the nitrogen or phosphorus. For the LSRWA effort, modelers opted to maintain the accepted, consistent particle composition that has been employed throughout the application of CBEMP. Uncertainty in the particle composition, and consequently, the processes by which particulate nutrients are transformed into biologically available forms still exists. (Pg. 50).

- Some uncertainty in computed storm effects on Chesapeake Bay would result from considering solely a January storm. Bay response to storms in other seasons might vary. To reduce this uncertainty the January storm was moved to June and to October. The June storm coincides with the occurrence of the notorious Tropical Storm Agnes, which resulted in the worst recorded incidence of storm damage to the Bay. The October storm corresponds to the occurrence of Tropical Storm Lee and is in the typical period of tropical storm events. (Pg. 50).

- CBEMP evaluated water quality impacts from a single large flow event (January 1996). Lower flow, more frequent events may also have a cumulative impact over time in the future. Future modelling work could investigate the potential effects of smaller more frequent events to reduce uncertainty and expand understanding of how various flows influence Chesapeake Bay water quality. (Pg. 50).

Comment DR-16: This study has a schizophrenic analyses and discussion considering that the 2010 TMDLs need to be revised and yet the models that established those numbers are acknowledged and used to determine the effectiveness of dredging in the DLSRWA.

- Chesapeake Bay Estuarine Models – used to compute the impacts of sediment and nutrient loads to the estuary on light attenuation, SAV, chlorophyll, and DO concentrations in Chesapeake Bay tidal waters. (Pgs. 39-40).

- The eutrophication model, referred to as the Chesapeake Bay Water Quality/Sediment Transport Model6, computes algal biomass, nutrient cycling, and DO, as well as numerous additional constituents and processes using a 15-minute time step. (Pg. 40).

- In addition, the Chesapeake Bay Water Quality/Sediment Transport Model incorporates a predictive sediment diagenesis component, which simulates the chemical and biological processes which take place at the bottom sediment-water interface after sediment is deposited (Di Toro, 2001; Cerco and Cole, 1994). (Pg. 40).

- The primary application period for the combined hydrodynamic model and eutrophication model covers the decade from 1991 - 2000. For LSRWA applications the 1991 - 2000 hydrologic record was retained as this is the hydrologic period that CBEMP is based upon. Additionally this is the same hydrologic period employed by the CBP partners in development of the 2010 TMDL (USEPA, 2010a).

Comment DR-17: More predictions and scientific buzz words in establishing variables and definitely less science. Why not used data from the same years or timeframe as the other model runs? The eutrophication model does not include Tropical Storm Lee given the timeframe of 1991 - 2000.

- In order to compute water quality impacts with CBEMP, nutrient loads associated with sediment (in particular, nutrient loads carried over Conowingo Dam as a result of sediment scour from the reservoir bottom) were calculated by assigning a fractional nitrogen and phosphorus composition to the scoured sediment (solids). The initial fractions assigned for nitrogen and phosphorus were based on analyses of sediment cores removed from the reservoir (Appendix C, Attachment C-1). However, further analysis was done to ensure the most appropriate nutrient composition of loads was being utilized. (Pg. 46).

Comment DR-18: Are these the same core samples that were limited to 1 foot? If not, from where were these sediment core samples taken? And why weren't these samples used in the AdH Model run?

SAV

- "SAV species in the upper Bay were strongly affected by Hurricane Irene and Tropical Storm Lee which increased river flow and sediment loads in this region for almost two months (Gurbisz and Kemp, 2013). However, the dense SAV bed on the Susquehanna Flats persisted through the storms demonstrating how resilient SAV beds can be to water quality disturbances (CBP, 2013)." (Pg. 71).

- Regarding oysters, Maryland's 2011 oyster survey conducted after Tropical Storm Lee indicated that those high freshwater flows from heavy rains in the spring and two tropical storms in late summer impacted oysters in the upper Bay, although ultimately representing a relatively small proportion of the total oyster population. The lower salinities proved to be beneficial to the majority of oysters in Maryland by reducing disease impacts to allow the yearling oysters to thrive (MDNR, 2012). (Pgs. 71-72).

Comment DR-19: How was sediment scour ruled out given that this analysis seems to be based on observations? Who at DNR made these observations? Do DNR field notes exist that make such an observation?

Major Storms

- "The "Big Melt" event occurred in January 1996. The instantaneous peak flow for this event was 908,000 cfs. (Pgs. 73-74).

- Hurricane Agnes was the largest flood in the Susquehanna River basin since 1896, when recording of flow began at Harrisburg, PA. During the Agnes event the flow over Conowingo Dam peaked at 1,098,000 cfs.

- "As discussed in Chapter 3, the LSRWA modelling efforts included Tropical Storm Lee and the January 1996 high-flow event because these storms were included in the hydrologic period of the modelling tools utilized for this effort and because there was existing collected data available for these storms." (Pg. 74).

- Attachment 4 of Appendix J includes detailed information on "Septic Systems." (Pgs. 29-33).

Comment DR-20: Septic systems are not discussed at all in the corresponding tables for the cost analysis in Attachments 2 and 3. Why not?

Comment DR-21: However, the flow rate for model runs was set at approx. 620,000 cfs. - so how does the LSRWA modelling account for these storms? Figure 4.7 seems to undermine the "1996 Big Melt" by capping the flow rate at 600,000 cfs.

- "On average, flows above 800,000 cfs. produced a scour load that comprised about 30 to 50 percent of the total load entering the Bay. Flows of this magnitude are rare with a recurrence interval of 40 years or more." (Pg. 76). Keep in mind, that Pg. 63 shows an event of 798,000 cfs. having an occurrence 1 in 25 years. The assumptions and conclusions regarding the potential number of storm events in a given interval are inconsistent and result in minimizing the adverse impacts on the Bay.

- SAV, Chlorophyll and light attenuation relied on three model storms: January, June and October. (Charts on Pgs. 80-83).

- The June scour event had an estimated increase in deep-channel DO water quality standard nonattainment (negative impact) of 1 percent, 4 percent, 8 percent, and 3 percent in segments. (Pg. 93).

- The severity of the DO hypoxia response estimated by the degree of nonattainment of the deep channel and deep-water DO standards was greatest in the June storm scenario, followed by the January and October storm scenarios. The seasonal differences in water quality response, despite the same magnitude of nutrient and sediment loads in the June storm, October storm, and January storm scenarios, is thought to be because of the fate and transport of nutrients in the different seasons. (Pg. 94).

- CBEMP does not model direct storm wave damage to aboveground or belowground SAV tissue, nor direct impacts of excess storm bottom erosion and deposition upon SAV. Accordingly, to consider these other effects of major storms on SAV, it was appropriate to consider the CBEMP model outputs as well as other recent and historical information in this study. Effects of storms can differ based on SAV bed health, size, and density. (Pg. 95). Admission.

Comment DR-22: To investigate the effect of the storm season, scenarios were completed with the January 1996 Susquehanna storm flows and loads moved to June and October 1996. (Scenario 6 from Table 4-9, with three CBEMP model runs). Only one model run occurred during the growing season. Effects are discussed in terms of light attenuation, chlorophyll and DO. (Pg. 91). The models do not account for direct storm wave damage to above ground or below ground SAV. (Pg. 95).

- "Nitrogen loads associated with the scoured sediment exceed the phosphorus loads, as noted in Table 4-9. The excess of nitrogen over phosphorus in Conowingo Reservoir bed sediment indicates that the scoured nitrogen load will exceed the scoured phosphorus load any time bottom material is scoured (eroded), regardless of the quantity of bottom material." (Pg. 96).

Sediment Management Strategy

- "Storms will continue to occur and will vary in track, timing and duration. Due to global climate change it is predicted that there will be increased intensity of precipitation in spring and winter potentially causing more frequent scour events." (Pg. 99).

- "Watershed loads of sediment, nitrogen and phosphorus will continue to decrease compared to today due to the continued implementation of Pennsylvania, New York and Maryland WIPs to meet the 2010 Chesapeake Bay TMDL allocations. Predicted higher temperatures and continued warming of Chesapeake Bay's tidal waters could have negative implications on DO causing intense hypoxia to occur substantially earlier or end substantially later in the year making it more difficult to meet Chesapeake Bay water quality standards, potentially increasing costs to achieve the Bay TMDL." (Pg. 99).

- "In reducing the amount of sediment available for a scour event, water quality could be improved and impacts to aquatic life could be reduced." (Pg. 100).

Comment DR-23: According to the Draft Report: "It is important to note that if suspended sediment was passively transported (*e.g.*, via modification of reservoir operations, flushing, sluicing, or agitation) as discussed in this section, a permit may not be required. However, if sediment transport were done actively through dredging or a pipeline, a permit would be required (Elder Ghigiarelli, MDE, Deputy Program Administrator, Wetlands and Waterways Program, Water Management Administration, personal communication, 2013). (Pg. 107) Does the Study group still believe that a permit would not be required under a new Maryland Gubernatorial Administration?

- "There are hundreds of combinations of ways to dredge, manage and place material. However, there are two main types of dredging – hydraulic dredging and mechanical dredging". (Pg. 110).

Comment DR-24: What type of dredging did the Draft Study focus on in their cost estimates?

- Quarries appear to be the best option for material placement due to: (1) they can accept wet or dry material; (2) large volumes could be placed; and (3) there are several quarries nearby that can have material pumped in directly from Conowingo Reservoir without the need for costly re-handling or trucking. (Pg. 120).

- Additional analyses characterizing sediment to be dredged including grain size, plasticity and percent moisture, metals, non-metals, pesticides, PCB's and PAH's, paint filter, and elutriate tests. (Pg. 120).

- Must meet state regulations (PADEP for PA and MDE for MD). Transport containers must be watertight. Long transport distance. Water may need to be decanted, requiring another pipeline to return the effluent to the Susquehanna River. Mine owners contacted had no interest in sediment because of limitations on their mining permits. (Pg. 124).

Dredging Effectiveness

- It was assumed that 3 mcy (2.4 million tons) were removed by dredging from an area above the Conowingo Dam on the eastern side of the reservoir approximately 1 to 1.5 miles north of the dam. This dredging area was selected because large amounts of sediment still naturally deposit at this location. Although changing the dredging area location will likely influence results, removing such a relatively small quantity of sediment will have a minimal impact on total load delivered to the Bay when large flood events occur. (Pg. 136). The estimated scouring of sediment and nutrients was reduced by 32 percent in comparison to scour with a 2011 bathymetry (with all other parameters remaining the same). Dredging had little effect on model simulated water quality conditions in the Chesapeake Bay. (Pg. 136).

- CBEMP estimated a decrease (a positive improvement) of 0.2 percent nonattainment in the deep channel DO water quality standard for segments. (Pg. 137).

- The results imply that if 31 mcy (25 million tons) of sediment were removed, there would be a 9 percent decrease in total load to the Bay (from 22.3 to 20.3 million tons), a 40 percent decrease in bed scour (from 3.0 to 1.8 million tons) and a 50 percent increase in reservoir sedimentation or deposition (from 4.0 to 6.0 million tons). (Pg. 139).

Comment DR-25: Please provide the data and models used for this analysis.

- "However, these calculations do not take into account that the storage capacity would be increasing and thus more incoming sediment could be depositing." (Pg. 139).

- It was assumed that the average Susquehanna River flow during the winter months was 60,000 cfs., approximately twice that of the median flow of about 30,000 cfs. At 60,000 cfs., the average suspended sediment measurement below the dam was assumed to be about 12 mg/L, which equates to a daily load of about 1,940 tons of sediment passing through the dam. (Pg. 140).

Comment DR-26: CBEMP model is being used to determine dredging effectiveness. How could this be the case given that the CBEMP model has many uncertainties? (*See* Pgs. 3-4 of this outline). Moreover, calculations do not take into account that storage capacity is increasing in the reservoir behind the dam.

Findings

- "Sediment bypassing results in increased suspended solids computed in the Bay during the bypassing period. The bypassed sediment settles quickly after bypassing stops." (Pg. 141).

- "CBEMP estimated that deep-channel DO and deep-water DO water quality standards were seriously degraded as a result of nutrients associated with the bypassed sediment." (Pg. 141).

- "Bypassing costs are still high but not as high as dredging. Bypassing is just as effective as dredging at increasing sediment deposition and reducing available sediment for scour events. However, this method increases total sediment loads to the Bay. The environmental costs (diminished DO, increased chlorophyll) are roughly 10 times greater than the benefits gained from reducing bed sediment scour in Conowingo reservoir." (Pg. 142).

Comment DR-27: NEPA is required for these investigations. "It should be noted that the LSRWA effort was a watershed assessment and not a detailed investigation of a specific project alternative(s) proposed for implementation. That latter would likely require preparation of a NEPA document. The evaluation of sediment management strategies in the assessment focused on water quality impacts, with some consideration of impacts to SAV. Other environmental and social impacts were only minimally evaluated or not evaluated at all. A full investigation of environmental impacts would be performed in any future, project-specific NEPA effort." (Pg. 143).

Public Participation Concerns

- "The team sent out study coordination letters to various federal and state resource agencies in February 2012 to inform agencies of the initiation of the study and to request the level of involvement each agency would like to have with the study. Two response letters were received requesting involvement in the study as well as various emails from agencies confirming their willingness to participate in study. A study initiation notice was distributed via email in February 2012 as well." (Pg. 147).

- "The team held quarterly meetings to discuss, coordinate, and review technical components of the assessment, as well as management activities. These meetings were open to all stakeholders to attend. Agendas and handouts were provided to stakeholders via email prior to the meeting and the meeting summary with items presented at quarterly meetings was posted to the public website after quarterly meetings. A total of 10 quarterly meetings were held from November 2011 to January 2014, with attendance ranging from 30 to 50 participants. These participants represented 19 different stakeholder groups." (Pg. 147).

- "Throughout the duration of the assessment, the LSRWA team coordinated with other pertinent Chesapeake Bay groups, so as to be included on their agendas to provide updates and get feedback on the LSRWA. Feedback received from these other Chesapeake Bay groups was reported back to the rest of the LSRWA team and was incorporated into this LSRWA report." (Pg 147).

- "Throughout the duration of the assessment, email updates were sent out periodically to interested stakeholders on study progress and news. This email distribution list was started by the original Sediment Task Force (included interested stakeholders) that Susquehanna River Basin Commission led in 1999 and 2000. The team has been updating this list since 2009 with people interested in this effort." (Pg. 147).

- "Prior to public release the draft LSRWA report was reviewed by the agencies involved in quarterly meetings. Additionally, the STAC sponsored an independent scientific peer review of the draft LSRWA report in June - August of 2014. STAC provides scientific and technical guidance to the Chesapeake Bay Program on measures to restore and protect the Chesapeake Bay. More information about STAC is located here: www.chesapeake.org/stac. Appendix I, Attachment I-7 contains the comments and LSRWA team responses to the LSRWA quarterly group's reviews and the STAC sponsored independent scientific peer review." (Pg. 147).

- At least one public meeting is expected to be held later in 2014. Once that meeting is held, a description of the meeting(s) will be placed here and will include a location, date, participants, and feedback received. All comments will become part of Appendix I, Attachment I-7. (Pg. 147).

Comment DR-28: Please explain how this study group involved public participation. How does the LSRWA's approach address NEPA public participation requirements and those required by the Federal Advisory committee Act (FACA)?

- Recommendation – U.S. EPA and Bay watershed jurisdictional partners should integrate findings from the LSRWA into their ongoing analyses and development of the seven watershed jurisdictions' Phase III WIPs as part of Chesapeake Bay TMDL 2017 mid-point assessment. (Pg. 160).

Comment DR-29: Having such findings integrate with 7 watershed jurisdictions requires a FACA approach. Was FACA ever discussed? If not, why not? If so, how was FACA addressed?

Finding #1: Conditions in the Lower Susquehanna reservoir system are different than previously understood. (Pg. 151).

- Conowingo Reservoir is essentially at full capacity; a state of dynamic equilibrium now exists. Previously, it was thought that Conowingo still had long-term net trapping capacity for decades to come.

- Storm event based scour of Conowingo Reservoir has increased. Previously, it was not fully understood how scouring was changing as the reservoirs filled. (Pg. 152).

- The LSRWA modelling efforts indicate that the scour threshold for the current Conowingo Reservoir condition ranges from about 300,000 cfs. to 400,000 cfs. (Pg. 152).

- Modelling simulations comparing current conditions of the Conowingo Reservoir to the mid-1990s indicate that a higher volume of sediment is scoured currently at flows above 150,000 cfs. in comparison to the mid-1990s, with the threshold for mass scouring occurring at about 400,000 cfs. (Pg. 152).

- Sediment transport is related to particle size. Storms can potentially scour the silts and clays (easier to transport) leaving behind the coarser sand-sized sediment. (Pg. 152).

Finding #2: The loss of long-term sediment trapping capacity is causing impacts to the health of the Chesapeake Bay ecosystem. (Pg. 153).

- The assessment indicates that the ecosystem impacts to the Chesapeake Bay result from the changed conditions and are due primarily to extra nutrients associated with the scoured sediment as opposed to the sediment itself.

Comment DR-30: Modelling estimates showed that the sediment loads (not including nutrients they contain) from Conowingo Reservoir scour events are not the major threat to Bay water quality. The models do not account for the sediment smothering that is occurring. Low DO was estimated to persist in the deeper waters of northern Chesapeake Bay for multiple seasons due to nutrient storage in the Bay's bed sediment and recycling between the bed sediment and overlying water column. (Pg. 153). This needs to be reviewed and there needs to be concern with the bed sediments and smothering.

- Full WIP implementation won't fully restore the Chesapeake Bay given changes to the Conowingo Reservoir sediment and associated nutrient trapping capacity. (Pg. 154).

- The Susquehanna River watershed, not the Conowingo Dam and its Reservoir, is the principal source of adverse pollutant impacts on upper Chesapeake Bay water quality and aquatic life. (Pg. 154).

Comment DR-31: So why has the U.S. EPA not declared the Susquehanna River (in Pennsylvania) impaired?

- On average flows above 800,000 cfs. produced scour load that comprised about 30 to 50 percent of the total load entering the Bay; however, an event of this magnitude is extremely rare with a recurrence interval of 40 years or more. (Pg. 155).

Comment DR-32: *See* Figure 4.1. (Pg. 62). Table 4.3 shows an event of 798,000 cfs. having an occurrence of 1 in 25 years. (Pg. 63). Exelon's relicensing application with FERC is for a 46 year license. So how is such an occurrence of flows above 800,000 cfs. a rarity? Why weren't the model runs conducted with a flow rate of at least 798,000 cfs., having an occurrence of 1 in 25 years?

APPENDIX A

Introduction – Facts

- Susquehanna River largest tributary to the bay transports about ½ of the total fresh water input.

- The three lower Susquehanna River reservoirs involve nearly 32 miles of river and have a designed storage capacity of 510,000 acre-feet at normal pool elevation. (Pg. 2).

- This Appendix begins with a discussion regarding a one dimensional model. Please keep in mind that the one dimensional model is utilized when water depth and laterally average conditions can provide adequate results to a problem and lateral sediment transport conditions are not considered.

- According to Appendix A the primary objective is to produce boundary conditions (data daily streamflow, sediment load and particle size) at a site monitored just upstream and at the upper Conowingo Reservoir. Between the Susquehanna River at Marietta, Pennsylvania streamgage (01576000) and the Susquehanna River at Conowingo, Maryland streamgage (01578310), Jan. 1, 2008 - Dec. 31, 2011. (Pg. 5).

- This one dimensional model was calibrated with downstream data from the USACE's bathymetric changes from 2008 - 2011.

Comment A-1: Two one dimensional models were used instead of more and current data and considering a three dimensional model.

Statements Regarding the Use and Limitations of Models in the DLSRWA

- Due to data limitations two one dimensional model simulations were produced: one for the modelling period 2008 - 2011 (representing net deposition) and a second for a high streamflow event using Tropical Storm Lee to represent net scour. (Pg. 1).

- Each simulation used the same model data inputs but model parameters were changed. The depositional model resulted in a net deposition of 2.1 million tons while the scour model resulted in a net loss of 1.5 million tons of sediments. (Pg. 1).

- Dynamic equilibrium results in increased loads that may have a greater impact on sediment and phosphorus that tend to transport in the particles phase and have less of an impact on nitrogen which tends to transport in a dissolved phase. (Pg. 4).

- It is implied that increasing concentrations and loads are due to the loss of storage capacity from a decrease in the scour threshold. These increases are not certain but likely involve changes in particle fall velocities, increased water velocity, transport capacities, and bed shear. (Pg. 4).

- The HEC-RAS one dimensional model simulates the capability of a stream to transport sediment, both bed and suspended flow, based on yield from upstream sources and current composition of bed. The HEC-RAS transport equations are designed mainly for sand and coarser particles. (Pg. 13).

Comment A-2: How does the HEC-RAS model account for clay sediments?

- Sediment loads entering and leaving a reservoir can be determined from a sediment (*i.e.*, transport) curve or from actual concentration data from upstream and/or downstream sites(s). (Pg. 11).

Comment A-3: Figure 6 (Pg. 1) portrays the discharge flow rate capped at 425,000 cfs., which triggers data manipulation concerns. Figure 7 portrays flow rate at approximately 625,000 cfs. The core samples utilized for the Conowingo Reservoir were limited to 8 samples of less than 12'' in depth. *See* Figures 7 and 8.

- At the time that this assessment began, there was concern about the issue of the reservoirs and their reduced trapping capacity because of the implications to sediment and the associated nutrient loads to the Chesapeake Bay and management of those loads. More specifically, there were significant implications to the then ongoing development of the Chesapeake Bay TMDL by EPA working collaboratively with the six watershed states and the District of Columbia. In the 2010 Chesapeake Bay TMDL report, EPA and its seven partner watershed jurisdictions documented their assumption that the Chesapeake Bay TMDL allocations were based on the Conowingo Dam and Reservoir's sediment and associated nutrient trapping capacity in the mid-1990s, the midpoint of the 10 years of hydrology (1991-2000) used in the underlying model scenarios (USEPA, 2010a). EPA documented within its 2010 Chesapeake Bay TMDL main report and supporting technical appendix that if future monitoring shows the trapping capacity of the dam were reduced, then EPA would consider adjusting the Pennsylvania, Maryland, and New York sediment and associated nutrient load reduction obligations based on the new delivered loads to ensure that they were offsetting any new loads of sediment and associated nutrients being delivered to Chesapeake Bay (USEPA, 2010a). (Pg. 9).

Comment A-4: Admission. It is interesting that they don't discuss this assumption in terms of its impact on the models.

- According to the DLSRWA the 52 flood gates that span the dam begin to open at a flow rate greater than 86,000 cfs. Each flood gate generally has the capability to pass up to about 15,000 cfs. (Pg. 14).

- During a large flood that requires the majority of the gate to be open, the spatial distribution of discharge shifts from the western side of the dam where the power plant resides, to the center of the channel. This shift in flow distribution and subsequent sediment load causes the sediment load on the eastern side of the reservoir t increase resulting in a high deposition rate in the area. (Page 14). "Thus depending on the reservoir inflows the spatial and quantitative fate of sediment in Conowingo Reservoir can be quite variable and difficult to stimulate with current modelling methods."

Comment A-5: Concerns expressed in the DLSRWA that the Conowingo Reservoir is quite variable and difficult to simulate. So how is the simulations conducted?

- A report prepared for the LSRWA study discusses modelling uncertainties in Attachment B-1. (Pg. 14).

- Susquehanna River Inflows- the AdH (2 dimensional) simulations used flow rates from 2008-2011- all but one - **Question:** what was the one's flow rate? (Pg. 15).

- Tropical Storm Lee (September 2011) with a peak discharge of 700,000 cfs. (Pg. 15) - 776,000 cfs. (Pg. 66).

Comment A-6: Peak flow rate is marginalized at 776,000 cfs. This rate seems to change throughout the report as a way to run the models with marginalized flow rates. The bathymetric discussion on Pg. 67 makes no sense.

- The HEC-RAS one dimensional model sediment rating curve produced two sediment inflow scenarios: scenario one no scour from upper reservoirs and scenario 2 with 1.8 million tons of scour from the upper two reservoirs for a total inflow load of 24 million tons. (Pg. 16).

Comment A-7: How are these numbers derived given the statement on Pg. 14 that stated the Conowingo Reservoir is quite variable and difficult to simulate?

- The one dimensional model HEC-RAS was used to provide data for the AdH model (two dimensional model). (Pg. 17). Figure 6 shows a sediment rating curve with this data at a flow rate slightly above 600,000 cfs. (Pg. 17). What does this purport to represent?

- In addition, the AdH sediment model requires bed sediments. This data was also manipulated as only 8 bed core samples were taken from the Conowingo Reservoir to a maximum depth of only 1 foot. Core samples were required to determine the inception of erosion (critical shear stress for erosion) and the erosion rate (Pg. 18) used to develop six material zones (Pg. 19). According to the DLSRWA the sediment bed in the AdH Model was approximately 3 feet. (Pg. 23). The properties of the lower 2 feet were either approximated from the SEDFlume data results (which is the one foot data) or determined from literature values. (Pg. 23).

Comment A-8: A general trend was established with this tenuous data which is used to account for sediment size and critical shear stress. Figure 11 is a not based on core samples but rather approximations. (Pg. 26). Figure 12's presentation of suspended sediment concentrations undermined Tropical storm Lee to 600,000 cfs. given that it relied on approximations from Figure 11.

Comment A-9: Because of the uncertainty of measured model boundary conditions the AdH two dimensional model was validated by comparing model output to the total suspended sample measurements below the Conowingo Dam. (Pg. 23). Where is this data from? How could these flow rates above the dam correlate with flow rates below the dam?

- "The hydrodynamics were successfully implemented in the AdH; however, the model was not capable of passing sediment through the gates, therefore, for this study the dam was modeled as an open boundary with downstream control represented by the water surface elevation at the dam. This limitation impacted how sediment was spatially distributed in the lower reach of the Conowingo Reservoir near the dam." (Pg. 60).

Comment A-10: This is an important factor to consider in the two dimensional AdH Model, yet the dam is somehow removed for the model run and flow rates above the dam are compared to flow rates below the dam. How does this account for scour from behind the dam and the circular river flow motion against the dam?

APPENDIX B

Two dimensional modelling results describe the transport of sediment solids and do not imply that a relationship exists between solids and after with nutrient loads. (Abstract (iii)).

Introduction

- The Susquehanna watershed is approximately 27,000 square miles. There exists three hydroelectric dams in the Lower Susquehanna River: Safe Harbor Dam (1931) – Lake Clarke located approximately 32 miles upstream of the Chesapeake Bay with water storage capacity of approximately 150,000 acre-feet; Holtwood Dam (1910) – Lake Aldred located approximately 25 miles upstream from Chesapeake Bay with water storage capacity 60,000 acre-feet; and Conowingo Dam (1928) which is approximately 10 miles upstream of the Bay with water storage capacity of 300,000 acre-feet. (Pg. 1).

Comment B-1: "Conowingo Reservoir currently is approaching a dynamic equilibrium state and continues to store inflowing sediments from non-flood periods." (Pg. 2) This discussion is not consistent or current throughout the DLSRWA as the Dam has indeed reached a state of dynamic equilibrium.

Background

- "The USGS estimates that the average inflow of sediment is about 3.2 million tons per year into the Conowingo reservoir, with deposition ranging from 1.0 to 2.0 million tons per year." (Pg. 5). HEC-6 model one dimensional mode under-predicted the trap efficiency. (Pg. 5).

Comment B-2: Exelon's report is cited as a good summary, which is concerning given that Exelon revised the USGS HEC-6 model and conducted a series of simulations to evaluate scour potential of the three reservoirs. (Pg. 5-6). Please keep in mind this is the same model (Exelon's HEC-6 model) that Langland criticized in his notes and review of the FERC required Exelon Sediment Transport Study.

Study Approach and Goals

- Models: Two dimensional model: AdH and HEC-RAS. (Pg. 7).

- Data: "The USGS provided reservoir surveys from 1996 and 2008 with Exelon Corporation providing the most recent 2011 survey. The survey was modified by USGS to represent a sediment capacity condition." (Pg. 7-8). "The 4-year flow period from

2008 - 2011 was simulated in the model. The flow and sediment entering the upstream model boundary (the channel below the dam of Lake Aldred) were provided by USGS from HEC-RAS (one dimensional model simulations of the 4 year period)." (Pg. 8).

Comment B-3: Not only is Exelon providing the model data to establish a full sediment capacity condition but the 1996 - 2008 reservoir data is being used with 2008 - 2011 flow data. The one dimensional model is not taking into account the impact of scour no matter what data manipulation is being considered. Why not use the USACE's bathymetric changes from 2008 - 2011 data (*see* Pg. 1) instead of Exelon's data? Wasn't there USGS data to consider?

<u>Description of Modelling Uncertainties</u>

- A report was prepared for the DLSRWA effort discussing modelling uncertainties. (Pg. 14).

Comment B-4: Where is this report?

- One dimensional models are typically utilized when depth and laterally average conditions can provide adequate results to a problem. Two dimensional models are appropriate when lateral sediment transport conditions need to be resolved. Model results are depth averaged with model results available throughout the domain area. Two dimensional models can be used to stimulate sediment transport over years or decades for long term simulations. Three dimensional models are the most complex and provide problem resolution in all three dimensions (*i.e.*, depth, lateral and longitudinal). However, three dimensional models are computationally intensive and require long periods of simulation time to rum relatively short problem durations. If the goal of a study is to better understand reservoir stratification in low flow, low turbulence conditions than a three dimensional model is required to differentiate vertical properties.

- "During a large flood that requires the majority of the gates to open, the spatial distribution of discharge shifts from the westerns side of the dam where the power plant resides, to the center of the channel. This shift in flow distribution and subsequent sediment load causes the sediment load on the eastern side of the reservoir to increase resulting in a high deposition rate in this area." (Pg. 14). According to Exelon: a flow rate greater than 86,000 cfs. the 52 flood gates that span the dam begin to open. Each flood gate generally has the capability to pass up to about 15,000 cfs." (Pg. 14).

Comment B-5: Having all gates operating at full capacity the flow rate would allow for 780,000 cfs. In addition two dimensional models are limited in the short term and are using data obtained from a one dimensional model.

<u>Model Flow and Sediment Boundary Conditions</u>

2008-2011 Time Period

- First two years had relatively low flows of approximately 300,000 cfs. The last two years had flows that reached or surpassed the scour threshold of 400,000 cfs. Tropical Storm Lee occurred in September 2011 with a peak discharge of approximately 700,000 cfs. (Pg. 15).

    - HECRAS Output Sediment 1st scenario indicated no scour from the upper two reservoirs and inflow of sediment into Conowingo of 22 million tons.
    - HECRAS Output Sediment 2nd Scenario indicated approximately 1.8 million tons of scour from the upper two reservoirs with inflow of sediment estimated at 24 million tons.

Comment B-6: According to the DLSRWA Tropical Storm Lee had a peak discharge of 776,000 cfs. (Page 66). The approximation marginalizes this storm by lowering the peak discharge to 700,000 cfs. Keep in mind that models aren't even running the flow rate at 700,000 cfs., but rather the 620,000 cfs. (Page 22).

- The scour load from the upper two reservoirs is needed because the maximum load may influence transport capacity in Conowingo and thus impact bed scour potential. Therefore, the 24 million ton HECRAS load was increased by 10 percent to reflect a potential maximum scour load from the upper reservoirs." (Pg. 17).

Comment B-7: What is the model or science behind this 10% increase?

- "Figures 6 and 7 show loads increasing exponentially after the 400,000 cfs. scour threshold…" (Pg. 17).

Comment B-8: Figure 6 shows that the AdH model is only considering a 600,000 cfs. flow rate and not a 700,000 cfs. that was initially discussed. (Pg. 17). Keeping in mind that as this is increasing exponentially these lower marginalized numbers significantly lower the scoured sediment amounts. How did these number associated with Tropical Storm Lee get to 600,000 cfs.? Again the actual numbers regarding Tropical Storm Lee (*i.e.*, the USGS number for Tropical Storm Lee is 709,000 cfs. (*see* Pg. 2 of Hirsch 2012 Report)) are being marginalized.

<u>Model Validation</u>

- SEDflume analysis of bed sediments. The AdH sediment model requires bed sediment properties for each layer in the bed. Eight bed core samples were taken from Conowingo. "The bed was sampled to a maximum depth of only one foot because the resistance of the more consolidated sediments at deeper depths." (Pg. 18).

Comment B-9: Figure 12 states 630,000 cfs. as the mean daily flow for Tropical Storm Lee. These numbers are being downplayed. The USGS number for Tropical Storm Lee is 709,000 cfs. (*See* Hirsch 2012 Report, Pg. 2). (Pg. 25). When simulated in the so-called "Hydrodynamic

Model" Tropical Storm Lee's flow velocity near the peak event was now 600,000 cfs. (Pg. 54). This data was used to address the sediment releases on the Susquehanna Flats SAV. One foot core sample limit makes no sense when other reports included much deeper samples.

- "A relatively small number of bed samples were taken from Conowingo Reservoir. Eight samples were used to represent the entire domain. Analysis of these samples revealed how the sediment size distribution coarsened with distance from the dam, and the subsequent variation of the critical shear stress and erosion rate. With such a small data set it was necessary to conduct a parametric model study in which variables were varied or adjusted to reflect the potential variation in bed properties."

Comment B-10: The meeting notes reveal that the core sample number was originally set at 16 instead of 8 and was reduced only due to cost concerns. (Pg. 28). Keep in mind that the HECRAS model was one dimensional and that the AdH model was used for a two dimensional approach to address lateral sediment transport conditions. Two dimensional model results are depth averaged throughout the domain area (which was stated earlier on Pg. 12) and are inadequate during well-mixed turbulent conditions. Not only is this model inadequate in predicting scour in high flow rate conditions but the data needed for the depth averaged in the domain area relied on only 8 samples of 1 foot depth. Due to the inadequate amount of samples, data had to be obtained from another model and assumptions had to be made. Given the foregoing what are the margins of error? This is a very serious concern given the limitations of both one dimensional and two dimensional models when considering sediment transport during turbulent conditions. (Pg. 12). The explanations associated with data and models have not shown model validation but rather the reverse.

Model Simulations – Impact of Temporal Change in Sediment Storage Capacity

- The scour load during Tropical Storm Lee comprised of 20% of Tropical Storm Lee's total load (*i.e.,* about 3 million tons of the 14.5 million tons). (Pg. 45). The reservoir will have more capacity as a result of this scouring. The large periodic storms like Tropical Storm Lee will continue to transport large quantities of sediment to the Bay which are much higher than the reduced scour loads resulting from sediment removal operations. (Pg. 45).

Comment B-11: The August 2012 USGS Hirsch Report determined sediment loads of 4 million tons from scour and 19 million tons of suspended solids. Why is this data different and why are these numbers being marginalized?

Simulation of Sediment Management Alternatives

- "Impact of Sediment Removal - assumed the removal of 2.4 million tons of sediments above the dam. Total outflow load to bay was reduced by about 1.4% from 22.3 to 22 million tons, scour load decreased by 10 % (from 3.0 to 2.7) and the net reservoir sedimentation increased by about 5.0% (4.1 to 4.3 million tons). For this simulation, the scour load decreased approx. 3.3 percent for every million cubic yards removed." (Pg. 47).

- "Although changing the dredging area location will likely influence model results, removing such a relatively small quantity of sediment will have a minimal impact on total load delivered to the Bay when large flood events occur." (Pg. 47).

Comment B-12: Simulation was run on inadequate data. *See* discussion, *infra*, in Section 6.

Conclusions

- "A number of conclusions can be drawn from the modelling study. Although the uncertainty of the modelling is high due to the uncertainty of sediment boundary conditions and model limitations, the existing versus alternate approach to simulations reveals change in sediment transport based on the alternate condition scenario." (Pg. 57).

Comment B-13: What is the meaning of this statement? That modelling uncertainty is high?

- The AdH sediment transport model results only estimated the transport and fate of sediments that enter the reservoir and scour from the bed. The model does not predict nutrient transport and does not imply any predictive relationship between nutrients and sediment transport. (Pg. 59).

Comment B-14: Nutrient transport is model limited and there is no relationship between nutrients and sediments.

Recommendations to Improve Future Modelling Efforts

- The AdH model was not capable of passing sediment through the gates, therefore, for the study the dam was modeled as an open boundary with downstream control represented by water surface elevation. (Pg. 60). This limitation impacted how sediment was spatially distributed in the lower reach of the Conowingo Reservoir near the dam.

Comment B-15: In this statement the DLSRWA admits its severe limitations. The model's limitations impacted how sediments were spatially distributed in the lower reach of the Conowingo Reservoir near the dam.

- Sediment transport models in general do not have a sophisticated approach to simulate fine sediment flocculation. The AdH model has the capability to relate flocculation to concentration, but not to other variables such as shear stress which determine flock particle size and overall fate. The ability to predict flocculation dynamics is critical to track the fate of sediment in a reservoir system. (Pg. 60).

Comment B-16: This is an admission by the DLSRWA regarding the inadequate modelling scheme utilized.

- Field data collection needs to continue both upstream and downstream of the Conowingo Dam to provide more information on reservoir balance. Currently, the suspended sediment samples are collected from one location near the power plant. (Pg. 60).

Comment B-17: This is an admission by the DLSRWA regarding the inadequate data.

Attachment B1 – Evaluation of Uncertainties in Conowingo Reservoir Sediment Transport Modelling, October 2012, Baltimore District Corps of Engineers, Stephen Scott

The Impact of Conowingo Dam on Hydraulics and Sediment Transport

- "The Presence of the dam creates a backwater effect, reducing the energy slope, thus reducing velocities and encouraging sedimentation. In the area adjacent to Conowingo Dam, circulation of water and sediment is directly impacted by both the Dam face and how water is discharged through the Dam.

- "There are 52 flood gates with a crest elevation of 89.2 feet NGVD 29. For flows exceeding 86,000 cfs., both the power plant and flood gates pass flow up to 400,000 cfs. At higher flows the power plant is shut down with all flow passing through the gates."

Significance of Low Flow Sediment Transport

- "Wind and wave action may impact how sediment moves through reservoir system."

- Suspended sediment transport is an inherently three dimensional process. Correction factor was used in the two dimensional model (AdH model) to account for three dimensional stratification by simulating three dimensional suspended sediment transport.

Comment B-17: How was this correction factor obtained? Does the correction factor also address the open boundaries once the dam was removed in the model run?

Attachment B2 – SEDflume Erosion Data and Analysis

- Cohesive sediment transports are a mixture of sand, silt, and clay particles. Cohesive forces are equivalent to or greater than the gravitational forces that dominate san transport. There are no quantitative methods available to determine erosion rate from cohesive sediment properties.

APPENDIX C

- "Application of the Chesapeake Bay environmental Model Package to examine the Impacts of Sediment Scour in Conowingo Reservoir on Water Quality in Chesapeake Bay," Report of the US Army Corps of Engineers.

- This report examines the impact of reservoir filling on water quality in the Chesapeake Bay with emphasis placed on chlorophyll, water clarity and DO.

- Models: numerous, predictive environmental models and transfer of information between the models. (Pg. 2).

- CBEMP consist of three independent modes: (1) Watershed Model (WSM 5.3.2); (2) Hydrodynamic model; and (3) WQM- Water Quality or Eutrophication Model.

- Analytical Model: Steady state – Reservoir volumetric inflow must equal volumetric outflow and sediment sources must equal sediment sink. Bottom shear stress is the product of shear velocity and fluid density. (Pg. 9).

- Results from Analytical Model: When volumetric flow is below the erosion threshold the solids concentration in the reservoir is independent of depth. (Pg. 10). As reservoir depth decreases the flow required to initiate erosion diminishes. (*Id*). When the erosion threshold is exceeded, the sediment concentration in the outflow is inversely proportional to depth. (Pg. 11). One significant insight is that the reservoir is never completely filled. Solids accumulate continuously until an erosion event occurs. As the reservoir fills, however, the flow threshold to initiate an erosion event diminishes. Erosion events become more frequent and severe. Equilibrium implies a balance between suspended solids inflows and outflows over a time period defined by erosion events. The conventional threshold for erosion of ≈ 11,000 m3 s-1 has a recurrence interval of five years (Langland, 2013) implying the equilibrium exists over roughly that period. If we believe the threshold for erosion is below 11,000 m3 s-1, when volumetric flow is below the threshold, the solids concentration in the reservoir is independent of depth. (Pg. 10). As reservoir depth decreases, the flow required to initiate erosion diminishes.

Comment C-1: The use of existing models and practices that the LSRWA points out as being advantageous to the DLSRWA since these tools could not be developed within the time and budget limitations of the LSRWA. The individual models within Chesapeake Bay Environmental Model Package (Watershed Model, Hydrodynamic Model, and Water Quality Model) are documented, reviewed and used. CBEMP relies on the flawed TMDL model.

- "The resources necessary to acquire raw observations, create model input decks, execute and validate the individual models within the CBEMP for the years 2008 - 2011 was beyond the scope of the LSRWA." (Pg. 17).

- Data limitations: "…[M]eans were required to transfer information from the 2008 - 2011 AdH application to the 1991 - 2000 CBEMP." (Pg. 17).

Comment C-2: What kinds of means were required?

- "The crucial transfer involved combining scour computed by AdH for Tropical Storm Lee with watershed loads computed by the WSM model for a January 1996 flood and scour event represented by the CBEMP. (Pg. 17). "The WSM provides computations of volumetric flow and associated sediment and nutrient loads throughout the watershed and at the entry points to Chesapeake Bay. Flow computations are based on precipitation, evapotranspiration, snow melt, and other processes. Loads are the result of land use, management practices, point-source wasteloads, and additional factors. The loads computed for 1991 - 2000 are no longer current and are not the loads utilized in the TMDL computation. To emphasize current conditions, a synthetic set of loads was created from the WSM based on 1991 - 2000 flows but 2010 land use and management practices. The set of loads is designated the "2010 Progress Run." The TMDL loads are a second set of synthetic loads created with the WSM. In this case, the 1991 - 2000 flows are paired with land uses and management practices sufficient to meet the TMDL limitations." (Page 17).

Comment C-3: Limited observations of sediment associated nutrients are available at the Conowingo outfall during the 1996 flood event.

- Major storm events occur at different times of the year. In order to examine the effect of seasonality of storm loads on Chesapeake Bay, the January 1996 storm was moved, within the model framework, to June and to October. The loads were moved directly from January to the other months. No adjustment was made for the potential effects of seasonal alterations in land uses. New Chesapeake Bay hydrodynamic model runs were completed based on the revised flows, to account for alterations in flow regime and stratification within the Bay. (Pg. 18).

Comment C-4: Limitations on the impact on growing cycles. Table 3-1 needs to reference the flow rate used in model runs. (Pgs. 20-21) What were the flow rates?

- Loads from the watershed are calculated by the CBP WSM for two configurations: existing conditions (2010 Progress Run) and total maximum daily load (TMDL). (Pg. 21).

- Nutrient loads associated with bottom erosion were calculated by assigning a fractional nitrogen and phosphorus composition to the eroded solids. The initial fractions assigned, 0.3% nitrogen and 0.1% phosphorus, were based on analyses of sediment cores removed from the reservoir (Cerco, 2012). (Pgs. 24-25).

Comment C-5: Sediment core samples from the reservoir were limited to 8 samples at less than 1 foot deep.

- Dilemma discussed in Appendix C (Pg. 25): Employment of the 1996 nutrient composition to characterize the nutrients associated with sediment eroded in 1996 results in reasonable agreement between observed and computed nutrients at the Conowingo outfall (Figures 4-5, 4-6) but presents a dilemma. Which nutrient fractions should be used in subsequent scenario analysis? The 1996 composition, which accompanied the 1996 event and was observed during the 1991 - 2000 scenario period? Or the 2011 composition which is more recent and characterizes a typical tropical storm event? In view of the dilemma, several key scenarios have been run with alternate composition, presenting a range of potential outcomes.

- The ADH model was run for several bathymetry sets including: existing (2008) bathymetry; equilibrium bathymetry; bathymetry following 1996 storm; and bathymetry resulting from dredging 2.3 x 106 m3 (3 million cubic yards).

- In all cases, the procedure for determining the scour load followed the same steps: Solids loads into and out of Conowingo Reservoir using the hydrologic record for the period 2008 to 2011were provided by the ADH model; Solids scour for two events in 2011 was determined by the excess of outflowing solids loads over inflowing solids loads; Scour for the 1996 hydrologic record was estimated by interpolation based on excess volume; Nutrient composition was assigned to the scoured solids based on 2011 observations; and For key scenarios, an alternate set of nutrient loads was constructed based on 1996 observed nutrient fractions.

Comment C-6: Mixing 1996 data for the ADH model that used the hydrogeological record for 2008 - 2011. When reviewing the tables in report please keep in mind that 1 cubic meter per second = 35.3146667 cfs. Table 4-3 (Pg. 29) sets the highest flow rate at 17,479 cubic meters per second multiplied by 35.3 result in 617,009 cubic feet per second, which is well below Tropical Storm Lee's flow rate. Table 4.4 (Pg. 30) is not much better at 621,986 cubic feet per second.

- Output Formats. A separate supplemental publication is planned to describe results of scenarios conducted for the EPA CBP. (Pg. 40).

- A scenario was run with Conowingo Reservoir removed from the system. This was accomplished by routing directly to the bay the calculated WSM loads into Conowingo Reservoir. The initial intent was to simulate a reservoir-full condition. In this interpretation, loads to the reservoir would pass directly through in the absence of deposition. This interpretation was superseded by a revised conceptual model in which settling occurs even under reservoir-full conditions.

APPENDIX D

- Estimated Influence of Conowingo reservoir Infill on Chesapeake Bay Water Quality.

- The Susquehanna River delivers about 41 percent of the nitrogen loads, 25 percent of the phosphorus loads, and 27 Percent of the suspended solids on an annual basis (CBOP 1991 - 2000 simulation period).

Comment D-1: The simulation period is flawed. Why was that simulation period, which doesn't take into account episodic event, such as Tropical Storm Lee, considered? As for the Phase 5.3.2 Watershed Model this relies on 2010 TMDLs. Doesn't the 5.3.2 model also have a problem with nutrient load estimations?

- The mid-point assessment of the Chesapeake TMDL is planned for 2017 to account for Conowingo Dam infill and to offset any additional sediment and associated nutrient loads to the Bay. (Pg. 3).

Comment D-2: Although the TMDL model is admittedly flawed for nutrient and sediment load, why is it still being used by the LSRWA team to estimate influence of the Conowingo reservoir infill on the Bay's water quality? Modelling for the Chesapeake Bay TMDL consisted of an assessment of the entire hydrologic period of 1991 - 2000, which only takes into account one high flow rate of the big ice melt in 1996. Why isn't flow rate ever discussed in terms of magnitude and velocity in the model? (Pg. 8).

APPENDIX E

Introduction

- May, 2, 2012 – Maryland Geological Survey (MGS) conducted 16 sediment grab samples (surficial grab samples) taken in the Susquehanna Flats area of the upper Chesapeake (Figure 1). (Pg. 2).

- Sample locations were determined through consultation with USACE based on existing sediment sample data available. (Pg. 2) Two samples sites located in the Susquehanna were not sampled because of concerns regarding bedrock.

- Sediment grab samples were analyzed for water content, bulk density and grain size. Two homogenous splits of each sample were processed with one for bulk property analyses and the other for gain-size characterization. (Pg. 4).

Comment E-1: How deep or what was the depth of these samples?

- Shephard's (1954) classification of sediment types presented in Figure 2. (Pg. 7).

Comment E-2: What is "1954 classification data"? Haven't the characteristics of sediments changed in the last 60 years?

- Table 3 – Results shows the field data of grain size based on the grab samples.

Comment E-3: The table emphasized the fact that samples were too shallow or very difficult to get. How were these limitations addressed?

APPENDIX F

- Need for updated chemical and physical measurements of suspended sediment flowing through Conowingo Dam.

- During four storm flow events in water year 2010 (October 1, 2010 - September 30, 2011) large volume samples were collected to support analysis of detailed suspended sediment with six fractions and physical and chemical measurements of sediments.

Comment F-1: What model runs used the USGS data described above?

- Ten samples were taken during four high flow events during water year 2011. The U.S. Department of Interior (MD-DE-DC Water Science Center, Baltimore, MD).

Comment F-2: At which high flow events were the ten samples taken during water year 2011?

- Table 4. Elements in suspended-sediment samples collected at the Susquehanna River at Conowingo, Maryland (USGS 01578310) were determined by cold vapor atomic absorption spectrophotometry.

Comment F-3: Were hazardous constituents such as PCBS also monitored in the ten samples? If not, why not?

APPENDIX G

- October 2011, Gomez and Sullivan Engineers conducted bathymetric surveys of the Conowingo Reservoir. These 2011 bathymetry survey data and methods were evaluated and approved by the USGS for the LSRWA's effort. Their efforts included: measured depth data combined with water surface elevation (WSE); the unit measured bottom depths several times per second, recorded averages. To account for the WSE difference, the WSE gradient between Conowingo Dam and Peach Bottom was used to determine the WSE throughout Conowingo Pond. (Pg. 3).

Comment G-1: How are the influences by Holtwood and the Muddy Run operations accounted for in this analysis? How were depth measurement points calculated between the two measurement areas?

- Sediment volume change for each cross section was calculated using the weighted and unweighted water volume methodologies. (Pg. 5).

Comment G-2: This study relied on a comparison of 2008 and 2011 data to get some insight into the sediment transport process focusing in the Conowingo Pond.

Comment G-3: Although these samples were taken in a short period of time they cannot really provide what the sediment transport rate would be with one major episodic event.

Comment G-4: Gomez and Sullivan stated that the 2011 cross-section data may serve as a reference point for future surveys. (Pg. 7). What additional surveys would be recommended by Gomez and Sullivan if these surveys were used as a reference point?

Comment G-5: According to Gomez and Sullivan's findings and conclusions, it appears that the zone of dynamic equilibrium has expanded farther downstream that in previous surveys, extending to about 3.7 miles upstream of the Conowingo Dam. (Pg. 8). Did any of the model runs account for this recent observation and conclusion? If not, how will this impact the model runs? Will scour amounts be adjusted to address this recent observation?

APPENDIX H

- A question that was not addressed in the DLSRWA is related to the various techniques for sediment management explored in the literature review of Appendix H. While different kinds of dredging are mentioned in the Appendix and in the body of the report, a technique known as hydro-suction dredging is mentioned several times in the Appendix but not mentioned explicitly in the DLSRWA. This technique would be especially useful for sediment bypassing because it makes use of the huge natural head difference between the reservoir and the river below the dam to maintain flow through a dredging pipe or bypass tunnel. (Pg. 35, Appendix 1-7).

Comment H-1: Was this technique considered in figuring the relatively low cost of bypassing, or not? Would it make a difference?

- The literature review in Appendix H ignored nutrients." (Pg. 35, Appendix 1-7).

- A literature search was conducted on managing watershed/reservoir sedimentation in Appendix H. Findings and lessons learned from the literature search were incorporated into refining sediment management strategies for this Assessment. Results of this literature search are presented in Appendix H.

Comment H-2: How could findings and lessons learned from case studies in which there is no consistency in the data presented for each LSRWA? For example, many of these case studies have no data for cost/funding or amount of sediment removed.

Comment H-3: Please explain why the case studies in Appendix H actually include the Susquehanna River Dams (*see* Pg. 26, No. 19). Oddly, the information contained for the Susquehanna River Dams is based on 1990 data. Why wasn't this information updated? How is old information and data useful and or important for the DLSRWA? If the Susquehanna River Dam information is outdated, how can the Study group ensure that case studies in Appendix H contain current and accurate information? Is this just a data dump that includes dams and reservoirs or was most of this information used for the DLSRWA? If it was used for the DLSRWA, how was it used?

- From the research found, especially overseas, warping technique was found to be often used where river water with high sediment loads is diverted onto agricultural land. The sediment deposition on the land enhances its agricultural value. (Pg. 52).

Comment H-4: Doesn't the warping technique increase the potential for erosion and greater sediment and nutrient runoff?

Comment H-5: Why does Appendix H include overseas sites located in China, Switzerland, Pakistan, etc.? Where is the value regarding such information?

- Minimizing Sediment Deposition includes a description of alternatives such as selectively diverting water. (Pg. 51).

Comment H-6: When these potential alternatives were identified, was there consideration given to the multiple uses of the Susquehanna reservoirs? For example the Peach Bottom Nuclear Plant relies on reservoir water for cooling, which begs the question: do these alternatives impact the industrial use of the Susquehanna River?

Comment H-7: One case study that was not listed in Appendix H is the Plainwell Impoundment located on the Kalamazoo River, Plainwell, Michigan. The dredged sediments associated with the Plainfield Impoundment contained levels of PCBs. Please keep in mind that recently EPA expressed this concern regarding the Conowingo sediments. This Plainwell Impoundment provided detailed cost data that could be very useful in the event that detectable levels of PCBs are present in the Conowingo sediments. Why was the Plainfield Impoundment overlooked? More information regarding the Plainfield Impoundment can be obtained from the following EPA Region V URL site: http://www.epaosc.org/site/site_profile.aspx?site_id=2815.

APPENDIX I-6

- The LSRWA revisited the goals that were developed for the study early on in the scoping process of the LSRWA in order to refine these goals. The purpose of the goals are to create bounds and focus for the team on what will be accomplished with the LSRWA and to communicate to stakeholders what the LSRWA will accomplish. Such goals included evaluating sediment management, and to determine the effects to the Chesapeake Bay from the sediment and nutrient storage located behind the dam. (Pg. 5).

- Exelon, the owner and operator of the dam, must undertake a variety of studies as requested by state and federal resource agencies to get an understanding of impacts of the dam. Several of the requested studies deal with sediment transport and accumulation in the dam system which relates to LSWRA efforts. At this time, most of the relicensing studies dealing with sediment transport and accumulation undertaken by Exelon are simply a compilation of existing literature and data. Their study findings were that 400,000 cfs. (cubic feet per second) is not the threshold where sediments are scoured from behind the Conowingo Dam and that overall Tropical Storm Agnes did not scour sediments but ended up depositing more sediment behind Conowingo Dam. Mike said that this latter finding is not supported by USGS at this time. (Pg. 5).

Comment I-6-1: Knowing that Exelon was responsible for studies dealing with sediment transport and accumulation behind the Dams as part of the license requirement, why did the LSRWA workgroup deicide to take on this task? Why would tax payer funds be used to perform these tasks when the burden was clearly on Exelon?

- Mike Langland noted in the past, USGS utilized a one dimensional HEC-6 model to assess sediment deposition and transport in the entire reservoir system including sediments from the watersheds. Mike noted that there were shortcomings to this model. As part of his LSRWA efforts, Mike will construct and calibrate an updated one dimensional HEC-RAS model that will route inflowing sediment through the reservoirs, accounting for both sediment deposition and erosion in the upper reservoirs. The output of this model will provide boundary conditions for the two dimensional model simulations that Steve will be conducting as part of his scope in the Conowingo Reservoir.

Comment I-6-2: STAC commented on limitations of the HEC-RAS and AdH models. These limitations were not made sufficiently clear in the DLSRWA. The HEC-RAS modelling effort was largely unsuccessful and the HEC-RAS simulation was largely abandoned as an integral part of the DLSRWA. (Pgs. 8-9, Appendix I-7). What were the limitations associated with the HEC-RAS model? Was USGS able to obtain a level of comfort with this model?

- Bruce Michael noted that there was minimal scouring during the spring 2011 high flow events. However, this was the worst year on record for hypoxia and second highest flow on record. (Pg. 8).

Comment I-6-3: Please provide the data that Bruce Michael based his observation on in the spring of 2011.

- Jeff noted that scouring occurred during Tropical Storm Lee from behind the Conowingo Dam. These sediments appeared to bypass the upper Bay and accumulated more in the middle Bay. The approach channels to the C&D Canal were scoured according to Philadelphia District and there did not appear to be significant burial of organisms since sediment was widely dispersed. (Pg. 8).

Comment I-6-4: Please provide the data source for Jeff's comments.

- Discussion ensued about the status of federal funding for this study. The study received funding for FY12 by mid-February. [Update: $300,000 received in February 2012.] The FY13 budget will be coming out in a few weeks and then it will be determined if funding is available for next FY. [Update: This project is not in the president's FY13 budget.] (Pg. 3 – January 23, 2012 Meeting at MDE).

Comment I-6-5: Again please explain why taxpayer money being used when the study should have been conducted by Exelon as part of the FERC relicensing application.

- Dave added that it is important as we finalize the watershed assessment that we make sure to refer back to the public outreach plan and follow what we have laid out to engage the public in the LSRWA. (Pg. 5).

Comment I-6-6: Why weren't the public involvement procedures established by the Federal Advisory Committee Act (FACA) followed and adhered to? What is this public outreach plan that is discussed above? Please provide a copy of this plan.

- Shawn Seaman will contact Michael Helfrich to notify him of quarterly meetings to see if he can attend. (Pg. 2).

Comment I-6-7: Is this how the public outreach plan works? There seems to be exclusivity involving who can participate.

- Herb mentioned that he, Secretary Summers (MDE) and Paul Swartz (Executive Director, SRBC) met with the Maryland delegation from the Eastern Shore. He noted that feedback from these meetings was that there is a lot of interest in water quality in the Bay; farmers feel like they are being picked on (it will be important to engage agriculture groups in study); and the costs of the implementation of the TMDL and the proposed "flush tax" to cover the cost of implementation of TMDL. (Pg. 5 – 2/16/2012).

Comment I-6-8: How were agriculture groups engaged in the DLSRWA? If not, why not?

- The Conowingo Dam has been undergoing the 5-year FERC relicensing process. Out of this relicensing process Exelon (owner and operator of Conowingo Dam) was required to conduct several studies that relate to sediment accumulation and transport. Year 2 study reports are due by January 23, 2012. Several contractors of Exelon attended the quarterly meeting and provided results of these studies to the LSRWA team. Marjie from URS explained that the objective of the sediment transport and accumulation study they conducted was to provide data that will be useful in the future development of an overall sediment management strategy for the Susquehanna River and Chesapeake Bay.

Comment I-6-9: Was Exelon's sediment transport and accumulation study relied upon or used in the overall sediment management study? Why didn't any workgroup member state that Exelon should be responsible for the LSRWA study given Exelon's contractor's (*i.e.*, URS) comment?

- Anna will send out an update via the large email distribution list that started with the original Sediment Task Force (includes academia, general public, federal, non-government organization (NGO), and state and counties representatives) notifying the group of LSRWA kick-off meeting and study start and will periodically update this group as the LSRWA progresses. (Action Items from November Meeting.)

Comment I-6-10: Was this update distributed? Did this update include future dates for meetings for all to attend? If so, why didn't the Clean Chesapeake Coalition receive this notice?

- Shawn will notify the team when the most recent Exelon study reports are released. Status – Recent report was sent out to the team; ongoing action. Shawn was not in attendance so Tom let the group know that the Exelon application for the Conowingo Dam license will be filed with FERC at the end of August [2012] and all required studies will be completed by the end of September with the exception of two fish studies. (Pg. 3 – 8/16/2012).

Comment I-6-11: Did LSRWA workgroup members review Exelon's required studies? If so, were deficiencies identified and discussed with Exelon and or its consultants?

- The LSRWA identified their mission as: "To comprehensively forecast and evaluate sediment and associated nutrient loads into and from the system of hydroelectric dams located on the Lower Susquehanna River above the Chesapeake Bay and consider structural and non-structural strategies to manage these loads to protect water quality and aquatic life in the Chesapeake Bay." (Pg. 4 – 8/16/2012).

Comment I-6-12: Did anyone on the LSRWA team question this mission, given that this was Exelon's obligation in the FERC relicensing application? How many scientists in the LSRWA were involved in this comprehensive study? Please provide their names and degrees. Did the LSRWA consist of any hydro engineers?

- Matt Rowe will compare the results from the analysis of sediment cores taken from behind the Conowingo dam in 2006 to the decision framework criteria laid out in the 2007 IRC report to help the team better understand the suitability of the sediments in the lower Susquehanna river watershed for innovative reuse options. (Pg. 2 – 12/26/2012).

Comment I-6-13: How does comparing 2006 data help in the decision making process? Doesn't Tropical Storm Lee in 2011 have a significant impact on this data?

- Currently the law firm Funk and Bolton is proposing and accepting money from counties for a study to be conducted by this law firm on the Bay TMDL. (Pg. 3 – 12/26/2012). Michael added that there has been concern raised by this coalition that MD has county WIPs while PA does not. Pat Buckley noted that PA has "WIP planning targets" in lieu of "County WIPs".

Comment I-6-14: Is there a reason why the Clean Chesapeake Coalition wasn't invited to attend this meeting? How does the Clean Chesapeake Coalition's attendance interfere with the LSRWA's mission to comprehensively forecast and evaluate sediment and associated nutrient loads into and from the system of hydroelectric dams located on the Lower Susquehanna River above the Chesapeake Bay and consider structural and non-structural strategies to manage these loads to protect water quality and aquatic life in the Chesapeake Bay? How is Funk & Bolton even relevant to this study?

- Carl noted that his previous efforts involved running modelling scenarios that removed Conowingo from the system to understand what it would look like with all sediments flowing into the bay and no longer being trapped by Conowingo. With this latest simulation, Carl looked at what the system would look like (*i.e.,* impacts on water quality) if there were a scouring event. More specifically, he took the system's current condition (Conowingo still trapping) with WIPs in place, using bathymetry from after the 1996 scour event. (Pg. 5 – 03/22/2013).

Comment I-6-15: How is a scoring event measured if the dam is removed in the model runs? How is the circular flow hitting the dam and scoring sediments adjusted in such a model run?

- Lew Linker noted that the results may not represent effects on SAV; a period of reduced light could really impact SAV. Carl noted that for the final report these final outputs need to be remedied. (Pg. 8 – 06/07/2013)

Comment I-6-16: Were these final outputs ever obtained? If so, please provide a copy of this study.

- Michael Helfrich noted that Carl's modelling is using the 4th biggest event we have on record to show storm scouring (the 1996 winter storm event). What about the storms that have occurred on record that were larger than this event? Also the loads (nutrient and solids) shown in Condition 6 (scour event in summer, fall, and winter) are less than loads in Conditions 3 - 5, which all included a simulation of the same storm event. Why is this? (Pg. 9 – 06/07/2013).

Comment I-6-17: Please provide an answer to Michael Helfrich's statement.

- "The group determined that data on nutrient (and sediment) in water outflows from Conowingo Pond was inadequate, and collecting data to fill gaps was scoped into the study. It was recognized that it would be useful to have additional information on Conowingo Pond bottom sediment biogeochemistry, particularly with regard to phosphorus. However, it was determined that existing information/data was adequate for study modelling purposes, and it was decided to not undertake such investigations in light of need to control study costs." (Pg. 3 – 09/24/2013).

Comment I-6-18: How does the use of old data to fill in the gaps effect the LSRWA's mission to comprehensively forecast and evaluate sediment and associated nutrient loads into and from the system of hydroelectric dams located on the Lower Susquehanna River above the Chesapeake Bay and consider structural and non-structural strategies to manage these loads to protect water quality and aquatic life in the Chesapeake Bay?

- With regard to (P) phosphorus biogeochemistry, Carl had identified Jordan and others (2008) as presenting a concept applicable to utilize for our situation. P is generally bound to iron in fine-grained sediments in oxygenated freshwater and of limited bioavailability. Under anoxic/hypoxic conditions iron is reduced and P can become more bioavailable. P rebinds to iron in sediments if oxygen is again present. P adsorbed to Conowingo Pond bottom sediments would remain bound to those sediments in the freshwater uppermost Bay. In saltwater, biogeochemical conditions change. Jordan and others (2008) indicate that as salinities increase above about 3-4 ppt/psu (parts per thousand/practical salinity units, P is increasingly released from sediments and becomes mobile and bioavailable to living resources, which is likely due to increased sulfate concentrations in marine water (*e.g.*, Caraco, N., J. Cole, and G. Likens, 1989. Evidence for Sulphate-controlled Phosphorus Release from Sediments of Aquatic Systems. (Pg. 3 – 09/24/2013).

Comment I-6-19: More recent studies show phosphorus is released and no longer bound to sediment s in the presence of higher salinity in water. Why weren't these more recent studies evaluated?

APPENDIX I 7

- The charge from STAC to the review team was: "You should focus your comments on the following [questions], but you are encouraged to provide additional comment that would improve the analyses, report or its recommendations." (Pg. 6).

Comment I-7-1: How were the questions developed that the review team focused on?

- "The science associated with assessing the evolving condition of the Lower Susquehanna River and its effects on the Chesapeake Bay is exceptionally challenging. As far as the reviewers are aware the Conowingo situation is truly unique. A major reservoir that had been an effective trap for fine sediment and associated nutrients has largely transitioned to one that no longer has an ability to perform this long-term function." (Pg. 6).

Comment I-7-2: If this were the case, how could the science associated with the LSRWA continuously flip flop back and forth on whether the reservoir still has trapping capacity or whether reservoirs are in dynamic equilibrium?

- "The goals stated in the main report (which stress both sediment and nutrient management) are inconsistent with the methodological approach taken by LSRWA (which mainly emphasized sediment) and appear not to be the study's original goals. This review recommends that the original goals of the study (*i.e.*, sediment management to extend the life of Conowingo Dam more than nutrient management to protect Chesapeake Bay water quality) be presented in the introduction followed by a fuller explanation of how and why the focus of the study evolved in time." (Pg. 7).

Comment I-7-3: If that is the case how adequately does the draft report stress both sediment and nutrient management?

- "It must also be stressed early and repeatedly that the dollar costs associated with alternative sediment management approaches specifically focus on the cost of reducing the amount of total sediment behind the dam, not on the cost of managing the impact of associated nutrients on the Chesapeake Bay. Further analysis would be required to appropriately rank the alternative strategies based on a more environmentally relevant total cost in terms of dollars per pound of nitrogen and/or phosphorus reduction." (Pg. 8).

Comment I-7-4: Such an analysis is extremely important and lost in the DLSRWA. If conducted, will the relevant total cost in terms of dollars per pound of nitrogen and/or phosphorus reduction be compared to all the BMPs and activities discussed in the DLSRA?

- "Although the report lists and discusses sources of uncertainty, it expresses the expected confidence intervals on its model predictions less often. Although there is no single accepted procedure for reporting uncertainty in the context of scenario modelling, a part of the report should more explicitly explain why confidence intervals on predictions are generally not provided." (Pg. 8).

Comment I-7-5: Why isn't there any reporting of uncertainty in the context of scenario modelling? Are the uncertainties that significant in terms of considering a margin of error analyses?

- "Key areas of concern which are expanded upon in response to Questions 3 and 4 include: (1) Stated sediment discharges from the Conowingo Dam are inconsistent with the literature. The report authors should either correct their numbers or present a clear explanation that reconciles why their estimates are significantly different from other estimates that are based on analysis of observed data. (2) Reduced deposition associated with reservoir infilling has been neglected. The fundamental issue motivating the LSRWA study is that the net trapping efficiency of Conowingo Reservoir has decreased dramatically over the past 15 to 20 years. Net trapping efficiency is the sum of increases in average annual scour and decreases in average annual deposition. However, the simulations and calculations in the study only considered the increase in scour. (3) Grain size effects within and exiting the reservoir were not sufficiently considered. The combination of two grain size effects – (i) changing grain size in time in the reservoir and (ii) the greater effects of fine sediment in transporting nutrients - mean that the effects of the reservoir on water quality have not reached a full dynamic equilibrium. However, the report did not address whether reservoirs were in dynamic equilibrium with respect to nutrients other than by assuming that if sediment was at equilibrium, then nutrients were also. (4) Limitations of the HEC-RAS and AdH models were not made sufficiently clear in the main report. The HEC-RAS modelling effort was largely unsuccessful, and the HEC-RAS simulation was largely abandoned as an integral part of the main report. Although consistent with four observed, integrated sediment-related properties of the system, the AdH model was not fully validated, and the AdH model was forced by boundary conditions outside the range of observed values. This means that the AdH model alone was not reliably predictive, and until the AdH model has been improved, observations should instead be emphasized to support the most important conclusions of the LSRWA study." (Pgs. 8-9).

Comment I-7-6: These are serious concerns and misinformation, how will this comment be addressed in the DLSRWA? The inconsistencies in data that pertains to sediment discharge, low rates, trapping capacity, dynamic equilibrium, grain size has a significant impact on model runs. How will this be addressed? How can Models be analyzed and compared with such inconsistencies? The DLSRWA authors should correct the fact that the Conowingo Dam is no longer trapping.

Comment I-7-7: If the AdH model alone was not reliably predictive, and needs substantial improvement, how can observations instead be emphasized to support the important conclusions of the study that relied heavily on the AdH two dimensional model? Does this statement mean that observations trump scientific data? Or does the statement mean that scientific data is not required?

- "Many of recommendations for future work and modelling tool enhancement are very good and are consistent with the views of this review." (Pg. 9).

Comment I-7-8: How could this statement be made given the statements above and the data inconsistencies and that the AdH model alone was not reliably predictive?

- "…[T]he HEC-RAS modelling effort was ultimately unsuccessful, and results of the HEC-RAS simulation did not form an integral part of the main report, and (ii) the existing application of the AdH model, although generally consistent with the validation data used, was not reliably predictive beyond constraints provided by a few integrated observations of sediment-related properties of the system."

Comment I-7-9: How can STAC say that these models did not provide an integral part of the report? If these models were not integral, why were they discussed and used? Why were these models used to identify concerns and also used to discuss the financial value of sediment management strategies if they were ultimately unsuccessful?

- The purpose of this assessment was to analyze the movement of sediment and associated nutrient loads within the lower Susquehanna watershed through the series of hydroelectric dams (Safe Harbor, Holtwood, and Conowingo) located on the lower Susquehanna River to the upper Chesapeake Bay. This included analyzing hydrodynamic and sedimentation processes and interactions within the lower Susquehanna River watershed, considering strategies for sediment management, and assessing cumulative impacts of future conditions and sediment management strategies on the upper Chesapeake Bay." A similar "purpose" statement appears in the Introduction. (Pgs. 5-6). Note that the word "nutrient" appears only once in the above statement, and the purpose of the study was mainly to address "sediment management".

Comment I-7-10: How was that purpose conducted through the use of unsuccessful modelling?

- "The report only briefly states that during the course of the study it became clear that nutrients were more important than sediment. More background is needed in the introduction regarding how and why this judgment was made and how the course of the study then evolved." (Pgs. 11-12).

Comment I-7-11: Once again the Report relies on assumptions. Is there any scientific background to this concern?

- "Although it is not specifically described as such in the draft report, the overall economic analysis in the LSRWA is in essence a cost-effectiveness analysis (CEA). In contrast to cost-benefit analysis in which the positive and negative impacts of alternatives are expressed and directly compared in monetary terms, CEA expresses some key impacts in non-monetary but still quantitative terms." (Pg. 14).

Comment I-7-12: Will a cost-benefit analysis be performed on this DLSRWA in terms of BMPs and sediment management strategies?

- "The report should also emphasize that further analysis would be required to appropriately rank the alternative strategies based on a more environmentally relevant total cost in terms of dollars per pound of nitrogen and/or phosphorus reduction." (Pg. 15).

Comment I-7-13: The Clean Chesapeake Coalition agrees with this comment. Will the final DLSRWA include alternative strategies based on environmental relevance with total cost in terms of dollars per pound of nitrogen and phosphorus reduction?

- "Although there is no single accepted procedure for reporting uncertainty in the context of scenario modelling, a part of the report should more explicitly explain why confidence intervals on predictions are generally not provided." (Pg. 16).

- **"**In many of the modeled scenarios, the changes in attainment of water quality criteria with fairly large management actions would appear to a non-technical reader to be very small. For instance, p. 135 states: "…estimated…nonattainment…of 1 percent, 4 percent, 8, percent, 3 percent…" One should ask if such estimates are statistically significant. Similarly, in appendix A, p. 25, the net deposition model indicated that ~2.1 million tons net deposition in the reservoirs occurred in 2008-11. This is the difference of two order-of-magnitude larger numbers (22.3M tons entered the reservoir, 20.2M tons entered the Bay). There is a rule-of-thumb in sedimentology: ±10% in concentration or transport is 'within error'." (Pg. 16).

Comment I-7-14: Does the precision of the computed difference fall within the margin of error in these metrics?

- On p. 113 the report states, "A close inspection of the model simulation results indicate that trace erosion does occur at lower flows (150,000 to 300,000 cfs.), which is a 1- to 2-year flow event. This finding is consistent with prior findings reported by Hirsch (2012)." The Hirsch (2012) findings are different from what is expressed here. The relevant statement from Hirsch (2012) is: "The discharge at which the increase [i.e., the increase in suspended sediment concentrations at the dam] occurs is impossible to identify with precision, though it lies in the range of about 175,000 to 300,000 cfs. Furthermore, the relative roles of the two processes that likely are occurring – decreased deposition and increased scour – cannot be determined from this analysis."

Comment I-7-15: Does the DLSRWA and the model runs account for such a discrepancy? If so, how? If not, why not?

- "Also on p. 190, the report indicates that, "The total sediment outflow load through the dam… increased by about 10 percent from 1996 to 2011…" These results are so strongly at odds with other published numbers on this subject that some explanation and discussion is certainly required. Hirsch (2012) reports an increase in flow-normalized flux over the period 1996-2011 of 97 percent (*see* Table 3 of Hirsch). Also, Langland and Hainly (1997) published an estimate of change in average flux from about 1997 to the time the reservoir is full of 250%. Reporting a 10% increase in light of these two other findings appears erroneous."

Comment I-7-16: Why weren't Hirsch's and Langland's numbers used instead of 10%?

- From STAC: "p. 138 Paragraph 2: Oysters are discussed here within a section that otherwise discussed the modelling and simulation activities. Is there a description of how model analysis was used in this report to determine flow and management effects on oysters? Whatever the case, it should be clearly stated where the oyster effects fit into this report and whether or not model simulations were used to understand effects on oysters."

- LSRWA Response: No specific modelling simulations were run to quantify oyster impacts. However this resource is of high interest so this qualitative language was added. This paragraph was deleted from this section since the context here is specific LSRWA simulation results (*i.e.*, quantified results). Section 2.7.4 discusses oysters and impacts from storm events summarizing a DNR report on effects from Tropical Storm Lee.

Comment I-7-17: Were model runs conducted by DNR to determine impact on oysters or was it based on observations? If based on observation were sediment levels that blanketed the oysters considered as an impact?

- "As described in Section 5.2, "the LSRWA team relied heavily on the Bay TMDL work done by CBP and state partners to develop the watershed management strategies. As such, the LSRWA team adopted the CBP methodology and unit costs as the representative alternative for a watershed management strategy; additional cost and design analyses were not undertaken." Citations are included where appropriate (e.g. U.S. Environmental Protection Agency (U.S. EPA). 2010), however, personal communication by LSRWA was required to ensure that LSRWA interpretations of CBP work on watershed BMPs/strategies were accurate." (Pg. 35).

Comment I-7-18: Throughout the report, statements are made that the Bay TMDL work needs to be reevaluated given that the Conowingo Dam no longer has the trapping capacity that was once considered. Given that the DLSRWA adopted the outdated CBP methodology, how could the team ignore additional cost and design alternatives?

- Attachment I-7 includes a letter from Exelon to the Army Corps of Engineers (dated July 18, 2014) thanking the Corps of Engineers for the opportunity to review and comment om the Draft LSRWA Study. (No Page number provided).

Comment I-7-19: Please explain why Exelon received the DLSRWA several months earlier to perform an extensive review of the main report and appendices. Why weren't other commenters, such as the Clean Chesapeake Coalition given that opportunity? Are we to expect that Exelon will assist the LSRWA study group in addressing our comments?

APPENDIX J

*****It is quite evident that the data and studies used in the Watershed Strategy Section are outdated and incorrect. Appendix J relies on the following incorrect statements:

- "Sediment deposition to Chesapeake Bay from the Susquehanna River is mitigated by the presence of three consecutive hydroelectric dams (Safe Harbor Dam, Holtwood Dam, and Conowingo Dam). These three dams form a reservoir system in the lower part of the River that These three dams form a reservoir system in the lower part of the River that has been trapping sediment behind the dams since they were constructed in 1910 (Holtwood Dam), 1928 (Conowingo Dam) and 1931 (Safe Harbor Dam). The uppermost two dams, Safe Harbor Dam and Holtwood Dam, have already reached their capacity to store sediment and sediment-related nutrients. Conowingo Reservoir, which is formed by Conowingo Dam, the lowermost and largest dam, has not reached storage capacity and is still capable of trapping." (Pgs. 1-2).

Comment J-2: Appendix J begins with incorrect information by expressing the remaining storage capacity of the Conowingo Dam. (Pg. 2). Given that this Appendix is used to develop a watershed strategy, a major concern and comment is how could this be accomplished if the current status of the Conowingo Dam is not properly delineated or understood?

*The Appendix discusses further the importance of the TMDLs and the CBP 5.3.2 Watershed model run established in 2010.

- The Chesapeake Bay Program developed the E3 scenario from a list of approved agriculture and urban/suburban BMPs using output from the Phase 5.3.2 Watershed Model, which is also used for tracking towards the TMDL. "The BMPs that are fully implemented in the E3 scenario were estimated to produce greater reductions than alternative practices that could be applied to the same land base (Jeff Sweeney, personal communication)."

Comment J-3: Is personal communication is now the new standard in determining scientific merit? What science is Jeff Sweeney using to make such an evaluation of BMPs and to make such a statement?

- The Chesapeake Bay Program also developed unit costs for the approved BMPs. Most, though not all, of the BMPs used in the E3 scenario have associated unit costs in either acres or feet. The primary source of the unit costs was the Bay Program approved list; however, in order to have as complete a cost estimate as possible, in the absence of unit costs from the Bay Program, costs from the Maryland Department of the Environment (MDE) (Greg Busch, MDE, personal communication), and costs from the Maryland

Department of Agriculture (MDA) (John Rhoderick, MDA, personal communication) were used. (Pg. 5).

Comment J-4: Is there a cost benefit analysis associated with these expected costs on local governments? If so, is it based on science and data or someone's personal communication?

- Agriculture unit costs ranged from $2 per acre to develop conservation management plans to $1,948 per acre for "loafing lot management" (stabilizing areas frequently and intensively used by animals, people, or equipment).

Comment J-5: Where is the source of this data? Is it from the unit cost estimates from the Bay Program and other sources used to develop a range in the cost of achieving the theoretical maximum amount of sediment reduction to the Conowingo Reservoir (discussed on Pg. 6)? If so, where is this data and what are the other sources?

- "The maximum available load of sediment per year that could be reduced by additional BMP implementation above and beyond the WIPs throughout the Susquehanna River watershed is approximately 95,000 tons (equivalent to 190,000,000 lbs of sediment per year; or 117,284 cubic yards per year) 2,000 lbs is equivalent to approximately 1 ton; 190,000,000 lbs divided by 2,000 equals 95,000 tons per year; approximately 81 tons are in 1 cubic yard; or 1600 kilograms/cubic meter; 95,000 divided by .81 equals 117,284 cubic yards per year) at a cost of 1.5 to 3.6 Billion dollars. The amount of 95,000 tons is an order of magnitude less of what is estimated to flow over Conowingo Dam into Chesapeake Bay on an average annual basis, which is approximately, 1.8 million tons (1993-2012 hydrology)." (Pgs. 5-6).

Comment J-6: This no longer seems to be the case given that the Conowingo Reservoir was considered a trap and not a source of sediments and nutrients in these calculations.

Comment J-7: Attachments 2 and 3 (Pgs. 11-12) of Appendix J state the following: "Cost estimates are provided for planning purposes only, and are based on generalized costs of implementation. Project specific design and cost estimates would be required prior to actual implementation of any of these alternatives." What are the generalized costs of implementation? How do these attachments provide anyone with a true understanding of costs if design and cost estimates are not considered in the total cost analyses?

- "EPA uses unit costs for agricultural sediment or nutrient controls identified in the WIPs from USDA's Environmental Quality Incentive Program (EQIP), where available, and WIPs and prior studies where EQIP estimates are not available. In selecting relevant studies, EPA excludes those prior to 2000, and relies on EQIP and WIP estimates where feasible because these costs likely represent the most recent and best estimates of actual implementation costs."

Comment J-8: The U.S. Department of Agriculture's Environmental Quality Incentive Program (EQIP) is currently an interim rule open for comment. In addition, Executive Order 12866 and 13563 "Improving Regulation and Regulatory Review," directs agencies to assess all costs and benefits of available regulatory alternatives and, if regulation is necessary, to select regulatory approaches that maximize net benefits (including potential economic, environmental, public health and safety effects, distributive impacts, and equity). Executive Order 13563 emphasizes the importance of quantifying both costs and benefits, of reducing costs, of harmonizing rules, and of promoting flexibility. The Clean Chesapeake Coalition would appreciate an assessment of all costs and benefits of available regulatory alternatives, in particular analyses of how the unit costs were derived for the DLSRWA.

Comment J-9: Throughout the Document it is stated that: "EPA annualizes capital costs over the specified life of the BMP." How does EPA annualize capital costs?

> Forest buffers are linear wooded areas along rivers, stream, and shorelines. The recommended buffer width for riparian forest buffers (agriculture) is 100 feet, with a 35-foot minimum width required. Upfront installation costs associated with forest buffers typically include site preparation, tree planting and replacement planting, tree shelters, initial grass buffer for immediate soil protection, mowing (during the first 3 years), and herbicide application (during the first three years).

Comment J-10: Forrest Buffers are listed as a BMP. Has anyone evaluated Sapropel concerns from decaying leaves and their ability to seriously decrease deep water oxygen and increase Hydrogen sulfide deposits?

- Estimates pertaining to unit cost in association with frequent maintenance and pumping of septic systems is expected to reduce nitrogen loadings. (Pg. 29).

Comment J-11: What is the origin of these estimates? Where is the financial cost data associated with these estimates?

<u>Attachment J2: Cost Documentation – General Assumptions</u>

- The Costs associated with the Charts presented in Attachment J2 are "concept-level costs for planning purposes only. Detailed design and cost estimate would be required for any future studies investigation implementation of any of these alternatives. All alternatives assume the dredging of a location in Conowingo Reservoir which currently has the highest amounts of deposition in the entire lower Susquehanna reservoir system; similar costs could be developed for the other lower Susquehanna reservoirs."

Comment J-12: Given the assumption above, will the design and cost estimates be the same if the purpose of the DLSRWA were to comprehensively forecast and evaluate sediment and associated nutrient loads into and from the system of hydroelectric dams located on the Lower Susquehanna River above the Chesapeake Bay and consider structural and non-structural strategies to manage these loads to protect water quality and aquatic life in the Chesapeake Bay? (Pg. 4 – 08/16/2012, Attachment I- 6).

Comment J-13: Screening level estimates are included in charts that evaluate available capacity. Does the available capacity evaluation consider that the Conowingo Reservoir is still trapping? In addition, estimates are based on assumptions in the screening level cost estimates. How are the financial benefit analyses achieved with assumptions being made for estimates? Is there a margin of error available for these estimates? What is the source for the cost estimates related to temporary dewatering sediment?

Attachment J-3

- This analysis is based on planning level sediment management concepts. To fully understand and evaluate effects of any of these concepts detailed designs would be required. Fatal Flaw-Determined by team that strategy should be dropped from consideration.

Comment J-14: What is the basis for these management concepts? What scientific studies and/or data were considered in developing such concepts? According to the summary "…because of amount of variables, representative alternatives were developed to cover ranges of costs each one of these variables could impact." What are those variables and alternatives developed?

- Attachments 2 and 3 on Pgs. 12-13 in Appendix J show the costs by practice across the three states. However, the current information does not make it possible to assess the variation in cost effectiveness of the various urban and agricultural BMPs in meaningful terms, such as the dollars per cubic yard of sediment removal. Importantly, the cost-effectiveness between practice types typically varies by one or two orders of magnitude. Hence, the current analysis aggregates all practices types and reports an overall cost estimate at $3.5 billion in Table 3 (or Table 6-3). Then the report provides an overall average cost effectiveness of $256-$597 per cubic yard in Table 6-6, and seems to imply that this watershed BMP approach is supposedly the most expensive. But this assessment that aggregates all practice types may overlook the high degree of heterogeneity in costs between practice types. (Pg. 35, Appendix 1-7).

Comment J-15: Please explain how such an analysis is beneficial to the DLSRWA.

- Attachment 4 of Appendix J on pp. 29-33 includes detailed information on "Septic Systems". However, septic systems are not discussed at all in the corresponding tables for the cost analysis in Attachments 2 and 3.

Comment J-16: Please provide the cost analyses by different States.

APPENDIX K

Introduction

- Lake Clarke shallowest- averaging 15 feet deep.
- Lake Aldred is the deepest, with greatest depths of 80 to 120 feet.
- The deepest areas of Conowingo Reservoir are located near the dam, depths averaging 55 feet along the Spillway gates and about 70 feet near the turbine gates. (Pg. 4).
- Rolling hills of the Piedmont in the vicinity of the Conowingo Dam above the valley range in elevation from 250 to 400 feet maximum.
- The uplands above the gorge near the vicinity of safe harbor and Holtwood dams rise to about 750 feet in elevation.
- Climate trends in the last two decades have shown wetter conditions on average, than in previous decades. Increased precipitation has produced higher annual minimum flows and slightly higher median flows during summer and fall (Najjar et al., 2010). (Pg. 5).

Comment K-1: Why aren't climate change or climate trends considered in the draft model runs? If there were indeed considered why are the model runs capped at a flow rate slightly above 620,000 cfs.?

- As of 2003, 23 percent of the Chesapeake Bay watershed is used for agriculture and almost 12 percent has been developed. (Pg. 5).
- Water circulation in the Bay is primarily driven by the downstream movement of fresh water in from rivers and upstream movement of salt water from the ocean. Less dense, fresher surface water layers are seasonally separated from saltier and denser water below by a zone of rapid vertical change in salinity known as the pycnocline (CBP, 2013). The pycnocline plays an important role in Bay water quality acting to prevent deeper water from being reoxygenated from above (Kemp et al., 1999). Pycnocline depth varies in the Bay as a function of several factors. It shows general long-term geographic patterns as summarized in Table K-4, but varies over shorter time periods as a function of precipitation and winds. (Page 8) During warm weather months it promotes stronger stratification that can last for extended periods during a year. Conversely, sustained winds in a single direction for several days can cause the pycnocline to tilt, bringing deeper water up into shallows on the margins of the Bay.

Comment K-2: How do any of the models account for this water circulation or wave movement?

- Because of this partial seasonal separation into layers, or strata, the Bay is classified as a partially stratified estuary. Division of surface from deeper waters varies depending on the season, temperature, precipitation, and winds. In late winter and early spring, melting snow and high streamflow increase the amount of fresh water flowing into the Bay, initiating stratification for the calendar year. During spring and summer, the Bay's surface waters warm more quickly than deep waters, and a pronounced temperature difference forms between surface and bottom waters, strengthening stratification. In autumn, fresher surface waters cool faster than deeper waters and freshwater runoff is at its minimum. The cooler surface water layer sinks and the two layers mix rapidly, aided by winds. During the winter, relatively constant water temperature and salinity occurs from the surface to the bottom (CBP, 2013). (Pg. 9).

- USACE and SRBC recognize the Susquehanna River basin as one of the most flood-prone basins in the United States from a human impacts perspective. Flow conditions can vary substantially from month to month; floods and droughts sometimes occur in the same year. Floods can scour large volumes from the river bed and banks, and convey large quantities of nutrients and sediment downstream. (Pg. 11).

- Salinity is an important factor controlling the distribution of Bay plants and animals. Salinity is the concentration of dissolved solids in water and is often discussed in terms of parts per thousand (ppt). In Maryland, Bay surface waters range from fresh in headwaters of large tidal tributaries to a maximum of about 18 parts per thousand (ppt) in the middle Bay along the Virginia border. Salinity varies during the year, with highest salinities occurring in summer and fall and lowest salinity in winter and spring. (Pg. 13).

- The ETM zone is an area of high concentrations of suspended sediment and reduced light penetration into the water column. Each of the Bay's major tidal tributary systems has an ETM zone near the upstream limit of saltwater intrusion. The Susquehanna River ETM zone occurs in the upper Bay main stem. The position of the ETMs changes seasonally and with large freshwater flow events from storms. The ETMs extend further downstream into the Bay during times of year when lower salinities occur and following major storm events, and further upstream when seasonally higher salinities occur. The ETM zone is produced by a complex interaction of physical and biological processes, including freshwater inflow, tidal and wave-driven currents, gravitational circulation, particle flocculation, sediment deposition and resuspension, and biogeochemical reactions. (Pg. 13).

- Tidal resuspension and transport are primarily responsible for the maintenance of the ETM zone at approximately the limit of saltwater intrusion. Generally, fine-grained riverborne sediment in the ETM zones is exported further downstream into the main Bay only during extreme hydrologic events. The mainstem Bay ETM zone occurs in the upper Bay; in this region, most of the fine-grained particulate matter from the Susquehanna River is trapped, deposited, and sometimes resuspended and redeposited.

The mainstem ETM zone acts as a barrier under normal conditions for southward sediment transport of material introduced into the Bay from the Susquehanna River (USGS, 2003).

Eutrophication

- Anthropogenic nitrogen and phosphorus nutrient pollution delivered to the Bay exceeds the Bay ecosystem's capability to process it without ill effect. The Bay's physical character and circulation patterns tend to retain water-borne materials, thus exacerbating the effect of anthropogenic pollution. The Bay's natural capability to buffer the incoming nutrient loads are governed by seasonal stratification and limited tidal mixing rate (Bever et al., 2013). Anthropogenic nutrient pollution to the Bay derives from agricultural runoff and discharges, wastewater treatment plant discharges, urban and suburban runoff, septic tank discharges, and atmospheric deposition of exhaust (CBP, 2013). Water bodies possess a range of nutrient availability conditions. Water bodies possessing ample or excessive nutrients whether from natural or human sources are said to be eutrophic. The Bay became eutrophic because of inputs of large quantities of anthropogenic nutrients. Excess nutrients in the water column from human sources fuel the growth of excess phytoplankton. Zooplankton, oysters, menhaden, and other filter feeders eat a portion of the excess algae, but much of it does not end up being consumed by these organisms. The leftover algae die and sink to the Bay's bottom, where bacteria decompose it, releasing nutrients back into the water, fueling further algal growth. During this process in warm weather months, bacteria consume DO until there is little or none left in deeper bottom waters (CBP, 2013). Within the Bay, nitrogen is the principal limiting-nutrient regulating phytoplankton. The limiting nutrient is that nutrient available in lowest supply in proportion to biological demand. However, phosphorus is the limiting nutrient for phytoplankton growth in low salinity Bay waters in spring. Phosphorus is typically the limiting nutrient in freshwater ecosystems. (Pg. 16).

- Nitrogen and phosphorus actually occur in a number of different forms in the environment that differ in their biological availability and effects on water quality. (Pg. 17). Total nitrogen (TN) includes nitrate, nitrite, ammonia, and organic nitrogen. (Pg. 17).

- Ammonia is the dominant dissolved nitrogen form in deeper waters during warm months. Nitrite is generally unstable in surface water and contributes little to TN for most times and places. Organic nitrogen (mostly from plant material, but also including organic contaminants) occurs in both particulate and dissolved forms, and can constitute a substantial portion of the TN in surface waters. However, it is typically of limited bioavailability, and often of minimal importance with regard to water quality. Conversely, nitrate and ammonia are biologically available and their concentration is very important.

- Total phosphorus (TP) includes phosphates, organic phosphorus (mostly from plant material), and other phosphorus forms. Phosphates and organic phosphorus are the main components of TP. Phosphates tend to attach to soil and sediment where their bioavailability varies as a function of environmental conditions. Dissolved phosphate is readily bioavailable to aquatic plant life, and consequently promotes eutrophication (USGS, 1999). Phosphorus binds to river sediments and is delivered to the Bay with sediment. (Pg. 17).

Comment K-3: What model is used to address how phosphorus is bound to sediments? How are phosphorus levels and its impact addressed in the DLSRWA?

- Nutrient transport in rivers is usually considered in two fractions – that portion conveyed in dissolved form and that portion carried as particulates. Particulates include mineral sediments and plant debris. During downstream transport, bacteria and other stream organisms take up dissolved nutrients and convert them to organic form. When organisms containing these nutrients die, the nutrients return to the water in inorganic form, only to be taken up yet again by other organisms. This cycle is referred to as nutrient spiraling.

- Nutrient pollutants delivered to the Bay vary year to year as a function of amount and timing of precipitation. Wet years deliver greater nutrient pollution to the Bay than dry years. For example, the amounts of nitrogen and phosphorus transported during Tropical Storm Lee (a September 2011 high-flow event) were very large compared to long-term averages for the Susquehanna River over the past 34 years. However, this difference is less pronounced for nitrogen than it is for phosphorus, because on average, a large part of the nitrogen flux is delivered in dissolved form. Specifically, the amounts transported during the Tropical Storm Lee event were estimated to be 42,000 tons of nitrogen and 10,600 tons of phosphorus. For comparison, the estimates of the averages for the entire period from 1978 to 2011 were 71,000 tons per year for nitrogen and 3,300 tons per year for phosphorus (Hirsch, 2012). (Pg. 17).

Comment K-4: How were the phosphorus levels, namely 10,600 tons, generated for Tropical Storm Lee? Did the 10,600 tons number take into account phosphorus bound to sediments?

- Phosphorus is conveyed in rivers as phosphate adsorbed to sediment particles. It is also conveyed bound to calcium, and as organic particles. The processes by which phosphorus is released from sediments is complicated and affected by biological as well as physical chemical processes. In oxygenated fresh water, phosphorus adsorbed to fine-grained sediments remains bound and has limited bioavailability. Under anoxic or hypoxic freshwater conditions, phosphorus becomes more bioavailable, but phosphorus rebinds to sediments if oxygen is again present. In the Bay's saltwater environment, biogeochemical conditions change causing phosphorus bioavailability to differ from in freshwater. As salinities increase above about 3 to 4 ppt, phosphorus bound to sediments is increasingly released and becomes mobile and bioavailable to living resources (Jordan et al., 2008; Hartzell and Jordan, 2012). The uppermost Bay remains generally below salinities of 3 ppt all year, which tends to favor phosphorus immobilization in sediments, but otherwise the Bay is salty enough to allow phosphorus release from sediments (CBP, 2013). (Pg. 19).

- Conowingo Reservoir water temperatures range from about 59°F to 91°F during the period of April through October. The reservoir remains relatively constant in temperature vertically for much of the year, but reservoir water can be up to several degrees cooler at the bottom than at the surface for brief periods. DO in Conowingo Reservoir becomes depleted in waters of the reservoir greater than 25-foot depth under conditions of low river inflow (less than 20,000 cfs.) and warm water temperatures (greater than 75°F). Reservoir DO levels occasionally drop below 2 mg/L (Normandeau Associates and GSE, 2011). USGS collected and analyzed water samples of Conowingo Reservoir outflow during high-flow events during water year 2011 (which ran from October 1, 2010 to September 30, 2011) for this assessment. (Pg. 22).

Comment K-5: How did the models take into account reservoir water temperature? What type of model analysis was used to account for DO levels?

- The Susquehanna River transports large volumes of sediment to the Chesapeake Bay. Two flood events, associated with Hurricanes Agnes (1972) and Eloise (1975), contributed approximately 44 million tons of sediment to the Bay. Recent estimates calculate that the Susquehanna River transports 3.1 million tons annually, depositing 1.9 million tons behind Conowingo Dam with the remaining 1.2 million tons deposited in the Chesapeake Bay (1996-2008 evaluation periods) (Langland, 2009). In the upper Bay, the Susquehanna River is the dominant source of sediment influx, supplying over 80 percent of the total sediment load in the area (SRBC Sediment Task Force, 2001). (Pg. 27).

DECEMBER 9, 2014 PUBLIC MEETING

Comment Public Meeting: The three individuals at the December 9, 2014 meeting at Harford Community College that presented the DLSRWA (Messrs. Bierly, Michael and Bier) suggested that the report will be used to determine who should have responsibility for addressing harm to the Bay caused by sediment scour. The discussion overlooked the decades of harm from scour that already has occurred and the fundamental evolution of the surface solids that now settle in the reservoirs. When the dams were new and the reservoirs behind the dams were deep, clays and silts in addition to the larger grained sands settled in the reservoirs behind the dams. The clays are the easiest sediments to scour as they are the finest grained and lightest solids to settle out of suspension and become more easily resuspended. The clays also probably bond the most phosphorus and other pollutants and nutrients. Silts lie somewhere in the middle and the sands are the heaviest and probably bond the least amount of sediments and nutrients. For decades, the dams have deprived the upper Bay of sands and have allowed the less desirable and more harmful clays and silts to be scoured and flushed into the Bay in deathly quantities during storm events. Such clays and silts also are more likely to become resuspended during turbulent weather in the Bay than the sands. Now, much of the material remaining on the floor of the reservoirs consists of sand, as the clays and silts have been flushed into the Bay for the last 80 years, while the sand, due to particle size and weight, has settled to the bottom and has less frequently been scoured into the Bay. There are studies that confirm these phenomena. Any consideration of responsibility for scour should take into account how the dams already have materially altered and damaged the Bay estuary by depriving it of the more beneficial sand while flushing in the more harmful clays and silts, until the present, when most of what remains to be scoured consists primarily of sand.

Comment Public Meeting: The three individuals at the December 9, 2014 meeting at Harford Community College that presented the DLSRWA (Messrs. Bierly, Michael and Bier) suggested that the report had received favorable peer review. Peer review can take on several formats but it most commonly is understood as review by qualified scientists of written scientific reports to test and to assess the methodology used to reach findings and conclusions and to access the confidence level in/validity of the findings made and the conclusions drawn in the report. It is hard to imagine that the DLSRWA was peer reviewed because the report does not begin to explain the methodology used to derive any findings or conclusions. Only upon reading thousands of pages of appendices can one begin to assess what work was performed, and even then only in the most cursory of manners. For example, the flow chart used to diagram the models used to generate data is cursory. Nowhere is the raw data underpinning different modelling efforts set forth, let alone being adequately explained. If there was any meaningful peer review of the DLSRWA, any report or appendix attached to the report, or any of the findings and conclusions in the report, please identify by name and qualifications the each person who conducted any peer review and attach any written findings conclusions, and input made by each such individual or group of individuals. There should be a peer review document. Please identify and provide a link to such document.

Any questions about the Coalition's comments concerning the DLSRWA may be directed to Jeff Blomquist (jblomquist@fblaw.com or 410-659-4982), Michael Forlini (mforlini@fblaw.com or 410-659-7769) or Chip MacLeod (cmacleod@fblaw.com or 410-810-1381).

Colleen Hicks
Manager Regulatory
and Licensing, Hydro
Exelon Power

300 Exelon Way
Kennett Square, PA 19348
(610)765-6791
colleen.hicks@exeloncorp.com

January 9, 2015

Anna Compton
Study Manager, Planning Division
Baltimore District, Corps of Engineers
10 South Howard Street
Baltimore, MD 21201

Re: Lower Susquehanna River Watershed Assessment Draft Report
Comments of Exelon Generation Company, LLC

Dear Anna:

Exelon Generation Company, LLC (Exelon) appreciates the opportunity to provide feedback and comments to the U.S. Army Corps of Engineers (Corps) on the Lower Susquehanna River Watershed Assessment (LSRWA) Draft Report ("Draft Report") distributed for review on November 13, 2014. The Draft Report represents a tremendous amount of work by the project partners and represents an important step in understanding the Susquehanna River/Chesapeake Bay (the Bay) water quality interactions.

Exelon also appreciates the LSRWA authors' responses to the comments Exelon filed on July 18, 2014.[1] After extensive review of the Draft Report, including its appendices, Exelon has again developed detailed comments which are contained in the accompanying tables. As you will see upon review of the comment tables, Exelon expanded upon the responsiveness summary contained in Appendix I to include a new column with additional comments to LSRWA author responses or new comments pertaining to report content. While some comments raised in July 2014 were addressed in the updated report, a number of significant concerns previously identified are still relevant to the latest draft and are discussed below. Exelon hopes that these comments will assist the Corps in developing the most technically sound and understandable document possible.

In addition to the comments provided by Exelon in July 2014, Appendix I Section I-7 also contains comments provided by the Scientific Technical Advisory Committee (STAC) as well as the responses of the LSRWA authors to those comments. Upon review of Appendix I it is clear that both STAC and Exelon agreed that the LSRWA was generally well done and was a useful exercise to ascertain general trends. STAC and Exelon, however, identified a number of important concerns with the assessment. These concerns included: (1) the manner in which nutrients were addressed throughout the report given

[1] A working draft of the LSRWA report was distributed for Stakeholder review on June 23, 2014. Exelon filed comments with the Corps on July 18, 2014. The LSRWA leads responded to the Exelon comments in the form of a responsiveness table which can be found in Appendix I, Section I-7 of the LSRWA Draft Report issued November 13, 2014.

their impact was not fully understood until late in the study process; (2) the significant uncertainties pertaining to HEC-RAS and AdH results; (3) the lack of a quantitative discussion of the effects model uncertainties may have on study findings; (4) the lack of a clear, easy to follow explanation regarding model input parameters and the manner in which various models interacted with one another; and (5) the lack of information needed to further understand the diagenesis rates discussed in Appendix C.

While Exelon realizes the limitations of time and budget, we think it is important for the LSRWA authors to carefully consider the limitations highlighted by STAC and Exelon and reflect them as changes to the main report and the appendices. Furthermore, the LSRWA response to STAC comments is incomplete at this time as the majority of responses for comments pertaining to the AdH model were cited as still being under development by the ERDC AdH modeler. Exelon would appreciate the opportunity to review and comment on these responses prior to the final draft of the report being issued.

While the content of the LSRWA Draft Report represents some changes from the version distributed in June 2014, the report and its findings are substantively the same as the previous draft. As such, the points raised by Exelon in the letter dated July 18, 2014 are still relevant. Specifically, these points include the following:

The LSRWA Draft Report represents a significant contribution to the understanding of the overall positive benefit Conowingo Dam (Conowingo) provides for the health of the Bay.

- The report makes several well-supported conclusions, including the following: (1) the majority of the sediment that enters the Bay during storm events originates from the watershed rather than from Conowingo Pond scour; (2) given the small contribution of sediment from Conowingo Pond, the primary impact to the Bay is from sediment and nutrients from the Susquehanna River and Chesapeake Bay watershed; and (3) implementation of Watershed Implementation Plans has the largest influence on the health of the Bay.
- Furthermore, the report concludes that, while Conowingo Pond is in dynamic equilibrium, the Pond will continue to trap sediments and associated nutrients into the future during depositional periods. The report also states that from 1993-2012, the annual trapping efficiency of Conowingo Pond was 55-60%. This finding, which is consistent with the assumptions of the Chesapeake Bay TMDL, highlights the day-to-day benefits that Conowingo provides to the Bay.

The finding that "nutrients, not sediment, have the greatest impact on Bay aquatic life," came up late in the study process, is not fully understood at this time, and requires further investigation.

- As currently written, the report makes numerous definitive statements in regard to the impacts of sediment-bound nutrients on Bay water quality while admitting this is a subject that is not fully understood and requires additional investigation.
- A discussion of supporting nutrient data and quantitative nutrient model assumptions is conspicuous by its absence in the report. The final report should either provide the field and model data supporting these conclusions, with any appropriate qualifiers, or simply list nutrient interactions in the Susquehanna River and Chesapeake Bay as areas requiring additional study.
- Due to the disproportional focus on Conowingo Pond sediment and nutrient dynamics, the report gives the impression that sediment-bound nutrients scoured from Conowingo Pond are the main

threat to Bay water quality; even though 70-80% of sediment that flows to the Bay during a major storm originates from the watershed upstream of Conowingo Pond (including scour from Lake Clarke and Lake Aldred). In contrast, the appendices (in particular Appendix C) indicate that all nutrients entering the Bay threaten water quality, whether they are watershed-derived or bound to scoured sediments.

While the study goals state that the LSRWA was intended to examine the "loss of sediment and associated nutrient storage within the reservoirs of the lower Susquehanna River," the discussion and findings of the report (including sediment management strategies) focus almost exclusively on Conowingo Pond.

- As currently drafted, the report understates the significance of sediment and nutrient loading from sources upstream of Conowingo Pond. The main report specifically states that 70-80% of sediment that flows to the Bay during a major storm originates from the watershed upstream of Conowingo Pond; yet rather than focus on those sources, the main report instead focuses primarily on Conowingo Pond scour.
- Due to the focus primarily on Conowingo Pond and not all three Lower Susquehanna River reservoirs, the report gives the impression that only Conowingo Pond scour has a potential impact on Bay health, when in fact all three reservoirs are in dynamic equilibrium and susceptible to episodic scour. In order for this study to be a true Lower Susquehanna River assessment, all three reservoirs (Lake Clarke, Lake Aldred, and Conowingo Pond) should be examined and discussed proportionately.

While the general uncertainties associated with the various models and sub-models are discussed in the report and appendices, it is unclear how these uncertainties may propagate through the Chesapeake Bay Environmental Model Package (CBEMP) results.[2] Thus, the reader has no way of knowing how the results of the CBEMP model are affected by the uncertainties discussed in the report and appendices. In particular we are concerned that:

- The uncertainties within the HEC-RAS sediment load outputs (as noted by the author) may materially impact the AdH model results.
- The AdH results were associated with a separate list of assumptions and additional uncertainties.
- A sensitivity analysis or other assessment was not conducted to determine how these collective HEC-RAS and AdH uncertainties may ultimately impact CBEMP model results and the nonattainment percentages that are listed throughout the main report.

Although the individual modeling methods, assumptions, inputs, and outputs are well explained in their respective appendices, it would be helpful for the reader to have a single point of reference within the main report to explain all interactions between the various models.

- While Figure 1-5 in the main report explains the model interaction in a general sense, we envision an accompanying figure and narrative within the main report to more specifically define the

[2] According to the LSRWA Draft Report, the Chesapeake Bay Environmental Model Package or CBEMP uses a variety of sub-models, input parameters, modeling methods and assumptions to estimate the water quality impacts of selected watershed and land use conditions, reservoir bathymetries, and flows.

interactions. We have resubmitted Attachment 1 as an example of what we believe such a figure could look like.

- In addition to model interactions, it is difficult to track the model input conditions and assumptions, water quality analysis periods, and attainment results for each LSRWA modeling scenario. While the Appendices describe these parameters for some of the modeling runs, they do not describe all modeling runs nor is there a single, clear point of reference in the main report where this information can be found. We suggest the Corps consider developing a table to explain all of the LSRWA runs described in Appendix C, plus add a brief summary of any water quality nonattainment for each scenario. We have resubmitted Attachment 2 as an example of such a table.
- If the Corps does not include Attachment 1 and/or 2 in the next draft of the report, confirmation that the information contained in the attachments is correct and answers to the questions posed would be appreciated.
- We also recommend including the "stoplight plot" analysis results in Appendix D for all of the scenarios described in Table 3-1 of Appendix C.

Finally, the report identified a number of recommendations for follow through actions that will allow for a better understanding of sediment and nutrient transport dynamics in the Lower Susquehanna River and the potential effect they may have on Bay water quality. As such, Exelon has agreed to fund a $3.5 million, 2-year study to address a number of these recommendations and provide additional information to better understand the impact of sediment-bound nutrients on Bay water quality. Exelon looks forward to working with the Maryland Department of Natural Resources, the Maryland Department of the Environment, the U.S. Geological Survey, the U.S. Environmental Protection Agency Chesapeake Bay Office, and the University of Maryland Center for Environmental Science over the next 2 years while completing this study.

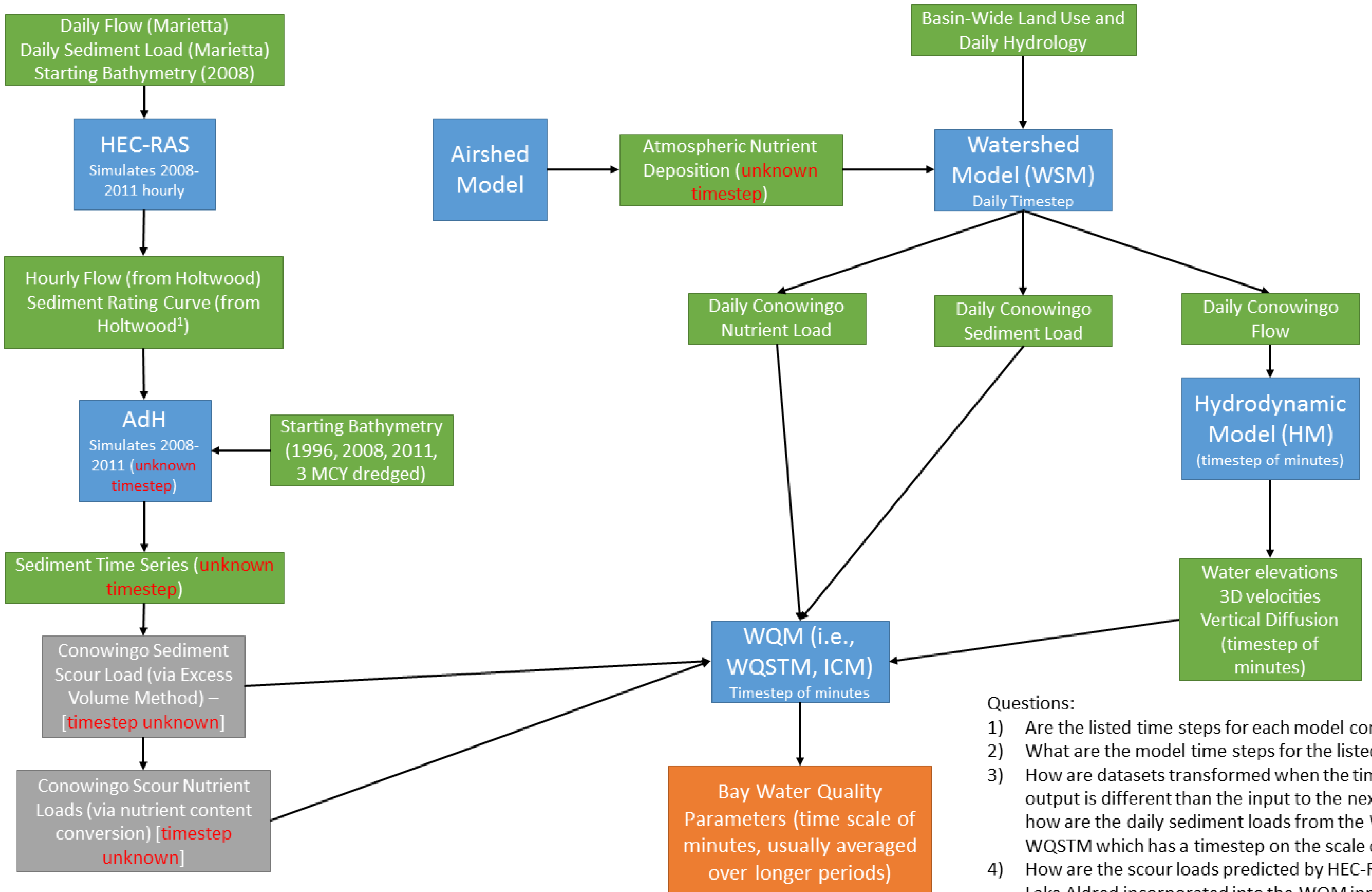
Detailed comments elaborating on the points discussed in this letter can be found in the accompanying tables as well as the letter and comments submitted on July 18, 2014. Exelon reserves the right to make additional comments in the future. We appreciate the opportunity to provide feedback and comments on the LSRWA Draft Report and look forward to continuing to work with project partners in the future. If you have any questions upon review of our comments, please feel free to contact me at (610) 765-6791 or colleen.hicks@exeloncorp.com or Tom Sullivan at (603) 428-4960 or tsullivan@gomezandsullivan.com.

Respectfully submitted,

Colleen E. Hicks

Colleen E. Hicks
Manager Regulatory and Licensing, Hydro
Exelon Power

Attachment 1: Description of WQSTM model interactions.



Questions:

1) Are the listed time steps for each model correct?
2) What are the model time steps for the listed unknowns (e.g., AdH)?
3) How are datasets transformed when the timestep of a model output is different than the input to the next model? For example, how are the daily sediment loads from the WSM translated into the WQSTM which has a timestep on the scale of minutes?
4) How are the scour loads predicted by HEC-RAS for Lake Clarke and Lake Aldred incorporated into the WQM inputs?

[1]The Holtwood sediment outflows were calculated from the HEC-RAS "scour" model, plus an additional 10% beyond the HEC-RAS predicted sediment load.

Attachment 2: Potential format for describing model inputs for each LSRWA scenario.
Footnotes are included to describe conditions common for all scenarios. Black text describes information taken from Appendix J-4. Blue text describes information taken from Appendix C.

Model Code	Description or Study Question	Models Used	Land Use (i.e., watershed sediment/nutrient loads)	HEC-RAS Model Run (scour or depositional)	Reservoir trapping efficiency	Reservoir Scour Load Method	Reservoir Sediment Nutrient Content	Time period analyzed for WQ Nonattainment	Deep Channel DO Nonattainment in CB4MH	Deep Channel DO Nonattainment in EASMH	Deep Channel DO Nonattainment in CHSMH
LSRWA-3	What is the system's condition when WIPS are in full effect and reservoirs have not all reached dynamic equilibrium?	CBEMP[1,2]	TMDL – WIPS in place	N/A	1991-2000 levels[3]	None	N/A	1993-1995	0%	0%	0%
LSRWA-4	What is the system's current (existing) condition?	CBEMP	2010 Land Use	N/A	1991-2000 levels	None	N/A	1993-1995	?	?	?
LSRWA-5	2010 land use with Conowingo reservoir removed from WSM. All sediments and nutrients pass through – no deposition or scour.	CBEMP	2010 Land Use	N/A	0%	N/A	N/A	Not analyzed?	?	?	?
LSRWA-6	TMDL land use with Conowingo reservoir removed from WSM. All sediments and nutrients pass through – no deposition or scour.	CBEMP	TMDL – WIPS in place	N/A	0%	N/A	N/A	Not analyzed?	?	?	?
LSRWA-20	2010 land use with sediment/nutrient from Conowingo scour added in.	HEC-RAS AdH CBEMP	2010 Land Use	?	Existing[4]	Excess volume method from AdH results (from 2011 bathymetry)	2011 Tropical Storm Lee	Not analyzed?	?	?	?
LSRWA-21	What is the system's condition when WIPS are in full effect, reservoirs have not all reached dynamic equilibrium and there is a winter scour event?	HEC-RAS[5] AdH[5] CBEMP	TMDL – WIPS in place	?	2011 levels	Excess volume method from AdH results (from 2011 bathymetry)	2011 Tropical Storm Lee	1996-1998	1%[6]	1%	1%
LSRWA-31	TMDL land use, sediment/nutrients from Conowingo scour added in.	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	1996 levels?	Excess volume method from AdH results (from 2011 bathymetry)	2011 Tropical Storm Lee	Not analyzed?	?	?	?
LSRWA-18	What is the system's condition when WIPS are not in effect, reservoirs have all reached dynamic equilibrium and there is a winter scour event?	HEC-RAS AdH CBEMP	2010 Land Use	?	"Conowingo Full" condition	Excess volume method from AdH results (from 2008 bathymetry)	2011 Tropical Storm Lee	1996-1998	?	?	?
LSRWA-30	What is the system's condition when WIPS are in full effect, the reservoirs have all reached dynamic equilibrium and there is a winter scour event?	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	"Conowingo Full" condition	Excess volume method from AdH results (from 2011 bathymetry)	2011 Tropical Storm Lee	1996-1998	?	?	?
LSRWA-22	TMDL land use, sediment/nutrients from Conowingo scour added in.	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	Existing	Excess volume method from AdH results (from 2008 bathymetry)	Jan 1996 flood event	Not analyzed?	?	?	?
LSRWA-23	TMDL land use, 1996 storm removed from hydrologic record and load record	? CBEMP	TMDL – WIPS in place	?	Existing	N/A?	N/A	Not analyzed?	?	?	?
LSRWA-24	What is the system's condition when WIPS are in full effect, reservoirs have not all reached dynamic equilibrium and there is a summer scour event?	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	2011 levels	Excess volume method from AdH results (from 2008 bathymetry)	2011 Tropical Storm Lee	1996-1998	?	?	?
LSRWA-25	What is the system's condition when WIPS are in full effect, reservoirs have not all reached dynamic equilibrium and there is a fall scour event?	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	2011 levels	Excess volume method from AdH results (from 2008 bathymetry)	2011 Tropical Storm Lee	1996-1998	?	?	?

Model Code	Description or Study Question	Models Used	Land Use (i.e., watershed sediment/nutrient loads)	HEC-RAS Model Run (scour or depositional)	Reservoir trapping efficiency	Reservoir Scour Load Method	Reservoir Sediment Nutrient Content	Time period analyzed for WQ Nonattainment	Deep Channel DO Nonattainment in CB4MH	Deep Channel DO Nonattainment in EASMH	Deep Channel DO Nonattainment in CHSMH
LSRWA-26	TMDL land use, January 1996 storm moved to June 1996	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	Existing	Excess volume method from AdH results (from 2008 bathymetry)	Jan 1996 flood event	Not analyzed?	?	?	?
LSRWA-27	TMDL land use, January 1996 storm moved to October 1996	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	Existing	Excess volume method from AdH results (from 2008 bathymetry)	Jan 1996 flood event	Not analyzed?	?	?	?
LSRWA-28	TMDL land use, sediment/nutrients from Conowingo scour added, 3 MCY dredged from Conowingo Pond.	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	Post dredging (3 MCY removed)	Excess volume method from AdH results (from 2008 bathymetry, dredged 3 MCY)	2011 Tropical Storm Lee	Not analyzed?	?	?	?
LSRWA-29	TMDL land use, sediment/nutrients from Conowingo scour added, 3 MCY removed from Conowingo Pond to represent bypassing, sediments/nutrients bypassed downstream from December-February every year.	HEC-RAS AdH CBEMP	TMDL – WIPS in place	?	Post dredging (3 MCY removed), bypassing during some months	Excess volume method from AdH results (from 2008 bathymetry, dredged 3 MCY)	2011 Tropical Storm Lee	Not analyzed?	?	?	?

[1]CBEMP is a suite of models used to assess Chesapeake Bay water quality conditions. Sub-models within CBEMP include the watershed model (WSM), a hydrodynamic model (HM) and a water quality/eutrophication model (WQM).

[2]CBEMP is always run for a hydrology period from 1991-2000.

[3]The specific trapping efficiency (e.g., 55%) used for the run should be listed in addition to the year range the trapping efficiency is associated with (e.g., 1991-2000).

[4]Appendix C lists "Existing" bathymetry for several runs, including LSRWA-3, LSRWA-4, LSRWA-20 and LSRWA-21). It is not clear if this is referring to trapping efficiencies or something else. Appendix J-4, pg. 1 lists LSRWA-4 and LSRWA-21 as having different trapping efficiencies, where LSRWA-4 has "1991-2000 levels", and LSRWA-21 has "2011 levels." It is not clear what 2011 levels means.

[5]AdH and HEC-RAS were always run using the four year 2008-2011 hydrology period (Jan 1, 2008 – Dec 31, 2011). The HEC-RAS outputs that were input into AdH were always the "scour" model results.

[6]We recommend that nonattainment calculations include one additional significant figure beyond the decimal point (e.g., 1.4% nonattainment instead of 1% nonattainment)

Questions/Comments:

1) Please verify that the data we have entered into this table are correct.
2) Please list specific trapping efficiencies (e.g., 55%) in addition to qualitative descriptors (e.g., 1991-2000 trapping levels).
3) What do "2011 levels" refer to as far as trapping efficiencies?
4) Please include an additional significant figure beyond the decimal point for nonattainment calculations (e.g., 1.4% nonattainment instead of 1% nonattainment)

LSRWA MAIN REPORT COMMENTS – JANUARY 2015

Comment #	Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change ?	Exelon Response/Additional Comment
1	General					Regarding citation of Study 3.17 – currently the LSRWA report cites the 2011 Initial report. The Final report should be cited as: URS Corporation and Gomez and Sullivan Engineers (GSE). 2012c. Downstream EAV/SAV study. (RSP 3.17). Kennett Square, PA: Exelon Generation, LLC.
2	General	Instead of presenting an equal focus on all three reservoirs, there are still points within the report that focus primarily on Conowingo. General sections of the report that present ideas or concepts not specific to Conowingo Pond by itself should reference the three reservoirs or reservoir complex.	Compton	Discussion in multiple sections about why Conowingo is emphasized. Also AdH modeling results are specific to Conowingo so data must be presented this way for accuracy. Mention of all three reservoirs and universal concepts are noted where appropriate.	No.	No further comment at this time
3	General	The "full" condition estimation should be more clearly explained. Pieces of the explanation are given throughout the report (Page 112, Appendix A-3), but there is not enough detail given in any one location (or even collectively throughout the report and appendices) to understand or follow how the estimation was derived.	Langland	The full condition is a term used to describe the storage capacity of a given reservoir. A reservoir is full when it can no longer effectively trap sediments and associated nutrients in the long term (decades). This language added to page 112. "Full" is better described as dynamic equilibrium which is described in detail on pages 109-110.) More detailed language has been added to Appendix A, Attachment A-3.	No.	Exelon is trying to more thoroughly understand what specific methods were used to estimate the 'full' bathymetry. It is not clear how this was done, or how the assumptions made as part of this process may ultimately influence the ADH model results.
4	General	The terminology "major scour event" is used throughout the report. Instead of referring to these events as major flood events, they are named major scour events. This predisposes the reader to assume major scouring is occurring when flows exceed 400,000 cfs, and while there is mass wasting occurring, that still doesn't mean the loads entering the bay are a higher percentage of scour than watershed-based sediments. For example, see page 81, paragraph 3.	Compton	Specific reference here was changed to "major flood event". In general throughout report, if discussion is on a storm event in the watershed "flood event" is stated if discussing impacts from the scour of reservoirs, then scour even, mass scour event is discussed, especially when differentiating impacts between watershed loads and scour loads.	Yes.	No further comment at this time
5	ES-2/paragraph 2	Paragraph focuses on sediments (no net trapping) with the potentially misleading implication that the same is necessarily true for nutrients. Nutrients, organic carbon, and other water quality aspects of sediments are reactive. If the residence times of nutrient-associated sediments are sufficient, labile materials may become refractory and non-reactive. Sediment transport is not necessarily equal to nutrient transport.	Cerco	We believe this paragraph is accurate and sufficient as written.	No.	No further comment at this time
6	ES-2/paragraph 3	Examples given are for sediment only. No information is given to determine if differences in flows are the cause of differences in sediment loads (W = Q C so if Q ↑, W ↑). No information is given to support the statement that reservoirs are trapping a smaller amount of nutrient loads from the upstream watersheds. No quantification of incoming or outgoing nutrient load.	Compton	Text altered to indicate that this conclusion is from a comparison of 1996 to 2011 bathymetry. Nutrients are discussed on ES-3. Also better quantification and reactivity of nutrients is identified as a recommendation of the study.	No.	The revised text states that bathymetric data were the basis for estimates of changing sediment loads; there is no quantification of incoming or outgoing nutrient loads. For example, if nutrients are preferentially present on the finest fraction of sediment particles (e.g., clays), then the relative change in trapping may be small (i.e., trapping of clays may never have been high). Thus, there is still a disconnect between trapping of sediment in general and trapping of sediment fractions that carry the most nutrients.

Comment #	Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change ?	Exelon Response/Additional Comment
7	ES-2/paragraph 3	"...upon analyzing the hydrology of the lower Susquehanna River from 2008-2011, this study estimated that the decrease in reservoir sediment trapping capacity from 1996-2011 (from Conowingo) resulted in a 10-percent increase in total sediment load to the Bay..., a 67-percent increase in bed scour..., and a 33-percent decrease in reservoir sedimentation..." Using a four year hydrology period is too short and contains an inordinate frequency of storms.	Scott	These data were the result of a comparison of the bathymetries, not a comparison of the 15 years between 1996 and 2011. Language updated to clarify this point.	Yes.	No further comment at this time
8	ES-3/paragraph 2 (full)	Use of phrase "Conowingo Reservoir material" implies that the reservoir is the source of material rather than the reservoirs being a site where transient storage appears.	Compton	Text altered to indicate bed sediment stored behind Conowingo.	Yes.	The phrases "Conowingo Reservoir material" to "bed sediment stored behind Conowingo Dam" mean the same thing. The point of the comment is that the assessment is predisposed to assume that all "excess" sediment generated during high flow is coming from Conowingo Pond. However, the uncertainties involved preclude such a definitive statement.
9	ES-5/paragraph 1 (full)	Important context is missing: what is the fraction of nutrients delivered to the Bay that originate from the watershed ("washload") versus the fraction that is in transient storage within Susquehanna River bed sediments ("bed material load")? This process needs to be clarified in the report.	Cerco	The fraction of the nutrient load delivered from the watershed vs. the fraction from bed scour varies depending on the scour event and on the duration of the averaging period. The fraction from scour will be relatively high during the event but much less when a period of years is considered. There is no single number which is applicable. Some insight into this effect is provided in Table 6-1 of Appendix C. In any event, the subject paragraph does not need revision based upon this comment.	No.	No further comment at this time
10	Chapter 1 – page 8 – 1st paragraph					The 2nd sentence is new and the reference cited, Pazzaglia and Gardner 1993, is inappropriate. This reference examines the state of the lower Susquehanna River in recent geologic time (≈ 10,000 – 20 million years ago), not historic time. This new sentence seems to refer to historic time prior to construction of the dams. If referring to historic time, a different citation should be used. If Pazzaglia and Gardner 1993 reference meant to be cited, add that this publication explores geologic conditions, not historic.
11	Page 10 - paragraph 2					Is the reference given as Gomez & Sullivan (2012) (RSP 3.11) [twice in this paragraph] really meant to be URS and Gomez & Sullivan (2012b)?

Comment #	Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change ?	Exelon Response/Additional Comment
12	CH. 1/P.11/Paragraph last(Sec 1.9) and Table 1-2	Assessment products include many overlapping, and not necessarily parsimonious, study elements. For example, the table states that HEC-RAS was used to compute sediment loads into Conowingo Pond. The Chesapeake Bay Watershed Model (CBWSM) also computes sediment loads to/though Conowingo Pond. How do they compare? SEDFLUME data were collected to determine erosion rates and erosion thresholds for sediment in Conowingo Pond. HEC-RAS, which was also used to calculate sediment transport, uses transport capacity relationships. How do the rates determined by the SEDFLUME work (and used in AdH) compared to calculations using HEC-RAS? Do they agree? The CBWSM also computes transport (because the reservoir is a node in the stream network) and uses an entirely different approach. How were differences handled? Which sediment load estimates were used to feed the CB water quality model (CE-QUAL-ICM) (Carl Cerco model)?	Langland/ Scott/ Cerco	HEC -RAS inputs of watershed loads compare well to CBWSM. USGS (HEC-RAS) annual average load for 1993 – 2012 is 1.5 million English tons/annum. This converts to 3.74 million kg/d. The WSM daily average load for 1991 – 2000 under 2010 Progress Run conditions is 3.06 million kg/d. The differences between the two estimates can be attributed to numerous factors including different summary intervals – 1993 – 2012 for USGS/HECRAS vs. 1991 – 2000 for the WSM. HECRAS also used some of the SEDflume data for estimation of several sediment model parameters.	No.	This comment is not meaningfully addressed without a change to the report to include this information and discuss the uncertainty. There are three different load estimates at Conowingo and each implies a different balance of transport processes: (1) Bay watershed model, (2) HEC-RAS, and (3) AdH. An attempt to identify or reconcile these differences in a quantitative way or recognize uncertainties does not appear to be made in the report. If AdH results differ from HEC-RAS results for Conowingo, is it appropriate to consider HEC-RAS results for upstream reservoirs to be reasonable?
13	CH. 1/P.17/Figure 1-5	Why is a sediment rating curve used as input to Conowingo reservoir instead of a time series output? HEC-RAS is capable of providing a time series, and appendix A says providing a sediment load time series was the modeling objective.	Langland	We tried both the rating curve and HEC-RAS model output. There were problems with the HEC-RAS model as you point out later in comment #75.	No.	No further comment at this time
14	CH. 1/P.18/Figure 1-6	Figure does not clarify which model feeds sediment estimates to CE-QUAL-ICM and how differences between estimates from models in the suite (CBWSM, HEC-RAS, and AdH) are handled.	Cerco/ Compton	The information on CE-QUAL-ICM loading is provided in Figure 1-5. The differences in the model suite are not the subject of these flow charts. This flow chart is meant to provide a simplified, broad picture of the analytical approach of the study tailored for a wide-audience.	No.	No further comment at this time. Please see comments in cover letter regarding Exelon's proposed Attachment 1 and 2.
15	CH.2/P.26/Paragraph 1 & 2	Table 5-6 of the main report is consistent with TMDL Appendix T in stating that the reservoir trapping capacity of Conowingo has been 55-60% from 1993-2012. Please elaborate on what trapping capacities were used in the various WSM model runs.	Linker/ Cerco	The LSRWA scenarios are fully described and characterized in Appendix D along with the estimated Conowingo bathymetries used in each scenario. That is the correct place for the scenario information and not page 75. Changes are unwarranted.	No.	We disagree that Appendix D adequately describes the input parameters for each run. It is important to understand the conditions of the scenario runs within the context of trapping capacity/efficiency as discussed in TMDL Appendix T.

Comment #	Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change ?	Exelon Response/Additional Comment
16	CH. 3/P.32/Paragraph 5(continues to P.33), see Footnote #5	Footnote #3 indicates that HEC-RAS was used to simulate conditions in Conowingo Pond. HEC-RAS and AdH results for Conowingo Pond should be compared and contrasted. The simulated mass over Conowingo Dam in both models should be tabulated and compared. Any differences in outcomes reflect uncertainties in the assessment process that need to be identified and quantified. Also, given that HEC-RAS is used to drive the upstream boundary for the AdH model domain, it is reasonable to assume that similar sorts of differences would occur through each reservoir if AdH were used to simulate the upstream part of the system too. The upstream watershed (over Holtwood Dam) is the main source of sediment (and nutrients) entering Conowingo Pond. Uncertainties there propagate downstream.	Langland	It would be useful to show this comparison if the data existed. We gave Steve Scott (AdH modeler) the daily sediment load files which he used to help develop his sediment rating curve. I believe he found as we did that the HEC-RAS was not generating enough sediment to match measurements at Conowingo. It is unknown how HEC-RAS performed in the upper two reservoirs due to lack of calibration data, but chances are it also under predicted the load coming in to Conowingo. That is the reason Steve increased the sediment load for the 2008-2011 simulation period from 22 to 24 million tons. It also provided a range of conditions for Steve to make predictions.	No.	No further comment at this time
17	CH. 3/P.33/Paragraph last	Use of HEC-RAS to simulate sediments with cohesive characteristics is problematic. The SEDFLUME results for Conowingo Pond provide a means to check on just how cohesive bedded sediments in the Lower Susquehanna are. SEDFLUME tests give information regarding the critical shear stress for erosion and erosion rate. If the critical erosion thresholds experimentally determined using the SEDFLUME differs substantially from the constraints that drive transport equations used in HEC-RAS, then HEC-RAS cannot be reasonably applied and cannot provide appropriate boundary conditions to drive AdH. The presumed occurrence of “dynamic equilibrium” in upstream reservoirs does not justify the use of HEC-RAS. As noted by the LSRWA, dynamic equilibrium does not imply that the sediment mass entering or leaving a reach of the stream will be equal on a day-to-day or month-to-month timeframe. It is not clear how the authors concluded that HEC-RAS provided understanding of physical processes in upstream reservoir if it does not represent the underlying physics of sediment transport.	Langland	Tying into comment number 32, that is why a rating curve was developed for AdH in Conowingo and the inflowing sediment from HEC-RAS was used as a backup.	No.	No further comment at this time
18						A good test of the AdH model would have been to start with the 2008 bathy and perform a continuous run of the model thru the date of the 2011 bathy and see how well the model reproduces the observed 2011 bathy
19	CH. 3/P.38/Paragraph 4 (full paragraphs)	“One source of uncertainty is the exact composition and bioavailability of nutrients associated with sediments scoured from the reservoir [Conowingo] bottom.” Yet throughout the document nutrients are discussed in absolute terms using definitive statements.	Cerco	This paragraph acknowledges clearly and upfront the uncertainties in composition and bioavailability. There is no need to repeat this statement throughout the report.	No.	No further comment at this time

Comment #	Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change ?	Exelon Response/Additional Comment
20	CH. 3/P.40/Paragraph 2 & 3 (full paragraphs)	Why was the AdH model (unknown time step) output at 2 hours to then be computed in the WQSTM model at 15 min?	Scott/ Cerco	The ADH time step is short, on the order of seconds to minutes, compared to the daily loadings. ADH computations from each time step were summed into daily loads for use in the WQ model.	No.	No further comment at this time
21	CH. 3/P.41/Paragraph 1	How are the scoured sediment and nutrient loads from Lake Clarke and Lake Aldred accounted for? Is it similar to the process for which Conowingo-scoured sediments (and thus nutrients) are superimposed on the WSM nutrient loads input to the WQM?	Cerco	Sediment loads from Lake Clarke and Aldred are not specifically identified in the Chesapeake Bay loads. The Chesapeake Bay model only “sees” loads at the Conowingo outfall. Loads from Clarke and Aldred are combined with other loading sources at this outfall. The only material superimposed on the WSM loads is scour calculated in Conowingo Reservoir.	No.	No further comment at this time
22	CH. 3/P.41/Paragraph 1	The discord in the timeframes simulated by the model is noteworthy in that it likely affects model outcomes. The Bay WQ model period is 1991-2000. The HEC-RAS and AdH simulations were 2008-2010. Given the non-linearity of sediment transport and associated nutrient transport, it is unclear how results for one timeframe were “adjusted” to a different timeframe that may have different conditions (e.g., precipitation, different winds, different land uses, etc.).	Cerco	The only adjustment that was necessary was to adjust the amount of scour calculated for TS Lee downwards to a value appropriate for the January 1996 storm. This procedure is detailed in Appendix C and comparisons are provided of computed and observed solids concentration at the Conowingo outfall for January 1996.	No.	No further comment at this time
23	CH. 3/P.41/Paragraph 2	“Phase 5.3.2 of the CB WSM provided daily sediment and nutrient loads from the watershed for application in the LSRWA effort.” How does this compare to the AdH time step for scour loads? From Cerco The ADH time step is short, on the order of seconds to minutes, compared to the daily loadings. ADH computations from each time step were summed into daily loads for use in the WQ model.	Cerco/ Scott	The AdH time step ranged from 1000 seconds for low flow conditions to 100 seconds for storms.	No.	No further comment at this time
24	CH. 3/P.44/Paragraph 4	What were the nutrients used for the AdH scour calculations? This appears to be explained on Page 92, Paragraph 1 but is still unclear. What about scour from upper two reservoirs?	Scott	No, nutrients were not in the AdH model	No.	No further comment at this time
25	CH. 3/P.45/Paragraph last (onto P.46)	Were these nutrient contents compared to Marietta samples to get an idea of what the ‘watershed’ makeup may have looked like?	Cerco	We did not find Marietta samples that provided relevant information for comparison with observations at Conowingo.	No.	Relevant data may be available from the Susquehanna River Basin Commission’s Nutrient Assessment Program (SNAP)

Comment #	Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change ?	Exelon Response/Additional Comment
26	CH. 3/P. 49-50	Based on the estimates of bioavailable nitrogen and phosphorus quoted here, which could potentially be resuspended and transported into Chesapeake Bay, there is a serious mismatch between the bioavailable fractions of TN and TP contained in the Conowingo Pond sediments and how they are incorporated in the CBEMP model wherein they are assumed to be approximately 85% bioavailable. Given this, it is likely that the CBEMP is over-estimating the release of Conowingo Pond nutrients from the sediment bed once they are deposited into the Bay sediments and therefore the model is over- estimating the change in non-attainment of the DO water quality standard	Cerco	The fractions assigned to G2 (slowly reactive) and G3 (inert) are based on long experience with the Bay model, as applied over the period 1985 – 2005. This interval includes multiple scour events so the assigned fractions are considered representative. Nevertheless, we acknowledge the reactivity of organic matter scoured from the reservoir bottom is an area of uncertainty. There are efforts underway to address this issue and this is a recommendation of the study.	No.	The comment was not meant to describe the G2 and G3 fractions in the SFM bed, but rather to point out that the current particulate organic matter coming in from the boundary is assumed to be all refractory. However, it may be possible that during a large scour event a major portion of the scoured particulate organic matter may be largely G3 and therefore putting this into the refractory pool (G2) may over-estimate the bioavailability of the combined watershed and scoured POM pool coming into the Bay. However, we acknowledge that a proposed study effort will be undertaken to address this issue.
27	CH. 4/P.59-60/Paragraph 3-4 (Sec. 4.2.1)	There is a shift in focus from transport in general for all three reservoirs (paragraph 3) to just transport within Conowingo Reservoir (paragraph 4). The same condition would be expected in all three reservoirs, not just Conowingo Pond.	Scott	There most certainly is scour in the upper two reservoirs that supply Conowingo. However, without field data to quantify it, it is very uncertain how much of the scour enters Conowingo. More field data measurements are needed below the dams.	No.	True, but still an important issue that warrants a statement in the report that is similar, if not the same, as Scott's response.
28	CH. 4/P.106/ Paragraph 4 (full paragraphs)	What does "trace" erosion mean? Is it resuspended sediment that is moved within the pond and does not pass the dam? Is it erosion of the thin unconsolidated layer?	Scott	erosion of the mixing layer in the reservoir. Very unconsolidated that mobilizes at low shear rates (.004 psf)	No.	The qualitative term "trace erosion" is used several times in text. Since this response indicates it refers to a quantitative condition, the use of this term should be defined when used in the text. Ditto for the term "mass erosion."
29	CH. 4/P.60-62/Paragraph USGS Scour Eqn	The basis for this is unclear. Its reliability is even more unclear particularly because the USGS equation is an empirical representation and simplification of an outcome that is itself uncertain because of uncertainties in upstream loads and processes. However you look at it, another problem is one of potential spurious self-correlation. Bed scour computed in AdH is related to discharge; so discharge occurs as a factor in both "independent" variables in the relationship.	Langland	Agree somewhat with your assessment. This is just a simple relation between MEASURED sediment loads from 2 sites, upstream and downstream of the reservoirs. The difference is most likely due to scour. You did note the error bars around each prediction to account for some of the uncertainty.	No.	No further comment at this time
30	CH. 4/P.65/Paragraph last (onto P.66)	This paragraph cites an 'active layer' depth of 2-3 feet. Specific study results that prove this statement should be provided or referenced. Appendix A of the LSRWA does not mention any 'thin unconsolidated mixing layer' as cited, and there is only a single reference to this in Appendix B which states that "[t]he top layer of Conowingo Reservoir sediments consists of a low density unconsolidated layer that may mobilize at lower flows."	Scott	The depth of sediments available for scour was assumed to be 2 - 3 feet in the model. Bed properties were measured in the SEDflume up to one foot of depth. The remaining 2 feet were estimated. Appendix B is the source of this info. Sentence in main report was changed from "The active layer has a depth …" to "For modeling purposes, the active layer is estimated to have a depth…"	Yes.	We were not clear in our first comment – our primary concern was the evidence behind the statement of a 'thin unconsolidated mixing layer', which we cannot find a satisfactory description of within the main report. Our concern is that the main report appears to step beyond what is stated in Appendix B.

Comment #	Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change ?	Exelon Response/Additional Comment
31	CH. 4/P.67/Table 4-4	The "full" condition bathymetry calculation is not well explained in the main report text. Upon investigation of Appendix A, it appears that the "full" estimation is based on assumption on how many acre-feet of sediment Conowingo Pond can store (146,000 acre-feet). The report does not provide any details regarding how this estimate of 146,000 acre-feet of sediment capacity was derived beyond general statements that recent bathymetry data were considered. Considering how frequently this "full" condition is cited throughout the report and Appendix A/B, more attention should be paid to how this value was arrived at, what assumptions were made and what methods were used to estimate this value.	Langland	The capacity of Conowingo is based upon original surveys from Conowingo Hydroelectric Company. The first estimation of the "full" capacity was made in Reed and Hoffman, 1996, USGS Report 96-4048. Some modifications have been made since that initial estimate based on more recent bathymetry. Additional details added to Appendix A. belong there. In response to comment #5, language was already added to para #1 on page 112.	Yes.	No further comment at this time
32	Page 66 (Nov report), end of last paragraph					Two new sentences were added to the bottom of <u>Bathymetry Comparisons</u> section explaining what "full" condition means – unfortunately they do not clarify the definition of dynamic equilibrium given elsewhere.
33	Page 69 (Nov report), end of last paragraph					The phrase "Hurricane Agnes in 1972" appears to have been inadvertently deleted from the last sentence after the word "excluding."
34	CH.4/P.73/Figure 4-5	The second panel in this figure indicates that silt deposition buried oyster beds. It's not clear if this is a proven impact, as earlier in the report (page 57), evidence was cited that disproved the 'sediment burial theory' following Tropical Storm Lee and indicated that oyster mortality was likely due to excessive fresh water and low salinities for an extended duration. This is reiterated again on page 138.	Spaur	Second figure shows extent of sediment plume, not extent of substantial sediment deposition. Change sentence "As a result, sediment runoff from Tropical Storm Lee was quite extensive compared to that of Hurricane Sandy, as depicted in Figure 5-6. " to "As a result, sediment runoff from Tropical Storm Lee was quite extensive compared to that of Hurricane Sandy and produced a large sediment plume in Bay waters, as depicted in Figure 5-6. Where sediment transported into the Bay would be deposited is controlled by waves and currents, thus mainstem Bay deep waters and protected headwater tributary settings would likely retain sediment from this storm, whereas higher energy shallow waters of the mainstem Bay would be expected to show negligible deposition (see Section 2.6.1)."	Yes.	Response appears to reference the second figure not the second panel (Tropical Storm Agnes June, 1972 – "silt deposition buried oyster beds.")

Comment #	Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change ?	Exelon Response/Additional Comment
35	Chapter 4(pp. 74-75)					Langland's response to the Riverkeeper comment (# 41) in Appendix I (page 7) indicates both the average peak flow for the Jan 1996 storm (630,000 cfs) and the instantaneous peak flow (908,000 cfs) are to be added to the text to match what is now figure 4-7. However, the text only mentions the 908,000 cfs value and the figure illustrates a 630,000 cfs value (but it shows up more as a transposed 603,000 cfs). The mean daily flow for the 24-hr period centered on the 908,000 cfs peak is reported in Langland and Hainly (1997) as 530,000 cfs. These discrepancies should be resolved.
36	CH.4/P.74/Paragraph 1	It's not clear what "Average peak flow" means – is that the peak daily average flow (and if so at what location), or the average of the peak flows measured along the river? Also, the event says there was an ice dam breached "within the reservoir itself" but the specific reservoir (Clarke, Aldred, or Conowingo) was not described. It is our understanding that the ice jam breached in the Safe Harbor impoundment.	Langland	Correct, there is no average peak flow. Replaced "Average" with "The"; peak flow value changed to 908,000 cfs.	Yes.	The first portion of this comment was adequately addressed, however, clarification was not provided in regard to the specific reservoir where the ice jam breached.
37	CH.4/ P.75/Paragraph last (onto P. 76)	Again Conowingo is specifically called out separately, while loads from Safe Harbor and Holtwood are just considered part of the "watershed" loads.	Langland	The design of the study was to model Conowingo since it was believed it had remaining capacity, was largest reservoir, and may have the greatest impact on the upper Bay	No.	We would like to see a breakdown of the model results for each reservoir similar to what is shown for Conowingo Pond, recognizing that there are little to no measured data available to assess accuracy. Additional information should be added to the report.
38	CH.4/P.76/Table 4-7	Is there a reason that the AdH results were not used here instead?	Langland	The AdH model could not generate all the data included in Table 5-7.	No.	It is unclear why the AdH model could not be used to estimate scour loads at various sized flood events.
39	Page 78 (Nov), 5th Paragraph					In the first sentence, recommend changing "versus scour from the Conowingo Reservoir" to "versus scour of watershed sediments stored in the Conowingo Reservoir"
40	CH.4/ P.80/Table 4-9	It would be more useful to the reader to list the absolute amount of nonattainment for each scenario, rather than a differential from other scenarios. It is difficult to 'back-calculate' the absolute nonattainment numbers from the differentials presented because of a lack of significant figures and because the 'baseline' scenario is different for several of the scenarios.	Linker	The critical period of the Chesapeake TMDL is 1993-95, but the year of the Big Melt high flow event on the Susquehanna was 1996, so a 1996-98 3-year period was used to capture the main scour event simulated in the LSRWA report. With the new 1996-98 period, the high flow event is simulated, but the scenario findings of the 1993-95 period are now lost. It is not a worthwhile exercise to compare the TMDL WIP or the 2010 scenarios on the 1996-98 period that is now disconnected to the 1993-95 hydrology and loads that the Chesapeake TMDL was based on. For this reason differential results are used.	No.	Our original comment still stands. We disagree that this would not be a worthwhile exercise.
41	CH.4/P.91/Paragraph 2	Is this 'updated nutrient composition' from Tropical Storm Lee applied to all sediments (i.e., watershed sediments and bed scour sediments) or just bed sediments? If it is applied to just bed sediments, this same nutrient composition should be applied to the scour from Lake Clarke and Lake Aldred as well as Conowingo Pond.	Cerco	The TS Lee composition is applied only to scoured bed sediments. There is no need to apply any adjustment to lake Clarke and Aldred sediments. These loads are incorporated into the loading to Conowingo Reservoir.	No.	No further comment at this time

Comment #	Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change ?	Exelon Response/Additional Comment
42	CH.4/P.97/Paragraph 3 (full paragraphs)	Paragraph focuses on AdH results for Conowingo Pond and purported loss of storage despite prior (and subsequent) text suggesting that changes in sediment transport are not expected to have a big impact on Bay water quality.	Scott	The reservoir is currently in a dynamic equilibrium for which deposition and scour continually occurs without a net change in storage. Sediments will deposit during low flows and scour during periodic storms. The loads from TS Lee did not demonstrate a long-term adverse impact to water quality. There was a short-term impact as would be expected.	No.	Given uncertainties in upstream loads to Conowingo reservoir and loads passing the Dam, what is the uncertainty associated with the mass estimates ascribed to erosion and deposition within Conowingo Pond?
43	CH. 5/P.100/ Paragraph 2	Goal of management not clearly stated. Stopping all sediment entering Bay is not possible or desirable.	Compton	Comment is vague. The referenced paragraph doesn't mention the word management or goal. There is no place the report that suggests stopping all sediment from entering the Bay. Goal/focus of the management strategies are adequately discussed in paragraphs 1 and 2.	No.	The nature of our comment is that the goal appears to be to reduce sediment loading to the Bay; however, this is not stated clearly in the report.
44	CH.5/P.102)Figure 5-2					Morris (1998) is not in the list references. This figure is not from Morris & Fan (1998). Believe the correct citation should be: Morris, G.L., (2014). Sediment management and sustainable use of reservoirs. In: Modern Water Resources Engineering (L.K. Wang and C.T. Yang, eds.). Humana Press. NY. Chapter 5. Pp. 279-338.
45	CH. 5/P.146-140	None of the evaluated dredging alternatives seem to consider sediment and nutrient (as well as other contaminant) releases during dredging. Such losses generally amount to several percent of all material handled	Compton/ Blama	Loss of sediment during mechanical dredging where material may fall from the bucket; regulations call this de minimis. When dredging is performed by hydraulic cutter head any contaminant attached to the sediment could be released due to the agitation of sediment. This can be calculated by running an elutriate test, however this test was not performed for the level analysis needed at the conceptual/watershed level. When dredging fines versus sand we lose more fines, so if we dredge more fines, we'd lose more material. Conversely, if we dredge more sand, we'd lose less. Language added to the report: When dredging is performed (hydraulically or mechanically) any contaminant attached to the sediment could be released during placement. To predict the release of contaminants elutriate tests can be performed. The standard elutriate test is used to predict the release of contaminants to the water column resulting from open water placement. The modified elutriate test is used to evaluate the release from a confined disposal facility. The results will vary depending on the grain size of the material being dredged. Since the LSRWA was a broad assessment of alternatives, elutriate tests were not performed on the potential dredged material. If specific dredging and placement sites are investigated in the future than it is recommended that	Yes.	No further comment at this time

Comment #	Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change ?	Exelon Response/Additional Comment
46	General Comment	Pertaining to all alternatives – not addressed are the potential environmental impacts as related to: aesthetics, air quality and greenhouse gases, soils, water quality, wetlands, groundwater, surface water, wetlands, floodplains, biological resources, cultural resources, land use, socioeconomic resources, recreation and tourism, utility and transportation infrastructure, public health and safety, and noise. In many cases the environmental impacts associated with a specific alternative may cause more harm than good.	Spaur/ Compton	This paragraph was inserted after last paragraph on page E-4 (before section titled "Future Needs of the Watershed") and after first paragraph on page 182 (before paragraph starting "Table 6-10 is a matrix....). "It should be noted that the LSRWA effort was a watershed assessment and not a detailed investigation of a specific project alternative(s) proposed for implementation. That latter would likely require preparation of a NEPA document. The evaluation of sediment management strategies in the assessment focused on water quality impacts, with some consideration of impacts to SAV. Other environmental and social impacts were only minimally evaluated or not evaluated at all. A full investigation of environmental impacts would be performed in any future, project-specific NEPA effort."	Yes.	While a NEPA level review of potential environmental impacts is well beyond the scope of such as assessment, it is not unreasonable for a watershed assessment to discuss the relative environmental impact of alternatives and to list specific resources to be considered for future analysis.
47	CH. 7/P.148/ Paragraph 2	"If a more detailed evaluation of the upper two reservoirs is required in the future, AdH would be the more appropriate model to apply." Given that this is used as the input to AdH to determine Conowingo Pond scour it would seem imperative to do this.	Scott	Detailed analysis of reservoir sediment transport is best performed with a 2D model. Although there was significant uncertainty in this application, improvements in the model through further research at ERDC will provide more capability with less uncertainty.	No.	No further comment at this time
48	CH. 7/P.148/ Paragraph 1-5 (all)	Recommendations for future use of HEC-RAS and AdH are unclear. A new 2-D version of HEC-RAS is now available. However, it is unclear if new sediment transport functionality (if any) would address the most basic limitations of the framework for using HEC-RAS. AdH also has limitations, some of which are beyond the limitation of the present flocculation approach.	Langland/ Scott	More capability is needed in AdH. The ability to simulate dam operations, particle flocculation dynamics and transport, and better sediment bed definition. Chapter 8 is not about future use of the model; it's about ideas for enhancements to those models. The new 2D HEC-RAS model does not have any specific additional sediment transport capability.	No	No further comment at this time
49	CH. 7/P.149/ Paragraph 4	Models are run for incongruent periods and hydrologic/sediment transport conditions. The appropriateness of substituting loads from models other than the Bay watershed model (e.g., HEC-RAS and AdH) as inputs to the Bay WQ model needs to be established.	Cerco	The only substitution of loads is to augment the watershed model results with estimated scour during the January 1996 storm. The estimate employs scour calculations from ADH during 2011. Appendix C clearly establishes that the calculated sediment concentration during January 1996 is vastly improved by addition of the scour loads. The Appendix also discusses and describes the result of various estimates of sediment composition on watershed model computed nutrient loads.	No.	No further comment at this time
50	CH. 8/P.150-151/Finding #1	The important point is to know if the trapping capacity assumed in the TMDL is the same as considered now. Based on reading Langland trapping efficiency data in Appendix T and this LSRWA report they are the same.	Langland	Good news. Thanks	No.	To clarify the original comment, is the trapping capacity assumed in the TMDL the same as is considered now? It appears based on this report and Langland trapping efficiency data in TMDL Appendix T that they are. Please confirm.
51	CH. 8/P.151/ entire page	This test simply restates assertions made earlier in the report --> consequently, prior comments regarding the appropriateness of model use in the evaluation as well as underlying uncertainties need to be investigated and further considered before such definitive findings can be stated.	Compton	The team/has disclosed all sources of known uncertainties and recommendations to address these which are discussed in various places throughout report package. Findings/conclusions are made in this context and are valid.	No.	No further comment at this time

Comment #	Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change ?	Exelon Response/Additional Comment
52	CH. 8/P.152/ Paragraph 2	Couldn't the amount of time for sediments to settle out increase if there is an increase in velocity due to decrease in depth? The statement may be too strong a statement since the time to settle is a unique combination of gravitational and fluid forces."	Langland/ Scott	No, because water is traveling faster, therefore, potentially, less time spent in reservoir.	No.	Based on the response of this comment, recommend revising the paragraph in question as shown below in red: "As the lower Susquehanna River reservoirs have filled, water depths have decreased and water velocity has increased. This has led to increasing the bed shear (which can result in more scour) and to decreasing the amount of time ~~for~~ sediments spend in the reservoir ~~to settle out of the water column~~, which thereby, reduces sediment deposition within the reservoir (Appendix A)."
53	CH. 8/P.152/ Paragraph 4	More detail on this trace erosion should be presented in the report, and this statement should cite relevant sections or appendices. As stated in a previous comment, Appendix A did not mention any 'thin unconsolidated mixing layer', and there was only a single reference to this in Appendix B which stated "The top layer of Conowingo Reservoir sediments consists of a low density unconsolidated layer that may mobilize at lower flows."	Scott/ Langland	It occurs, but is not significant as compared to storm flows above 400,000 cfs and was not a focus of this assessment. Recommendations section outlines focus on understanding deposition and scour and flows below 400,000 cfs.	No.	No further comment at this time
54	CH. 8/P.154/ 2nd Full Paragraph					Recommended revision to wording at the end of Finding #2: "To achieve the required water quality conditions under the Chesapeake Bay TDML, full attainment of the states' Chesapeake Bay water quality standards, the extra nutrient loads associated with sediment scoured from the three reservoirs ~~Conowingo Reservoir~~ must be offset by equivalent nutrient load reductions."

LSRWA APPENDIX COMMENTS – JANUARY 2015

APPENDIX A – SEDIMENT RESERVOIR TRANSPORT SIMULATION OF THREE RESERVOIRS IN THE LOWER SUSQUEHANNA RIVER BASIN, PENNSYLVANIA USING HEC-RAS, 2008-2011

	Original Exelon Comment	Langland Response	Exelon Response/Additional Comment
GENERAL APPENDIX COMMENTS	The model depends on how upstream boundary conditions (BCs), sediment bed properties, and transport processes are represented in order to “calibrate” the model to reproduce measured downstream BCs. With respect to the sediment BC, USGS used a function where upstream TSS = 0.007 $Q^{0.9996}$. For all practical purposes, this is a linear relationship between TSS and Q. Although there is a lot of spread in the data, the maximum concentration reported at any Q is 700 mg/L (with a more general trend around 300 mg/L). Extrapolating the upstream BC function to the high flow of interest leads to TSS = 835 mg/L when Q = 1.2e6 cfs. This extrapolated TSS concentration is just ~15% more than the maximum reported value (and less than 3x more than the general trend value of ~300 mg/L). [If the upstream reservoirs are believed to in dynamic equilibrium (and Holtwood reservoir is very shallow), the increase in TSS concentration is modest given the factor of 2 extrapolation of flow beyond the limit of measurements.] In contrast, the downstream BC was represented using a parabolic function where downstream TSS = 4e-09 Q^2 – 0.0007 Q + 34.313. As before, there is a lot of scatter in the data but it is harder to see on the graph because the y-axis goes to such a high limit that typical values appear compressed. Nevertheless, typical values are on the order of 300 mg/L to ~1000 mg/L (at 600,000 cfs) with a maximum value of 3,000 mg/L (at 600,000 cfs). This may not be a reasonable representation of the downstream BC. Further, the form of this relationship presents a curious situation for several reasons: • the linear term, TSS = -0.0007 Q, is nearly identical in magnitude but opposite in direction to the upstream BC function • the quadratic term, TSS = 4e-09 Q^2, implies that concentration increase geometrically for a linear increase in flow • because the linear term is essentially equal to the upstream load (and opposite in sign), the mass represented quadratic term must be transported off the bed in the model in order for simulated TSS concentrations at the downstream boundary to equal measured values. When extrapolated, the relationship implies that TSS = ~5,000 mg/L when Q = 1.2e6 cfs. Not only is this concentration very high, it is 40% more than the maximum reported concentration of 3,000 mg/L (assuming that this 3,000 mg/L value is representative and not impacted by a sampling or measurement error), ~5x greater than other values measured at 600,000 cfs and ~10x higher than more typical values. There is no basis to determine if this downstream BC TSS relationship is reasonable or appropriate, particularly when extrapolated to 1.2e6 cfs. This situation is further exaggerated because the exponents in the sediment transport capacity/erosion relationships selected for HEC-RAS (1 for Parthenadies, 6/7 for Laursen) are much less than the value of 2 in the downstream BC relationship. This means that the model is forced to scour tremendous amounts of sediment from the reservoir bed to match downstream TSS levels. In short, with this downstream boundary, the model can only compute massive bed erosion and must be set-up so that erodible limits are sufficient to allow massive bed erosion.	Suspended-sediment concentration (SSC) was used not TSS, there is a bias difference in lab methods that generate an error when sand is present. The TSS method by using an aliquot taken at the middle of the sample potentially does not capture the heavier sands that have already settled. There are a lot of great discussion points here, linear vs quadratic relations, BC in and out of the reservoirs, maximum “measured” sediment concentrations, sediment recession, etc. It is important to note that the sediment concentrations shown in the sediment rating curves may NOT be the maximum concentrations. This is most likely the case at Marietta when the first (and highest at ~700 mg/L) measurement for the T.S. Lee event was 3 days after the peak. Most likely this was well after the sediment peak and on the recession side of the sediment hydrograph. This monitoring location is just upstream of the reservoirs. The downstream site reflects the cumulative effect of the Susquehanna River and 3 reservoirs and therefore the sediment rating curve might be expected to be different than a rating curve outside of a reservoir system. The quadratic form of the equation suggests a different source of sediment than the linear upstream. as you mention, scoured bed sediments. This is reflected in the” measured” data at the Conowingo site. I’m not sure how you define “massive bed erosion”. The conclusion of the model simulation was the model “UNDER ESTIMATED” the amount of sediment when compared to “measured data” at Conowingo.	No revisions in the report appear to relate to this comment. Uncertainty bounds for both the upstream and downstream load estimates from measurements should be evaluated. There are no means to determine how much overlap may exist in these estimates. Understanding overlap in estimates is important because the difference between the downstream load and the sum of the upstream loads and tributary inputs empirically defines the amount of bed scour. All load estimates are extrapolated to high flow to represent high flow events. The functional form of load estimation equations can have a pronounced impact on inferences of bed scour. If 2 points in the downstream load estimate data set were treated as outliers (TSS = ~1,200 mg/L at Q = ~390,000 cfs; and TSS = ~3,000 mg/L at Q = 610,000 cfs), the implied curvature where TSS rapidly increases with Q at high flow in the downstream boundary load estimate would be reduced (or eliminated). Thus the quadratic term speaks more to a likely error in model boundary conditions rather than a different source of sediment. Moreover, correlation does not imply causation; cause cannot be inferred; particularly because the USGS analysis appears that it does not account for the time of travel between Marietta and Conowingo. The fact that the model was judged to underestimate the empirical TSS load passing Conowingo Dam speaks to errors in representing erosion and deposition processes in the reservoir. Table 2 (p. 12) of the revised report indicates a high clay fraction in the sediment bed. The inference is that the sediment is substantially cohesive. The transport formulations selected are not applicable to such sediment. The model is largely set to operate on a transport

	Original Exelon Comment	Langland Response	Exelon Response/Additional Comment
			capacity limited basis (with infinite supply down to erodible limits). In contrast, reality may be more of a case where, due to sediment cohesion, the system is supply limited. Ultimately, the USGS' assessment that the model underestimates the TSS load leaving Conowingo is more a reflection of the method used to estimate upstream and downstream loads rather than an assessment of the model. Underestimation of loads at Conowingo could be the result of errors or uncertainties in any of the following: (1) (overestimating) the empirical load at Conowingo, (2) the upstream load, (3) watershed loads, and (4) scour from the bed. The report does not adequately deal with these issues and instead advances a priori conclusion that scour within Conowingo reservoir is the source of sediments.
	At a minimum, confidence intervals should be established for the upstream and downstream boundary conditions and alternative formulations should be explored for the functional relationships used for both BCs.	Selecting 2 different sediment transport functions for the model was the attempt to place some confidence interval in overall sediment transport from Conowingo.	Use of alternative sediment transport functions (which are themselves not applicable to the types of sediment being modeled) does not establish confidence intervals. This is a question of statistics; given the TSS and flow values used in the regressions shown in Figures 6 and 7, what are the confidence limits? Do the confidence limits of the upstream and downstream load estimates overlap? This is unrelated to sediment transport functions.
	There is a link with the SEDFLUME data too (and the AdH report) for cohesive transport. As noted in the AdH report (Section 6.1 of Appendix B), the sampling tube could not penetrate the substrate indicating highly consolidated sediments. The AdH report notes that most of the cores were less than 1 foot in length. However, erodible depths in the HEC-RAS model ranged from 0 feet just downstream of each dam where the bed is composed of gravels, boulders, and bed rock to 20 feet in the deepest sediment accumulation areas. This seems a bit inconsistent.	I did not collect the SEDFLUME data, but I am aware of some of the difficulties in the collection. Previous cores collected by USGS in 2000 and analyzed by University of Maryland, go down much deeper (average of 5 feet, deepest one 11.5 feet) and contain particle size information at incremental levels. In general, particle size becomes courser with depth, but there are many areas with erodible fines at depths greater than 5 feet. Just because the erodible depth is set to 20 feet, that does not mean the model is going to erode down that deep.	Did the HEC-RAS model show erosion depths greater than the depths to successful SEDflume collection? The maximum depth of erosion in the HEC-RAS model should be compared to the physical information implied by difficulty collecting SEDflume core deeper than 1 ft.
			Starting with the second sentence on page 4, in the citation for the URS and Gomez & Sullivan publication, "USR" is used in multiple locations.

Chapter / Section	Page	Paragraph	Original Exelon Comment	Langland Response	Exelon Response/Additional Comment
2.0 / Background	4	Bottom of middle one	Fall velocities do not change with water velocity, transport capacities and shear. Statement is incorrect.	Agree removed "due to"	The response to the original comment is satisfactory; however, the last two sentences of this paragraph are somewhat unclear: "The report implies increasing concentrations and loads are due to the loss of storage capacity from a decrease in the scour threshold. Reasons for this increase are not certain but likely involve changes in particle fall velocities, increased water velocity, transport capacities, and bed shear." Please provide further clarification.
2.0 / Background	5	Figure			This figure indicates that sediment transport by means of density currents is an important process in reservoirs. What evidence is there that this is occurring in Conowingo Pond?
4.1.2 / Sediment	11	Figure 6	Here and elsewhere (USGS regression equation) sediment transport curves are developed based on suspended sediment samples. Suspended samples do not capture bed load which is not estimated in the report. In addition there is always part of the water column on the bottom (usually with the highest concentrations) where the sampling device cannot collect data. I did not see any explanation of how the bed load or unmeasured loads were considered, if at all, in the analyses.	On page 24, under model limitations and uncertainty, this issue is addressed.	Other than "initial conditions or boundary conditions in a model may not be well known" (page 22) there appeared to be no discussion about the uncertainty in the inflowing load based on our review of the cited section. Not including bedload or unmeasured load at the upstream boundary does not appear to be addressed.
5.0 / Calibration	18	Top of page	Only flows from two tributaries were included – any estimate of flow percentage missing from ungaged tributaries? Should be able to estimate by comparing outflow from Conowingo with sum of inflows from Marietta and gaged tributaries.	This was an additional exercise completed and included in attachment 1	Is the reference to Attachment A-1 of the report or to a different one? Did not see anything about this in A-1.
6.0 / Model Uncertainty	24	4	Lots of problems were encountered with appropriate fall velocities for cohesive sediment. As recommended by HEC, the grain size distribution should reflect the flocs rather than discrete grains.	We did not have information about the floc size.	This should be identified as a limitation or uncertainty.
6.0 / Model Uncertainty	24	7	Statement is not exactly true. HEC-RAS solves sediment transport by size class.	With limited capacity	Original comment still stands. Item #7 is still incorrect in that sediment load is determined by size class using whatever transport formula was chosen (some are bed load only, some are total load) and the capacity limiters mentioned in the response.
6.0 / Model Uncertainty	24		Missing a paragraph #9 which would point out that the hydrograph is being simulated by a series of steady flow pulses, and sediment transport is assumed at equilibrium for each flow pulse. This is different from true unsteady flow (non-equilibrium transport) models.	May be a little too technical to explain without adding more information on the difference (advantage, disadvantage) between steady and unsteady models	Should be listed as a limitation. Can put something simple without further explanation required, e.g., "the model simulates flow hydrographs via a series of steady flow pulses."
7.0 / Results	25	1	Why is there poor agreement with bathymetry?	Model performance and added "the estimated change"	The report should have an explanation for the poor agreement.
7.0 / Results	25	Last			The Duan et al. reference is not very pertinent as her work on the Rillito Wash was for an ephemeral sand bed riverine system as opposed to a perennial silt dominated reservoir environment.

Chapter / Section	Page	Paragraph	Original Exelon Comment	Langland Response	Exelon Response/Additional Comment
7.0 / Results	25	Last	Model results are being compared to ESTIMATOR and scour equation results rather than directly to measured data. The model parameters were adjusted and a separate scour model with different parameters was created for the single Tropical Storm Lee event. This does not lend a lot of confidence to model results.	Agree, and one the important findings' of the study, that the HEC- RAS might not be the best choice of a model in this reservoir system	No further comment at this time
7.0 / Results	29	first			The first sentence that models were calibrated to samples is misleading in that there was no comparison of computed versus measured (based on concentration) sediment load but rather of percentages of sand/silt/clay
Appendix A-1	35	Table A1	It appears that the results were computed with Log-Pearson Type III distribution. The Appendix should note that this distribution is not always applicable for controlled systems.	I noted the difference might be due to flow regulation.	Noting that the difference between the in and out curves may be due to flow regulation is not the same as recognizing that the assumed distribution itself may not be appropriate for regulated systems.
Attachment A-1	38	2	It is not clear how the Gomez and Sullivan (2012) bathymetry data were used in computing estimated scour loads from the lower Susquehanna River reservoirs for three reasons: 1) the 2011 survey described in Gomez and Sullivan (2012) was limited to Conowingo Reservoir (no bathymetry was collected in Lake Clarke or Lake Aldred); 2) the Gomez and Sullivan (2012) study compared bathymetry data from three years apart (2008-2011) and did not make an assessment of the 2011 flood event's specific contribution; and 3) the Gomez and Sullivan (2012) study calculated that there was net deposition from over the three year period from 2008-2011, not net scour.	Good points. 1 and 2. The GSE bathymetry was not the only data used to develop the equation. As the discussion indicates, the prediction equation is a tool, that allows a "quick" estimate of scour from the reservoir system, not just Conowingo. Based on the regression diagnostics, error bounds are plotted on figure A4. 3. Correct the study did indicate net deposition during the 2008-2011 interval, however that does not imply no scour during the short term T.S. Lee event.	No further comment at this time
Appendix A-1	38-39	Figure A4	Not clear how scour loads were computed and curve developed, important as used for model calibration. Also based on suspended load measurements only (no bedload).	Scour loads are defined as sediment capable of being lifted from the bed become "SUSPENDED" and transported through the dam. The bed is always moving to some degree, however, this study (and most of Chesapeake Bay Program is concerned with what exits the dam, not necessary how movable is the bed.	The original question remains. How were scour loads computed and curves developed? Also, it appears the regression equation in the Figure has changed since the last draft even though the data appears to be the same. Not sure what happened here?
Attachment A-1	40	Table A2	Table A2 predicts the amount of scour exiting the Lower Susquehanna River reservoir system by using an equation fit to data from 1993-2011. Yet, 'scour' predictions are made for events as far back as 1936, when the reservoir system likely experienced much different sediment dynamics than it does in modern times. Additionally, it is not clear what criteria were used to estimate the scour load for these events, as the relationship between the two columns does not appear to fit a monotonic relationship.	Good point, I used the estimated trapping efficiency (table later in section) to estimate the scour load for storms previous to 1972.	No further comment at this time

Chapter / Section	Page	Paragraph	Original Exelon Comment	Langland Response	Exelon Response/Additional Comment
Attachment A-1	42	1	As velocity increases and bed shear increase, wouldn't the time for sediments to settle out also increase, not decrease?	NO, velocity increases, lessening the amount of time for sediment to settle out.	It seems the authors are referring to the time available to settle out in the reservoir and not the time it takes to settle. The text and author's response here are not clear. The sentence in question is: *"As the reservoir fills with sediment, the velocity increases, perhaps increasing the bed shear (can result in more scour) and decreasing the amount of time for sediments to settle out of the water column thereby reducing deposition."* Under the scenario of increased flow velocity and bottom shear, a particle in suspension will remain in suspension longer. That is, it will take longer to settle out of the water column. If the author means to communicate that there is less time available for the particle to settle out of the water column **in the reservoir** because it is being transported out of that system faster, this should be clearly stated.

LSRWA APPENDIX COMMENTS – JANUARY 2015

APPENDIX B – SEDIMENT TRANSPORT CHARACTERISTICS OF CONOWINGO RESERVOIR

	Original Exelon Comment	Scott Response	Exelon Response/Additional Comment
GENERAL APPENDIX COMMENTS	Lots of discussion about erosion threshold and SEDflume data but not much about deposition shear stress threshold. Are these set equal in the model?	Because of uncertainty in flocculation dynamics, there was no minimum depositional shear stress (based on particle fall velocity of individual particles	Floccing is given importance and described on page 13, it is identified as one of three most critical model uncertainties on page 14, it is presented as a needed improvement to the AdH model on page 60, and it is identified as a source of uncertainty in the main report (2nd paragraph of page 38 in November version). However, I did not see this uncertainty described in Attachment B-1.
	The AdH model TSS upstream boundary condition is directly from the USGS HEC-RAS application. As noted in comments on Appendix A, USGS used a function where upstream TSS = 0.007 $Q^{0.9996}$. For all practical purposes, this is a linear relationship between TSS and Q. Although there is a lot of spread in the data, the maximum concentration reported at any Q is 700 mg/L (with a more general trend around 300 mg/L). It would be worth reviewing the basis and functional form for this upstream TSS BC. Uncertainty bounds and confidence limits for this relationship should also be established.	Agree. Perhaps the field data collection effort by Exelon and USGS can provide more data for such as effort.	This comment does not appear to have been addressed by a revision to the report.
	The AdH model TSS downstream boundary condition differs from the USGS HEC-RAS application. Whereas the USGS TSS downstream BC fit a parabolic function to the data and did not force the relationship to pass through the maximum point (TSS = 3,000 mg/L at Q = 600,000 cfs), the relationship used for AdH is forced through this maximum value. Consequently, at a flow of 600,000 cfs, AdH is calibrated to yield even more erosion than the USGS model. It would be worth reviewing the basis and functional form for this upstream TSS BC. Uncertainty bounds and confidence limits for this relationship should also be established.	The USGS did not use this linear function. They used actual data. The maximum value of their actual data set was more like 2700 mg/l. The AdH downstream output of TSS was based on both pass through sediment and bed scour contribution. The output of AdH was not forced through any curvefit. The actual measured values of concentration discharged through Conowingo were plotted as an exponential function that did pass through the maximum value.	AdH simulations attempt to approximate the load implied by the product of flow and concentration (Q times C) at Conowingo Dam. The load implied by the data reflects uncertainties in measurements and the timing of those measurements relative to flow conditions (i.e., rising limb, versus falling limb, etc.). The issue is whether the handful of high concentrations measured at Conowingo Dam, or not measured upstream, are accurate and reflective of the true load. The original comment was intended to express these concerns rather than to imply that AdH was curvefit. What effort was put into screening and evaluating the data?
	Boundary conditions should be reviewed to establish defensible ranges/relationships and quantify uncertainties.	Agree.	It is unclear if any action was taken based on this comment.
	SEDFLUME cores only penetrated to ~1 ft or less. In some cases the depth of scour identified in Figure 5 often exceeds 1 ft and can exceed 5-8 ft in several locations. Such model results are extrapolations beyond the range of measurements. Cores for the SEDFLUME could not penetrate sediment so it is likely that the erosion resistance of sediment at depth could be much more than at 1 ft below grade.	I agree. I increased the erosion threshold considerably for these deeper depths (greater than 1 ft) up to 5 – 6 pascals	This comment does not appear to have been addressed by a revision to the report.
			Appendix B-1 mentions transport by density currents several times as a process of sediment transport in reservoirs. What evidence is there that this is occurring in Conowingo Pond?

Chapter / Section	Page	Paragraph	Original Exelon Comment	Scott Response	Exelon Response/Additional Comment
Abstract **NEW**	ii	1			Recommend deleting the 1st paragraph of abstract. As currently written, it comes off largely as the opinion of others (i.e. USGS). Besides, it is not needed given content of rest of abstract.
1 / Introduction **NEW**	1-2	3 at bottom of p. 1 and on to top of pg. 2			How is enforcement of a TMDL standard related to perception of steady-state sedimentation in a reservoir?
1 / Introduction **NEW**	2	1			Statement that "[i]n the absence of large flow events, the majority of sediments that enter the two upstream reservoirs transport to the lowermost Conowingo Reservoir" has no clear basis. The AdH report only covers the Conowingo Reservoir; it does not extend to consider reservoirs upstream. This statement should either have a citation, reflecting the work/opinion of others, or it should be deleted.
2 / Background	4-5	Entire Section			This section seems as if it is a summary of work by others; however, there are relatively few direct citations. Recommend updating to include the appropriate citations.
2 / Background	5	Bottom	"HEC-6 model did better when included coarser sediments." By using only suspended samples you are missing out on coarser particles that might transport as bedload	Agree.	To state this as a question, is the potential lack of coarser material at the upstream boundary considered in the uncertainty analysis?
3 / Approach and Goals	8-9		Goals stated more clearly here than in main report. This description should be incorporated into the main report.	Main report will be updated.	This comment does not appear to have been addressed by a revision to the report.
4 / Description of Modeling Uncertainties	All		This section does a much better job of describing the uncertainties associated with the AdH results than the main report does. Specifically page 14, paragraph 2 which states that "Because of these uncertainties the AdH model may potentially over-predict to some degree transport of bed sediment through the dam." These points, for all models, need to be more clearly made and emphasized in the main report.	Main report will be updated.	This comment does not appear to have been addressed by a revision to the report.
5.1 / Susquehanna River Flows	15	2	While 2008-2011 did have a range of flows, the frequency of the flows is not comparable to the long-term record.	Agree. TS Lee was 13 year return event.	No further comment at this time
5.2 / HEC-RAS output rating	16	1	USGS model input taken from inflowing suspended load not considering bedload – missing coarser materials?	Agree. Bedload not sampled	See response 4 rows up.
5.2 / HEC-RAS Output Rating Curve	16	2	It is not clear what exactly was input into AdH from HEC-RAS – was it an hourly time series of suspended sediment load, or was the flow time series simply correlated to a sediment rating curve that was constructed from data output by HEC-RAS?	HECRAS produced sediment loads for mean daily flows for different size classes. AdH used this for the inflowing sediment rating curve into Conowingo	No further comment at this time
5.2 / HEC-RAS output rating	17	1	Conservatively high inflowing sediment load assumed and used for all other simulations. This does not appear to have been stressed or explained well in the main report.	The USGS used measured suspended sediment concentration data to create a sediment rating curve into the uppermost reservoir. The output to the AdH model was based on HECRAS output to Conowingo.	To confirm, we understand that the HEC-RAS sediment load was increased by 10% to account for the under prediction of sediment loads.

Chapter / Section	Page	Paragraph	Original Exelon Comment	Scott Response	Exelon Response/Additional Comment
5.2 / HEC-RAS output rating	17	1	What is the basis for increasing the HEC-RAS load 10%?	I believe HECRAS underestimated scour load from the upper two reservoirs	No further comment at this time
6 / Model Validation **NEW**	22-32	Entire Section			In the absence of data that were considered sufficient for calibration, please explain how parameterizing AdH to reproduce results from USGS studies independently validates AdH results: 1. If USGS results are driven by empirical load estimates (or regression equations) that assume different functional relationships for upstream and downstream locations, and scour is imputed by the difference between downstream and upstream estimates, do AdH simulations parameterized to reproduce USGS results provide an independent confirmation of those results? 2. If AdH is constrained by SEDflume core measurements, what are upper and lower bound limits of AdH solids concentrations given upper and lower bound parameterizations based on SEDflume core data (without limiting the erodible depth of sediment as described to 1 ft)?
6 / Model Validation	22 & 23	2 & 2	One of the data sources used to validate the AdH model was the USGS data collected from the catwalks of Conowingo Dam. This data is not representative of the entire river cross-section. Moreover, if any of this data was collected during Tropical Storm Lee, the data may have been collected when the Station was shut down.	Agree	No further comment at this time
6 / Model Validation	23	3	"The properties of the lower two feet were either approximated from the SEDflume results or determined from literature values." It would be useful to have a table of these properties.	I estimated increases in shear stress from literature.	This comment does not appear to have been addressed by a revision to the report.
7.1 / General flow and bed shear distribution in Conowingo Reservoir	34	1	Middle of paragraph, sentence starting with "This channel was not included…" and next sentence should include a citation.	Agree.	This comment does not appear to have been addressed by a revision to the report
7.6 / Discussion	46	2	What inflow load scenario was used where the relative load from Conowingo (versus the overall watershed) was up to 30% of the incoming load?	Inflow scenario was 24 million tons over the four years, 10 million tons from TS Lee	No further comment at this time
7.6 / Discussion	46	2	Last sentence of paragraph is speculative and goes to the uncertainty of using the HEC-RAS model as the input to the AdH model	Agree	This comment does not appear to have been addressed by a revision to the report
9 / Impact of releases on flats	52+	General	The description of this downstream model has much less detail and is shorter than the sections dealing with the upstream model.	Agree	This comment does not appear to have been addressed by a revision to the report
9 / Impact of releases on flats	53-54	1, Fig. 34	What is the reference for the ratio of roughness with SAV?	The AdH user's manual	Add reference to Berger et al. to text and/or figure.
9.2 / Sediment results	55	1	No description is given of the upstream or downstream boundary conditions. Assuming that the U/S BC is the outflow from the U/S AdH model, but which run? Or were measured SSCs used?	The upstream boundary was an arbitrary flow, not Specific Conowingo outflow.	Does not answer the question of what was used in the modeling exercise that produced the figures and led to conclusions.
10.1 / Conclusions	57	1 & 3	Reinforces the importance of large less frequent events to sediment movement.	Agree	No further comment at this time

Chapter / Section	Page	Paragraph	Original Exelon Comment	Scott Response	Exelon Response/Additional Comment
11 / Recommendations to Improve Future Modeling Efforts	60	1	"…the model was not capable of passing sediment through the gates...this limitation impacted how sediment was spatially distributed in the lower reach of Conowingo Reservoir near the dam." How did it impact sediment? Further understanding on the exact impacts and uncertainty associated with this needs to be included in the Appendix and the main report.	Initially, we tried to input dam operations into the model (sequential opening and closing of gates as flood flows passed), however, the sediment transport component of the gate operation did not become operational during the conduct of the study. Opening the gates will affect the distribution of sediment from the powerhouse to the center of the channel, thus impacting sedimentation on the Eastern side of the dam (just upstream).	No further comment at this time
B-1, 6.0 Discussion & Conclusions	B-1		Using the provided graphs, the 86,000 cfs limit where all flows pass through the powerhouse accounts for about 30% of the annual sediment load. This should be mentioned.	Doesn't that depend on storm frequency? Not sure about that. Maybe "average" annual sediment load.	Original comment was based on Figure 5. Maybe the ordinate (y-axis) should be labeled average annual load? It is notable that 70% of the average annual load does NOT go through the powerhouse (usually due to larger events).

LSRWA APPENDIX COMMENTS – JANUARY 2015

APPENDIX C – APPLICATION OF THE CBEMP TO EXAMINE THE IMPACTS OF SEDIMENT SCOUR IN CONOWINGO RESERVOIR ON WATER QUALITY IN THE CHESAPEAKE BAY

GENERAL APPENDIX COMMENTS	Original Exelon Comment	Cerco Response	Exelon Response/Additional Comment
	The use of metric units when everything else is in English unnecessarily confuses the issue.		

Chapter / Section	Page	Paragraph	Original Exelon Comment	Cerco Response	Exelon Response/Additional Comment
Chapter 3	18	3	Although period examined has a range of flows, how representative is the flood frequency during this period with the long-term flood frequency?	The report indicates two erosion events (flow > 11,000 $m^3\ s^{-1}$) occurred during the ten-year simulation period. These events were in April 1993 and January 1996. Langland's report indicates flows in excess of 400,000 $ft^3\ s^{-1}$ (11,000 $m^3\ s^{-1}$) have a recurrence interval of five years. Two events in ten years correspond well with the expected recurrence.	Does the use of the 1996 storm event combined with the high nutrients observed in 2011 make for either a worst case, or at least very conservative, estimate of Bay impacts?
Chapter 3	19	3	How was the Conowingo Pond equilibrium condition determined?	The equilibrium bathymetry was determined by the team that modeled Conowingo Reservoir (Mike Langland, Steve Scott, and associates). This question must be answered by that team.	Original comment still stands. Please address as appropriate following the next round of LSRWA comment review.
Chapter 4	23	Entire Chapter	How are the scoured sediment and nutrient loads from Lake Clarke and Lake Aldred accounted for? Is it similar to the process for which Conowingo-scoured sediments (and thus nutrients) are superimposed on the WSM nutrient loads input to the WQM as described in Chapter 4 of Appendix C?	Sediment loads from Lake Clarke and Aldred are not specifically identified in the Chesapeake Bay loads. The Chesapeake Bay model only "sees" loads at the Conowingo outfall. Loads from Clarke and Aldred are combined with other loading sources at this outfall. The only material superimposed on the WSM loads is scour calculated in Conowingo Reservoir.	While author's response is correct, it still does not address the upper reservoir issue directly.
Chapter 4	23	1	"The loads at the head of the reservoir system are supplemented by inputs from the local watersheds immediately adjacent to the reservoirs." It would be useful if there were a figure depicting this either in the main report of this Appendix (or both).	A figure such as this one might be included in the main report. This doesn't appear to be a critical deficiency.	It would be useful to the reader to have such a figure.
Chapter 4	26	3	Bullet 5 – "For key scenarios, an alternate set of nutrient loads was constructed based on 1996 observed nutrient fraction." These should be included and discussed in the main report.	The results from these scenarios are reported in the appendix to this report.	Given the uncertainty of the exact composition of the nutrients, the main report should include discussion about the results from the scenarios which used the alternate nutrient loads.
Chapter 4	32	Figure 4-1	Assuming that the Calculated eroded particulate nitrogen and phosphorus referenced are from AdH? Please confirm.	No, ADH does not calculate nutrients. The calculated eroded nutrients are based on ADH calculations of eroded sediment and on observed fractions of nutrients associated with sediments.	No further comment at this time
Chapter 6	48	last	How does this statement impact the LSRWA conclusions? Does it result in a greater modeled impact to the Bay from scour when applying the CBEMP? "The predominant role of net scour loads, reported here, is in contrast to the companion reports to this one (Scott and Sharp, 2013; Langland, 2013) in which scour is assigned a lesser fraction of the total storm loads."	This report emphasizes the marginal impact of a scour event on Bay water quality. The marginal impact of a scour event depends on the magnitude of the scour event. The magnitudes of the scour events in 1996 and in TS Lee were similar. The ADH computation of scour during TS Lee is 2.64 million metric tons. The scour calculated for 1996 is 2.37 million metric tons. The marginal impact of the scour load is not affected by the watershed load.	No further comment at this time

Chapter / Section	Page	Paragraph	Original Exelon Comment	Cerco Response	Exelon Response/Additional Comment
Chapter 6	53	1	The last sentence may also be interpreted as a quantification of the benefit of Conowingo Dam to the Bay when depositional.	During depositional periods, the retention of nutrients in Conowingo Reservoir is apparently of benefit to the Bay.	No further comment at this time
Chapter 6	**NEW**				Last paragraph at bottom of page 53 in public draft report, makes a strong case that the Conowingo Dam is still providing WQ benefits. Similar argument at bottom of page 55 in public draft report.
Chapter7	119	1	"Model results can be reported with extensive precision, consistent with the precision of the computers on which the models are executed. Despite the precision, model results are inherently uncertain for a host of reasons including uncertain inputs, variance in model parameters, and approximations in model representations of prototype processes." This statement and the rest of this section do a much better job of clearly stating the uncertainties associated with models and model results than the main report does. While the main report does generally acknowledge some model limitations/uncertainties it does not do as good of a job as the Appendices in stating how uncertain some of these results may be.	The potential to alter the main report to reflect this section of Appendix C is left to the authors of the main report.	The main report should state as clearly as the Appendix does how uncertain some of these results may be.
Chapter 7	120	2	While uncertainty due to bioavailability of the nutrients is acknowledged and while the "scoured" refractory nutrients are handled in the same fashion as the other boundary nutrients could an estimate be made of how the scoured nutrients might be different than the current assumption of 86% of refractory PON going to G2 and 14% of refractory PON going to G3 (based on Cerco and Noel, 2004)? We believe that SFM computed G2 and G3 is likely to be the other way around with G3 > G2 for organic matter that has been in the sediment bed for several years, as would be the case between scour events in Conowingo Pond.	The material on the bottom of Conowingo Reservoir has not all been there for several years. Material is deposited continuously, including fresh organic matter from phytoplankton in the reservoir. The fractions assigned to G2 and G3 are based on long experience with the Bay model, as applied over the period 1985 – 2005. This interval includes multiple scour events so the assigned fractions are considered representative. Nevertheless, we acknowledge the reactivity of organic matter scoured from the reservoir bottom is an area of uncertainty. Our understanding is that experiments are planned to address this issue.	No further comment at this time
Chapter 7	**NEW**	119-120			The new report should acknowledge that another area of uncertainty is how much of the nutrient load coming from the three reservoir system is due to the Conowingo Pond alone versus a combination of all three reservoirs, since they are all likely to be in some form of dynamic equilibrium. Needs to be addressed with a more refined model of the three reservoirs.
Chapter 7	120	3	It is stated that the SEDflume studies reported in Appendix B "indicate erosion does not occur below 9,300 m^3s^{-1} (330,000 cfs)." Please clarify if the author is referring to the beginning of "mass bed erosion" as defined in Appendix B. If so, shouldn't the value be 400,000 cfs?	The commonly accepted threshold for mass erosion is 400,000 cfs. The text will be revised.	No further comment at this time

LSRWA APPENDIX COMMENTS – JANUARY 2015

APPENDIX D – ESTIMATED INFLUENCE OF CONOWINGO INFILL ON THE CHESAPEAKE BAY TMDL

Chapter / Section	Page	Paragraph	Original Exelon Comment	Linker Response	Exelon Response/Additional Comment
Introduction	3	3	The last portion of this paragraph starting with "During the 2017 Midpoint Assessment…" discusses decisions being made regarding any necessary adjustments to the CB TMDL. It should be clearly noted here that Appendix T of the TMDL discusses actions that will be taken in the event that the status of Conowingo Pond changes from previously understood conditions. The language used should be that contained in TMDL Appendix T.	Appendix T is correctly cited, referenced, and characterized in Appendix D. It's clear from the text what's directly quoted and what's paraphrased. The citation and attribution is entirely correct and changes are unwarranted.	To clarify, Appendix T of the TMDL already takes into consideration actions that should be taken if it is found that Conowingo Pond has reached dynamic equilibrium. The TMDL specifically states, "…if future monitoring shows the trapping capacity of the dam is reduced, then EPA would consider adjusting Pennsylvania, Maryland, and New York 2-year milestones loads based on the new delivered loads."
Results	21	Figure 5	While the differential values are useful, it is helpful for the reader to also list absolute nonattainment values rather than just relative values.	Listing the absolute values for Scenario LSRWA-21 and LSRWA-3 (and explaining why the 1996-1998 period is different from the 1993-1995 period and the reason they're different , etc., etc. would add confusion, not clarity. Adding absolute nonattainment values is unwarranted.	We disagree; having absolute nonattainment values is the only way to compare various loading scenarios and time periods. We understand the goal of reducing confusion and improving clarity, but we feel these data need to be provided somewhere for the public to digest. We cannot fully evaluate the modeling scenarios without this critical piece.
Results / LSRWA Results: Non-Management Scenarios	22-23	3 & 4	Why were the points of comparison changed for the June and October events from the comparisons made earlier in the section?	In the seasonal scenarios the comparison is being made among the January, June, and October seasons (or months) and the No Storm Scenario of LSRWA-23 allowed the comparison of the three seasons to be made. In this case we're looking at the relative difference among the different seasons and the use of LSRWA-23 is appropriate.	No further comment at this time
Results / LSRWA Results: Non-Management Scenarios	22-23	June/Oct	It would be helpful if the stop-light tables 2a and 2b could be expanded to include the results from the various LSRWA scenarios. It is not clear at all as to whether the scenarios that are run with the nutrients collected with the 1996 scour event are significantly different that those using the 2011 water quality data. For example, for the June event, it is surprising that the non-attainment was reduced from 4% to 2% (a 50% reduction) for the Deep-Channel Attainment for Bay segment CB4MH comparing LSRWA26 vs. LSRWA-24, while no other changes in attainment were found.	Different simulation years (93-95) in table 2a and 2b from 1996-1998 period which contains the January 1996 Big Melt event.	No further comment at this time, but this comment highlights the importance of developing a summary table similar to the one included in the attachment to our cover letter.

Chapter / Section	Page	Paragraph	Original Exelon Comment	Linker Response	Exelon Response/Additional Comment
Results / LSRWA Results: Non-Management Scenarios	25	Table 3	1) It would be useful to add a row for each of these columns specifically indicating which years are being analyzed for WQ attainment. 2) The nonattainment's should be listed with more significant figures (e.g., 1.4% nonattainment instead of 1% nonattainment) 3) The absolute nonattainment values (e.g., LSRWA-21 had 19% deep channel DO nonattainment in segment CBMH4) should be listed in addition to the relative nonattainment numbers (e.g., an increase of 1% nonattainment over the Base TMDL Scenario (LSRWA-3))	1) The text on (example page 18 paragraphs 2 and 3) provides sufficient information on when the 1996-1998 simulation period is used in order to simulate the January 1996 storm. 2) A single significant figure is sufficient and is consistent with the level of significance typically reported in the Chesapeake TMDL. 3) Listing both the absolute value and the base value along with the difference between the base scenario is from the base as suggested would be redundant, confusing, and unwieldy.	Please see our previous comment (2nd comment, page D-1). We believe it is crucial that absolute nonattainment values are provided somewhere in order for the reader to comprehensively evaluate the model results.
Results / LSRWA Results: Non-Management Scenarios	25-26	Tables 3-5	Why aren't LSRWA-22, 26, 27 discussed in these tables?	LSRWA-22, 26, and 27 are discussed in the text.	Important to note that only the worst case scenarios are presented in the tables.
Conclusions	29	1	It is stated that the TMDL simulation period of 1991-2000 "was a condition prior to the current dynamic equilibrium state of sediment infill of the Conowingo Reservoir." However, an agreed timing of the onset of dynamic equilibrium is not clear in this report; nor is the relationship with changes in trapping efficiency. For example, Table 5-6 has the trapping efficiency of Conowingo Reservoir remaining at 55-60% for the time period 1993-2012. But Table 1-1 says dynamic equilibrium was first reached in the mid-2000s. Is this a contradiction?	The exact date of the onset of dynamic equilibrium in the Conowingo Reservoir is unknown. But a definitive statement from the LSRWA report is that the Conowingo Reservoir is <u>now</u> in dynamic equilibrium. At some time prior to 2000 it was not. There is no contradiction.	No further comment at this time
Conclusions	31	1	"During episodic high flow scour events, large nutrient loads are delivered to Chesapeake Bay." The term "scour events" lead the reader to believe that the scour is responsible for all nutrient loads going to the Bay when in fact the vast majority of the loads originate from watershed sources upstream of Conowingo Pond and the Lower Susquehanna Reservoirs. This comment is true of any reference to "scour events" throughout the main report and appendices.	The scenarios referred to in the conclusion section separated the loads from the watershed and the scoured loads from the Conowingo by the difference between scenarios as described in the results section. The increase in nonattainment in Deep Water and Deep Channel DO (described in the results and discussed in the conclusions) were specifically because of the scoured nutrients from the Conowingo Reservoir.	As stated in the updated text and pointed out by STAC in their review, DO water quality standards are greatly affected by seasonality; that is, the summer hypoxic period is the season of concern and "a small difference in DO during this period makes a big difference to living resources…" As stated in the Appendix, deep-water and deep-channel DO water quality standards are on a "knife-edge of attainment". STAC went on to say that, "it strikes the reviewers that changes in chlorophyll and dissolved oxygen associated with "normal" inter-annual variability in climate and nutrient loading are much higher than those associated with additional Conowingo Dam-derived nutrients as simulated here."
Conclusions	31	3	The last sentence of this paragraph discusses how the TMDL will account for changes in the trapping capacity of Conowingo Pond as per TMDL Appendix T. When discussing the TMDL and changes in Conowingo Pond trapping capacity throughout this Appendix, and the main report, it is important to always use consistent language from Appendix T in regard to how this will be handled.	Appendix T is correctly cited, referenced, and characterized in Appendix D. It's clear from the text what's directly quoted and what's paraphrased. The citation and attribution is entirely correct and changes are unwarranted.	See first response at beginning of table

Chapter / Section	Page	Paragraph	Original Exelon Comment	Linker Response	Exelon Response/Additional Comment
LSRWA uncertainty			The CBEMP assumes that refractory organic nitrogen coming into the system and depositing to the sediment is 84% G2 and 16% G3 (Cerco and Noel, 2004). However, it is likely that scoured sediments from Conowingo Pond would have the reverse distribution G2 > G3. A model scenario should be constructed to evaluate this condition.	Agreed that the research now underway into the proportions of refectory and labile organics in Conowingo Reservoir sediments is needed in order to be definitive regarding the G2 and G3 fractions in the Conowingo bed.	No further comment at this time

LSRWA APPENDIX COMMENTS – JANUARY 2015

APPENDIX E – MGS SUSQUEHANNA FLATS SAMPLING RESULTS

Page	Original Exelon Comment	Ortt Response	Exelon Response/Additional Comment
General	The bathymetric map does not indicate the elevation datum for the contours.	Contour info added.	The location map of the first draft (Figure 1) has been replaced with a NOAA bathymetric map. Contours, however, are not legible.
Page 2; paragraph 1			The Susquehanna River drainage does not include six states; it includes three states.
Page 2; paragraph 1			What is meant by 'increasing' in the sentence: "In addition to an increasing amount of sediments being deposited behind Conowingo Dam in the Conowingo Reservoir, there is an increasing quantity of sediment that is delivered to the Chesapeake Bay by bypassing the dam."? Increasing relative to what?
Page 2; paragraph 4			Where were samples #1 and #2 to be located in the Susquehanna River?
Page 4; paragraph 3			Please indicate that the Bennett and Lambert method provides wet bulk density values.
Page 4; paragraph 4			Remove comma after Kerhin and others.
Page 5; paragraph 1 Captions of figures 2 and 3			Correct citations are Shepard (1954) and Folk (1974), not Shepard's (1954) or Folk's (1974). Remove apostrophe.
Page 6; last paragraph			Insert period at end of sentence.
Page 7; figure 2			Caption should indicate that the classification is based on percent of sediment size classes in sample. Otherwise the numbers on the tertiary diagram are not explained.
Page 7; figure 3			The sediment type codes in the tertiary diagram should be explained, as per Table 7.
Page 8; table 3			The columns labeled #alive and #dead appear to refer to clams. Please note this on table. The footers (#6, #12, #17) are not lined up nor are they clear as to meaning. Please clarify.
Page 9; table 4			Please note that color notations (e.g., 5 YR 3/4) are in accordance with the Munsell color system. "Asian" for sample 7 should be capitalized.

Page	Original Exelon Comment	Ortt Response	Exelon Response/Additional Comment
Page 11; figure 4			This is a very important graph. It may show up better if printed in landscape view. To help the reader understand this graph, interpretive footnotes may be useful, e.g., the steeper the slope the better the sorting; the 50% mark is the median grain size; etc.
Page 14; table 7			Please note that bulk density is wet bulk density.

LSRWA APPENDIX COMMENTS – JANUARY 2015

APPENDIX F – U.S. GEOLOGICAL SURVEY CONOWINGO OUTFLOW SUSPENDED SEDIMENT DATA REPORT

	Original Exelon Comment	Blomquist Response	Exelon Response/Additional Comment
GENERAL APPENDIX COMMENTS	Cover letter states "samples were collected along a representative cross-section from the catwalk on Conowingo Dam…" Conowingo Dam catwalk sampling is not representative of the channel cross-section at the dam.	The data transmittal letter dated February 10, 2012, represents an accurate assessment of the relation between catwalk and cross- sectional variability, given the analysis of available historical USGS quality control data.	The reader of this letter may take the originally commented upon statement as meaning the data collected are representative of the river at the dam. In a published document prepared by USGS it is noted these data are only representative of the river in front of the turbines. That is, in the USGS Quality-Assurance Project Plan (QAPP) for the Maryland River Input Monitoring Program and Nontidal Network Stations for the period July 1, 2013 to June 30, 2014 (Updated July 2013) available at: http://www.chesapeakebay.net/documents/MD_RIM_QAPP_2013_2014.pdf it is written: "Previous testing at Conowingo Dam has shown that this approach provides a representative sample for flows confined to the turbines. However, sampling from the turbines can be unrepresentative of spillway discharges since the flows originate from different locations in the reservoir's vertical profile." The Introduction of this Appendix should include the same language.
	A brief report to accompany the data would be useful (in addition to the cover letter provided). The report could highlight the sampling methods used, field conditions, hydrograph, sampling comments/notes, etc. In its current form, the Appendix does not provide the reader with very many details about the sampling event(s).	The data were collected using standard methods for the site as outlined in the QAPP on file with EPA CBPO. Streamflow records for the periods represented by these samples as well as the analytical results themselves are publically available at http://waterdata.usgs.gov. Limited time and funds availability precluded the preparation of a separate report detailing these data.	While it is understood that a brief report goes beyond the time and funding constraints of this effort, a more detailed Introduction providing a general overview of the sampling methods, field conditions, hydrograph, sampling notes/comments, etc. would be helpful to the reader to put the data collected into context.
			The sampling does not appear to take into account the travel time of the water and sediment through the reservoir system during a storm event. It would be useful if the author could provide comment on what effects this may have on the use of the data and any subsequent results/conclusions.

LSRWA APPENDIX COMMENTS – JANUARY 2015

APPENDIX G – 2011 EXELON CONOWINGO BATHYMETRY SURVEYS

GENERAL APPENDIX COMMENTS	Original Exelon Comment
	No Comments

LSRWA APPENDIX COMMENTS – JANUARY 2015

APPENDIX H – LITERATURE SEARCH FINDINGS REPORT

GENERAL APPENDIX COMMENTS	Original Exelon Comment
	No comments

LSRWA APPENDIX COMMENTS – JANUARY 2015

APPENDIX I – STAKEHOLDER INVOLVEMENT

Section	Page	Exelon Comment
I-7 / LSRWA Response to STAC Review	General	In response to STAC comments pertaining to the AdH model, there are multiple references to "Response under development by ERDC AdH modeler" yet no response is actually provided. Please provide a response for each of these instances.
I-7/LSRWA Response to STAC Review	17	The graph in Appendix A (Figure 7) does not appear to have been updated as indicated.
I-7/LSRWA Response to STAC Review	28	The notes to Figure 1-6 (Main Report) do not appear to have been changed as indicated.
I-7/LSRWA Response to STAC Review	29	The definition of saprolite does not appear to have been added as indicated.
I-7/LSRWA Response to STAC Review	29	The deletion of 'river' does not appear to have been made as indicated (now in Appendix K).

LSRWA APPENDIX COMMENTS – JANUARY 2015

APPENDIX J – PLAN FORMULATION

Chapter / Section	Page	Paragraph	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Exelon Response/Additional Comment
Attachment J-1	2	2	The implication that sediment plumes as represented by TS Lee in Figure 3 are due to scour from Conowingo Reservoir is incorrect. As noted in the main report, these plumes are predominantly comprised of sediment from the watershed upstream of Conowingo Reservoir.	Michael	Page 2, paragraph 2 – change the last sentence to "The massive plume of sediment that occurred following Tropical Storm Lee extended from the Conowingo Dam past the mouth of the Patuxent River (Figure 3) and originated both from the watershed and from scour behind the dam.", with the majority of the sediment coming from the watershed.	Please make "dam" plural. That is, change to: "…from scour behind the dams."
Attachment J-2	3 tables		Pertaining to all alternatives – not addressed are the potential environmental impacts associated with each alternative. Environmental resources that could be impacted could include: aesthetics, air quality and greenhouse gases, soils, water quality, wetlands, groundwater, surface water, wetlands, floodplains, biological resources, cultural resources, land use, socioeconomic resources, recreation and tourism, utility and transportation infrastructure, public health and safety, and noise.	Compton	LSRWA effort was a watershed assessment and not a detailed investigation of a specific project alternative(s) proposed for implementation. That latter would require preparation of a NEPA document. The evaluation of sediment management strategies in the assessment focused on water quality impacts, with some consideration of impacts to SAV. Other environmental and social impacts were only minimally evaluated or not evaluated at all. A full investigation of environmental impacts would be performed in any future, project-specific NEPA effort.	No further comment at this time
Attachment J-4	1	Table	It is not clear what reservoir bathymetry/trapping efficiency means. If it is simply referring to trapping efficiency, then it should be stated as such. The actual trapping efficiencies should be listed as well (e.g., 55%) rather than just a level associated with a time period.	Compton	For scenarios 2-6 the input parameter is actual reservoir bathymetry per AdH. The exception is Scenario 1, which did not use AdH but was the TMDL/WSM only run which considered trapping rates/efficiency of the 1990s (which was around 55%). What is most important is what era is represented in the simulation which is depicted.	It would be useful to the reader to have the trapping efficiency explicitly listed for each scenario. Please see our example matrix provided as an attachment to our cover letter.
Attachment J-4	1,7	Table	It's not clear how nonattainment differentials are be compared between LSRWA-30 and LSRWA-3 (on page 7), since page 1 of this report says that the nonattainment's were calculated for different time periods for the two runs (1993-1995 for LSRWA-3, 1996-1998 for LSRWA-30). Similar comment for LSRWA-4 and LSRWA-18.	Compton	The CBEMP utilizes the 1991-2000 hydrologic period. For the criteria assessment procedure, a 3-year critical period (1993-95) was used as the period for assessing attainment of the water quality standards for several LSRWA model scenarios. The 1993–1995 critical period was chosen based on key environmental factors, principally rainfall and streamflow, which influenced attainment of the DO water quality standards for the deep-water and deep-channel habitats (USEPA, 2010a). Since the January 1996 high flow event was outside the 1993-95 critical period, the 1996-98 hydrologic period was used as the assessment period for LSRWA modeling scenarios that included an evaluation of a storm event.	No further comment at this time
Attachment J-4	1,7,8	Table	The DO nonattainment's should be listed by segment (similar to pieces from the stoplight plots), and must be listed as absolute numbers as opposed to differentials from other runs, as it becomes confusing for the reader to follow which runs are being compared to other runs. Also, the nonattainment's should carry an additional significant figure (e.g., 1.4% instead of 1%).	Compton/ Linker	Organizing nonattainment by segment does not work in the format of the table. As comment states Appendix D stoplight plots organizes by segment if reader wants to view it this way. Listing the absolute nonattainment values is unwarranted. Significant figures will remain as we received comments earlier on that that amount of precision was not conducive.	As noted in some Appendix D comments, we believe listing absolute nonattainment values by segment would be useful. We also understand that providing the data in this report may be difficult. We are interested in the absolute nonattainment values if there is another way for them to be provided.

LSRWA APPENDIX COMMENTS – JANUARY 2015

APPENDIX K – EXISTING CONDITIONS OF THE WATERSHED

Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change?	Exelon Response/Additional Comment
P. 1, Paragraph 1	While the last portion of this paragraph describes why the discussion is focused on Conowingo it does not explain why there is no focus on the two upstream reservoirs. Why are these reservoirs not discussed at the same level of detail as Conowingo?	Spaur	Modify sentence "As such, it has potentially a large influence on the Chesapeake Bay during storm events due to scouring of nutrients and sediments stored behind this dam." to "Holtwood and Safe Harbor Dams were known to be at equilibrium at the start of this assessment. Because Conowingo was not believed to be in dynamic equilibrium and it reaching that condition could have a potentially large effect on the Bay, more attention is focused on Conowingo Dam than Holtwood or Safe Harbor Dams in this section."	Yes.	To be consistent, the report should acknowledge that Holtwood and Safe Harbor are in "dynamic equilibrium" The revised text still does not quantify or adequately describe how much more important Conowingo Pond loads are to Susquehanna River sediment loads versus loads from Lake Clarke or Lake Aldred. In general, throughout the report and appendices a satisfactory reason has not been given as to why so much more importance has been placed on Conowingo Pond scour as opposed to scour from Lake Clarke and Lake Aldred.
P. 1, Paragraph 1	This paragraph, and the third paragraph in particular, attempt to explain why Conowingo Pond is of particular importance; however, they do not quantify or adequately describe how much more important it is to Susquehanna River sediment loads versus Lake Clarke and Lake Aldred.	Spaur	Dealt with by response to #35.	Yes.	It is hard to follow why believing Lake Clarke and Lake Aldred are in dynamic equilibrium means that they are not capable of having an equally important impact on Bay health. We understand that the initial focus was on Conowingo because it appeared to be fundamentally different (larger in size, trapping more) than the other two reservoirs, but now that we understand that all three reservoirs have reached dynamic equilibrium, we feel that future efforts should be more evenhanded between all three impoundments.
P. 5, Paragraph 4 (last part of Section K.2)	The report identifies that climate change has resulted in recent years being wetter. In general, wetter years would mean increased watershed sediment delivery and transport through the reservoirs. This potentially conflicts with the conclusion that loads are increasing as a consequence of reduced trapping/dynamic equilibrium. It is unclear how earlier statements regarding decreases in trapping can be evaluated without first establishing how hydrologic (and land use) changes impact the watershed the river system.	Spaur	Added sentence to paragraph 2 on page 97, before "All of the Table 4-1 scenarios…" "However, there were no modeling runs formulated for forecasted climate change conditions; a general discussion of global climate change impacts can be found in Section 5.1.4. "	Yes.	The original comment is still valid. The revision does not address the fact that conclusions are made that focus on sediment transport within Conowingo Reservoir without also noting that watershed changes and responses to climate also contribute to changes in sediment and nutrient delivery to the Bay.
P. 11, Paragraph 3	The Exelon study cited (RSP 3.12) does not mention contributions to vertical circulation in the reservoir.	Spaur	Citation corrected to "(Normandeau Associates and GSE, 2011)" -- see comment response #48 for citation details.	Yes.	The corrected citation should be for the final report which is 2012, not 2011. A similar citation change was made at the end of the 2nd preceding paragraph (page 11). That change was incorrect. At the end of the first paragraph on page 11 of Appendix K the citation should be URS and Gomez & Sullivan (2012a).

Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change?	Exelon Response/Additional Comment
P. 16, Paragraph 4	Statement that nutrients released from bottom sediments provide a substantial portion of the nutrients required by phytoplankton is perhaps a little simplified. First, as noted, vertical stratification limits the vertical exchange of dissolved oxygen between the surface and bottom waters (as pointed out on page 34 paragraph 4) and, therefore, the vertical exchange of bottom water nutrients to surface waters is also limited. In addition, as pointed out in paragraph 3 of page 33, nutrients are recycled and reused many times over as they move downstream in rivers towards the Bay. They are also recycled and re-used in the Bay as well. Bottom nutrients are likely to contribute to the production of surface phytoplankton, but it is not clear what the balance between surface recycling of nutrients and bottom release of nutrients is in determining algal productivity.	Spaur	Concur that complicated topic, so will further simplify/generalize. Change "Nutrients contained in Bay bottom sediments are re-released into the water column seasonally, and these regenerated nutrients provide a substantial portion of the nutrients required by phytoplankton in summer, particularly in the middle Bay. " to "Nutrients contained in Bay bottom sediments are re-released into the water column seasonally, and these regenerated nutrients provide a substantial portion of the nutrients required by phytoplankton, particularly in the middle Bay. "	Yes.	Suggest adding “could” as shown in red “ Nutrients contained in Bay bottom sediments are re-released into the water column seasonally, and these regenerated nutrients could provide a substantial portion of the nutrients required by phytoplankton, particularly in the middle Bay. "
P. 18, Paragraph 3	“Monitoring of nutrients in the Susquehanna River has shown that the flow-adjusted annual concentrations of total nitrogen, total phosphorus, and suspended sediment delivered to the dams have been generally decreasing since the mid-1980s.” It is unclear how much of any trends are due to increasing data density over time and reduced uncertainty. There may be some apples and oranges comparisons beneath everything. As stated in the Zhang et al. (2013) paper, there is interpolation and extrapolation in load estimates. The next statements that “This decrease is attributed to the success of environmental management measures. However, total nitrogen, total phosphorus, and suspended sediment loads from Conowingo Reservoir itself to the Chesapeake Bay have shown an increasing trend since the mid-1990s, indicating decreasing reservoir trapping capacity (Zhang et al., 2013)” need further evaluation. Changes in sediment export from the River could also include changing sediment delivery from the watershed. It is unclear how the data analysis on which these statements rely was performed	Spaur	Change middle sentence from "This decrease is attributed to the success of environmental management measures." to "Environmental management measures in the watershed contributed to this decrease." to be less precise over relative importance of management measures versus other causes.	Yes.	Original comment is still valid.

Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change?	Exelon Response/Additional Comment
P. 18, Paragraph 3	Zhang et al (2013) refers specifically to the reservoir system (reservoirs plural) and loads from the Conowingo Dam outlet. To quote from their conclusions: "Flow-normalized loads of SS, PP, and PN at the outlet of the Conowingo Reservoir have been generally rising since the mid-1990s. The reservoirs' capacity to trap these materials has been diminishing, and the Conowingo Reservoir has neared its sediment storage capacity."	Spaur	Change last sentence in paragraph (already recently revised as per above) from "One study has indicated that loads of total nitrogen, total phosphorus, and suspended sediment from Conowingo Reservoir to the Chesapeake Bay are increasing and attributes this to decreasing reservoir trapping capacity (Zhang et al., 2013)." to "One study has indicated that loads of total nitrogen, total phosphorus, and suspended sediment from the reservoir system of the lower dams to the Chesapeake Bay are increasing and attributes this to decreasing trapping capacity of Conowingo Reservoir (Zhang et al., 2013)."	Yes.	The revised statement still does not reflect the cited Zhang et al 2013 appropriately. Suggested edits are shown in red (page 18 of Appendix K): "One study has indicated that loads of ~~total~~ particulate nitrogen, ~~total~~ particulate phosphorus, and suspended sediment from the reservoir system of the lower dams to the Chesapeake Bay are increasing and attributes this, in part, to decreasing trapping capacity of Conowingo Reservoir (Zhang et al., 2013)." Furthermore, the actual statement from Zhang is "Flow-normalized loads of SS, PP, and PN at the outlet of the Conowingo Reservoir have been generally rising since the mid-1990s. The reservoirs' capacity to trap these materials has been diminishing, and the Conowingo Reservoir has neared its sediment storage capacity." Zhang says reservoirs (plural).
P. 22, Paragraph 4	The citation to Exelon (2011) regarding DO in the reservoir is not the 2011 report in the References section. The 2011 Exelon study RSP 3.1 should be cited for this statement.	Spaur	Changed citation to (Normandeau Associates and GSE, 2011). Added reference but used the format that Exelon requested in comment #1. New reference = Normandeau Associates, Inc., and Gomez and Sullivan Engineers. 2011. *Seasonal and Diurnal Water Quality in Conowingo Pond and below Conowingo Dam* (RSP 3.1). Kennett Square, PA: Exelon Generation, LLC.	Yes.	Please cite the final report which is 2012, not 2011.
P. 26, Paragraph 1	The report cites Hartwell and Hameedi (2007) for the proposition that "[t]idal portions of the Anacostia River, Baltimore Harbor, and the Elizabeth River are hotspot areas of contaminants." However, Hartwell and Hameedi (2007) does not mention the Anacostia River, and the figure with the sites of greatest contamination does not include the Anacostia.	Spaur	Change reference to instead be "CBP, 2013" (That these are the three "hottest" contaminated regions of Bay is widely reported and not dependent upon an individual report.)	Yes.	Hartwell and Hameedi (2007) needs to be removed from the reference section in the main report.
P. 29, Paragraph 3	"TP probably does not show a pattern of decrease with depth into the sediment." Personal communication with Langland is cited here but what is Langland's basis for this comment?	Spaur	Add clause "Because the phosphorus adsorbed to bottom sediments is minimally bioavailable and not being utilized by organisms nor reacting chemically," prior to beginning of sentence "TP probably does not show a pattern of decrease with depth into the sediment (Michael Langland, Hydrologist, U.S. Geological Survey, personal communication, 2014). Comment based on years of collected data observations.	Yes.	No further comment at this time

Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change?	Exelon Response/Additional Comment
P. 29, Paragraph 2	Based on the estimates of bioavailable nitrogen and phosphorus quoted here, which could potentially be resuspended and transported into Chesapeake Bay, there is a serious mismatch between the bioavailable fractions of TN (96% typically of limited bioavailability) and TP (0.6-3.5% plant available) contained in the Conowingo Pond sediments and how they are incorporated in the CBEMP model, wherein they are assumed to be approximately 85% bioavailable, once they enter into the bay and are deposited back to the sediment bed in the Bay. Therefore, it is likely that the CBEMP is over- estimating the release of Conowingo nutrients from the sediment bed once they are deposited into the Bay sediments, and therefore the model is over-estimating the change in non-attainment of the DO water quality standard.	Spaur	The context here is IMMEDIATE bioavailability. Immediate added before bioavailability in this paragraph and this statement added: "The nutrients stored behind the dam that are not in immediately bioavailable forms might, however upon burial in the Bay bottom might be expected to gradually become bioavailable from microbial processes in the sediment (Michael Langland, Hydrologist, U.S. Geological Survey, personal communication, 2014). "	Yes.	No further comment at this time
P. 29, Paragraph 4	The paragraph starting with “the sediment retained behind Conowingo Dam…” seems odd in that the focus is exclusively on Conowingo. Even if the measurements are from Conowingo Pond, it seems like the description would be applicable to all three reservoirs given that the sediments (and nutrients) are derived from the watershed. How do these measurements compare to the assumptions for labile and refractory carbon and nutrient distributions used to drive the Bay WQ model? Is/was this information used to update the bay WQ model?	Spaur	Statement at beginning of Section 2 informs reader why we focus on Conowingo. However, concur with need to provide additional information on sediments and nutrients of upper two dams. Please insert the following new paragraph covering this topic after paragraph 2 (p. 44, June 23 version): “TN and TP in bottom sediment samples collected in Lake Clarke considered vulnerable to scour ranged from 3.3 to 5.3 g/kg and 0.8 to 1.2 g/kg, respectively. TN and TP in bottom sediment samples collected in Lake Aldred considered vulnerable to scour ranged from 1.2 to 5.7 g/kg and 0.3 to 0.5 g/kg, respectively. Lake Clarke had higher clay content than Lake Aldred at these locations, likely accounting for greater TP content. Clay content of bottom sediments in downstream Lake Clarke remained consistent in comparison of findings of studies conducted in 1990 versus 1996. Conversely, clay content in bottom sediments in downstream portions of Lake Aldred decreased from 1990 to 1996 (Langland and Hainly, 1997).”	Yes.	No further comment at this time

Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change?	Exelon Response/Additional Comment
P. 29, Paragraph 7	The report does not appear to discuss the potential impacts that the particulate coal may have on collected data or model predictions, nor whether it is uncommon to have an 11-percent coal content.	Spaur	Unlikely that additional future coal to be transported into Bay from sediment behind the dams would have much effect on the Bay. The upper Bay already contains substantial coal as was stated in Section 2.6, and has for probably more than a century. Evaluating effects of additional coal input is one of many specific topics that were not evaluated in this assessment. An environmental impact statement covering any proposed project would be the appropriate place to specifically address this. However, we should change existing sentence on p. 38, 2nd paragraph in "Bay Bottom Materials and Processes" subsection from "Abundant coal occurs in Susquehanna Flats sediments (Robertson, 1998)." To "Abundant coal occurs in Susquehanna Flats sediments transported into the Bay from coal mining in the Susquehanna Basin (Robertson, 1998)." This would better clarify source and timing of coal deliveries to the Bay (coal mining having begun in earnest in Basin by early 1800s). (On side note, I skimmed MGS [1988] and Robertson [1998], but neither of these provides specific information on how much coal occurs in Bay's flats sediments, other than to state that it's abundant in certain strata near the surface.)	Yes.	The importance of coal content is not the effect of future transport to the Bay, but how its presence may influence chemical measurements of sediments.
P. 29-30, Paragraph 7 & 1	Focus is only on Conowingo: what about the other reservoirs?	Spaur	See Comment #35.	No.	See Exelon comment to first two rows of this table on page 1
P. 35, Paragraph 2	There appear to be many other substantial declines in total SAV acres that are not explained by storm events (figure 2-16 and figure 2-17). There is no narrative around this, leaving the reader with the impression that storm events are the primary reason for SAV abundance declining even though a close inspection of the graph doesn't necessarily prove this connection. In fact, Kemp et al (1983) examined potential reasons for the decline bay-wide and at the Flats from the mid-60s to 1983 and concluded that storms played a secondary role.	Spaur	Topic of SAV trends related to storms, eutrophication, and other stressors is covered adequately in last paragraph on bottom of p. 48. No change needed.	No.	No further comment at this time

Page Number/ Section	Original Exelon Comment	LSRWA Lead	LSRWA Lead Response	Report Change?	Exelon Response/Additional Comment
P. 38, Paragraph 1	The first sentence states that "no SAV beds were mapped immediately below Conowingo Dam in the non-tidal and tidal Susquehanna River over the period 1997-2012." Exelon RSP 3.17 mapped SAV at the mouth of Octoraro Creek and at the island complex at near the mouth of Deer Creek (Robert, Wood, and Spencer Islands) and at Steel Island along the opposite bank in 2010 surveys.	Spaur	Change paragraph "No SAV beds were mapped immediately below the Conowingo Dam in the non-tidal and tidal Susquehanna River over the period 1997-2012. However, SAV was frequently mapped in the non-tidal and tidal river downstream to the river mouth from the 1990s through 2010 (VIMS, 2013)." to "VIMS mapped no SAV beds immediately below the Conowingo Dam in the non- tidal and tidal Susquehanna River over the period 1997-2012. However, VIMS frequently mapped SAV in the non-tidal and tidal river downstream to the river mouth from the 1990s through 2010 (VIMS, 2013). SAV was found to occur in 2010 downstream of Conowingo Dam at creek mouths and islands between the dam and Port Deposit in shallow areas with fine-grained sediment and low water velocities (URS and GSE , 2011).	Yes.	SAV was found to occur in 2010 downstream of Conowingo Dam at creek mouths and islands between the dam and Port Deposit in shallow areas with coarser-grained sediment (sand and cobble) near sources of sediment supply and reduced flow velocities (tributary mouths and a protected island complex) (URS and GSE , 2012c). Study 3.17 should be cited with the final report year (2012). Thus, in the references section it should become 2012c.

Appendix J:
Plan Formulation

Attachment J-1:
Sediment Management Options for the Conowingo Dam Restricting Sediment in the Watershed by Implementing Best Management Practices

Attachment J-2:
Cost Documentation “Factsheets” and Summary Table of Costs

Attachment J-3:
Summary Table of Sediment Management Alternative Evaluation

Attachment J-4:
Summary Table of Major Modeling Scenarios and Results

Attachment J-5:
Summary of Model Inputs and Results for Each Significant LSRWA Model Run

Attachment J-1:
Sediment Management Options for the Conowingo Dam Restricting Sediment in the Watershed by Implementing Best Management Practices

Sediment Management Options for the Conowingo Dam
Restricting Sediment in the Watershed
by
Implementing Best Management Practices

Introduction

The purpose of this report is to examine how implementation of best management practices related to the E3 scenario (Everything, Everywhere, by Everyone) for the Chesapeake Bay can potentially reduce sediment loads to the Susquehanna River and to develop a range of costs to implement those practices.

The Susquehanna River extends 444 miles from its source at Otsego Lake near Cooperstown, NY to the head of the Chesapeake Bay at Havre de Grace, MD and drains 27,510 square miles from tributaries in New York, Pennsylvania, and Maryland (Susquehanna River Basin Commission) (Figure 1).

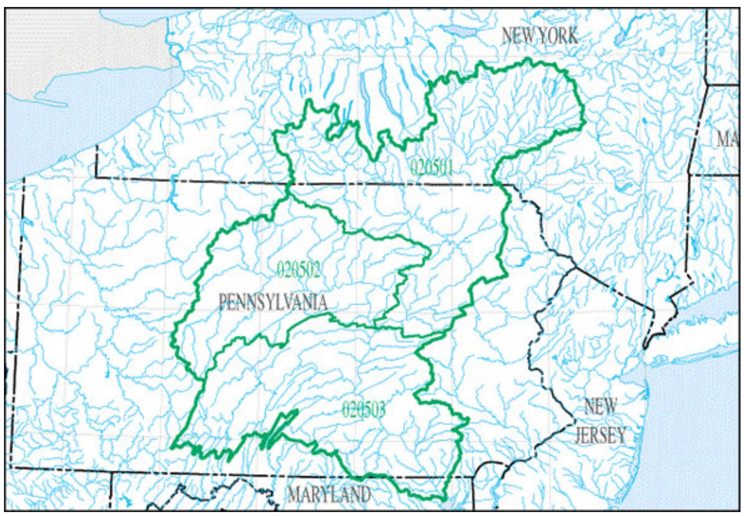


Figure 1. Susquehanna River watershed (Mansfield University).

The Susquehanna River is the nation's 16th largest river and of all the tributaries, it contributes the largest amount of freshwater flow, nutrients, and sediment to the Chesapeake Bay. The 1990-2012 average monitored sediment load to the Chesapeake Bay measured from the non-tidal areas of the Bay's nine largest rivers was 5.4 million tons per year, which does not include the sediment loads generated in the Coastal Plain (Chesapeake Bay Program). The 1990-2012 average monitored sediment load from the Susquehanna River was 2.15 million tons per year, or approximately 40 percent of the total load from non-tidal areas (Figure 2) (Joel Blomquist, personal communication).

Sediment transport by streams and rivers is a natural process; however, the delivery of excess sediment can have many deleterious effects, which include increased loads of nutrients, increased dredging of navigation channels, and adverse impacts to submerged aquatic vegetation and bottom-dwelling (benthic) organisms (Scientific and Technical Advisory Committee, 2000).

Sediment deposition to Chesapeake Bay from the Susquehanna River is mitigated by the presence of three consecutive hydroelectric dams (Safe Harbor Dam, Holtwood Dam, and Conowingo Dam). These three dams form a reservoir system in the lower part of the River that has been trapping sediment behind the dams since they were constructed in 1910 (Holtwood Dam), 1928 (Conowingo Dam) and 1931 (Safe Harbor Dam). The uppermost two dams, Safe Harbor Dam and Holtwood Dam, have already reached their capacity to store sediment and sediment-related nutrients. Conowingo Reservoir, which is formed by Conowingo Dam, the lowermost and largest dam, has reached approximately 92 percent of its sediment storage capacity and is therefore in a state of dynamic equilibrium (Langland, 2015).

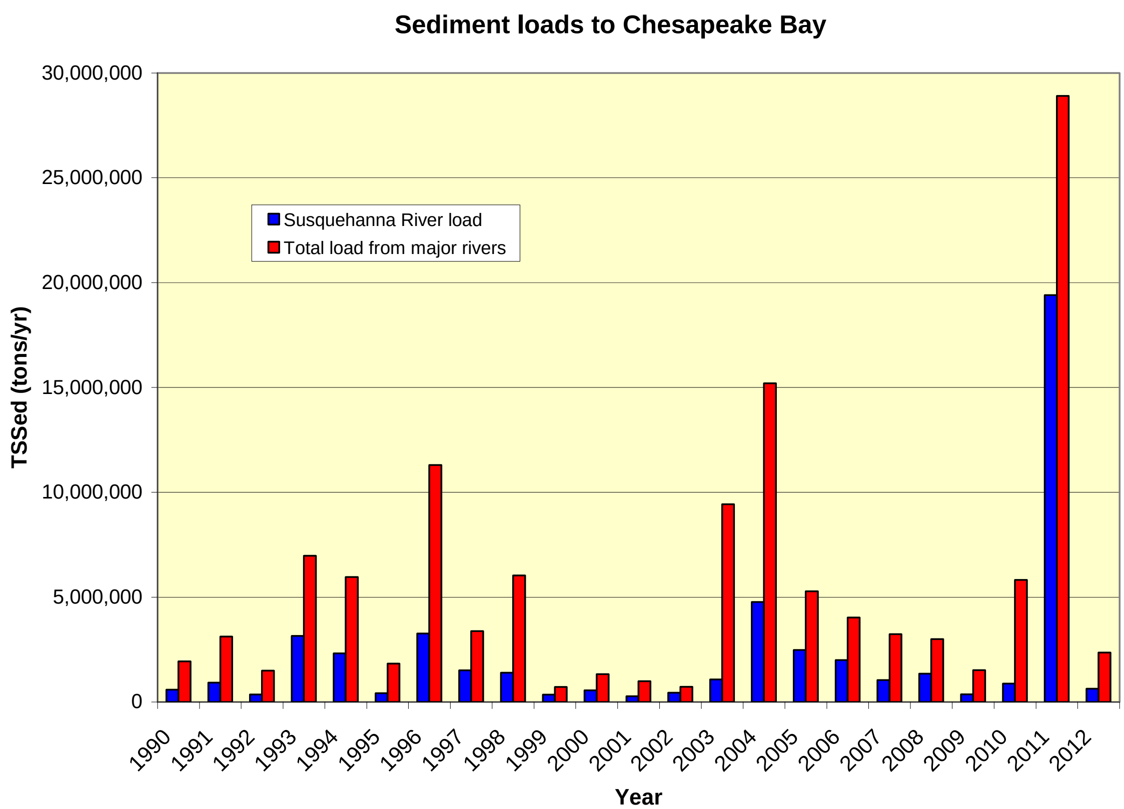


Figure 2. Total sediment loads and Susquehanna River sediment loads to Chesapeake Bay

Although the Conowingo Reservoir has not reached its full capacity, there is little room left. As a result, during periods of high flow trapped sediment may be re-suspended and deposited below Conowingo Dam in the upper Chesapeake Bay. These re-suspension or major scour events (flows greater than 400,000 cubic feet per second) occurred in June 1972 during Tropical Storm Agnes, the floods of September 1975 and January 1996, and more recently in September 2011 during Tropical Storm Lee. Recent studies suggest that scouring may be occurring more frequently and that sediment concentrations and loads at high flows have increased over the past ten years (2002-2011; Hirsch, 2012). These scour events result in massive plumes of sediment such as the one that occurred following Tropical Storm Lee, which extended past the mouth of the Patuxent River (Figure 3) and originated from both the watershed and from scour behind the dams, with the majority of sediment coming from the watershed. It is currently estimated that the percent of scour to total load ranges from 20 percent to 37 percent (average 30 percent) for flows of 400,000 to 800.000 cubic feet per second (Langland, 2015).

Excess sediment and nutrient loads from all sources have resulted in the Bay not meeting its water quality standards for dissolved oxygen, water clarity, and chlorophyll-a, an indicator of algal biomass, and led the U.S. Environmental Protection Agency (EPA) to list the Bay as an impaired water-body. In December 2010 the EPA and Chesapeake Bay Program watershed partners Maryland, Pennsylvania, New York, Virginia, West Virginia, Delaware, and the District of Columbia implemented a Chesapeake Bay-wide Total Maximum Daily Load (TMDL) or "pollution diet," which set limits of 185.9 million pounds of nitrogen, 12.5 million pounds of phosphorus, and 6.45 billion pounds (3.2 million tons) of sediment per year. The

Figure 3. NOAA satellite image showing sediment plume following Tropical Storm Lee in September 2011.

sediment TMDL would represent a 20-percent reduction over current Bay-wide loads. The EPA computer model estimated sediment loads to the Susquehanna River from New York, Pennsylvania, and Maryland and their TMDL allocations appear in Table 1.

Table 1. Modeled sediment loads and TMDL allocations for New York, Pennsylvania, and Maryland from the Chesapeake Bay Program Phase 5.3.2 Watershed Model run for 2012 (U.S. EPA, 2010).

State	Current load (million pounds/year)	Allocated load (million pounds/year)
New York	317	293
Pennsylvania	2,200	1,741
Maryland	68	63
Total	**2,585**	**2,097**

To achieve the reductions outlined in the TMDL each of the six states and the District of Columbia developed watershed implementation plans (WIPs) which outline the best management practices (BMPs) they will put in place to meet their nutrient load allocations. Although there are state allocations for sediment loads in the TMDL they are not defined in the WIPs, because it is anticipated that achieving the TMDL goals for nitrogen and phosphorus will result in a sediment load reduction that exceeds the sediment load allocation. According to the WIPs for New York, Pennsylvania, and Maryland BMP implementation levels outlined in the plans to meet nutrient allocations are estimated to surpass the sediment planning targets (i.e., lower the loads) by approximately 62 million pounds per year.

Beyond the WIPs

Additional load reductions can theoretically be achieved by implementing the “E3” scenario, which calls for jurisdictions to implement every feasible practice everywhere (Everything, Everywhere, by Everyone). If the E3 scenario were implemented it is estimated that a total of 190 million pounds of sediment per year would be reduced Bay-wide (this includes the 62 million pounds per year that would be reduced by implementing the WIPs to meet the TMDL goals). It is important to note that the E3 scenario is a “what-if” scenario of watershed conditions with theoretical maximum levels of managed controls on load sources. There are no cost and few physical limitations to implementing the BMPs in the E3 scenario. Generally, E3 implementation levels and their associated reductions in nutrients and sediment could not be achieved for many practices, programs, and control technologies when considering physical limitations and levels of participation by the jurisdictions, therefore the estimated sediment load reductions and BMP implementation levels beyond the WIPs should be considered theoretical boundaries of maximum implementation and load reductions.

Methods and Assumptions

The Chesapeake Bay Program developed the E3 scenario from a list of approved agriculture and urban/suburban BMPs using output from the Phase 5.3.2 Watershed Model, which is also used for tracking towards the TMDL. Currently, there are 34 agriculture and 20 urban/suburban U.S. EPA Chesapeake Program-approved BMPs that are used to assess progress toward the Bay-wide TMDL (Attachment 1) and this list is constantly expanding to add new BMPs, and including revised BMPs to update existing practices (Kevin DeBell, Ph.D., personal communication). The list of approved BMPs used in the E3 scenario was developed by consensus among the seven jurisdictions in the Chesapeake Bay partnership at a series of expert panels, with workgroup and subcommittee approval. The technologies, practices, and programs selected by the partnership have been previously reported by the jurisdictions as part of annual model assessments, milestones, tributary strategies, and WIPs. The E3 scenario does not include the full suite of practices due to the goal of achieving maximum load reductions. The BMPs that are fully implemented in the E3 scenario were estimated to produce greater reductions than alternative practices that could be applied to the same land base (Jeff Sweeney, personal communication).

When implemented across the Susquehanna River watershed, these practices would in theory achieve significant reductions of sediment delivered to the reservoir behind Conowingo Dam. The model run outlined practices for New York, Pennsylvania, and Maryland and the units, in either acres or feet, required to achieve the reductions. There were 12 agriculture practices needed in New York, 13 in Pennsylvania, and 11 in Maryland. Examples include planting cover crops on over 1 million acres of farm land across the three states, improving pasture management on 591,000 acres, and developing conservation plans for approximately 3 million acres. There were nine urban/suburban practices needed for New York, 15 for Pennsylvania, and 18 for Maryland. Examples include installing a variety of storm water management practices on 1.1 million acres of land, controlling sediment on 171,000 acres, and restoring 77,000 feet of urban streams. Resource practices (forest harvesting and improving dirt and gravel roads) were also needed; however, these could be considered a subset of agriculture practices.

The Chesapeake Bay Program also developed watershed-wide unit costs for the approved BMPs, which are draft, subject to change, and part of a larger report that is still under review. Most, though not all, of the BMPs used in the E3 scenario have associated unit costs in dollars per acre per year or dollars per foot per year based on 2010 dollars. The primary source of the unit costs was the Bay Program approved list; however, in order to have as complete a cost estimate as possible, in the absence of unit costs from the Bay Program, costs from the Maryland Department of the Environment (MDE) (Greg Busch, personal communication), and costs from the Maryland Department of Agriculture (MDA) (John Rhoderick, personal communication) were used. In cases where costs for a jurisdiction were not available, a cost that was available for one jurisdiction was used for all three. Low and high costs were available for urban/suburban BMPs, though not for agriculture.

Agriculture unit costs were available for all three states. For New York, nine costs were obtained from the Bay Program-approved list, two were from MDE, and one from MDA. Costs for ten of the 13 agriculture BMPs for Pennsylvania were obtained from the Bay Program, two were from MDE, and one was from MDA. For Maryland, nine unit costs came from the Bay Program, two were obtained from MDE and one from MDA. Agriculture unit costs ranged from $2 per acre per year to develop conservation management plans to $482 per acre per year for wetland restoration.

Eight of the nine unit costs for New York urban/suburban BMPs were obtained from the Bay Program-approved list and one was obtained from MDE. Twelve unit costs were available from the Bay Program list for Pennsylvania, one from MDE, and no unit costs were available for the remaining two practices. Sixteen unit costs for Maryland were from the Bay Program list and two were obtained from MDE. There were two resource practices for New York and Pennsylvania, and one for Maryland. In the absence of unit costs from the Bay Program, costs from MDE were used for all three states. No costs were available for urban growth reduction, abandoned mine reclamation, and erosion and sediment control on dirt and gravel roads in

Pennsylvania, and erosion and sediment control on dirt and gravel roads in New York. These missing data represent an area of uncertainty in this analysis.

Five of the unit costs for urban/suburban BMPs were divided by the Bay Program into new/re-development and retrofits. The annual cost estimates for this project assumed that 10 percent of the urban/suburban practices would be implemented as new construction or re-development and 90 percent would be retrofits (retrofits are more costly than new construction or re-development). Some examples of urban/suburban unit costs are provided in Table 2.

Table 2. Examples of units costs for urban/suburban BMPs (Draft – subject to change).

		New/re-development (dollars/acre/year)			Retrofits (dollars/acre/year)		
Practice		NY	PA	MD	NY	PA	MD
Bio-swales	Low	$420	$395	$394	$612	$575	$574
	High	$1,549	$1,456	$1,453	$2,404	$2,258	$2,255
Impervious surface reduction	Low	$11,438	$11,438	$11,438	$11,438	$11,438	$11,438
	High	$17,222	$17,222	$17,222	$17,222	$17,222	$17,222
Urban forest buffers	Low	$121	$153	$92	$121	$153	$92
	High	$121	$153	$92	$121	$153	$92
Urban infiltration	Low	$663	$623	$622	$1,014	$953	$951
	High	$1,562	$1,468	$1,465	$2,545	$2,391	$2,387

Conclusions

The output from the Chesapeake Bay Program's Phase 5.3.2 Watershed Model, which was used to develop the practices in terms of the units acres or feet of BMP needed to implement the E3 scenario, was combined with the unit cost estimates from the Bay Program and other sources to develop a range in the annual cost of achieving the theoretical maximum amount of sediment reduction to the Conowingo Reservoir. One example of a BMP used in the Phase 5.3.2 Watershed Model run for the E3 scenario was wetland restoration. The number of acres in each state was multiplied by the respective unit cost in each state in dollars per acre per year to derive the cost for that BMP. The model used restoration of 133,140 acres of wetlands in Pennsylvania, 192 acres in Maryland, and 142,541 acres in New York at a combined annual cost of approximately $132,078,000. The cost of restoring wetlands for each state was combined with the cost of implementing the remaining agriculture and urban/suburban BMPs to derive the estimated annual costs by jurisdiction and the totals that appear in Table 3. The high cost estimates to implement the E3 scenario are provided in Attachment 2 and Attachment 3 for agriculture and urban/suburban BMPs, respectively. Unit costs and a description of the BMPs are provided in Attachment 4. The costs in Attachment 4 are draft, subject to change, and excerpted from a larger report that is in draft form and pending review. BMP cost efficiencies in terms of cost of BMP per pound of sediment reduced are provided in Attachment 5.

Table 3. Estimated costs by jurisdiction and annual costs to implement the E3 scenario

State	Low cost estimate	High cost estimate
Maryland	$8,429,749.50	$15,701,723.79
New York	$108,746,113.36	$139,680,705.69
Pennsylvania	$1,399,225,005.62	$3,356,594,812.19
Total	**$1,516,400,868.48**	**$3,511,977,241.67**

The low and high costs of implementing the E3 scenario in terms of dollars per cubic yard of sediment reduced per year are $12,929 and $29,944, respectively. These estimates are based on 95,000 tons of sediment reduced in the E3 scenario, and a conversion factor of 1 cubic yard of dredged material equaling 0.81 tons for a total of 117,284 cubic yards.

The cost of implementing the E3 scenario in Pennsylvania is considerably higher than New York and Maryland because most (76.2 percent) of the Susquehanna River watershed is in Pennsylvania. Maryland has the smallest part of the watershed (1 percent) and therefore the smallest cost. Twenty-two percent of the watershed is in New York.

The maximum available load of sediment that could be reduced by additional BMP implementation above and beyond the WIPs throughout the Susquehanna River watershed is approximately 95,000 tons per year. Based on the U.S. Geological Survey monitored loads for 1993 through 2012 this is about 4 percent of what is estimated to flow over Conowingo Dam into Chesapeake Bay on an average annual basis, which is approximately, 2.4million tons. Given the relatively small reduction in sediment reaching Conowingo Dam and the high cost, implementing the E3 scenario as a means to reduce scour events does not appear economically or practically feasible. Note that these numbers are subject to change and will be refined based on further analysis and review.

References

Blomquist, J. D. (24 October 2013). Interview by W. D. Romano [e-mail]. Lower Susquehanna River Watershed Assessment, U.S. Army Corps of Engineers. Maryland Department of Natural Resources, Annapolis, MD.

Busch, G. C. (26 August 2013). Interview by W. D. Romano [e-mail]. Lower Susquehanna River Watershed Assessment, U.S. Army Corps of Engineers. Maryland Department of Natural Resources, Annapolis, MD.

Chesapeake Bay Program. Sediment loads and river flow to the Bay. Chesapeakebay.net. Retrieved 24 October 2013, from http://www.chesapeakebay.net/indicators/indicator/sediment_loads_and_river_flow_to_the_bay.

DeBell, K. M. (9 September 2013). Interview by W. D. Romano [e-mail]. Lower Susquehanna River Watershed Assessment, U.S. Army Corps of Engineers. Maryland Department of Natural Resources, Annapolis, MD.

Hirsch, R.M. (2012). Flux of nitrogen, phosphorus, and suspended sediment from the Susquehanna River Basin to the Chesapeake Bay during Tropical Storm Lee, September 2011, as an indicator of the effects of reservoir sedimentation on water quality: U.S. Geological Survey Scientific Investigations Report 2012–5185, 17 p.

Langland, M. J. (2015). Sediment transport and capacity in three reservoirs, lower Susquehanna River basin, Pennsylvania and Maryland (1900-2012): U.S. Geological Survey Open-File Report 2014-1235.

Mansfield University. What is a watershed? www.geoggeol.mansfield.edu. Retrieved 27 October 2013, from http://www.google.com/imgres?imgurl=http://geoggeol.mansfield.edu/geoggeol/what-can-i-study/images/susquehanna-river-watershed.jpg&imgrefurl=http://geoggeol.mansfield.edu/what-can-i-study/what-is-a-watershed.cfm&h=405&w=590&sz=126&tbnid=9G2IwgHGn_zjlM:&tbnh=90&tbnw=131&zoom=1&usg=__rc4o7aX9MN1BnvbR5UoKD2L3R0Q=&docid=ga2xfN61LI_D6M&sa=X&ei=q4tyUpONCYjk4APIxoCgBw&ved=0CC0Q9QEwAQ

Rhoderick, J. (13 September 2013). Interview by W. D. Romano [telephone conversation]. Lower Susquehanna River Watershed Assessment, U.S. Army Corps of Engineers. Maryland Department of Natural Resources, Annapolis, MD.

Scientific and Technical Advisory Committee, 2000. The impact of Susquehanna sediments on the Chesapeake Bay, Workshop Report, 29 p.

Susquehanna River Basin Commission. SRBC information sheet. SRBC.net. Retrieved 26 October 2013, from http://www.srbc.net/pubinfo/docs/Susq%20River%20Basin%20General%20(11_06).PDF.

Sweeney, J. D. (31 October 2013). Interview by W. D. Romano [e-mail]. Lower Susquehanna River Watershed Assessment, U.S. Army Corps of Engineers. Maryland Department of Natural Resources, Annapolis, MD.

U.S. Environmental Protection Agency (2010). Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment. United States Environmental Protection Agency. Retrieved 27 October 2013, from http://www.epa.gov/reg3wapd/tmdl/ChesapeakeBay/tmdlexec.html.

Attachment 1:
List of U.S. EPA Chesapeake Bay Program Approved Best Management Practices

Chesapeake Bay Program Agriculture WIP BMPs
Alternative Watering Facilities
Ammonia Emissions Reduction
Animal Waste Management Systems - All
Animal Waste Management Systems – Livestock
Animal Waste Management Systems – Poultry
Barnyard Runoff Control
Capture and Reuse
Carbon Sequestration and Alternative Crops
Commodity and Small Grains Cover Crops
Conservation Plans
Conservation Tillage
Continuous No-Till
Cover Crops
Cropland Irrigation Management
Dairy Precision Feeding and Forage Management
Decision Agriculture
Enhanced Nutrient Management
Forest Buffers
Grass Buffers
Horse Pasture Management
Land Retirement
Liquid Manure Injection
Loafing Lot Management
Manure Transport - All
Manure Transport - Inside
Manure Transport - Outside
Mortality Composters
Non-Urban Stream Restoration
Nutrient Management
Phytase - Poultry
Phytase - Swine
Precision Intensive Rotational Grazing
Prescribed Grazing
Stream Access Control
Tree Planting
Water Control Structures
Wetland Restoration

Chesapeake Bay Program Urban/suburban WIP BMPs
Bioretention
Bioswale
CSO Separation
Dry Detention and Extended Detention Basins
Dry Detention Ponds/Hydrodynamic Structures
Erosion and Sediment Control
Forest Conservation
Impervious Surface Reduction
Retrofit Storm water Management
Street Sweeping
Urban Tree Planting
Urban Filtering Practices
Urban Forest Buffers
Urban Grass Buffers
Urban Infiltration Practices
Urban Nutrient Management
Urban Stream Restoration
Vegetated Open Channels
Wetlands and Wet Ponds
Storm Water Management by Era

Attachment 2:
Agriculture BMPs and Annual Costs to Implement the E3 Scenario
(Draft – subject to change)

Agriculture Practices	Units	2025 WIP + Sediment E3 Above Conowingo MD COST	2025 WIP + Sediment E3 Above Conowingo NY COST	2025 WIP + Sediment E3 Above Conowingo PA COST
Continuous NoTill	acres			
Other Conservation-Till	acres	$115,758.52	$2,392,456.27	$19,670,287.79
Conservation Tillage w/ Continuous NoTill	acres			
Cover Crop	acres	$288,474.70	$7,189,841.55	$29,678,349.48
Commodity Cover Crop	acres	$39,804.08	$899,469.56	$6,961,589.96
Commodity+Cover Crop	acres			
Pasture Alternative Watering	acres			
Prescribed Grazing	acres	$41,189.64	$2,206,643.78	$6,268,654.32
Horse Pasture Management	acres			
Stream Access Control with Fencing	acres	$882.49	$1,175,313.30	$1,351,218.12
Pasture Management Composite	acres			
Forest Buffers on Fenced Pasture Corridor	acres	$2,796.31	$2,916,190.89	$4,252,490.95
Grass Buffers on Fenced Pasture Corridor	acres			
Forest Buffers	acres	$503,236.96	$22,956,978.89	$117,758,978.66
Wetland Restoration	acres	$284,372.46	$22,018,893.26	$62,900,937.79
Land Retirement	acres	$80,944.75	$5,222,798.14	$7,324,194.16
Grass Buffers	acres			
Tree Planting	acres			
Carbon Sequestration	acres			$1,362,273.32
Conservation Plans	acres	$20,527.66	$1,336,017.45	$4,638,982.20
NonUrban Stream Restoration	feet	$2,537.57	$2,365,995.57	$2,433,605.80
Barnyard Runoff Control	acres	$11,799.38	$650,392.88	$3,407,132.71
Loafing Lot Management	acres			

Attachment 3:
Urban/suburban BMPs and Annual Costs to Implement the E3 Scenario
(Draft – subject to change)

		2025 WIP + Sediment E3	2025 WIP + Sediment E3	2025 WIP + Sediment E3
		Above Conowingo	Above Conowingo	Above Conowingo
		MD	NY	PA
		COST	COST	COST
Urban/Suburban Practices	**Units**			
Wet Ponds & Wetlands	acres	$176,953.31	$9,045,758.07	$122,795,122.53
Dry Ponds	acres	$262,894.83		$24,348,873.16
Extended Dry Ponds	acres	$116,172.73	$196,473.21	$26,540,271.74
Infiltration Practices	acres	$154,279.40	$27,679,287.11	$1,125,730,593.15
Filtering Practices	acres	$7,532,657.80	$7,774,856.42	$1,436,536,251.46
BioRetention	acres	$1,759.12		
BioSwale	acres	$24,053.29		
Vegetated Open Channel	acres	$50,061.60		
SWM by Era (1985-2002)	acres	$1,238,988.53		
SWM by Era (2002-2010)	acres	$645,246.86		
Retrofit Stormwater Management	acres	$165,852.02		
Stormwater Management Composite	acres			
Erosion and Sediment Control	acres	$40,084.45	$43,122.31	$4,039,577.85
Extractive Erosion and Sediment Control	acres		$13,273,106.72	$199,519,476.84
Forest Conservation	acres	$0.00		
Urban Growth Reduction	acres			
Impervious Surface Reduction	acres	$2,288,287.14	$2,381,785.38	$36,665,104.12
Forest Buffers	acres	$19,702.72		$2,182,307.54
Tree Planting	acres	$3,702.60		$141,150.28
CSO Connection	acres			$63,973,358.56
Urban Stream Restoration (feet)	feet	$39,221.40	$1,589,997.00	$2,978,751.42
Street Sweeping (lbs)	lbs	$1,538,662.24		
Street Sweeping	acres		$5,058,038.42	$39,165,795.80
Abandoned Mine Reclamation	acres			
Resource Practices				
Forest Harvesting BMPs	acres	$10,819.26	$1,307,289.51	$3,969,482.49
Dirt&Gravel Road E&S (feet)	feet			

Attachment 4:

U.S. Environmental Protection Agency Approved Best Management Practices

(Draft – subject to change, do not quote or cite)

This attachment describes the development of unit costs for each source category. Estimates of annualized costs reflect a 5% discount rate. Also included are the incremental costs for other actions.

Agricultural Sources

The Phase II WIPs identify a wide range of agricultural practices included in the accompanying spreadsheet of implementation levels [and thus included in the Chesapeake Bay Watershed Model (CBWM)]. This analysis includes only those practices in the spreadsheets and current watershed model.

EPA uses unit costs for agricultural sediment or nutrient controls identified in the WIPs from USDA's Environmental Quality Incentive Program (EQIP), where available, and WIPs and prior studies where EQIP estimates are not available. In selecting relevant studies, EPA excludes those prior to 2000, and relies on EQIP and WIP estimates where feasible because these costs likely represent the most recent and best estimates of actual implementation costs. For example, most states within the Bay watershed indicate that cost share payments represent average BMP costs estimated based on previously implemented contracts or unit costs (from sources such as RSMeans, vendor/local dealer quotes or estimates from technical assistance providers) and typical farm or operation size. In cases where documentation is insufficient to determine the basis for the estimates or conversion to the desired units of BMP implementation is not possible, EPA does not use the cost data.

When using EQIP costs, EPA estimates total implementation costs (or the sum of individual practice components), including funded amounts. For example, unit costs from the EQIP cost share program typically represent 75% of the total cost for a given unit of implementation in Maryland (Morgarte, 2011), West Virginia (Wolfe, 2011), Pennsylvania (Frantz, 2011), Delaware (Garrahan, 2011), New York (Swartz, 2011), and Virginia (Faulkner, 2011). As such, to estimate the total costs of BMPs based on EQIP costs, EPA multiplies the EQIP costs by 1.33 (1/0.75).

Exhibit 1 summarizes average unit costs for each agricultural practice, described in the following sections. Jurisdiction-specific estimates are available for only a subset of practices. When using unit costs, EPA uses overall average costs when jurisdiction-specific costs are not available.

Exhibit 1: Summary of Annual Unit Costs for Agriculture BMPs (2010$)

Chesapeake Bay WIP BMPs	Unit Costs							Units
	Average	DE	MD	NY	PA	VA	WV	
Alternative Watering Facilities	$30	NA	NA	NA	NA	NA	NA	$/acre/yr
Ammonia Emissions Reduction	$37	$46	$45	NA	$39	$46	NA	$/AU/yr
CAFO Animal Waste Management Systems - All	$170	NA	NA	NA	NA	$170	NA	$/AU/yr
AFO Animal Waste Management Systems - All	$170	NA	NA	NA	NA	$170	NA	$/AU/yr
CAFO Animal Waste Management Systems - Livestock	$194	NA	NA	NA	NA	$194	NA	$/AU/yr
AFO Animal Waste Management Systems - Livestock	$194	NA	NA	NA	NA	$194	NA	$/AU/yr
CAFO Animal Waste Management Systems - Poultry	$72	NA	NA	NA	NA	$72	NA	$/AU/yr
AFO Animal Waste Management Systems - Poultry	$72	NA	NA	NA	NA	$72	NA	$/AU/yr
Barnyard Runoff Control	$567	$822	$446	NA	NA	$434	NA	$/acre/yr
Capture and Reuse	$971	NA	$971	NA	NA	NA	NA	$/acre/yr
Carbon Sequestration and Alternative Crops	$18	NA	NA	NA	NA	NA	NA	$/acre/yr
Commodity and Small Grains Cover Crops	$67	$23	NA	NA	NA	$110	NA	$/acre/yr
Conservation Plans	$2	NA	$2	NA	NA	NA	NA	$/acre/yr
Conservation Tillage	$0	NA	NA	NA	NA	NA	NA	$/acre/yr
Continuous No-Till	$0	NA	NA	NA	NA	NA	NA	$/ac/yr
Cover Crops	NA	$52	$68	$75	$40	$109	$98	$/ac/yr
Cropland Irrigation Management	$42	$19	$92	NA	$25	$31	NA	$/acre/yr

Exhibit 1: Summary of Annual Unit Costs for Agriculture BMPs (2010$)

Chesapeake Bay WIP BMPs	Unit Costs							Units
	Average	DE	MD	NY	PA	VA	WV	
Dairy Precision Feeding and Forage Management	-$10	NA	NA	-$10	NA	NA	NA	$/AU/yr
Decision Agriculture	$25	$30	$32	NA	$13	NA	NA	$/acre/yr
Enhanced Nutrient Management	$8	NA	$9	NA	NA	NA	NA	$/acre/yr
Forest Buffers	$219	$177	$295	$231	$293	$94	NA	$/acre/yr
Grass Buffers	NA	$189	$204	$147	$191	$93	$123	$/acre/yr
Horse Pasture Management	$22	NA	NA	$20	NA	$23	NA	$/acre/yr
Land Retirement	$169	NA	$169	NA	NA	NA	NA	$/acre/yr
Liquid Manure Injection	$60	NA	$60	NA	NA	NA	NA	$/acre/yr
Loafing Lot Management	$1,541	NA	$1,943	NA	NA	$1,140	NA	$/acre/yr
Manure Transport - All	$28	NA	NA	NA	NA	NA	NA	$/ton/yr
Manure Transport - Inside	$16	NA	NA	NA	NA	NA	NA	$/ton/yr
Manure Transport - Outside	$39	NA	NA	NA	NA	NA	NA	$/ton/yr
CAFO Mortality Composters	$377	NA	NA	$28	$88	$1,120	$217	$/AU/yr
AFO Mortality Composters	$377	NA	NA	$28	$88	$1,120	$217	$/AU/yr
Non-Urban Stream Restoration	$7	NA	$7	NA	$5	NA	$8	$/feet/yr
Nutrient Management	NA	-$1	$6	$2	-$1	$12	$10	$/acre/yr
Phytase - Poultry	-$61	NA	NA	NA	NA	NA	NA	$/AU/yr
Phytase - Swine	-$41	NA	NA	NA	NA	NA	NA	$/AU/yr
Precision Intensive Rotational Grazing	$74	$53	$93	NA	NA	NA	$75	$/acre/yr
Prescribed Grazing	NA	$33	$15	$13	$16	$28	$9	$/acre/yr
Stream Access Control	$5,312	NA	NA	NA	NA	NA	NA	$/acre/y

Exhibit 1: Summary of Annual Unit Costs for Agriculture BMPs (2010$)

Chesapeake Bay WIP BMPs	Unit Costs							Units
	Average	DE	MD	NY	PA	VA	WV	
								r
Tree Planting	$171	$162	$212	NA	$255	$112	$155	$/acre/yr
Water Control Structures	$18	NA	NA	NA	NA	$18	NA	$/acre/yr
Wetland Restoration	NA	$475	$460	$543	$442	$384	$410	$/acre/yr

Alternative Watering Facilities and Stream Access Control

Alternative water facilities involve the use of permanent or portable livestock water troughs placed away from the stream corridor. The water supplied to the facilities can come from any source including pipelines, springs, wells, and ponds. In-stream watering facilities such as stream crossings or access points are not considered in this definition. As discussed in the model documentation, the CBWM also defines stream access control as excluding a strip of land with fencing along the stream corridor to provide protection from livestock. The fenced areas may be planted with trees or grass, or left to natural plant succession, and can be of various widths. The implementation of stream fencing provides stream access control for livestock but does not necessarily exclude animals from entering the stream (e.g., through in-stream crossing or limiting watering facilities).

Weiland et al. (2009) developed unit costs for three off-stream watering alternatives: off-stream watering with no fencing (i.e., alternative watering facilities), and off-stream watering with fencing and with or without stream crossings (i.e., stream access control). For this analysis, EPA converts these costs into dollars per acre per year by dividing by the estimated costs by model farm size (50 acres) and annualizing over 20 years (based on the useful life of the practice).

Ammonia Emission Reductions

Ammonia emission reductions can include litter amendments like alum that suppress the formation of ammonia from ammonium in litter, biofilters attached to animal enclosure ventilation systems that detoxify ammonia, or lagoon covers that prevent volatilization from loss due to wind.

Costs are based on EQIP estimates and a study from Moore (2005). To convert EQIP estimates from dollars per square feet to dollars per AU, EPA assumes that 25,000 chickens would be housed in buildings 16,000 square feet in size (U.S. EPA, 2001a). Annual costs represent capital costs annualized over 10 years, or the reported annual costs of the practice, depending on the study.

Animal Waste Management Systems

Animal waste management systems involve controls designed for proper handling, storage, and utilization of wastes generated from confined animal feeding operations (CAFOs). This typically includes a means of collecting, scraping, or washing wastes from confinement areas into appropriate waste storage structures such as lagoons, ponds, or tanks for liquid wastes, and storage sheds or pits for solid wastes.

The animal waste management system costs represent estimates from actual systems installed in Virginia in 2009 and 2010 (VA DCR, 2011a). To provide consistent units from which to estimate costs associated with Phase II WIPs, EPA converts all cost estimates into dollars per animal units (AUs) per year. For this analysis, 1 AU equals 0.74 dairy cows, 1.14 beef cow, 2.67 to 9.09 hogs, 250 layers, 455 broilers, or 67 turkeys. (Costs can also be converted into dollars per manure acre by assuming 1 manure acre equals 145 AUs.) EPA annualizes capital costs over the specified life of the BMP (5 to 15 years, with 10 years being the most typical life of the BMP reported in the studies), and assumes annual O&M equal to 5% of BMP installation costs to estimate total annual costs.

Because the exact control mechanisms are not specified in the project list, it is difficult to determine the factors driving the unit costs.

Barnyard Runoff Controls

Barnyard runoff controls involve controlling runoff from barnyard areas (e.g., roof runoff control, diversion of clean water from entering the barnyard). Because barnyard runoff controls primarily target reductions in sediment loads, which are not necessarily related to the presence or type of animal on a farm, EPA develops unit costs in terms of dollars per system per year first and then converts these costs into dollars per acre per year for multiplication by the units in the inputs. To estimate annual costs, EPA annualizes capital costs over 15 years (EQIP practice life), assuming no annual O&M costs.

Unit cost estimates for barnyard runoff controls reflect three data sources:

- VA NRCS (2011) – provides estimates for typical project sizes based on average unit costs for various system components.
- MDA (2012) – estimates unit costs a single system based on past experience.
- DE CIW (2010) – provides unit costs in linear feet and the length (in feet) of an average system.

To develop the conversion factor for converting from dollars per system to dollars per acre, EPA uses values reported in the Delaware and New York WIPs and the corresponding credited acres used as input in the CBWM. For example, the Delaware WIP provides a goal of installing 120 systems by 2025, which corresponds to 181 acres in the CBWM, or an average of 1.5 acres/barnyard runoff control system. For New York, the average is 0.95 acres/structure based on information in the WIP that 1,000 dairy farms would install barnyard runoff, corresponding to 948 acres in the CBWM. The average value for the two states is 1.23 acres per structure.

Capture and Reuse

Capture and reuse entails the use of lined return ditches or other collections methods to lined holding ponds that retain excess irrigation water runoff and capturing stormwater runoff. Water can then be recirculated for irrigation on other vegetation capable of trapping nutrients.

EPA estimates costs for capture and reuse based on MDA (2012) and annualizes the costs over the useful life of the equipment (10 years).

Carbon Sequestration and Alternative Crops

Carbon sequestration and alternative crops involve the conversion of cropland to hay land (warm season grasses) in which the hay land is managed as permanent, providing a mechanism for sequestering carbon within the soil.

Turhollow (2000) provides estimates of potential unit costs for carbon sequestration as described in EPA's 2003 Use Attainability Analysis (UAA) document. The costs include establishment, maintenance, harvest, transportation, and installation based on an average yield rate of five tons per acre per year. EPA (2003) estimates a potential for revenue from annual sale of biomass as a fuel source for a co-fired coal and biomass generator, value of CO_2 credits for replacing fossil fuel with biomass fuel, and value of CO_2 credits for additional soil carbon sequestration to range from $229/acre to $261/acre. Unit costs minus installation are approximately $260/acre. Because this is not a contractual BMP, there is no reason to expect a farmer to incur annual harvest and transportation costs if the fuel sales and CO_2 credits for fuel-switching do not offset annual costs. Therefore, EPA estimates that the maximum cost for this BMP is the installation cost, annualized over 10 years.

Commodity and Small Grains Cover Crops

Commodity and small grains cover crops are cover crops that may be harvested for grain, hay, or silage and receive nutrient applications after March 1 of the spring following establishment. The difference in costs from traditional cover crops is the additional revenue farmers may receive from harvesting the crops. Due to a lack of revenue data on harvested crop values for these types of crops, EPA uses the average of the cost share payments from the Delaware and Virginia EQIP programs as an estimate of the average annual unit cost for commodity cover crops.

Conservation Plans

Conservation plans consist of a combination of agronomic, management and engineered practices that protect and improve soil productivity and water quality, and prevent deterioration of natural resources on all or part of a farm. Plans may be prepared by staff working in conservation districts, natural resource conservation field offices, or a certified private consultant. In all cases the plan must meet technical standards. Note, that implementation of conservation plans may include a number of various BMPs, the combination of which is likely to be farm-specific.

Most of the WIPs refer to conservation plans as Soil Conservation and Water Quality Plans. EPA estimates unit costs for all jurisdictions based on an estimate from the Maryland Phase I WIP by dividing total estimated costs by estimated acres of implementation (MDE, 2010). To estimate annual costs, EPA annualizes the per acre cost over 10 years (useful life of plan).

Conservation Tillage

Conservation tillage involves planting and growing crops with minimal disturbance of the surface soil. Conservation tillage requires two components: (a) a minimum 30% residue coverage at the time of planting and (b) a non-inversion tillage method. No-till farming is a form of conservation tillage in which the crop is seeded directly into vegetative cover or crop residue with little disturbance of the surface soil. Minimum tillage farming involves some disturbance of the soil, but uses tillage equipment that leaves much of the vegetation cover or crop residue on the surface.

Boyle (2006) indicates that conservation tillage is profit neutral. Thus EPA set costs equal to zero.

Continuous No-Till

Continuous no-till farming consists of crop planting and management practices in which soil disturbance by plows, disk, or other tillage equipment is eliminated. Continuous no-till involves no-till methods on all crops in a multi-crop, multi-year rotation.

Boyle (2006) indicates that conservation tillage is profit neutral. Thus EPA set costs equal to zero.

Cover Crops

Cover crops involve the planting and growing of cereal crops (non-harvested) with minimal disturbance of the surface soil. Different species are accepted for credit as well as, different times of planting (early, late, and standard), and fertilizer application restrictions. The estimated unit costs for various combinations of planting times (early, late, and standard), planting methods (drilled, aerial, and other), and crop types (rye, rye on soy, rye on corn, barley, barley on soy, barley on corn, wheat, wheat on soy, and wheat on corn).

EPA develops jurisdiction-specific estimates based on EQIP program costs for various cover crops and planting seasons. Based on information in Weiland et al. (2009), EPA assumes that the opportunity cost of the land used in this practice to be zero since cover crops are typically planted on land that would have otherwise lain fallow.

Cropland Irrigation Management

Cropland irrigation management is a practice that decreases climatic variability and maximizes crop yields. The potential nutrient reduction benefit stems not from the increased average yield (20-25%) of irrigated versus non-irrigated cropland, but from the greater consistency of crop yields over time matched to nutrient applications. This increased consistency in crop yields provides a subsequent increased consistency in plant nutrient uptakes over time matched to applications, resulting in a decrease in potential environmental nutrient losses.

To estimate unit costs, EPA relies on EQIP payment information on irrigation water plans in Delaware, Pennsylvania, and Virginia, as well as the Maryland Phase I WIP, which provided estimates of total costs and practice implementation acres. For the EQIP costs, EPA estimates unit costs annualizing over3 years, and adds annual implementation costs. The Maryland Phase I WIP estimates include a capital component for irrigation equipment. Thus, EPA annualizes the Maryland costs over 15 years (useful life of irrigation equipment).

Dairy Precision Feeding

Dairy precision feeding reduces the quantity of phosphorous and nitrogen fed to livestock by formulating diets within 110% of Nutritional Research Council (NRC) recommended level to minimize the excretion of nutrients without negatively affecting milk production.

A number of studies indicate that dairy precision feeding results in a net cost savings to the farmer from a reduction in feed costs. However, because the CBPO definition indicates that feed levels must be within 110% of NRC recommended levels, EPA only uses data from studies indicating such. For example, Cerosaletti et al. (2004) conducted two different feed experiments, and found cost savings associated with precision feeding of $72 per cow per year and $7.30 per cow per year. However, the first experiment used forages that contained phosphorus levels that were higher than 110% of NRC recommended levels; additional phosphorus reductions would have increased total costs. Thus, EPA only uses the results indicating savings of $7.30 per cow per year.

EPA converts unit costs to AUs assuming 0.74 dairy cows per AU. EPA assumes all unit costs are annual.

Decision Agriculture

Decision agriculture is described as an information and technology based management system that is site specific and uses data on one or more of the following: soils, crops, nutrients, pests, moisture, or yield for optimum profitability, sustainability, and protection of the environment.

Decision agriculture encompasses a broad range of potential activities and can vary based on farm-specific characteristics. EPA uses unit costs of this practice from Pennsylvania EQIP, the Delaware Phase I WIP, and the Maryland Phase II WIP. The Pennsylvania and Delaware estimates are in dollars per acre per year. However, the Maryland estimate is for the capital cost associated with GPS equipment and is annualized over 5 years (useful life of GPS equipment).

Enhanced Nutrient Management

Enhanced nutrient management is nutrient management in which the nutrient management rates of nitrogen application are optimized to minimize excess fertilizer while maintaining crop yields (i.e., set 35% higher than crop needs to ensure nitrogen availability under optimal growing conditions). Farmers may receive an incentive and/or crop insurance payment to cover the risk of yield loss. However, given the potential economic benefit to the farmer and practice's increased use in the watershed such incentives may not be necessary under the TMDL. MDA (2012) estimates enhanced nutrient management costs of $10 per acres. Because nutrient management plans typically last for 3 years, EPA annualizes costs over 3 years to estimate annual costs. Total enhanced nutrient management costs represent the cost of a regular nutrient management plan plus the additional payments associated with the practice.

Forest Buffers

Forest buffers are linear wooded areas along rivers, stream, and shorelines. The recommended buffer width for riparian forest buffers (agriculture) is 100 feet, with a 35-foot minimum width required. Upfront installation costs associated with forest buffers typically include site preparation, tree planting and replacement planting, tree shelters, initial grass buffer for immediate soil protection, mowing (during the first 3 years), and herbicide application (during the first three years).

EPA develops jurisdiction-specific unit costs based on EQIP data from Maryland, New York, and Pennsylvania; two studies described in EPA's 2003 UAA document (Hairston-Strang, 2002; and MDA, 2002); average installation and land rental costs from the Delaware Phase I WIP (DE CIW, 2010); and average total installation costs across various individual projects reported in the Virginia BMP and CREP Query Tool. To estimate total annual costs, EPA annualizes upfront installation costs at over 75 years (useful life of buffers based on MD DNR, 1996), and adds annual opportunity/land rental costs to account for land taken out of production. For sources that do not include estimates of opportunity costs, EPA uses the average annual opportunity/land rental costs from sources that provide such information.

Grass Buffers

Grass buffers are linear strips of grass or other non-woody vegetation maintained between the edge of fields and streams, rivers, or tidal waters that help filter nutrients, sediment, and other pollutant from runoff. The recommended buffer width for riparian grass buffers (agriculture) is

100 feet, with a required minimum of 35 feet. Upfront installation costs associated with grass buffers typically include seed, fertilizer and lime, and labor and equipment associated with seed and fertilizer application.

EPA develops jurisdiction-specific unit costs based on EQIP data from Maryland, New York, Pennsylvania, Virginia, and West Virginia and average installation and land rental costs from the Delaware Phase I WIP (DE CIW, 2010). To estimate total annual costs, EPA annualizes upfront installation costs over 10 years (useful life of buffers based on MD DNR, 1996) and added annual opportunity/land rental costs to account for land taken out of production. For sources that do not include estimates of opportunity costs, EPA uses the average annual costs from those sources.

Horse Pasture Management

Horse pasture management involves stabilizing overused small pasture containment areas (animal concentration area) adjacent to animal shelters or farmstead. Simpson and Weammert (2009) indicate that horse pasture management involves maintaining a 50% pasture cover with managed species and managing high traffic areas. They also specify that animal trails and walkways and heavy use protection must be implemented in combination with either pasture and hayland planting or prescribed grazing.

To estimate average costs for this BMP, EPA uses information from VA NRCS (2011) and New York's Phase I WIP (NYSDEC, 2010). VA NRCS (2011) provides information on average installation size and unit costs for each component (animal trails and walkways, heavy use protection, pasture and hayland planting, and prescribed grazing) and estimated costs for various combinations of control scenarios:

- Animal trails and walkways with pasture and hayland planting
- Animal trails and walkways with prescribed grazing
- Heavy use protection with pasture and hayland planting
- Heavy use protection with prescribed grazing.

EPA estimates the average total cost across the scenarios, and annualizes over the estimated useful life (15 years) to estimate annual costs. EPA converts unit costs in dollars per system per year to dollars per acre per year using a typical pasture size in VA of 120 acres.

NYSDEC (2010) reports capital unit costs in dollars per acre and O&M costs in dollars per acre per year. To estimate annual costs, EPA annualizes capital over 15 years, and adds O&M.

Land Retirement

Land retirement is a practice that takes marginal and highly erosive cropland out of production by planting permanent vegetative cover such as shrubs, grasses, and/or trees.

Unit costs for land retirement represent the cost of planting the permanent cover as well as opportunity costs associated with taking land out of production. Note that farmers could also allow native cover to regrow but this could take several years and, thus, delay benefits of taking the land out of production. Thus, EPA assumes that costs include planting of permanent cover.

The Maryland Phase I WIP (MDE, 2010) contains estimates of total costs and total acres in which the state plans to implement land retirement. EPA estimates unit costs for all jurisdictions by dividing total costs by implementation acres. EPA assumes that the estimated cost includes opportunity/land rental costs associated with taking land out of production because the unit cost is slightly higher than the estimated unit costs for grass buffer, which also include opportunity costs. EPA annualizes the costs over 10 years (the length of a typical land retirement contract; other assumptions may be more appropriate under a regulatory framework).

Liquid Manure Injection

Manure injection is the subsurface application of manure from cattle, swine, or poultry. This practice reduces nutrient losses for both surface runoff and ammonia emissions. However, this practice is not appropriate for tillage incorporation or other post surface application incorporation methods.

Cost data are limited for this practice. EPA uses EQIP payment information on waste utilization injection in Maryland to estimate potential unit costs.

Loafing Lot Management

Loafing lot management is the stabilization of areas frequently and intensively used by people, animals, or vehicles by establishing vegetative cover, surfacing with suitable materials, and/or installing needed structures. This BMP does not include poultry pad installation.

EPA estimates unit costs based on data from the Virginia BMP and CREP Query Tool (VA DCR, 2011b), which provides data on total project costs and the number of acres of BMP installed from which to calculate unit costs for each project and average unit costs across all projects. EPA annualizes project costs over 10 years (life of project specified in the query tool).

Manure Transport

Manure transport is a practice in which manure is transported by truck from the county of origin to another or out of the watershed. Manure transported to another county in the watershed results in increased manure mass in the receiving county.

Unit costs vary based on the amount of manure transported and the travel distance (e.g., trucking and fuel costs). EPA uses estimates of average unit costs for system types (e.g., lagoon, slurry, and dry) and hauling methods (USDA, 2003). EPA escalates costs based on the change in price of diesel gas ($1.42/gal in 2003 to $3.89/gal in 2011) using the Retail On-Highway Diesel Price Index compiled by the Bureau of Transportation Statistics. For transport of manure within the watershed, EPA assumes a travel distance of 5.5 miles, and for transport outside of the watershed EPA assumes a travel distance of 40 miles. The units are in dollars per wet ton per year.

Mortality Composting

Mortality composting involves a physical structure and process for disposing of dead livestock. Farmers combine the composted material with poultry litter and land apply the materials based on nutrient management plan recommendations.

All unit costs are based on EQIP payment schedules from Pennsylvania, New York, Virginia, and West Virginia. EPA converts unit costs from EQIP in dollars per square feet of capacity into dollars per AU based on mortality rates for each animal type (e.g., 0.75% for dairy cow, 5% for layers, 14% for broilers and turkeys, 3% for nursery pigs, and 3.5% for breeding pigs), a depth of 5 feet (U.S. EPA, 2001), specific animal weights (e.g., 1400 lbs for dairy, 2 lbs for layers, 4 lbs for broilers, 15 lbs for turkeys, 40 lbs for nursery pigs, and 160 lbs for breeding pigs), and dead animal volume per pound (e.g., 20 ft^3/lb for dairy, 2 ft^3/lb for poultry, and 10 ft^3/lb for swine). EPA annualizes capital costs over 10 years.

Non-urban Stream Restoration

Non-urban stream restoration involves collection of site-specific engineering techniques used to stabilize an eroding streambank and channel. These are areas not associated with animal entry.

Jurisdiction-specific costs for Pennsylvania and West Virginia reflect unit costs from EQIP programs and estimate for Maryland are from the state's Phase I WIP, calculated by dividing total estimated costs by estimated acres of implementation (MDE, 2010). Costs for the remaining jurisdictions represent the average of the above estimates. To estimate annual per feet costs, EPA annualizes total project costs over 20 years.

Nutrient Management

Nutrient management consists of a comprehensive plan that describes the optimum use of nutrients to minimize nutrient loss while maintaining yield. A nutrient management plan details the type, rate, timing, and placement of nutrients for each crop, as determined through soil, plant tissue, manure, and/or sludge testing to assure optimal application rates.

EPA develops jurisdiction-specific nutrient management costs based on EQIP unit costs for plan development and implementation from all six Bay states. Where necessary, EPA annualizes costs over 3 years (life of plan; retesting is necessary to ensure proper nutrient management approximately every 3 years) to obtain annual unit costs. To account for potential cost savings resulting from decreased fertilizer use, EPA subtracts estimates from VA SWCD (2008).

Phytase

Phytase is an enzyme added to poultry-feed that helps poultry absorb phosphorus. The addition of phytase to poultry feed allows for more efficient nutrient uptake by poultry, which in turn allows decreased phosphorus levels in feed and less overall phosphorus in poultry waste.

EPA bases unit costs on a study by Baker and Augspurger (2007) which reports costs in dollar per ton of feed and a report from the Chesapeake Bay Commission (2004) that provides annual costs in dollar per animal unit. To convert to dollars per AU, EPA assumed 0.00516 ton of feed per poultry lifetime (Angle, 2004) and 0.34 ton of feed per swine lifetime (Walker, 1992) and that the average broiler lifetime is 7 weeks (Jacob and Mather, 1998) and the average swine lifetime is 24 weeks from farrow to finisher (USDA, 2009).

Precision Intensive Rotational Grazing

Precision intensive rotational grazing is a practice that utilizes more intensive forms of pasture management and grazing techniques to improve the quality and quantity of the forages grown on pastures and reduce the impact of animal travel lanes, animal concentration areas, or other degraded areas of the upland pastures. This practice can be applied to pastures intersected by streams or upland pastures outside of the degraded stream corridor (35 feet width from top of bank). It also requires intensive management of livestock rotation, also known as Managed Intensive Grazing systems (MIG), that have very short rotation schedules.

Unit costs for this practice represent the average of EQIP costs from Delaware, Maryland, and West Virginia.

Prescribed Grazing

Prescribed grazing is a practice that utilizes a range of pasture management and grazing techniques to improve the quality and quantity of the forages grown on pastures and reduces the impact of animal travel lanes, animal concentration areas, or other degraded areas. Prescribed grazing can be applied to pastures intersected by streams or upland pastures outside of the degraded stream corridor (35 feet width from top of bank).

Unit costs represent the average of EQIP costs from all six Bay states. To annualize costs, EPA assumes that planning occurs over a 3 year period.

Tree Planting

Tree planting involves planting any tree, except those used to establish riparian forest buffers, that target highly erodible areas or those identified as critical resource areas.

Costs for Delaware, Pennsylvania, Virginia, and West Virginia are based on unit costs from state EQIP programs. Where EQIP costs are given in units of dollar per tree or seedling, EPA assumes that farmers would plant approximately 200 trees per acres to convert all costs into units of dollars per acre. To convert costs to an annual basis, EPA annualizes total per acre costs over 75 years (useful life of trees based on MD DNR, 1996) and adds an opportunity cost associated with taking land out of production.

For Maryland, the tree planting BMP in the watershed model represents vegetative environmental buffers on poultry operations. EPA annualizes practice costs over 10 years and does not include the estimate in the average calculation for states without EQIP estimates as described above.

Water Control Structures

Water control structures involve installing and managing boarded gate systems in agricultural land that contains surface drainage ditches.

EPA develops unit costs for all jurisdictions based on typical project sizes and average unit costs in Virginia (VA NRCS, 2011). Total annual costs represent upfront installation costs annualized over 10 years (typical EQIP practice life). To develop the conversion factor to convert from dollars per system to dollars per acre, EPA uses MDA (2012) estimate of 29 acres per water control structure.

Wetland Restoration

Wetland restoration involves activities that reestablish the natural hydraulic condition in a field that existed prior to the installation of subsurface or surface drainage. Projects may include restoration, creation, and enhancement acreage.

EPA develops unit costs for Maryland and Pennsylvania based on costs from EQIP programs and unit costs for New York based on the state's Phase I WIP (NYSDEC, 2010). Costs for the remaining states represent the average of the above three estimates. Total annual costs represent upfront installation costs annualized over 15 years (typical EQIP practice life) plus annual opportunity costs (based on state land rental payments for the practice).

Resource Practices

Exhibit 2 summarizes the unit cost of the four principal BMPs that address the resource practices source category. The practices are described below.

Exhibit 2: Unit Costs for Resource Practices (2010$)

BMP	Average Annual Unit Costs								Units
	Average	DC	DE	MD	NY	PA	VA	WV	
Abandoned Mine Reclamation	$615	NA	NA	NA	NA	$615	NA	NA	$/acre/yr
Forest Harvesting	$64	NA	NA	NA	NA	$97	$31	NA	$/acre/yr
Extractive Erosion and Sediment Control	$145	NA	NA	NA	NA	NA	NA	NA	$/acre/yr
Road Erosion and Sediment Control	$1	NA	NA	NA	NA	$1	NA	NA	$/feet/yr
NA = Not available.									

Abandoned Mine Reclamation

Abandoned mine reclamation stabilizes the soil on lands mined for coal or affected by mining, such as wastebanks, coal processing, or other coal mining processes. The practice affects the distribution of pervious and impervious areas modeled (USEPA, 2010).

EPA derives unit costs for this practice based on Pennsylvania Department of Environmental Protection (PADEP, 2004), which provides capital and O&M unit costs on a per acre basis, and annualizes capital costs over a 20-year useful life.

Dirt and Gravel Road Erosion and Sediment Control

Dirt and gravel roads, such as roads that provide access to sites used for logging or other resource practices activity, are an important source of sediment to the Bay. This is because unimproved roads often lack stormwater management controls to minimize erosion impacts to local streams during severe rainfall events, resulting in fully erosion and high sediment loads to streams. Such roads are particularly prevalent in rural areas of the Ridge & Valley, Piedmont, and Allegheny Plateau (CBP, 2011).

The CBWM provides credits for measures aimed at reducing the amount of sediment runoff from dirt and gravel roads through the use of driving surface aggregates (DSA), berm removal, additional drainage outlets, raising the road profile, and grade breaks. The model defines three specific practices (Scheetz and Bloser, 2008):

- *Driving Surface Aggregate and Raising the Roadbed*, which involves using durable and erosion resistant road surface[1] and raising the road elevation to restore natural drainage patterns;
- *Driving Surface Aggregate and Raising the Roadbed, with Outlets*, which involves, in addition to the measures above, creating new outlets in ditch to reduce channelized flow reaching a stream[2]; and
- *Outlets only*, which involves adding drainage outlets alone, without changes to the driving surface or regarding of the roadbed.

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[1] The durability comes from using an aggregate distribution that is specifically designed for use as road surface. In addition to being less susceptible to erosion and associate pollutant runoff, the use of this mixture reduces long-term maintenance costs.

[2] Installing additional drainage outlets reduces concentrated flow, peak flow discharges and sediment transport and delivery from unpaved roads and ditches into streams, and can increase infiltration (Klimkos and Scheetz, 2009).

PADEP (2004) provide a general cost estimate for erosion and sediment control. For this analysis, EPA assumes that the capital costs of all three sub-practices listed above are the same: $10.39 per linear foot (in 2010 dollars) and annualizes these costs over 20 years.

Extractive Erosion and Sediment Control

Extractive erosion and sediment control measures are implemented mainly on mining lands. This practice is not defined in the most recent documentation for the CBWM, but may include activities such as regrading mine spoils/highwalls or revegetation. For this analysis, EPA estimates control costs based on EPA's BMP guidance manual for coal remining (USEPA, 2000), annualizing over 10 years (the assumed average life of a mine), updating to 2010 dollars using the CPI.

Forest Harvesting Practices

Commercial tree harvest operations disturb ground cover, expose mineral soil, and open the forest floor to rainfall.

The CBWM provides credits for measures aimed at reducing sediment and nutrient pollution to water bodies originating from forest harvesting activities at managed levels. The model defines forest harvesting practices as a suite of BMPs that minimize the environmental impacts of road building, log removal, site preparation and forest management.

EPA uses unit costs for these practices from PADEP (2004) and Weiland et al. (2009). Costs presented in Weiland et al. (2009) are based on forest harvesting practices implemented in Virginia and represent the average of coastal and Piedmont unit costs. EPA escalates the costs from the 2004 and 2007 dollars used in the two sources, respectively, to 2010 dollars using the CPI. Costs for other jurisdictions in the Bay represent the average of the two states.

Urban Stormwater

Impervious surfaces in urban areas, like roads, rooftops, and parking lots, channel stormwater runoff directly to streams, tributaries and to the Bay by preventing infiltration into the ground. This runoff carries with it heavy loads of nutrients and sediments. Runoff from developed land (urban and suburban) was responsible for approximately 8% of the total nitrogen, 14.5% of the total phosphorus and 15.9% of the total sediment load into the Bay in 2009 (NAS, 2011).

The TMDL seeks to cap total nitrogen loads from urban runoff to 15.6 million pounds, total phosphorus to 1.7 million pounds, and total sediment to 798 million pounds per year.

To achieve this goal, Bay jurisdictions have developed strategies that include measures aimed at reducing the amount of pollutants carried with the runoff (e.g., reduction in fertilizer application), measures aimed at reducing or controlling the runoff (e.g., use of bioretention, impervious surface reduction, and wet ponds), and measures aimed at improving the natural filtering capacity of tributaries in urban areas (e.g., stream restoration).

EPA uses unit costs for most urban stormwater practices from the Center for Watershed Protection (CWP, 2007) and EPA updates construction costs using the ENR construction cost index (CCI; 2006 = 7751, 2010 = 8802). The costs include the capital costs for construction, design and engineering costs (calculated as a percent of construction costs), costs for ongoing operation and maintenance (typically calculated as a percent of construction costs), and land opportunity costs, where applicable. The costs represent dollars per impervious acre of land treated. Because the acre basis used to specify the level of implementation in the Phase II WIPs is either the acres covered by the control or the total acres treated (e.g., acres over which forest buffers are installed or acres of turf with reduced fertilizer),[3] EPA uses conversion factors provided in King and Hagan (2011) (e.g., 3.7 acres of urban grass buffer treat 1 impervious acres of land). To convert impervious acres treated to total acres treated, EPA multiplies the unit costs by the percent of impervious urban land in each jurisdiction, based on land use acres from the 2010 No Action Phase 5.3 model run (shown in **Exhibit**3).

Exhibit 3: Percent Impervious Urban Land in Bay Jurisdictions

Jurisdiction	Percent of Urban Land that is Impervious
Total Watershed	25.9%
District of Columbia	51.3%
Delaware	24.3%
Maryland	25.3%
New York	27.0%
Pennsylvania	25.4%
Virginia	26.2%
West Virginia	25.3%

EPA annualizes upfront capital costs (construction and design and engineering) over the estimated useful life of each practice, using a 5% discount rate. EPA uses this same 5% discount rate to annualize land opportunity costs, but treating land as an asset without a finite life (i.e., perpetuity). For the analysis discussed below, EPA assumes default land costs of $100,000 per impervious acre. EPA calculates annual unit cost per impervious acre of each control by summing the annualized capital and land opportunity costs and the O&M costs, and then converts to dollars per acres treated or BMP installed as described above.

Exhibit4 summarizes available costs for the urban stormwater management practices credited to the Bay jurisdictions. The following sections describe the derivation of unit costs for each practice.

[3] See uncertainty section for a discussion of the basis assumed for acres

Exhibit 4: Summary of Annual Unit Costs for Urban Stormwater Controls (2010$)[1]

Chesapeake Bay WIP Practices	Annual Unit Costs							Units
	Average	DC	DE	MD	NY	PA	VA	WV	
New/Redevelopment									
Bioretention	$875	$1,733	$822	$856	$913	$858	$884	$854	$/acre treated/yr
Bioswale	$704	$1,395	$662	$689	$735	$690	$712	$688	$/acre treated/yr
Dry Detention and Extended Detention Basins	$196	$387	$184	$191	$204	$192	$198	$191	$/acre treated/yr
Dry Detention Ponds/Hydrodynamic Structures	$775	$1,535	$728	$759	$809	$760	$783	$757	$/acre treated/yr
Erosion and Sediment Control	$540	$1,070	$508	$529	$564	$530	$546	$527	$/acre treated/yr
Urban Tree Planting	$65	NA	$12	$85	NA	$108	$53	$70	$/acre treated/yr
Urban Filtering Practices	$2,371	$4,697	$2,228	$2,321	$2,475	$2,325	$2,397	$2,315	$/acre treated/yr
Urban Infiltration Practices	$865	$1,713	$812	$846	$902	$848	$874	$844	$/acre treated/yr
Vegetated Open Channels	$835	$1,654	$785	$818	$872	$819	$844	$815	$/acre treated/yr
Wetlands and Wet Ponds	$201	$398	$189	$197	$210	$197	$203	$196	$/acre treated/yr
SWM by Era	$0	NA	NA	$1,547	NA	NA	NA	NA	$/acre treated/yr
Retrofit of Existing Development									
Bioretention	$1,286	$2,548	$1,209	$1,259	$1,342	$1,261	$1,300	$1,256	$/acre treated/yr
Bioswale	$1,062	$2,104	$998	$1,040	$1,109	$1,041	$1,074	$1,037	$/acre treated/yr
Dry Detention and Extended Detention Basins	$503	$997	$473	$493	$525	$494	$509	$491	$/acre treated/yr

Exhibit 4: Summary of Annual Unit Costs for Urban Stormwater Controls (2010$)[1]

Chesapeake Bay WIP Practices	Annual Unit Costs								Units
	Average	DC	DE	MD	NY	PA	VA	WV	
Dry Detention Ponds/Hydrodynamic Structures	$775	$1,535	$728	$759	$809	$760	$783	$757	$/acre treated/yr
Impervious Surface Reduction	$14,214	$14,214	$14,214	$14,214	$14,214	$14,214	$14,214	$14,214	$/acre installed/yr
Retrofit Stormwater Management	$1,000	NA	NA	$1,000	NA	NA	NA	NA	$/acre treated/yr
Urban Tree Planting	$65	NA	$12	$85	NA	$108	$53	$70	$/acre installed/yr
Urban Filtering Practices	$2,371	$4,697	$2,228	$2,321	$2,475	$2,325	$2,397	$2,315	$/acre treated/yr
Urban Forest Buffers	$86	NA	$27	$92	$121	$153	$35	NA	$/acre installed/yr
Urban Grass Buffers	$47	NA	$39	$56	$36	$68	$45	$37	$/acre installed/yr
Urban Infiltration Practices	$1,366	$2,705	$1,283	$1,337	$1,425	$1,339	$1,381	$1,333	$/acre treated/yr
Vegetated Open Channels	$835	$1,654	$785	$818	$872	$819	$844	$815	$/acre/yr
Wetlands and Wet Ponds	$473	$937	$444	$463	$494	$464	$478	$462	$/acre treated/yr
Other[2]									
CSO Separation	$16,703	$16,703	NA	NA	NA	NA	NA	NA	$/acre/yr
Forest Conservation	$0	$0	$0	$0	$0	$0	$0	$0	$/acre installed/yr
Street Sweeping	$916	NA	NA	NA	NA	NA	NA	NA	$/acre installed/yr

Exhibit 4: Summary of Annual Unit Costs for Urban Stormwater Controls (2010$)[1]

Chesapeake Bay WIP Practices	Annual Unit Costs								Units
	Average	DC	DE	MD	NY	PA	VA	WV	
Urban Nutrient Management	$19	NA	NA	NA	NA	NA	NA	NA	$/acre installed/yr
Urban Stream Restoration	$60	NA	NA	NA	NA	NA	NA	NA	$/feet installed/yr

1. Capital and land opportunity costs annualized at 5%.
2. Not applicable to new development/redevelopment, or no differentiation in unit costs between new development/redevelopment available.

Bioretention

Bioretention involves an excavated pit backfilled with engineered media, topsoil, mulch, and vegetation. These practices are planting areas installed in shallow basins in which the storm water runoff is temporarily ponded and then treated by filtering through the bed components, and through biological and biochemical reactions within the soil matrix and around the root zones of the plants.

The watershed model inputs are in units of the acres treated per year. EPA uses unit costs for bioretention from the CWP (2007), who estimated average costs for new installations and retrofits in dollars per acre of impervious surface treated by the control per year. EPA annualizes construction costs over 25 years. EPA calculates average annual O&M costs as 2.5% of new installation capital costs (EPA, 2011). EPA includes opportunity cost for land assuming that the planted area occupies 6% of the impervious acres treated by the control, of which 50% are developable (King and Hagan, 2011).

Since this practice is designed to treat total runoff from a site, however, EPA converts the total annual unit costs on a per impervious acre basis into costs per total acres treated using the average fraction of impervious acres within the urban land uses in each jurisdiction, as described above.

Bioswale

Bioswales typically consist of a swaled drainage course with gently sloped sides that are filled with vegetation, compost, and/or riprap. With a bioswale, the load is reduced because, unlike other open channel designs, there is treatment through the soil. A bioswale is designed to function as a bioretention area.

The watershed model inputs are in units of the acres treated per year. EPA uses unit costs for bioswales from the CWP (2007), who estimated average costs for new installations and retrofits in dollars per acre of impervious surface treated by the control per year. EPA annualizes construction costs over 50 years (EPA, 2005). EPA calculates average annual O&M costs as 6% of new installation capital costs (EPA, 2011).EPA includes opportunity cost for land assuming that the planted area occupies 4% of the impervious acres treated by the control, of which 50% are developable (King and Hagan, 2011).

Since this practice is designed to treat total runoff from a site, however, EPA converts the total annual unit costs on a per impervious acre basis into costs per total acres treated using the average fraction of impervious acres within the urban land uses in each jurisdiction, as described above.

CSO Separation

CSO separation involves disconnecting the storm drain and overflow from the sanitary sewer system. Unit costs are based on estimates from the CSO long-term control plan for the District of Columbia.

Dry Extended Detention Ponds

Dry extended detention ponds are similar to dry detention ponds but are designed to detain stormwater for a longer period of time, thereby improving treatment effectiveness.

EPA uses unit costs from CWP (2007) expressed in dollars per impervious acres treated, and annualizes over the estimated 50-year life of the control (USEPA, 2005) EPA calculates annual O&M costs as 5% of capital costs (King and Hagan, 2011). EPA calculates land opportunity costs based on the fraction of impervious land occupied by the pond (10%), and the fraction developable (50%; King and Hagan, 2011).

Finally, EPA converts the unit costs on a per impervious acre basis into costs per total acres treated using the average fraction of impervious acres within the urban land uses in each jurisdiction, as described above.

Dry Detention Ponds and Hydrodynamic Structures

Dry detention basins are depressions or basins created by excavation or berm construction that temporarily store runoff and release it slowly via surface flow or groundwater infiltration following storms and that are designed to dry out between storm events. The basins do not typically contain vegetation like bioretention and bioswales. Hydrodynamic structures are devices designed to improve quality of stormwater using features such as swirl concentrators, grit chambers, oil barriers, baffles, micropools, and absorbent pads that are designed to remove sediments, nutrients, metals, organic chemicals, or oil and grease from urban runoff (USEPA, 2010).

EPA uses estimated unit costs of the two BMPs from King and Hagan (2011) expressed on a per impervious acre basis. The estimates are based on the average of costs reported separately for dry detention ponds and hydrodynamic structures. EPA annualizes the pre-construction and construction costs over 50 years. EPA estimates annual O&M costs as the average of the two practices, based on 2% of new installation capital costs (EPA, 2011). EPA calculates the land opportunity costs assuming that the control occupies 10% of the impervious land area treated, of which 50% is developable (King and Hagan, 2011).

Finally, EPA converts the unit costs on a per impervious acre basis into costs per total acres treated using the average fraction of impervious acres within the urban land uses in each jurisdiction, as described above.

Erosion and Sediment Control

Erosion and sediment control practices are measures to protect water resources from sediment pollution and increases in runoff associated with land development activities. By retaining soil on-site, sediment and attached nutrients are prevented from leaving disturbed areas and polluting streams (USEPA, 2010).

EPA uses estimated unit costs for this practice from King and Hagan (2011), who estimated average costs based on a typical 14-acre development project involving silt fences, sediment ponds, and related practices. EPA assumes the costs represent the dollar per acre treated. EPA annualizes pre-construction and construction costs over 20 years.

Forest Conservation

Forest conservation currently only applies to Maryland where it represents the implementation of the Maryland Forest Conservation Act that requires developers to maintain at least 20% of a development site in trees (forest condition) (USEPA, 2010).

Because this practice involves keeping existing forests, EPA assumes that it imposes no incremental capital or O&M costs (e.g., any lost development opportunity for this practice is offset by cost savings).

Impervious Urban Surface Reduction

As the name implies, impervious urban surface reduction involves reducing existing impervious area of urban development to facilitate infiltration and reduce stormwater runoff.

EPA uses unit costs of this practice from CWP (2007), annualizing construction costs over the 20-year useful life. EPA calculates land opportunity costs assuming that 50% of acres used for the control are developable (King and Hagan, 2011). EPA then adds the annualized upfront costs to the annual O&M (calculated as 5% of construction costs) to estimate the total annual cost of this practice.

In applying cost estimates provided by CWP (2007), EPA assumes that half of the impervious surface is asphalt and half is concrete. To account for maintenance costs of these surfaces that would occur in the absence of reduction in these impervious surfaces, EPA subtracts half of the estimated asphalt and concrete maintenance costs from the O&M costs associated with impervious surface reduction since there is uncertainty regarding the type of land being replaced with a pervious surface. EPA assumes that concrete surfaces would not need maintenance, but that asphalt surfaces would need re-paving every 12 years at a cost of $2 to $3 per square foot, based on estimates from the City of Rockville (2010) and the Permeable Interlocking Pavement Institute (2012).

Retrofit Stormwater Management

EPA estimates costs of this practice by averaging costs for all practices for which retrofit unit costs are available.

Street Sweeping

In the watershed model, street sweeping includes both street sweeping and storm drain cleanout practices (USEPA, 2010). The model provides credits on for the two sub-practices on the basis of the frequency ("mechanical monthly") or loading reductions ("pounds").

EPA uses costs of this practice from King and Hagan (2011). The costs account for the purchase of street sweepers (average of mechanical and vacuum style equipment). EPA annualizes the capital costs over 20 years. Since the practice applies to impervious acres specifically, EPA does not make any further adjustment.

Urban Tree Planting

Urban tree planting involves planting trees on urban pervious areas at a rate that would produce a forest-like condition over time. The intent of the planting is to eventually convert the urban area to forest. If the trees are planted as part of the urban landscape, with no intention to convert the area to forest, then the planting would not count as urban tree planting (U.S. EPA, 2010).

Since the cost of tree planting is likely to be consistent across agricultural and urban areas, EPA uses jurisdiction-specific unit costs from EQIP. For EQIP costs in units of dollar per tree or seedling, EPA assumes approximately 200 trees per acres to convert to units of dollars per acre. To convert costs to an annual basis, EPA annualizes total per acre costs over 75 years (useful life of trees based on MD DNR, 1996). For this practice, EPA does not account for land costs, since planting trees can often increase the value of property through functional and aesthetic benefits (e.g. Nowak et al., 2002).

Urban Filtering Practices

Urban filtering practices are measures that capture and temporarily store runoff and pass it through a filter bed of either sand or an organic medium. There are various sand filter designs, such as aboveground, belowground, and perimeter designs. An organic media filter uses another medium besides sand to enhance pollutant removal for many compounds because of the increased cation exchange capacity achieved by increasing the organic matter. The systems require yearly inspection and maintenance to receive pollutant reduction credit (U.S. EPA, 2010).

The watershed model includes this control in total acres treated per year. EPA uses unit costs for these practices from the CWP (2007), who estimated average construction costs in terms of dollars per impervious acre filtered per year. EPA annualizes construction costs over 25 years. EPA estimates annual O&M costs as 5% of new installation capital costs. EPA includes opportunity cost for land assuming that the control occupies 5% of the impervious land treated, of which 50% is developable (based on King and Hagan, 2011).

Since this practice is designed to treat total runoff from a site, however, EPA converts the unit costs on a per impervious acre basis into costs per total acres treated (the units in the watershed model) using the average fraction of impervious acres within the urban land uses in each jurisdiction.

Urban Forest Buffers

Urban forest buffers involve planting an area of trees at least 35 feet wide on one side of a stream, usually accompanied by trees, shrubs and other vegetation that is adjacent to a body of water. The riparian area is managed to maintain the integrity of stream channels and shorelines, to reduce the impacts of upland sources of pollution by trapping, filtering, and converting sediments, nutrients, and other chemicals (USEPA, 2010).

EPA assumes that costs associated with establishing forest buffers in urban areas are comparable to those of establishing forest buffers in agricultural areas. EPA develops jurisdiction-specific unit costs based on EQIP data from Maryland, New York, and Pennsylvania; two studies described in EPA's 2003 UAA document (Hairston-Strang, 2002; and MDA, 2002); average installation and land rental costs from the Delaware Phase I WIP (DE CIW, 2010); and average total installation costs across various individual projects reported in the Virginia BMP and CREP Query Tool. To estimate total annual costs, EPA annualizes upfront installation costs over 75 years (useful life of buffers based on MD DNR, 1996). EPA does not adjust for land costs, since buffers are necessarily located adjacent to streams, which are unlikely to be developable due to zoning restrictions.

Urban Growth Reduction

Urban growth reduction is the change from forecast urban land use to non-urban land use (USEPA, 2010). Because this practice involves unknown land use changes in the future, EPA did not estimate incremental costs or benefits as they would be speculative. EPA anticipates that any increase in costs could be offset by cost savings through reduced needs for infrastructure or services.

Urban Infiltration Practices

Urban infiltration practices use a depression to form an infiltration basin where sediment is trapped and water infiltrates the soil. No underdrains are associated with infiltration basins and trenches, because by definition these systems provide complete infiltration. Design specifications require infiltration basins and trenches to be built in good soil; they are not constructed on poor soils, such as C and D soil types. Engineers are required to test the soil before approval to build is issued. To receive credit over the longer term, jurisdictions must conduct yearly inspections to determine if the basin or trench is still infiltrating runoff (USEPA, 2010).

The CBWM differentiates between those BMPs that use sand and/or vegetation and those that do not. BMPs with sand and/or vegetation are assumed to be slightly more effective at removing nitrogen (85% effectiveness vs. 80%).

The watershed model includes this practice in terms of total acres treated. EPA uses unit costs for these practices from the CWP (2007), who estimated average costs for infiltration basin construction in terms of impervious acres treated. EPA annualizes the construction cost over 50 years and adds the annualized value to the average O&M, which EPA estimates as 4% of new installation capital (EPA, 2011). EPA includes opportunity cost for land assuming that the control occupies 10% of the impervious land treated, of which 50% is developable (based on King and Hagan, 2011).

Finally, since this practice is designed to treat total runoff from a site, EPA converts the unit costs on a per impervious acre basis into costs per total acres treated (the units in the watershed model) using the average fraction of impervious acres within the urban land uses in each jurisdiction.

Urban Nutrient Management

Urban nutrient management involves public education (targeting urban/suburban residents and businesses) to encourage reduction of excessive fertilizer use. EPA's Nutrient Subcommittee's Tributary Strategy Workgroup has estimated that urban nutrient management reduces nitrogen loads by 17% and phosphorus loads by 22% (USEPA, 2010).

EPA estimates urban nutrient management costs based on average costs for soil test kits, assuming one test kit per household, and the median lot size for a house of 0.27 acres (according to Census data). To estimate annual costs, EPA annualizes the soil test kit cost over the life of the test results (3 years).

Urban Stream Restoration

This practice involves the restoration of the urban stream ecosystem by restoring the natural hydrology and landscape of a stream, to improve habitat and water quality conditions (USEPA, 2010).

The watershed model includes this practice in terms of linear feet of stream. EPA uses estimates for this practice from King and Hagan (2011), who estimate costs per impervious acre treated. EPA annualizes the pre-construction and construction costs over 20 years. EPA assumes that land opportunity costs are negligible as development is generally not allowed in close proximity to streams.

Since this practice is designed to apply specifically to buffers along urban streams, EPA converts the unit costs (expressed by King and Hagan on a per impervious acre basis) into costs per linear foot of stream restored (the units in the watershed model) assuming that 100 linear feet of restored stream treats 1 acre of impervious area (King and Hagan, 2011).

Vegetated Open Channels

Vegetated open channels are practices that convey stormwater runoff and provide treatment as the water is conveyed. Runoff passes through either vegetation in the channel, subsoil matrix, and/or is infiltrated into the underlying soils.

EPA uses the unit cost of this practice from King and Hagan (2011). EPA annualizes construction and preconstruction (estimated as a percent of construction costs) costs over 20 years. EPA estimates annual O&M costs as 6% of capital costs (EPA, 2011). EPA calculates land opportunity costs assuming that 50% of acres are developable and that 4% of the impervious land area treated by the control would be covered by the channel (King and Hagan, 2011).

Since this practice is designed to treat total runoff from a site, however, EPA converts the total annual unit costs on a per impervious acre basis into costs per total acres treated (the units in the watershed model) using the average fraction of impervious acres within the urban land uses in each jurisdiction, as described above.

Wet Ponds and Wetlands

Wet ponds and wetlands used as a BMP for managing urban stormwater runoff are man-made landscape features that have characteristics and functions similar to their natural counterparts. Wet ponds are depressions or basins created by excavation or berm construction that receive sufficient water via runoff, precipitation, and groundwater to contain standing water year-round at depths too deep to support rooted emergent or floating-leaved vegetation (in contrast with dry ponds, which dry out between precipitation events). Wetlands, on the other hand, have soils that are saturated with water or flooded with shallow water that support rooted floating or emergent aquatic vegetation (e.g. cattails). Some systems can contain submergent vegetation or emergent vegetation along the shorelines, blurring the distinction between the two (USEPA, 2010).

EPA uses unit costs for these controls from the CWP (2007), who estimated average costs for new installations and retrofits in dollars per impervious acre treated. EPA annualizes construction costs over 50 years (EPA, 2005) and calculates average annual O&M costs as 5% of new installation capital costs (EPA, 1999). EPA includes opportunity cost for land assuming that the control occupies 4% of the impervious land treated by the control, of which 50% are developable (King and Hagan, 2011). .

Since this practice is designed to treat total runoff from a site, however, EPA converts the total annual unit costs on a per impervious acre basis into costs per total acres treated (the units in the watershed model) using the average fraction of impervious acres within the urban land uses in each jurisdiction, as described above.

SWM by Era

Stormwater management by era accounts for underreporting of current progress in implementing urban controls in Maryland. Rather than reporting progress for individual urban practices, the jurisdiction defined stormwater management eras and estimated acreage controlled in each era. In the watershed model, each era is associated with a pollutant loading reduction efficiency for TN, TP, and sediment based on regulatory requirements during the period. To estimate unit costs for these controls, EPA uses the average unit cost of all controls for which new/redevelopment unit costs are available, and assumes that retrofits are included under the jurisdictions Retrofit Stormwater.

Attachment 5:

U.S. Environmental Protection Agency Approved Cost Efficiencies for

Best Management Practices of Delivered TSS

(Draft – subject to change, do not quote or cite)

			Cost Per Pound Reduced		
Sector	**BMP**	**BMP Short Name**	**Low**	**Mid**	**High**
Ag	Poultry Litter Treatment (alum, for example)	**Alum**	-	-	-
Ag	Animal Waste Management System	**AWMS**	-	-	-
Ag	Barnyard Runoff Control	**BarnRunoffCont**	$0.41	$0.77	$5.48
Ag	Irrigation Water Capture Reuse	**CaptureReuse**	-	-	-
Ag	Alternative Crops	**CarSeqAltCrop**	$0.06	$0.09	$0.20
Ag	Heavy Use Poultry Area Concrete Pads	**ConcretePads**	$3.37	$11.67	$29.17
Ag	Soil Conservation and Water Quality Plans	**ConPlan**	$0.52	$1.88	$6.43
Ag	Conservation Tillage - Total Acres	**ConserveTollTotAcres**	$0.10	$0.88	$2.88
Ag	Cover Crop Standard Drilled Wheat	**CoverCropSDW**	$0.79	$16.81	-
Ag	Cropland Irrigation Management	**Cropirrmgmt**	-	-	-
Ag	Decision Agriculture	**DecisionAg**	$3.43	$6.86	$13.71
Ag	Sorbing Materials in Ag Ditches	**DitchFilter**	-	-	-
Ag	Enhanced Nutrient Management	**EnhancedNM**	$2.50	$5.00	$10.00
Ag	Forest Buffers	**ForestBuffers**	$0.16	$0.78	$2.65
Ag	Grass Buffers; Vegetated Open Channel - Agriculture	**GrassBuffers**	$0.25	$0.97	$1.56
Ag	Horse Pasture Management	**HorsePasMan**	$3.28	$46.15	$600.00
Ag	Land Retirement to hay without nutrients (HEL)	**LandRetireHyo**	$0.23	$0.73	$3.52
Ag	Land Retirement to pasture (HEL)	**LandRetirePas**	$0.10	$0.38	$1.13
Ag	Dairy Manure Incorporation	**LiquidInjection**	-	-	-
Ag	Loafing Lot Management	**LoafLot**	$1.13	$6.72	$91.55
Ag	Mortality Composters	**MortalityComp**	-	-	-
Ag	Non Urban Stream Restoration; Shoreline Erosion Control	**NonUrbStrmRest**	$3.34	$5.15	$5.31

Attachment 5:

U.S. Environmental Protection Agency Approved Cost Efficiencies for

Best Management Practices of Delivered TSS (continued)

(Draft – subject to change, do not quote or cite)

			Cost per Pound Reduced		
Sector	**BMP**	**BMP Short Name**	**Low**	**Mid**	**High**
Ag	Nutrient Management	**NutMan**	$1.75	$3.50	$7.00
Ag	Off Stream Watering Without Fencing	**OSWnoFence**	$1.84	$5.90	$27.56
Ag	Stream Access Control with Fencing	**PastFence**	$0.02	$0.06	$0.46
Ag	Poultry Litter Incorporation	**PoultryInjection**	-	-	-
Ag	Poultry Phytase	**PoultryPhytase**	-	-	-
Ag	Prescribed Grazing	**PrecRotGrazing**	$2.09	$11.76	$85.71
Ag	Tree Planting; Vegetative Environmental Buffers — Poultry	**TreePlant**	$0.27	$2.05	$16.38
Ag	Precision Intensive Rotational Grazing	**UpPrecIntRotGraze**	$3.37	$7.32	$28.57
Ag	Water Control Structures	**WaterContStruc**	-	-	-
Ag	Wetland Restoration	**WetlandRestore**	$0.61	$1.66	$2.82
Manure	Manure Transport	**-**	-	-	-
Forest	Forest Harvesting Practices	**ForHarvestBMP**	$0.08	$0.22	$0.49
WWTP	Set Permitted Load	**WWLoadReduction**	-	-	-
Urban	Abandoned Mine Reclamation	**AbanMineRec**	-	-	-

Attachment 5:

U.S. Environmental Protection Agency Approved Cost Efficiencies for

Best Management Practices of Delivered TSS (continued)

(Draft – subject to change, do not quote or cite)

			Cost per Pound Reduced		
Sector	**BMP**	**BMP Short Name**	**Low**	**Mid**	**High**
Urban	Bioretention/raingardens	**BioRetUDAB**	$2.15	$6.00	$16.72
Urban	Bioswale	**BioSwale**	$1.67	$7.55	$254.05
Urban	Dry Detention Ponds and Hydrodynamic Structures	**DryPonds**	$24.86	$100.08	$1,951.50
Urban	Erosion and Sediment Control	**EandS**	$0.36	$0.84	$2.12
Urban	Erosion and Sediment Control on Extractive, excess applied to all other pervious urban	**EandSext**	$1.20	$3.55	$8.70
Urban	Dry Extended Detention Ponds	**ExtDryPonds**	$2.55	$4.66	$87.44
Urban	Urban Filtering Practices	**Filter**	$3.50	$12.31	$252.63
Urban	Urban Forest Buffers	**ForestBufUrban**	$1.65	$4.22	$9.78
Urban	Forest Conservation	**ForestCon**	-	-	-
Urban	Impervious Urban Surface Reduction	**ImpSurRed**	$4.17	$13.53	$27.69
Urban	Urban Infiltration Practices - no sand\veg no under drain	**Infiltration**	$3.83	$9.60	$75.01
Urban	Urban Infiltration Practices - with sand\veg no under drain	**InfiltWithSV**	$3.19	$11.85	$17.37
Urban	Permeable Pavement w/ Sand, Veg. - A/B soils, underdrain	**PermPavSVUDAB**	$39.35	$73.67	$103.55
Urban	MS4 Permit-Required Stormwater Retrofit	**RetroSWM**	$4.10	$12.80	$256.01
Urban	Street Sweeping 25 times a year-acres (formerly called Street Sweeping Mechanical Monthly)	**StreetSweep**	$6.49	$24.62	$50.02
Urban	Urban Nutrient Management	**UrbanNutMan**	-	-	-
Urban	Urban Tree Planting; Urban Tree Canopy	**UrbanTreePlant**	$13.01	$29.63	$107.80
Urban	Urban Stream Restoration; Shoreline Erosion Control; Regenerative Stormwater Conveyance	**UrbStrmRest**	$13.02	$20.50	$31.64
Urban	Vegetated Open Channel - Urban	**VegOpChanNoUDAB**	$1.78	$4.87	$9.66
Urban	Wet Ponds and Wetlands	**WetPondWetland**	$2.27	$6.08	$130.32

Attachment J-2:
Cost Documentation "Factsheets" and Summary Table of Costs

Lower Susquehanna River Watershed Assessment
Summary of Representative Sediment Management Alternatives

	Innovative Reuse	Open Water Placement			Upland Placement			
	Alternative 1	Alternative 2A	Alternative 2B	Alternative 2C	Alternative 3A	Alternative 3B	Alternative 3C	Alternative 3D
Physical Description								
Sediment to be removed, cubic yards	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Sediment to be removed, tons	810,000	810,000	810,000	810,000	810,000	810,000	810,000	810,000
Type of dredging	Hydraulic	Hydraulic	Hydraulic	Hydraulic	Hydraulic	Mechanical	Hydraulic	Hydraulic
Transportation method	Pipeline	Pipeline + barge	Pipeline	Pipeline	Pipeline	Barge + transfer + trucking	Pipeline + dike + trucking	Pipeline + discharge pipe
Distance to be transported, miles	10	8+32	3	3	13	0+0+14	3+0+12	14 + 4
Location/type of containment site	Bainbridge, slurry screened, water returned, solids stockpiled	Drying/transfer site near Susquehanna State Park, with dike construction	N/A	N/A	Will need dike construction at quarry for dewatering to extend project life	Shoreline transfer site	Nearby drying site required with dike construction	Will need dike construction at quarry for dewatering to extend project life
Final destination of material	Concrete block market	Pooles Island	Susquehanna River, approximately 1 mile d/s of Conowingo Dam	Susquehanna River, approximately 1 mile d/s of Conowingo Dam	Stancills Quarry	Mason-Dixon Quarry (Belvidere site)	Mason-Dixon Quarry (Belvidere site)	Mason-Dixon Quarry (Belvidere site)
Number of dredging cycles that facility could be used before capacity is reached	Facility has a useful life of more than 40 years	Unknown, due to local sediment transport	No limitation	No limitation	5	29	23	23
Land to be purchased, acres	100	420	1-2	1-2	2-5	15	420	2-5
Production Calculations								
Volume to be removed, cubic yards	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000	1,000,000
Volume in pipeline, cubic yards	4,000,000	4,000,000	4,000,000	4,000,000	4,000,000	N/A	4,000,000	4,000,000
Volume to be disposed of, cubic yards	N/A	1,500,000	N/A	N/A	1,500,000	1,200,000	1,500,000	1,500,000
Number of dredges	1	1	3	2	1	8	1	1
Number of pipelines	1	1	3	2	1	0	1	1
Number of barge loads per day	N/A	2	N/A	N/A	N/A	10	N/A	N/A
Number of truck loads per day	N/A	N/A	N/A	N/A	N/A	400	500	N/A
Dike volume, cubic yards	N/A	140,000	N/A	N/A	140,000	N/A	140,000	140,000
Booster pumps required	3	7	6	4	12	0	2	14
Months of operation	Year-round	Year-round	October-February (5 months)	July-March (9 months)	Year-round	Year-round	Year-round	Year-round
Actual operational time, days per year	330	250	83	125	250	250	250	250
Total sediment removal capacity, cubic yards per day	4,000	4,000	12,000	8,000	4,000	4,000	4,000	4,000

	Alt. 1 Low	Alt. 1 High	Alt. 2A Low	Alt. 2A High	Alt. 2B Low	Alt. 2B High	Alt. 2C Low	Alt. 2C High	Alt. 3A Low	Alt. 3A High	Alt. 3B Low	Alt. 3B High	Alt. 3C Low	Alt. 3C High	Alt. 3D Low	Alt. 3D High
One-Time Investment Costs	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Real estate/land purchase	$0		$4,200,000	$8,400,000	$10,000	$40,000	$10,000	$40,000	$20,000	$100,000	$150,000	$300,000	$4,200,000	$8,400,000	$20,000	$100,000
Legal and financial services	$27,600,000		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Design and study costs	$13,300,000		$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000
Booster pump construction	$2,300,000		$2,100,000	$2,100,000	$1,800,000	$1,800,000	$1,200,000	$1,200,000	$3,600,000	$3,600,000	$0	$0	$600,000	$600,000	$4,200,000	$4,200,000
Permanent pipeline construction	$1,800,000		$1,300,000	$2,100,000	$1,400,000	$2,300,000	$1,000,000	$1,600,000	$2,100,000	$3,400,000	$0	$0	$500,000	$800,000	$2,900,000	$4,700,000
Transfer site/dike construction	$0		$1,100,000	$2,200,000	$0	$0	$0	$0	$1,100,000	$2,200,000	$0	$0	$1,100,000	$2,200,000	$1,100,000	$2,200,000
Dredging and dewatering plant	$28,600,000		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Reuse manufacturing plant	$108,200,000		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal	$181,800,000		$10,700,000	$19,800,000	$5,210,000	$9,140,000	$4,210,000	$7,840,000	$8,820,000	$14,300,000	$2,150,000	$5,300,000	$8,400,000	$17,000,000	$10,220,000	$16,200,000
Annualized, $/year	Costs to be offset by generated revenues		$456,000	$844,000	$222,000	$390,000	$179,000	$334,000	$376,000	$610,000	$92,000	$226,000	$358,000	$725,000	$436,000	$691,000
O&M/Removal Costs	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Tipping fee (costs reduced by any generated revenues)	$39,000,000	$50,000,000	$0	$0	$0	$0	$0	$0	$1,500,000	$7,500,000	$12,000,000	$18,000,000	$15,000,000	$22,500,000	$15,000,000	$22,500,000
Dredging + transportation	$0	$0	$15,000,000	$20,000,000	$10,000,000	$15,000,000	$5,000,000	$10,000,000	$20,000,000	$25,000,000	$40,000,000	$70,000,000	$20,000,000	$30,000,000	$20,000,000	$25,000,000
Manufacturing processing	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Construction design and management	$0	$0	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000
Subtotal	$39,000,000	$50,000,000	$16,000,000	$22,000,000	$11,000,000	$17,000,000	$6,000,000	$12,000,000	$22,500,000	$34,500,000	$53,000,000	$90,000,000	$36,000,000	$54,500,000	$36,000,000	$49,500,000
Cost per Cubic Yard (assumes yearly removal)	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
One-time investment cost, $/cy	$182		$11	$20	$5	$9	$4	$8	$9	$14	$2	$5	$8	$17	$10	$16
Annualized investment cost, $/cy/year	$0	$0	$0	$1	$0	$0	$0	$0	$0	$1	$0	$0	$0	$1	$0	$1
Annual removal cost, $/cy/year	$39	$50	$16	$22	$11	$17	$6	$12	$23	$35	$53	$90	$36	$55	$36	$50
Total annual cost, $/cy/year	$39	$50	$16	$23	$11	$17	$6	$12	$23	$35	$53	$90	$36	$55	$36	$50

	Alternative 1	Alternative 2A	Alternative 2B	Alternative 2C	Alternative 3A	Alternative 3B	Alternative 3C	Alternative 3D
Major Limitations	Substantial commitment to continual use would be required	Currently not allowed by law; large parcels adjacent to the river may be very difficult to find	Environmental impacts; NMFS concerns	Environmental impacts; NMFS concerns		Large parcels adjacent to the reservoir may be difficult to find	Large parcels expected to be difficult to find nearby	Effluent from dewatering will need to be pumped back to the Susquehanna River

General Assumptions:

These are concept-level costs for planning purposes only. Detailed design and cost estimate would be required for any future studies investigation implementation of any of these alternatives.
All alternatives assume the dredging of a location in Conowingo Reservoir which currently has the highest amounts of deposition in the entire lower Susquehanna reservoir system; similar costs could be developed for the other lower Susquehanna reservoirs.

Technical Assumptions:

Real estate cost = farmland cost in Harford/Cecil County, MD; range of cost = $10,000 to $20,000 per acre; based on Internet search of agricultural land June 2013; assume large tracts of land available.
Annualization factor = 23.456 for interest = 3.500% and project life of 50 years Rounding factor for annualization = 3
Each hydraulic dredge has its own separate pipeline and associated booster pump system, with a production capacity of 4,000 cubic yards per day; cost per booster pump = $300,000
Hydraulic dredging process will add a signficant amount of volume to the pipeline; assume pipeline will contain 4 times the dredging volume.
Drying process will be able to remove a signficant amount of the water that is pumped in with the dredged material; assume that material to be transported after drying is 1.5 times the original dredging volume.
Production capacity for one mechanical dredge = 500 cubic yards per day; material volume is increased by 20%, a factor of 1.2 (compared to original dredged volume), during dredging process
Barge capacity varies; for transport to Pooles Island, each barge is expected to hold 2,500 cubic yards; for in-reservoir dredging, the capacity would be much smaller, only 500 cubic yards/barge.
Permanent pipeline cost = $160,000 to $260,000 per mile ($30-50 per linear foot).
Transfer site/dike construction cost = 5-foot high dike for 3 feet of material, assume 2 cycles per year, $8-16/cy construction cost
Tipping fee for Stancils Quarry is assumed to be $1-5/cy with a total volume available of 9Mcy; tipping fee for Mason-Dixon Quarry is based on $10-15/cy and a total volume available of 35Mcy; the tipping fees are applied to the dredged amount for pipeline delivery and to the trucked amount for truck delivery; outright purchase of quarry could be another option to tipping fees.
Universal conversion factor; 1 cubic yard of dredged material = 0.81 tons of sediment based on bulk density value of 1600 kilograms/meter ^{3}.

Lower Susquehanna River Watershed Assessment
Summary of Representative Sediment Management Alternatives

	Innovative Reuse		Open Water Placement						Upland Placement							
	Alternative 1		Alternative 2A		Alternative 2B		Alternative 2C		Alternative 3A		Alternative 3B		Alternative 3C		Alternative 3D	
Physical Description																
Sediment to be removed, cubic yards	3,000,000		3,000,000		3,000,000		3,000,000		3,000,000		3,000,000		3,000,000		3,000,000	
Sediment to be removed, tons	2,430,000		2,430,000		2,430,000		2,430,000		2,430,000		2,430,000		2,430,000		2,430,000	
Type of dredging	Hydraulic		Hydraulic		Hydraulic		Hydraulic		Hydraulic		Mechanical		Hydraulic		Hydraulic	
Transportation method	Pipeline		Pipeline + barge		Pipeline		Pipeline		Pipeline		Barge + transfer + trucking		Pipeline + dike + trucking		Pipeline + discharge pipe	
Distance to be transported, miles	10		8+32		3		3		13		0+0+14		3+0+12		14 + 4	
Location/type of containment site	Bainbridge, slurry screened, water returned, solids stockpiled		Drying/transfer site near Susquehanna State Park, with dike construction		N/A		N/A		Will need dike construction at quarry for dewatering to extend project life		Shoreline transfer site		Nearby drying site required with dike construction		Will need dike construction at quarry for dewatering to extend project life	
Final destination of material	Concrete block market		Pooles Island		Susquehanna River, approximately 1 mile d/s of Conowingo Dam		Susquehanna River, approximately 1 mile d/s of Conowingo Dam		Stancills Quarry		Mason-Dixon Quarry		Mason-Dixon Quarry		Mason-Dixon Quarry (Belvidere site)	
Number of dredging cycles that facility could be used before capacity is reached	Facility has a useful life of more than 40 years		Unknown, due to local sediment transport		No limitation		No limitation		2		10		8		8	
Land to be purchased, acres	100		1,250		1-2		1-2		2-5		44		1,250		2-5	
Production Calculations																
Volume to be removed, cubic yards	3,000,000		3,000,000		3,000,000		3,000,000		3,000,000		3,000,000		3,000,000		3,000,000	
Volume in pipeline (4X), cubic yards	12,000,000		12,000,000		12,000,000		12,000,000		12,000,000		N/A		12,000,000		12,000,000	
Volume to be disposed of, cubic yards	N/A		4,500,000		N/A		N/A		4,500,000		3,600,000		4,500,000		4,500,000	
Number of dredges	3		3		8		4		3		24		3		3	
Number of pipelines	3		3		8		4		3		0		3		3	
Number of barge loads per day	N/A		7		N/A		N/A		N/A		29		N/A		N/A	
Number of truck loads per day	N/A		N/A		N/A		N/A		N/A		1,200		1,500		N/A	
Dike volume, cubic yards	N/A		420,000		N/A		N/A		420,000		N/A		420,000		420,000	
Booster pumps required	9		21		16		8		36		0		6		42	
Months of operation	Year-round		Year-round		October-February (5 months)		July-March (9 months)		Year-round		Year-round		Year-round		Year-round	
Actual operational time, days per year	330		250		94		188		250		250		250		250	
Total sediment removal capacity, cubic yards per day	12,000		12,000		32,000		16,000		12,000		12,000		12,000		12,000	
One-Time Investment Costs	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Real estate/land purchase	$0		$12,500,000	$25,000,000	$10,000	$40,000	$10,000	$40,000	$20,000	$100,000	$440,000	$880,000	$12,500,000	$25,000,000	$20,000	$100,000
Legal and financial services	$65,700,000		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Design and study costs	$21,600,000		$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000
Booster pump construction	$6,800,000		$6,300,000	$6,300,000	$4,800,000	$4,800,000	$2,400,000	$2,400,000	$10,800,000	$10,800,000	$0	$0	$1,800,000	$1,800,000	$12,600,000	$12,600,000
Permanent pipeline construction	$5,400,000		$3,800,000	$6,200,000	$3,800,000	$6,200,000	$1,900,000	$3,100,000	$6,200,000	$10,100,000	$0	$0	$1,400,000	$2,300,000	$8,600,000	$14,000,000
Transfer site/dike construction	$0		$3,400,000	$6,700,000	$0	$0	$0	$0	$3,400,000	$6,700,000	$0	$0	$3,400,000	$6,700,000	$3,400,000	$6,700,000
Dredging and dewatering plant	$56,600,000		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Reuse manufacturing plant	$212,000,000		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal	$368,100,000		$28,000,000	$49,200,000	$10,610,000	$16,040,000	$6,310,000	$10,540,000	$22,420,000	$32,700,000	$2,440,000	$5,880,000	$21,100,000	$40,800,000	$26,620,000	$38,400,000
Annualized, $/year	Costs to be offset by generated revenues		$1,194,000	$2,098,000	$452,000	$684,000	$269,000	$449,000	$956,000	$1,394,000	$104,000	$251,000	$900,000	$1,739,000	$1,135,000	$1,637,000
O&M/Removal Costs	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Tipping fee (costs reduced by any generated revenues)	$87,000,000	$117,000,000	$0	$0	$0	$0	$0	$0	$4,500,000	$22,500,000	$36,000,000	$54,000,000	$45,000,000	$67,500,000	$45,000,000	$67,500,000
Dredging + transportation	$0	$0	$45,000,000	$60,000,000	$30,000,000	$45,000,000	$15,000,000	$30,000,000	$60,000,000	$75,000,000	$120,000,000	$210,000,000	$60,000,000	$90,000,000	$60,000,000	$75,000,000
Manufacturing processing	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Construction design and management	$0	$0	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000
Subtotal	$87,000,000	$117,000,000	$46,000,000	$62,000,000	$31,000,000	$47,000,000	$16,000,000	$32,000,000	$65,500,000	$99,500,000	$157,000,000	$266,000,000	$106,000,000	$159,500,000	$106,000,000	$144,500,000
Cost per Cubic Yard (assumes yearly removal)	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
One-time investment cost, $/cy	$123		$9	$16	$4	$5	$2	$4	$7	$11	$1	$2	$7	$14	$9	$13
Annualized investment cost, $/cy/year	$0	$0	$0	$1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1	$0	$1
Annual removal cost, $/cy/year	$29	$39	$15	$21	$10	$16	$5	$11	$22	$33	$52	$89	$35	$53	$35	$48
Total annual cost, $/cy/year	$29	$39	$16	$21	$10	$16	$5	$11	$22	$34	$52	$89	$36	$54	$36	$49
Major Limitations	Substantial commitment to continual use would be required		Currently not allowed by law; large parcels adjacent to the river may be very difficult to find		Environmental impacts; NMFS concerns		Environmental impacts; NMFS concerns				Large parcels adjacent to the reservoir may be difficult to find		Large parcels expected to be difficult to find nearby		Effluent from dewatering will need to be pumped back to the Susquehanna River	

General Assumptions:

These are concept-level costs for planning purposes only. Detailed design and cost estimate would be required for any future studies investigation implementation of any of these alternatives.
All alternatives assume the dredging of a location in Conowingo Reservoir which currently has the highest amounts of deposition in the entire lower Susquehanna reservoir system; similar costs could be developed for the other lower Susquehanna reservoirs.

Technical Assumptions:

Real estate cost = farmland cost in Harford/Cecil County, MD; range of cost = $10,000 to $20,000 per acre; based on Internet search of agricultural land June 2013; assume large tracts of land available.
Annualization factor = 23.456 for interest = 3.500% and project life of 50 years Rounding factor for annualization = 3
Each hydraulic dredge has its own separate pipeline and associated booster pump system, with a production capacity of 4,000 cubic yards per day; cost per booster pump = $300,000
Hydraulic dredging process will add a signficant amount of volume to the pipeline; assume pipeline will contain 4 times the dredging volume.
Drying process will be able to remove a signficant amount of the water that is pumped in with the dredged material; assume that material to be transported after drying is 1.5 times the original dredging volume.
Production capacity for one mechanical dredge = 500 cubic yards per day; material volume is increased by 20%, a factor of 1.2 , during dredging process
Barge capacity varies; for transport to Pooles Island, each barge is expected to hold 2,500 cubic yards; for in-reservoir dredging, the capacity would be much smaller, only 500 cubic yards/barge.
Permanent pipeline cost = $160,000 to $260,000 per mile ($30-50 per linear foot).
Transfer site/dike construction cost = 5-foot high dike for 3 feet of material, drying time of 2 months per cell, $8-16/cy construction cost
Tipping fee for Stancils Quarry is assumed to be $1-5/cy with a total volume available of 9Mcy; tipping fee for Mason-Dixon Quarry is based on $10-15/cy and a total volume available of 35Mcy; the tipping fees are applied to the dredged amount for pipeline delivery and to the trucked amount for truck delivery; outright purchase of quarry could be another option to tipping fees.
Universal conversion factor; 1 cubic yard of dredged material = 0.81 tons of sediment based on bulk density value of 1600 kilograms/meter^3.

Lower Susquehanna River Watershed Assessment
Summary of Representative Sediment Management Alternatives

	Innovative Reuse	Open Water Placement			Upland Placement			
	Alternative 1	Alternative 2A	Alternative 2B	Alternative 2C	Alternative 3A	Alternative 3B	Alternative 3C	Alternative 3D
Physical Description								
Sediment to be removed, cubic yards	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
Sediment to be removed, tons	4,050,000	4,050,000	4,050,000	4,050,000	4,050,000	4,050,000	4,050,000	4,050,000
Type of dredging	Hydraulic	Hydraulic	Hydraulic	Hydraulic	Hydraulic	Mechanical	Hydraulic	Hydraulic
Transportation method	Pipeline	Pipeline + barge	Pipeline	Pipeline	Pipeline	Barge + transfer + trucking	Pipeline + dike + trucking	Pipeline + discharge pipe
Distance to be transported, miles	10	8+32	3	3	13	0+0+14	3+0+12	14 + 4
Location/type of containment site	Bainbridge, slurry screened, water returned, solids stockpiled	Drying/transfer site near Susquehanna State Park, with dike construction	N/A	N/A	Will need dike construction at quarry for dewatering to extend project life	Shoreline transfer site	Nearby drying site required with dike construction	Will need dike construction at quarry for dewatering to extend project life
Final destination of material	Concrete block market	Pooles Island	Susquehanna River, approximately 1 mile d/s of Conowingo Dam	Susquehanna River, approximately 1 mile d/s of Conowingo Dam	Stancills Quarry	Mason-Dixon Quarry	Mason-Dixon Quarry	Mason-Dixon Quarry (Belvidere site)
Number of dredging cycles that facility could be used before capacity is reached	Facility has a useful life of more than 40 years	Unknown, due to local sediment transport	No limitation	No limitation	1	6	5	5
Land to be purchased, acres	100	2,080	1-2	1-2	2-5	72	2,080	2-5
Production Calculations								
Volume to be removed, cubic yards	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000	5,000,000
Volume in pipeline (4X), cubic yards	20,000,000	20,000,000	20,000,000	20,000,000	20,000,000	N/A	20,000,000	20,000,000
Volume to be disposed of, cubic yards	N/A	7,500,000	N/A	N/A	7,500,000	6,000,000	7,500,000	7,500,000
Number of dredges	5	5	12	7	5	40	5	5
Number of pipelines	5	5	12	7	5	0	5	5
Number of barge loads per day	N/A	12	N/A	N/A	N/A	48	N/A	N/A
Number of truck loads per day	N/A	N/A	N/A	N/A	N/A	2,000	2,500	N/A
Dike volume, cubic yards	N/A	700,000	N/A	N/A	700,000	N/A	700,000	700,000
Booster pumps required	15	35	24	14	60	0	10	70
Months of operation	Year-round	Year-round	October-February (5 months)	July-March (9 months)	Year-round	Year-round	Year-round	Year-round
Actual operational time, days per year	330	250	104	179	250	250	250	250
Total sediment removal capacity, cubic yards per day	20,000	20,000	48,000	28,000	20,000	20,000	20,000	20,000

	Alt 1 Low	Alt 1 High	Alt 2A Low	Alt 2A High	Alt 2B Low	Alt 2B High	Alt 2C Low	Alt 2C High	Alt 3A Low	Alt 3A High	Alt 3B Low	Alt 3B High	Alt 3C Low	Alt 3C High	Alt 3D Low	Alt 3D High
One-Time Investment Costs	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Real estate/land purchase	$0		$20,800,000	$41,600,000	$10,000	$40,000	$10,000	$40,000	$20,000	$100,000	$720,000	$1,440,000	$20,800,000	$41,600,000	$20,000	$100,000
Legal and financial services	$88,000,000															
Design and study costs	$26,100,000		$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000	$2,000,000	$5,000,000
Booster pump construction	$11,300,000		$10,500,000	$10,500,000	$7,200,000	$7,200,000	$4,200,000	$4,200,000	$18,000,000	$18,000,000	$0	$0	$3,000,000	$3,000,000	$21,000,000	$21,000,000
Permanent pipeline construction	$9,000,000		$6,400,000	$10,400,000	$5,800,000	$9,400,000	$3,400,000	$5,500,000	$10,400,000	$16,900,000	$0	$0	$2,400,000	$3,900,000	$14,400,000	$23,400,000
Transfer site/dike construction	$0		$5,600,000	$11,200,000	$0	$0	$0	$0	$5,600,000	$11,200,000	$0	$0	$5,600,000	$11,200,000	$5,600,000	$11,200,000
Dredging and dewatering plant	$78,200,000															
Reuse manufacturing plant	$298,800,000		$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Subtotal	$511,400,000		$45,300,000	$78,700,000	$15,010,000	$21,640,000	$9,610,000	$14,740,000	$36,020,000	$51,200,000	$2,720,000	$6,440,000	$33,800,000	$64,700,000	$43,020,000	$60,700,000
Annualized, $/year	Costs to be offset by generated revenues		$1,931,000	$3,355,000	$640,000	$923,000	$410,000	$628,000	$1,536,000	$2,183,000	$116,000	$275,000	$1,441,000	$2,758,000	$1,834,000	$2,588,000
O&M/Removal Costs	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
Tipping fee (costs reduced by any generated revenues)	$130,000,000	$195,000,000	$0	$0	$0	$0	$0	$0	$7,500,000	$37,500,000	$60,000,000	$90,000,000	$75,000,000	$112,500,000	$75,000,000	$112,500,000
Dredging + transportation	$0	$0	$75,000,000	$100,000,000	$50,000,000	$75,000,000	$25,000,000	$50,000,000	$100,000,000	$125,000,000	$200,000,000	$350,000,000	$100,000,000	$150,000,000	$100,000,000	$125,000,000
Manufacturing processing	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0	$0
Construction design and management	$0	$0	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000	$1,000,000	$2,000,000
Subtotal	$130,000,000	$195,000,000	$76,000,000	$102,000,000	$51,000,000	$77,000,000	$26,000,000	$52,000,000	$108,500,000	$164,500,000	$261,000,000	$442,000,000	$176,000,000	$264,500,000	$176,000,000	$239,500,000
Cost per Cubic Yard (assumes yearly removal)	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High	Low	High
One-time investment cost, $/cy	$102		$9	$16	$3	$4	$2	$3	$7	$10	$1	$1	$7	$13	$9	$12
Annualized investment cost, $/cy/year	$0	$0	$0	$1	$0	$0	$0	$0	$0	$0	$0	$0	$0	$1	$0	$1
Annual removal cost, $/cy/year	$26	$39	$15	$20	$10	$15	$5	$10	$22	$33	$52	$88	$35	$53	$35	$48
Total annual cost, $/cy/year	$26	$39	$16	$21	$10	$16	$5	$11	$22	$33	$52	$88	$35	$53	$36	$48

	Alternative 1	Alternative 2A	Alternative 2B	Alternative 2C	Alternative 3A	Alternative 3B	Alternative 3C	Alternative 3D
Major Limitations	Substantial commitment to continual use would be required	Currently not allowed by law; large parcels adjacent to the river may be very difficult to find	Environmental impacts; NMFS concerns	Environmental impacts; NMFS concerns		Large parcels adjacent to the reservoir may be difficult to find	Large parcels expected to be difficult to find nearby	Effluent from dewatering will need to be pumped back to the Susquehanna River

General Assumptions:

These are concept-level costs for planning purposes only. Detailed design and cost estimate would be required for any future studies investigation implementation of any of these alternatives.

All alternatives assume the dredging of a location in Conowingo Reservoir which currently has the highest amounts of deposition in the entire lower Susquehanna reservoir system; similar costs could be developed for the other lower Susquehanna reservoirs.

Technical Assumptions:

Real estate cost = farmland cost in Harford/Cecil County, MD; range of cost = $10,000 to $20,000 per acre; based on Internet search of agricultural land June 2013; assume large tracts of land available.
Annualization factor = 23.456 for interest = 3.500% and project life of 50 years Rounding factor for annualization = 3
Each hydraulic dredge has its own separate pipeline and associated booster pump system, with a production capacity of 4,000 cubic yards per day; cost per booster pump = $300,000
Hydraulic dredging process will add a signficant amount of volume to the pipeline; assume pipeline will contain 4 times the dredging volume.
Drying process will be able to remove a signficant amount of the water that is pumped in with the dredged material; assume that material to be transported after drying is 1.5 times the original dredging volume.
Production capacity for one mechanical dredge = 500 cubic yards per day; material volume is increased by 20%, a factor of 1.2 , during dredging process
Barge capacity varies; for transport to Pooles Island, each barge is expected to hold 2,500 cubic yards; for in-reservoir dredging, the capacity would be much smaller, only 500 cubic yards/barge.
Permanent pipeline cost = $160,000 to $260,000 per mile ($30-50 per linear foot).
Transfer site/dike construction cost = 5-foot high dike for 3 feet of material, drying time of 2 months per cell, $8-16/cy construction cost
Tipping fee for Stancils Quarry is assumed to be $1-5/cy; tipping fee for Mason-Dixon Quarry is based on $10-15/cy; the tipping fees are applied to the dredged amount for pipeline delivery and to the trucked amount for truck delivery; outright purchase of quarry could be another option to tipping fees.
Universal conversion factor; 1 cubic yard of dredged material = 0.81 tons of sediment based on bulk density value of 1600 kilograms/meter ^{3}.

SCREENING LEVEL ESTIMATE

1 - Innovative Reuse

HarborRock Light Weight Aggregate

Logistics and Assumptions to Remove: 1 Million CY, 3 Million CY, and 5 Million CY of Sediment from Conowingo Reservoir

SCENARIO

Hydraulic dredges will be used to remove sediment from the Conowingo Reservoir. It is envisioned the slurry from the dredge will be pumped to a site along the shore line where it will pass over a series of screens to remove large debris or rocks, items nominally greater than 1 inch in diameter or length. This large material will be sold or disposed. The slurry will fall into a sump where it will be pumped downstream in a pipeline to a HarborRock placement site located at the Bainbridge property west east of Port Deposit. The HarborRock site will be 100 acres. The slurry from the pipeline will again pass over a series of screens to seperate the solids by size fractions that will be segreated and stored on site for subsequent drying and use. Some of water will be stired and used on site for process applications and the remainer will flow by seperate pipeline down to the Susquehanna River for discharge. The LWA will use the silts and clay material to make its lightweight aggreagte (LWA) product. For each CY dredged nominally 0.7 tons of LWA will be produced. The LWA will be distributed for sale by truck and by barge.

ASSUMPTIONS/BASIS FOR ESTIMATE:

This fact sheet makes a number of assumptions and qualifications in regards to removing sediment behind the Conowingo Dam via dredging and pumping the dredged sediment thru pipes to a location where a industrial plant can mechanical dewater the piped sediment. Once dewatered the dry sediment can be placed into a gas fired kiln to create Light Weight Aggregate (LWA) for construction material.

First – This initial effort only includes dredging for the Conowingo Dam in the Conowingo Reservoir. In the future other fact sheets could be developed for dredging Safe Harbor and Holtwood Dams.

Second – A CY of sediment is estimated to contain 0.81 tons of solid matter. harborRock has also assumed that a CY of sediment will contain debris or other materials, such as large stones, that are unsuitable for making LWA and that this fraction amounts to 5% of the weight in solids or 0.04 tons per CY of sediment. Therefore, a CY of sediment contains 0.77 tons of dry solid matter suitable to make LWA. In a rotary kiln, a bone dry ton of input material (sediment) yields nominally 0.9 tons of Light Weight Aggregate (LWA). Therefore, 1 CY of sediment will yield 0.69 tons of bone dry LWA, 0.7 tons for simplicity. Alternatively, 1 million CYs of sediment will yield 700,000 tons of LWA.

Rotary kilns may be sized to match the annual throughput need. For this project it would be easy to design a kiln to process 1 .0 million CY per year of sediments, therefore necessitating 1, 3 or 5 kilns as the project grows. This is perfectly acceptable and the modularity allows for project expansion and expenditure of funds as needed. This method however does increase the number of operating systems and total cost. Alternatively, if it were known that 3 million CY per year were required to be processed, 2 kilns, each rated to process 1.5 million CYs per year would be selected or 3 kilns each rated for nominally 1.67 million CYs per year if the goal was to process 5.0 million CYs per year. For purposes of this analysis 1 kiln will be used for 1 MCY, 2 kilns for 3 MCY and 3 kilns for 5 MCY and the corresponding ancillary systems.

Fourth - HarborRock's Sediment Management Fee, in addition to the revenue earned from the sale of its LWA product, is the amount needed to offset their cost “All – In” capital and operating costs for the LWA plant and provide a return on equity to its investers. these costs include operating all the equipment necessary to remove the sediments from the reservoir through pumping them to a location, producing and selling the lightweight aggregate product.

Description of Site and/or dewatering Locations and Processing Facility Where Applicable

This alternative consists of acquisition of **100 acres** of land the where a Light Weigh Aggregate (LWA) Plant will be constructed, which converts sediment behind the Conowingo Dam into light weight aggregate. The beneficial use of the dredged material is the creation of Light Weight Aggregate (LWA), which can be used for construction purposes. Suitable sites would be **100 acres and will** need access to roads, rail, and or barge infrastructure. One or more dredges would be needed in addition a pipeline and pumps to move the dredged material to the processing plant. The Plant will comprise of DM Slurry Storage tanks , Filter Press's and Flash Dryers, Pellet Extruders, Thermal Processing Kilns, Coolers, smoke stacks, Air Emission Control, Turbines for electrical generation, and a structure to house said equipment. The representative site would be located in the area 15 miles between Conowingo Dam and Holtwood dam and up to 5 miles inland from the river, or could be further downstream and up to 5 miles inland from the river in the 10 mile area between Havre De Grace and Conowingo Dam. The area available for a facility is only limited the hydraulic pumping distance. At the plant, the dredged material will be unloaded, stocked in the DM Slurry Tanks, and then Processed. Additional area will be needed to stockpile the light weight aggregate that is produced. It is assumed that the water from the dewatering process will be pumped back the Susquehanna river.

Evaluation of Available Capacity:

Total Amount of Material to be dredged (CY)	Sediment to be Removed Tons @ 0.81 tons per Cubic Yard	Number of Dredges at (400 CY/hr solids at 10 hour days or 4000 CY/day or 1000000 CY/yr) per Dredge	Actual CY of Sediment Plus Water Volume Hydraulically Dredged (water adds 4 times the original volume)	Distance to be Piped (miles)	
1,000,000	810,000	1	4,000,000	10	
3,000,000	2,430,000	3	12,000,000	10	
5,000,000	4,050,000	5	20,000,000	10	

Total Amount of Material to be dredged (CY)	Number of Pipes	Number of Booster pumps	Acreage Needed for Factory (acres)	Acreage Needed for Storage of Hydraulically Dredged Material (acres)	Total Acreage Neededl (acres)
1,000,000	1	3	80	20	100
3,000,000	3	9	80	20	100
5,000,000	5	15	80	20	100

Total Amount of Material to be dredged (CY)	Number of Slurry Screening Operations	Number of Rotary Dryers	Number of Flash Dryers	Number of Pellet Extruders	
1,000,000	2	1	1	4	
3,000,000	4	2	2	8	
5,000,000	6	4	4	16	

Ideally, there would be a site of approximately 2 acres size on-shore at the Conowingo Resevoir to allow for slurry screening to remov
debris and a collection station of the outputs from the multiple dredges to allow for uniform and consisnet pumping of the slurry downs
Removing large debris from the slurry initially will improve reliability, save time and cost.

Total Amount of Material to be dredged (CY)	Number of Kilns	Number of Coolers	Number of Smoke Stacks	Number of Air Emission Controllers	
1,000,000	1	1	1	1	
3,000,000	2	2	2	2	
5,000,000	3	3	3	3	

Multiple stacks are proposed to allow for maximum reliability and up time for operations. The loss of a kiln or other device in a single t
would then only affect that train.

COSTS

One-Time Investment Costs

Total Amount of Material to be dredged (CY)	Design and study costs (includes development, permitting and engineering)	Legal and Financial services (includes capitalized interest, debt service and major maintanence reserve funds and fees)	Booster pump construction	Permanent pipeline construction	Dredging & dewatering plant	Reuse manufacturing plant, buildings & shipping equipment	TOTAL
1,000,000	13,339,450	27,645,057	2,250,000	1,800,000	28,553,813	108,239,629	$181,827,948
3,000,000	21,599,677	65,652,691	6,750,000	5,400,000	56,637,522	212,015,378	$368,055,267
5,000,000	26,099,677	88,044,244	11,250,000	9,000,000	78,196,230	298,780,385	$511,370,536

O&M/Removal Costs

Total Amount of Material to be dredged (CY)	Manufacturing processing	Management and financial repayment (30 yrs.)	TOTAL
1,000,000	$43,136,320	$17,095,261	60,231,581
3,000,000	$120,478,090	$31,758,675	152,236,765
5,000,000	$203,180,414	$42,499,175	245,679,589

Sales Revenue

Total Amount of Material to be dredged (CY)	Net LWA Rrevenue (gross sales minus profit)
1,000,000	$11,907,480
3,000,000	$42,461,770
5,000,000	$67,780,000

Tip Fee Range - Privately financed

Total Amount of Material to be dredged (CY)	Expected	Low	High
1,000,000	$48	$46	$50
3,000,000	$37	$34	$39
5,000,000	$36	$32	$39

Tip Fee Range - Publically financed

Total Amount of Material to be dredged (CY)	Expected	Low	High
1,000,000	Unknown	$39	$40
3,000,000	Unknown	$29	$33
5,000,000	Unknown	$26	$33

Note:

If the total quantity to be dredged annually is known at start of design, then there may be fewer total systems, stacks etc. used.
Elimination of Booster pumps and pipeline one-time investment costs lowers Tip Fee by $1.00 - 2.00/CY
There is 1 pipeline and associated booster pumps per 1 MCY.
Economies of scale would result if pipeline were designed to maximum flow, eliminating multiple pipes. It would appear a good size for the pipeline would be 3.42 MCY. At this size, increasing operational days from 250 to 365 increases annual flow by a factor
Private Finance = 80% debt finaced over 30 years at 5.25% per annum.
Public Finace = 100% debt finaced at 3.75% per annum for 50 years

SCREENING LEVEL ESTIMATE

2A - Open Water Placement

Pooles Island Open Water Placement

Logistics and Assumptions to Remove: 1 Million CY, 3 Million CY, and 5 Million CY of Sediment from Conowingo Reservoir

SCENARIO

Hydraulic dredges will be used to remove sediment from the Conowingo Reservoir, then using a pipeline from the dredge the removed sediment will be pumped downstream to a temporary placement site that is available near Port Deposit. At this location material can be dewatered and loaded into barges. Once the dredged material is placed onto the barges it will be moved to a placement site at Pooles Island, Md.

ASSUMPTIONS/BASIS FOR ESTIMATE:

1) The Pooles Island placement area is assumed to be 350 acres, the expansion of the Pooles Island site connects G-West to Site 92. Allowable fill would be to a depth to -11' MLLW.

2) The 350 ac site is identified as having 4.7 mcy of capacity which would result in an 8.3 ft placement thickness (4,700,000cy x 27cf/cy /350 ac / 43560 cf/ac = 8.32 ft thick). The assumption holds that Pooles Island capacity to handle new material recharges yearly allowing for 4.7 CY of material to be placed every year.

3) Assume 1 cy of sediment contains 0.81 tons of solids.

4) An initial estimate and sizing of a dredge for Conowingo reservoir placement indicated that a dredge such as the Jet Dragon 870 should be suitable for dredging the Conowingo Reservoir at 400 CY / hr. A Jet Dragon 870 Dredge costs 1.5 million. (Based on discussion and materials from Ellicott Dredging Company who have dredges such as the dragon cutter head line which can dredge from 100 to 1000 CY/hr)

5) This estimate will be based on the assumption that there are 250 work days per year and up to 10 work hours days.

6) Approximately 7 boosters per pipe at $300,000 per booster will be needed to get hydraulically dredged material to a temporary placement site that is assumed to be available across the river from Port Deposit (circled in green in the picture below) the dredge will push the sediment for the first mile then booster pumps are needed every mile thereafter.

7) The Legislative restrictions for open water placement at Pooles Island would be lifted or suspended. Opposition from the fishing community will be assuaged.

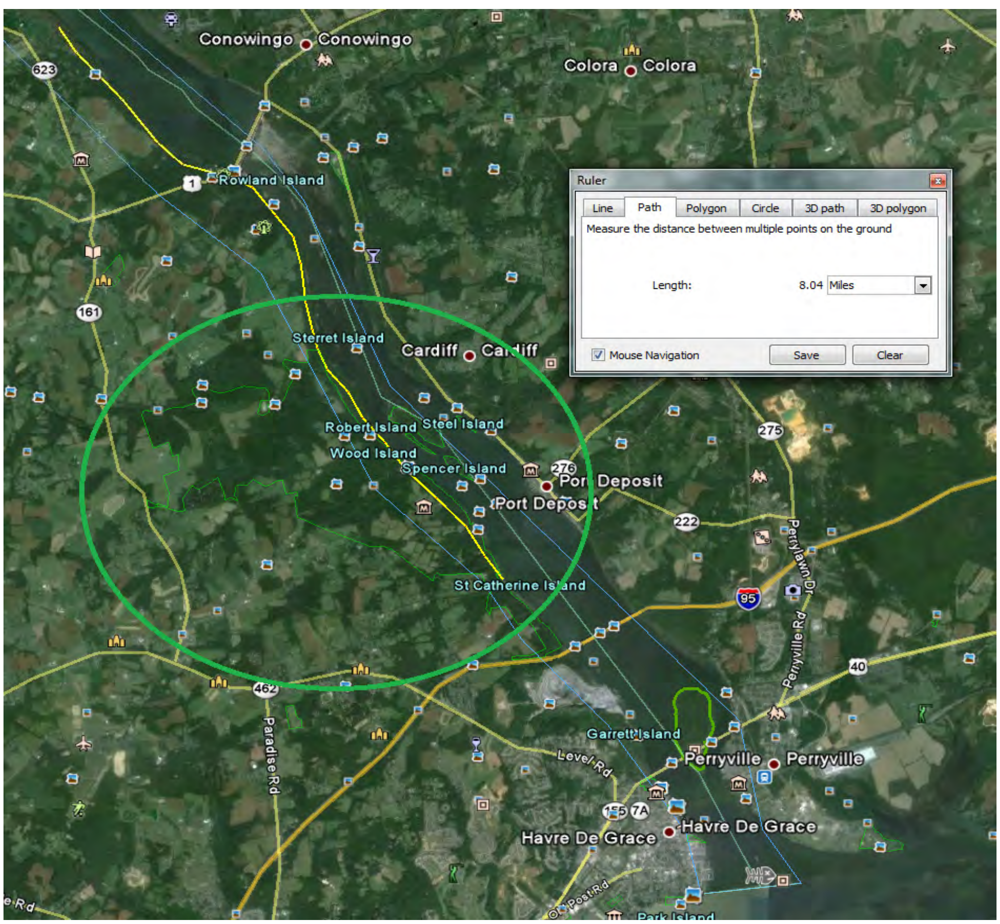
8) Dredged material would first be removed from the reservoir via hydraulic dredging and pumped to a temporary holding site near Port Deposit. This site would be a number of acres surrounded by a sediment holding dike which will contain the dredged material while it is dewatered by working and trenching the material with bulldozers. Drying the material will take approximately 4 months per cell.

9) After the sediment is dewatered the material will then be mechanically loaded into barges via clam shell dredge or large excavators and transported to the Pooles Island placement site ~30 Miles by barge The material would then be pumped from the barge into the Pooles Island open water site.

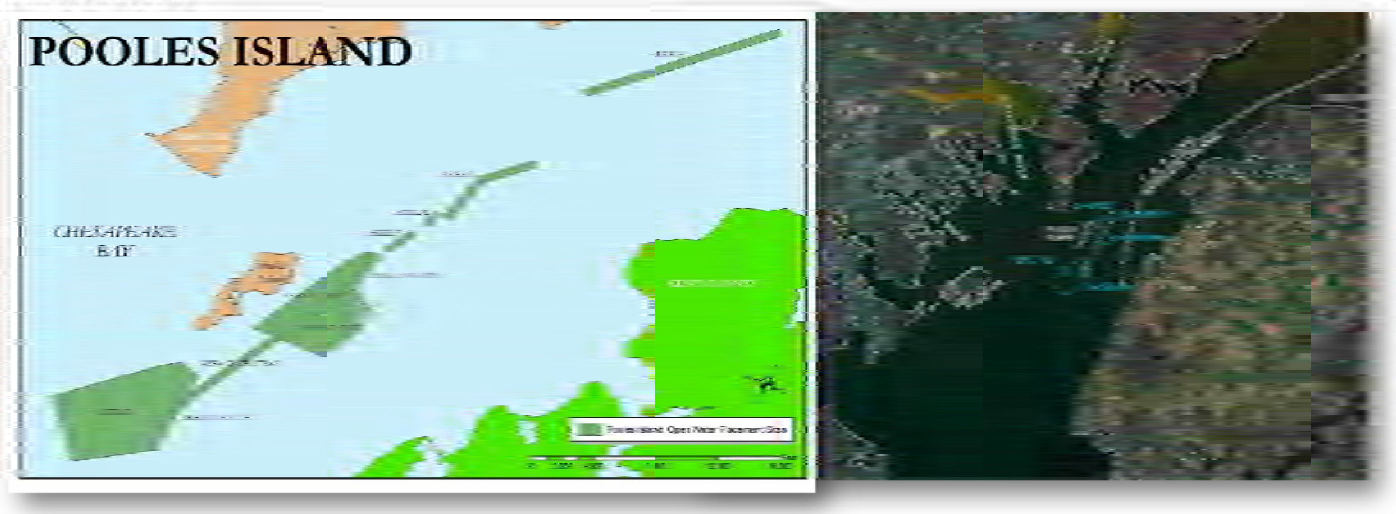
10) We are assuming a 2500 cy / barge will have access to transfer sites at our temporary dewatering site

11) Equipment needed: Dredge's, Pipe, Booster Pumps, Excavators (enough to remove the same amount of material that the dredge pumps per hour), Bulldozers (to trench and move material for drying), Barges.

Potential temporary placement sites across river from Port Deposit in the Susquehanna St Park with access to River.



Location of Pooles island



Evaluation of Available Capacity:

Total Amount of Material to be dredged (CY)	Number of Dredges at (400 CY/hr solids at 10 hour days or 4000 CY/day or 1000000 CY/yr) per Dredge	Number of days to dredge amount at given number of dredges.	Actual CY of Sediment Plus Water Volume Hydraulically Dredged	Distance to be Piped (miles)	Number of Pipes	Number of Booster pumps	Equivalent Acreage of Hydraulically Dredged Material @ 3 ft or 1 yd depth
1,000,000	1	250	4,000,000	8	1	7	800
3,000,000	3	250	12,000,000	8	3	21	2,500
5,000,000	5	250	20,000,000	8	5	35	4,100

Total (CY) of Sediment Plus Water Volume Placed into Temporary Holding Cells During One Year	Equivalent Acreage of Hydraulically Dredged Material @ 3 ft or 1 yd depth	Acreage needed for 6 drying Cells which are used 2 times per year for temporary placement	Area of one Drying Cell (acres)	Dike Length in Feet for 6 cells	Dike Volume in CY for 6 cells at 5 ft elevation	Dewatered Volume of Material (1.5 times original amount dredged)
4,000,000	800	420	70	33,200	140,000	1,500,000
12,000,000	2,500	1,250	210	99,600	420,000	4,500,000
20,000,000	4,100	2,080	350	166,000	700,000	7,500,000

Temporary Dewatering Sediment Cells and Associated Months of Handling

	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	
Pump	1	2	3	4	5	6	Cycle 1
Dry	2,3,4,5	3,4,5,6	4,5,6,7	6,7,8,9	7,8,9,10	8,9,10,11	
Remove	6	7	8	9	10	11	
Pump	7	8	9	10	11	12	Cycle 2
Dry	8,9,10,11	9,10,11,12	10,11,12,1	11,12,1,2,	12,1,2,3	1,2,3,4	
Remove	12	1	2	3	4	5	

Volume of Material to be barged to Pooles Island After Drying (CY)	Volume of Dried Material per Drying Cell (CY)	Area of one Drying Cell (acres)	Transfer pads and associated 400 Cy/hr transfer excavators per Drying Cell	Number of barge loads per day	Number of loads per year at 2500 cy/barge	Percentage of Material Dredged per year that Pooles island can Handle per year (%)	# of dredging cycles that facility could be used before capacity is reached
1,500,000	130,000	70	1	2	600	100	Unknown
4,500,000	380,000	210	4	7	1,800	100	Unknown
7,500,000	630,000	350	7	12	3,000	63	Unknown

SCREENING LEVEL ESTIMATE

2B - Open Water Placement

5 Months of Sediment Bypassing

Logistics and Assumptions to Remove: 1 Million CY, 3 Million CY, and 5 Million CY of Sediment from Conowingo Reservoir

SCENARIO

Hydraulic dredges will be used to remove sediment from the Conowingo Reservoir, then using a pipeline from the dredge the removed sediment will be pumped past Conowingo Dam downstream to a release point bypassing sediment over 5 months from October - February.

ASSUMPTIONS/BASIS FOR ESTIMATE:

1) Assume 1 cy of sediment contains 0.81 tons of solids.

2) An initial estimate and sizing of a dredge for Conowingo reservoir placement indicated that a dredge such as the Jet Dragon 870 should be suitable for dredging the Conowingo Reservoir at 400 CY / hr. A Jet Dragon 870 Dredge costs 1.5 million. (Based on discussion and materials from Ellicott Dredging Company who have dredges such as the dragon cutter head line which can dredge from 100 to 1000 CY/hr)

3) This estimate will be based on the assumption that there are approximately 105 work days in five months and up to 10 work hours days.

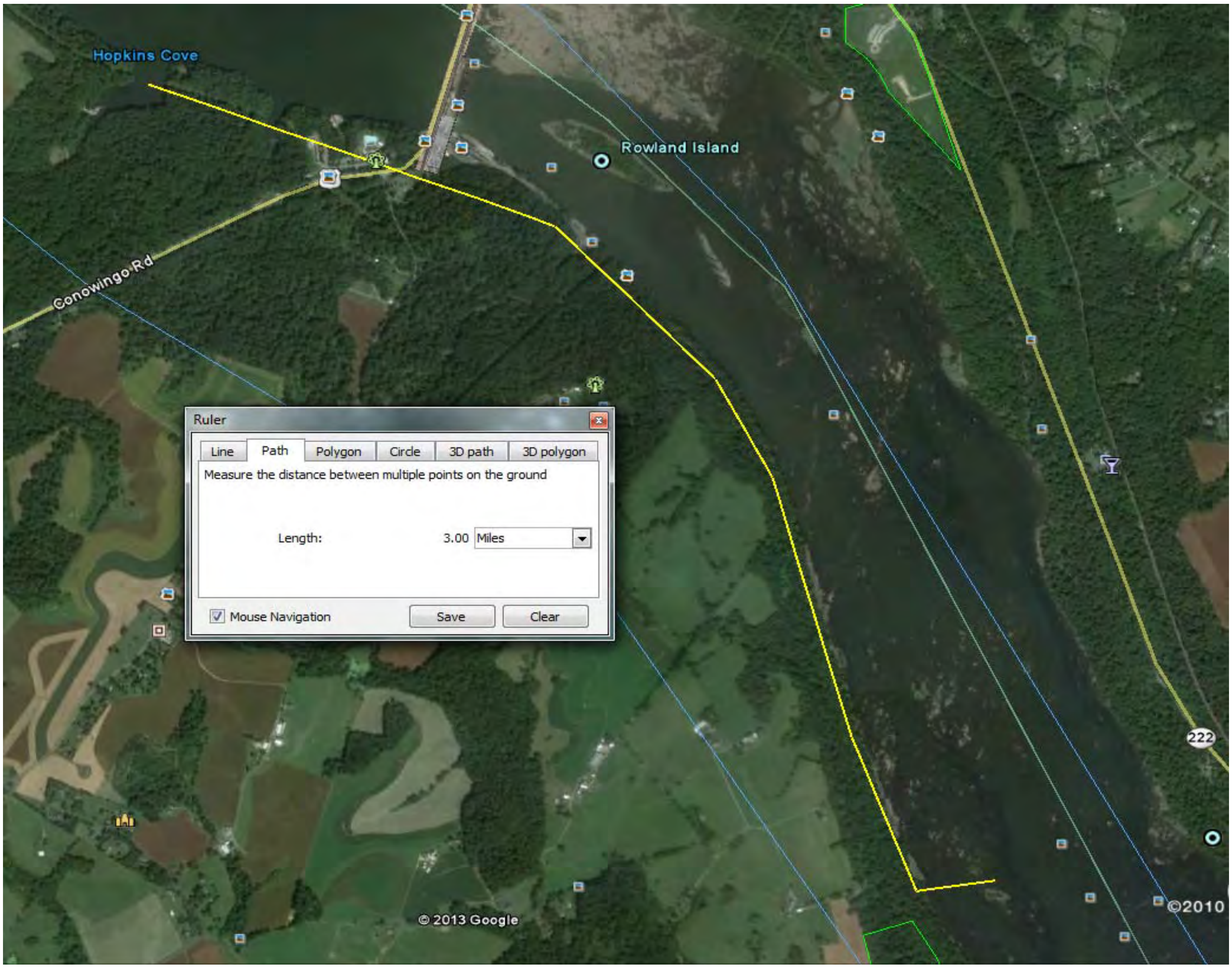
4) A sediment release point can be found down stream of the dam where channel hydraulics would promote sustainable sediment transport.

5) Approximately 2 boosters per pipe at $300,000 per booster are needed to get hydraulically dredged material past Conowingo Dam. The dredge will push the sediment for the first mile then booster pumps are needed every mile thereafter.

6) The Legislative restrictions for open water placement would be lifted or suspended. Opposition from the fishing community will be assuaged.

7) Equipment needed: Dredge's, Pipe, Booster Pumps.

Sediment Pipe around Conowingo Dam and location of Down Stream Release point in the Susquehanna River.



Evaluation of Available Capacity:

Total Amount of Material to be dredged (CY)	Number of Dredges at (400 CY/hr solids at 10 hour days or 4000 CY/day per Dredge at 21 days per month or 84000 CY per month	Number of days to dredge amount at given number of dredges.	Actual CY of Sediment Plus Water Volume Hydraulically Dredged	Distance to be piped (miles)	Number of Pipes	Number of Booster pumps	Percentage of Material Dredged per year that can be Bypassed per year (%) (No Total Capacity Limit)
1,000,000	3	83	4,000,000	3	3	6	100
3,000,000	8	94	12,000,000	3	8	16	100
5,000,000	12	104	20,000,000	3	12	24	100

SCREENING LEVEL ESTIMATE

2C - Open Water Placement

9 Months of Sediment Bypassing

Logistics and Assumptions to Remove: 1 Million CY, 3 Million CY, and 5 Million CY of Sediment from Conowingo Reservoir

SCENARIO

Hydraulic dredges will be used to remove sediment from the Conowingo Reservoir, then using a pipeline from the dredge the removed sediment will be pumped past Conowingo Dam downstream to a release point bypassing sediment over 9 months from July-March.

ASSUMPTIONS/BASIS FOR ESTIMATE:

1) Assume 1 cy of sediment contains 0.81 tons of solids.

2) An initial estimate and sizing of a dredge for Conowingo reservoir placement indicated that a dredge such as the Jet Dragon 870 should be suitable for dredging the Conowingo Reservoir at 400 CY / hr. A Jet Dragon 870 Dredge costs 1.5 million. (Based on discussion and materials from Ellicott Dredging Company who have dredges such as the dragon cutter head line which can dredge from 100 to 1000 CY/hr)

3) This estimate will be based on the assumption that there are approximately 190 work days in nine months and up to 10 work hours days.

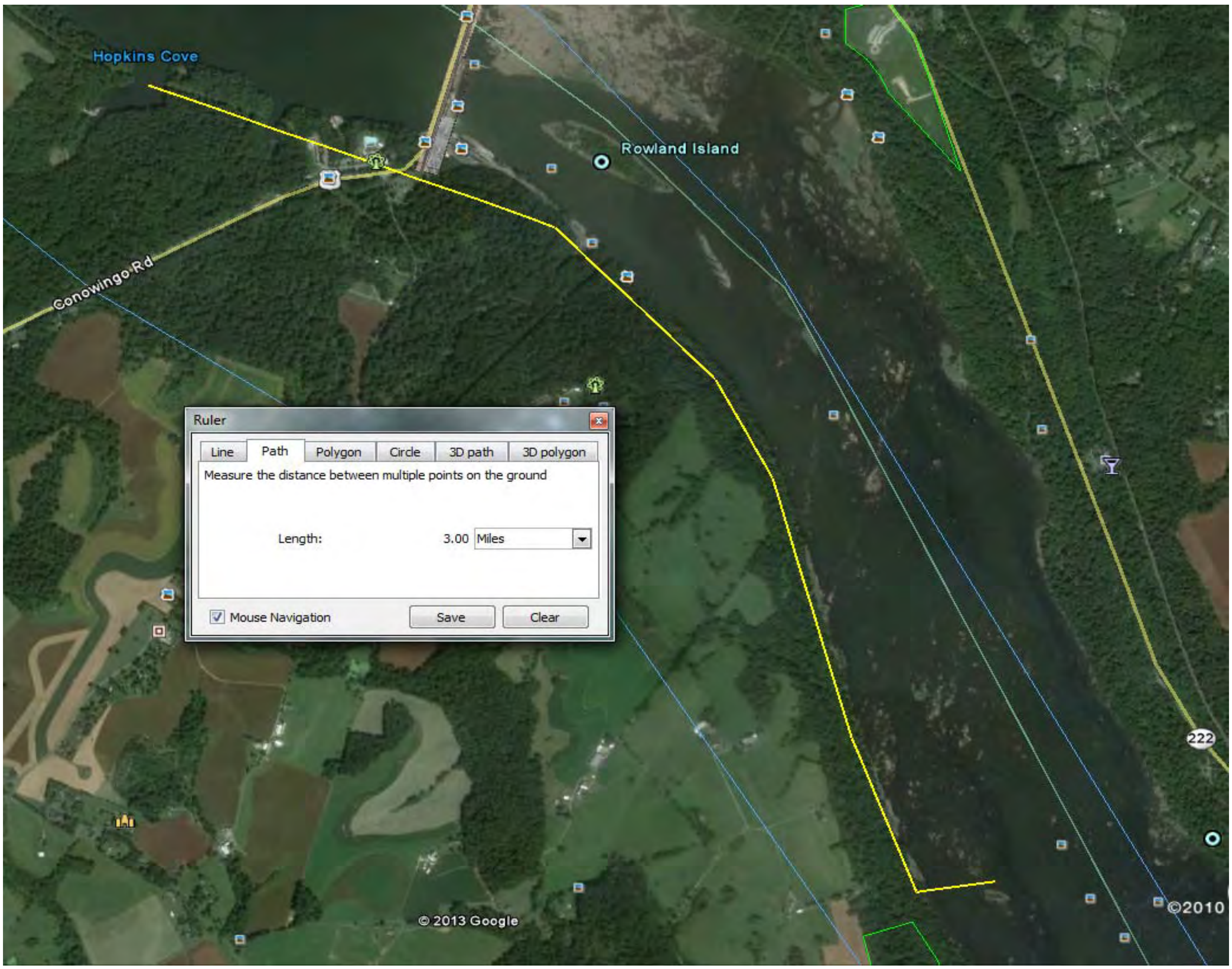
4) A sediment release point can be found down stream of the dam where channel hydraulics would promote sustainable sediment transport.

5) Approximately 2 boosters per pipe at $300,000 per booster are needed to get hydraulically dredged material past Conowingo Dam. The dredge will push the sediment for the first mile then booster pumps are needed every mile thereafter.

6) The Legislative restrictions for open water placement would be lifted or suspended. Opposition from the fishing community will be assuaged.

7) Equipment needed: Dredge's, Pipe, Booster Pumps.

Sediment Pipe around Conowingo Dam and location of Down Stream Release point in the Susquehanna Rive



Evaluation of Available Capacity:

Total Amount of Material to be dredged (CY)	Number of Dredges at (400 CY/hr solids at 10 hour days or 4000 CY/day per Dredge at 21 days per month or 84000 CY per month	Number of days to dredge amount at given number of dredges.	Actual CY of Sediment Plus Water Volume Hydraulically Dredged	Distance to be piped (miles)	Number of Pipes	Number of Booster pumps	Percentage of Material Dredged per year that can be Bypassed per year (%) (No Total Capacity Limit)
1,000,000	2	125	4,000,000	3	2	4	100
3,000,000	4	188	12,000,000	3	4	8	100
5,000,000	7	179	20,000,000	3	7	14	100

SCREENING LEVEL ESTIMATE

3A - Upland Placement

Stancil Quarry Upland Placement

Logistics and Assumptions to Remove: 1 Million CY, 3 Million CY, and 5 Million CY of Sediment from Conowingo Reservoir

SCENARIO

Hydraulic dredges will be used to remove sediment from the Conowingo Reservoir, then using a pipeline from the dredge the removed sediment will be pumped downstream to a dewatering site at Stancil Quarry before it is placed in a permanent site that is available at Stancil Quarry.

ASSUMPTIONS/BASIS FOR ESTIMATE:

1) Assume 1 cy of sediment contains 0.81 tons of solids.

2) An initial estimate and sizing of a dredge for Conowingo reservoir placement indicated that a dredge such as the Jet Dragon 870 should be suitable for dredging the Conowingo Reservoir at 400 CY / hr. A Jet Dragon 870 Dredge costs 1.5 million. (Based on discussion and materials from Ellicott Dredging Company who have dredges such as the dragon cutter head line which can dredge from 100 to 1000 CY/hr)

3) This estimate will be based on the assumption that there are 250 work days per year and up to 10 work hours days.

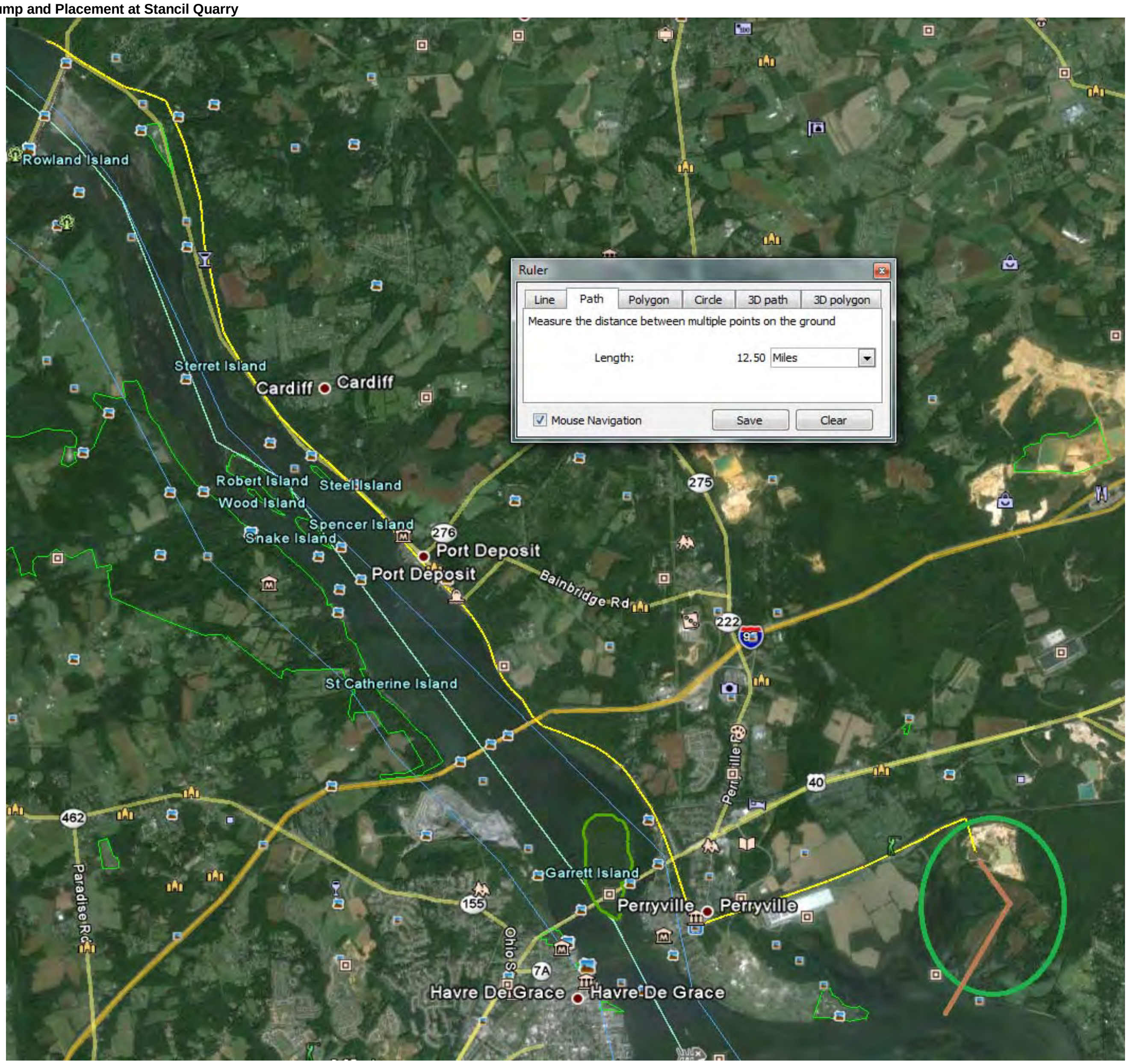
4) Approximately 12 boosters per pipe at $300,000 per booster will be needed to get hydraulically dredged material to Stancil Quarry. The dredge will push the sediment for the first mile then booster pumps are needed every mile thereafter.

5) Dredged material would first be removed from the reservoir via hydraulic dredging and pumped 13 miles to a holding area at Stancil Quarry where it can be dewatered to the Susquehanna flats. Once the material is dewatered it can be placed perminantly in final fill areas at the quarry. The dewatering site at the quarry would be a number of acres surrounded by a sediment holding dike which will contain the dredged material while it is dewatered by working and trenching the material with bulldozers. Drying the material will take approximately 4 months per cell.

6) After the sediment is dewatered the material will then be pushed and moved via bulldozer and excavator to a final fill location within Stancil Quarry.

7) Equipment needed: Dredge's, Pipe, Booster Pumps, Excavators, Bulldozers (to trench and move material for drying).

Pump and Placement at Stancil Quarry



Evaluation of Available Capacity:

Total Amount of Material to be dredged (CY)	Number of Dredges at (400 CY/hr solids at 10 hour days or 4000 CY/day or 1000000 CY/yr) per Dredge	Number of days to dredge amount at given number of dredges.	Actual CY of Sediment Plus Water Volume Hydraulically Dredged	Distance to be Piped (miles)	Number of Pipes	Number of Booster pumps	Equivalent Acreage of Hydraulically Dredged Material @ 3 ft or 1 yd depth
1,000,000	1	250	4,000,000	13	1	12	800
3,000,000	3	250	12,000,000	13	3	36	2,500
5,000,000	5	250	20,000,000	13	5	60	4,100

Total (CY) of Sediment Plus Water Volume Placed into Temporary Holding Cells During One Year	Equivalent Acreage of Hydraulically Dredged Material @ 3 ft or 1 yd depth	Acreage needed for 6 drying Cells which are used 2 times per year for temporary placement	Area of one Drying Cell (acres)	Dike Length in Feet for 6 cells	Dike Volume in CY for 6 cells at 5 ft elevation	Dewatered Volume of Material (1.5 times original amount dredged)
4,000,000	800	420	70	33,200	140,000	1,500,000
12,000,000	2,500	1,250	210	99,600	420,000	4,500,000
20,000,000	4,100	2,080	350	166,000	700,000	7,500,000

Temporary Dewatering Sediment Cells and Associated Months of Handling

	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	
Pump	1	2	3	4	5	6	Cycle 1
Dry	2,3,4,5	3,4,5,6	4,5,6,7	6,7,8,9	7,8,9,10	8,9,10,11	
Remove	6	7	8	9	10	11	
Pump	7	8	9	10	11	12	Cycle 2
Dry	8,9,10,11	9,10,11,12	10,11,12,1	11,12,1,2,	12,1,2,3	1,2,3,4	
Remove	12	1	2	3	4	5	

Volume of Material for Permanent placement at Stancil Quarry After Drying (CY)	Volume of Dried Material per Drying Cell (CY)	Area of one Drying Cell (acres)	Percentage of Material Dredged per year that Stancil Quarry can Handle per year (%)	# of dredging cycles that facility could be used till capacity is reached
1,500,000	130,000	70	Unknown	6
4,500,000	380,000	210	Unknown	2
7,500,000	630,000	350	Unknown	1

SCREENING LEVEL ESTIMATE

3B - Upland Placement

Mason Dixon Quarry Upland Placement - Mechanical Dredge

Logistics and Assumptions to Remove: 1 Million CY, 3 Million CY, and 5 Million CY of Sediment from Conowingo Reservoir

SCENARIO

Mechanical dredges will be used to remove sediment from the Conowingo Reservoir and place that sediment into barges, then the barges will circulate between the dredges and the southern shoreline where their contents will be offloaded via excavators. The southern shoreline was chosen due to the rail line on the northern shoreline, which would make offloading the barges too expensive or potentially unfeasible. There will be staging areas on the southern shoreline for the transfer of dredge material from each barge to the trucks An excavator at each transfer site will then place the wet material into trucks able to hall 12 cy of wet material. Each staging area will have one excavator which will unload the barge and transfer its contents to the trucks at a assumed rate of one truck every 10 minutes. The trucks will then cross the Conowingo Bridge and drive to Mason Dixon Quarry where they will unload their contents, and return to be filled again.

ASSUMPTIONS/BASIS FOR ESTIMATE:

1) Assume 1 cy of sediment contains 0.81 tons of solids.

2) An initial estimate of the sizing of a mechanical dredge for Conowingo reservoir suggested a mechanical dredge capable of removing remove 500 CY / day would be the minimum size dredge needed..

3) This estimate will be based on the assumption that there are 250 work days per year and up to 10 work hours days.

4) Pipes or pumping of sediment infrastructure are not needed for the logistics of this example.

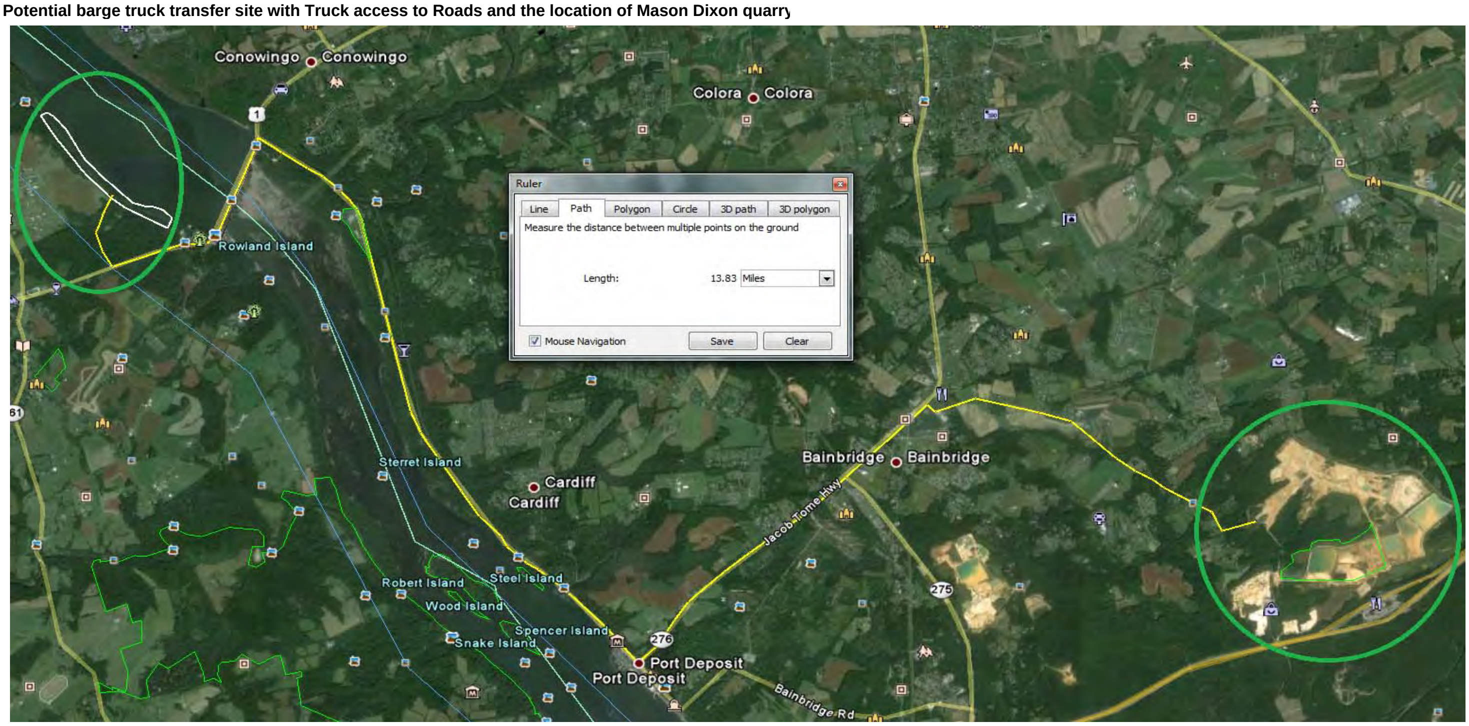
5) Dredged material would first be removed from the reservoir via mechanical dredging and barged to a transfer sites on the Conowingo Reservoir southern shore. There the wet material will be transferred to trucks via excavators. The material will then be trucked to Mason Dixon Quarry for final placement.

6) The depth necessary to move the required number of 500 CY barges is present or can be dredged, and the dock structure to allow excavators to transfer sediment from barge to truck will be able to be constructed.

7) Any temporary to permanent road structures to allow sediment trucks to access state, or county roads and highways will be built, and all road access for the large number of trucks will be approved.

8) Equipment needed: Mechanical Dredge, Barges, Trucks, Excavators, and Bulldozers (to move material at Mason Dixon Quarry).

Potential barge truck transfer site with Truck access to Roads and the location of Mason Dixon quarry



Evaluation of Available Capacity: Based on Mechanical Dredging

Total Amount of Material to be dredged (CY)	Number of Dredges at 500 CY/day per Dredge	Number of days to dredge amount at given number of dredges.	Actual CY of Sediment Plus Water Volume Mechanically Dredged (1.2 times original amt.)	Number of Barge Loads per day at 500 CY per barge	~ Total Number of Truck Loads Per Day @ ~42 Truck Loads per Barge	~ Total Number of Truck Loads Per Year	Number of Transfer sites at 6 trucks per hour per transfer site
1,000,000	8	250	1,200,000	9.6	400	100000	10
3,000,000	24	250	3,600,000	28.8	1200	300000	29
5,000,000	40	250	6,000,000	48.0	2000	500000	48

Transfer Area Acreage needed at 1.5 acres per Transfer Site	Volume of Material for Permanent placement at Mason Dixon Quarry (CY)	Percentage of Material Dredged per year that Mason Dixon can Handle per year (%)	# of dredging cycles that facility could be used till capacity is reached
15	1,200,000	Unknown	29
44	3,600,000	Unknown	10
72	6,000,000	Unknown	6

SCREENING LEVEL ESTIMATE

3C - Upland Placement

Mason Dixon Quarry Upland Placement - Hydraulic Dredge

Logistics and Assumptions to Remove: 1 Million CY, 3 Million CY, and 5 Million CY of Sediment from Conowingo Reservoir

SCENARIO

Hydraulic dredges will be used to remove sediment from the Conowingo Reservoir, then using a pipeline from the dredge the removed sediment will be pumped downstream to a dewatering site that is across the Susquehanna River from Port Deposit. At this location material can be dewatered then once dried the material can be placed onto the trucks via excavators to be moved to a final placement site at Mason Dixon Quarry.

ASSUMPTIONS/BASIS FOR ESTIMATE:

1) Assume 1 cy of sediment contains 0.81 tons of solids.

2) An initial estimate and sizing of a dredge for Conowingo reservoir placement indicated that a dredge such as the Jet Dragon 870 should be suitable for dredging the Conowingo Reservoir at 400 CY / hr. A Jet Dragon 870 Dredge costs 1.5 million. (Based on discussion and materials from Ellicott Dredging Company who have dredges such as the dragon cutter head line which can dredge from 100 to 1000 CY/hr)

3) This estimate will be based on the assumption that there are 250 work days per year and up to 10 work hours days.

4) Approximately 2 boosters per pipe at $300,000 per booster will be needed to get hydraulically dredged material to past Conowingo Dam 3 miles to a temporary placement site assumed to be available (the area outlined in white in picture below) across the Susquehanna River from Port Deposit . The dredge will push the sediment for the first mile then booster pumps are needed every mile thereafter.

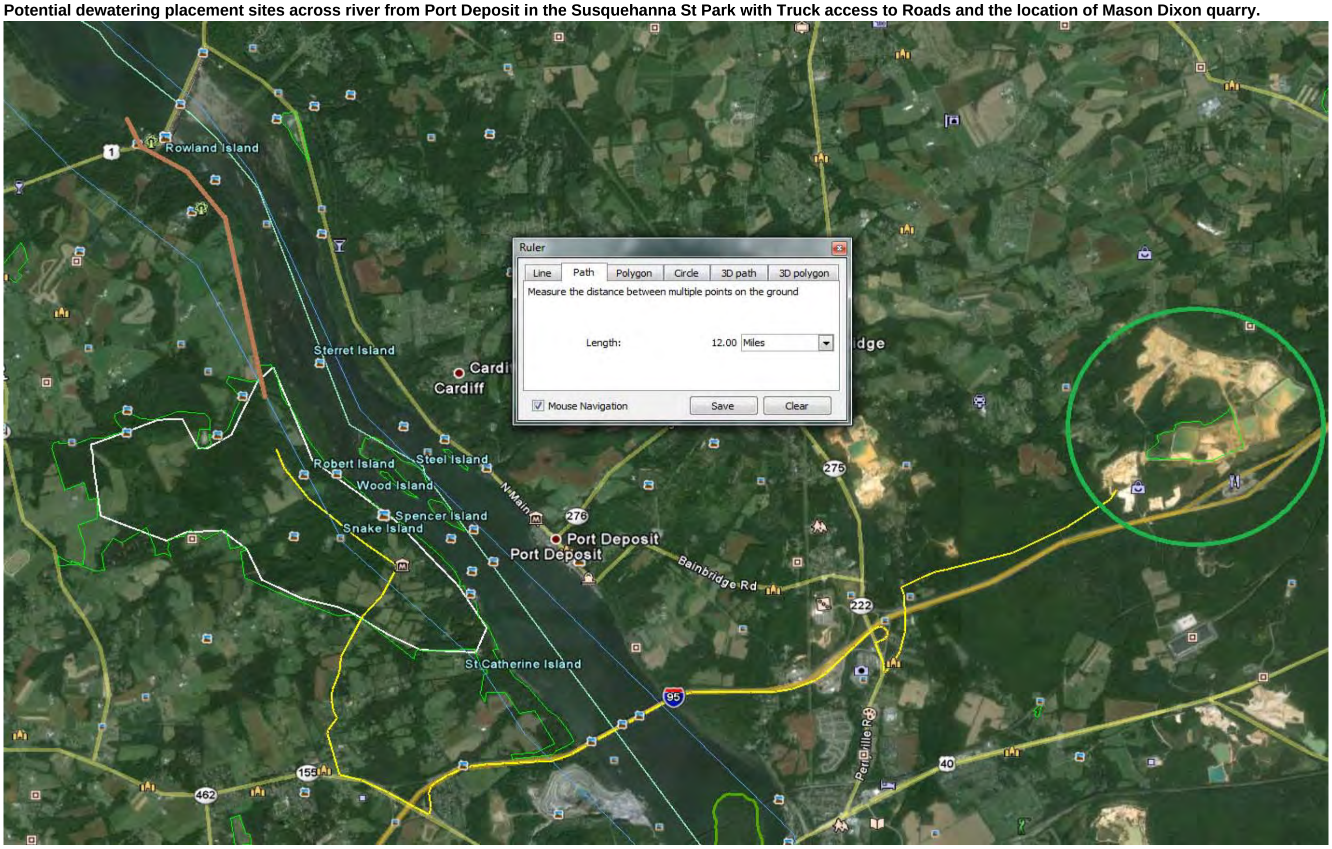
5) Dredged material would first be removed from the reservoir via hydraulic dredging and pumped 3 miles to a holding area across the river from Port Deposit, where it can be dewatered. Once the material is dewatered it can be loaded onto trucks to be transported to Mason Dixon Quarry. The dewatering site would be a number of acres surrounded by a sediment holding dike which will contain the dredged material while it is dewatered by working and trenching the material with bulldozers. Drying the material will take approximately 4 months per cell.

6) After the sediment is dewatered the material will then be mechanically loaded into trucks via excavators and transported to the Mason Dixon Quarry final placement site ~12 Miles by truck and going over the Millard E. Tydings Bridge which is part of interstate 95 and driving on other state and Local Roads roads and some temporary roads created for this project. The material would then be offloaded from the trucks to the final placement site at the quarry.

7) Any temporary to permanent road structures to allow sediment trucks to access state, or county roads and highways will be built, and all road access for the large number of trucks will be approved.

8) Equipment needed: Dredge's, Pipe, Booster Pumps, Excavators, Bulldozers (to trench and move material for drying), and Trucks.

Potential dewatering placement sites across river from Port Deposit in the Susquehanna St Park with Truck access to Roads and the location of Mason Dixon quarry.



Evaluation of Available Capacity:

Total Amount of Material to be dredged (CY)	Number of Dredges at (400 CY/hr solids at 10 hour days or 4000 CY/day or 1000000 CY/yr) per Dredge	Number of days to dredge amount at given number of dredges.	Actual CY of Sediment Plus Water Volume Hydraulically Dredged	Distance to be Piped (miles)	Number of Pipes	Number of Booster pumps	Equivalent Acreage of Hydraulically Dredged Material @ 3 ft or 1 yd depth
1,000,000	1	250	4,000,000	3	1	2	800
3,000,000	3	250	12,000,000	3	3	6	2,500
5,000,000	5	250	20,000,000	3	5	10	4,100

Total (CY) of Sediment Plus Water Volume Placed into Temporary Holding Cells During One Year	Equivalent Acreage of Hydraulically Dredged Material @ 3 ft or 1 yd depth	Acreage needed for 6 drying Cells which are used 2 times per year for temporary placement	Area of one Drying Cell (acres)	Dike Length in Feet for 6 cells	Dike Volume in CY for 6 cells at 5 ft elevation	Dewatered Volume of Material (1.5 times original amount dredged)
4,000,000	800	420	70	33,200	140,000	1,500,000
12,000,000	2,500	1,250	210	99,600	420,000	4,500,000
20,000,000	4,100	2,080	350	166,000	700,000	7,500,000

Temporary Dewatering Sediment Cells and Associated Months of Handling

	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5	Cell 6	
Pump	1	2	3	4	5	6	Cycle 1
Dry	2,3,4,5	3,4,5,6	4,5,6,7	6,7,8,9	7,8,9,10	8,9,10,11	
Remove	6	7	8	9	10	11	
Pump	7	8	9	10	11	12	Cycle 2
Dry	8,9,10,11	9,10,11,12	10,11,12,1	11,12,1,2,	12,1,2,3	1,2,3,4	
Remove	12	1	2	3	4	5	

Volume of Material for Permanent placement at Stancil Quarry After Drying (CY)	Volume of Dried Material per Drying Cell (CY)	Area of one Drying Cell (acres)	~ Total Number of Truck Loads Per Year	Number of Transfer sites at 6 trucks per hour over 10 hours per transfer site	Percentage of Material Dredged per year that Mason Dixon Quarry can Handle per year (%)	# of dredging cycles that facility could be used till capacity is reached
1,500,000	130,000	70	125000	9.0	Unknown	23
4,500,000	380,000	210	375000	25.0	Unknown	8
7,500,000	630,000	350	625000	42.0	Unknown	5

SCREENING LEVEL COST ESTIMATE

3D - Upland Placement

Mason Dixon Belvidere Quarry Upland Placement - Hydraulic Dredge

Logistics and Assumptions to Remove: 1 Million CY, 3 Million CY, and 5 Million CY of Sediment from Conowingo Reservoir

SCENARIO

Hydraulic dredges will be used to remove sediment from the Conowingo Reservoir, then using a pipeline from the dredge the removed sediment will be pumped downstream directly to the Mason Dixon (Belvidere Plant) Quarry in Cecil County Md., where it can be dewatered and permanently placed at the site.

ASSUMPTIONS/BASIS FOR ESTIMATE:

1) Assume 1 cy of sediment contains 0.81 tons of solids.

2) An initial estimate and sizing of a dredge for Conowingo reservoir placement indicated that a dredge such as the Jet Dragon 870 should be suitable for dredging the Conowingo Reservoir at 400 CY / hr. A Jet Dragon 870 Dredge costs 1.5 million. (Based on discussion and materials from Ellicott Dredging Company who have dredges such as the dragon cutter head line which can dredge from 100 to 1000 CY/hr)

3) This estimate will be based on the assumption that there are 250 work days per year and up to 10 work hours days.

4) Approximately 13 boosters per pipe at $300,000 per booster will be needed to get hydraulically dredged material to Mason Dixon Belvidere Quarry. The dredge will push the sediment for the first mile then booster pumps are needed every mile thereafter.

5) Dredged material would first be removed from the reservoir via hydraulic dredging and pumped over 13 miles to a holding area at Mason Dixon Belvidere Quarry where it can be dewatered to ***the Susquehanna River or to the Susquehanna flats approximately 5 miles away.*** Once the material is dewatered it can be placed permanently in final fill areas at the quarry. ***The dewatering site will be a number of acres surrounded by a sediment holding dike which will contain the dredged material while it is dewatered by working and trenching the material with bulldozers. Drying the material will take approximately 4 months per cell.***

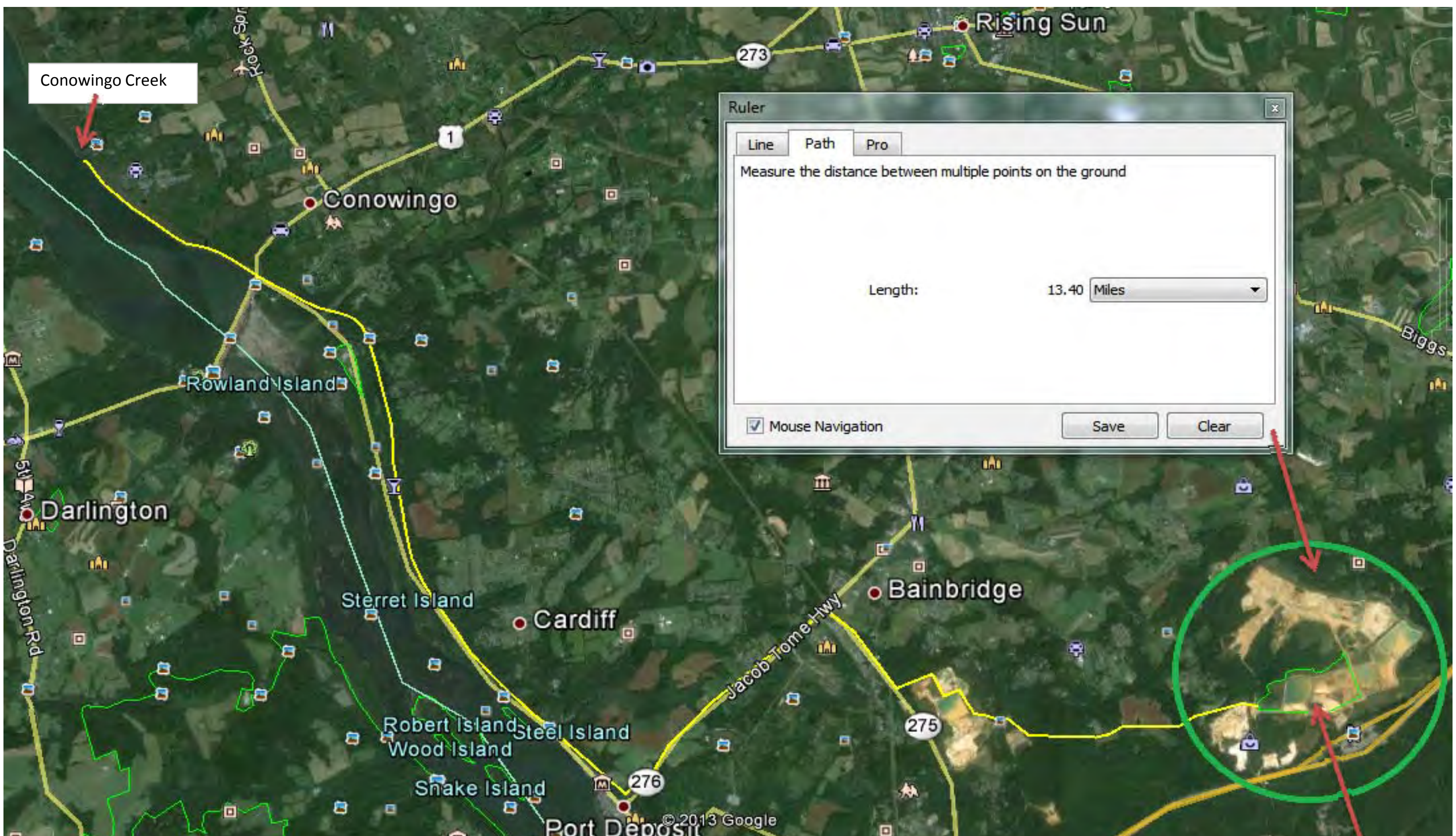
6) Where needed the pipeline can be constructed along roads, rail lines and thru areas of farm land or forest.

7) Initially the dredges will pump sediment under the train trestle on Old Conowingo Creek in order to cross under the rail lines, and move the material in the pipeline from water to land.

8) Cells will be set up to dewater the sediment at the Quarry and Effluent will be pumped back to the Susquehanna River or the Susquehanna Flats area 5 miles away. After the sediment is dewatered the material will then be pushed and moved via bulldozer and excavator to a final fill location within the Quarry.

9) Equipment needed: Dredge's, Pipe, Booster Pumps, Excavators, Bulldozers (to trench and move material for drying).

Location of Proposed Pipeline and Mason Dixon Belvidere Quarry in Cecil County Md.



Belvidere Quarry

Evaluation of Available Capacity:

Total Amount of Material to be dredged (CY)	Number of Dredges at (400 CY/hr solids at 10 hour days or 4000 CY/day or 1000000 CY/yr.) per Dredge	Number of days to dredge amount at given number of dredges.	Actual CY of Sediment Plus Water Volume Hydraulically Dredged	Distance to be Piped (miles)	Number of Pipes	Number of Booster pumps	Equivalent Acreage of Hydraulically Dredged Material @ 3 ft. or 1 yd. depth
1,000,000	1	250	4,000,000	***14***	1	***13***	800
3,000,000	3	250	12,000,000	***14***	3	***39***	2,500
5,000,000	5	250	20,000,000	***14***	5	***65***	4,100

Total (CY) of Sediment Plus Water Volume Placed into Temporary Holding Cells During One Year	***Equivalent Acreage of Hydraulically Dredged Material @ 3 ft. or 1 yd. depth***	***Acreage needed for 6 drying Cells which are used 2 times per year for temporary placement***	***Area of one Drying Cell (acres)***	***Dike Length in Feet for 6 cells***	***Dike Volume in CY for 6 cells at 5 ft. elevation***	***Dewatered Volume of Material (1.5 times original amount dredged)***	***Distance to Pipe Effluent from Dewatering Operation (miles) using 2 pumps***
4,000,000	***800***	***420***	***70***	***33,200***	***140,000***	***1,500,000***	***5***
12,000,000	***2,500***	***1,250***	***210***	***99,600***	***420,000***	***4,500,000***	***5***
20,000,000	***4,100***	***2,080***	***350***	***166,000***	***700,000***	***7,500,000***	***5***

Temporary Dewatering Sediment Cells and Associated Months of Handling

	Cell 1	***Cell 2***	***Cell 3***	***Cell 4***	***Cell 5***	***Cell 6***	
Pump	***1***	***2***	***3***	***4***	***5***	***6***	
Dry	***2,3,4,5***	***3,4,5,6***	***4,5,6,7***	***6,7,8,9***	***7,8,9,10***	***8,9,10,11***	***Cycle 1***
Remove	***6***	***7***	***8***	***9***	***10***	***11***	
Pump	***7***	***8***	***9***	***10***	***11***	***12***	
Dry	***8,9,10,11***	***9,10,11,12***	***10,11,12,1***	***11,12,1,2,***	***12,1,2,3***	***1,2,3,4***	***Cycle 2***
Remove	***12***	***1***	***2***	***3***	***4***	***5***	

Volume of Material for Permanent placement at Mason Dixon Belvidere Quarry After Drying (CY)	***Volume of Dried Material per Drying Cell (CY)***	***Area of one Drying Cell (acres)***	Percentage of Material Dredged per year that Mason Dixon Belvidere Quarry can Handle per year (%)	# of dredging cycles that facility could be used before capacity is reached
1,500,000	***130,000***	***70***	Unknown	23
4,500,000	***380,000***	***210***	Unknown	8
7,500,000	***630,000***	***350***	Unknown	5

SCREENING LEVEL ESTIMATE

4 - Watershed Management Strategy

Implement "E3" Scenario

Logistics and Assumptions to Reduce Sediment Yield: 243,000 CY from Conowingo Reservoir

SCENARIO DESCRIPTION

Total maximum daily loads (TMDLs) have been established for nutrients (phosphorus and nitrogen), which will be met through watershed implementation plans (WIPs). After meeting the nutrient TMDLs there will still be available sediment reduction by implementing the "E3" scenario (everyone doing everything technically feasible everywhere in the watershed) beyond the WIPs.

ASSUMPTIONS/BASIS FOR ESTIMATE:

1) Assume 1 CY of sediment contains 0.81 tons of solids.

2) Model runs that were used to develop the "E3" scenario will result in the sediment reductions described in the scenario.

3) The unit costs to implement the "E3" scenario will not change greatly over time.

4) Jurisdictions will be able to secure adequate funding and political support.

Description of POTENTIAL SITE/Locations/Include PHOTOS, FIGURE, MAP

Best management practices will be implemented in the Susquehanna River watershed in areas of New York, Pennsylvania, and Maryland above Conowingo Dam.

Description of POTENTIAL BMPs PHOTOS, FIGURE

Two examples of best management practices that could be implemented in urban areas are pervious pavers and rain gardens, which allow overland flow generated during storms to slowly infiltrate. This will reduce runoff and erosion and help to reduce sediment loads.

Two examples of agriculture best management practices are cover crops and covered manure sheds. Cover crops help to reduce erosion and sediment loads and manure sheds reduce nutrient inputs to local water systems and ultimately the Bay.

Attachment J-3:
Summary Table of Sediment Management Alternative Evaluation

Summary of Sediment Management Alternative Evaluation
Lower Susquehanna River Watershed Assessment

		Description	*Fatal Flaw?*	*Evaluation*								*Alternative Development*			*Water Quality results*	
Strategy No.	**Sediment Management Strategy**			**Acreage**	**Lifespan (years)**	**Capacity in Cubic Yards (CY) Yearly/Lifespan Volumes**	**Access**	**Tipping fee ($)**	**Distance from Reservoirs**	**Pros**	**Cons**	**Alternative Developed?**	**Sediment impacts**	**Cost**	**Modeling Run Completed?**	**TMDL Impacts**
	WATERSHED STRATEGIES (Reduce Sediment Yield from the Watershed)															
1	Agricultural BMP's	See Attachment J-1 for full suite of Ag BMP's. There are 37 CBP approved BMP's. LSRWA team utilized results of BMP evaluation done for TMDL process.	No	Variable	N/A	N/A	Variable	N/A	N/A	Low environmental impacts	Few opportunities available above WIP Implementation	Yes. See Factsheet 4 of Attachment J-2 and more description in Attachment J-1. Combination of Strategy 1 and 2.	Strategy is part of "E3" Scenario (Alternative). Maximum available load of sediment per year available to be reduced above WIPS is 197,500 tons (244,000 cy/395 million pounds) of sediment annually (NY, PA, MD).	Average annual unit costs estimated to be $357/acre/year for Ag BMP's and $2781/$/acre/year for Urban/Suburban BMP's. See J-1 for full discussion of costs. $1.5B-$3.5B Total cost for implementation.	No. This Alternative was not modeled. Sediment reduction is about 1/7 what is estimated to flow over Conowingo Dam into Chesapeake Bay on an average annual basis (1 million tons).	
2	Urban/Suburban BMP's	See Attachment J-1 for full suite of BMP's. There are 20 CBP approved BMP's. LSRWA team utilized results of BMP evaluation done for TMDL process.	No	Variable	N/A	N/A	Variable	N/A	N/A	Low environmental impacts	Few opportunities available above WIP Implementation	Yes. See Factsheet 4 of Attachment J-2 and Attachment J-1. Combination of Strategy 1 and 2.	Strategy is part of "E3" Scenario (Alternative). Maximum available load of sediment per year available to be reduced above WIPS. Reduction in 197,500 tons (244,000, 395 million pounds) of sediment annually (NY, PA, MD)	Average annual unit costs estimated to be $357/acre/year for Ag BMP's and $2781/$/acre/year for Urban/Suburban BMP's. See J-1 for full discussion of costs. $1.5B-$3.5B Total cost for implementation.	No. This Alternative was not modeled. Sediment reduction is about 1/7 what is estimated to flow over Conowingo Dam into Chesapeake Bay on an average annual basis (1 million tons).	
	MINIMIZE SEDIMENT DEPOSITION WITHIN RESERVOIRS (Route Sediments Passively through Reservoirs)															
3	Flushing/empty Flushing	Flushing re-mobilizes sediments previously deposited in a reservoir by drawing down the water level and letting the water flow out through low-level outlets in the dam. Water flowing through the reservoir scours sediments and passes them through the dam.	Yes. Competing water uses, operational limitations, structural constraints, and safety considerations.													
4	Density Current Venting	Gravity flow of turbid waters of different density. The density difference being a function of the differences in temperature, sal content or silt content of the two fluids. Density currents occur when sediment laden water enters an impoundment, plunges beneath the clear water and travels downstream to the face of the dam. When the density current is strong enough and lasts long enough, the sediment laden water can be discharged through low-level outlets. Method only applicable in reservoirs where, and when, such density currents occur, and their high carrying capacity can be used to pass sediment through reservoirs.	Yes. Competing water uses, operational limitations, structural constraints, and safety considerations.													

(NOTE: Bold scores represent those that have been "flagged" to receive particular consideration because of significant interest or impact)

Summary of Sediment Management Alternative Evaluation
Lower Susquehanna River Watershed Assessment

		Description	*Fatal Flaw?*	*Evaluation*								*Alternative Development*			*Water Quality results*	
Strategy No.	**Sediment Management Strategy**			**Acreage**	**Lifespan (years)**	**Capacity in Cubic Yards (CY) Yearly/Lifespan Volumes**	**Access**	**Tipping fee ($)**	**Distance from Reservoirs**	**Pros**	**Cons**	**Alternative Developed?**	**Sediment impacts**	**Cost**	**Modeling Run Completed?**	**TMDL Impacts**
5	Agitation Dredging	Removal of bottom material by using equipment to raise it temporarily in the water column and currents to carry it away via various methods of dredging. Once the fine sediment is suspended in the water column, it can be transported downstream via stream flow and passed through the dam by way of release operations.	Yes. Competing water uses, operational limitations, structural constraints, and safety considerations.													
6	Sluicing	Removal of sediments from a reservoir bypassing water and sediments through outlets located at a low level of the dam. Sluicing also removes sediment by either completely scouring deposited sediment in the vicinity of the sluice gates or lowering the general level of deposits upstream. Sluicing requires timing of the release to periods of high volume, high sediment concentration inflows to the reservoir.	Yes. Competing water uses, operational limitations, structural constraints, and safety considerations.													
	INCREASE OR RECOVER VOLUME (Includes placement options)															
7	Dam Removal	Remove one or all three dams	Yes. This strategy was deemed impractical, infeasible, with little benefit due to multiple uses of dams to Chesapeake Bay population.													
8	Enlarge Dams/Construct New dams	Larger Dam/more dams	Yes. This strategy was not evaluated any further. Deemed impractical, infeasible, with little benefit and simply kicks the can down the road and would have environmental impacts.													
9	Tunnel By-pass	Pass course sediment around the dam by tunnel	No	N/A	N/A	Lifespan Capacity Variable Yearly Capacity Variable	N/A	0	Variable	Potential for long term management, supply of course, medium, and fine-grained sediment to replenish downstream habitats, deliver sediment at less ecologically critical times of year, i.e. winter.	Tunnel abrasion, incurring maintenance)e, high cost for installation (80-160 million) and high annual maintenance (1 million).	No. No further evaluation done due to rarity of such a strategy and high costs.				

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Summary of Sediment Management Alternative Evaluation
Lower Susquehanna River Watershed Assessment

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Strategy No.	**Sediment Management Strategy**			**Acreage**	**Lifespan (years)**	**Capacity in Cubic Yards (CY) Yearly/Lifespan Volumes**	**Access**	**Tipping fee ($)**	**Distance from Reservoirs**	**Pros**	**Cons**	**Alternative Developed?**	**Sediment impacts**	**Cost**	**Modeling Run Completed?**	**TMDL Impacts**
10	Beneficial Reuse (Lightweight Aggregate)	This evaluation focus on light-weight aggregate. LWA can be sold commercially for construction use. Harbor Rock estimates that a facility to process the dredged material would vary in size depending on the amount of material requiring processing on a daily basis; for efficiency purposes, the facility would require year-round operation. The unit cost for the operation would benefit from economies of scale (larger facilities would have lower unit cost values); however, the ability of the lightweight aggregate market to absorb increased production may reduce the viability of large operations. Other commercial uses for dredged material include landfill capping, and cement blocks.	No	50-100	Greater than 40 yrs	Lifespan Capacity -- Yearly Capacity 1 Kiln handles 1Mil. tons per year. Can have Multiple Kilns	Road, barge	20-25	10 to 15	40 yr Plant lifespan; beneficial use of material	Material must be dried, high cost; have to build plant; Limited by amount dredged; Material will need to be dried	Yes. See Factsheet 1 of Attachment J-2. Looked at removal of 1,3,5 million cy annually. Similar sediment and water quality effects would be anticipated as laid out in Strategies 25, 34 and 38.	Strategy was developed into an Alternative looking at Dredging/processing 1, 3 and 5 mcy per year. Modeling simulated one time removal of 3 mcy and selected an area behind Conowingo. Determined to be an ideal location due to high deposition rate. Removing 2.4 million tons resulted in a reduction of 300,000 tons sediment available for scour. Approximately a 3% reduction in sediment available for scour during a storm event for every 1 mcy removed.	1 mcy annually-$39-50 cy; 3mcy annually- $29-$39 cy; 5mcy annually-26$-39cy.		
11	Biological Dredging/Floating Wetlands (Brinjac)	Artificial wetland matrix made of inert recycled plastic; compacts sediment potentially making sediments less likely to move during storm events. Could be constructed in the river as islands. The wetlands would require regular harvesting and annual maintenance.	No	Variable	Indefinite	Lifespan Capacity is variable requires annual maintenance and harvesting of plants.	N/A	0	N/A-Technology is mobile	No tipping fee low environmental impact potential to offset dredging impacts.	Annual maintenance, doesn't reduce sediment, not a stand alone strategy would need to be implemented with another strategy to have benefits. Would not withstand extreme storm events.	No. Since this could only be done in conjunction with dredging (i.e. doesn't reduce sediment avaialble for scour) a representative alternative was not developed.				
12	Island Creation in Susquehanna River or upper Bay.	Placement site. "Tear drop" islands in Susquehanna river and upper Bay.	No	Variable	Indefinite	Lifespan Capacity Variable, until island is filled. Yearly Capacity Volume depends on island size and volume dredged per year.	Pipeline, barge	0	Max. 75	Material can be wet; no tipping fee; beneficial use; more flexibility in amount of material that can go to this site .	Environmental hurdles; state law forbids island creation in the Bay; material must be sandy or contained; barges with associated load and unload fees; Environmental regulations; erosion.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				

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Summary of Sediment Management Alternative Evaluation
Lower Susquehanna River Watershed Assessment

		Description	*Fatal Flaw?*	*Evaluation*								*Alternative Development*			*Water Quality results*	
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13	Smith Island Creation	Placement site	No	Variable	Indefinite	Lifespan Capacity Variable, until island is filled. Yearly Capacity Volume depends on island size and volume dredged per year.	Barge	0	128	Material can be wet; no tipping fee; beneficial use; more flexibility in amount of material that can go to this site .	Possible erosion; environmental hurdles; material must be pure sand; barges will be involved and there will be the associated load and unload fees; confinement is necessary; longer transport distance than for man-made islands near the dams; water quality certificate; tidal wetlands permit/authorization required	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				
14	Fringe Wetland Creation	Placement site	No	Variable	Indefinite	Lifespan Capacity Variable, until wetland is filled. Yearly Capacity Small volume depends on the wetland size.	Road, pipeline, barge	0	Max. 75	Material can be piped; material can be wet; no tipping fee; beneficial use; more flexibility in amount of material that can go to this site.	Possible erosion of material; material must be sandy or contained by hay bales or coir logs barges will be involved and there will be the associated load and unload fees; confinement is necessary; smaller amounts of material can be placed vs. island creation; water quality certificate; tidal wetlands permit/authorization required.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				
15	Manufactured Soil	Dredged material for use as soil or for solid amendments such as (agriculture, mining etc.)	No	Variable	Indefinite	Lifespan Capacity -- Yearly Capacity Variable	Road, pipeline, barge	0	Variable	No tipping fee; volume depends on demand for material; beneficial use.	Material must be dried, high cost; must have other material to mix dredge material with, such as compost; need confinement	Due to readily available data that has been vetted through Chesapeake Bay community for years as a potentially feasible innovative re-use alternative from Harbor Rock (light weight aggregate) this strategy was not selected as an innovative reuse strategy to be evaluated further. However Similar sediment and water quality effects would be anticipated as laid out in Strategy 11. Costs would vary depending on details of processing.				
16	Dyke Marsh (Potomac, MD)	Placement site	No	245	Indefinite	Lifespan Capacity -- Yearly Capacity 2,000 cy/day; ~700,000 cy/year; dependent on whether they have a placement cell available at needed time.	Pipeline, barge	0	230	Most likely no tipping fee	Barges will be involved and associated load and unload fees; environmental hurdles; longer transport distance than for man-made islands near the dams; erosion; confinement necessary; water quality certificate; tidal wetlands permit/authorization required.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				

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17	Blackwater	Placement site	No	Variable	Indefinite	Lifespan Capacity Variable, wetland creation, enhancement. Yearly Capacity Volume depends on size of wetland creation and volume dredged per year.	Barge, Road	0	100-125	Wetland creation and beneficial use; Flood protection for refuge;	Barges will be involved and associated load and unload fees; environmental hurdles; longer transport distance than for areas near the dams; water quality certificate; tidal wetlands permit/authorization required .	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				
18	Pump Downstream (Active By-passing)	Pass sediments around dams via a bypass during less critical (non-storm, flow) periods so that the reservoirs maintain storage capacity for high-sediment transport storm events to reduce amount of sediment passed during storm event.	No	N/A	N/A	Lifespan Capacity Variable Yearly Capacity Variable	N/A	0	N/A	Lower costs, potential for long term management, supply of course, medium, and fine-grained sediment to replenish downstream habitats, deliver sediment at less ecologically critical times of year, i.e. winter.	Increased turbidity levels downstream, changes in water chemistry, impacts of sediment-removal upstream, consultation with regulatory agencies to develop an upper limit of sediment concentration needs to minimize impacts, out flowing sediment concentration has to be regularly monitored and controlled, regulatory (i.e., permitting) issues, outflow must be in an area of the river where velocities are sufficient to continue to move the material, benthic organism and/or SAV may be covered by release of sediment downstream; Potential impact to existing habitat such as the SAV beds, spawning fish habitat, etc.	Yes. See Attachment J-2 and Factsheet 2B and 2C. Both alternatives looked at hydraulic dredging, pipeline same removal location from Conowingo and placement downstream. 2B is 1,3,5 mcy in winter months and 2B is 1,3 or 5 mcy July-March, 9 months.	1,3,5 mcy or sediment removed for each strategy. Approximately a 3% reduction in sediment available for scour during a storm event for every 1 mcy removed. Modeling of 3mcy for 3 months (variation of 2A) and 9 months (2C) showed that daily loads in Bay increased from 1,940 to 28,607 tons per day if by-passing occurred in 3 winter months and to 10,829 tons per day for 9 months (variation of 2C). See Attachment J-4 for details.	For 1mcy removed annually 2B is $11-17 a cy while 2C is $6-12 a cy. For 3 mcy removed annually 2B is $10-16 a cy while 2C is $5-11 a cy. For 5mcy removed annually 2B is $10-16 a cy while 2C is $5-11 a cy. 2C is cheaper because there is 1 less dredge and pipeline is required. Costs appear cheaper per/cy to remove 1 vs. 3 million a year while costs appear the same between 3 and 5 mcy.	Yes. See Attachment J-4 for details. Modeling looked at annual by-passing (a variation of 2B and 2C) 3mcy, 3 months of the year. Which resulted in widespread diminished water quality from the head of the bay to the mouth of the Potomac river.	2-5% increases in non-attainment for 5 segments of the Bay for deep channel DO and --2% increases in non attainment for 4 segments of the Bay for deep Water DO
19	Pooles Island Placement	Placement site. See Factsheet 2A in Attachment J-5 for more details.	No	1,700	Indefinite	Lifespan Capacity Unknown Yearly Capacity 5,000,000 cy/year	Barge	0	32	Material can be wet; no tipping fee.	Currently cannot place material here legally; if could, materia would need to be barged, therefore load and unload fees; environmental hurdles	Yes. See Attachment J-2 and Factsheet 2A. Involved hydraulic dredge and pipeline to a drying site and piping to a barge travel to Poole's island and then pump.	1,3,5 mcy removed annually. Modeling simulated one time removal of 3 mcy and selected an area behind Conowingo. Determined to be an ideal location due to high deposition rate. Removing 2.7 million tons resulted in a reduction of 300,000 tons sediment available for scour. Approximately a 3% reduction in sediment available for scour during a storm event for every 1 mcy removed.	Annualized: 1mcy -$16-23/cy; 3mcy- $16-21/cy; 5mcy- 16-21 mcy	Yes. See Attachment J-4 for details. Effects were most obvious in the summer following a scour event. DO improvements and chlorophyll reduction were observed along the trench of the bay from Baltimore Harbor to the mouth of the Potomac and into the Potomac trench.	Decrease in non attainment by 1% in one segment of the bay in comparison "Base" No action taken modeling scenario.
20	Ocean Placement	Placement site.	No	N/A	Indefinite	Lifespan Capacity Unlimited Yearly Capacity Depends on volume dredged per year	Barge	0	240	Material can be wet; no tipping fee; most likely larger volumes could be acceptable.	Very large distance; environmental hurdles; barges will be involved and there will be the associated load and unload fees must pass bioassay tests.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				

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21	Wolf Trap and Rappahannock, VA	Placement site.	No	N/A	Indefinite	Lifespan Capacity -- Yearly Capacity 500,000 cy/year to 1,000,000+ cy/year	Barge	0	155	Larger volumes could be accepted.	Need Virginia approval; large distance; environmental hurdles; barges with associated load and unload fees; maybe not enough barges to do job; material must be dewatered($); currently used by MPA; water quality certificate; tidal wetlands permit/authorization required .	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				
22	Purchase Land	Placement site/Staging Area for processing dredged material for final placement.	No	Variable (100+)	Indefinite	Lifespan Capacity Variable, until land is filled. Yearly Capacity Volume depends on land size and volume dredged per year	Road, pipeline, barge	N/A	Variable	Potentially large capacity; could help as a place to dry material for other sites.	Cost; must meet state regulations (PADEP for PA and MDE for MD); transport containers must be watertight; distance; purchase of land will be needed. Maybe zoning hurdles or contamination/groundwater issues, water may need to be decanted, requiring another pipeline to return the effluent to the river	This strategy is discussed as a component of other strategies mainly to be utilized as a dewatering and/or transfer site.				
23	Shirley Plantation	Placement site.	No	1,800	Indefinite	Lifespan Capacity -- Yearly Capacity 500,000 cy/year 1,000,000 +40-60 million in mine reclamation	Road, barge	$50/cy	270	Large capacity; potential to help with reclamation	Must meet VA chemical criteria and regulations; transport containers must be watertight; distance; water may need to be decanted, requiring another pipeline to return the effluent to the river; water quality certificate; tidal wetlands permit/authorization required.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				
24	Mines	Placement site.	No	Variable	Indefinite	Lifespan Capacity Variable, until mine is filled. Yearly Capacity Volume depends on mine size and volume dredged per year.	Road, pipeline, barge	Unknown	Variable	Large capacity; reclamation	Must meet regulations; transport containers must be watertight; distance; water may need to be decanted, requiring another pipeline to return the effluent to the river; Mine owners contacted had no interest in sediments because of limitations on their mining permits.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				
25	Modern Landfill (York, PA)	Placement site.	No	80	8	Lifespan Capacity 240,000 cy Yearly Capacity TBD	Road, rail	$30/ton	37**	Some capacity; distance	Tipping fees; dry material; high cost; water may need to be decanted, requiring another pipeline to return the effluent to the river; Regulations: PADEP has limits on what sediment can be placed; sediment is either classified as clean or waste based on certain criteria; if material is considered waste special handling is required, which adds more cost.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				

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26	Republic Materials Landfill (Conestoga, PA)	Placement site.	No	80	26	Lifespan Capacity 240,000 cy Yearly Capacity TBD	Road, rail	$30/ton	46	Some capacity; distance	Tipping fees; dry material; high cost; water may need to be decanted, requiring another pipeline to return the effluent to the river; Regulations: PADEP has limits on what sediment can be placed; sediment is either classified as clean or waste based on certain criteria; if material is considered waste special handling is required, which adds more cost.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				
27	Scarboro Landfill (Aberdeen, MD)	Placement site.	No	106	Unknown	Lifespan Capacity 318,000 cy Yearly Capacity TBD	Road, pipeline	To be determined	13*	Some capacity; distance	Tipping fees; dry material; high cost; water may need to be decanted, requiring another pipeline to return the effluent to the river; PADEP has limits on what sediment can be placed; sediment is either classified as clean or waste based on certain criteria; if material is considered waste special handling is required, which adds more cost.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				
28	Stancil Quarry (Perryville, MD)	Placement site.	No	70	Unknown	Lifespan Capacity 9,000,000 cy Yearly Capacity TBD	Road, pipeline	$4/cy	13*	Large capacity; Potential to be pumped directly	Must meet state regulations for MD; tipping fees; may only take dry material; drying; water may need to be decanted, requiring another pipeline to return the effluent to the river; high cost; watertight transport; distance. Potential actions such as: Ground water protection design elements - (1) 4ft unsaturated soil / groundwater tbl. (2) 12" A full sediment characterization must be performed w/ TCLP test impermeable cover material (3) A venting system for the gas (4) a leachate collection system (5) Worst case, a liner.	Yes. See Factsheet 3A within Attachment J-2. Involves hydraulic dredging behind Conowingo and piping to dewatering site at Stancil quarry than placed permanently at Stancil's.	1,3,5 mcy removed annually. Modeling simulated one time removal of 3 mcy and selected an area behind Conowingo. Determined to be an ideal location due to high deposition rate. Removing 2.4 million tons resulted in a reduction of 300,000 tons sediment available for scour. Approximately a 3% reduction in sediment available for scour during a storm event for every 1 mcy removed.	Annualized: 1mcy -$23-35/cy; 3mcy- $22-34/cy; 5mcy- $22-33 mcy	Yes. See Attachment J-4 for details. Effects was most obvious in the summer following a scour event. DO improvements and chlorophyll reduction were observed along the trench of the bay from Baltimore Harbor to the mouth of the Potomac and into the Potomac trench.	Decrease in non attainment by 1% in one segment of the bay in comparison "Base" No action taken modeling scenario.
29	Port Deposit Quarry (MD)	Placement site.	No	68	Indefinite	Lifespan Capacity 3,250,000 cy Yearly Capacity TBD	Road, rail, pipeline	0	3.5*	Large capacity; Potential to be pumped directly	Must meet state regulations for MD); tipping fees; may only take dry material; drying; water may need to be decanted, requiring another pipeline to return the effluent to the river ($); watertight transport; distance. Potential actions such as: Ground water protection design elements - (1) 4ft unsaturated soil / groundwater tbl. (2) 12" A full sediment characterization must be performed w/ TCLP test impermeable cover material (3) A venting system for the gas (4) a leachate collection system (5) Worst case, a liner.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				
30	Penn/MD Materials Quarry (Peach Bottom, PA)	Placement site.	No	60	25-30	Lifespan Capacity 9,000,000 cy Yearly Capacity TBD	Road, pipeline	To be determined	5*	Large capacity; Potential to be pumped directly	Must meet state regulations (PADEP for PA and MDE for MD); tipping fees; may only take dry material; drying; water may need to be decanted, requiring another pipeline to return the effluent to the river ($); watertight transport; distance. Potential actions such as: Ground water protection design elements - (1) 4ft unsaturated soil / groundwater tbl. (2) 12" A full sediment characterization must be performed w/ TCLP test impermeable cover material (3) A venting system for the gas (4) a leachate collection system (5) Worst case, a liner.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				

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31	Penn/MD Materials Quarry (Skippack, PA)	Placement site.	No	100	Unknown	Lifespan Capacity 300,000 cy Yearly Capacity TBD	Road	To be determined	72	Some capacity	Must meet state regulations for PA, tipping fees; may only take dry material; drying; water may need to be decanted, requiring another pipeline to return the effluent to the river; high cost; watertight transport; long pumping distance. Potential actions such as: Ground water protection design elements - (1) 4ft unsaturated soil / groundwater tbl. (2) 12" A full sediment characterization must be performed w/ TCLP test impermeable cover material (3) A venting system for the gas (4) a leachate collection system (5) Worst case, a liner.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				
32	Mason Dixon Quarry (Belvidere Plant, MD)	Placement site.	No	565	40	Lifespan Capacity 35,000,000 cy Yearly Capacity TBD	Road, pipeline	To be determined	12.5*	Large capacity; Potential to be pumped directly	Must meet state regulations for MD); tipping fees; may only take dry material; drying; water may need to be decanted, requiring another pipeline to return the effluent to the river ($); watertight transport; distance. Potential actions such as: Ground water protection design elements - (1) 4ft unsaturated soil / groundwater tbl. (2) 12" A full sediment characterization must be performed w/ TCLP test impermeable cover material (3) A venting system for the gas (4) a leachate collection system (5) Worst case, a liner.	Yes. See Factsheet 3D within Attachment J-2. 3D involves hydraulically dredging material and pumping direct to quarry downstream.	1,3,5 mcy removed annually. Modeling simulated one time removal of 3 mcy and selected an area behind Conowingo. Determined to be an ideal location due to high deposition rate. Removing 2.4 million tons resulted in a reduction of 300,000 tons sediment available for scour. Approximately a 3% reduction in sediment available for scour during a storm event for every 1 mcy removed.	Annualized cost for 1 mcy for 3B is 53-90/cy; for 3C is $36-50/cy; 3D- $36-50/cy. For 3 mcy 3B is 52-89/cy; for 3C is $36-54/cy; 3D- $36-49/cy. For 5mcy for 3B is $52-88/cy; for 3C is $36-53/cy; 3D- $36-48/cy. 3D appears cheapest than 3C and 3B most expensive. In general values is better the more you remove annually.	Yes. See Attachment J-4 for details. Effects war most obvious in the summer following a scour event. DO improvements and chlorophyll reduction were observed along the trench of the bay from Baltimore Harbor to the mouth of the Potomac and into the Potomac trench.	Decrease in non attainment by 1% in one segment of the bay in comparison "Base" No action taken modeling scenario.
33	Mason Dixon Quarry (Perryville Plant, Perryville, MD)	Placement site.	No	107	40	Lifespan Capacity 21,400,000 cy Yearly Capacity TBD	Road, pipeline	To be determined	12.3*	Large capacity; Potential to be pumped directly	Must meet state regulations for MD); tipping fees; may only take dry material; drying; water may need to be decanted, requiring another pipeline to return the effluent to the river ($); watertight transport; distance. Potential actions such as: Ground water protection design elements - (1) 4ft unsaturated soil / groundwater tbl. (2) 12" A full sediment characterization must be performed w/ TCLP test impermeable cover material (3) A venting system for the gas (4) a leachate collection system (5) Worst case, a liner.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				
34	Mason Dixon Quarry (Cecil Plant, Cecil County MD)	Placement site.	No	150	40	Lifespan Capacity 0 cy Yearly Capacity TBD	Road, pipeline	To be determined	10*	Large capacity; Potential to be pumped directly	Must meet state regulations for MD); tipping fees; may only take dry material; drying; water may need to be decanted, requiring another pipeline to return the effluent to the river ($); watertight transport; distance. Potential actions such as: Ground water protection design elements - (1) 4ft unsaturated soil / groundwater tbl. (2) 12" A full sediment characterization must be performed w/ TCLP test impermeable cover material (3) A venting system for the gas (4) a leachate collection system (5) Worst case, a liner.	Yes see Factsheet 3B and 3C within Attachment J-2. 3B involves mechanical dredging material to barge than offloading to staging area than loading to truck than offloading to permanent quarry. 3C involves hydraulic dredging material and pumping to temporary site to dewater than trucked to quarry.				

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Lower Susquehanna River Watershed Assessment

		Description	Fatal Flaw?	Evaluation								Alternative Development			Water Quality results	
Strategy No.	Sediment Management Strategy			Acreage	Lifespan (years)	Capacity in Cubic Yards (CY) Yearly/Lifespan Volumes	Access	Tipping fee ($)	Distance from Reservoirs	Pros	Cons	Alternative Developed?	Sediment impacts	Cost	Modeling Run Completed?	TMDL Impacts
35	Mason Dixon Quarry (Westgate Plant, York County MD)	Placement site.	No	21	Indefinite	Lifespan Capacity 3,060,000 cy Yearly Capacity TBD	Road, rail	To be determined	38	Large capacity; closer to dams	Must meet state regulations for MD); tipping fees; may only take dry material; drying; water may need to be decanted, requiring another pipeline to return the effluent to the river ($); watertight transport; distance. Potential actions such as: Ground water protection design elements - (1) 4ft unsaturated soil / groundwater tbl. (2) 12" A full sediment characterization must be performed w/ TCLP test impermeable cover material (3) A venting system for the gas (4) a leachate collection system (5) Worst case, a liner.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				
36	Pensy Supply sites quarry (PA)	Placement site.	No	--	Unknown	Initially indicating that they do not have the ability to assist in the disposal of material	Road, rail	--	Up to 100 miles	Large capacity; one company; multiple sites	Must meet state regulations for PA, tipping fees; may only take dry material; drying; water may need to be decanted, requiring another pipeline to return the effluent to the river; high cost; watertight transport; long pumping distance. Potential actions such as: Ground water protection design elements - (1) 4ft unsaturated soil / groundwater tbl. (2) 12" A full sediment characterization must be performed w/ TCLP test impermeable cover material (3) A venting system for the gas (4) a leachate collection system (5) Worst case, a liner.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				
37	Eastern Industries Sites, Quarry (PA)	Placement site.	No	--	Unknown	They have not replied to multiple inquiries	Road, rail	--	Up to 100 miles	Large capacity; one company; multiple sites	Must meet state regulations for PA, tipping fees; may only take dry material; drying; water may need to be decanted, requiring another pipeline to return the effluent to the river; high cost; watertight transport; long pumping distance. Potential actions such as: Ground water protection design elements - (1) 4ft unsaturated soil / groundwater tbl. (2) 12" A full sediment characterization must be performed w/ TCLP test impermeable cover material (3) A venting system for the gas (4) a leachate collection system (5) Worst case, a liner.	Not selected as a strategy to be evaluated further as a representative alternative. However similar sediment and water quality effects would be anticipated as laid out in Strategies 11, 20, 29, 33; costs are anticipated to be higher than these strategies.				

* Acceptable Pumping Distance

** 11 Miles from Safe Harbor, Acceptable Pumping Distance

This analysis is based on planning level sediment management concepts.

To fully understand and evaluate effects of any of these concepts detailed designs would be required

Fatal Flaw-Determined by team that strategy should be dropped from consideration.

** A number of factors could be varied to develop alternatives and corresponding concept costs. For example how material is dredged: mechanical or hydraulic. Where material is dredged: behind any three of the reservoirs.

How material is transported to dewatering site and/or placement site: (truck, rail, barge, direct pump); how material is dewatered: rotationally via cells, via equipment. Final placement site: further distance, topography. How much material is removed, how often, and what time of year.

Because of amount of variables, representative alternatives were developed to cover ranges of costs each one of these variables could impact.

(NOTE: Bold scores represent those that have been "flagged" to receive particular consideration because of significant interest or impact)

Attachment J-4:
Summary Table of Major Modeling Scenarios and Results

Lower Susquehanna River Watershed Assessment
Baseline and Future Predicted Conditions

	1. What is the system's current (existing) condition? **"LSRWA-4"**	2. What is the system's condition if the WIPs are in full effect and reservoirs have not all reached dynamic equilibrium? **"LSRWA-3" "BASE"**	3. What is the system's condition when WIPS are in full effect, reservoirs have not all reached dynamic equilibrium and there is a winter scour event? **"LSRWA-21"**	4. What is the system's condition when WIPS are not in effect, reservoirs have all reached dynamic equilibrium and there is a winter scour event? **"LSRWA-18"**	5. What is the system's condition when WIPs are in full effect, the reservoirs have all reached dynamic equilibrium and there is a winter scour event? **"LSRWA-30"**	6. What is the system's condition if WIPs are in full effect, reservoirs have not all reached dynamic equilibrium and a scour event occurs during (a) summer **"LSRWA 24"** (b) fall **"LSRWA 25"** or (c) winter **"LSRWA 21"?**
Modeling Parameters	Models used: CBEMP Land use: 2010 land use. Hydrology: 1991-2000. Reservoir bathymetry/Trapping efficiency: 1991-2000 levels. Scouring: No net scouring of reservoirs accounted for during this period. Stoplight Analysis Attainment period: 1993-1995	Models used: CBEMP Land use: WIPS in place. Hydrology: 1991- 2000 CBEMP. Reservoir bathymetry/Trapping efficiency: 1991-2000 levels. Scouring: No net scouring of reservoirs accounted for during this period. Stoplight Analysis Attainment period:1993-1995	Models used: HEC-RAS/ADH+CBEMP Land use: WIPS in place. Hydrology: 2008-2011 HEC-RAS/ADH; 1991-2000 CBEMP. Reservoir bathymetry/Trapping efficiency: 2011 levels. Scouring: Jan 96 event flow and solids adapted from ADH/HEC-RAS/2011 event nutrient composition. Stoplight Analysis Attainment period: 1996-1998	Models used: HEC-RAS/ADH+CBEMP Land use: 2010 land use. Hydrology: 2008-2011 HEC-RAS/ADH; 1991-2000 CBEMP. Reservoir bathymetry/Trapping efficiency: Computed "full" Conowingo levels. Scouring: Jan 96 event flow and solids adapted from ADH/HEC-RAS/2011 event nutrient composition. Stoplight Analysis Attainment period: 1996-1998.	Models used: HEC-RAS/ADH+CBEMP Land use: WIPs in place. Hydrology: 2008-2011 HEC-RAS/ADH; 1991-2000 CBEMP. Reservoir bathymetry/Trapping efficiency: Computed "full" Conowingo levels. Scouring: Jan 96 event flow and solids adapted from ADH/HEC-RAS/2011 event nutrient composition. Stoplight Analysis Attainment period: 1996-1998.	Models used: HEC-RAS/ADH+CBEMP Land use: WIPs in place. Hydrology: 2008-2011 HEC-RAS/ADH; 1991-2000 CBEMP. Jan. 1996 event moved to June and October. Reservoir bathymetry/Trapping efficiency: 2011 levels. Scouring: Jan 96 event flow and solids adapted from ADH/HEC-RAS /2011 event nutrient composition occurring in January, June and October. Stoplight Analysis Attainment period: 1996-1998. *This analysis estimates storm scour loads in conjunction with watershed loads calculated from CBEMP in order to discern differences in seasonal impacts.

	1. What is the system's current (existing) condition? **"LSRWA-4"**	2. What is the system's condition if the WIPs are in full effect and reservoirs have not all reached dynamic equilibrium? **"LSRWA-3"** **"BASE"**	3. What is the system's condition when WIPS are in full effect, reservoirs have not all reached dynamic equilibrium and there is a winter scour event? **"LSRWA-21"**	4. What is the system's condition when WIPS are not in effect, reservoirs have all reached dynamic equilibrium and there is a winter scour event? **"LSRWA-18"**	5. What is the system's condition when WIPs are in full effect, the reservoirs have all reached dynamic equilibrium and there is a winter scour event? **"LSRWA-30"**	6. What is the system's condition if WIPs are in full effect, reservoirs have not all reached dynamic equilibrium and a scour event occurs during (a) summer "**LSRWA 24"** (b) fall "**LSRWA 25**" or (c) winter "**LSRWA 21"?**
General Water Quality Effects	Conditions are usually worst during wet periods of high loading and stratification. Results emphasize summer average (June-August) during wet year (1996).	Predicted WQ improvements (over #1/LSRWA 4) with WIPS in place. Hypoxia reduced, less anoxic conditions, DO levels increase, chlorophyll concentrations and light attenuation decrease.	DO would be depressed in comparison to WIPS in place with no scouring event (#2, LSRWA 3). Storm timing important. Winter scour has minimal impacts to WQ by summer.	Scour under "full" conditions was similar to scour with current conditions (2011 bathymetry). This shows that by 2011, the reservoirs are essentially "full". When flow is below scour threshold full-reservoir conditions are similar to non-full conditions. Solids settle even when reservoir is "full" and settlement rate is not dependent on bathymetry. When flow is below the scour threshold, loads from the reservoir are the same between current bathymetry (2011) and reservoir "full" conditions. Consequently, water quality in the bay is the same, as long as there is no scour event. A full reservoir is influential when scour takes place; more material is scoured under reservoir-full conditions.	When flow is below scour threshold WQ conditions are similar whether reservoir is "full" or not.	June storm has the most deleterious effect on summer water quality. October storm has the least deleterious effect, followed by the January storm.

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Dissolved Oxygen (DO)	Bottom-water hypoxia (DO < 1 mg/L) for a 60-km reach extending 80 to 140 km below the Conowingo dam. Bottom waters in this reach exhibit complete anoxia on occasion.	Bottom-water hypoxia (DO < 1 mg/L) in a 20-km reach (was 60-km reach when WIPS are not in effect) extending 80 to 100 km below Conowingo. Minimum summer-average DO is ~ 0.5 mg/L. Occasional excursions to zero (anoxia) mg/L still predicted.	The additional loads from the scour event depress summer-average, bottom-water, DO by 0.05 mg/L for roughly 60 km along the bay axis (along the centerline following the channel) in the summer following the storm. (in comparison to #2 (LSRWA 3/Base) DO values vary-The effect is diminished in shallow areas relative to deeper areas. There are freshwater flow pulses and meteorological events which cause the effect on DO to vary over the course of a season.	Summer-average DO is depressed by 0.04 mg/L (in comparison to scenario #1/LSRWA-4) along a 100 km reach of bay bottom. Examination of the marginal effects on DO can be deceptive: in the region of the worst hypoxia, at the worst location, under existing conditions, average DO is almost zero. It can't go much lower. Therefore DO isn't depressed much because there is nowhere to go. Elsewhere, DO might average 0.5 mg/L so it can go down by 0.5. The greatest magnitude of depression is not where DO is worst, on average.	If a scour event occurs, average bottom DO concentration is depressed by 0.05 mg/L for 60 to 80 km along the bay axis. With WIPS in place, summer-average DO is higher than under 2010 conditions. Since summer-average DO is higher, it can go lower before hitting zero. So the magnitude of depression can be worse for the WIPS than for 2010.	The DO response to a storm is two-phased. As storm water passes there is an initial sharp decrease reflecting the DO concentration in the storm water and, perhaps, the effects of vertical density stratification. Following storm passage, a secondary DO depression results from oxidation of organic matter produced by storm-generated nutrient loads. June storm, the two phases are difficult to separate. Summer-average bottom-water DO depression at the head of the trench (fixed bathymetric feature in Bay) is 0.4 mg/L or more in comparison to Scenario 2. January storm- DO depression (same location as June storm) is 0.2 mg/L and October storm depression is 0.1 mg/L Spatial extent of the storm influence is large and DO depression is readily detected in the lower portion of the Potomac River which joins Chesapeake Bay roughly 200 km below Conowingo Dam.

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Chlorophyll Concentration (CHL)	Greatest average CHL concentrations (more than 10 µg/L) occur in surface waters of 60-km reach extending 80 to 140 km below the Conowingo dam.	Surface CHL concentration in this reach declines by 3 µg/L, relative to the current condition, to ~ 7 µg/L.	CHL (summer average) increases by 0.3 µg/L in the worst areas (in comparison to #2 (LSRWA-3/base). The effect on CHL is spatially extensive. An increase of 0.2 µg/L or more extends 150 km along bay axis in the summer following the storm.	CHL (summer average) increases by 0.2 µg/L for a 100 km reach of the bay axis	CHL increases by 0.3 µg/L in the 20 km reach where CHL is maximum. CHL increases by 0.2 µg/L for 120 km or more along the bay axis. It is possible for CHL to increase (worsen) with WIPS in place due to the fact that with WIPS in place the nutrient limitation of algae is more stringent; therefore the added nutrients from the scour event can stimulate a bit more chlorophyll.	CHL response to a storm is two-phased. CHL concentration declines immediately as the storm water passes then CHL increases, stimulated by the nutrients introduced by the storm. January storm, spring bloom, CHL increases as much as 5 µg/L, although the bloom largely precedes the critical SAV growing season. In the summer subsequent to the storm, the increase in CHL concentration is between 0.5 and 1 µg/L over a large reach of the bay, extending to the mouth of the Potomac River. October storm – CHL increases by 0.5 µg/L. June storm introduces nutrients at the beginning of the seasonal peak in primary production, summer-average CHL concentration increases as much as 3 µg/L.

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Light Attenuation (KE)	Greatest computed KE, ~ 1.9/m, occurs immediately downstream of the Conowingo outfall and declines rapidly with distance away from the dam. A secondary peak, 1.2/m, occurs downstream, in the turbidity maximum located 40 km below Conowingo Dam. Guidelines indicate KE should not exceed 1.5/m for survival of SAV at the one-meter depth.	KE just below Conowingo declines by 0.5/m, relative to the current condition (scenario 1), to 1.4/m and by 0.4/m to 0.8/m within turbidity maximum (TM, moves according to flow, during most summers TM is located 20 to 40 km upstream of the head of the trench.).	Summer-average KE increases by 0.01/m (in comparison to(LSRWA-3). Additional solids load disperse and settle before SAV growing season (April-October). KE increase attributed to the organic matter, phytoplankton and detritus, stimulated by the scoured nutrient load. Although solids may be subject to resuspension, the January scour effect on summer KE is negligible. Nutrients associated with the storm event are persistent into summer, while solids are short-lived. They settle out but they are recycled though the chemical and physical processes that the bottom sediments undergo. The effect of the scoured nutrients diminishes with time but is visible five summers subsequent to the scour event.	Impact of the winter scour event on summer KE is minimal (less than 0.02/m increase). This increase due to phytoplankton and organic matter associated with scoured nutrients rather than scoured sediments.	KE increase is ~ 0.01/m or less since additional solids disperse and settle before summer. The minimal KE effects are almost identical to predictions with reservoirs still trapping (i.e. 2011 bathymetry/KE impacts are about the same if there is winter storm whether the reservoir is "full" or as it is now (still trapping) which is expected since the solids scoured have ample time to settle before the critical SAV growth period.	Solids loads from the June storm remain in suspension during the subsequent summer months resulting in KE increase of 2/m to 4/m (in comparison to scenario 2/LSRWA-3/Base) for a reach extending 60 km downstream of the dam . Solids loads from the January and October storms are dispersed and settle long before the subsequent SAV growing season and have negligible effect on KE during this period.

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Sediment Loads	CBEMP calculated average solids load over the 10-yr period is 3,056 metric ton/d. Maximum daily load is 181,910 metric ton/d.	CBEMP calculated average solids load over the 10-yr period) is 2,307 metric ton/d. Maximum daily load is 134,960 metric ton/d.	CBEMP calculated - Scour event adds 2.4 metric tons of solids in addition to watershed loads over a four day period.	CBEMP calculated - Scour event adds 2.4 metric tons of solids in addition to watershed loads, over a four day period.	CBEMP calculated- Scour event adds 2.4 metric tons of solids in addition to watershed loads, over a four day period.	CBEMP calculated - The simulated storm event totals 2.78 million metric tons solids over seven days. This includes watershed and scour loads.
Nutrient Loads	Nitrogen- The average total nitrogen load is 147.9 metric ton/d. Of this, 62.9 tons are particulate (organic) nitrogen associated with sediments. Phosphorus- The average total phosphorus load is 6.31 metric tons/day. Of this, 5.22 tons are particulate phosphorus associated with sediments.	Nitrogen- The average total nitrogen load is 104 metric tons/day. Of this, 46.1 tons are particulate (organic) nitrogen associated with sediments. Phosphorus-The average total phosphorus load is 4.72 metric tons/day. Of this, 3.87 tons are particulate phosphorus associated with sediments.	Nitrogen- Scour event adds 7,100 metric tons particulate (organic) nitrogen in addition to watershed loads over a four day period. Phosphorus- Scour event adds 2,400 metric tons particulate phosphorus in addition to watershed loads over a four day period.	Nitrogen-Scour event adds 7, 100 metric tons particulate (organic) nitrogen, in addition to watershed loads over a four day period. Phosphorus – Scour event adds 2,400 metric tons particulate phosphorus, in addition to watershed loads over a four day period. The amount scoured is virtually equal to the amount scoured under existing bathymetry, indicating the existing bathymetry is very close to full.	Nitrogen- Scour event adds 7,100 metric tons Particulate (organic) nitrogen in addition to watershed loads, over a four day period. Phosphorus – Scour event adds 2,400 metric tons particulate phosphorus in addition to watershed loads over a four day period. The amount scoured is not affected by WIPS.	Nitrogen- The simulated storm event adds 13,016 metric tons total nitrogen over seven days. This includes watershed and scour loads. Phosphorus- The simulated storm event adds 2,888 metric tons total phosphorus over seven days. This includes watershed and scour loads.

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Deep Channel DO Water Quality Standard Achievement for Total Maximum Daily Load (TMDL)	Widespread non-attainment of TMDL of Deep Channel DO. Non-attainment of 23% in the CB4 mainstem, 14% in Eastern Bay, and 28% in the Lower Chester River. This and other areas of non-attainment in the Deep Channel amounted to more than half of the Deep Channel habitat in the Bay.	Complete attainment of the Deep Channel DO standard was estimated to be attained.	An estimated increase of 1% nonattainment at CB4MH, EASMH and CHSMH over Scenario 2(LSRWA-3/Base).	An increase of 1% nonattainment above Scenario 1 (LSRWA- 4) for CB4MH and PATMH.	Increase of 1% nonattainment over Scenario 2 (LSRWA-3/Base) was estimated at CB4MH, EASMH, and CHSMH.	Generally, a June high flow storm event has the most detrimental influence on Deep Channel DO followed by a storm of the same magnitude in January and then October. A 'no large storm" condition has the highest level of Deep Channel DO attainment. The June high flow event scenario (LSRWA-24) had an estimated increase in Deep-Channel nonattainment of 1%, 4%, 8% and 3% in segments CB3MH, CB4MH, CHSMH and EASMH when compared to the No Storm Scenario.

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Deep Water DO Water Quality Standard Achievement for TMDL	Widespread non-attainment of TMDL of Deep Water DO. Estimated Non-attainment of 11% in CB4 mainstem, 2% in Eastern Bay and 11% in Lower Chester River.	Complete attainment of the Deep Water DO standard was estimated to be attained.	An estimated increase of 1% nonattainment over Scenario 2(Base/LSRWA 3) was estimated at CB4MH, CB5MH.	An estimated increase of 1% nonattainment over Scenario 2 was estimated at CB3MH and PAXMH.	An estimated increase of 1% non-attainment over Scenario 2 (Base/LSRWA 3) was estimated at CB4MH and CB5MH.	Generally a June high flow event has the most detrimental influence on Deep Channel DO followed by a storm of the same magnitude in January and then October. A "no large scour event" has the highest levels of Deep Water DO attainment. June high flow event scenario (LSRWA-24) had an estimated increase in Deep-Water nonattainment of 1% in segments CB4MH, CB5MH, and EASMH respectively over Scenario 2(LSRWA-3/Base). For October attainment was the same as Scenario 2 (LSRWA-3/Base).
Open Water DO Water Quality Standard Achievement for TMDL	Widespread, but not complete attainment of the Open Water DO standard was estimated.	Complete attainment was estimated.	Complete attainment was estimated.	Complete attainment was estimated.	Complete attainment was estimated.	Complete attainment was timated.

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Submerged Aquatic Vegetation (SAV) clarity water quality Achievement for Total Maximum Daily Load	Complete attainment was estimated.	Complete attainment was estimated.	Complete attainment was estimated.	Complete esattainment was estimated.	Complete attainment was estimated.	Complete attainment was estimated.

Lower Susquehanna River Watershed Assessment
Sediment Management Scenarios

	1. What are the effects of agitation dredging?	2. What are the effects of strategic dredging? **"LSRWA 28"**	3a. What are the effects of passing sediment downstream for 3 winter months, one time?	3b. What are the effects of passing sediment downstream for 3 winter months, over-time for a period of 10 years? **"LSRWA 29"**	4. What are the effects of passing sediment downstream for 9 months?	5. What are the effects of extreme removal out of system) restoring to 1996 bathymetry? **"LSRWA 31"**	6. What are the effects of long-term strategic dredging over time for a period of 10 years?	7. What are the effects of moving sediment from scour areas to depositional areas?	8. What are the effects of increasing Best management practices in the watershed above that required to meet TMDL?
Modeling Parameters	Models used ADH. Land use: Not determined. Hydrology: Five runs varying between 30,000-400,000 cfs on ADH. Reservoir bathymetry/Trapping Capacity: Not determined. Scouring: Not determined. Concept: Re-suspending reservoir bed sediments into the water column by mechanical means through the outlet structures of the dam.. Goal was to determine minimum flow required to maintain the resuspended sediment in suspension to allow transport through outlet structures. Stoplight Analysis Attainment period: Not Determined.	Models used: HEC-RAS/ADH and CBEMP Land use: WIPS in place. Hydrology: 2008-2011 (ADH). 1991-2000 (CBEMP). Reservoir bathymetry/Trapping Capacity: 2011, 3 mcy (2.4 million tons) removed. Scouring Jan 96 event flow and solids/2011 event nutrient composition. Concept: One time removal, of 3 mcy (2.4 million tons) from reservoir system. An area behind Conowingo was selected, 1.0 – 1.5 miles above the dam. Dredging area selected based on the highest deposition rate. Stoplight Analysis Attainment period: 1996-1998	Models used: Google Earth and GIS Desktop Analysis. Land use: Not determined, this was a desktop calculation Hydrology Not determined, this was a desktop calculation Reservoir bathymetry/Trapping Capacity: Not determined, this was a desktop calculation Scouring: Not determined, this was a desktop calculation Concept: 2.4 million tons (3mcy) bypassed over 3 months' time (90 days), one year. Dec -Feb time period. Stoplight Analysis Attainment period: Not Determined.	Models used: CBEMP Land use: WIPs in place. Hydrology: 1991-2000 (CBEMP). Reservoir bathymetry/Trapping Capacity: 2011, 3mcy removed Scouring: Jan 96 event flow and solids/2011 event nutrient composition Concept: 2.4 million tons (3mcy) bypassed over 3 months' time (Dec-Feb) every year for 10 years. Stoplight Analysis Attainment period: 1996-1998	Models used: Google Earth and GIS Desktop Analysis. Land use: Not determined, this was a desktop calculation. Hydrology: Not determined, this was a desktop calculation. Reservoir bathymetry/Trapping Capacity: Not determined, this was a desktop calculation. Scouring: Not determined, this was a desktop calculation. Concept: 2.4 million (3 mcy) tons bypassed over 9 months time, one year (270 days (Sept. – Apr) time period. Stoplight Analysis Attainment period: Not Determined	Models used: HEC-RAS/ADH and CBEMP. Land use: WIPS in place. Hydrology: 2008-2011 (ADH). 1991-2000 (CBEMP). Reservoir bathymetry/Trapping Capacity: 1996. Scouring: Jan 96 event flow and solids/2011 event nutrient composition. Concept: The 1996 bathymetry was modeled. This bathymetry has 25 million tons (31 mcy) less sediment than the 2011 bathymetry. Stoplight Analysis Attainment period: 1996-1998	Models used: Google Earth and GIS Desktop Analysis. Land use: Not determined, this was a desktop calculation. Hydrology: Not determined, this was a desktop calculation. Reservoir bathymetry/Trapping Capacity: Not determined, this was a desktop calculation. Scouring: Not determined, this was a desktop calculation. Concept: Removing 3mcy on an annual basis for 10 years. Stoplight Analysis Attainment period: 1996-1998	Models used: None. Google Earth and GIS Desktop Analysis. Land use: Not determined, this was a desktop calculation. Hydrology: Not determined, this was a desktop analysis. Reservoir bathymetry/Trapping Capacity: Not determined, this was a desktop calculation. Scouring: Not determined, this was a desktop calculation. Concept: Dredging areas within reservoir where scour occurs and placing dredged material in areas within reservoir that is still depositional. Stoplight Analysis Attainment period: Not Determined	Models used: None. Google Earth and GIS Desktop analysis. Land use: Above TMDL/WIP requirements. Hydrology: Not determined, this was a desktop analysis. Reservoir bathymetry/Trapping Capacity: Not determined, this was a desktop calculation. Scouring: Not determined, this was a desktop calculation. Concept: Implementing BMP's Based on CBP E3 scenario includes additional BMPs, in Susquehanna River Watershed above planned WIPs. Scenario estimates a reduction of 243, 000 cubic yards (197, 500 tons) annually. Stoplight Analysis Attainment period: Not Determined.

	1. What are the effects of agitation dredging?	2. What are the effects of strategic dredging? **"LSRWA 28"**	3a. What are the effects of passing sediment downstream for 3 winter months, one time?	3b. What are the effects of passing sediment downstream for 3 winter months, over-time for a period of 10 years? **"LSRWA 29"**	4. What are the effects of passing sediment downstream for 9 months?	5. What are the effects of extreme removal out of system) restoring to 1996 bathymetry? **"LSRWA 31"**	6. What are the effects of long-term strategic dredging over time for a period of 10 years?	7. What are the effects of moving sediment from scour areas to depositional areas?	8. What are the effects of increasing Best management practices in the watershed above that required to meet TMDL?
Sediment loads	A minimum flow of 150,000 cfs is required to ensure transport of sediment through dam. This flow occurs on average 12 days per year, usually in the spring which is critical time of year for living resources. Also conditions could be unsafe for operations.	ADH calculated that with strategic dredging the total load to the Bay (2008-2011 time period) was reduced by 1.4 percent from 22.3 to 22.0 million tons. The scour load decreased by 10% from 3.0 to 2.7 million tons and the net reservoir sedimentation increased by 5.0% (4.1-4.3 million tons). Scour load decreased by 3.3% for every million cubic yards removed. CBEMP calculated (1991-2000) time period) that the Jan 1996 scour load was reduced by 32% in comparison to same scour event with existing reservoir bathymetry.	Calculated that daily load to bay increased from 1,490 to 28,200 tons per day for 90 days assuming a base flow of 60,000 cfs out of Conowingo Dam. Total loads	CBEMP calculated an additional sediment load of 2.18 million metric tons/annum.	Calculated a daily load to bay increasing from 1,490 to 8,900 tons per day for 270 days. The impact to daily load concentrations is more severe over 3 months of bypass operations and less concentrated over 9 months of bypass operations. The 9 month bypass approach will have the effect of discharging loads during the SAV growing season which is unacceptable.	Dredging back to 1996 ADH calculated 1.8 million tons of scour for Tropical Storm Lee vs. 3 million tons of scour with 2011 bathymetry thus dredging resulted in a 66% percent reduction in scour load (simulation period 2008 -2011). Total sediment load to the bay with 1996 bathymetry was 20.3 million tons while with 2011 bathymetry it was 22.3 representing a 10% decrease in total load to the Bay. Reservoir sedimentation was 6.0 million tons with 1996 bathymetry and 4.0 million tons compared to 2011 thus a 33% increase in deposition. CBEMP (1991-2000 time periods) calculated that dredging back to the 1996 bathymetry reduced scour of the January 1996 storm by 45% of the scour load of a "full" Conowingo.	In theory this would amount to 31 mcy, roughly the amount equivalent to dredging Conowingo back to 1996 bathymetry. Approximately 1.5 million tons of sediment is estimated to accumulate every year in Conowingo Reservoir. If you removed 3 million cubic yards per year (2.4 million tons per year) for 10 years, you do not go back to the 1996 bathymetry. In addition, because you are increasing storage capacity, more incoming sediment is depositing. Assuming the deposition is 1.5 million tons a year you deposit 15 million and remove 24 million over 10 years, with a net removal of 9 million tons over 10 years (net removal of 0.9 million tons per year). In reality, the benefits are likely to be less than Scenario 5 since deposition will occur during the ten-year interval.	Sediment storage capacity will not change and building up another section of the reservoir with sediment may change flow patterns and induce scour in other areas.	Determined that the maximum available sediment per year that could be reduced by additional BMP implementation above and beyond the WIP implementation throughout the lower Susquehanna River Watershed is approximately a reduction of 243, 000 cubic yards (197, 500 tons) annually. This is about 1/5th of what is estimated to flow over the Conowingo Dam into the Chesapeake Bay on a average annual basis (approximately, 1M tons/year).

	1. What are the effects of agitation dredging?	2. What are the effects of strategic dredging? **"LSRWA 28"**	3a. What are the effects of passing sediment downstream for 3 winter months, one time?	3b. What are the effects of passing sediment downstream for 3 winter months, over-time for a period of 10 years? **"LSRWA 29"**	4. What are the effects of passing sediment downstream for 9 months?	5. What are the effects of extreme removal out of system) restoring to 1996 bathymetry? **"LSRWA 31"**	6. What are the effects of long-term strategic dredging over time for a period of 10 years?	7. What are the effects of moving sediment from scour areas to depositional areas?	8. What are the effects of increasing Best management practices in the watershed above that required to meet TMDL?
Nutrient Loads	Not determined.	The nitrogen scour load estimated by CBEMP for the January 1996 storm with strategic dredging is 4,815 metric tons organic nitrogen. The phosphorus scour load estimated by CBEMP is 1,605 metric tons particulate phosphorus. These represent 32% reductions from 1996 scour load calculated with 2011 bathymetry.	The one-time additional nutrient load estimated by CBEMP are 6,545 tons organic nitrogen and 2,182 tons particulate phosphorus.	The additional organic nitrogen and particulate phosphorus loads associated with bypass estimated by CBEMP are 6,545 metric tons/annum and 2,182 metric tons/annum respectively.	Not Determined.	The nitrogen scour load estimated by CBEMP for the January 1996 storm with extreme long-term removal is 3.942 metric tons organic (particulate) nitrogen. The phosphorus scour is 1,314 metric tons particulate phosphorus. These represent 45% reductions from scour load calculated with 2011 bathymetry by CBEMP.	Under ideal circumstances the benefits from this scenario would be the same as Scenario 5. These are the benefits realized from net removal of 3 mcy/year for 10 years. In reality, the benefits are likely to be less since deposition will occur during the ten-year interval. Results in Column 5 should be regarded as the "best case" results from long-term strategic dredging.	Not Determined.	We have no projections for nutrient loads reductions to accompany the solids load reductions. .

	1. What are the effects of agitation dredging?	2. What are the effects of strategic dredging? **"LSRWA 28"**	3a. What are the effects of passing sediment downstream for 3 winter months, one time?	3b. What are the effects of passing sediment downstream for 3 winter months, over-time for a period of 10 years? **"LSRWA 29"**	4. What are the effects of passing sediment downstream for 9 months?	5. What are the effects of extreme removal out of system) restoring to 1996 bathymetry? **"LSRWA 31"**	6. What are the effects of long-term strategic dredging over time for a period of 10 years?	7. What are the effects of moving sediment from scour areas to depositional areas?	8. What are the effects of increasing Best management practices in the watershed above that required to meet TMDL?
General Water Quality Effects	Not determined.	Effects of this one-time dredging are most obvious in the summer following the scour event. Dissolved oxygen improvements extend along the trench of the bay from Baltimore Harbor to the mouth of the Potomac and into the Potomac trench. Reductions in chlorophyll are roughly of the same extent. Limited benefits are seen in light attenuation, primarily because the scoured sediments settle our or are dispersed before the SAV growing season.	It was determined this scenario did not merit the time and resources necessary to complete it in full. Dredging and bypassing for solely one year is an unlikely management strategy. We project the effects of one year of bypassing would be no worse in magnitude than Column 3b. The temporal extent would be limited primarily to the summer season following the bypassing. Detrimental effects would diminish with time thereafter.	Water quality deteriorates as a result of sediment bypassing. The effects are widespread, ranging from near the head of the bay to the mouth of the Potomac River and beyond. The lower Potomac River is affected as well. Diminished water quality is seen in all years of our simulation since the bypassing takes place in all years.	Not Determined.	The benefits from dredging back to 1996 conditions extend from above Baltimore harbor to the mouth of the Potomac River and, in some years, into the Potomac River. Since the benefit comes from a one-time storm event, the extent and magnitude of the benefits generally diminish with time following the storm.	The benefits from this scenario, when dredging is completed as a best (but unlikely) case are the same as Scenario #5.	Not Determined.	The water quality effects will vary from year to year depending on hydrology and annual loading. Experience with other scenarios indicates the benefits from solids reductions are limited since the loads largely enter during non-critical periods for SAV. We have no projections for nutrient loads reductions to accompany the solids load reductions.
Dissolved Oxygen (DO)	Not determined.	Summer-average DO improvements are largely 0.01 to 0.02 mg/L. Occasional improvements up to 0.04 mg/L are seen limited areas.	Potential declines of 0.2 to 0.3 mg/L estimated for the summer immediately following the bypassing. This estimate is based on results of the model run completed with sediment bypassing for ten years.	Summer-average declines of 0.2 to 0.3 mg/L are widespread. DO declines more than 0.3 mg/L in portions of the deep trench at the head of the bay.	Not Determined.	The improvement in summer-average DO is 0.02 to 0.04 mg/L in widespread regions of the bay and lower Potomac. Occasional improvements in excess of 0.04 mg/L are noted. The benefits are primarily in the one or two summers following the storm event.	The benefits from this scenario, when dredging is completed, are the same as Scenario 5.	Not Determined.	Not Determined.

	1. What are the effects of agitation dredging?	2. What are the effects of strategic dredging? **"LSRWA 28"**	3a. What are the effects of passing sediment downstream for 3 winter months, one time?	3b. What are the effects of passing sediment downstream for 3 winter months, over-time for a period of 10 years? **"LSRWA 29"**	4. What are the effects of passing sediment downstream for 9 months?	5. What are the effects of extreme removal out of system) restoring to 1996 bathymetry? **"LSRWA 31"**	6. What are the effects of long-term strategic dredging over time for a period of 10 years?	7. What are the effects of moving sediment from scour areas to depositional areas?	8. What are the effects of increasing Best management practices in the watershed above that required to meet TMDL?
Chlorophyll Concentration (CHL)	Not determined.	Chlorophyll reductions are largely in the range 0.02 to 0.05 ug/L, with limited regions showing improvements greater than 0.05 ug/L. The improvements are spatially-extensive in the summer following the scour event but diminish in successive years.	Potential increases of 0.5 to 1.5 ug/L for the SAV growing season following the bypassing.	Chlorophyll increases, during the SAV growing season, from 0.5 to 1.5 ug/L over large portions of the upper bay. Excursions greater than 2 ug/L are seen in limited areas.	Not Determined.	Summer-average chlorophyll declines by 0.02 to 0.05 ug/L in a large expanse of the bay and lower Potomac River. The spatial extent of the benefits diminishes with time following the storm event	The benefits from this scenario, when dredging is completed, are the same as Scenario 5.	Not Determined.	Not Determined.
Light Attenuation (KE)	Not determined.	Little change occurs in light attenuation, approximately 0.01/m. The improvement is minimal because the SAV growing season is months after the scour event.	Minimal effects on light attenuation. The solids from bypassing will settle out of the system before the SAV growing season.	Light extinction increases by 0.01 to 0.025/m in the reach of the bay from head to the Potomac River. The increases are attributed to increased chlorophyll rather than suspended sediments.	Not Determined.	Improvements in light attenuation during the SAV growing season are minimal, 0.01/m or less. As with other scenarios, the solids effects from a winter storm do not extend into the prime growing season.	The benefits from this scenario, when dredging is completed, are the same as Scenario 5.	Not Determined.	Not Determined.
Deep Channel DO Water Quality Standard Achievement for Total Maximum Daily Load	Not determined.	An (improved) decrease of 0.2% non-attainment over Scenario with WIPs in effect, existing bathymetry, scour event in winter (LSRWA 21/ Scenario 3 of Baseline and Future conditions table) was estimated for CB3MH and CB4MH and a 0.1% decrease in non-attainment in EASMH.	Not Determined.	An estimated increase of non-attainment of 4% at CB3MH, 5% at CB4MH , 3% at CHSMH, 4% at EASMH, and 2% at PATMH over Scenario with WIPS in effect, existing bathymetry, scour event in winter (LSRWA 21/ Scenario 3 of Baseline and Future conditions table.	Not Determined.	An (improved) decrease of non-attainment over Scenario with WIPS in effect, existing bathymetry, scour event in winter (LSRWA 21/ Scenario 3 of Baseline and Future conditions table) of 0.3% at CB3MH, 0.5% at CB4MH, and 0.2% at EASMH was estimated at CB4MH was estimated.	Not Determined.	Not Determined.	Not Determined.

	1. What are the effects of agitation dredging?	2. What are the effects of strategic dredging? **"LSRWA 28"**	3a. What are the effects of passing sediment downstream for 3 winter months, one time?	3b. What are the effects of passing sediment downstream for 3 winter months, over-time for a period of 10 years? **"LSRWA 29"**	4. What are the effects of passing sediment downstream for 9 months?	5. What are the effects of extreme removal out of system) restoring to 1996 bathymetry? **"LSRWA 31"**	6. What are the effects of long-term strategic dredging over time for a period of 10 years?	7. What are the effects of moving sediment from scour areas to depositional areas?	8. What are the effects of increasing Best management practices in the watershed above that required to meet TMDL?
Deep Water DO Water Quality Standard Achievement for Total Maximum Daily Load	Not determined.	An (improved) decrease of 0.1% nonattainment over Scenario with WIPs in effect, existing bathymetry, scour event in winter (LSRWA 21/ Scenario 3 of Baseline and Future conditions table) was estimated for CB4MH.	Not determined.	Estimated increases of 2% nonattainment at CB4MH, 1% non-attainment at CSHMH, EASMH, MD5MH and PATMH Scenario with WIPs in effect, existing bathymetry, scour event in winter (LSRWA 21/ Scenario 3 of Baseline and Future conditions table).	Not determined.	An (improved) decrease of nonattainment over Scenario with WIPs in effect, existing bathymetry, scour event in winter (LSRWA 21/ Scenario 3 of Baseline and Future conditions table) was estimated to be 0.3% at CB3MH, 0.5% at CB4MH, and 0.2% at EASMH was estimated.	Not determined.	Not determined.	Not determined.
Open Water DO Water Quality Standard Achievement for Total Maximum Daily Load	Not determined.	Complete attainment of open water DO standard was estimated.	Not determined.	Complete attainment of open water DO standard was estimated.	Not determined.	Complete attainment of open water DO standard was estimated.	Not determined.	Not determined.	Not determined.
Submerged Aquatic Vegetation (SAV) clarity water quality Achievement for Total Maximum Daily Load	Not determined.	Complete attainment was estimated.	Not determined.	Complete attainment was estimated.	Not determined.	Complete attainment was estimated.	Not determined.	Not determined.	Not determined.

- Conversion: 1 mcy =.81 tons

Attachment J-5:
Summary of Model Inputs and Results for Each Significant LSRWA Model Run

Attachment J-5:
Summary of Model Inputs and Results for Each Significant LSRWA Model Run

The accompanying table provides a summary of the significant model runs performed during this watershed assessment. For each LSRWA model run, the run is described by the study question being evaluated, the models used, the watershed load in terms of the land use conditions, the Conowingo Reservoir bathymetry, the scour load method, and the sediment nutrient content. In addition, the non-attainment analytical time period and results are presented for those model runs where nonattainment was analyzed.

This is a summary of all significant model runs performed for the Lower Susquehanna River Watershed Assessment involving the Chesapeake Bay Environmental Modeling Package (CBEMP). However, there were additional alternative scenarios evaluated which did not involve the CBEMP model. These scenarios are discussed in other tables in the main report (Tables 3-2 and 5-7). ERDC/EPA-CBPO ran roughly 30 modeling runs utilizing CBEMP. Modeling runs were denoted by "LSRWA-number." Only the significant modeling runs are reported here. A number of modeling runs conducted early in the study were supplanted as the modeling team developed improved information and understanding.

Summary of Model Inputs and Results for Each Significant LSRWA Model Run

Model Run	Description or Study Question	Models Used	Land Use (i.e., watershed sediment/nutrient loads)	Reservoir Bathymetry	Reservoir Scour Load Method	Reservoir Sediment Nutrient Content	Time Period Analyzed for WQ Nonattainment	Deep-Channel DO Nonattainment in CB4MH	Deep-Channel DO Nonattainment in EASMH	Deep-Channel DO Nonattainment in CHSMH
LSRWA-3	What is the system's condition when WIPS are in full effect and reservoirs have not all reached dynamic equilibrium?	CBEMP[1,2]	TMDL – WIPs in place	1991-2000 condition	None	N/A	1993-1995	0%	0%	0%
LSRWA-4	What is the system's current (existing) condition?	CBEMP	2010 land use	1991-2000 condition	None	N/A	1993-1995	23%	14%	28%
LSRWA-5	2010 land use with Conowingo reservoir removed from WSM. All sediments and nutrients pass through – no deposition or scour.	CBEMP	2010 land use	N/A	N/A	N/A	Not analyzed	Not analyzed	Not analyzed	Not analyzed
LSRWA-6	TMDL land use with Conowingo reservoir removed from WSM. All sediments and nutrients pass through – no deposition or scour.	CBEMP	TMDL – WIPs in place	N/A	N/A	N/A	Not analyzed	Not analyzed	Not analyzed	Not analyzed
LSRWA-18	What is the system's condition when WIPS are not in effect, reservoirs have all reached dynamic equilibrium and there is a winter scour event?	HEC-RAS AdH CBEMP	2010 land use	"Conowingo Full" condition	Excess volume method from AdH results (from 2008 bathymetry)	2011 Tropical Storm Lee	Not analyzed	Not analyzed	Not analyzed	Not analyzed
LSRWA-20	2010 land use with sediment/nutrient from Conowingo scour added in.	HEC-RAS[3] AdH CBEMP	2010 land use	2008 condition	Excess volume method from AdH results (from 2011 bathymetry)	2011 Tropical Storm Lee	Not analyzed	Not analyzed	Not analyzed	Not analyzed
LSRWA-21	What is the system's condition when WIPS are in full effect, reservoirs have not all reached dynamic equilibrium and there is a winter scour event?	HEC-RAS AdH CBEMP	TMDL – WIPs in place	2011 condition	Excess volume method from AdH results (from 2011 bathymetry)	2011 Tropical Storm Lee	1996-1998	1%	1%	1%
LSRWA-22	TMDL land use, sediment/nutrients from Conowingo scour added in	HEC-RAS AdH CBEMP	TMDL – WIPs in place	2008 condition	Excess volume method from AdH results (from 2008 bathymetry)	January 1996 flood event	1996-1998	1%	1%	1%
LSRWA-23	TMDL land use, 1996 storm removed from hydrologic record and load record	CBEMP	TMDL – WIPs in place	2008 condition	N/A	N/A	Not analyzed	Not analyzed	Not analyzed	Not analyzed
LSRWA-24	What is the system's condition when WIPS are in full effect, reservoirs have not all reached dynamic equilibrium and there is a summer scour event?	HEC-RAS AdH CBEMP	TMDL – WIPS in place	2011 condition	Excess volume method from AdH results (from 2008 bathymetry)	2011 Tropical Storm Lee	1996-1998	4%	8%	3%
LSRWA-25	What is the system's condition when WIPS are in full effect, reservoirs have not all reached dynamic equilibrium and there is a fall scour event?	HEC-RAS AdH CBEMP	TMDL – WIPS in place	2011 condition	Excess volume method from AdH results (from 2008 bathymetry)	2011 Tropical Storm Lee	1996-1998	0%	0%	2%
LSRWA-26	TMDL land use, January 1996 storm moved to June 1996	HEC-RAS AdH CBEMP	TMDL – WIPs in place	2008 condition	Excess volume method from AdH results (from 2008 bathymetry)	January 1996 flood event	Not analyzed	Not analyzed	Not analyzed	Not analyzed

Summary of Model Inputs and Results for Each Significant LSRWA Model Run

Model Run	Description or Study Question	Models Used	Land Use (i.e., watershed sediment/nutrient loads)	Reservoir Bathymetry	Reservoir Scour Load Method	Reservoir Sediment Nutrient Content	Time Period Analyzed for WQ Nonattainment	Deep-Channel DO Nonattainment in CB4MH	Deep-Channel DO Nonattainment in EASMH	Deep-Channel DO Nonattainment in CHSMH
LSRWA-27	TMDL land use, January 1996 storm moved to October 1996	HEC-RAS AdH CBEMP	TMDL – WIPs in place	2008 condition	Excess volume method from AdH results (from 2008 bathymetry)	January 1996 flood event	Not analyzed	Not analyzed	Not analyzed	Not analyzed
LSRWA-28	TMDL land use, sediment/nutrients from Conowingo scour added, 3 MCY dredged from Conowingo Pond	HEC-RAS AdH CBEMP	TMDL – WIPs in place	Post dredging (3 MCY removed)	Excess volume method from AdH results (from 2008 bathymetry, dredged 3 MCY)	2011 Tropical Storm Lee	1996-1998	0.2%	0.1%	0%
LSRWA-29	TMDL land use, sediment/nutrients from Conowingo scour added, 3 MCY removed from Conowingo Pond to represent bypassing, sediments/nutrients bypassed downstream from December-February every year	HEC-RAS AdH CBEMP	TMDL – WIPs in place	Post dredging (3 MCY removed), bypassing during some months	Excess volume method from AdH results (from 2008 bathymetry, dredged 3 MCY)	2011 Tropical Storm Lee	1996-1998	5%	4%	3%
LSRWA-30	What is the system's condition when WIPS are in full effect, the reservoirs have all reached dynamic equilibrium and there is a winter scour event?	HEC-RAS AdH CBEMP	TMDL – WIPs in place	"Conowingo Full" condition	Excess volume method from AdH results (from 2011 bathymetry)	2011 Tropical Storm Lee	1996-1998	1%	1%	1%
LSRWA-31	TMDL land use, sediment/nutrients from Conowingo scour added in.	HEC-RAS AdH CBEMP	TMDL – WIPs in place	1996 condition	Excess volume method from AdH results (from 2011 bathymetry)	2011 Tropical Storm Lee	Not analyzed	Not analyzed	Not analyzed	Not analyzed

NOTES:

1. This is a summary of all significant CBEMP model runs performed for the Lower Susquehanna River Watershed Assessment. However, there were additional alternative scenarios evaluated which did not involve the CBEMP model. These scenarios are discussed in other tables in the main report (Tables 3-2 and 5-7).
2. ERDC/EPA-CBPO ran roughly 30 modeling runs utilizing CBEMP. Modeling runs were denoted by "LSRWA-number." Only the significant modeling runs are reported here. A number of modeling runs conducted early in the study were supplanted as the modeling team developed improved information and understanding.
3. CBEMP is a suite of models used to assess Chesapeake Bay water quality conditions. Sub-models within CBEMP include the watershed model (WSM), a hydrodynamic model (HM) and a water quality/eutrophication model (WQM).
4. CBEMP is always run for a hydrologic period from 1991-2000. AdH and HEC-RAS were always run using the four-year 2008-11 hydrologic period (January 1, 2008 through December 31, 2011).
5. HEC-RAS informed the AdH model but did not explicitly determine the daily sediment loads and rating curves used in the AdH model.

Appendix K:
Existing Conditions of the Watershed

Table of Contents

List of Tables

List of Figures

Appendix K
Existing Conditions of the Watershed

The Chesapeake Bay and its watershed are among the most well-studied and best-understood estuaries and watersheds in the world. This section presents information germane to the lower Susquehanna River including the series of dams and reservoirs on the river, as well as the Chesapeake Bay watershed. At times, discussion will focus on the Conowingo Reservoir (and its dam) since it is the largest and most downstream reservoir. Holtwood and Safe Harbor Dams were known to be in dynamic equilibrium at the start of this assessment. Because Conowingo Reservoir was not believed to be in dynamic equilibrium and its reaching that condition could have a potentially large effect on the Bay, more attention is focused on Conowingo Dam than Holtwood or Safe Harbor Dams in this section.

This document summarizes information readily available on the CBP's website accessible at http://www.chesapeakebay.net, and the SRBC website, which is accessible at http://www.srbc.net. References are provided in the text for specific information that is from less readily available sources, such as from primary literature or government agency or privately-funded studies (gray literature). Substantial monitoring has been conducted in the vicinity of Conowingo Dam to meet various permitting requirements over the last several decades under the auspices of the MDNR Power Plant Research Program (Patty et al., 1999).

Several investigations were conducted specifically for this study to obtain additional detailed existing conditions information needed for modeling and plan formulation purposes. Reports from these investigations, conducted by Maryland Geological Survey (MGS), US Geological Survey (USGS), and US Army Corps of Engineers (USACE) Engineer Research and Development Center (ERDC), are presented in other appendices to this report package. Findings of those investigations applicable to sediment and associated nutrient management strategy development are discussed in Chapters 4 and 5 of the main report of this assessment instead of being presented in this section.

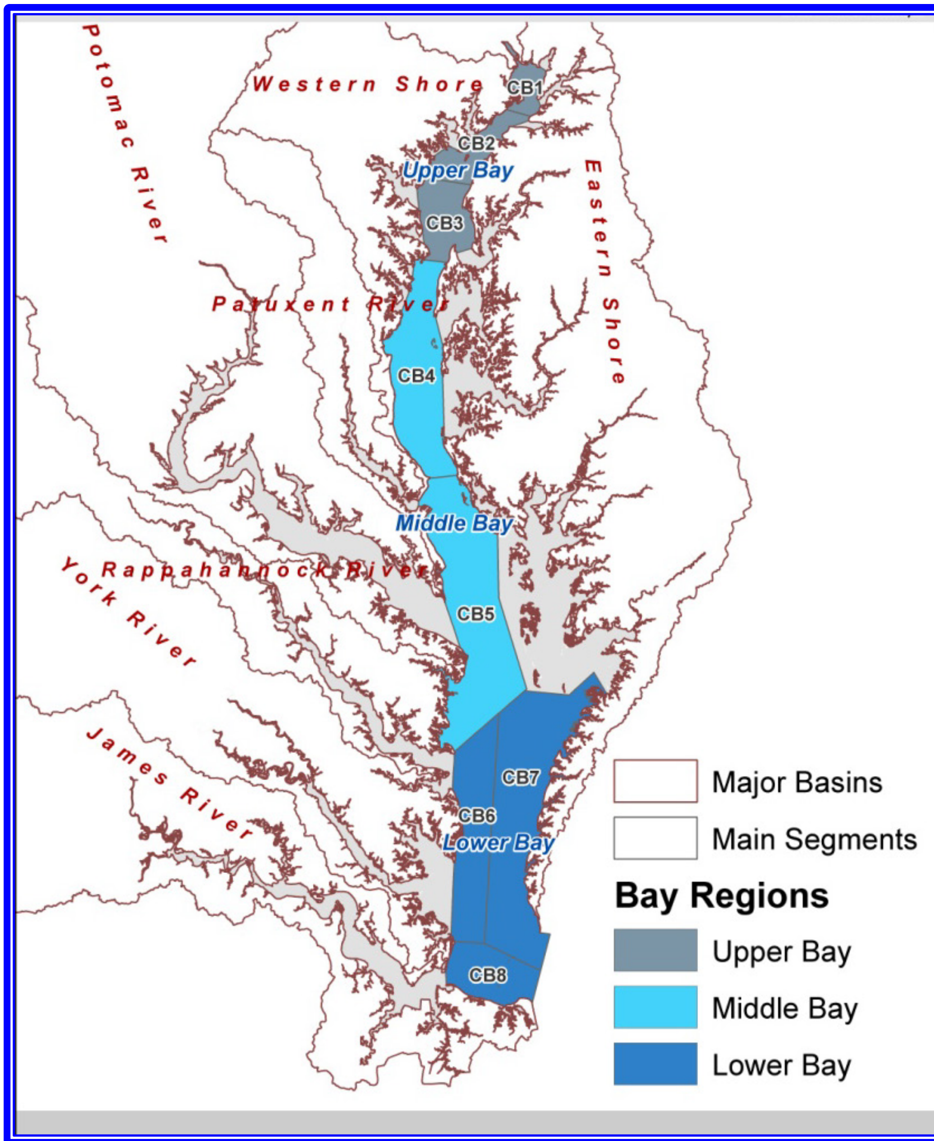
This section presents information on the Bay in terms of upper, middle, and lower Bay, as described in Table K-1 and depicted in Figure K-1. This geographic subdivision correlates with Bay salinity patterns. By this geographic subdivision, the upper Bay lies in Maryland waters, the middle Bay includes waters within Maryland and Virginia, and the lower Bay lies within Virginia.

For the Susquehanna River basin, this section presents information based on whether it applies to the lower Susquehanna River subbasin, other subbasins in the basin, or the entire basin, as appropriate. The lower Susquehanna River subbasin is that region of the Susquehanna River basin downstream of Sunbury, PA, to Havre de Grace, MD, excluding the Juniata River subbasin, as shown in Figure 1-1 of the main report of this assessment.

Table K-1. Bay Regions and Geographic Location

Region	Bay and Tributaries
Upper	North of the Chesapeake Bay Bridge to mouth of the Susquehanna River
Middle	Chesapeake Bay Bridge south to the mouth of the Rappahannock River/Tangier Island
Lower	South of the Rappahannock River mouth/Tangier Island to the mouth of Chesapeake Bay

Figure K-1. Major Regions of the Chesapeake Bay Mainstem



Source: Chesapeake Bay Program.

K.1 PHYSIOGRAPHY AND TOPOGRAPHY

K.1.1 Chesapeake Bay

The Chesapeake Bay is oriented north/south lengthwise with much of its interior remote from oceanic influences or flushing seawater. Table K-2 presents a summary of the Bay's physical characteristics. The Bay possesses a large watershed in relation to its surface water area; for every acre of water, there is more than 14 acres of land – a primary reason for the influence that its land use has on Bay water quality. The Bay is predominantly shallow and flat-floored, but possesses a deep axial channel in the mainstem and then other local deep-channel segments in tributary waterways. Additionally, dredged channels merge with these natural deep areas down the Bay mainstem, as well as on many of the tributary rivers (CBP, 2013).

At its northern end from the mouth of the Susquehanna River to about the area of Spesutie Island/Elk Neck, the Bay possesses a broad area of shallow water called Susquehanna Flats, which is depicted in Figure K-2. This area constitutes the delta of the Susquehanna River, and consists of shoals and sandbars extending for several miles in an east-west and north-south direction (Robertson, 1998). Much of this area is vegetated with submerged aquatic vegetation (SAV). Several deeper water channels extend out from the mouth of the Susquehanna River into the upper Bay and flats. Only the navigation channel extending from Havre de Grace to the south fully connects with waters of equivalent depth in the mainstem Bay. Shallow waters of the Susquehanna River delta in the upper Bay expanded substantially in area following European settlement, and the expansive shallow flats that exist today largely derive from anthropogenic sedimentation (Gottschalk, 1945).

Susquehanna River

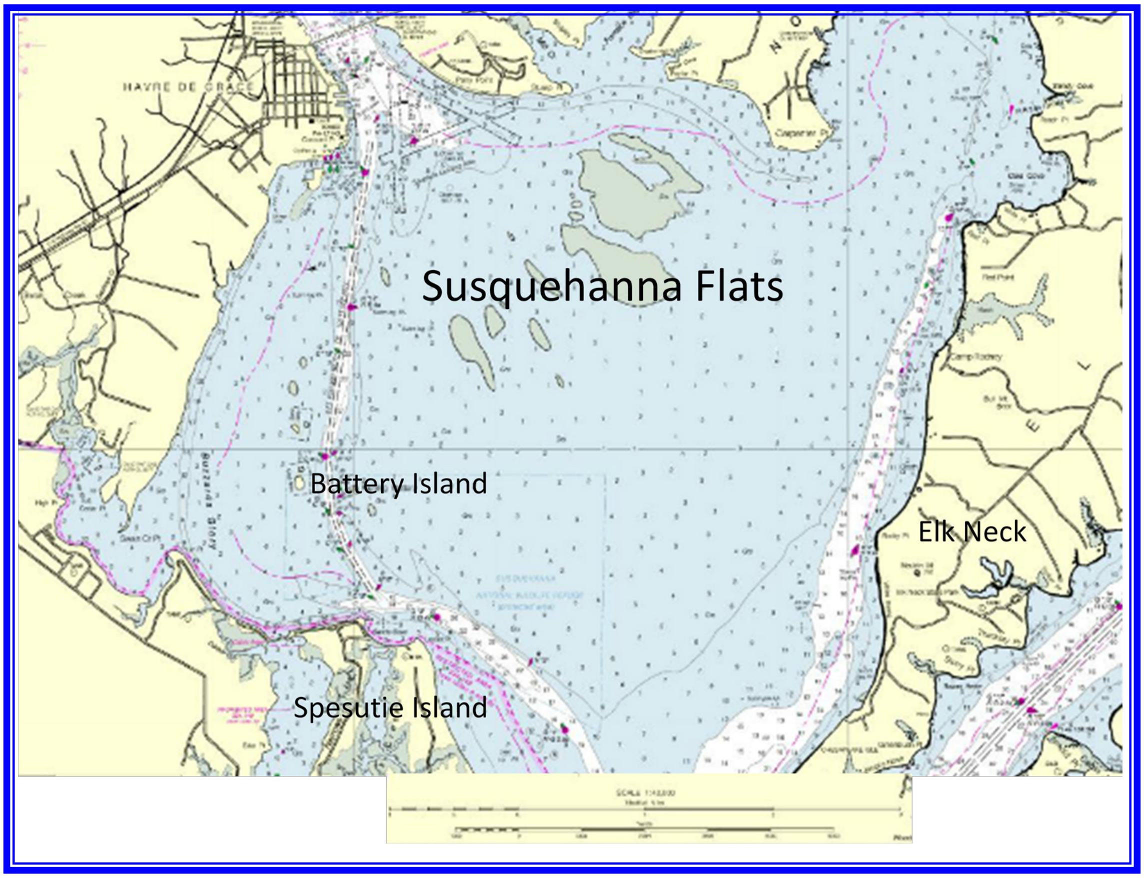
Most of the basin's headwaters originate on the Appalachian Plateau, and the river crosses the Ridge and Valley and Piedmont physiographic provinces before reaching the Bay. The mainstem Susquehanna River has an average gradient of 5 feet per mile, but has many areas of locally steeper gradients through riffles and rapids. The width of the Susquehanna River varies greatly along its length. The river is several hundred feet in width where it enters Pennsylvania from New York,

Table K-2. Chesapeake Bay Metrics

Characteristic	Metric
Length	200 miles
Width	4 miles at Aberdeen, MD, to 30 miles at Cape Charles, VA
Average Depth	21 feet
Maximum Depth	174 feet
Water Surface Area	4,480 square miles
Water Volume	18 trillion gallons
Watershed Area	64,000 square miles

Source: CBP, 2013.

Figure K-2. Susquehanna Flats



Notes: The light gray-green areas are intertidal; the light blue areas are less than 6 feet deep; and the white areas are greater than 6 feet deep MLLW (mean lower low water).
Source: NOAA NOS (National Oceanic and Atmospheric Administration National Ocean Service) Nautical Chart 12274.

increasing to about a half mile in width in natural sections of the river below Conowingo Dam. River width is increased greatly in the reservoirs immediately upstream of the Safe Harbor, Holtwood, and Conowingo Dams, to as much as a mile (PFBC, 2011).

K.1.2 Conowingo Reservoir, Lake Aldred, and Lake Clarke

Each of the three lower Susquehanna reservoirs contains islands at its upstream end. Water depths in Lake Clarke and Conowingo Reservoir increase towards the downstream end (where the dam is located). In contrast, Lake Aldred's greatest depths occur in the middle of the lake, and lake depth decreases near the dam.

Lake Clarke is the shallowest, averaging about 15 feet deep. Lake Aldred is the deepest, with greatest depths of 80 to 120 feet. The deepest areas of Conowingo Reservoir are located near the dam, with reservoir depths averaging about 55 feet along the spillway gates and about 70 feet near the turbine gates. Substrate depth near Conowingo Dam is controlled by turbulence from the turbines (Langland and Hainly, 1997).

K.1.3 Upland in Vicinity of Dams

The three dams of interest to this study lie across the Susquehanna River within the valley carved out by the river. Rolling hills of the Piedmont in the vicinity of Conowingo Dam above the river valley range in elevation from 250 to 400 feet maximum. The uplands above the river gorge in the vicinity of Safe Harbor and Holtwood Dams rise to about 750 feet in elevation. The dams flooded lower elevation lands in the river valley.

Conowingo Dam lies about 8 miles upstream of the boundary between the Piedmont and Coastal Plain physiographic provinces on the Susquehanna River. The southern portion of the lower Susquehanna River subbasin lies in the Piedmont physiographic province. The vicinity of the Safe Harbor, Holtwood, and Conowingo Dams is underlain by metamorphosed rock that is resistant to erosion. This material caused the river to carve a deep gorge into the bedrock in a narrow river valley (SRBC, Subbasin Information, 2013). Historic and active quarries produce large topographic depressions in upland areas.

K.2 CLIMATE

The Susquehanna River basin possesses a sub-temperate and humid climate. Continental weather conditions include cold winters with snow events and warm to hot summers. Within the basin, precipitation and temperature are largely influenced by latitude and elevation. Both precipitation and temperature increase from north to south and from west to east. Average annual air temperatures are approximately 44°F in the northern portion of the basin and 53°F in the southern portion. Average annual precipitation in Susquehanna River basin ranges from approximately 33 to 49 inches. An estimated 52 percent of this total precipitation is lost by evapotranspiration; the remaining 48 percent infiltrates to groundwater or results in overland flow and streamflow runoff (SRBC, 2013a).

Across the Susquehanna River basin, precipitation events can be severe, ranging from localized thunderstorms to regional hurricanes. Storms that generate flooding in the study area include northeasters and tropical storms. Northeasters can produce precipitation for a duration of up to several days, and occur most frequently between December and April. Tropical storms produce intense runoff over a shorter period of time, usually occurring between July and October.

Climate trends in the last two decades have shown wetter conditions on average, than in previous decades. Increased precipitation has produced higher annual minimum flows and slightly higher median flows during summer and fall (Najjar et al., 2010). Section 4.1.4 of the main report of this assessment covers the topic of forecast climate change in more detail.

K.3 LAND USE

Land use is the human use of land – the natural and built environment features covering the earth's surface that comprise land cover. As of 2003, 23 percent of the Chesapeake Bay watershed is used for agriculture and almost 12 percent has been developed. Developed lands are concentrated in the vicinity of the cities of Baltimore, Norfolk, Richmond, Harrisburg, Scranton, Binghamton, and Washington, DC, and their respective suburbs and radiating development corridors. Most of the remaining land is forested. Agricultural land use shows a downward trend over the last several decades, while developed land use shows an increasing trend over the same time period (CBP, 2013).

Land use patterns vary greatly within the Susquehanna River watershed, but range generally from primarily forested in the upstream portions of the basin, to primarily agricultural and urban in the downstream portions of the basin. These land use patterns specific to Susquehanna River watershed are illustrated further in Table K-3 and Figure K-3.

Of the six subbasins in the Susquehanna River watershed, the lower Susquehanna subbasin is the most developed. The lower Susquehanna subbasin is a major production area for hydroelectricity by virtue of the geomorphic conditions, history, and proximity to human population favoring its development there. Some of the most productive agricultural lands and largest population centers of the Susquehanna River basin are located in the lower Susquehanna subbasin. Intense agricultural activity occurs in many of the fertile soils throughout the subbasin. Significant urban areas include York, Lancaster, and Harrisburg, all in Pennsylvania (SRBC, 2013a).

Land use affects anthropogenic nutrient inputs to the Bay and streams of the Susquehanna River watershed. Excess nutrient inputs to the Bay are the principal stressor to the Bay ecosystem. Agricultural and urban land uses generate nitrogen and phosphorus nutrient pollution, while forests tend to retain most of the atmospherically deposited pollution they receive. Fertilized soils yield more phosphorus nutrient pollutants when eroded than non-fertilized soils. Even though forest is the largest single land cover in the Bay watershed, runoff from agricultural and urban lands often bypasses forests and is substantial enough to overwhelm the mitigating effects of forests on water quality, and Bay health is compromised as a result.

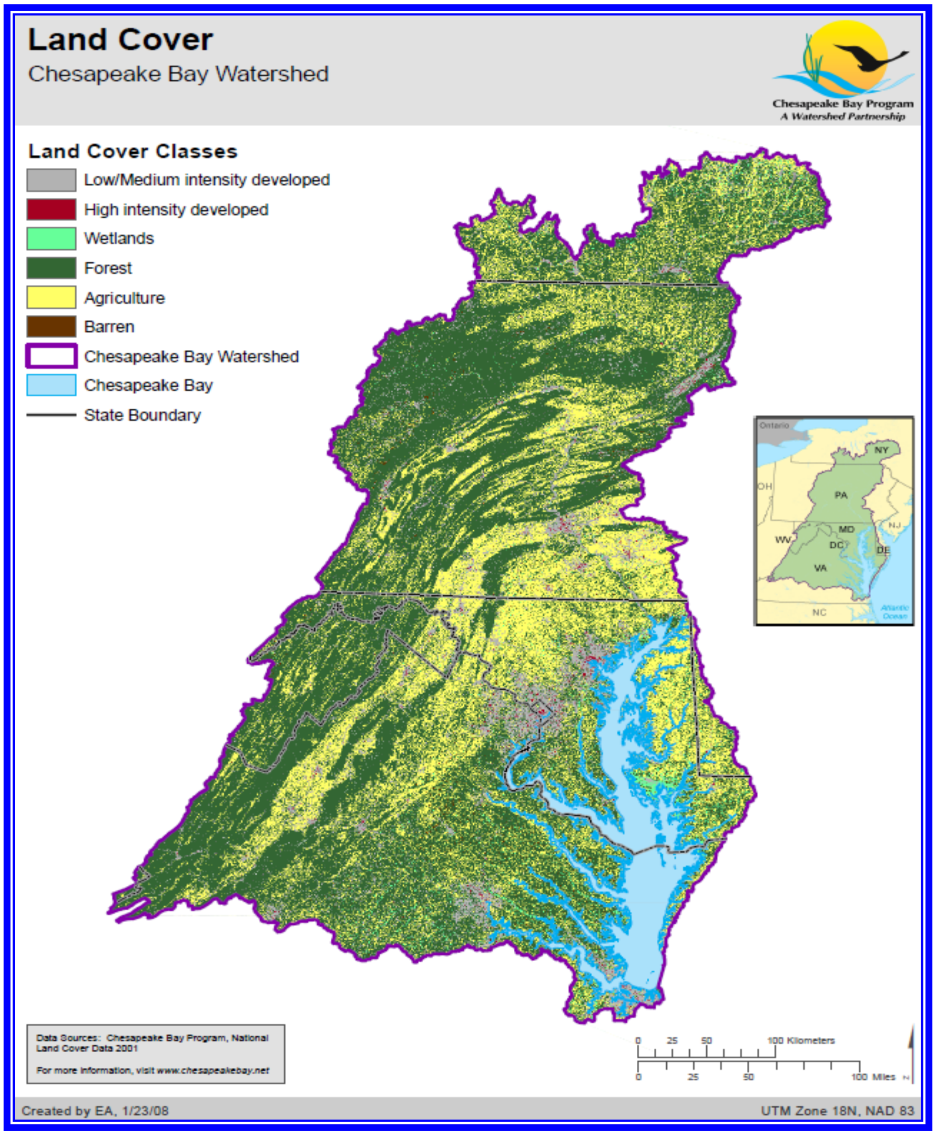
Land use also affects sediment transport processes. Agriculture and timber production can cause increased upland erosion and delivery of sediments to streams. Urbanization promotes increased runoff, which exacerbates streambank and channel erosion. Delivery of excess sediments to the Bay is of concern because of environmental and navigational impacts.

Table K-3. Land Use as Percentage of Basin Area

River Basin	Open Water	Developed	Natural Vegetation	Cultivated	Vegetated Wetland	Barren
Susquehanna	1	4	65	27	1	0
Lower Susquehanna	2	9	45	42	1	0

<u>Notes</u>: Numbers do not add up to 100 percent due to rounding.
Source: USGS, 2006.

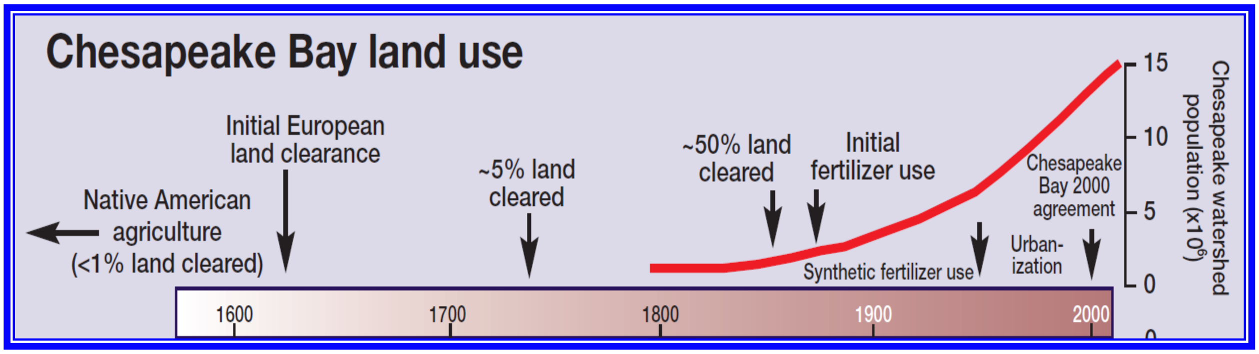
Figure K-3. Land Cover in the Chesapeake Bay Watershed in 2001



Source: Susquehanna River Basin Commission (SRBC).

The Susquehanna River basin was almost entirely forested prior to European settlement. After European settlement, large-scale deforestation and land use conversion occurred due to increased agriculture, energy demands (charcoal made from wood), and industrial logging. Deforestation peaked in the early 1900s when only 30-percent forest cover remained in the basin. Since then, forest cover has increased substantially from natural afforestation of abandoned agricultural lands, as well as the institution of modern forestry and soil conservation practices, which include planting trees (TNC, 2010). Figure K-4 illustrates these land use historical changes.

Figure K-4. Timeline of Land Use Activities from European Settlement to Present



Source: Modified from Willard and Cronin, 2007.

K.4 HYDROLOGY

K.4.1 Bay and Tidal Waters

The Chesapeake Bay is the largest estuary in the United States, and the watershed discharging into the Bay includes parts of six states (Delaware, Maryland, New York, Pennsylvania, Virginia, and West Virginia) and all of the District of Columbia. Approximately one-half of the water in the Chesapeake Bay comes from the 150 major rivers and streams in the Chesapeake drainage basin, with the Susquehanna River being the principal source of fresh water to the Bay. Atlantic Ocean water entering through the Bay mouth comprises the other half (CBP, 2013).

Bay Circulation from Rivers to Ocean

Water circulation in the Bay is primarily driven by the downstream movement of fresh water in from rivers and upstream movement of salt water from the ocean. A gradient of increasing salinity is produced proceeding oceanward. Tides pump water into and out of the Bay. In addition to salinity differences, the earth's rotation affects Bay circulation. Inflowing ocean water hugs the Eastern Shore, while outflowing Bay water hugs the Western Shore. Wind can mix the Bay's waters and occasionally reverse the direction of the flows. Major storm and flood events cause the general circulation patterns to break down (CBP, 2013).

Currents in the open waters of the middle and upper Bay are typically less than about 1 knot (1 knot is 1 nautical mile per hour, or about 1.7 feet per second). Currents through narrows and natural or dredged channels through shallow water can have velocities of up to several feet/second during ebb and flood tides. Currents in the broad shallows of the Susquehanna Flats area of the upper Bay during the SAV-growing season are typically very sluggish, and even during the non-growing season are often less than about 0.3 knots because water movement tends to be slowed by frictional forces in shallow water. Water exchange driven by tides and wind in the vicinity of the Susquehanna Flats is focused into distinct channels. Within these channels, current velocities on the order of up to several feet per second occur. Currents in the upper Bay during major Susquehanna River flow events were modeled for this study; information on this effort is presented in Appendix B of this assessment report.

Water Column

In response to regional climate variation and its relatively shallow water depths, Bay surface water temperatures fluctuate through the year, ranging from about 34°F in winter to 84°F in summer (CBP, 2013). The variation in Bay annual surface water temperatures is among the widest of any estuary in the world (Murdy, 1997, cited in Buccheister et al., 2013) due to the relatively shallow average water depths.

Less dense, fresher surface water layers are seasonally separated from saltier and denser water below by a zone of rapid vertical change in salinity known as the pycnocline (CBP, 2013). The pycnocline plays an important role in Bay water quality acting to prevent deeper water from being reoxygenated from above (Kemp et al., 1999). Pycnocline depth varies in the Bay as a function of several factors. It shows general long-term geographic patterns as summarized in Table K-4, but varies over shorter time periods as a function of precipitation and winds. When substantial freshwater inflow occurs during warm weather months it promotes stronger stratification that can last for extended periods during a year. Conversely, sustained winds in a single direction for several days can cause the pycnocline to tilt, bringing deeper water up into shallows on the margins of the Bay.

Table K-4. Pycnocline Depth by Bay Region

Bay Region	Pycnocline Depth Below Surface (feet)
Upper	9 to 12
Middle	18 to 36
Lower	12 to 30

Source: Kemp et al., 1999.

Because of this partial seasonal separation into layers, or strata, the Bay is classified as a partially stratified estuary. Division of surface from deeper waters varies depending on the season, temperature, precipitation, and winds. In late winter and early spring, melting snow and high streamflow increase the amount of fresh water flowing into the Bay, initiating stratification for the calendar year. During spring and summer, the Bay's surface waters warm more quickly than deep waters, and a pronounced temperature difference forms between surface and bottom waters, strengthening stratification. In autumn, fresher surface waters cool faster than deeper waters and freshwater runoff is at its minimum. The cooler surface water layer sinks and the two layers mix rapidly, aided by winds. During the winter, relatively constant water temperature and salinity occurs from the surface to the bottom (CBP, 2013).

Water Level Variations

Normal water level variations in the Chesapeake Bay are generally dominated by astronomical tides, although wind and freshwater discharge into the Bay have impacts as well. The tidal range is 2.8 feet at the mouth of the Bay at the Atlantic Ocean. Progressing northward up through the lower and middle Bay, the tidal range diminishes, but unevenly. The tidal range is higher at the same latitude along the Eastern Shore, as compared to the Western Shore. In the middle Bay, the tidal range reaches a minimum of 1.0 feet along Maryland's Western Shore, having a range of as much as 1.8 feet on the corresponding Eastern Shore. The tidal range increases somewhat in the upper Bay, and funneling effects increase tidal range in some tidal tributaries. The tidal range at the mouth of the Susquehanna River is 1.7 feet. Strong winds have the ability to force water in and out of the Bay, which can temporarily alter water levels. The most extreme changes in water levels occur due to storm surge caused by northeasters and hurricanes (Boicourt et al., 1999). Sea level in the Bay varies seasonally in accompaniment with prevailing wind patterns; it is typically higher in the summer than in the winter (Boicourt et al., 1999; Zervas, 2001).

K.4.2 Watershed and Surface Nontidal Waters

The Susquehanna River is the longest river located entirely within the U.S. portion of the Atlantic drainage, flowing 444 miles from Otsego Lake, NY, to the Chesapeake Bay. The drainage basin covers 27,510 square miles, including half of the land area of Pennsylvania and portions of New York and Maryland. The basin contains more than 49,000 miles of waterways. There are six major subbasins: the upper Susquehanna, Chemung, middle Susquehanna, West Branch, Juniata, and lower Susquehanna. The Susquehanna watershed encompasses over 43 percent of the Chesapeake Bay's total drainage area. The lower Susquehanna River subbasin contains numerous tributary watersheds, including Conestoga River, Conodoguinet Creek, Swatara Creek, West Conewago Creek, Penns Creek, Codorus Creek, Pequea Creek, Muddy Creek, Octoraro Creek, and Deer Creek (SRBC, 2013a).

The Susquehanna River basin includes free-flowing as well as dammed rivers. The Susquehanna mainstem is a large free-flowing river over most of its length downstream to Safe Harbor Dam in Pennsylvania. Over its free-flowing length, the river has several run-of-river dams (the final being the York Haven Dam about 14 miles downstream of Harrisburg, PA), but these have minimal water storage and do not create upstream reservoirs. Downstream of York Haven Dam, three major hydropower dams impound large segments of the Susquehanna River, creating lake environments: Safe Harbor Dam (Lake Clarke), Holtwood Dam (Lake Aldred), and Conowingo Dam (Conowingo Reservoir or Pond).

Non-tidal streamflow varies seasonally. Winter months have relatively high-flows due to low evapotranspiration and snowmelt delivering water to streams in moderately high pulse events. Streamflows peak during spring months as snowmelt increases. High pulse events are highest in magnitude and frequency during this season. More than 50 percent of the mean annual flow is delivered between March and May. Flows are lowest between July and October, when evapotranspiration rates are highest. The magnitude of median daily streamflow is significantly higher (approximately 10 times) in spring than in the summer and fall when flows are at their lowest because of evapotranspiration (TNC, 2010). During extreme flood events, strong river currents extend downstream into the upper Bay.

During the period 1985 to 2010, USGS determined that the annual average flow in the Susquehanna River near Conowingo, MD, ranged from a minimum of 23,560 cfs (cubic feet per second) to a maximum of 65,540 cfs. Median annual average flow over this time period was 35,575 cfs (Zhang et al., 2013). Droughts and storms produced substantially lesser and greater flows, respectively, over that time period, however.

USACE and SRBC recognize the Susquehanna River basin as one of the most flood-prone basins in the United States from a human impacts perspective. Flow conditions can vary substantially from month to month; floods and droughts sometimes occur in the same year. Floods can scour large volumes from the river bed and banks, and convey large quantities of nutrients and sediment downstream. Floods can occur in any month, but are most frequent in the spring months in response to rain on snowmelt events or rain on saturated soils. Floods in winter months occur typically in response to rain on snow events, possibly combined with ice jams (as in January 1996). Coastal storms or severe hurricanes typically cause summer floods (Shultz, 1999; SRBC, 2013a). Hurricane Agnes (June 1972) was the most severe flood in recent history. Flow was nearly 1 million cubic feet per second (cfs) at the Harrisburg gage, which is more than 60 times median daily streamflow (TNC, 2010; SRBC, 2013a). Together, Hurricane Irene and Tropical Storm Lee contributed more than 2 feet of rain on much of the watershed between August 27 and September 8, 2011, resulting in flows peaking at 778,000 cfs, 41 times the normal September flow of 18,800 cfs. This is the third highest flow measured at Conowingo Dam since recordkeeping began (MDNR, 2012). Although there are numerous flood control reservoirs in the basin, the cumulative hydrologic impact of these structures on the magnitude of flood events reaching the three lower dams is minimal.

The flows and water levels of the lower Susquehanna River are affected by four conventional hydroelectric stations (York Haven, Safe Harbor, Holtwood, and Conowingo) and one pumped storage project (Muddy Run). River flows in the lower basin are highly variable during any given year. Flows and water levels below each hydroelectric station fluctuate considerably based primarily on natural flow variations resulting from precipitation events, but also from electric power demand, water withdrawal, recreational use, hydropower project-related operational constraints, and point and nonpoint source discharges (URS and Gomez and Sullivan, 2012a).

Conowingo Reservoir, Lake Aldred, and Lake Clarke

Conowingo Reservoir straddles the boundary between Pennsylvania and Maryland, whereas Lakes Aldred and Clarke lie entirely in Pennsylvania. Table K-5 presents information on the physical characteristics of the three reservoirs.

Conowingo Reservoir is occasionally subject to strong winds during storm events that may result in wind-generated wave action along shorelines of the reservoir, islands, and tributaries. These winds in combination with incoming river flows and outgoing dam flows contribute to vertical circulation in the reservoir (Normandeau Associates and GSE, 2012).

Table K-5. Physical Characteristics of Manmade Water Bodies on Lower Susquehanna River

Dam	Water Body	Width Range (miles)		Channel Length (miles)
		Minimum	Maximum	
Conowingo	Conowingo Reservoir	0.3	1.3	14.7
Holtwood	Lake Aldred	0.2	1.0	8.1
Safe Harbor	Lake Clarke	0.6	1.7	9.3

Source: Hainly et al., 1995.

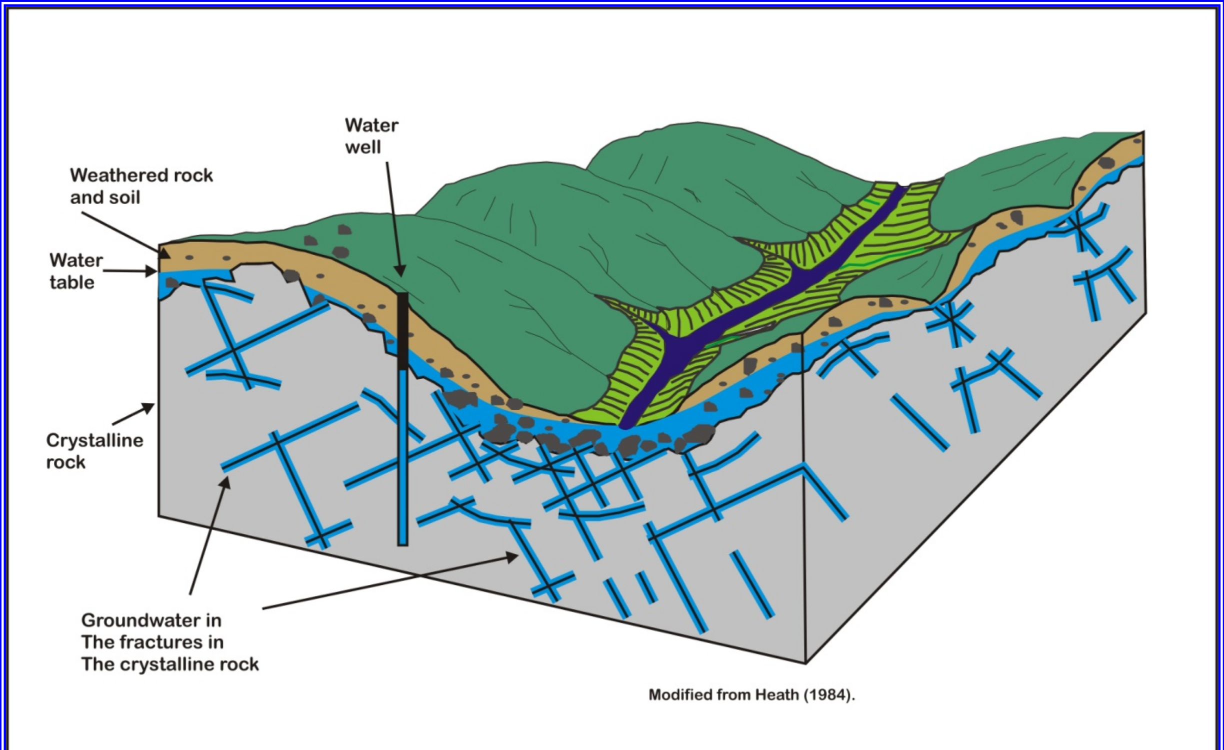
Environmental History

Changes in forest cover directly influenced historic hydrology. Following European settlement, as a consequence of reduced forest cover, streams and rivers had higher base flows during the summer and fall months. Base flows were higher because fewer trees resulted in a decrease in evapotranspiration during the growing season. Periods of low forest cover are also associated with flashier hydrographs (TNC, 2010). Water yield and sediment load from the landscape increased following European settlement with denudation from deforestation and farming (Seagle et al., 1999).

K.4.3 Groundwater

Groundwater in the Piedmont occurs at the base of saprolite (decomposed rock that has weathered in place) and in underlying bedrock. Generally, most groundwater in the crystalline rock of the Maryland Piedmont is contained in the saprolite; there is very little storage capacity in the rocks themselves, as depicted in Figure K-5. Groundwater in bedrock occurs in fluid-filled fractures in the rock, including joints and faults. These features may be subsequently expanded through weathering of the bedrock. Joints and fractures are recharged by water from the overlying saprolite (Nutter and Otton, 1969). Groundwater in Harford and Cecil Counties, MD, is typically somewhat acidic, soft to moderately hard, and may occasionally have high iron concentrations (Nutter, 1977; Otton et al., 1988). Low amounts of total dissolved solids are also common in the area's groundwater.

Figure K-5. Typical Piedmont Hydrogeologic Condition in the Chesapeake Bay Watershed



K.5 WATER QUALITY

Water quality considers chemical, physical, and biological characteristics of water. Of principal interest to this study are water quality characteristics affecting aquatic life. These include salinity, temperature, dissolved oxygen (DO), water clarity, and nutrient content. Natural physical characteristics of waterways, as well as effects of human activities, control water quality. Section 2.1 of the main report of this assessment provides information on the Clean Water Act as it relates to water quality.

K.5.1 Chesapeake Bay

Salinity

Salinity is an important factor controlling the distribution of Bay plants and animals. Salinity is the concentration of dissolved solids in water and is often discussed in terms of parts per thousand (ppt). In Maryland, Bay surface waters range from fresh in headwaters of large tidal tributaries to a maximum of about 18 parts per thousand (ppt) in the middle Bay along the Virginia border, as illustrated in Figure K-6. Salinity varies during the year, with highest salinities occurring in summer and fall and lowest salinity in winter and spring. Table K-6 provides water salinities and their classifications. Waters with 0.5 ppt to 30 ppt are described as brackish, while concentrations less than 0.5 ppt are considered fresh (CBP, 2013). Bay salinity affects other water quality parameters by controlling microbial activity and processes in the water column and sediment.

Seasonal stratification produces vertical salinity differences in warm weather months in the middle and lower Bay. Waters below the pycnocline may be several to more than 10 ppt greater in salinity than surface waters in warm water conditions. Vertical salinity differences are greatest when substantial freshwater inflow occurs during warm weather months (Maryland BayStat, 2013).

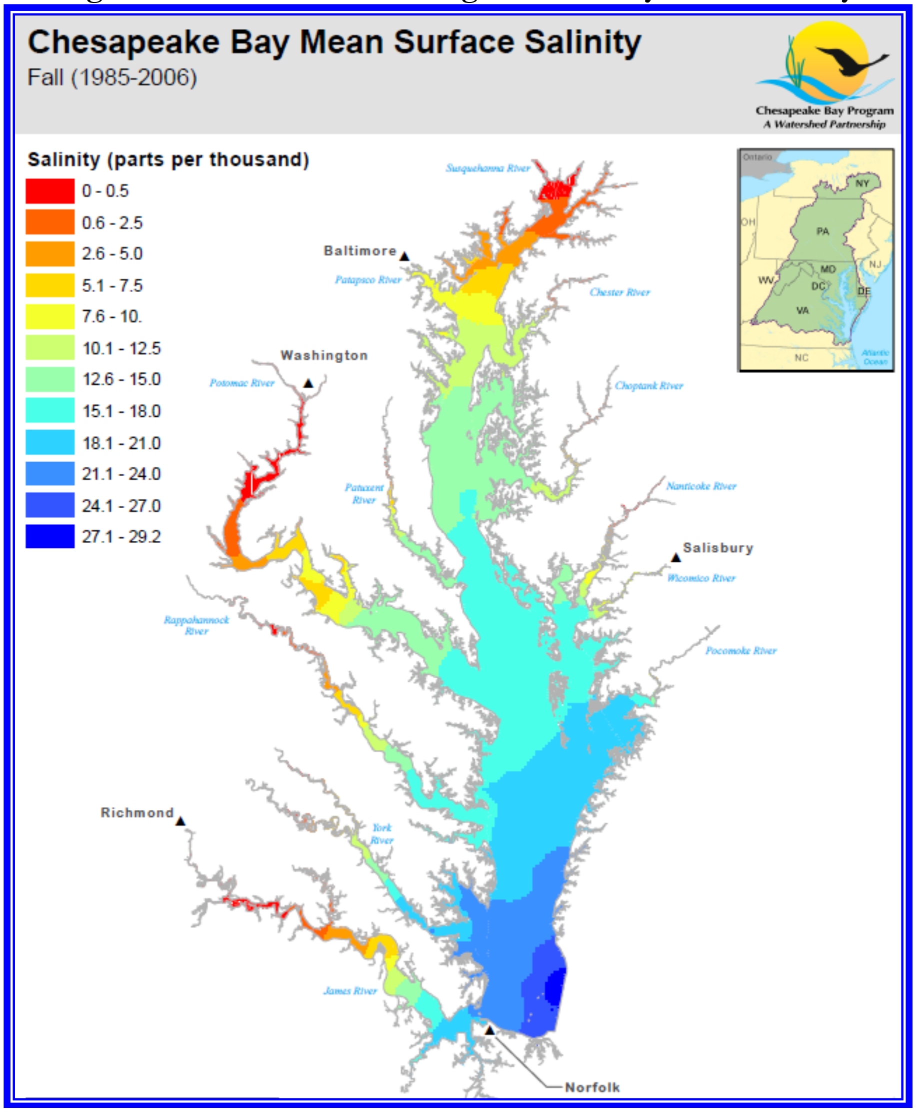
The Susquehanna River provides about half of the Bay's freshwater inflow. The relative importance of the Susquehanna River as a source of freshwater inflow becomes greater progressing northward in the Bay. The Susquehanna River provides 87 percent of freshwater inflow for the portion of the Bay north of the Potomac River (Boicourt et al., 1999).

Table K-6. Water Salinity Classification and General Occurrence in Bay Mainstem

Water Salinity (ppt)	Venice System Salinity Classification	Common Term	Bay Region Generally Occurring In
0 to 0.5	Fresh	Fresh	Upper
0.5 to 5	Oligohaline	Brackish	Upper
5 to 18	Mesohaline	Brackish	Middle
18 to 30	Polyhaline	Brackish	Lower

Classification Source: Cowardin et al., 1979.

Figure K-6. Maximum Average Annual Bay Water Salinity

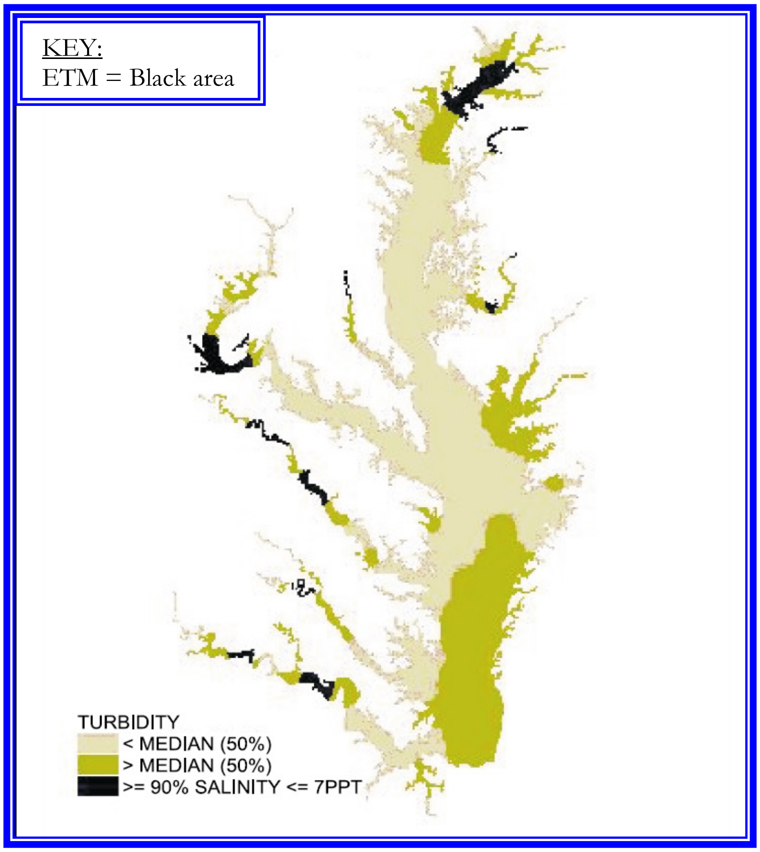


Source: Chesapeake Bay Program.

Estuarine Turbidity Maxima (ETM)

The ETM zone is an area of high concentrations of suspended sediment and reduced light penetration into the water column. Each of the Bay's major tidal tributary systems has an ETM zone near the upstream limit of saltwater intrusion, as shown in Figure K-7. The Susquehanna River ETM zone occurs in the upper Bay mainstem. The position of the ETMs changes seasonally and with large freshwater flow events from storms. The ETMs extend further downstream into the Bay during times of year when lower salinities occur and following major storm events, and further upstream when seasonally higher salinities occur. The ETM zone is produced by a complex interaction of physical and biological processes, including freshwater inflow, tidal and wave-driven currents, gravitational circulation, particle flocculation, sediment deposition and resuspension, and biogeochemical reactions.

Figure K-7. General Locations of ETMs



However, tidal resuspension and transport are primarily responsible for the maintenance of the ETM zone at approximately the limit of saltwater intrusion. Generally, fine-grained river-borne sediment in the ETM zones is exported further downstream into the main Bay only during extreme hydrologic events.

The mainstem Bay ETM zone occurs in the upper Bay; in this region, most of the fine-grained particulate matter from the Susquehanna River is trapped, deposited, and sometimes resuspended and redeposited. The mainstem ETM zone acts as a barrier under normal conditions for southward sediment transport of material introduced into the Bay from the Susquehanna River (USGS, 2003).

Eutrophication

Anthropogenic nitrogen and phosphorus nutrient pollution delivered to the Bay exceeds the Bay ecosystem's capability to process it without ill effect. The Bay's physical character and circulation patterns tend to retain water-borne materials, thus exacerbating the effect of anthropogenic pollution. The Bay's natural capability to buffer the incoming nutrient loads are governed by seasonal stratification and limited tidal mixing rate (Bever et al., 2013). Anthropogenic nutrient pollution to the Bay derives from agricultural runoff and discharges, wastewater treatment plant discharges, urban and suburban runoff, septic tank discharges, and atmospheric deposition of exhaust (CBP, 2013).

Water bodies possess a range of nutrient availability conditions. Water bodies possessing ample or excessive nutrients whether from natural or human sources are said to be eutrophic. The Bay became eutrophic because of inputs of large quantities of anthropogenic nutrients. Excess nutrients in the water column from human sources fuel the growth of excess phytoplankton. Zooplankton, oysters, menhaden, and other filter feeders eat a portion of the excess algae, but much of it does not end up being consumed by these organisms. The leftover algae die and sink to the Bay's bottom, where bacteria decompose it, releasing nutrients back into the water, fueling further algal growth. During this process in warm weather months, bacteria consume DO until there is little or none left in deeper bottom waters (CBP, 2013). Within the Bay, nitrogen is the principal limiting-nutrient regulating phytoplankton. The limiting nutrient is that nutrient available in lowest supply in proportion to biological demand. However, phosphorus is the limiting nutrient for phytoplankton growth in low salinity Bay waters in spring. Phosphorus is typically the limiting nutrient in freshwater ecosystems (Harding et al., 1999; CBP, 2013).

Oftentimes, pollution analyses consider total nitrogen and phosphorus contained in sediments and the water column. Nitrogen and phosphorus actually occur in a number of different forms in the environment that differ in their biological availability and effects on water quality. Total measurements lump together these different forms in a manner that makes interpreting their environmental effect difficult.

Total nitrogen (TN) includes nitrate, nitrite, ammonia, and organic nitrogen. As typically measured in labs and for the purposes of this section, ammonia also includes ammonium. Nitrate is the primary form of nitrogen in dissolved form in surface waters. Ammonia is a dissolved form of nitrogen that occurs in surface waters less commonly than nitrate. However, ammonia is the dominant dissolved nitrogen form in deeper waters during warm months. Nitrite is generally unstable in surface water and contributes little to TN for most times and places. Organic nitrogen (mostly from plant material, but also including organic contaminants) occurs in both particulate and dissolved forms, and can constitute a substantial portion of the TN in surface waters. However, it is typically of limited bioavailability, and often of minimal importance with regard to water quality. Conversely, nitrate and ammonia are biologically available and their concentration is very important for water quality (USGS, 1999; Friedrichs et al, 2014).

Total phosphorus (TP) includes phosphates, organic phosphorus (mostly from plant material), and other phosphorus forms. Phosphates and organic phosphorus are the main components of TP. Phosphates tend to attach to soil and sediment where their bioavailability varies as a function of environmental conditions. Dissolved phosphate is readily bioavailable to aquatic plant life, and consequently promotes eutrophication (USGS, 1999). Phosphorus binds to river sediments and is delivered to the Bay with sediment.

Nutrients contained in Bay bottom sediments are re-released into the water column seasonally, and these regenerated nutrients could provide a substantial portion of the nutrients required by phytoplankton, particularly in the middle Bay. Thus, nutrients mobilized from bottom sediments stimulate algal production and play an important role in Bay eutrophication. Phosphate and ammonium are typically released from sediments under anoxic conditions, with releases being relatively small in sediments in oxygenated waters. Nutrient fluxes from the sediment into the water column have been found to be greatest in the middle Bay, intermediate in the lower Bay, and least in the upper Bay (Cowan and Boynton, 1996).

Excess nutrients in the water column produce a soup of live and dead organic material; this soup impedes settling of sediments and the combined organic material and sediments degrade water clarity and create turbid conditions (CBP STAC, 2007). Suspended sediments in the water column normally derive from wave and tidal energy resuspending bottom sediments, as well as shoreline erosion. Generally, wave energies can move bottom sediments down to about a 6-foot depth, generating suspended sediments in the water column throughout Bay shallows (USACE, 2011). Following major storm events, watershed runoff can contribute suspended sediments that remain in the water column for periods of days (Gallegos et al., 2005; CBP STAC, 2007). Loss of oysters from the Bay has greatly reduced the Bay's natural filtering capability (Newell, 1988), and the loss of SAV has rendered greater shallow water area vulnerable to wave resuspension of bottom materials during the growing season.

Conveyance of Excess Nutrients Into Chesapeake Bay

Nutrient pollutants entering Chesapeake Bay originate from point and non-point sources. Point source pollutants originate from a specific, identifiable physical location such as from the end of a pipe or discharge channel. Point-source nutrients entering the Bay originate primarily from wastewater treatment plants, although some come from industries. Non-point source pollutants do not originate from an identifiable, specific physical location. Non-point source pollutants include nutrients that run off croplands, feedlots, lawns, parking lots, and streets. Nutrients that enter waterways via air pollution, groundwater, or septic systems are also classified as non-point sources (CBP, 2013).

Nutrient transport in rivers is usually considered in two fractions – that portion conveyed in dissolved form and that portion carried as particulates. Particulates include mineral sediments and plant debris. During downstream transport, bacteria and other stream organisms take up dissolved nutrients and convert them to organic form. When organisms containing these nutrients die, the nutrients return to the water in inorganic form, only to be taken up yet again by other organisms. This cycle is referred to as nutrient spiraling (Schlesinger, 1991).

Nutrient pollutants delivered to the Bay vary year to year as a function of amount and timing of precipitation. Wet years deliver greater nutrient pollution to the Bay than dry years. For example, the amounts of nitrogen and phosphorus transported during Tropical Storm (TS) Lee (a September 2011 high-flow event) were very large compared to long-term averages for the Susquehanna River over the past 34 years. However, this difference is less pronounced for nitrogen than it is for phosphorus, because on average, a large part of the nitrogen flux is delivered in dissolved form. Specifically, the amounts transported during the TS Lee event were estimated to be 42,000 tons of nitrogen and 10,600 tons of phosphorus. For comparison, the estimates of the averages for the entire period from 1978 to 2011 were 71,000 tons per year for nitrogen and 3,300 tons per year for phosphorus (Hirsch, 2012).

Nitrogen pollutants originate primarily from agriculture; urban runoff, wastewater releases, and atmospheric deposition are also substantial sources (CBP, 2013). Nitrogen pollution moves through the watershed in many forms and through many pathways from its sources (fertilizer, manure, atmospheric deposition, or point source discharges) to receiving waters. A portion of transport of nitrogen in the watershed occurs underground, as dissolved nitrate is moved through the soil by infiltration and into slow-moving aquifers. Transport also occurs through surface runoff in dissolved and particulate forms and associated episodic cycles of stream and river channel deposition, scour, and redeposition. Nitrogen pollutant delivery to the Bay differs from phosphorus pollutant delivery in that minimal phosphorus is transported to the Bay through the atmosphere and groundwater (CBP STAC, 2013).

Phosphorus pollutants originate primarily from agriculture; urban runoff and wastewater releases are also substantial sources (CBP, 2013). Nonpoint source phosphorus is strongly correlated to watershed and stream channel erosion rates because phosphorus is typically bound to sediments. Erosion rates in turn vary as a function of streamflow (precipitation) and land use. Soils to which phosphorus has been added for fertilizer yield more phosphorus when eroded than other soils (Najjar et al., 2010). Phosphorus transport to the Bay occurs primarily during storm events that produce runoff and cause phosphorus bound to sediment to be carried into streams where they can be desorbed through biogeochemical processes or deposited, only to be resuspended and redeposited by subsequent storm events (CBP STAC, 2013).

Phosphorus is conveyed in rivers as phosphate adsorbed to sediment particles. It is also conveyed bound to calcium, and as organic particles. The processes by which phosphorus is released from sediments is complicated and affected by biological as well as physical chemical processes. In oxygenated fresh water, phosphorus adsorbed to fine-grained sediments remains bound and has limited bioavailability. Under anoxic or hypoxic freshwater conditions, phosphorus becomes more bioavailable, but phosphorus rebinds to sediments if oxygen is again present. In the Bay's saltwater environment, biogeochemical conditions change causing phosphorus bioavailability to differ from in freshwater. As salinities increase above about 3 to 4 ppt, phosphorus bound to sediments is increasingly released and becomes mobile and bioavailable to living resources (Jordan et al., 2008; Hartzell and Jordan, 2012). The uppermost Bay remains generally below salinities of 3 ppt all year, which tends to favor phosphorus immobilization in sediments, but otherwise the Bay is salty enough to allow phosphorus release from sediments (CBP, 2013).

Monitoring of nutrients in the Susquehanna River has shown that the flow-adjusted annual concentrations of TN, TP, and suspended sediment delivered to the dams have been generally decreasing since the mid-1980s. With corrections to account for year-to-year variation in river flows, over the 20-year period from 1990 to 2010, TN and sediment loads delivered to the Bay from the Susquehanna River showed statistically significant declines of 26 percent and 17 percent, respectively. TP loads declined by 7% over this time period, but the trend was not statistically significant (Langland et al., 2012). Environmental management measures in the watershed contributed to this decrease. One study has indicated that loads of particulate nitrogen, particulate phosphorus, and suspended sediment from the reservoir system of the lower dams to the Chesapeake Bay are increasing, and attributes this, in part, to decreasing trapping capacity of Conowingo Reservoir (Zhang et al., 2013).

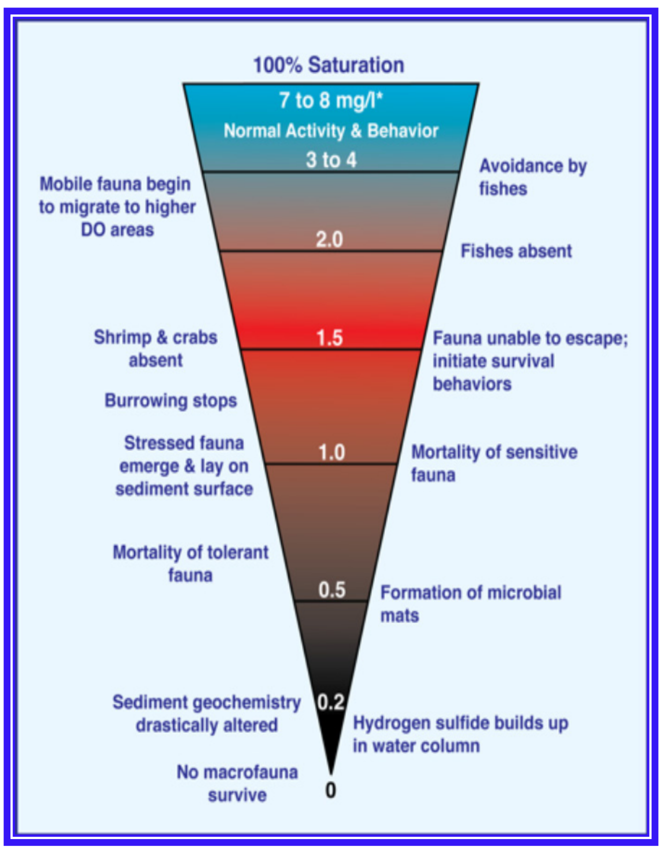
Dissolved Oxygen (DO)

Dissolved oxygen (DO) is critical to aquatic life in the Chesapeake Bay. Aquatic creatures, other than some microbes, need oxygen to survive. DO concentrations vary depending on location and time of year, based on temperature, salinity, nutrient levels, and biological uptake. Many factors interact to determine the DO content of Chesapeake Bay tidal waters. Nutrient loading, water column stratification, wind and tidal mixing, and water temperatures are important factors (CBP, 2013).

DO concentrations of 5 mg/L (milligrams per liter) or greater allow Bay aquatic life to thrive. At DO levels below 2 mg/L, the water is considered hypoxic, and when DO drops below 0.2 mg/L, it is considered anoxic. DO levels tolerable by aquatic life vary, with some organisms being more tolerant of low DO than others, as depicted in Figure K-8. Non-mobile and poorly mobile organisms, such as oysters, clams, benthic invertebrates such as some worms, are unable to relocate when low DO conditions occur. Mobile organisms, such as fish and crabs, can avoid low DO waters. However, chronically low levels of DO in the Chesapeake Bay reduce availability of inhabitable deep-channel and deep open-water habitat on a large scale. Availability of associated forage food for demersal (bottom-dwelling) fish species is also consequently reduced substantially, as illustrated in Figure K-9. Hypoxia (low oxygen) consequently reduces the numbers and catch of demersal fish species (Buchheister et al., 2013).

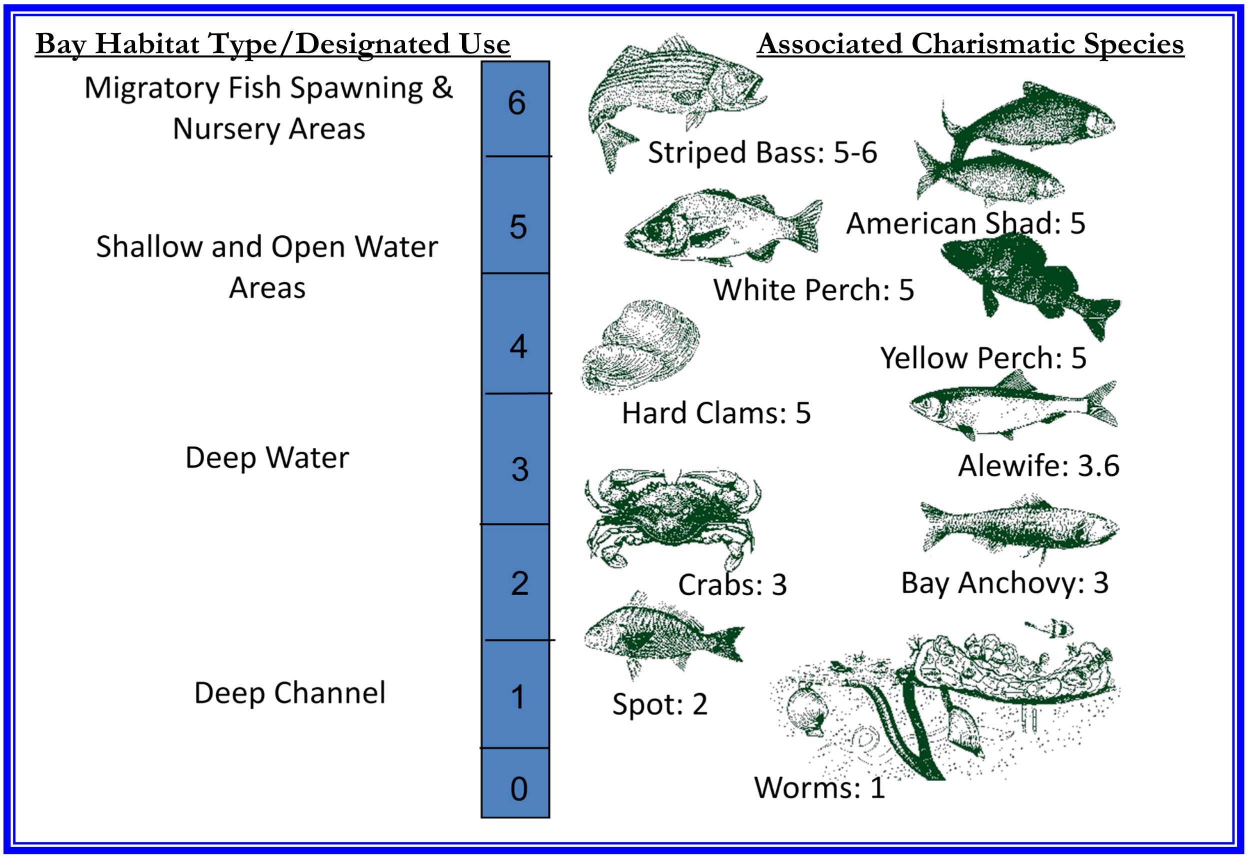
The upper Bay mainstem is not generally influenced by hypoxia; waters tend to remain oxygenated. Conversely, hypoxia typically impacts the middle and lower Bay mainstem. The pycnocline is typically the boundary between oxic (fully oxygenated) above and hypoxic or anoxic waters below in warm weather months. Oxygen consumed by respiration (principally by bacteria) below the pycnocline is only poorly replaced by oxygen from the atmosphere and photosynthesis above the pycnocline. More severe near-absence of oxygen conditions (anoxia) occur perennially in the deep channel (below 39 feet in depth) in the middle Bay and in certain bowl-shaped areas of the Bay's bottom (CBP, 2013; Versar, 2013).

Figure K-8. Dissolved Oxygen Content of Bay Water and Effects on Living Things



Source: http://www.vims.edu/newsandevents/topstories/dead_zone_volume.php.

Figure K-9. Minimum Oxygen Survival Requirements (mg/L)



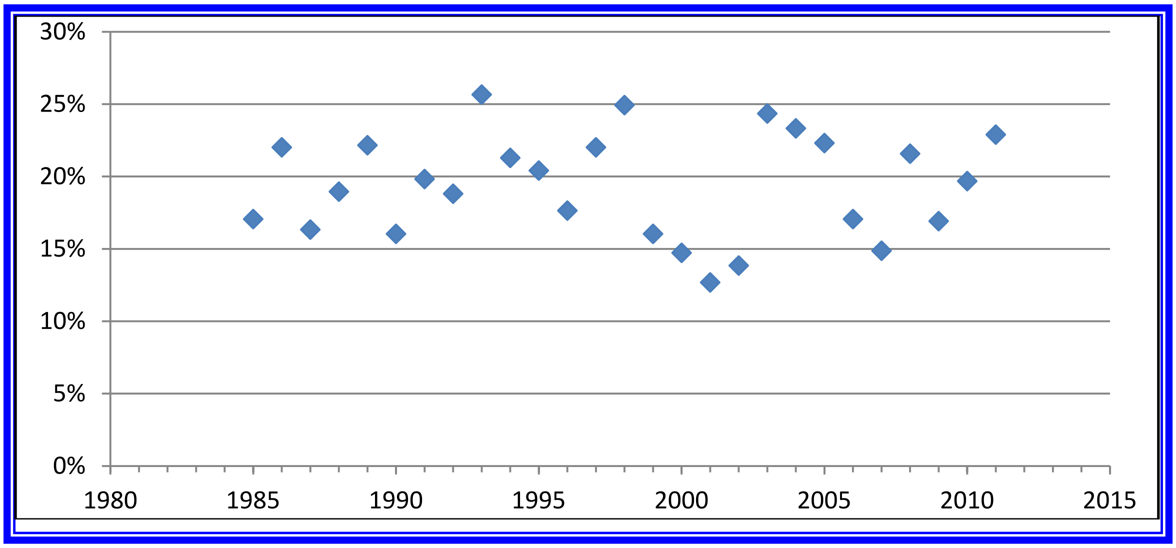
Source: Batiuk et al., 2009.

Hypoxia in the Bay generally begins in late spring to early summer (May to June), is most extreme in July, and ends by October. Over the period 1985 to 2009, hypoxic volumes showed a trend of increasing in early summer but decreasing in later summer (Murphy et al., 2011). Hypoxic conditions in the Bay vary from year to year. Bever et al. (2013) determined that from 1985 to 2011, the maximum percentage of Bay volume that was hypoxic ranged from 13 to 26 percent. Over this time period, 20 percent was the median annual maximum percentage of Bay hypoxic volume; Figure K-10 displays a time series of the annual hypoxic percentages.

Historic Water Quality

Investigations of bottom sediments have determined that some natural oxygen depletion in deeper waters of the Bay occurred in the 17th through 19th centuries driven by variations in river discharge, with low oxygen being associated with wet periods and high oxygen being associated with drought periods. Effects of European settlement were negligible at this time. Initial anthropogenic eutrophication of Chesapeake Bay began about 200 years ago. Signs of increased phytoplankton and decreased water clarity first appeared about 100 years ago. Anthropogenic nutrient loading rates increased markedly following World War II, concomitant with the pronounced increase in the use of artificial fertilizers. Severe, recurring deep-water hypoxia first became evident in the 1950s. The

Figure K-10. Annual Maximum Percent of Bay Water Volume Hypoxic



Hypoxia is <2.0 mg/L. Source: Bever et al., 2013.

resultant massive dead zone that occurs every year in warm weather months is unprecedented in the geologic and environmental history of the Chesapeake Bay ecosystem (Karlsen et al., 2000; Boesch, 2002; Kemp et al., 2005). Nitrogen inputs are currently entering the Bay at about 7 times greater than natural levels (Howarth et al., 2002). Phosphorus inputs from anthropogenic sources are entering the Bay at a rate about 16.5 times greater than natural levels (Seagle et al., 1999).

Conversely, the Bay was actually healthier at the times of highest known sediment inputs in the late 19th and early 20th centuries than at present. Although soil erosion increased nutrient inputs above natural rates, the nutrient input rates were substantially less than that provided from other anthropogenic sources following World War II, as described above.

K.5.2 Susquehanna River and Conowingo Reservoir

The Susquehanna River is a principal source of nutrients delivered to the Bay. Total phosphorus is one of the parameters that most often exceed standards. Excess phosphorus derives from fertilizer and animal and human waste. SRBC employs water quality standards for physiochemical and biological parameters to assess water quality of the Susquehanna River and its major tributary rivers through their Large Rivers Monitoring Program. Through the program's history, the Susquehanna River's documented water quality has been stable and fairly good with only very few limit violations, primarily temperature and total sodium. Instantaneous DO concentrations in river margin habitat of the Susquehanna River do fall below the 4.0 mg/L minimum water quality standard established by PADEP on occasion, while adjacent main channel concentrations did not fall below the minimum standard (PFBC, 2011).

Conowingo Reservoir water temperatures range from about 59°F to 91°F during the period of April through October. The reservoir remains relatively constant in temperature vertically for much of the year, but reservoir water can be up to several degrees cooler at the bottom than at the surface for brief periods. DO in Conowingo Reservoir becomes depleted in waters of the reservoir greater than 25-foot depth under conditions of low river inflow (less than 20,000 cfs) and warmwater temperatures (greater than 75°F). Reservoir DO levels occasionally drop below 2 mg/L (Normandeau Associates and GSE, 2012).

USGS collected and analyzed water samples of Conowingo Reservoir outflow during high-flow events during water year 2011 (which ran from October 1, 2010 to September 30, 2011) for this assessment. Appendix F presents a report on that effort.

K.6 SEDIMENTS AND GEOLOGY

K.6.1 Chesapeake Bay

Geologic Evolution

The Chesapeake Bay formed as the sea level rose over the last 10,000 years following the last Ice Age, and drowned what was formerly part of the Susquehanna River valley (Colman et al., 2002). The Bay continues to grow in area by several hundred acres per year as a consequence of shoreline erosion and land inundation driven by continuing sea-level rise (USACE, 2011).

Bay Bottom Materials and Processes

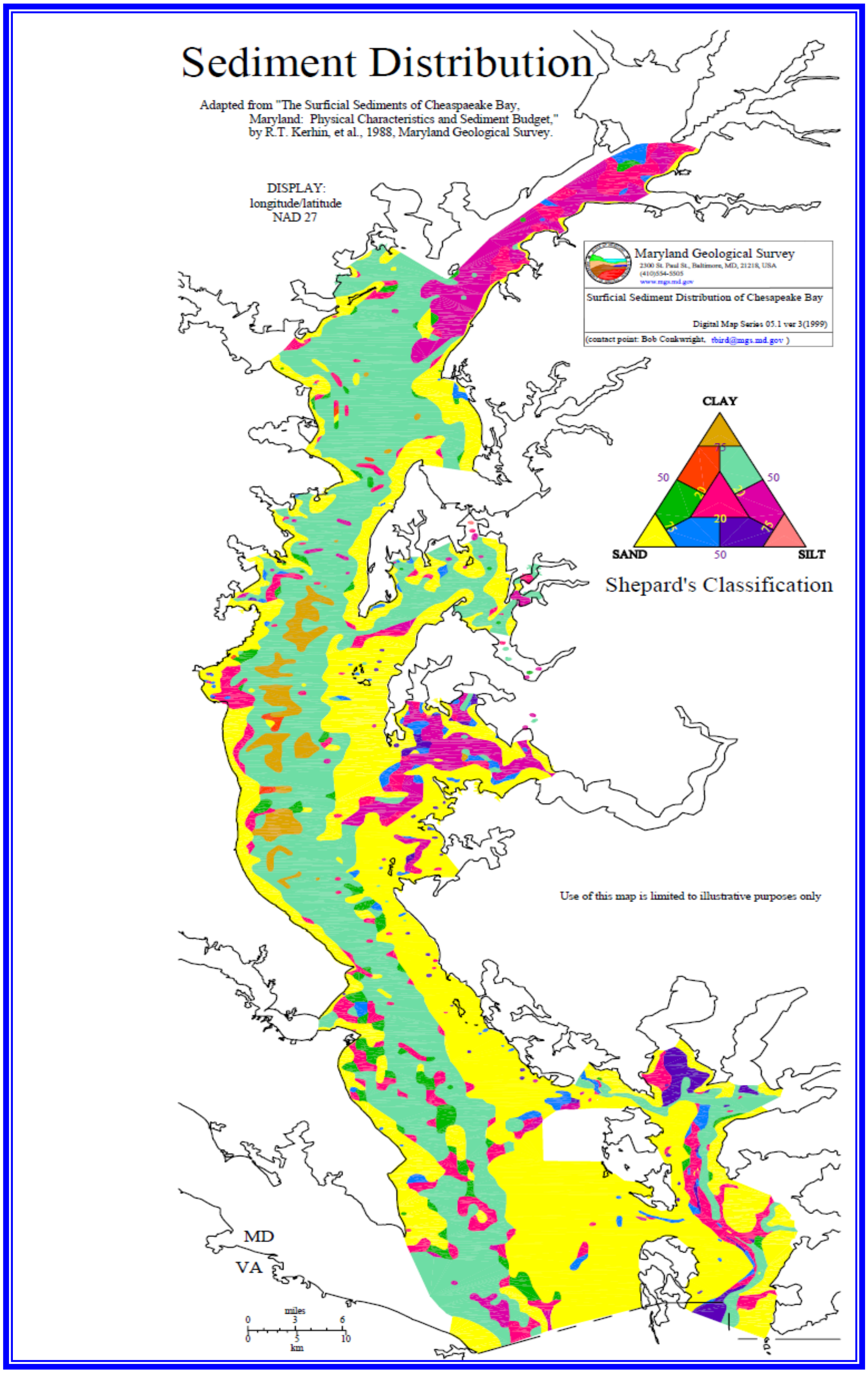
The Bay bottom consists predominantly of unconsolidated (i.e., not turned to rock) sediments. Shallow waters of the Bay out to about 15-foot depth have sands. Surficial bottom sediment in deeper waters of the Bay consists predominantly of silty clay as shown in Figure K-11. In the ETM of the upper Bay, the bottom is predominantly clayey silt (MDNR, 1988).

Surficial bottom sediments in the Susquehanna Flats consist of sand with a general fining trend away from the mouth of the Susquehanna River. Abundant coal occurs in Susquehanna Flats sediments, which were transported into the Bay from coal mining in the Susquehanna basin (Robertson, 1998). The Susquehanna Flats sediments are predominantly sand presumably because wave action at shallow depths removes finer sediments.

Investigations conducted for this study characterized bottom sediments of the uppermost Bay in 2012 where bottom sediment is not mapped in Figure K-11. Findings of these investigations are presented in Appendix E of this assessment report.

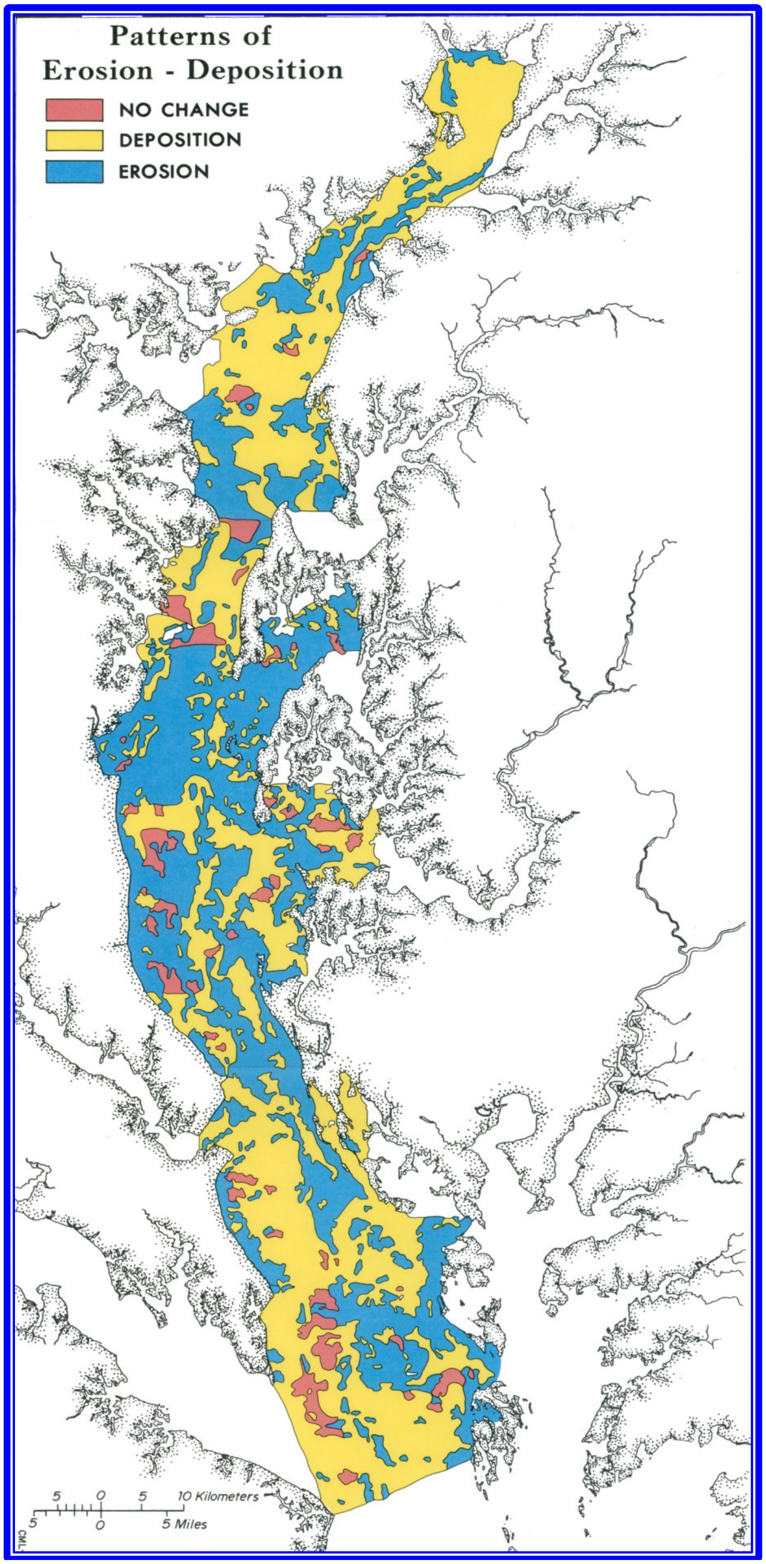
Recent sediments on the Bay bottom derive from upland (watershed) and shoreline erosion, in-Bay biological production, and atmospheric sources (dust), as well as the Atlantic Ocean in the lower Bay (Colman et al., 2002). However, in substantial areas of the Bay, erosion from waves and currents prevents deposition of new sediments on the Bay bottom. In these erosional areas, pre-Chesapeake Bay sediments from ancient riverine, estuarine, and marine environments are sometimes exposed (MDNR, 1988). Figure K-12 portrays regions of Bay bottom and whether erosional or depositional processes dominate. Processes producing these patterns occurred naturally over geologic time as the Bay evolved, driven by rising sea level. Conversely, human activity has induced substantial deposition in headwater tributaries and in the Susquehanna Flats over the last few centuries.

Figure K-11. Bottom Sediment Grain Size Distribution



Source: MDNR, 1988.

Figure K-12. Depositional and Erosional Areas on Bay Bottom



Source: MGS, 1988.

Toxic contaminants enter the Bay from atmospheric deposition, dissolved and particulate runoff from the watershed, and direct discharge. Bay sediments accumulate many toxic contaminants, including metals (such as arsenic, cadmium, chromium, and mercury), butyl-tins, polycyclic aromatic hydrocarbons (PAHs), and chlorinated compounds (polychlorinated biphenyls [PCBs], chlorinated pesticides, furans, and dioxins). Contaminants accumulate in mud (fine-grained sediments) while sands tend to retain few contaminants. Generally, sediments in the mainstem of the Bay are relatively uncontaminated. Depositional areas containing fine-grained sediments in the Susquehanna Flats area and the upper portions of the deep trough have higher concentrations of contaminants than the middle and lower Bay.

Most tributaries have higher contaminant concentrations than the mainstem. Tidal portions of the Anacostia River, Baltimore Harbor, and the Elizabeth River are hotspot areas of contaminants (CBP, 2013).

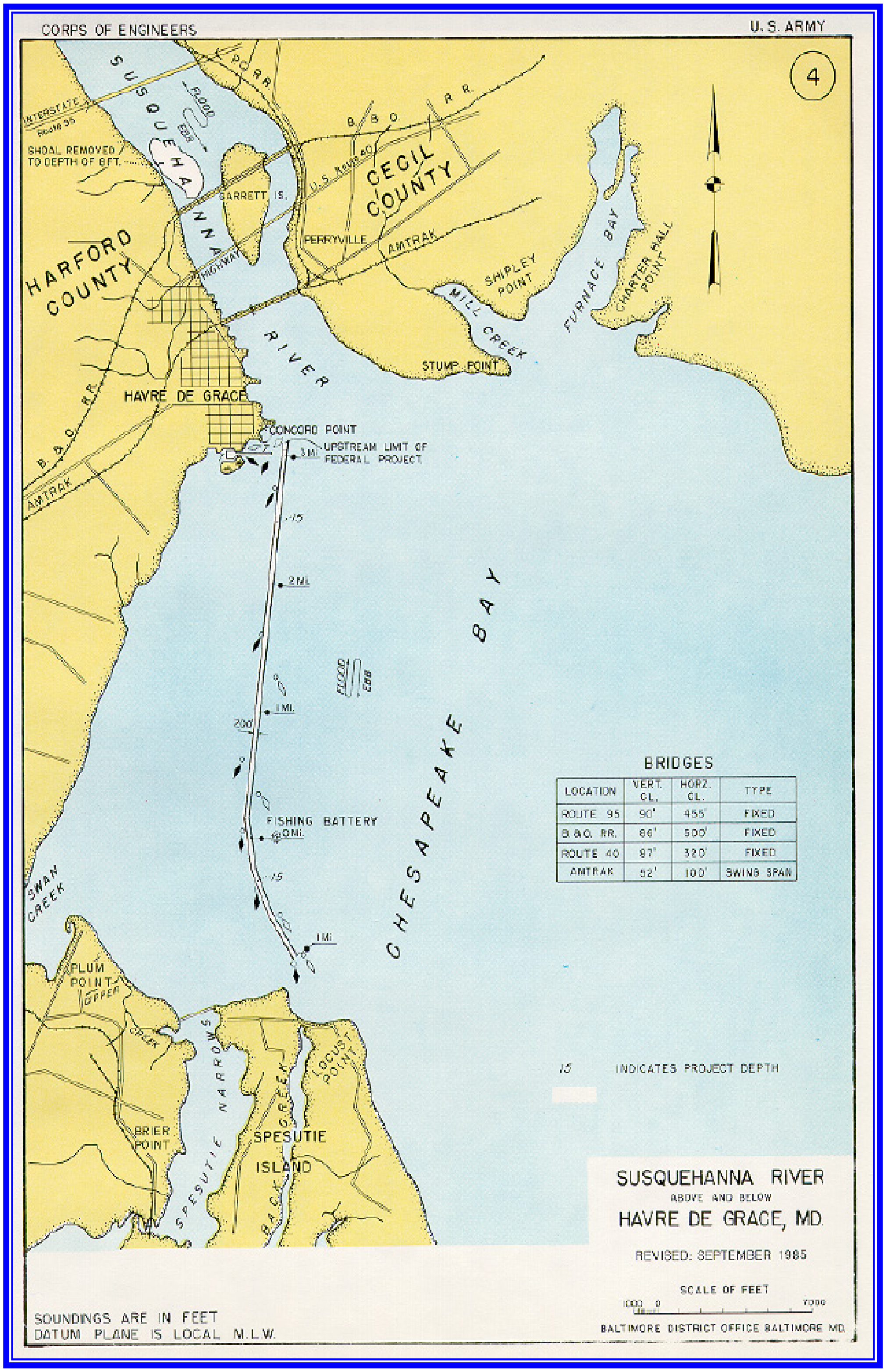
Eroded sediments from upland and riverine sources enter the Bay in quantities considerably greater than natural levels as a consequence of human activities and landscape alterations. Accumulating sediments shoal navigation channels. Nutrients adsorbed to fine-grained sediments derived from eroded topsoil contribute to eutrophication. Fine-grained sediments can remain suspended in Bay waters for extended periods of time because of eutrophic conditions. This reduces water clarity, limiting growth of SAV.

The Susquehanna River transports large volumes of sediment to the Chesapeake Bay. Two flood events, associated with Hurricanes Agnes (1972) and Eloise (1975), contributed approximately 44 million tons of sediment to the Bay. Recent estimates calculate that the Susquehanna River transports 3.1 million tons annually, depositing 1.9 million tons behind Conowingo Dam with the remaining 1.2 million tons deposited in the Chesapeake Bay (1996-2008 evaluation periods) (Langland, 2009). In the upper Bay, the Susquehanna River is the dominant source of sediment influx, supplying over 80 percent of the total sediment load in the area (SRBC Sediment Task Force, 2001).

However, historical data indicates that long-term erosional erosional areas can occur in this region along the northern shoreline bottom, and along the north/south channel bottom west of Susquehanna Flats (MDNR, 1988). The latter channel contains the USACE Susquehanna River/Havre de Grace navigational channel, purposefully located in this natural deeper water area; the location of the navigation channel is shown in Figure K-13. During the growing season from April through October, large SAV beds occur on shallows in the Susquehanna Flats in the center of the uppermost Bay. The SAV beds promote sedimentation within the shallows, and dampen wave energy that could otherwise erode bottom sediment (Gurbisz and Kemp, 2013; CBP, 2013).

Major flood events and wave energy are likely the major factors controlling the geomorphic character of the Susquehanna Flats (Larry Sanford, Professor, University of Maryland, Center for Environmental Science, personal communication, 2013). Although no research has yet been specifically conducted on the topic, it is likely that there was a great increase in sand delivery to the upper Bay following European settlement from anthropogenic erosion in the Susquehanna River basin. Sand delivery from the Susquehanna River into Chesapeake Bay would probably have peaked in the early 1900s. Then, following construction of the lower Susquehanna River dams, sand

Figure K-13. Location of USACE Susquehanna/Havre de Grace Navigation Project



Source: USACE, 1985.

delivery to the upper Bay would presumably have been disproportionately reduced compared to fines in the early 20th century.

Locally along the Bay shoreline and in nearshore waters, gravels, cobbles, and boulders as well as blocks of iron sandstone and other partially indurated (turned to rock) sediments from otherwise buried geologic materials occur where waves or currents have exposed them (USACE, 2011). The tidal Susquehanna River is unique in Maryland's portion of Chesapeake Bay in that it has a hard rock bottom where Piedmont rocks are exposed. Elsewhere in Maryland's portion of the Bay, Piedmont rock is deeply buried under sediment and not exposed on the bottom or shoreline.

K.6.2 Conowingo Dam and Vicinity

Upland Geologic Materials

Conowingo, Holtwood, and Safe Harbor Dams all lie within the Piedmont physiographic province and rest on hard metamorphic rock. Hard rock of the Piedmont is naturally exposed in locations where erosion exposes it, such as along rivers and steep slopes. Otherwise, rock in the Piedmont is typically buried by soil and decomposing rock known as saprolite. In the Maryland portion of the Piedmont, saprolite can range from just a few feet to more than 100 feet, while the average thickness is around 45 feet (Nutter and Otton, 1969). In Harford County, the average thickness of saprolite is thought to be 33 to 50 feet thick (Dingman and Ferguson, 1956; Nutter, 1977). Similarly, the average saprolite thickness in Cecil County is 41 feet (Otton et al., 1988).

Upland areas adjacent to the dams and along the Susquehanna River are underlain by a variety of hard metamorphic and sedimentary rock types northward of the dam and southward down to the boundary with the Coastal Plain physiographic province which lies several miles downstream of Conowingo Dam. In the Coastal Plain, layers of unconsolidated sediments overlie Piedmont hard rock. The Piedmont province slopes downward southeasterly at a rate of about 500 feet per mile below the Coastal Plain, although the contact between the two provinces has many irregularities. Piedmont hard rock is buried by increasingly thick Coastal Plain sediments proceeding southeastwardly from the boundary between the two provinces (MDNR, 1969 and 1990; Means, 2010). Investigations conducted for this study by MGS characterized the lowermost Susquehanna River bottom in the reach between Conowingo Dam and tidal waters. This information can be found in Appendix E of this Assessment.

Principal mineral resources of the area are rock and crushed stone from quarries in the Piedmont, and sand and gravel from Coastal Plain sediments. These geologic materials support the building and construction industries. Substantial rock for shoreline stabilization along Chesapeake Bay is quarried from quarries in the Port Deposit area. Historically, additional mineral commodities produced from the vicinity included building and decorative stone, roofing, slate, iron, chromite, talc, feldspar, and clay. Multiple inactive quarries occur within several miles of the Susquehanna River in Pennsylvania and Maryland (Shultz, 1999; MDNR, 1969 and 1990; Means, 2010).

Conowingo Reservoir, Lake Aldred, and Lake Clarke Substrate

Prior to construction of the dams on the lower Susquehanna River, minimal alluvial sediment storage occurred. Geomorphic features instead consisted of a bedrock channel flowing through gorges, the latter of which contained a series of terraces (Pazzaglia and Gardner, 1993).

The bodies of water formed behind the dams contain outcrops of Piedmont rock on areas of the bottom and shoreline subject to strong currents and or waves. The lakes have deposits of boulders and cobbles on the bottom in areas where strong river currents deposit them. Otherwise, Piedmont hard rock underlying the lakes is covered with sediment consisting of sand and mud (silt and clay). All the lakes have coal in their bottom sediments from upstream mining operations. Coal deposited in Lake Clarke and Lake Aldred was dredged from the lake bottom from the 1950s until about the time of Hurricane Agnes. Conowingo Reservoir and Lake Clarke show a general trend of increasing thickness of sediment proceeding downstream; Lake Aldred sediments are thickest near the middle of the lake (Hainly et al., 1995).

Bottom sediments in Conowingo Reservoir show a gradation from the upstream end of the reservoir to the area adjacent to the dam. At the upstream end, reservoir bottom sediments are mostly sand. Progressing downstream, the bottom sediments become increasingly fine, consisting of silts and clays (Hainly et al., 1995).

The sediment retained behind Conowingo Dam contains substantial quantities of nitrogen and phosphorus nutrients. The nutrients occur predominantly in muds; conversely sands have minimal nutrient content. TP in Conowingo Reservoir sediments was found to range from 0.3 to 1.4 grams per kilogram; TN was found to range from 1.5 to 6.9 grams per kilogram. However, about 96 percent of the TN consisted of organic nitrogen which is of limited immediate bioavailability. Organic nitrogen concentration decreased with depth into the sediment. Phosphorus immediately available to plants comprised only 0.6 to 3.5 percent of the TP (Langland and Hainly, 1997).

Soils typically contain approximately 0.8 grams TP per kilogram of soil, while river particulates typically contain approximately 1.15 grams TP per kilogram (Schlesinger, 1991). Because the phosphorus adsorbed to bottom sediments is minimally bioavailable and not being utilized by organisms nor reacting chemically, TP probably does not show a pattern of decrease with depth into the sediment. The nutrients stored behind the dam that are not in immediately bioavailable forms might, however, upon burial in the Bay bottom be expected to gradually become bioavailable from microbial processes in the sediment (Michael Langland, Hydrologist, U.S. Geological Survey, personal communication, 2014).

TN and TP in bottom sediment samples collected in Lake Clarke considered vulnerable to scour ranged from 3.3 to 5.3 g/kg and 0.8 to 1.2 g/kg, respectively. TN and TP in bottom sediment samples collected in Lake Aldred considered vulnerable to scour ranged from 1.2 to 5.7 g/kg and 0.3 to 0.5 g/kg, respectively. Lake Clarke had higher clay content than Lake Aldred at these locations, likely accounting for greater TP content. Clay content of bottom sediments in downstream Lake Clarke remained consistent in a comparison of studies conducted in 1990 versus 1996. Conversely, clay content in bottom sediments in downstream portions of Lake Aldred decreased from 1990 to 1996 (Langland and Hainly, 1997).

In summary, although vast quantities of nitrogen and phosphorus nutrients are stored in sediments behind the dam, they occur predominantly in forms which would not be of immediate bioavailability upon delivery to the Bay. These nutrients though may eventually become available to contribute to eutrophication if eroded and delivered to the Bay.

Human activities throughout the Susquehanna River basin have generated sediment contaminants that occur in varying levels in the system. Sediment studies in the Susquehanna River have identified several contaminants such as organocholorine insecticides, PCBs, radionuclides, and PAHs (PFBC, 2011).

Conowingo Reservoir sediments have about an 11-percent coal content derived from mining upstream. The concentrations of metals, radionuclide contamination, and overall organic contaminant concentrations are comparable to those found in the upper Bay mainstem. PCBs from the Susquehanna River appear to be readily transported into the upper Bay, while pesticides and PAHs appear to be trapped behind the dams. Compared to the Bay, reservoir sediments have lower levels of chemicals typically contained in seawater but absent from fresh water. The latter include sulfur which occurs as sulfate in seawater but is only minimally present typically in fresh water (SRBC, 2006a).

Substrate composition in the littoral zone (upper 10 feet) of Conowingo Reservoir transitions from gravel-cobble-boulder in the upper range of water level fluctuation to a gravel and sand mix at somewhat greater depths. In the lower range of the upper 10 feet of water, silt becomes dominant on the bottom. Steeply sloping rock outcrops occur along much of the western shoreline (URS and GSE, 2012a).

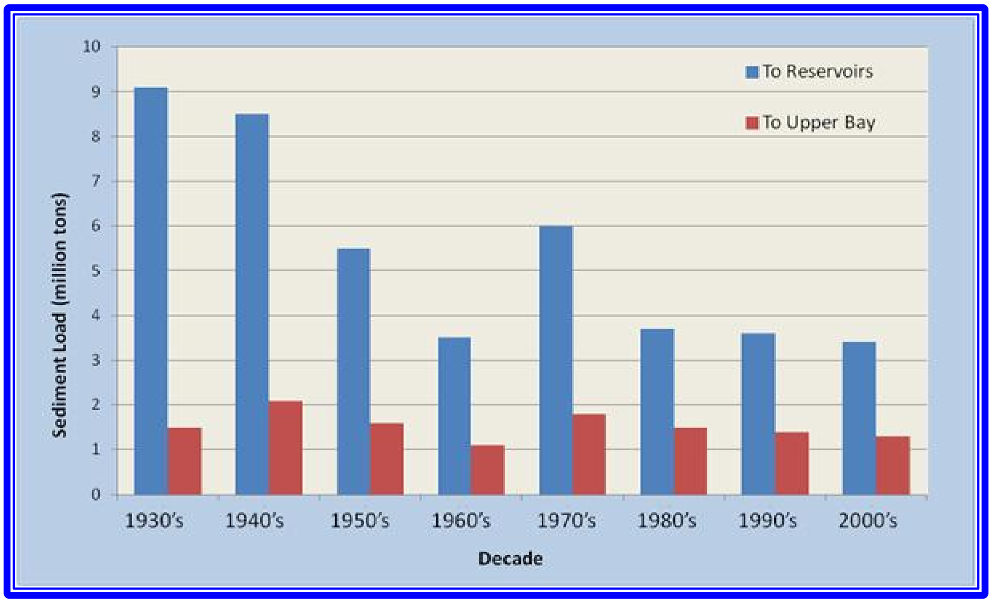
K.6.3 Environmental History – Watershed Erosion and River and Bay Sedimentation

Upland erosion in the Bay watershed increased substantially following European settlement from deforestation, farming, and mining. Consequently, sediment inputs to the rivers and Bay greatly increased, with rates peaking sometime between the late 1800s and early 1900s, with a decline generally occurring from the 1930s onward (Curtin et al., 2001; Langland, 2000; USGS, 2003). The long-term sediment inflow and outflow trends are depicted in Figure K-14.

Floodplains and an extensive array of dams and millponds throughout the Bay watershed trapped a substantial portion of these sediments, which continue to erode and flow into the Bay today (Walter and Merritts, 2008). Numerous headwater tidal tributaries on Maryland's Western Shore and along the Potomac River in Virginia demonstrated pronounced increased sedimentation rates following European settlement with shoaling so severe that navigation was prevented and tidal wetlands grew over accumulating sediments (Gottschalk, 1945).

Tremendous quantities of sediment were deposited into the upper Bay and onto the Susquehanna Flats from erosion in the Susquehanna River basin. The average water depth over an area of 32 square miles of the upper Bay was reduced by 2½ feet from the 1840s through 1930s (Gottschalk, 1945). Sediment accumulation measured from coring on the flats determined that about 7 feet of sediment was deposited on the flats from the 1890s to 1990s (Robertson, 1998). Thus, the character of the Susquehanna Flats today is largely the consequence of human activity in the Susquehanna

Figure K-14. Long-Term Trend in Inflowing and Outflowing Sediments



Notes: *The difference in the bars represents the amount of sediment trapped in the reservoirs. These amounts represent annual averages during a particular decade.*
Since 1929, approximately 430 million tons of sediment were transported into the lower Susquehanna reservoirs. Of this amount, approximately 290 million tons (70 percent) were trapped, and approximately 140 million tons were transported to the Chesapeake Bay.

Source: USGS, Appendix A.

River basin (Gottschalk, 1945). Sedimentation rates to deep-water portions of the Bay have increased by a factor of 4 to 5 over pre-European settlement rates (Colman and Bratton, 2003). Conversely, sediment accumulation on the shallower margins of the Bay overall is relatively slow and does not show consistent patterns related to European settlement, instead occurring at about pre-European settlement rates (Colman et al., 2002; USGS, 2003).

K.7 AQUATIC LIFE AND HABITATS

K.7.1 Plankton

Plankton are a wide variety of floating plants and animals, phytoplankton and zooplankton respectively, that live in the water and are, by in large, passively carried by currents. Phytoplankton include various green, red, and blue-green algae. Phytoplankton are the basis of most aquatic food chains. Zooplankton include microscopic animals, larvae of larger animals, and jellies (gelatinous zooplankton). Jellies include comb jellies (various ctenophora) and sea nettles (jellyfish, *Chrysaora quinquecirrha* and other species). Zooplanktons serve as food for many larger aquatic animals (MDNR, 2013). Nutrients supplied from coastal runoff and vertical mixing in the water column support a relatively high abundance of phytoplankton in the shallow waters of the Bay where sunlight can penetrate. Phytoplankton populations vary seasonally, with peak abundances occurring in late winter through spring and then again in summer. Limited fall blooms also occur. Water temperatures and seasonal variation in nutrient availability in the water column control phytoplankton population dynamics; phytoplankton themselves consume nutrients from the water as their populations increase (MDNR, 2013).

Nutrient loading increases to the Bay are believed to have greatly increased populations of jellies. Consequent excess consumption of finfish larval zooplankton by jellyfish is likely influencing Bay finfish populations (Purcell et al., 1999).

K.7.2 Submerged Aquatic Vegetation (SAV)

Submerged aquatic vegetation (SAV) is underwater plants that can occur to depths where water clarity is adequate for the plants to grow. SAV can grow in shallow water to minimum depths where air exposure is harmful to the plants. SAV occurs in both tidal and nontidal waters of the Chesapeake Bay watershed, in both salt and fresh water. The term SAV is generally used to refer to rooted plants. Underwater algal beds also occur in aquatic habitats that are similar in appearance from above the water surface to SAV beds, and provide similar ecological functions. SAV beds provide important habitat for numerous fish and wildlife species (CBP, 2013).

Chesapeake Bay SAV

SAV beds are among the Bay's most valued resources, but unfortunately are particularly vulnerable to turbidity during their growing season from April through October. SAV in the Bay occurs from about the lower range of the tide to depths of up to 6 feet; the distribution of SAV in the Bay is shown in Figure K-15. SAV is generally absent from deeper waters because of inadequate light penetration through turbid water conditions. SAV species occurring in the Bay are least diverse in the higher salinity regions, where only two rooted plant species are found. SAV beds increase in diversity as salinity decreases. Beds in freshwater and oligohaline portions of the Bay may contain more than 10 rooted plant species, as documented in Table K-7. SAV occurring in the Bay includes both native and exotic species; all are considered to have value as habitat for Bay aquatic life. Large SAV beds serve to dampen water turbidity within the bed itself, although water clarity controlling the health of most beds is primarily governed by Bay water quality (Orth et al., 2010; VIMS, 2013).

SAV in the Chesapeake Bay is perhaps the most extensively studied SAV resource in the world. Chesapeake Bay has possibly the best long-term data set allowing for chronicling status and trends, with comprehensive surveys dating from the late 1970s through present, with other records available from the 1930s onward (Orth et al., 2010). Studies of SAV remnants in sediment demonstrate that SAV coverage initially increased following European settlement, presumably as a consequence of somewhat increased nutrient availability, and perhaps increased availability of shallow water habitat from excess anthropogenic sedimentation (Brush and Hilgartner, 2000). SAV coverage declined drastically in the 1960s in accompaniment to water quality declines associated with nutrient loading and loss of oysters from disease and overharvesting.

Hurricane Agnes in 1972 compounded the impacts of eutrophication, and caused a dramatic Bay-wide SAV decline. SAV recovered somewhat over following decades, but exhibits pronounced interannual variation, as seen in Figure K-16. SAV beds tend to decline in years with high freshwater discharges immediately before and during the growing season. Conversely, successive drought years facilitate SAV bed recovery. These trends occur because wet years bring in greater

Figure K-15. Historic and Recent SAV Distribution in Bay

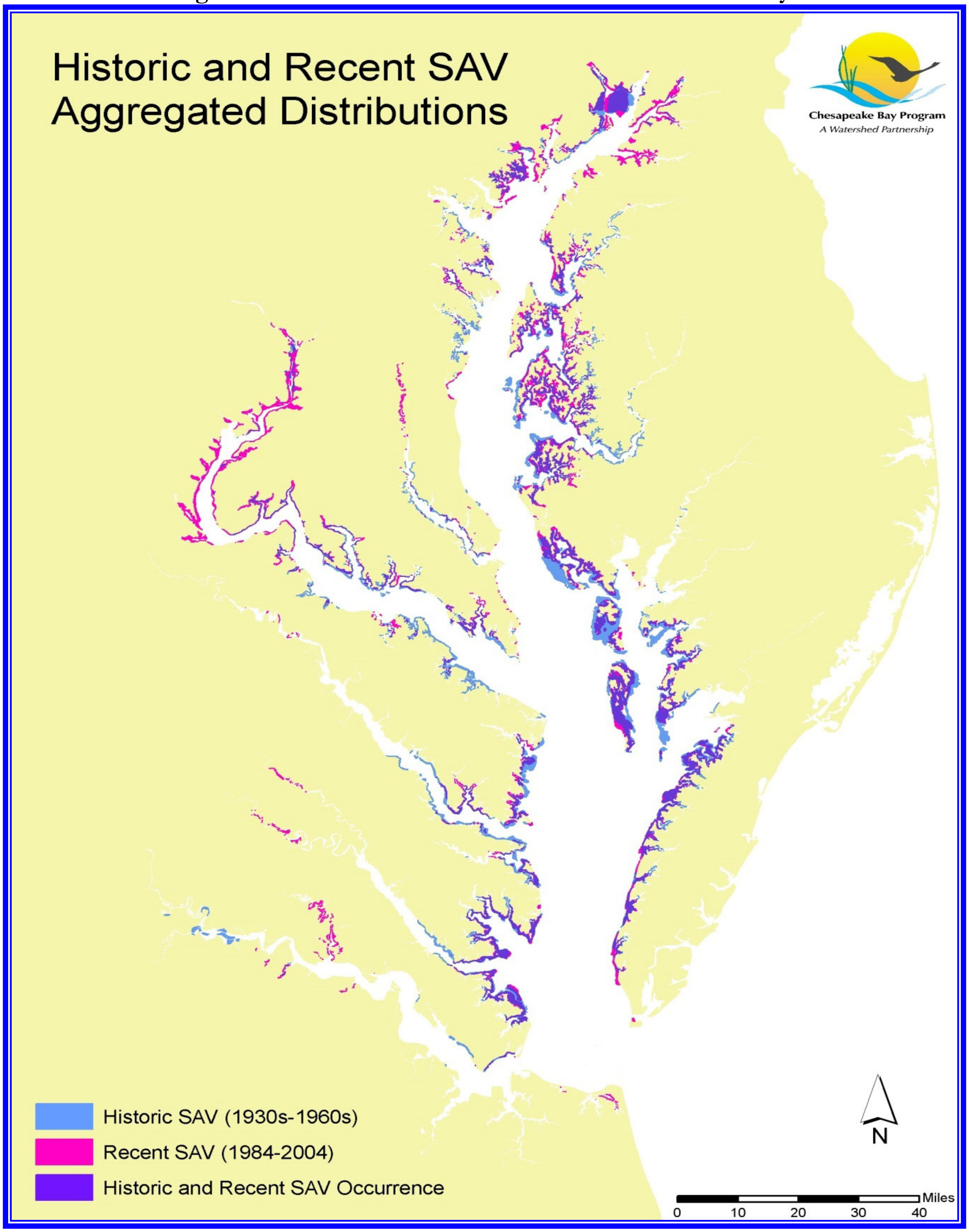
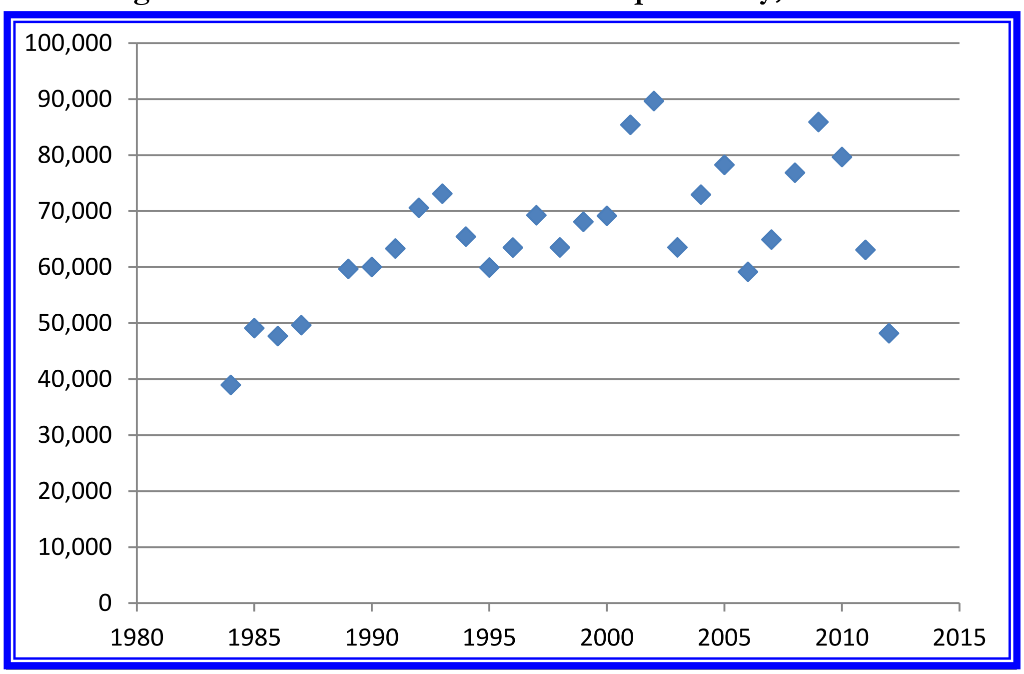


Table K-7. Chesapeake Bay SAV Species by Water Salinity

Common Name	Scientific Name	Salinity		
		Low	Medium	High
Coontail	*Ceratophyllum demersum*	x		
Common waterweed	*Elodea canadensis*	x		
Water stargrass	*Heteranthera dubia*	x		
Hydrilla	*Hydrilla verticillata*	x		
Water milfoil	*Myriophyllum spicatum*	x		
Southern naiad	*Najas guadalupensis*	x		
Spiny naiad	*Najas minor*	x		
Curly pondweed	*Potamogeton crispus*	x		
Redhead grass	*Potamogeton perfoliatus*	x	x	
Slender pondweed	*Potamogeton pusillus*	x		
Widgeon grass	*Ruppia maritima*		x	x
Sago pondweed	*Stuckenia pectinata*	x	x	
Wild celery	*Vallisneria americana*	x		
Horned pondweed	*Zannichellia palustris*	x	x	
Eelgrass	*Zostera marina*		x	x

Source: Orth et al., 2010.

Figure K-16. Total SAV Acres in Chesapeake Bay, 1984-2013



<u>Notes</u>: There is no data for the year 1988.
Source: VIMS, 2013.

nutrient loads, promoting eutrophic conditions and decreasing water clarity. Other factors also affect SAV, including grazing by mute swan (*Cygnus olor*) and bottom-disruption by bottom-feeding organisms such as the cownose ray (*Rhinoptera bonasus*) (Orth et al., 2010).

The CBP Partnership has set a 185,000-acre SAV restoration goal based on total area of known SAV occurrence over the period of Bay-wide data from the 1930s through 2004 (CBP, 2013). Grasses attained their greatest coverage over the last several decades in 2002 when 90,000 acres were observed (Maryland BayStat, 2013). While a substantial improvement over the historic lows of the 1970s through 1980s, SAV beds still only occupied 49 percent of their known historic coverage. It is considered likely that SAV historically occupied even greater than 185,000 acres in Chesapeake Bay prior to the 1930s based on the distribution of suitable habitat (Orth et al., 2010).

The Susquehanna Flats SAV bed is the single largest SAV bed in the Bay and the region is one of the best recovered regions in the Bay. SAV in the uppermost Bay was historically pronounced in the first half of the 20th century, and its use by waterfowl prompted establishment of a National Wildlife Refuge along the Susquehanna Flats' western shore. After undergoing a general gradual trend of decline in the 1960s and early 1970s, SAV on the Susquehanna Flats collapsed after Hurricane Agnes in June 1972. SAV then remained at a low level through the 1980s and 1990s. Early in the 21st century, it recovered to pre-Agnes levels and then underwent dramatic expansion in 2005-06 facilitated by several years of drought conditions, as demonstrated in Figures K-17 and K-18 (Orth et al., 2010; Gurbisz and Kemp, 2013). Extent of the beds on the flats have varied in response to large storm events, with a minor decline occurring following Hurricane Ivan in 2004 but with substantial decline following Tropical Storm Lee in 2011 (Gurbisz and Kemp, 2013).

Susquehanna River SAV

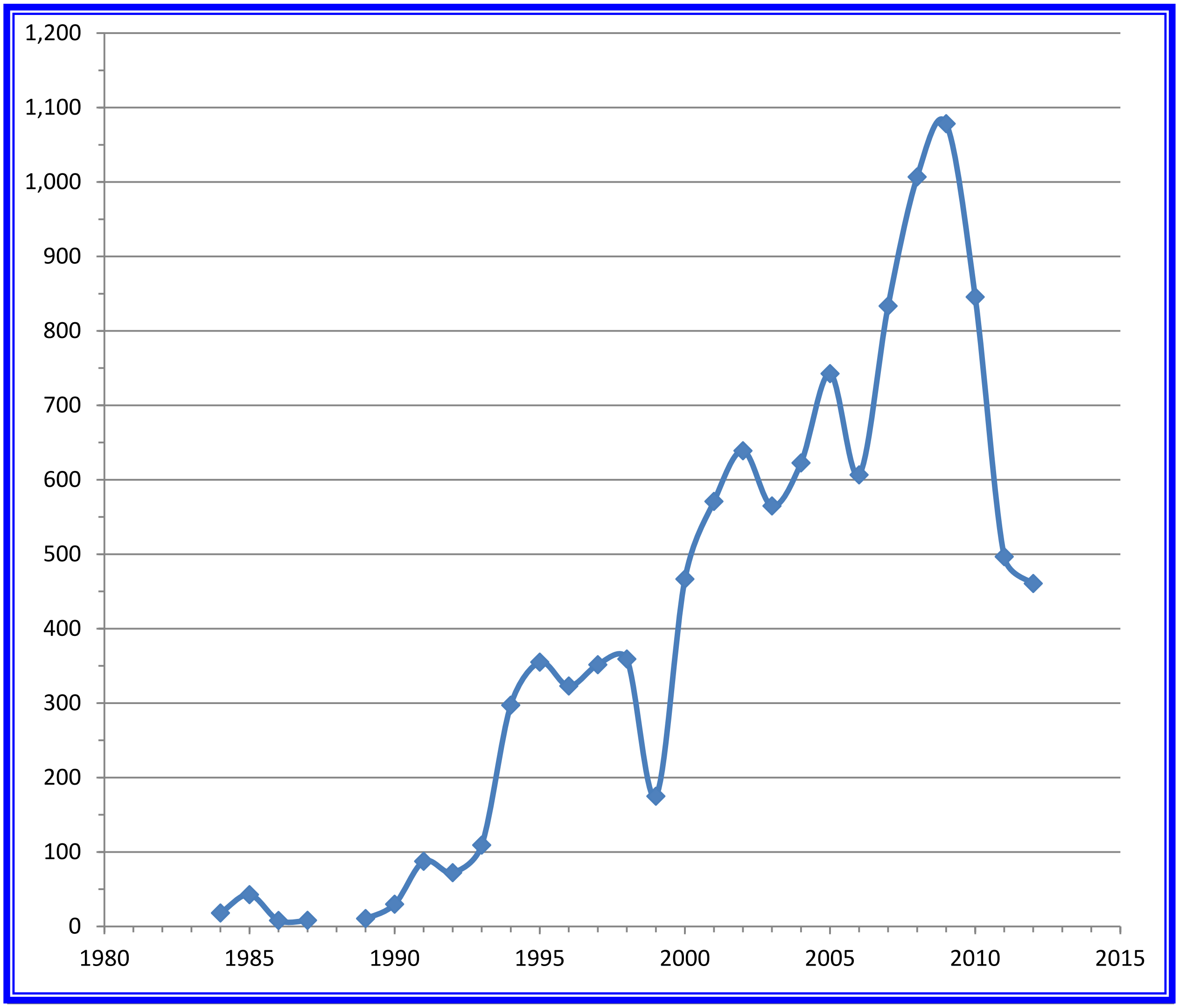
VIMS mapped no SAV beds immediately below the Conowingo Dam in the non-tidal and tidal Susquehanna River over the period 1997-2012. However, VIMS frequently mapped SAV in the non-tidal and tidal river downstream to the river mouth from the 1990s through 2010 (VIMS, 2013). SAV was found to occur in 2010 downstream of Conowingo Dam at creek mouths and islands between the dam and Port Deposit in shallow areas with coarser-grained sediment (sand and cobble), near sources of sediment supply and reduced flow velocities (tributary mouths and a protected island complex (URS and GSE, 2012c).

In free-flowing non-tidal segments of the river, SAV occurs within portions of the active channel that are permanently inundated during the growing season. SAV stems and leaves are susceptible to damage or death by atmospheric exposure during the growing season. One of the Susquehanna River basin's most abundant SAV species is riverweed (*Podostemum ceratophyllum*). Riverweed is a perennial found in moderate to high velocity riffles (TNC, 2010). Riverweed does not occur in the Chesapeake Bay proper.

Conowingo Reservoir SAV

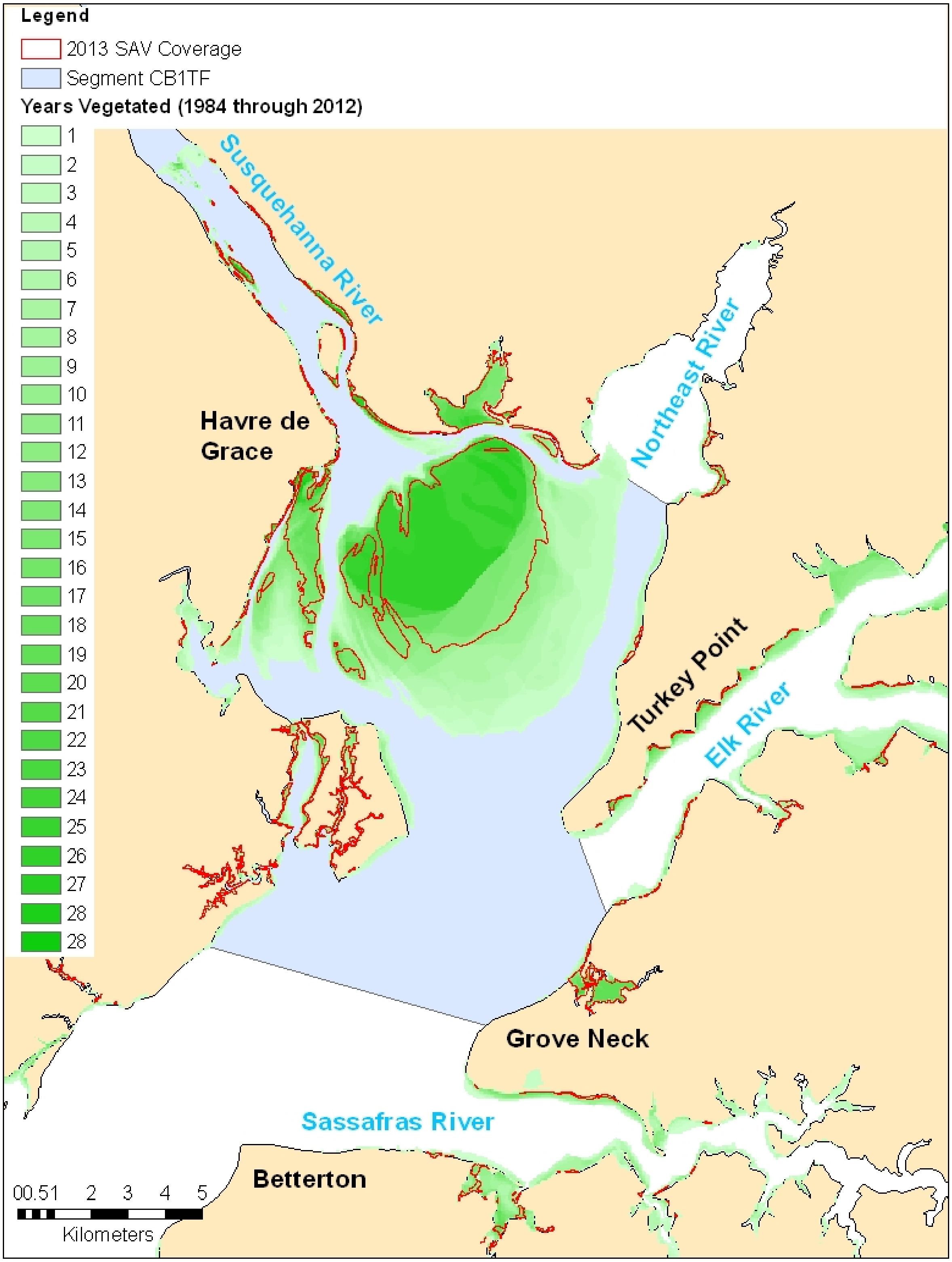
SAV occurs on unconsolidated alluvial deposits in the upper portion of the Conowingo Reservoir. SAV surveys in the reservoir conducted in 2010 found a total of seven species, but hydrilla (*Hydrilla verticillata*), a tolerant invasive species, dominated the coverage in the majority of locations where

Figure K-17. SAV Abundance for Northern Chesapeake Bay Segment 1



<u>Notes</u>: *SAV abundance is shown in acres.*
Segment 1 = CB1TF1, which contains the mouth of the Susquehanna River and Susquehanna Flats.

Figure K-18. SAV Bed Occurrence in Northern Chesapeake Bay Segment 1



SAV was growing. Hydrilla is also common in Chesapeake Bay. SAV in the reservoir covered 321 acres during this 2010 survey. Changes in water levels have the potential to decrease the extent of or dewater SAV beds (URS and GSE, 2012a).

Well-established SAV communities appear to be absent from the bedrock dominated portions of the Susquehanna River above Conowingo Reservoir. In general, steep rock-dominated shorelines do not provide habitat for SAV because of absence of bottom habitat within the photic zone (URS and GSE, 2012a).

K.7.3 Wetlands

Nearly 1.5 million acres of wetlands occur in the Chesapeake Bay watershed; 1.3 million acres are non-tidal and 200,000 acres are tidal (CBP, 2013). The tidal wetlands water regime is controlled by sea level and flood with tidal water at high tides. Non-tidal wetlands have water levels independent of sea level. Tidal and nontidal wetlands are divided into several general vegetation types. Emergent wetlands, generally called marshes, are vegetated by grasses, sedges, and other leafy, non-woody plants. Shrub wetlands are dominated by woody shrubs. Forested wetlands, often called swamps, are dominated by trees.

Chesapeake Bay Tidal Wetlands

Tidal wetlands provide habitat for numerous animals and plants, and debris from plants exported from tidal wetlands supports the Chesapeake Bay food web. Tidal wetlands are found along the shores of the Bay and in tidal portions of rivers. New tidal wetlands form as the rising sea floods the land, and on recent sediment deposits in tidal waters. Tidal brackish and salt wetlands generally range from a low elevation of about mean water to a maximum elevation of about spring-tide high water. Tidal freshwater wetlands can have floating leaved plants that grow permanently inundated, thus they can occur to below mean lower low water.

Tidal marshes found along the Chesapeake Bay are divided into three general categories corresponding to salinity of their waters: freshwater marshes of the upper Bay, brackish marshes of the middle Bay, and salt marshes of the lower Bay. Tidal wetlands of the uppermost Bay are typically described as being freshwater because they largely share the same vegetation as freshwater wetlands. However, tidal freshwater wetlands actually occur at sites of fresh to oligohaline salinities. Along the shoreline of the lower Susquehanna River and in the upper Chesapeake Bay, tidal wetland parcels occur locally in wave-protected tidal portions of creeks and rivers draining into the Bay. In the uppermost Bay, steep topography along the shoreline disfavors expansive tidal wetlands formation.

History of the Tidal Wetlands

Historic trends in Bay tidal wetlands have not been quantified accurately (Tiner and Burke, 1995). It is probable that a net loss since European settlement has occurred as habitat destruction via erosion and inundation driven by rising sea level has exceeded tidal wetland formation. New tidal wetlands form via migration onto the drowning mainland, and in delta and other settings on new sediment deposits. This loss trend was probably primarily natural, but exacerbated by human actions (Stevenson et al., 2000). Direct anthropogenic loss occurred as a consequence of filling and canal construction prior to the early 1970s, when modern environmental laws protecting wetlands were enacted. Approximately 0.5 percent of the Bay's tidal wetlands were lost over the period 1982 to 1989, with the majority of these losses occurring via conversion to open water (Tiner et al., 1994). There is a declining trend in tidal wetland abundance in the Chesapeake Bay now driven primarily by wetland conversion to open water occurring at a faster rate than new tidal wetland formation. Land change statistics show a 2,600-acre loss between 1996 and 2005 (CBP, 2013).

Tidal wetlands of the Bay are actually favored by conditions of sediment availability. Tidal wetlands in riverine settings receive greater mineral sediment input than do tidal wetlands isolated from regular tidal flows and are consequently less vulnerable to effects of rising sea level (U.S. Climate Change Science Program, 2009). Substantial areas of tidal wetlands formed on the Western Shore, historically in river valleys where excess sediment conveyed in from anthropogenic erosion was deposited intertidally (Gottschalk, 1945). Tidal wetlands did not form on the Susquehanna River delta from excess erosion in the Susquehanna River basin during the 19th and 20th centuries, however.

Susquehanna River Wetlands

Non-tidal wetlands are not flooded by the tides and contain fresh water. Non-tidal wetlands occur on floodplains bordering streams and rivers, on the shores of lakes and ponds, in depressions, and in broad, flat low-lying areas that drain poorly.

In the Susquehanna River basin, non-tidal wetlands occur within portions of the river channels and floodplains with a semi-permanent inundation frequency, typically on islands, edges of bars, and terraces. A variety of plant communities occur within the river channels as a function of ice scour, inundation, and soil development. Where severe flood and ice scour occurs, inundation duration is seasonal to temporary flooding, and geologic deposits occur but soil development is minimal, then herbaceous (non-woody) plants typically occur during the growing season. Plant growth of these wetlands dies back in non-growing season months, and these sites may appear unvegetated early in the growing season and in non-growing season months. During the growing season, emergent beds can tolerate inundation under high-flow conditions and exposure under low-flow conditions, but the frequency and duration of inundation and exposure can impact the condition of emergent vegetation. Where severity of ice scour is moderate on flats, bars, and low terraces of islands and banks, shrub communities often occur. Where ice scour is low and inundation duration just temporary, floodplain forests occur (TNC, 2010).

Downstream of Conowingo Dam, non-tidal shrub and forested wetlands are shown by the National Wetlands Inventory to occur along one or both shorelines of the Susquehanna River, as well as on islands in the river. Marsh occurs at the lowest, wettest sites as a consequence of the water base level being tidal and thus substantially less affected by seasonal low-flow conditions. Wetlands with woody vegetation occur generally at somewhat higher elevations.

Conowingo Reservoir Wetlands

Wetland vegetation occurs in crevasses on the protected downstream side of rocks in the bedrock-dominated portions of the reservoir. As typical river energy conditions diminish further downstream, wetlands become more prominent, growing in sediment deposits within cracks in the rock surfaces and bedrock islands. Wetlands are present primarily at sites of accumulating sediment, where it covers the hard-bottom substrate particularly along the margins of tributaries flowing into the reservoir. Emergent wetlands occur on point bars in shallow tributaries and at the confluences of tributaries with Conowingo Reservoir. Water level fluctuations in Conowingo Reservoir over the range at which they are typically managed have negligible effects on SAV there (URS and GSE, 2012a).

K.7.4 Benthic Invertebrates

Benthos is the community of organisms that live in or on the bottom sediment of water bodies. Benthos includes mobile and immobile organisms. Benthic invertebrates are animals without a backbone that live on top of or within bottom sediments in aquatic ecosystems.

They are often used as indicators of water quality and ecological health due to their abundance, known pollution tolerances, and limited mobility. A typical healthy benthic community includes species characteristic of unstressed communities. In a polluted environment, these species would be replaced by species more tolerant of pollution. Most degraded communities would also tend to have fewer species, fewer large organisms deep in the sediment, and a lower total mass of organisms (Versar, 2013).

Chesapeake Bay

The benthic community of the brackish Bay includes a wide variety of organisms including clams, oysters, small shrimp-like crustaceans, and worms. Benthic invertebrates provide food for many larger organisms, including bottom-feeding fish. Oxygen is the single best predictor of benthic density in Chesapeake Bay in the summer. At low oxygen levels, biomass is extremely low, resulting in substantial loss of benthic production and foraging habitat for fish and crabs. Benthic animals in deeper waters of the Bay are the principal group affected by poor water quality. Benthic monitoring shows that about one-fourth of the Bay benthos exhibit severely degraded conditions, about 20 percent show degraded conditions, 10 percent show marginal conditions, and about 45 percent are meeting program goals.

The upper Bay is healthier than the middle Bay. About 30 to 50 percent of the upper Bay has generally failed to meet restoration goals over the period 1995-2012. Approximately 50 to 80 percent of the middle Bay fails to meet benthic goals, largely because of hypoxic conditions. The lower Bay shows about 25- to 50-percent failure to meet restoration goals over the 1995-2012 period (Versar, 2013).

Regions of the Maryland mainstem deeper than 39 feet are subjected to summer anoxia and have consistently been found to be azoic (without higher life forms) in benthic sampling (Versar, 2013).

Oysters (Eastern oyster, *Crassostrea virginica*) are naturally absent from the upper portion of the upper Bay in the vicinity of Susquehanna Flats because salinity conditions there are too low for them to grow (generally oysters need salinities to be greater than 5 ppt). Oysters occur in the lower portion of the upper Bay, as well as the middle and lower regions of Chesapeake Bay. The most northerly oyster beds in the Bay occur in the vicinity of Pooles Island about 20 miles south of the

Susquehanna River mouth (MDNR, 2012). North of the Potomac River, oysters historically occurred in vast "beds" on the Bay bottom in water from 5 to 30 feet deep. Shells of these beds had some vertical relief off the Bay bottom sufficient to disfavor sedimentation on live oysters. From the Potomac River southward, oyster reefs occurred that had relief of up to several feet off the Bay bottom. These oyster reefs extended into intertidal waters and formed navigation hazards (Smith et al. 2003; Woods et al., 2004).

Intense overfishing and exotic disease/parasites caused a dramatic decline in oyster populations in the 20th century. Chesapeake Bay oyster resources underwent a 90- to 99-percent population and habitat loss. Oysters are filter feeders. Anthropogenic oyster loss exacerbated effects of Bay eutrophication on water quality by causing loss of filtration services that oysters historically provided. This loss further impaired water clarity to the detriment of SAV (Newell and Ott, 1999). Because of their ecological and commercial importance, a wide array of public and private efforts is underway to restore Bay oyster populations and habitat. Limited commercial harvesting of oysters occurs in Maryland and Virginia, but regulations limit the harvests and are designed to maintain oyster populations (CBP, 2013).

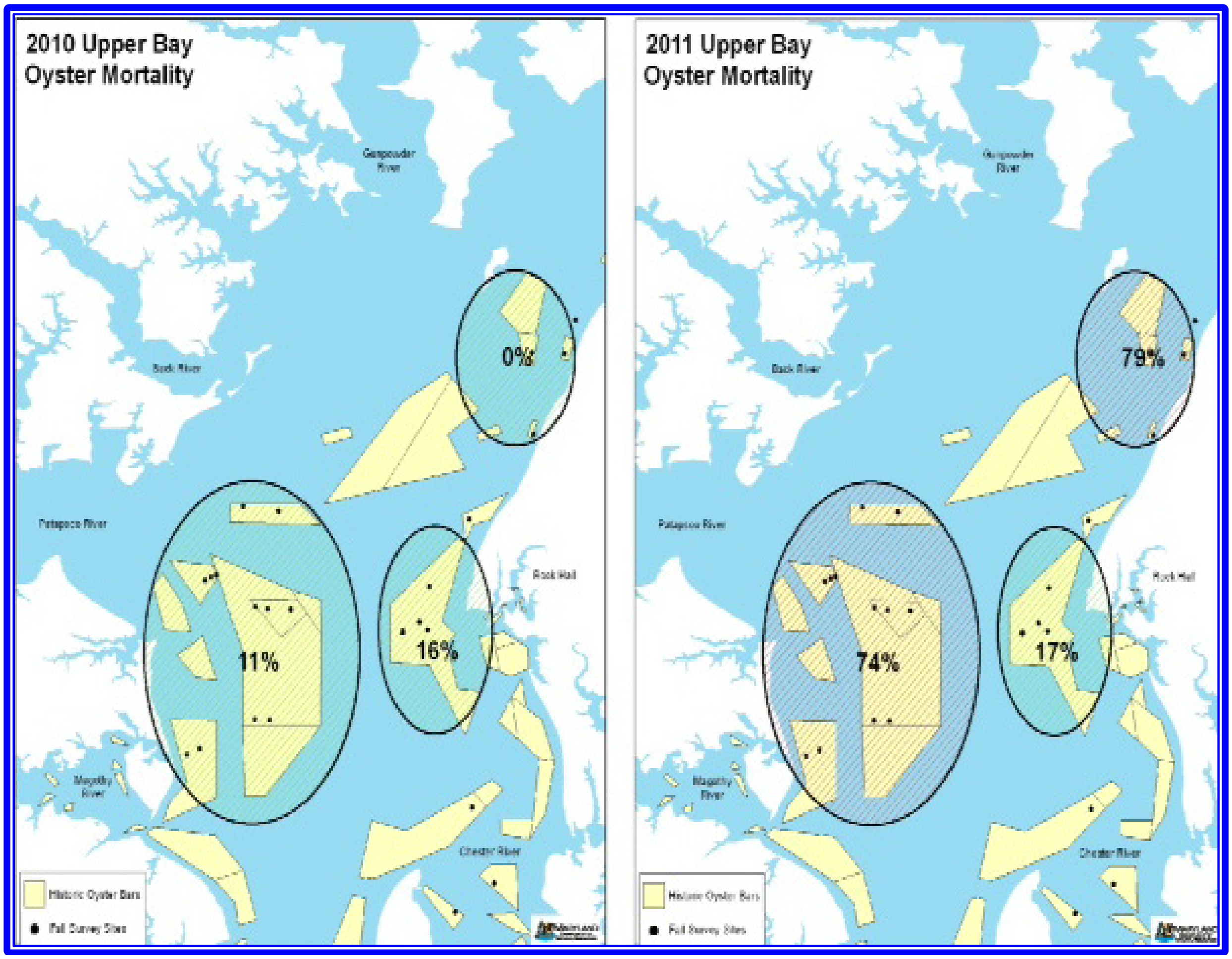
Oysters can survive substantial sedimentation, provided they are healthy and able to produce shells that maintain bed habitat and vertical structure (Smith et al., 2003). Sedimentation on former oyster beds today is generally occurring at rates characteristic of pre-European settlement conditions. Vast oyster beds generally did not occur in headwater tributary and deepwater locations where anthropogenic increases in Bay sedimentation rates have occurred. However, as a consequence of overharvesting, diseases, loss of physical habitat, and poor water quality, existing oyster populations are incapable of producing sufficient shell to enable beds to keep up with natural sedimentation. Sedimentation of former beds renders the substrate less suitable for oysters, ultimately eliminating bed habitat.

Oysters closest to the heads of tidal tributaries are susceptible to mortality from freshets. Widespread oyster losses in the Chesapeake Bay induced by excessive fresh water have occurred many times this century, with severe die-offs in 1909, 1944, 1958, 1972, and 1993 (MDNR, 2012).

MDNR investigated oyster mortality from Tropical Storms Lee and Irene by comparing findings of the annual fall oyster surveys of 2010 and 2011; these findings are shown in Figure K-19 (MDNR, 2013). The four northernmost bars suffered a cumulative mortality of 79 percent in 2011, compared with 0 percent in 2010. Higher than normal mortalities were observed down the Bay on the Western Shore, where combined observed mortality for six bars sampled in fall 2011 was 74 percent, a sevenfold increase over 2010 (11 percent). In contrast, there were no observed excess mortalities in the middle Bay from Sandy Point southward. Oysters in these areas seemed to be in prime condition.

Burial of the oysters due to sediment from Hurricane Irene (August 2011) and Tropical Storm Lee (September 2011) was suspected initially as the cause for high mortalities in fall 2011. However, investigations indicated that this is not the case. Live fouling organisms, including barnacles, mussels, and bryozoans, were found attached to the oysters and shells on these bars. Had the oysters been smothered by sediment, these organisms would not have been able to attach to the oyster shells and would not have survived. The likeliest cause of high mortality was determined to be excessive fresh water and its resultant lack of salinity, for an extended duration in the upper Bay.

Figure K-19. MDNR Fall Oyster Surveys, 2010 vs. 2011 Oyster Mortality



The fact that mortality was highest in the upper Western Shore, where salinity is lowest, reinforces this hypothesis. In summary while oysters are vulnerable to excess sedimentation because of the failure to produce sufficient shell, low salinity conditions restrict oyster beds from occurring within about 20 miles of the Susquehanna River. This substantial distance from the mouth of the Susquehanna River to extant oyster beds limits sediment that can be delivered to these beds from the river. Oysters in the lowermost section of the upper Chesapeake Bay appear to be more vulnerable to the effects of freshets (influx of fresh water typically from rain events) than sediment. Additionally, oysters occurring at greater depths in the lowermost upper Bay are probably vulnerable to effects of hypoxia and anoxia.

The benthic community of the uppermost freshwater Bay includes aquatic insects, snails, and clams comparable to freshwater non-tidal habitats. These organisms diminish downstream in the Bay as salinity increases (White, 1989).

Susquehanna River Benthic Invertebrates

Benthic macroinvertebrates of free-flowing river habitats include aquatic insects, crayfish, clams, snails, and worms. Macroinvertebrate communities of the mainstem lower Susquehanna River have been stable with indices reflecting mostly non-polluted and slightly polluted conditions, with a small number of moderately impaired conditions and no severely polluted conditions (PFBC, 2011).

Conowingo Reservoir Benthic Invertebrates

Conowingo Reservoir provides habitat for benthic macroinvertebrates typical of rivers as well as lakes (URS and GSE, 2012a).

K.7.5 Finfish

Chesapeake Bay

The uppermost Chesapeake Bay is a spawning and nursery ground for seven species of anadromous fish, including striped bass (*Morone saxatilis*), white perch (*Morone Americana*), yellow perch (*Perca flavescens*), American shad (*Alosa spadissima*), alewife (*Alosa pseudoharengus*), blueback herring (*Alosa aestivalis*), and hickory shad (*Alosa mediocris*) (Funderburk et al., 1991). Abundant shallow water (less than 3 feet deep), low salinities in spring, abundance of coarse bottom (sand, gravel, and cobble), abundant SAV, and retention of planktonic eggs and larvae above the ETM make this an important Bay fish habitat (NMFS coordination, Appendix I).

The upper Bay is also nursery habitat for numerous other finfish that spawn in Bay waters and nearshore coastal ocean waters off the Bay mouth. These include Atlantic menhaden (*Brevoortia tyrannus*), bluefish (*Pomatomus saltatrix*), spot (*Leiostomus xanthurus*), Atlantic croaker (*Micropogon undulates*), winter flounder (*Pseudoharengus americanus*), and Bay anchovy (*Anchoa mitchilli*) (Funderburk et al., 1991). High zooplankton content and detritus associated with the ETM make this nursery critical to maintenance of stock abundance for these mid-Atlantic species (NMFS coordination, Appendix I).

The upper Bay also provides habitat for many typical freshwater fish species. These species range well into brackish waters of the Bay, with their downstream extent dependent on their tolerance to salinity. Freshwater fish occurring in the upper Bay include a variety of darters, suckers, minnows, pickerel, sunfish, catfish, and other species (White, 1989)."

Fish species occurring along the length of the Bay differ as a function of salinity and other factors. The middle and lower regions of the Bay have greater biomass of fish species that spawn on the Continental Shelf, as well as sharks and rays, compared to the upper Bay. The upper Bay contains greater biomass of anadromous species that spawn in low salinity waters (Buccheister et al., 2013). Generally, the lower and middle Bay regions have more diverse and changing fish assemblage than the upper Bay through the year, primarily because of migration of many species. However, the upper Bay typically has more fish species occurring at any one place through the year because there is less turnover of species through the year (Buccheister et al., 2013).

Low DO levels limit distribution and abundance of fish, because fish avoid waters where DO drops below 4 mg/L. Demersal (bottom-oriented) fish of the Bay have had a substantial seasonal reduction in habitat availability with onset of vast anthropogenic hypoxia or anoxia. Forage for demersal fish in the middle Bay is reduced due to hypoxia and eutrophication stress, likely detrimentally affecting Atlantic croaker, white perch, and spot (Buccheister et al., 2013). Bay anchovy is one of the Bay's most important forage fish (food for larger fish). This year-round, open-water Bay resident, inhabits shallows during warm weather months, but moves to deep-water habitats in Bay in winter. The abundance of this species appears to have declined over the last several decades (CBP, 2013). Were it not for low DO conditions, Bay anchovy would likely utilize deep-water habitat of the Bay as a feeding ground and as a refuge from predators during warmwater months (Ludsin et al., 2009).

Susquehanna River and the Reservoirs

The three dams form manmade fish blockages which are probably the most important in the Chesapeake Bay watershed, having essentially eliminated access to the Susquehanna River basin for migratory fish ascending or descending the river to the Bay. Migratory fish species affected include various species of shad and river herring, as well as American eel (*Anguilla rostrata*). Construction of the dams contributed to regional declines of the populations of the migratory fish that formerly made use of upstream river habitat in much greater numbers than today. All three dams have fish passage projects in place to reduce the impacts of the dams to fish migration patterns. Improving passage of migratory fish through the dams is a topic of ongoing concern in relicensing of the Conowingo Dam hydropower (CBP, 2013).

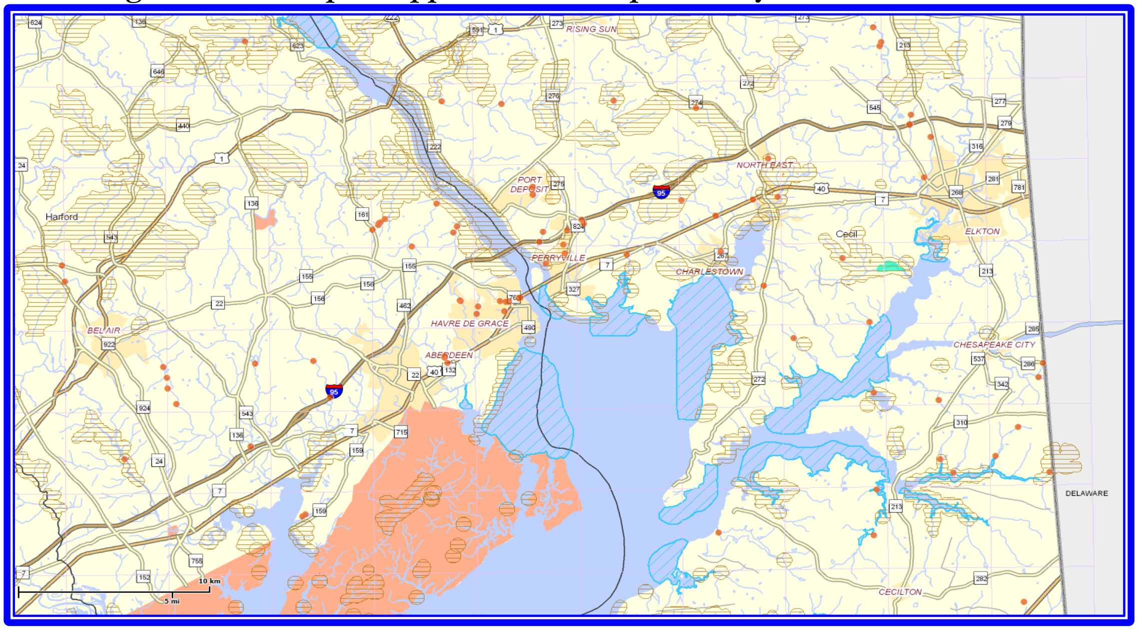
The reservoirs provide habitat for numerous freshwater fishes. In Conowingo Reservoir, principal resident fish species include gizzard shad (*Dorosoma punctatus*), largemouth bass (*Micropterus salmoides*), smallmouth bass (*Micropterus dolomieu*), walleye (*Sander vitreus*), channel catfish (*Ictalurus punctatus*), and a variety of minnows (Cyprinidae family). Optimal spawning habitat for the majority of species occurs over shallow vegetated and unvegetated gravel substrates. Gizzard shad and channel catfish will also spawn over shallow sandy habitat and shallow vegetated silt substrates. Shallow unvegetated gravel substrates and shallow vegetated sand substrates are preferred environments for the adult life stage of the majority of principal fish species. Adult gizzard shad, largemouth bass, channel catfish, and minnows also prefer shallow silt substrates containing vegetation. These habitat types are well represented in the littoral zone of Conowingo Reservoir, providing generally good quality habitat for recreationally and ecologically important fish species in the Susquehanna River (URS and GSE, 2012a).

K.7.6 Birds

The shoreline along the uppermost Bay near the Susquehanna River has been delineated as a historic waterfowl staging and concentration area by MDNR, as shown in Figure K-20 (MDNR, 2013).

The lower Susquehanna River is extremely important to migratory waterfowl and increasingly more important to waterfowl production in the Atlantic flyway. The area is an important wintering and migration area for greater snow geese (*Chen caerulescens*), tundra swans (*Cygnus columbianus*), and American black ducks (*Anas rubripes*), and also supports significant numbers of breeding waterfowl, primarily mallards (*Anas platyrhynchos)* and wood ducks (*Aix sponsa)*. Wintering birds are found

Figure K-20. Map of Uppermost Chesapeake Bay Waterfowl Habitats



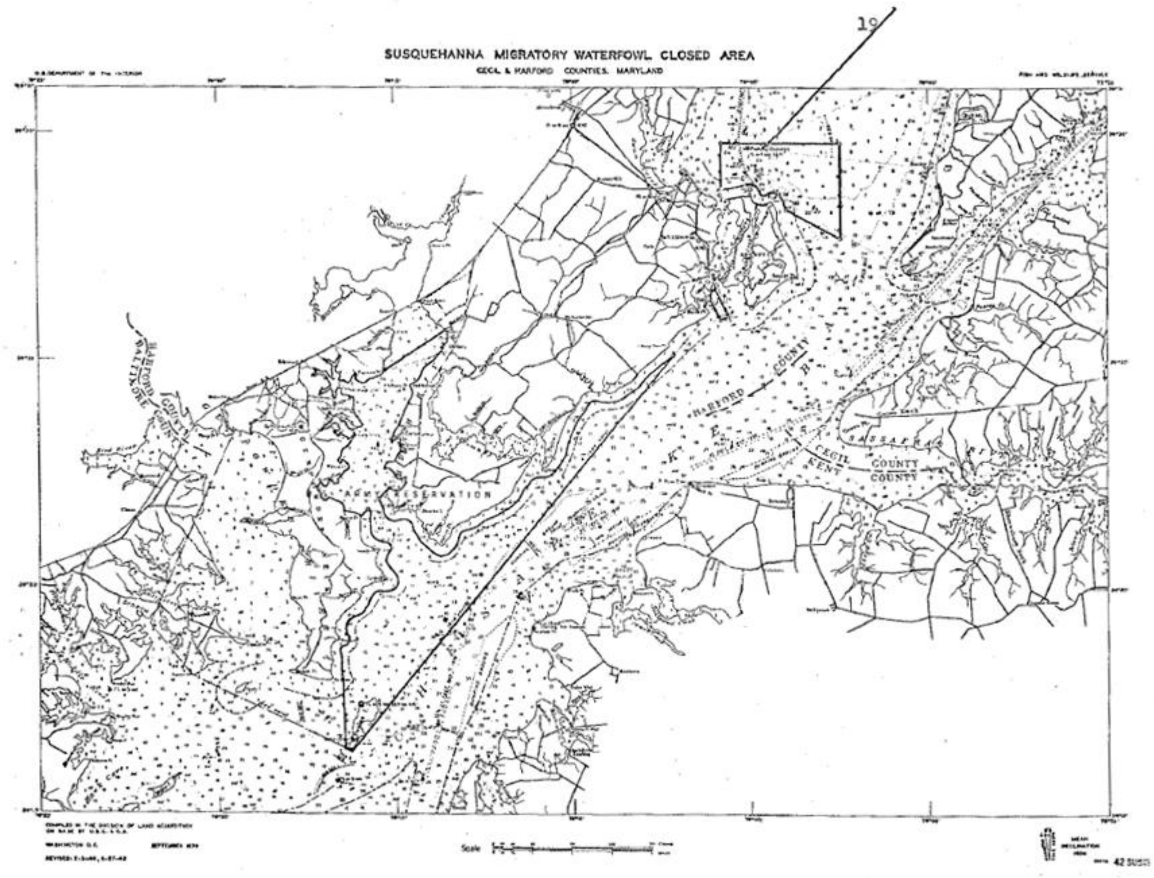
Notes: *Blue-diagonal hatched polygons are important waterfowl habitats.*
Red area is the Aberdeen Proving Ground, a U.S. Army materials testing site.
Source: *Prepared from http://dnr.maryland.gov/ccp/coastalatlas/index.asp.*

predominantly in the river mouth, whereas spring staging birds are distributed across the landscape (Ducks Unlimited, no date).

The upper Bay at the mouth of the river was formerly an important habitat for migratory waterfowl, with hundreds of thousands of individuals making use of the large SAV beds present in the early to mid-20th century. Because of its importance for waterfowl, 13,363 acres of water in the upper Chesapeake Bay and Battery Island were designated as a National Wildlife Refuge (NWR) in presidential proclamations and an executive order over the years from 1939-42; the extent of the NWR is shown in Figure K-21. Battery Island is located at the mouth of the Susquehanna River in Harford County, MD, about 3 miles south of Havre de Grace. The refuge extended from Battery Island to the Bush River along the western shore and primarily consisted of large areas of open water and SAV that were seasonally closed during waterfowl season. Waterfowl use of the area declined dramatically in the 1960s in concert with declines in SAV. Because of the dramatic decrease in waterfowl numbers and submerged vegetation in the area, the presidential proclamations designating the waters of the area as a NWR were lifted on September 1, 1978, and the waters were returned to the State of Maryland. Battery Island is the only extant, designated remnant of the former Susquehanna NWR. Today, only a few thousand geese typically utilize the waters around Battery Island during the winter months (http://www.fws.gov/northeast/susquehanna; USFWS, 2013).

Bird species utilizing Conowingo Reservoir include great blue heron *(Ardea herodias)*, green heron (*Butorides virescens)*, tern species, gull species, double crested cormorant (*Phalacrocorax auritus)*, spotted sandpiper (*Actitis macularia),* belted kingfisher (*Ceryle alcyon*), bald eagle (*Haliaeetus leucocephalus)*, and

Figure K-21. Map of Historic Susquehanna NWR Showing Boundaries



osprey (*Pandion haliaetus)*. Osprey and bald eagle nest along the Conowingo shoreline (URS and GSE, 2012a).

K.8 AIR QUALITY

Air quality is affected by natural and manmade emissions. The former include dust, forest fires, and lightning. Natural emissions occurring at natural rates and within natural ranges are not typically thought of as pollutants in that these produce air quality characteristic of the region. Air pollution derives from manmade emissions from large stationary sources such as power plants and manufacturing facilities, small stationary sources such as dry cleaners and gas stations, mobile sources such as vehicles and equipment, and agricultural sources, including livestock, poultry, and pesticides. The Chesapeake Bay airshed, or area of land from which airborne pollutants can travel to reach the Bay, covers approximately 570,000 square miles (nine times as large as the watershed) and extends from North Carolina in the south, west to Indiana, and north to Canada. On its eastern boundary, the airshed includes western and central New York, western New Jersey, and the Eastern Shore. This region includes the Baltimore-Washington metropolitan region which has among the nation's worst ground-level ozone problems.

Air pollution from the airshed falls back to the earth's surface, affecting people and terrestrial and aquatic environments. Forests absorb some air pollution. A portion of the air pollution falling back to earth and waters is transported into waterways and ultimately into Chesapeake Bay. Principal air pollutants of concern to freshwater and saltwater aquatic ecosystems of the Susquehanna River basin and Chesapeake Bay include nitrogen and contaminants (metals such as mercury, and chemicals such as PCBs and PAHs). Contaminants accumulate in some aquatic organisms in nontidal and tidal waters at levels locally harmful or toxic to the organisms, as well as to people that consume affected shellfish and finfish. Contaminants accumulate locally in fine-grained sediments, posing risk to aquatic life exposed to these sediments. Nitrogen washes into the Bay and contributes to eutrophication. Approximately one-fourth to one-fifth of the nitrogen reaching the Bay derives from air pollution (CBP, 2013).

K.9 WATERSHED VALUES

Uses of the lower Susquehanna River subbasin landscape by people align closely with land cover and land use. Agricultural lands are used to produce food for people and forage for livestock. Forested lands produce timber and produce clean water for streams. Urban lands provide places for people to live and work. Extraction of rocks and minerals also occurs to provide materials for construction and other uses. Some solid waste from human activities is disposed of in landfills. Waters of the Susquehanna River provide drinking water for numerous people in Pennsylvania and Maryland, and provide water for a variety of industrial and agricultural uses. Of particular importance to this study, water in the lower subbasin is used to generate hydropower, providing electricity for a wide area of southeastern Pennsylvania. Waters of the Susquehanna River are also used recreationally for boating and fishing.

K.9.1 Human Population

The Chesapeake Bay watershed has a population of more than 17 million people (CBP, 2013). The Susquehanna River basin itself has a population of 4.1 million people (SRBC, 2013a). The lower Susquehanna River subbasin has a population of 1.9 million, nearly half of the total Susquehanna River basin's population (SRBC, 2013a).

K.9.2 Community Setting

This section provides an overview of political entities of interest of the lower Susquehanna River corridor and was prepared by reviewing and summarizing a variety of readily available geographic maps.

Conowingo Dam sits astride the Susquehanna River in Maryland with its western landing in Harford County and its eastern landing in Cecil County. No incorporated municipalities in either county are located near the dam. Incorporated municipalities lie downstream of the dam along the Susquehanna River: Havre de Grace in Harford County, and Port Deposit and Perryville in Cecil County. The remaining lands along the river are unincorporated and under the governance of the respective counties. Maryland counties are not subdivided into townships, although they can contain incorporated municipalities with their own local governments distinct from that of the county in which they occur.

Unlike Maryland, Pennsylvania counties are subdivided into townships. Safe Harbor and Holtwood Dams have their western landings in York County and their eastern landings in Lancaster County. Each dam lies close to the respective community close to its eastern landing after which it is named. However, neither Safe Harbor nor Holtwood, both in Lancaster County, are incorporated municipalities. Holtwood is a village within Martic Township. Safe Harbor is a community located within Conestoga Township. That said, Safe Harbor Dam's eastern landing is actually within Manor Township which lies immediately northwest of Conestoga Township. The western landings of Safe Harbor Dam and Holtwood Dam lie in Chanceford Township and Lower Chanceford Township, respectively, both in York County. These communities are all effectively suburbs of Lancaster, PA and York, PA.

K.9.3 <u>Water Supply</u>

People in rural areas obtain drinking water from groundwater wells. Historically, people used water from the saprolite in the Piedmont. Today, groundwater for drinking is drawn from bedrock fractures and joints because of lower risk of contamination from surface sources. People in more densely populated areas obtain potable water from a variety of surface water sources.

Both Lake Clarke and Conowingo Reservoir are currently a surface water source for several entities, as detailed in Table K-8. SRBC has no records of significant intakes from Lake Aldred, presumably because of its more remote locale. Downstream of Conowingo Dam, several municipalities obtain water from the Susquehanna River. In Cecil County, Port Deposit and Perryville utilize water from the river. Both municipalities identify excess sediment as concerns for continued water use (Cecil County, 2008). In Harford County, the city of Havre de Grace has a water withdrawal permit for 10 million gallons per day from the Susquehanna River. The city's intake is exposed to tidal influence when the discharge from Conowingo Dam is low; consequently, its water quality can be impacted by salinity (SRBC, 2006c).

K.9.4 <u>Transportation Infrastructure</u>

Railroad tracks of Norfolk-Southern parallel the Susquehanna River on its eastern bank. The tracks connect to Perryville, MD, in the south, and to Harrisburg and other points in Pennsylvania in the north. These tracks pass on the east side of Conowingo, Holtwood, and Safe Harbor Dams. No railroad bridges cross near any of the three dams. The southwest/northeast-oriented railroad tracks of the CSX Corporation cross the lowermost Susquehanna River at Havre de Grace and Perryville, MD. Amtrak also has a bridge crossing between Havre de Grace and Perryville on southwest/northeast-oriented tracks.

U.S. Route 1 crosses the Susquehanna River over the Conowingo Dam. No roads cross over the Susquehanna River on either Holtwood or Safe Harbor Dams. Route 1 typically conveys about 12,270 vehicles across the bridge per day (MDOT, 2013). Pennsylvania Route 372 crosses the Susquehanna River about 1 mile downstream of Holtwood Dam. No highway bridges cross the Susquehanna River in the vicinity of Safe Harbor Dam.

Table K-8. Entities Using the Lower Susquehanna Reservoirs as a Water Source

Reservoir	Entity	Usage
Conowingo Reservoir	Peach Bottom Atomic Power Station, York County, PA City of Baltimore, MD Harford County, MD	Cooling Municipal water supply Public water supply (provided by Baltimore's system)
	Chester Water Authority, PA	Water supply utility, serving areas of southeast Pennsylvania and northern Delaware
	York Energy Center, PA	Water source
Lake Clarke	Columbia Water Company, PA	Municipal water supply
	Lancaster City Water System, PA	Municipal water supply
	Red Lion Borough Municipal Authority, PA	Municipal water supply
	Wrightsville Borough Municipal Authority, PA	Municipal water supply
	York Water Company, PA	Municipal water supply

Source: For Conowingo information, URS and GSE, 2012a*; for Lake Clarke information, SRBC records.*

K.9.5 Navigation

USACE maintains a navigation channel called the Susquehanna River at Havre de Grace Project (previously shown in Figure K-13) that extends from Havre de Grace at the mouth of the Susquehanna River along the west side of the Susquehanna Flats to waters of 15-foot depth in the upper Bay 4 miles southward (USACE, 2012). The project provides for: (1) a channel 200 feet wide and 15 feet deep from that depth in Chesapeake Bay to Havre de Grace, (2) removal of the shoal opposite Garrett Island to a depth of 8 feet, and (3) maintenance of the existing small boat harbor (380 feet wide, 400 feet long) with an approach channel 75 feet wide to a depth of 7 feet. The most recent dredging occurred in 2012 with the removal of 200,000 cubic yards of sand. The dredged material was placed to expand Battery Island and subsequently planted to provide habitat for waterfowl.

Navigable reaches occur in the Susquehanna River. However, the river is typically shallow, and boulders and rock outcrops are common, limiting commercial navigation in the river (PFBC, 2012).

Historically, there were canals on both the west and east banks of the lower Susquehanna River. The Susquehanna Canal on the east bank ran from the Chesapeake Bay to the Pennsylvania line in Maryland. The canal was completed in 1802 and closed in 1840. A canal on the west bank of the Susquehanna River called the Susquehanna and Tidewater Canal ran from Havre de Grace, MD, to Wrightsville, PA. The canal was completed in 1840 and ceased operations in 1894, although it was in decline through much of the late 19th century (Wikipedia, 2013).

K.9.6 Recreational Water Activities/Uses

Recreational boating and fishing opportunities abound in Chesapeake Bay. Numerous private marinas and boat ramps provide access points for boats. There are also a limited number of public marinas and boat ramps. While the Bay shoreline is publicly owned, infrequent public access points from land effectively limit public shoreline use where privately owned lands lie adjacent to the Bay. Efforts are underway to increase public access to the Bay (CBP, 2013).

The uppermost Chesapeake Bay and its tributary rivers are a notable sport-fishing area. Fish species caught shift through the months of the year reflecting movements of migratory fish into and out of the upper Bay, as well as availability of resident fish. Fish caught typically start with yellow perch in February. Then white perch, striped bass, and shad are caught in March and April. Largemouth bass (*Micropterus salmoides*) become a target species beginning in May. In the summer and fall, striped bass, perch, and various species of catfish are caught (MDNR, 2003).

The upper Chesapeake Bay in the vicinity of Susquehanna Flats is notable in that low salinities restrict jellyfish, and waters there are swimmable throughout warm weather months. A number of public beaches that provide swimming opportunities are located along the shoreline. In contrast, the middle and lower Bays generally support large numbers of sea nettles in warm weather months and are unswimmable at those times.

Shallow depths and numerous rock obstructions limit boating opportunities in the Susquehanna River. However, small boat users who have knowledge of river conditions do make ready use of the river. In contrast, the series of lakes created by the lower Susquehanna River dams provide practical boating opportunities for sailing, water skiing, and fishing. The lakes have a variety of marinas, boat ramps, picnic grounds, playgrounds, and other recreational facilities. In addition, the lakes and adjacent lands provide opportunities for hunting waterfowl and large and small game, as well as hiking (PFBC, 2012). Heated effluent discharged from the Peach Bottom Atomic Power Station into Conowingo Reservoir attracts game fish during the winter and creates an extended open-water fishing season (SRBC, 2006a).

K.10 HYDROELECTRIC DAM STRUCTURES AND OPERATIONS

The three major hydroelectric facilities on the lower Susquehanna River, from upstream to downstream, are Safe Harbor Hydroelectric Station (at Safe Harbor Dam), Holtwood Hydroelectric Station (at Holtwood Dam), and Conowingo Hydroelectric Generating Station (at Conowingo Dam). The locations of these facilities are shown in Figure 1-2 of the main report. A comparison of their engineering attributes is included in Table K-9. Safe Harbor, Holtwood, and Conowingo are all peaking hydroelectric facilities that utilize limited active water storage reservoirs to generate electricity during peak generation periods. Because they supply power only occasionally, during critical peak demand times, the power supplied commands a much higher price per kilowatt hour than base load power.

Table K-9. Engineering Attributes of the Lower Susquehanna Hydroelectric Dams

Facility	River Miles from Chesapeake Bay	Dam Height (feet)	Dam Length (feet)	Reservoir Area (acres)	Usable Storage (acre-feet)	Normal Pool Elevation (feet, NGVD29)	Generating Capacity (megawatts)	Hydraulic Capacity (cfs)
Safe Harbor Dam and Lake Clarke	32	75	4,869	7,424	53,750	224.2 – 227.2	417.5	110,000
Holtwood Dam and Lake Aldred	24	55	2,392	2,400	14,700	163.5 – 169.75	196[1]	61,460[2]
Conowingo Dam and Reservoir	10	94	4,648	8,625	75,400[3]	104.7 – 109.2	573	86,000

Notes: [1] *Post-expansion total generation capacity.*
[2] *Post-expansion total hydraulic capacity.*
[3] *Usable storage in FERC-allowable pool (101.2 feet to 109.2 feet). Storage from 104.7 feet to 109.2 feet is approximately 40,000 acre-feet.*

Source: Gomez and Sullivan Engineers, 2012.

K.10.1 Safe Harbor Hydroelectric Station

Safe Harbor is owned by Safe Harbor Water Power Corporation. Construction started in November 1929, and the project became operational in December 1931. Safe Harbor Dam is a concrete gravity dam. Its outlet infrastructure consists of 3 double leaf regulating gates and 28 flood gates. The normal pool elevation range is from 224.2 to 227.2 feet (NGVD29, National Geodetic Vertical Datum of 1929). Safe Harbor does not currently have a minimum flow requirement. The original project license expired in 1980. When the project was relicensed, its owner proposed to add an additional five generating units to increase the authorized installed capacity from 230 megawatts (MW) to the current capacity of 417.5 MW. Because of this substantial redevelopment, the Federal Energy Regulatory Commission (FERC) issued a 50-year license for the project. Safe Harbor's current license expires in 2030.

K.10.2 Holtwood Hydroelectric Station

The Holtwood facility is owned by PPL Holtwood, LLC (PPL). Construction began in 1905, and the project began operation in 1910. The dam is an overflow-type structure raised by wooden flashboards and an inflatable rubber dam. No flood gates are installed at the dam. Prior to a 2010-14 expansion, Holtwood had an installed capacity of 107 MW and an estimated hydraulic capacity of 31,500 cfs. In the past decade, FERC issued PPL a license amendment to expand the capacity at Holtwood. Construction began in 2010 and is projected to be complete in 2014. Table K-9 shows the total generation capacity and hydraulic capacity following completion of this expansion. As part of the project expansion license agreement, PPL agreed to supply Conowingo with a continuous inflow of 800 cfs from the Holtwood Dam, and a daily volumetric flow equivalent to 98.7 percent of

Conowingo's minimum continuous flow requirement aggregated over a 24-hour period, or net inflow. Holtwood's current license expires in 2030.

K.10.3 Conowingo Hydroelectric Generating Station

The Conowingo Dam facility is owned by Exelon Generation, LLC. Construction started in 1926, and the project became operational in 1928. Conowingo Dam is a concrete gravity dam. The dam forms Conowingo Reservoir, with a surface area of 8,625 acres.

FERC license requirements allow Conowingo Reservoir elevation to fluctuate from 101.2 to 110.2 feet NGVD29. However, water levels are primarily confined to elevations between 107 and 109 feet NGVD29, and rarely fall below 106 feet NGVD29 (URS and GSE, 2012a).

Flow over the ogee spillway sections (S-shaped control weirs) is controlled by 50 stony-type crest gates and two regulating gates. Each crest gate is 22.5 feet high by 38 feet wide and has a discharge capacity of 16,000 cfs at a reservoir elevation of 109.2 feet NGVD29. The two regulating gates are 10 feet high by 38 feet wide and have a discharge capacity of 4,000 cfs per gate at a reservoir elevation of 109.2 feet NGVD29. Each gate is lifted vertically by crane and can be set either fully open or fully closed with no intermediate setting. The total discharge capacity of the gates is approximately 808,000 cfs. Conowingo currently has seven Francis turbines (with a flow capacity of approximately 6,700 cfs each) and four Kaplan turbines (approximately 9,700 cfs each). Figure K-22 shows an aerial view of the downstream side of the dam and its regulating gates

The Conowingo Reservoir extends approximately 14 miles from Conowingo Dam upstream to the lower end of the Holtwood Dam tailrace. The reservoir has a design storage capacity of 310,000 acre-feet, of which 75,400 acre-feet are usable storage. The reservoir provides water for diverse uses including hydropower generation, water supply, industrial cooling water, recreational activities, and various ecological resources. Relative to hydropower generation, Conowingo Reservoir serves as the lower reservoir for the 800-MW Muddy Run Pumped Storage Project (Muddy Run), located 12 miles upstream of the Conowingo Dam. It also serves as the source of cooling water for the 2,186-MW Peach Bottom Atomic Power Station, located approximately 7 miles upstream of Conowingo Dam (URS and GSE, 2012a).

Managing Conowingo Reservoir requires an integrated and complex operational approach. The Conowingo license is set to expire on August 14, 2014. FERC, the licensees, and stakeholders have been involved in the integrated licensing process for Conowingo Dam over the past several years. A final license application was submitted to FERC on August 13, 2012, requesting a new license. Section 2.3 in the main report of this assessment provides more details on licensing requirements and status.

Figure K-22. Conowingo Dam Aerial

Photo credit: USACE, 1980.