Deep Creek Lake
Water Quality Monitoring Program, 2013-2014

Scope of Work

Submitted by:

Monitoring and Non-Tidal Assessment Division
Resource Assessment Service
MD Department of Natural Resources

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Project Name: Deep Creek Lake Water Quality Monitoring Program, 2013-2014

Project Requested By: Deep Creek Lake Workgroup/MD Park Service

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Project Description

Background

Deep Creek Lake is located in Garrett County, Maryland near the community of McHenry. It is the largest reservoir in Maryland (surface area - 3,900 ac.) within a 64.7 mi^2 watershed area. The normal depth of the reservoir near the spillway is 50 feet and the reservoir has a maximum capacity of 145,000 acre-feet (Weisberg, et al.; 1985) with a reported shoreline length of 65 miles. This reservoir was formed in 1925 when Deep Creek was impounded for hydroelectric power generation. At that time, the region around the lake was sparsely populated. Today, the lake continues to provide a source of water to generate electric power, but it is also used intensively for water-based recreation (fishing, swimming, boating, skiing). Much of the lake shoreline is developed with an increasing density of seasonal and permanent residential homes, condominiums and commercial development.

In 2000, the State of Maryland acquired the lake bottom and shoreline buffer from GPU, the utility company that owned these properties, to be managed as public lands by the Department of Natural Resources' (DNR) Park Service. With this acquisition, DNR has had to address management issues unique to this facility (e.g., requests for dock permits, crossing permits and development pressure in the shoreline buffer, complaints from the public about algal blooms, sedimentation, and shoreline erosion). Any effort to develop management goals and address water quality and aquatic resource issues requires a solid foundation of information about current conditions, natural cycles, and an understanding about how the lake, its watershed and ecosystem function.

Over the past 60 years, there have been a number of water quality and aquatic resource surveys of the lake, many of these have been related to sport fisheries and their management. The State has not included any lakes in its long-term water monitoring program, so existing water quality studies in Deep Creek Lake have been short-term or focused on specific areas or pollutants. These results are not suitable for evaluating annual and seasonal conditions and variability that is needed for watershed planning.

Water quality and resource studies in the watershed prior to 1970 are difficult to find and monitoring objectives and data quality are usually unknown. Occasional observations and summaries indicate that in the 1940's and early 1950's, Deep Creek Lake was generally unproductive with a low diversity of aquatic plants and fish and occasional reports of an out-of-balance sport fishery. Since then, changes in management of lake water levels and fishery management efforts have resulted in an excellent fishery for bass, perch and walleye.

In the 1970's, concerns the possibility of acidification of the lake due to abandoned coal mine drainage initiated several water quality and geological studies. Results of these studies showed that acid inputs were not severe and were effectively buffered by existing limestone outcrops and treatment systems that have significantly reduced acidity from old mines.

A long-term, but limited fish tissue contaminant survey by the MD Department of the Environment (MDE) has shown that several fish species are contaminated by elevated methylmercury concentrations. Because of high levels of this contaminant in some fish species, MDE has issued an advisory suggesting adults, women of child-bearing age and children limit their consumption of chain pickerel, small- and largemouth bass, and yellow perch from the lake (*http://www.mde.maryland.gov/programs/marylander/citizensinfocenterhome/documents/www.mde.state.md.us/assets/document/maryland%20fish%20advisories%202011.pdf*). Because of this advisory, MDE has added Deep Creek Lake to its listing of impaired waters (Category 4a) defined for the US Environmental Protection Agency (*http://www.mde.maryland.gov/programs/Water/TMDL/Integrated303dReports/Documents/Integrated_Report_Section_PDFs/IR_2012/MD_2012_DRAFT_Integrated_Report_F.4.pdf*). It should be noted that this is not an uncommon finding in the State's lakes and the source of mercury in these fish is often attributed to air pollution - much of which is ascribed to coal-fired electric generating stations in the Ohio River valley.

Seasonally low dissolved oxygen in the deep waters of the lake during the summer reduces available habitat available to fish and invertebrates in the lake, but an assessment of phosphorus levels by MDE *http://www.mde.state.md.us/programs/Water/TMDL/ApprovedFinalTMDLs/Pages/wqa_final_deep_creek_Nut.aspx*) showed that much of this is naturally occurring due to sediment oxygen demand and is not a result of nutrient pollution and excessive algal blooms.

The Garrett County Health Department has conducted the longest continuous survey of Deep Creek Lake through its seasonal bathing beach survey (Memorial to Labor Day weekends) of the State Park beach, community beach areas and some open lake sites.

In tributary streams to the lake, poor community health indices of benthic macroinvertebrates and fish in some locations have been found along with low pH levels in Cherry Creek due to past mining and natural wetland drainage in the watershed. This survey, in sites often visited by DNR monitoring efforts, has been supplemented by citizen monitoring efforts supported by MD DNR's Stream Waders program, which has sampled sites in Deep Creek Lake tributary streams in 2004 and 2006 and annually since 2008 (*http://mddnr.chesapeakebay.net/mbss/streamwaders.cfm*

A report to the Garrett County Commissioners (ERM, 2007) stated that lake and watershed modeling results showed that potential land development activities in the lake watershed would have only minor effects on lake water quality. The report also reported that these results were uncertain because of the lack of long-term and comprehensive water quality data.

In early 2008, after discussions with Deep Creek Lake Management staff about monitoring water quality in the lake, staff in DNR’s Monitoring and Non-Tidal Assessment and Tidewater Ecosystem Assessment Divisions developed a Scope of Work for a lakewide and stream monitoring program. With approval and funding from the Park Service, a water quality monitoring program in Deep Creek Lake was initiated in April 2009. At selected mainstem lake and lake tributary cove sites, *in-situ* measurements have been recorded and, at many sites, water samples have been collected seasonally for analysis of nutrients and productivity (measured as relative algal levels using the biological pigment - chlorophyll). Samples have been collected at each site in the spring (April or March), summer (May through September), fall (Oct or November) and, because of varying ice conditions in winter (December or January), samples only near the US 219 and Glendale Road bridges. With few modifications, this water quality monitoring plan has been continued and would be implemented for a fifth year (through FY2014).

Over the past four years, there have been several modifications to this program - some of which would be continued through FY2014:

In 2010-2011, automatic water sampling equipment was installed at USGS gage sites on two lake tributary streams (Cherry Creek and Poland Run) to collect stormflow samples in order to estimate nutrient and sediment loadings to the lake. While sampling at the Poland Run site ended in September 2012 because the gage was removed because of poor siting, monthly baseflow samples were collected and two storm samples were collected each quarter (conditions permitting) and sent to laboratories for analysis of nutrients (*MD DHMH Laboratories Administration*) and sediments (*US Geological Survey Sediment Laboratory*).

Beginning in 2010, in response to complaints from a number of property owners and a request from the Lake Manager and Lake Workgroup, DNR began the first of a two-year assessment of submerged aquatic grasses to identify macroalgae and plants growing in the lake along with their distribution and abundance. Six quantitative transect sites surveyed in the late spring to early fall the lake from shallow to deep waters are targeted to identify, define the seasonal and spatial distribution and begin to quantify aquatic vegetation in the lake. These results were to be coupled with a seasonal aerial photogrammetric survey of the lake to assess the distribution of aquatic plants across the lake, however, this did not work as expected as high water clarity created such a deep photic zone that there was too little contrast to differentiate plant from the bottom. In the late spring and summer of 2012, complete shoreline surveys of the lake were initiated using a side-scan sonar to define and quantify the extant of larger aquatic plants throughout the lake. Use of the transect and shoreline survey approaches permit seasonal assessment of the growth, species distribution and biomass of aquatic plants in the lake and will be continued in FY2014.

In a separate agreement with Park Service, MD Geological Survey initiated a precision bathymetric survey of the lake in 2010 and collected sediment samples for analysis of contaminants. Using older topographic maps, estimates of sediment deposition rates were reported. This effort was expanded in 2011-2012 with a side-scan sonar survey of the lake and additional sediment cores resulting in a detailed assessment of areas where sediments were accumulating, not changing or eroding.

Project goals

There are four principal goals of the 2013-2014 monitoring program:

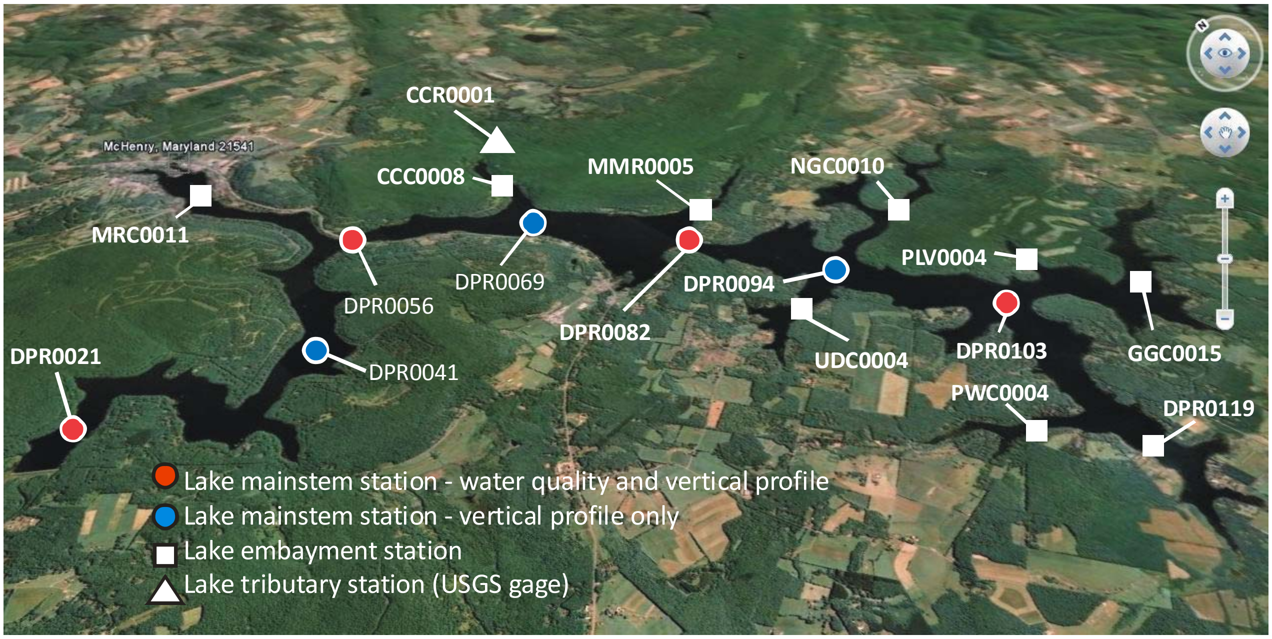
1. *Complete a fifth year of seasonal water quality monitoring efforts at seven sites in the mainstem of Deep Creek Lake and in nine tributary cove sites to define the current water quality conditions and seasonal ranges of physical conditions in the lake and nutrient and productivity levels, through June 2014.*
2. *Continue monthly and stormflow-event monitoring of nutrient and sediment concentrations at the US Geological Survey gage site on Cherry Creek through and assess data and draft load estimates from the now discontinued Poland Run site.*
3. *Assess aquatic vegetation in Deep Creek Lake by:*
   - *defining the distribution and relative abundance of aquatic vegetation species present in the lake through diver transect surveys*
   - *determining lake-wide distribution of Eurasian watermilfoil in the lake*
4. *Assess water quality conditions and help develop a public presentations on the State of the Lake and work with the Deep Creek Lake Workgroup .*
5. *Provide information about water quality and related recommendations to a working group of State and county agency staff and citizens tasked with the development of a Deep Creek Watershed Management Plan in 2014.*

Monitoring design and sampling procedures

The Deep Creek Lake water quality monitoring effort for 2013-2014 is guided by continuing monitoring efforts in the lake since 2009 with a primary goal being to define spatial and seasonal variation in the water quality characteristics and primary productivity in the lake. Because of wind-driven mixing, limited stream inflow and controlled discharges from the lake, horizontal water quality gradients are gradual. Sampling sites in the mainstem lake are regularly spaced between the upper and most downstream end of the lake (Figure 1, Table 1). Because seasonal thermal stratification (layering) occurs between the late spring and early fall in deeper lake sites (7+m depth), mainstem lake water quality samples will be collected for analysis of nutrients, particulates and primary productivity one meter below the surface and one meter above the bottom at every other mainstem site.

In contrast, select sites in Deep Creek Lake's major tributary embayments or coves were identified as being representative of tributary conditions and/or past monitoring efforts. In shallower, tributary embayments, wind-driven mixing circulates water resulting in higher levels of nutrients and suspended sediment and more spatial variability than in mainstem lake sites. Because of different land uses in these watersheds and in nearshore areas, embayment water quality conditions will vary more than mainstem lake sites.

Figure 1. Sampling stations, Deep Creek Lake Water Monitoring Program, 2013-2014



In selecting sites to monitor, consideration was given to sites that had been sampled in earlier studies of the lake (e.g., MD Department of the Environment for TMDL water quality modeling and trophic assessments, special acid deposition surveys, DNR for water quality and fisheries surveys, bacterial monitoring by Garrett County Health Department and other water quality surveys by the US Environmental Protection Agency and Frostburg University).

Water quality monitoring efforts are focused on the critical summer period (May through September) when the lake is stratified and aquatic life may be stressed due to high temperatures and low oxygen levels. Additional samples are collected the spring (March or April) and fall (November-December) when the lake should be thoroughly mixed. During the winter, sensors may be lowered if there is access to open waters off the US Route 219 and Glendale Road bridges (near DPR0056 and DPR0082) or through the ice if the surface is frozen sufficiently to allow access - also near the two bridge sites.

Table 1. Deep Creek Lake water quality monitoring program stations

DNR Station	Waterbody	River Mile	Latitude (dd mm N) NAD83	Longitude (dd mm W) NAD83	Description
Mainstem lake monitoring sites					
DPR0021	Deep Ck Lake	2.1	39 30.8500	79 23.1333	N of Slide Hollow, 0.4 m above spillway at deepest point,
DPR0041	Deep Ck Lake	4.1	39 30.6333	79 21.6333	N. Bee Tree Hollow, deepest spot (***in-situ*** **only**)
DPR0056	Deep Ck Lake	5.6	39 31.6667	79 20.7167	N side of MD Route 219 Bridge, deepest spot
DPR0069	Deep Ck Lake	6.9	39 31.1750	79 19.3950	Cherry Ck Cove mouth – mid-channel (***in-situ*** **only)**
DPR0082	Deep Ck Lake	8.2	39 30.4000	79 18.7000	N side of Glendale Rd. bridge
DPR0094	Deep Ck Lake	9.4	39 29.4880	79 18.0310	Between N Glade/Hoop Run Coves – (***in-situ*** **only)**
DPR0103	Deep Ck Lake	10.3	39 28.6167	79 17.5000	NW Turkey Neck, deepest location
Lake embayment monitoring sites					
MRC0011	Marsh Run Cove	1.6	39 33.0033	79 21.2460	Between ski area and McHenry - lake embayment
CCC0008	Cherry Ck Cove	0.8	39 31.8160	79 19.1610	Near mouth of Cherry Ck. Cove - lake embayment
MMR0005	Meadow Mtn. Run Cove	0.4	39 30.7344	79 18.0972	0.5 mi NE of Glendale Rd. bridge - lake embayment ***
NGC0010	North Glade Cove	1.0	39 29.8080	79 16.9212	SW of Harvey Peninsula - lake embayment
UDC0004	Hoop Pole Cove	0.4	39 29.3568	79 18.7188	N of end of Boy Scout Rd - lake embayment
PLV0004	Poland Run Cove	0.4	39 28.8720	79 16.7880	Mid-distance between head and lake -lake embayment
GGC0015	Green Glade Cove	1.5	39 28.3500	79 16.3638	0.5 mi E of Turkey Neck, 0.2 mi NW of Hazelhurst at deepest cross section point - lake embayment
PWC0004	Pawn Run Cove	0.4	39 27.9312	79 18.7230	Mid-distance between head/Deep Creek Cove
DPR0116	Deep Creek Cove	0.6	39 27.4902	79 18.1758	Deep Creek Lake embayment
Lake tributary monitoring sites - enhanced nontidal stream monitoring					
CCR0001*	Cherry Creek	0.2	39 32.2335	79 18.9510	Cherry Creek at State Park Rd Bridge - USGS 03075905

* Enhanced CORE stream station (monthly routine and storm flow sampling)

Mainstem lake water quality monitoring activities

In each lake/embayment site, conductivity, pH, temperature and dissolved oxygen are measured directly in the field with a calibrated instrument sonde in each of select months (March/April, May, June, July, August, September, and November/December) (Table 2). These measures will be recorded at 0.5 m below the surface, 1 m below the surface and at 1 m intervals to 0.5 m above the bottom (Table 3).

At each lake/tributary station (Table 1), water quality samples are collected using a submersible pump with an inlet positioned 1 m below the surface. At four selected mainstem, an additional water quality sample is collected by pump 1 m above the bottom. Water samples are filtered at the time of collection and filters/sample bottles are identified for dissolved and particulate fraction analysis. Samples for chlorophyll determinations are filtered through a Whatman Type GF/F glass fiber filter upon collection, stored on ice in a dark bottle (not to exceed 8 hours) and then frozen.

Lake levels reported by the Deep Creek Lake Power Station are recorded in the morning before a monitoring run is initiated. Weather conditions, observations of conditions, notes about sampling variance or problems are recorded. Additional details concerning sampling procedures can be found in Tables 3 and 4.

Lake embayment/cove water quality monitoring activities

In the lake's major tributary embayments or coves (identified as larger embayments or embayments with management concerns), sampling sites were identified as representative of tributary conditions and/or past monitoring efforts. Because of different land uses in these watersheds and in nearshore areas, embayment water quality conditions may be unique.

In shallower tributary embayments, wind-driven mixing circulates water throughout higher levels of nutrients and suspended sediment and more spatial variability than in the mainstem lake because of:

1) higher watershed drainage area:water volume ratio, which should contribute a proportionally higher level of nutrients and sediments into the lake,
2) higher proportion of shallow water areas that are susceptible to wind mixing and
3) lower flushing rate (longer retention time).

It should be noted that a number of tributary coves are quite elongated and narrowed, so there can be a defined water quality transition from riverine-to-lake water quality conditions compared to variability in other, more open embayment coves. An assessment of representative monitoring sites has not been evaluated, but other monitoring efforts, such as shallow water monitoring in some areas of the lake in 2010 and 2011 by MDE may be helpful in evaluating these monitoring sites.

Lake/stream studies

An additional 18 samples are accounted for in this scope to provide flexibility for additional QC samples or special sampling in the lake or in tributary streams during the year as directed by the Lake Manager and RAS managers.

Table 2. Deep Creek Lake water quality monitoring program schedule, 2013-14.

Date	FY2012 SOW Task	Tributary stream WQ/sediment samples
Apr 2013	Submit DRAFT 2013 Monitoring Report and DRAFT FY 2014 Scope of Work to Deep Creek Lake Workgroup for review Collect lake/stream water quality samples (2012-2013)	*FY13 SOW* monthly grab sample 2 stormflow samples
May 2013	Update 2014 SOW/Submit final SOW to DNR-Park Service Prepare agreements with MD DHMH and USGS sediment laboratories. Collect lake/stream water quality samples	
Jun 2013	Collect lake/stream water quality samples Conduct aquatic plant transect survey	
Jul 2013	***Initiate FY 2014 monitoring / assessment plan*** Collect lake/stream water quality samples Conduct lakewide Eurasian watermilfoil survey Prepare water quality summary for State of the Lake address	*FY14 SOW* monthly grab sample 2 stormflow samples
Aug 2013	Collect lake/stream water quality samples Conduct aquatic plant transect survey	
Sep 2013	Collect lake/stream water quality samples Conduct aquatic plant transect survey Provide water quality update for Property Owners Association meeting	
Oct 2013	Collect ONLY stream water quality samples Submit 1st quarterly report	monthly grab sample 2 stormflow samples
Nov 2013	Collect lake/stream water quality samples	
Dec 2013	Collect ONLY stream water quality samples	
Jan 2014	Collect sub-ice mainstem lake (2 sites) and stream water quality samples Submit 2nd quarterly report	monthly grab sample 2 stormflow samples
Feb 2014	Collect ONLY stream water quality samples Submit semi-annual bills for reimbursement	
Mar 2014	Collect lake/stream water quality samples	
Apr 2014	Collect ONLY stream water quality samples Submit DRAFT 2014 Scope of Work for review and participate in Deep Creek Lake Workgroup meeting	monthly grab sample 2 stormflow samples
May 2014	Collect lake/stream water quality samples Draft Final 2009 - 2014 Deep Creek Lake Water Quality Report Submit 3rd quarterly report	
Jun 2014	Collect lake/stream water quality samples Conduct lakewide Eurasian watermilfoil survey Prepare water quality summary for State of the Lake address	
Jul 2014	Submit final monitoring report and billings Complete Final 2009 - 2014 Deep Creek Lake Water Quality Report Submit 4th quarterly report	*Wrap-up*

Table 3. Deep Creek Lake water quality monitoring program – *in-situ* field measurement parameters/analysis specifications, 2013-2014

Parameter	Method/Reference	Sample Preservation	Holding Time	Minimum Detection Limit
*Temperature	*N.B.S.-calibrated EPA 1979 #170*	N/A	< 5 min.	0.1□C
*Dissolved oxygen	*Membrane Probe EPA 1979 #360*	N/A	< 5 min.	0.2 □g/L
*pH	*Glass Probe EPA 1979 #50*	N/A	< 5 min.	0.5 units
*Specific conductance	*Conductivity Bridge APHA #205*	N/A	< 5 min.	5 □mhos/cm
*Secchi disc depth	*8-inch Black/White*	N/A	< 5 min.	0.1 m

Table 4. Deep Creek Lake water quality monitoring program - water quality parameters - MD Dept Health and Mental Hygiene laboratory specifications, 2013-2014

Parameter	**Method/Reference**	**Sample Preservation**	**Holding Time**	**Minimum Detection Limit**
Ammonium	*EPA 1993 #350.1 (Lachat Flow Injection Analyzer)*	Iced/Frozen	48 hrs./ 28 days	0.0016 mg/L
Particulate nitrogen	*Exeter method 440*	Filtered, Frozen	28 days	0.003 mg N
Total dissolved nitrogen	*Alkaline persulfate digestion followed by EPA 1993 #353.2*	Iced/Frozen	48 hrs./ 28 days	0.034 mg/L
Nitrate + nitrite	*EPA 1993 #353.2 (Lachat Flow Injection Analyzer)*	Iced/Frozen	48 hrs./ 28 days	0.003 mg/L
Nitrite	*EPA 1993 #353.2 (Lachat Flow Injection Analyzer)*	Iced/Frozen	48 hrs./ 28 days	0.002 mg/L
Orthophosphate	*EPA 1993 #365.1 (Lachat Flow Injection Analyzer)*	Iced/Frozen	48 hrs./ 28 days	0.002 μg/L
Particulate phosphorus	*Muffling of sample, addition of HCl, followed by EPA 1993 #365.1*	Filtered, Frozen	28 days	0.0003 mg/L
Total dissolved phosphorus	*Alkaline persulfate digestion followed by EPA 1993 #365.1*	Iced/Frozen	48 hrs./ 28 days	0.006 mg/L
Suspended solids	*EPA 1983 #160.2*	Iced	7 days	0.8 mg/L
Chlorophyll α Phaeophytin α	*Spectrophotometric SM 20^{th} Ed. #10200 H*	Filtered, Frozen	4 weeks	0.1 mg/L - lowest QC sample
Turbidity	*EPA 1993 #180.1*	Iced	48 hrs.	0.0056 NTU
Total alkalinity	*Titration SM 20^{th} Ed. #2320 B*	Iced	14 days	1 mg/L $CaCO_3$ (MDL is NA)

Lake tributary stream water quality monitoring activities

In 1980, Maryland DNR initiated a stream sampling site on Cherry Creek as part of the State's Basic Water Monitoring Program (CORE/Trend) defined by the US EPA. In 2007, the US Geological Survey installed automated water level (streamflow) gages in lower Cherry Creek (USGS 03075905); an effort supported by the MD Park Service. This site provides near real-time water level/streamflow data (http://waterdata.usgs.gov/md/nwis/rt) that can be used in concert with water samples to determine loadings (tons nutrients and sediments) delivered to the lake under different land use and watershed sizes.

Water quality samples are collected from this Cherry Creek site using the same sampling frequency, methodology and equipment as stream samples being collected from many nontidal streams in the Chesapeake Bay watershed to determine nutrient and sediment loadings, trends in loadings and yields from different land uses (Romano, 2009 - (http://www.dnr.state.md.us/streams/pubs/117_QAPP.pdf). Each month, "baseflow" samples are collected from each site. If the stream is sufficiently wide and deep, water samples are collected using a depth-integrating sampler along a transect of five equally-spaced sites across the stream or if the stream is narrow and shallow, a single, vertically-integrated sample is collected mid-stream. The use of an ISCO sampler is often set to automatically collect water samples during storm events at predefined stream levels.

Samples for assessing suspended sediment are labeled and stored until a sufficient number of samples are collected. These are then forwarded to the US Geological Survey's Sediment Laboratory in Louisville, KY for standard sediment analysis (Table 5).

Table 5. Deep Creek Lake water quality monitoring program - stream sediment analysis - USGS-KY Sediment laboratory

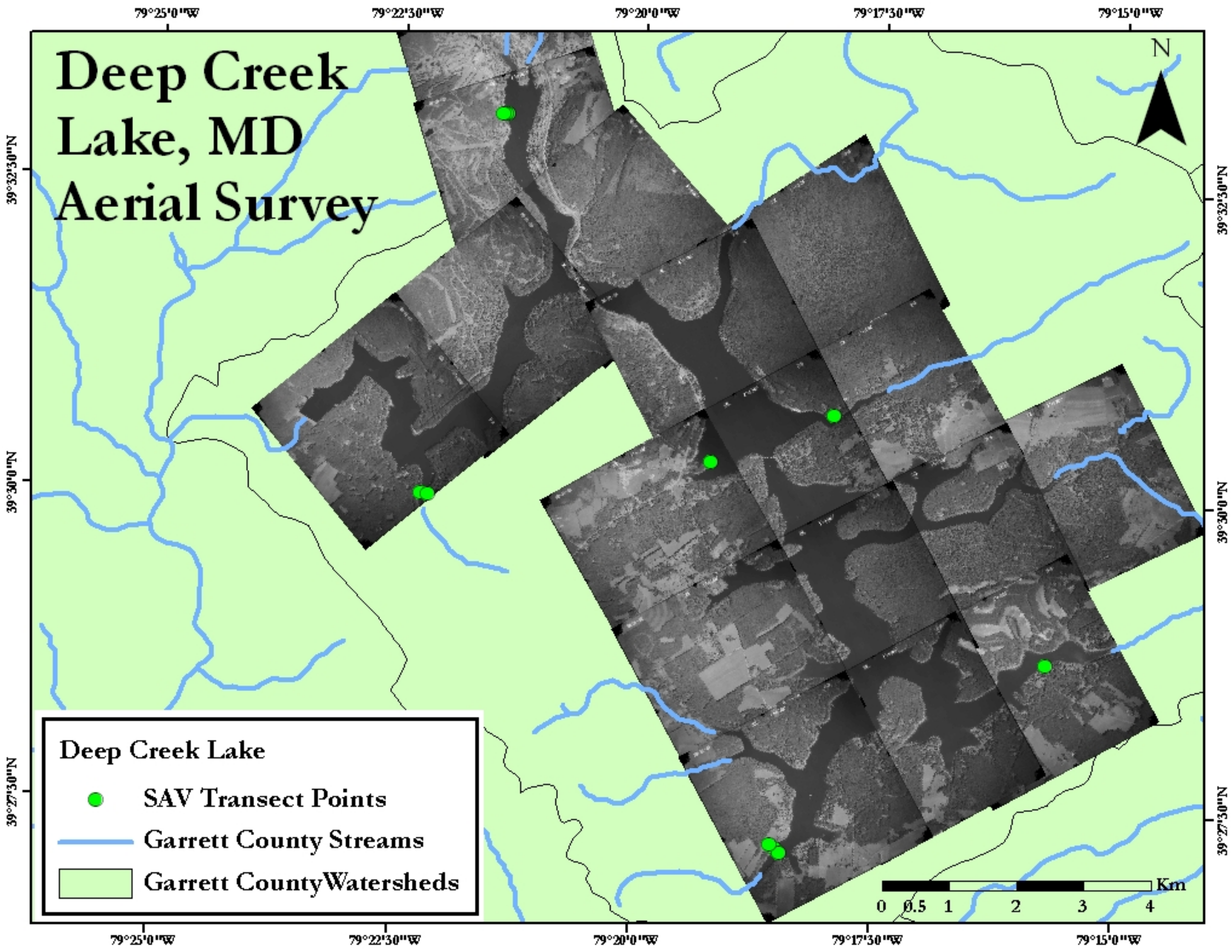
Parameter	Method/Reference	Sample Preservation	Holding Time	Minimum Detection Limit
Suspended sediment	*Filtration or evaporation (for very high concentrations) -Shreve and Downs, 2005.*			0.1 mg

Lake aquatic vegetation monitoring activities

The type, distribution and abundance of aquatic vegetation will be surveyed along selected shoreline transects during the growing season by Resource Assessment Survey staff. Diver transects will be used to collect samples for identification and determination of abundance and biomass. Methods will follow those used by DNR in assessing Chesapeake Bay aquatic vegetation (see *Orth, et al., 2010 - http://web.vims.edu/bio/sav/sav09/index.html)*.

The aquatic vegetation monitoring effort for 2013-2014 will focus on "shallow" water areas of the lake. Six transects visited annually since 2010 will be revisited several times during the growing season (Figure 2). Divers will conduct transect surveys to identify species density, composition, and distribution. In addition, shallow water areas along the entire shoreline of the lake will be examined to document the presence and abundance of Eurasian watermilfoil (*Myriophyllum spicatum*) during the summer with a followup survey in late spring 2014.

Figure 2. Aerial survey of Deep Creek Lake and location of aquatic plant transects



Monitoring protocols

The Maryland Department of Natural Resources' Quality Management Plan for Environmental Data Collection defines how the Department's data collection, management, analysis and reporting activities ensure that data used to support management decisions are of the highest quality. Specific details about data collection activities, laboratory analyses, instrument operations and safety practices are guided by Standard Operating Protocols (see http://mddnr.chesapeakebay.net/eyesonthebay/documents/e_d_q.cfm). This Scope of Work provides a detailed management summary of the proposed monitoring effort.

In each lake station, local weather and environmental conditions will be recorded. Using a calibrated instrument sonde will be used to measure a vertical profile of select water quality measures (Table 3) and samples for more quantitative laboratory analysis will be collected using a submersible pump for samples near the surface and, for some deep mainstem lake stations, near the bottom. Samples for laboratory analysis will be processed, labeled and shipped to the Department of Health and Mental Hygiene laboratory in Baltimore for analysis of select measures (Table 4) in accordance with DNR's CORE field monitoring protocols. Data from field replicate samples will be analyzed to assess data quality.

In addition to parameters that are directly measured, additional water quality parameters will be derived from the results of certain analyses:

Total nitrogen	=	Particulate nitrogen + Total dissolved nitrogen
Dissolved organic nitrogen	=	Total dissolved nitrogen - (Ammonium + Nitrate+Nitrite)
Total phosphorus	=	Particulate phosphorus + Total dissolved phosphorus
Dissolved organic phosphorus	=	Total dissolved phosphorus - Total dissolved phosphorus

Data quality requirements and assessments

Data collected at each sampling station provides site-specific information. At each station, a surface grab sample is collected at mid-channel. For the mainstem lake sites, an additional sample is collected from near bottom. This sampling strategy is sufficient to categorize both the relatively well-mixed embayments and thermally-stratified mainstem lake areas. Identical parameters are measured at most monitoring stations, allowing data to be compared at a particular station both within- and between years. With several years of data, results help define natural range and variability and, with a long enough data record, trends may be defined, as well.

Water quality samples are collected and delivered to the Department of Health and Mental Hygiene (DHMH) Laboratory by field personnel or by courier. Data sheets, summaries and chain-of-custody forms accompany these samples to the laboratory. Data produced from laboratory analysis and field measurements then follow a controlled pathway to computer files under the direction of a data processing manager. While the chain-of-custody controls and documentation are not as stringent as for samples that are collected for enforcement purposes, proper documentation of sample handling and accounting does apply.

All instrumented sondes are calibrated both prior to and after their use for measuring temperature, pH, dissolved oxygen and conductivity. Calibration information is recorded in field log books. Field and laboratory personnel follow manufacturer's instrument maintenance recommendations defined in SOPs.

Sediment samples are labeled, stored and shipped to the US Geological Survey Sediment Laboratory for determining sediment concentration. Sampling, sample handling and sample analysis conform to the non-tidal sampling QAPP and USGS laboratory SOPs (Table 5).

Quality assurance samples will be analyzed and field audits conducted to ensure that the data collected are accurate and precise.

All instrumented sondes are calibrated both prior to and after their use for measuring temperature, pH, dissolved oxygen and conductivity. Calibration information is recorded in field log books. Field and laboratory personnel follow manufacturer's instrument maintenance recommendations defined in SOPs.

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Data usage

Water quality/productivity data collected by a fixed station network will be analyzed and reported to the Deep Creek Lake workgroup, Deep Creek Lake Management Office and Lake Policy Board, Property Owners Association, Garrett County commissioners and the public through reports and presentations. These data will be available for review, provide a basis for developing lake management policies that will protect water quality and will be useful for educational purposes. These data also will be forwarded to MDE for review for listing use support in the State's Integrated Report. Copies of datasets will be provided to the Lake Management office and posted on the Deep Creek Lake website for public access.

Aquatic vegetation data will be collected and processed in the manner that the State's Submerged Aquatic Vegetation (SAV) assessments are conducted to assess aquatic plant communities in Maryland's tidal waters. Samples of all types of aquatic vegetation will be collected and preserved as reference material that will be used to develop an identification guide for aquatic vegetation in the lake. The spatial and seasonal distribution and biomass of aquatic vegetation will be defined through shoreline surveys and diver transects. These results will be provided to the Deep Creek Lake workgroup, Deep Creek Lake Management Office and Lake Policy Board.

Suspended sediment samples collected during a range of streamflows in two selected tributary streams will help define the loading (mass) and rate of sediment being transported from the surrounding watershed into Deep Creek Lake. The procedures followed by the Northeastern Region, Kentucky District sediment laboratory for concentration determination Shreve and Downs (2005).

Data from this effort, summary statistics and lake water quality results will be submitted to the Lake Management Office and the Deep Creek Lake Workgroup annually as a report and presentation. Data will be posted on DNR's Deep Creek Lake WMA Internet page and eventually to the EPA's Water Quality Exchange (WQX) system for public access. Streamflow data from the US Geological Survey's Cherry Creek gage may be obtained from the US Geological Survey website: http://waterdata.usgs.gov/md/nwis/uv/?site_no=03075905&PARAmeter_cd=00065,00060 .

Documentation and data reduction

Record-keeping begins at the time that samples are collected. Field measurements are recorded on field data sheets. A chemistry data sheet is initiated at the time of collection for each set of samples that are submitted to the laboratory for analysis. These sheets accompany the samples to the lab and are signed in when received. Following analysis, data are entered onto chemistry data sheets. Data are entered into Microsoft Excel spreadsheets, which are reviewed manually and graphically. The laboratories keep original analysis sheets. Original field sheets are retained and filed by DNR's field office.

Numerous checks have been instituted to ensure that errors in the final data set are virtually eliminated. Both field and chemistry data sheet entries are double-checked by those making the quantitative determinations. To reduce analytical errors, the computer calculates some parameters from analyzed values. Other manual reviews occur and any discrepancies or unusual observations are discussed with the field or laboratory staff.

Water quality data are available from DNR's Resource Assessment Service upon request. Data summaries are provided in reports and presentations. Streamflow data from the two gages in the watershed as well as other nearby gage sites may be obtained from the US Geological Survey website: http://waterdata.usgs.gov/MD/nwis/.

Reports

Information about recent water quality conditions and study findings will be developed for the Secretary of Natural Resources' annual "State of the Lake" presentation to the Property Owners Association (24 July 2013), and for meetings of the Deep Creek Lake Workgroup at times throughout the year.

A summary report of lake and stream water quality conditions during the last 5 years of monitoring (2009-2014) will be submitted by September 30, 2014. Copies of the data collected will be provided for use and archive for future comparative studies. Copies of this report will be available from the Deep Creek Lake NRMA website.

Relevant articles about water quality and results from the monitoring effort will be posted on the Deep Creek Lake Natural Resources Management website (http://www.dnr.state.md.us/publiclands/western/deepcreeknrma.asp) on a periodic basis.

Program cost

Costs associated with this water quality portion of this project principally address a portion of the salary/benefits of a Natural Resources Biologist from DNR's Monitoring and Non-Tidal Assessment Program stationed in Western MD (0.65 FTE) as well as supplies, equipment and costs for laboratory analysis of a suite of chemical and physical parameters and biological pigments (MD Department of Health and Mental Hygiene (DHMH) laboratory in Baltimore) and stream sediments (USGS Sediment Laboratory in Lexington, KY). Generally, water quality monitoring program costs are slightly less than 2012-2013 costs due to reductions in sediment analyses.

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