FLOOD AND INUNDATION MITIGATION STRATEGIES
CITY OF ANNAPOLIS, MARYLAND
EASTPORT AREA

Prepared for

City of Annapolis
Department of Neighborhood and Environmental Programs

Prepared by

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1.0 INTRODUCTION

1.1 STUDY PURPOSE

This study was prepared by Whitney, Bailey, Cox & Magnani, LLC at the request of the City of Annapolis. The City is looking to identify option to mitigate flood events in the vicinity of the Eastport area of Annapolis.

The goal of this study was to 1) Identify the most likely extent of sea level rise in the Chesapeake Bay, 2) Identify the highest observed storm surges in the Annapolis area, 3) Identify and map areas susceptible to flooding now and projected into the future, 4) Identification of structural options for protecting property in flood threatened areas, and 5) Estimation of design and construction costs associated with the structural protection measures.

1.2 STUDY AREA

The study area in this report is the Eastport area of the City of Annapolis which is bounded on the North by Spa Creek, the East by the confluence of Spa Creek and the Severn River, the South by Back Creek and the West by the City of Annapolis. The study was limited to the area east of State Street and encompassed approximately 17 independent storm drain outfalls throughout. Figure 1-1 shows the limits of the study area.

1.3 PROBLEM IDENTIFICATION/FLOOD CONDITIONS

Flooding that occurs at Eastport is generally caused by high tides and storm surges associated with Tropical Cyclones (Hurricanes) and Northeasters. Flood conditions are at their worst when storms pass the area to the west of the Chesapeake Bay. This is caused by the southeasterly winds driving water into the mouth of the Bay and piling the water up against the Bay's head.[1]

Hurricane Isabel (2003) was one such storm that tracked to the west of the Bay producing record breaking storm surges in the Chesapeake Bay. According to the Federal Emergency Management Agency (FEMA) Flood Insurance Study for the City of Annapolis (May 4, 1981), the 100-year flood elevation for this area is estimated to be 7.78 feet. Figure 1-2 shows the area of the FEMA 100-year floodplain.

Minor localized flooding may be experienced on a periodic basis in some locations due to tidal fluctuations, the relative ground elevation, and the intensity of a particular rain event. Along the south side of Eastport, adjacent to Back Creek, ground elevations vary from approximately elevation 3.5 to elevation 8.0. Along the east side of Eastport, adjacent to the Severn River, ground elevations vary from approximately elevation 6.0 to elevation 10.5. Along the northern side of Eastport, adjacent to Spa Creek, ground elevations vary from approximately elevation 3.0 to elevation 5.0.

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[1] Li, Zhong, Boicourt, Zhafng, Zhang, Ming, Liejun, William C., Shunli, Da-Lin. "Hurricane-induced storm surges, currents and destratification in a." *GEOPHYSICAL RESEARCH LETTERS* 33.L02604 (2006): 1-4. Web. 10 Jun 2010. <http://www.atmos.umd.edu/~dalin/Li-etal-storm-surge-grl06.pdf>.

FIGURE 1-1 STUDY AREA MAP

1.4 DATA COLLECTION

This study was conducted using existing data pertaining to topography, soils, floodplains, tidal data and weather data. Much of the data was extracted from data found on the National Oceanographic and Atmospheric Administration (NOAA) web site. Table 1-1 outlines the data sources used for this study.

TABLE 1-1: DATA SOURCES		
Data Type	Source	Use/Comments
Topography	Base mapping layers, including topography, were provided by the City of Annapolis.	All base mapping layers were in AutoCADD and were provided electronically.
Soils	Natural Resource Conservation Service	
Floodplain Elevations	FEMA's Flood Insurance Study (FIS) for City of Annapolis, MD, Panel No. 240009 0005B dated 11/04/1981.	The FIS shows elevations in NGVD 29 datum; FIS shows 100-year flood elevation at 7.0 feet NGVD 29. This is equivalent to 7.8 feet in NGVD 88.
Storm Drain Infrastructure	Storm drain AutoCADD layers provided by City of Annapolis.	Storm drain drawings were used to understand the system.
Tidal Data	National Oceanographic and Atmospheric Administration (NOAA)	

The following provides additional information regarding the data collection phase of the study.

Soils

According to soil data found on the National Resources Conservation Service (NRCS) website, the majority of the Eastport area is constructed on material described as "Urban Land" in the soil information. The northern side of Eastport between 6th Street and the Severn River and north of Severn Avenue is described as "Udorthents, loamy, sulfidic substratum". No soil borings were taken as part of this concept study. Soil information from the NRCS indicate the material is fair to poor for subgrade material and generally highly corrosive to concrete suggesting that construction of structurally measures will require additional attention.

Storm Drain System

Our analysis based on GIS data and aerial photographs identified 17 outfall locations along the perimeter of our study area. We did not identify any outfall that currently has a gate installed to keep saltwater from backing up into the stormwater system. Several of the outfalls are located below the water surface elevation which reduces the efficiency of the storm drain system. Hydraulic calculations for the storm drain systems can be found in the appendices.

Flood Plain

According to the Federal Emergency Management Agency the 100-year flood elevation for the Eastport area is estimated to be 7 feet according to the National Geodetic Vertical Datum of 1929 (NGVD 29). Current surveys are based on North American Vertical Datum of 1988 (NAVD 88) which correlates to a 100-year flood elevation of 7.8+/-   Figure 1-2 shows the 100-year floodplain.

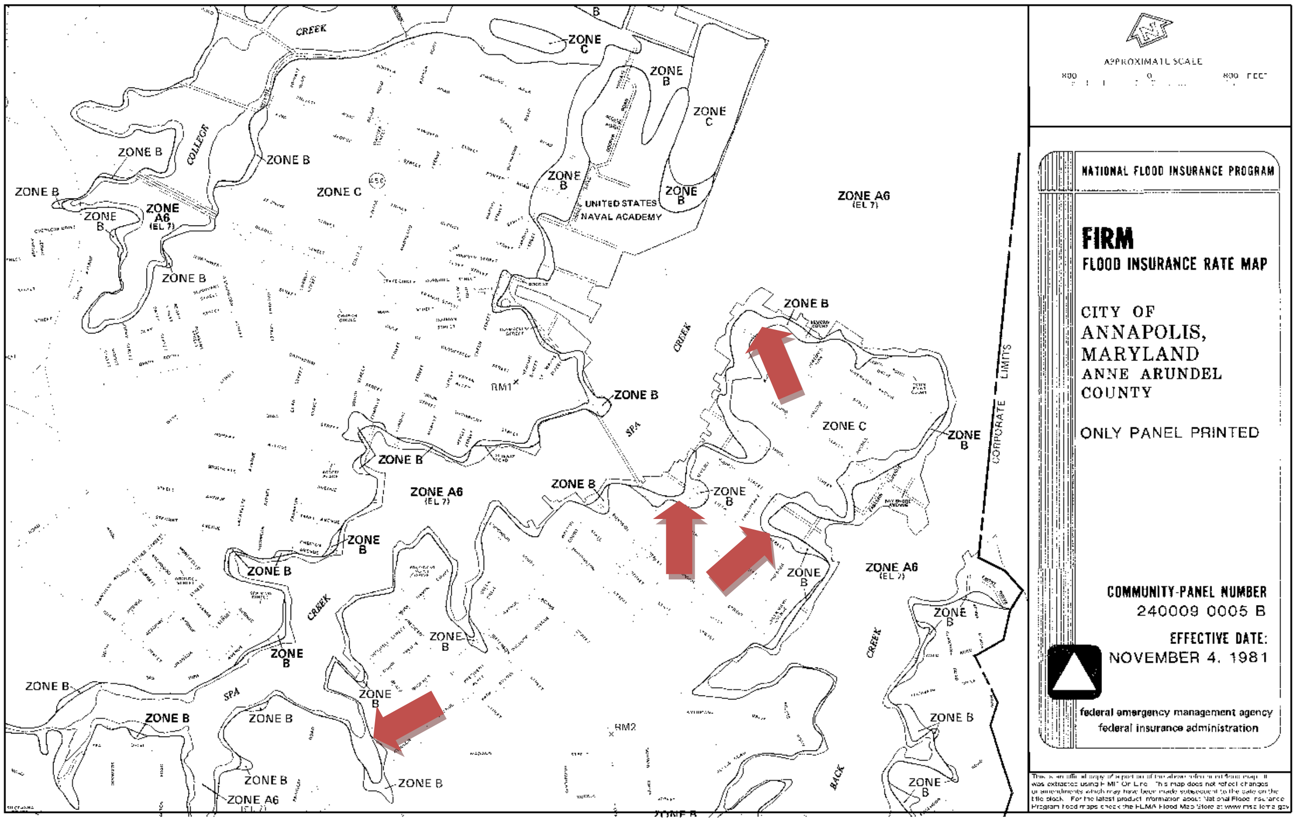


FIGURE 1-2: 100-YEAR FLOODPLAIN

2.0 SEA LEVEL RISE

Sea level changes have been going on since the beginning of time. The Chesapeake Bay is the drowned, ancestral valley of the Susquehanna River. Continuous tide gauge records around the Chesapeake Bay show that the rate of sea-level rise during the 20th century has not been constant and that modern rates are more rapid than those determined by geologic studies conducted two decades ago. The current rate of sea-level rise at the mouth of the Chesapeake is about 4 millimeters per year (about 1.3 feet per century) and decreases northward. Tide gauges with longer periods of record, like that at Solomons Island, Md., midway along the length of the bay, record mean sea level since 1937 and illustrate a 3-millimeter-per-year rate of rise (about 1 foot per century).[2]

[2] "The Chesapeake Bay: Geologic Product of Rising Sea Level." U.S. Geological Survey, 18 11 1998. Web. 14 Jun 2010. <http://pubs.usgs.gov/factsheet/fs102-98/>.

3.0 STORM SURGE

Storm surge is simply water that is pushed toward the shore by the force of the winds swirling around a storm. This advancing surge combines with the normal astronomical tides to create the storm tide, which can increase the mean water level several feet. In addition, wind driven waves are superimposed on the storm tide. This rise in water level can cause severe flooding in coastal areas, particularly when the storm tide coincides with the normal high tides.

From January 1, 2010 to September 30, 2010 high tides in the Annapolis area were recorded between a high of elevation 3.51 feet on September 30 to -1.85 feet on January 3. NOAA predicts the astronomical tides every year. The predicted high tide for January 25 was 0.12 feet. Weather data from Weather Underground (wunderground.com) indicates a storm with relatively strong winds (16 mph with gusts of 34 mph) from the south was occurring on this date and coincided with the high tide. The difference between the predicted high tide and the observed high tide is the storm surge.

The Sea, Lake, and Overland Surges from Hurricanes (SLOSH) model is the computer model utilized by the National Oceanic and Atmospheric Administration (NOAA) for coastal inundation risk assessment and the operational prediction of storm surge. The SLOSH model computes the maximum potential impact of the storm in these "computational domains" based on storm intensity, track, and estimates of storm size provided by hurricane specialists at NHC.[3] The SLOSH model has an advertised accuracy of plus or minus 20%.

SLOSH models are run by Emergency Management Agencies to make preparedness decisions. According to a May 2, 2006 article in the Insurance Journal, recent SLOSH models indicate the potential for 18 or 20 feet storm surges in Baltimore at high tide during a Category 4 hurricane – 10 feet above Isabel's high water mark; Annapolis would see slightly lower levels. Figures 3-1 and 3-2 illustrate the potential surges for the region.

[3] "Hurricane Research Division." *Hurricane FAQ*. NOAA, May 14, 2010. Web. 15 Jun 2010. <http://www.aoml.noaa.gov/hrd/tcfaq/F7.html>.

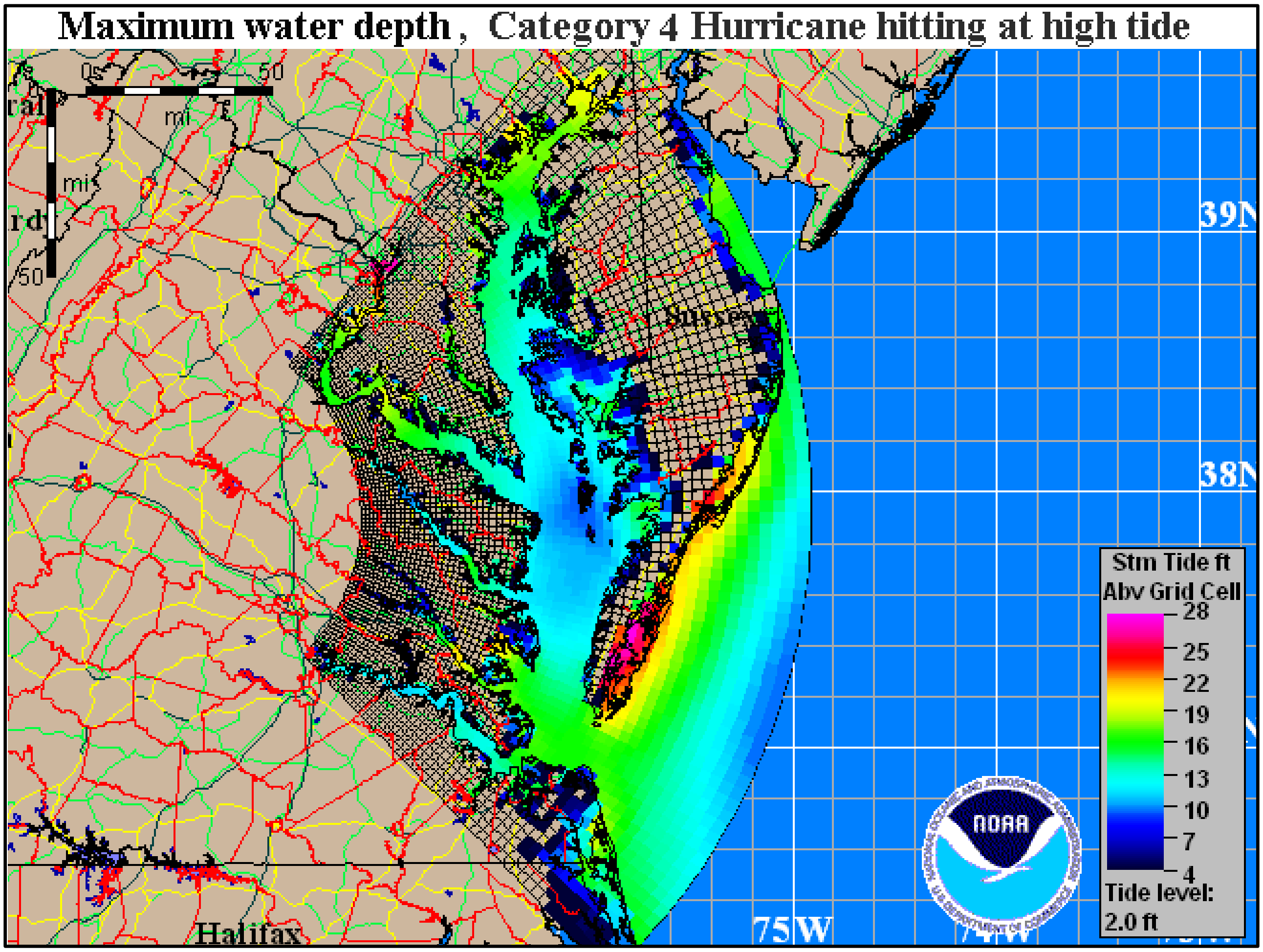
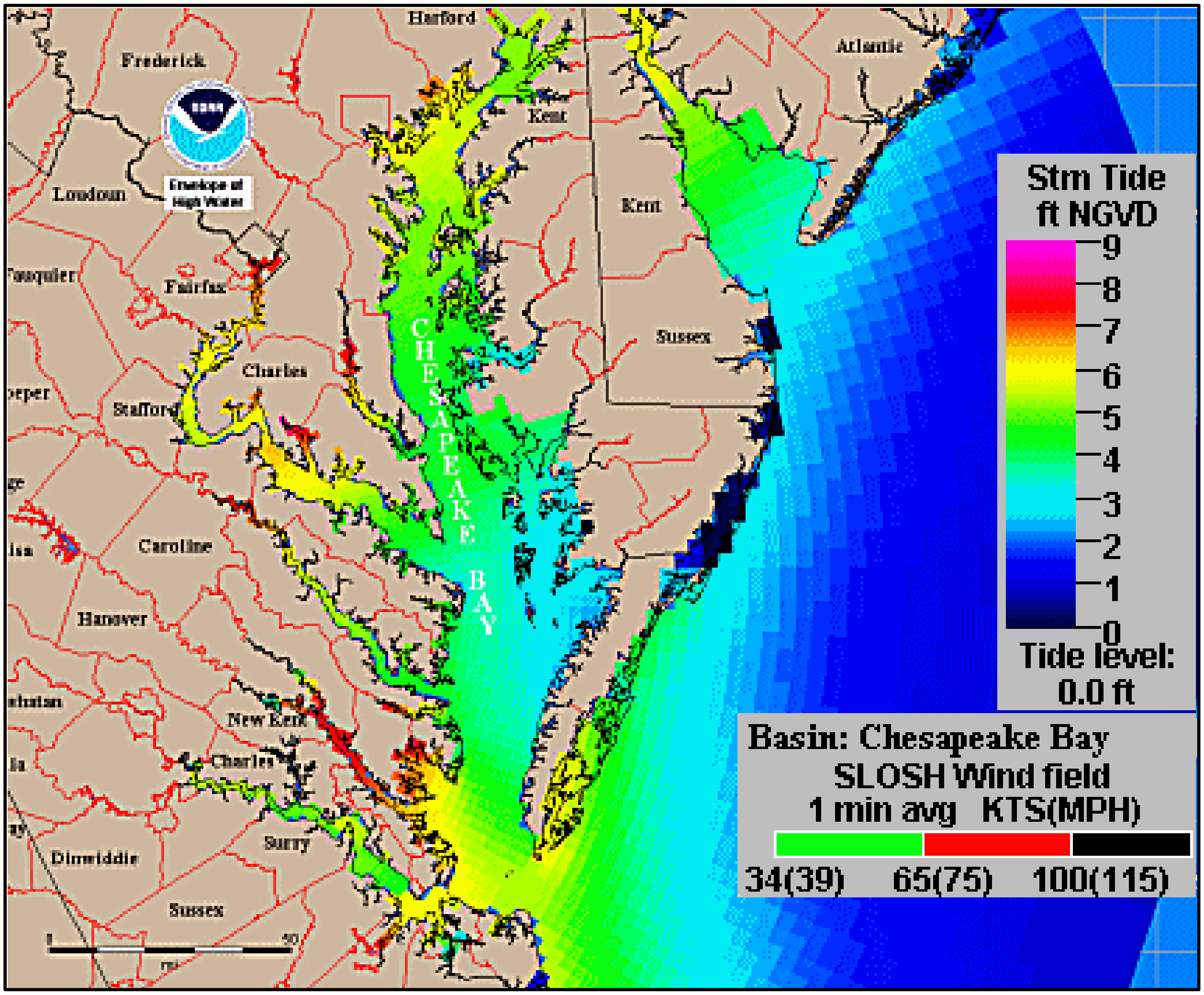


FIGURE 3-1 CHESAPEAKE BAY WATER DEPTH – 2009 SLOSH MODEL[4]

[4] "Storm Surge Inundation Maps for the U.S. Coast." *Weather Underground* . Weather Underground , 2010. Web. 16 Jun 2010. <http://www.wunderground.com/hurricane/MidAtlSurge.asp>.



MAXIMUM WATER LEVELS REACHED THROUGHOUT THE BAY OVER THE COURSE OF THE STORM SURGE. OUTPUT FROM THE SEA, LAKE, AND OVERLAND SURGE FROM HURRICANES (SLOSH) COMPUTER MODEL, RUN WITH ACTUAL STORM DATA5

FIGURE 3-2 STORM SURGE MODEL OF ISABEL FLOODING[6]

[5] W. Shaffer, 2003, National Oceanic and Atmospheric Administration (NOAA)

[6] Hennessee, Lamere; Halka, Jeffrey P. "Hurricane Isabel and Shore Erosion in Chesapeake Bay, Maryland ." *Coastal and Estuarine Geology Program*. MD Department of Natural Resources, Dec. 2004. Web. 16 Jun 2010. <http://www.mgs.md.gov/coastal/isabel/index.html>.

4.0 FLOOD SUSCEPTIBLE AREAS

The flooding caused by hurricane Isabel was nearly equivalent to the 100-year flood as noted on the Federal Emergency Management Agency (FEMA) Flood Insurance Study for the City of Annapolis (May 4, 1981). The FEMA map identifies the flood limits as varying from the edge of land to approximately 600 feet inland along Fourth Street between Chesapeake Avenue and Chester Avenue. The elevation for this limit has been confirmed with the City of Annapolis GIS topography and is shown on Figure 4-1.

Based on the current rise in the sea level, the limit of flooding is expected to increase as shown on Figure 4-2. This limit is based on a six (6") inch rise in sea level by the year 2050. Figures 4-1 &4-2 also identifies the approximate locations of the 17 storm drain outfalls, labeled A through Q.

FIGURE 4-1: CURRENT 100-YEAR FLOODPLAIN

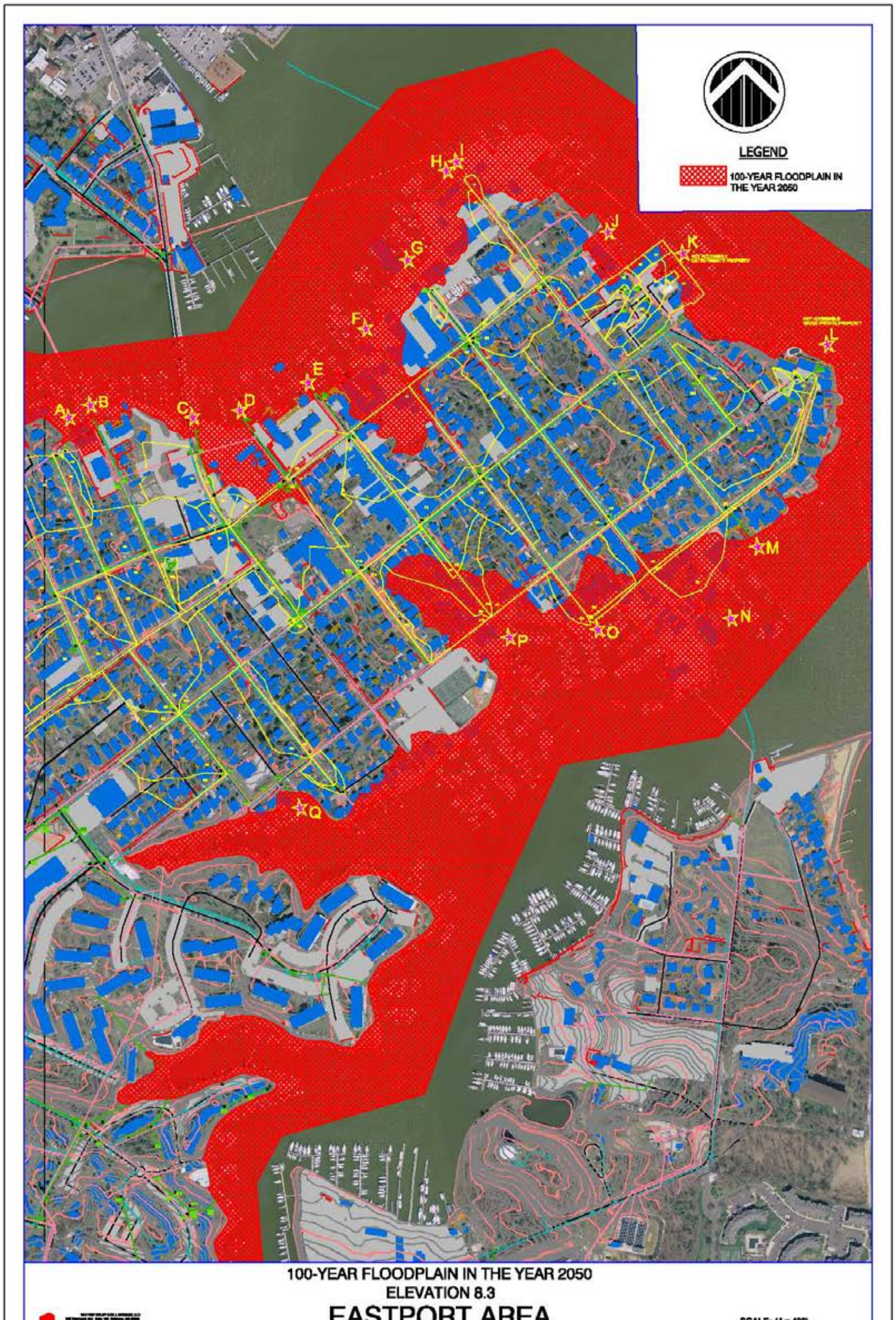


FIGURE 4-2: 100-YEAR FLOODPLAIN IN THE YEAR 2050

FIGURE 4-3A: PROJECTED HIGHEST LUNAR TIDE FLOODPLAIN IN THE YEAR 2050

FIGURE 4-3B: PROJECTED HIGHEST LUNAR TIDE FLOODPLAIN IN THE YEAR 2050

5.0 FLOOD DAMAGE REDUCTION MEASURES

The United States Naval Academy, underwent a Flood Damage Reduction Analysis in 2006. The report prepared by the Army Corp of Engineers detailed the measures available and they are presented here.

Flood damage reduction consists of two basic techniques – structural and non-structural. Structural methods modify the flood and "take the flood away from people" by measures such as levees, floodwalls, and dams. Non-structural flood damage reduction techniques basically "take the people away from the floods" leaving the flood to pass unmodified. Non-structural techniques consist of measures such as relocation, flood proofing, acquisition, and flood preparedness. To familiarize the reader with these flood damage reduction measures, general descriptions are presented below.

- Structural Techniques
  - Levees and Berms (small levees)
  - Floodwalls
  - Sea Walls
  - Closures
  - Pumping Station
  - Portable Coffer Dam
- Non-Structural Techniques
  - Elevation
  - Relocation
  - Demolition and Reconstruction
  - Flood Proofing
  - Dry Flood Proofing
  - Wet Flood Proofing

5.1 STRUCTURAL TECHNIQUES

The types of structural measures that were investigated include levees and berms, floodwalls, sea wall modifications, closure, and portable coffer dam structures. Floodwalls, berms, sea walls, and portable coffer dam are freestanding structures located adjacent to or away from the building that prevent the encroachment of floodwaters. They may completely surround the building or buildings, or protect only the low side of the property. Unlike other flood proofing measures, a well designed and constructed freestanding floodwall or berm results in no water pressure on the structure itself. Consequently, as long as the floodwall or berm holds or is not overtopped, the building should not be exposed to damaging hydrostatic or hydrodynamic forces. Another advantage with this technique is that there is no need to make major structural alterations to the building.

When constructing a floodwall or levee around buildings, sump pumps must be incorporated to provide proper interior drainage from groundwater seepage and rainwater from the building side of the protection.

Floodwalls, berms and sea walls require periodic maintenance, including removing debris from any check valves on pump discharge pipes after each storm, inspecting the sump pump for proper operation, and maintenance of the flap gates. In addition, the property owner will have to inspect levees for signs of erosion, settlement, animal burrows, and trees. Floodwalls need inspection for signs of cracking and spalling. Construction of floodwalls and berms may require local, state and/or Federal permits.

Floodwalls, levees/berms, or coffer dams can create a false sense of security about property protection. Every flood is different, and one could exceed the design height and overtop the floodwall or berm at anytime. For this reason, the protected area should always be evacuated prior to flooding.

If a floodwall, sea wall, berm, or coffer dam fails due to overtopping, damage to the protected structure will be as great or greater than if no protection was provided. Additional damage could result because it takes longer to remove the flood water from the inside of the floodwall or berm once flood levels subside.

5.1.1 Levees or Berms

Typically, levees and berms are constructed of compacted fill taken from locally available impervious soils. Depending upon the availability of suitable local soil, levees may be one of the least expensive flood proofing measures. Levees and berms have the advantage of being compatible with the landscape since they are easy to shape. The property owner can plant grass and other forms of light vegetation on an earthen levee to help prevent erosion and provide aesthetic enhancement.

Although levees may be attractive in terms of economics and appearance, one potential drawback is the amount of property space required. To minimize erosion and to provide adequate stability, their embankment slopes must be fairly gentle, usually a ratio of one vertical to two or three horizontal. A levee's width will be several times its height. This option is not considered feasible for the City of Annapolis since there is limited room

5.1.2 Floodwalls

Similar to levees, floodwalls also keep water away from the building. However, floodwalls are constructed of stronger materials, are thinner, take less space, and generally require less maintenance than levees. Floodwalls can be constructed using a variety of designs and materials. By taking into account the individual building design, siting, and topography; a floodwall can be constructed that not only protects a building, but also enhances its appearance.

A temporary flood control wall (Figure 5-1) – installed when needed and removed when the threat is over – is an option. This method is similar to Closures. Temporary flood walls can vary in height to accommodate the change in existing elevation and optimize cost. However, installation time should also be a considered factor. It typically takes approximately a day to install 1000 linear feet of 6 feet high barriers, which means the system may need to begin installation three or more days prior to the flood event. A temporary flood wall is a good solution to prevent flooding in the Eastport area.

FIGURE 5-1: TYPICAL TEMPORARY FLOOD CONTROL WALL[7]

5.1.3 Sea Walls

In certain situations, a sea wall may already exist that may be modified to be used as a flood protection measure. Similar to a floodwall, sea walls take up little space and can be constructed of various materials. Sea walls are not considered feasible for the Eastport Area.

5.1.4 Closures

Closures must be provided for roads, sidewalks, driveways, and other openings left in a floodwall or levee. Closures act to close the openings in floodwalls and levees and prevent water from entering. They can be of a variety of shapes, sizes, and materials. In some cases closures are permanently attached to the closure structure abutments using hinges so that they can remain open when there is no flood threat, such as a swing gate (Figure 5-2). Another type of closure is a roller gate that slides into place along a track (Figure 5-3). There are also stop log closures which are portable, normally stored in a convenient location, and put into place when a flood threatens (Figure 5-4). Typically, sandbags must be placed at the bottom of most closure structures to prevent leakage.

[7] Courtesy of Flood Control America, Inc, www.floodcontrolam.com

FIGURE 5-2: TYPICAL SWING GATE CLOSURE STRUCTURE

Closures can be considered as an option only if a flooding situation provides sufficient warning time to properly install them. The need for both sufficient warning time and human action is critical, since all closure systems require personnel to install them and make certain they are properly sealed. Closures that are stored between floods must be readily accessible. Swing gates and roller gates take less time to install than stop log structures, which must be transported to the site and put in place. Typically, swing and roller gates can be installed in less than two hours. However, stop log structures can take 2-3 hours to install a small pedestrian closure structure, and roughly 3-6 hours for a larger vehicular closure structure. The effectiveness of an entire system will be compromised if the closures are stored such that flooding renders them inaccessible, or if even one closure is improperly installed. Closure systems are most effective where there are a limited number of openings. If there are too many, leakage could overwhelm and defeat the system.

FIGURE 5-3: TYPICAL ROLLER GATE CLOSURE STRUCTURE

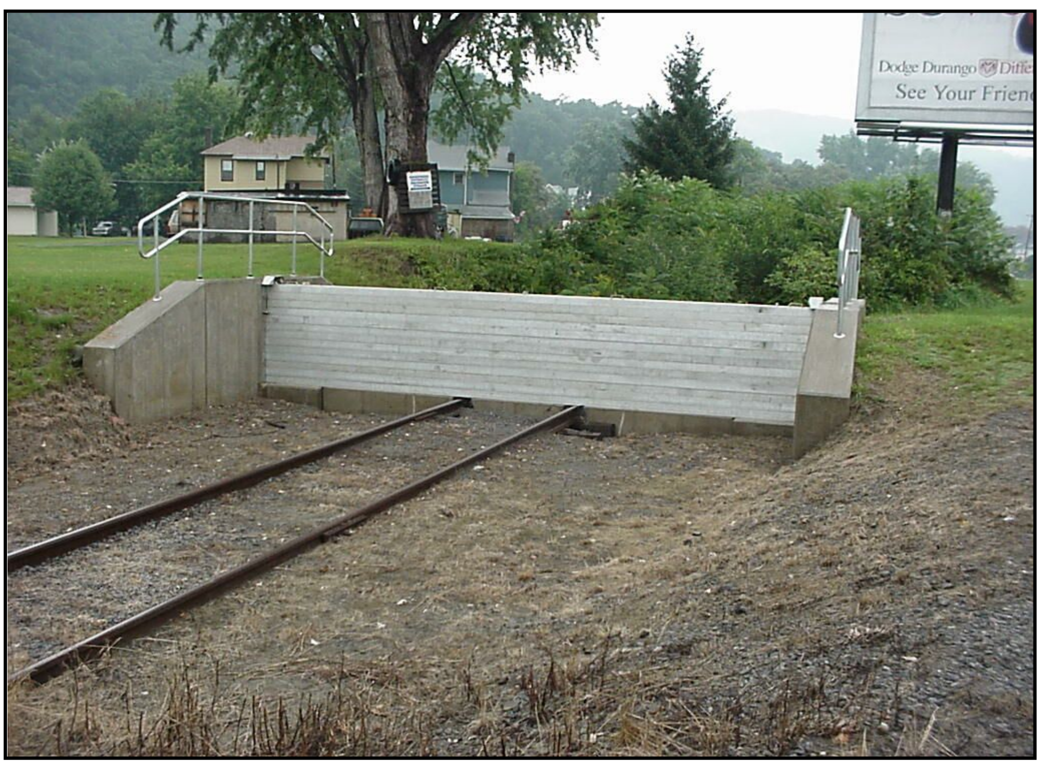


FIGURE 5-4: TYPICAL STOP LOG CLOSURE STRUCTURE

In addition to closure structures for roads, sidewalks, etc., closure gates need to be provided for any storm pipe to prevent back flow. Any sewers or drain pipes passing through or under a floodwall or levee will require closure valves (Figures 5-5 & 5-6) to prevent backup and flooding inside the building and protected area.

Because there will likely be ample warning time (2-3 days) prior to a flood event, closures are a potential option for use with the floodwall alternatives.

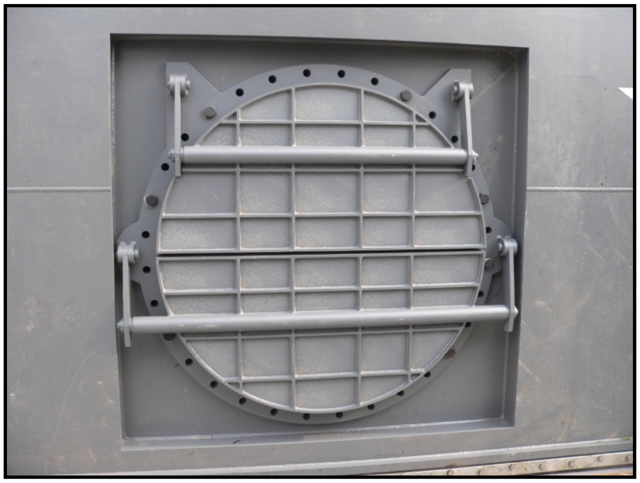


FIGURE 5-5: FLAP VALVE

FIGURE 5-6: RUBBER DUCKBILL VALVE

5.1.5 Pumping Station

The flooding caused by surging storm drains will require additional measures to prevent rainfall that would normally be discharged into the open water from just ponding within the city streets. Pumping stations could be used to discharge the excess water into the bay. However, since there are multiple outfalls located a considerable distance apart along the Eastport waterfront, installation of a permanent pumping station at each outfall is not practical for the area.

Another option is to use temporary pumps in conjunction with floodwalls. Pumping stations would be installed at the “dry” side (land side) of the floodwalls. Flap Valves or Duckbill valves would be installed at the outfalls to keep sea water from backing up into the storm drain systems. Noting that storm drains are typically designed to handle a ten year frequency event (a storm that has a ten percent chance of happening in any given year), large amounts of water are still expected to flow through the city streets to the low point near any potential floodwall. During flood events, temporary pumps could be brought in to handle the multiple outfall locations, pumping the water trapped on the “dry” side of the floodwalls and discharging the water into the bay. If Portable Coffer Dams are considered, pumps will be required for filling those units, and therefore, would be readily available during a flood event.

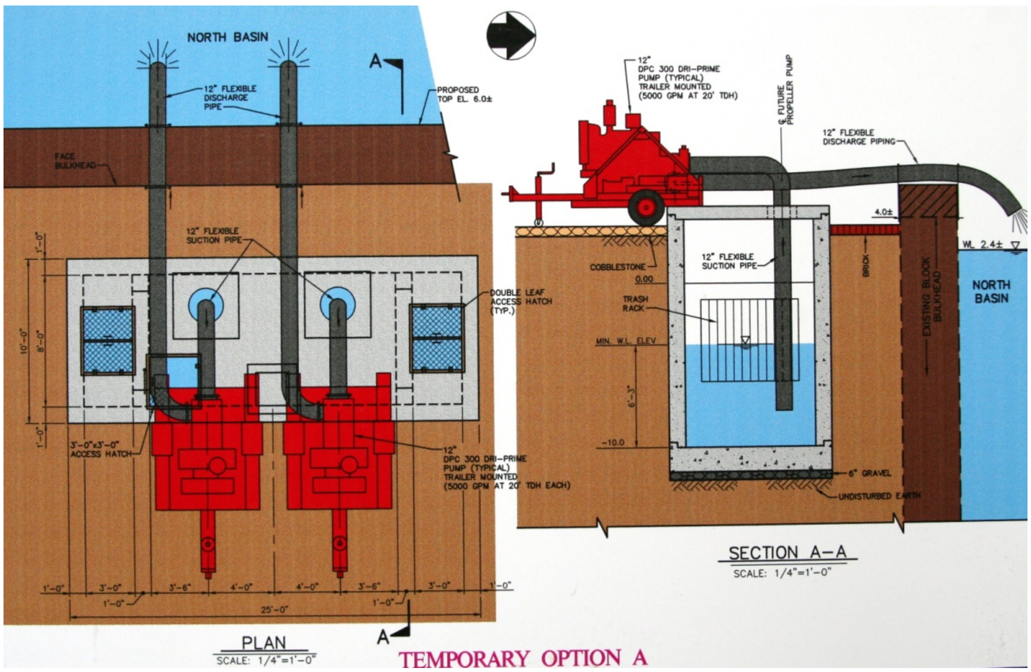


FIGURE 5-7: TEMPORARY PUMP STATION

5.1.6 Portable Coffer Dams

Portable coffer dams are another method that can be used to protect Eastport from flooding. The coffer dam, made of commercial grade vinyl coated polyester, is a water inflated dam which consists of a self contained single tube with an inner restraint baffle/diaphragm system for stability. The dam has ability to stand alone as a positive water barrier without any additional external stabilization devices. The system can be installed easily in the field when needed and removed when the threat is over. Once laid out, it can be inflated using any available water source. Each unit is up to 100 feet long and 8 feet high. With 2 feet of freeboard, it can control water up to 6 feet high. Portable coffer dam units can be joined together by overlapping end to end at any angle to protect large areas.

The system is lightweight, compact in storage, easy to install, repairable, reusable, and less expensive than some previous mentioned methods. However, there are few things that need to be considered when using this system. The unit cannot be installed too close to any building or structure (to avoid adding pressure on walls), and should be used where there is at least 25 feet of open space available for installation. Installation time should also be a considered factor. It typically takes approximately a day to install 500 linear feet of 8 feet high barriers with two pumps, which means the system may need to begin installation six or more days prior to the flood event. A Portable Coffer Dam is a good solution to prevent flooding at the Eastport. However, at areas where space is not available, other method(s) will need to be used.

FIGURE 5-8: COFFER DAM PROTECTING SHORELINE[8]

[8] Courtesy of Independent Flood Defence Products, www.ifdp.co.uk

FIGURE 5-9: TYPICAL PORTABLE COFFER DAM[9]

[9] Courtesy of Sconsa Environmental Services, www.water-dam.com

FIGURE 5-10: POTENTIAL FLOODING BEHIND FLOOD WALLS

5.2 NON-STRUCTURAL TECHNIQUES

5.2.1 Elevation

Elevation involves raising the building in place so that the lowest floor is above the flood level for which flood proofing protection is provided. The building is jacked up and set on a new or extended foundation. Elevation is not an option for the buildings in the Eastport Area.

5.2.2 Relocation

Relocating a building is the most dependable, but generally the most expensive, way to flood proof. This method involves moving the building to another location away from flood hazards, either to a higher elevation on the existing lot or to a new site. This procedure involves raising the building, as described above and placing it on a trailer. The building is then transported to a new location and placed on a new foundation. Relocating the buildings in the Eastport Area was not considered a feasible option.

5.2.3 Demolition and Reconstruction

If a free standing building is found to lie within a flood prone area, the owner may opt to demolished the building and construct a new one at a higher elevation. The other option is for the existing building to be raised so that the finished floor is above the projected floodplain. These options, of course, would be at great expense for the property owner(s).

5.2.4 Flood Proofing

There are two types of flood proofing techniques: dry flood proofing and wet flood proofing. Dry flood proofing keeps the floodwaters from entering the structure, while wet flood proofing allows the floodwaters to enter the building, but minimizes the damages.

Dry Flood Proofing

Dry flood proofing typically involves sealing the exterior building walls with waterproofing compounds, impermeable sheeting, or other materials and using shields for covering and protecting openings from floodwaters. Shields can be used on doors, windows, vents, and other building openings. Shields placed directly on buildings must be strong enough and sufficiently watertight to withstand flood forces. Sewer lines should be fitted with cutoff or check valves that close when flood waters rise in the sewer to prevent backup and flooding inside the building.

Generally, dry flood proofing should only be employed on buildings constructed of concrete block or brick veneer on a wood frame. Weaker construction materials, such as a wood frame without a brick veneer, will fail at much lower water depths from hydrostatic forces. Even brick or concrete block walls should not be flood proofed above a height of approximately three feet, due to the danger of structural failure from hydrostatic forces, unless a structural engineer has confirmed that the building is designed to handle the forces.

Some waterproofing compounds cannot withstand significant water pressure or may deteriorate over time. For effective dry flood proofing, a good interior drainage system must be provided to collect the water that leaks through the sealant or sheeting and around the shields. These systems can range from small wet-vacs to a group of collection drains running to a central point from which water is removed by a sump pump. Though dry flood proofing may seem simple, it is a sophisticated method that requires full understanding of the possible dangers stemming from poor planning, design, or installation.

Most wall materials, except for some types of high-quality concrete, will leak unless special construction techniques are used. These techniques require a high level of workmanship if they are to be effective. For flood proofing existing structures, the best way to seal a wall is to add an additional layer of brick with a seal between the two layers. It is possible to apply a sealant to the outside of a brick or block wall, but any coating must be applied carefully. Cement- or asphalt-based coatings are the most effective materials for sealing a brick wall, while clear coatings such as epoxies and polyurethanes tend to be less effective. As a result, the aesthetic advantages of a brick wall are lost with the use of better sealant coatings.

The difficulty and complexity of sealing a structure also depends on the type of foundation, since all structural joints, such as those where the walls meet foundations or slabs, require treatment. For very low flood levels, such as a few inches of water, a door can be flood proofed by installing a waterproof gasket and reinforcing the door jamb, hinge points, and latch or lockset and coating it with a waterproof paint or sealant.

If there is a chance of higher flood levels, some type of shield will be needed. If the expanse across the door is three feet or greater, the shield will have to be constructed of heavy materials, such as heavy aluminum or steel plate. The resulting weight may require the shield to be permanently installed, using either a hinged or slide-in design. Typical hinged and drop-in gates for a doorway are shown in Figure 5-2. The frame for such installations must be securely anchored into the structure. When windows are exposed to flooding, some form of protection is needed because standard plate glass cannot withstand flood forces. One solution is to brick up all or part of the window. It may also be possible to use glass block, instead of brick, to admit light.

FIGURE 5-11: TYPICAL HINGED GATE AND DROP-IN GATE (courtesy of Reelan Industries)

For normal-sized windows, shields can also be used. They should be made of materials such as heavy plexiglas, aluminum, or framed exterior plywood. These can be screwed in place, or slid into predesigned frame slots. Another alternative is to replace the glass with heavy plexiglas; however, the window must be sealed shut and waterproofed using water resistant caulking. Dry flood proofing is not considered as an option for the Eastport Area.

Wet Flood Proofing

Wet flood proofing allows the structure to flood inside while ensuring that there is minimal damage to the building and its contents. Interior flooding allows water forces on the inside of the building walls to counteract the hydrostatic forces on the outside, thus reducing the chance of structural damage. When the structure is designed for wet flood proofing, vulnerable items, such as utilities, appliances, and furnaces, should be relocated or waterproofed with plastic bags and sheeting. Utilities and appliances may be moved permanently or temporarily to a place in the building higher than a selected flood level, or to a small addition that would serve as a utility room.

If there is no space for relocating utilities, appliances, and other contents, these items may be protected in place. In the case of very shallow flooding, a mini-floodwall built around these items would provide protection. For deeper waters, they could be elevated on a platform or suspended overhead from floor or ceiling joists.

The property owner must have sufficient warning time to employ wet flood proofing methods by temporarily moving items. In addition, the property owner must be aware that flooding an area containing a source of electricity or hazardous materials can be dangerous. Also, clean-up will be required after each flood.

Wet flood proofing is not considered as an option for the Eastport Area.

6.0 ESTIMATING DESIGN AND CONSTRUCTION COSTS

Flood protection measures of public areas for the Eastport Area are very limited due to the fact that the vast majority of the land is privately owned. Protecting Eastport from major flooding events will necessitate a public/private partnership in order to fully utilize available options. Given that most of the Eastport area is privately owned, public protection is limited to relatively small areas that have few items requiring protection. Presuming that property damage is to be minimized throughout the Eastport area, the roughly 12,200 linear feet of shoreline will need protection. In addition to structural measures for surface flooding, sewer and electrical services will need to be evaluated to determine if they could be affected by water in flood events. Backflow preventers would need to be installed at each sewer connection.

From the available information, a combination of floodwalls, coffer dams, temporary pumps, backflow preventers, flap valves and duckbill valves will be needed. Based on data provided by manufacturers, costs have been estimated for purchase of materials and some design. **Labor costs** for installation, removal, storage places (for temporary protecting systems), operating, and maintenance of protection measures have not been investigated and **are not included in the cost estimates.**

Unlike permanent structures (flap/duckbill valves, floodwall foundations and backflow preventers) only need to be installed once, labor cost for temporary systems (floodwalls, coffer dams, and pumps) should include the cost of both installation and removal at every flood events. For floodwalls installation, minimum of three people would be needed to complete the installation before the flood occurs. Coffer dams installation requires more people, six to eight people would be needed. In addition, these temporary systems, except for the pumps that could be rented from local rental companies, require storage places when they are not in use. Cost for these storage places, either from being built or rental, should be taken into account in the detailed design phase.

Item	Quantity	Cost/Unit	Total Cost
Flap Valve/Duckbill Valve	17 EA	$2,500	$42,500
Floodwall	6000 LF	$500	$3,000,000
Floodwall Foundations	6000 LF	$50	$300,000
Temporary Pumps	10 EA	$30,000	$300,000
Backflow Preventers	300 EA	$750	$225,000
Collection Chambers	Allowance	$300,000	$300,000
Total			$4,167,500

TASKS TO BE CONDUCTED DURING THE DETAILED DESIGN PHASE

During a detailed design phase, many technical issues must be further evaluated, and other typical approval procedures must be completed. The following list identifies some of the tasks that should be completed as part of a detailed design phase:

- Coordinate with local/state/Federal agencies and receive specific permits/approvals
- Prepare an Environmental Assessment
- Evaluate the interior drainage further to confirm the location and size of pumping stations
- Perform subsurface exploration and laboratory testing along the actual project alignment to aid in designing the floodwall
- Further evaluate the design of the floodwall, including depth/height needed, and the design of the footings
- Survey proposed alignment for verification of slopes, easements, available space, obstructions
- Select exact alignment of floodwall/cofferdam based on location of utilities, trees, and other structures

APPENDICIES

7.1 10-YEAR STORM DRAIN ANALYSIS

7.2 100-YEAR STORM DRAIN ANALYSIS

APPENDIX

7.1 10-YEAR STORM DRAIN ANALYSIS

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STORM SEWER DESIGN (10yr. Storm)

Job No. 2006041200
Sheet

PROJECT: Eastport Area
LOCATION: Annapolis, Maryland
CATEGORY: Storm Drain Analysis

	By	Date
Computed	JLA	11/01/07
Checked		

STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	A1	1.69		0.33	0.56		10	5.00	7.00	3.90																
A1	A2		1.69			0.56	10	5.00	7.00	3.90	Circular	15	0.012	0.841	1.227	0.31%	33.0	3.18	0.17							
	A2	0.51		0.27	0.14		10	5.00	7.00	0.96																
A2	A3		2.20			0.70	10	5.17	6.97	4.85	Circular	15	0.012	0.841	1.227	0.48%	50.0	3.95	0.21							
	A3	0.22		0.67	0.15		10	5.00	7.00	1.03																
A3	OUTFALL		2.42			0.84	10	5.38	6.92	5.83	Circular	15	0.012	0.841	1.227	0.69%	117.0	4.75	0.41							

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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	B1	0.53		0.40	0.21																					
B1	MH9		0.53			0.21	10	5.00	7.00	1.48	Circular	15	0.012	0.841	1.227	0.04%	41.0	1.21	0.56							
	B1A	0.71		0.42	0.30																					
B1A	MH9					0.30	10	5.00	7.00	2.09	Circular	18	0.012	1.365	1.767	0.03%	35.0	1.18	0.49							
MH9	MH5					0.51	10	5.00	7.00	3.57	Circular	18	0.012	1.365	1.767	0.10%	157.0	2.02	1.29							
	B3	2.08		0.43	0.89																					
B3	MH5					0.89	10	5.00	7.00	6.26	Circular	18	0.012	1.365	1.767	0.30%	19.0	3.54	0.09							
	B2	1.27		0.34	0.43																					
B2	MH5					0.43	10	5.00	7.00	3.02	Circular	18	0.012	1.365	1.767	0.07%	9.0	1.71	0.09							
MH5	B4					1.33	10	5.00	7.00	9.28	Circular	30	0.012	5.330	4.909	0.04%	271.0	1.89	2.39							
	B4	1.79		0.29	0.52																					
B4	B6					1.85	10	5.00	7.00	12.92	Circular	30	0.012	5.330	4.909	0.08%	280.0	2.63	1.77							
	B6	1.67		0.37	0.62																					
B6	MH14					2.46	10	5.00	7.00	17.24	Circular	30	0.012	5.330	4.909	0.15%	46.0	3.51	0.22							
	B5	1.28		0.38	0.49																					
B5	B7					0.49	10	5.00	7.00	3.40	Circular	18	0.012	1.365	1.767	0.09%	22.0	1.93	0.19							
	B7	1.21		0.38	0.46																					
B7	MH14					0.95	10	5.00	7.00	6.62	Circular	18	0.012	1.365	1.767	0.34%	25.0	3.75	0.11							
MH14	MH3					3.41	10	5.00	7.00	23.87	Circular	30	0.012	5.330	4.909	0.29%	232.0	4.86	0.80							
	B9	1.58		0.35	0.55																					
B9	MH3					0.55	10	5.00	7.00	3.87	Circular	18	0.012	1.365	1.767	0.12%	19.0	2.19	0.14							

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PROJECT: Eastport Area
LOCATION: Annapolis, Maryland
CATEGORY: Storm Drain Analysis

	By	Date
Computed	JLA	11/01/07
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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	B8	0.99		0.35	0.35																					
B8	MH3					0.35	10	5.00	7.00	2.43	Circular	18	0.012	1.365	1.767	0.05%	14.0	1.37	0.17							
	B10	0.23		0.42	0.10																					
B10	MH3					0.10	10	5.00	7.00	0.68	Circular	15	0.012	0.841	1.227	0.01%	148.0	0.55	4.48							
MH3	OUTFALL					4.41	10	5.00	7.00	30.84	Circular	30	0.012	5.330	4.909	0.48%	719.0	6.28	1.91							

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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	C1	0.8		0.57	0.46																					
C1	C2					0.46	10	5.00	7.00	3.19	Circular	15	0.012	0.841	1.227	0.21%	21.0	2.60	0.13							
	C2	1.7		0.57	0.97																					
C2	MH8					1.43	10	5.00	7.00	9.98	Circular	15	0.012	0.841	1.227	2.03%	28.0	8.13	0.06							
	C3	1.54		0.62	0.95																					
C3	MH8					0.95	10	5.00	7.00	6.68	Circular	15	0.012	0.841	1.227	0.91%	45.0	5.45	0.14							
MH8	C5					2.38	10	5.00	7.00	16.66	Circular	30	0.012	5.330	4.909	0.14%	151.0	3.39	0.74							
	C4	0.28		0.54	0.15																					
C4	C5					0.15	10	5.00	7.00	1.06	Circular	18	0.012	1.365	1.767	0.01%	48.0	0.60	1.34							
	C5	0.24		0.66	0.16																					
C5	C6					2.69	10	5.00	7.00	18.83	Circular	30	0.012	5.330	4.909	0.18%	226.0	3.83	0.98							
	C7	1.79		0.59	1.06																					
C7	C6					1.06	10	5.00	7.00	7.39	Circular	18	0.012	1.365	1.767	0.42%	42.0	4.18	0.17							
	C6	0.16		0.49	0.08																					
C6	OUTFALL					3.82	10	5.00	7.00	26.77	Circular	36	0.012	8.658	7.069	0.14%	104.0	3.79	0.46							

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	By	Date
Computed	JLA	11/01/07
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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	D1	0.09		0.33	0.03																					
D1	D2					0.03	10	5.00	7.00	0.21	Circular	18	0.012	1.365	1.767	0.00%	41.0	0.12	5.81							
	D2	0.04		0.35	0.01																					
D2	MH6					0.04	10	5.00	7.00	0.31	Circular	18	0.012	1.365	1.767	0.00%	369.0	0.17	35.52							
	D3	0.58		0.36	0.21																					
D3	MH4					0.21	10	5.00	7.00	1.46	Circular	18	0.012	1.365	1.767	0.02%	29.0	0.83	0.58							
MH4	MH6					0.21	10	5.00	7.00	1.46	Circular	18	0.012	1.365	1.767	0.02%	226.0	0.83	4.55							
MH6	MH1					0.25	10	5.00	7.00	1.77	Circular	24	0.012	2.938	3.142	0.01%	344.0	0.56	10.19							
	D4	3.63		0.35	1.27																					
D4	D5					1.27	10	5.00	7.00	8.89	Circular	18	0.012	1.365	1.767	0.61%	18.0	5.03	0.06							
	D5	1.66		0.43	0.71																					
D5	D6					1.98	10	5.00	7.00	13.89	Circular	18	0.012	1.365	1.767	1.49%	24.0	7.86	0.05							
	D6	0.54		0.67	0.36																					
D6	MH1					2.35	10	5.00	7.00	16.42	Circular	18	0.012	1.365	1.767	2.08%	31.0	9.29	0.06							
	D7	0.28		0.64	0.18																					
D7	MH1					0.18	10	5.00	7.00	1.25	Circular	18	0.012	1.365	1.767	0.01%	23.0	0.71	0.54							
MH1	OUTFALL					2.78	10	5.00	7.00	19.44	Circular	24	0.012	2.938	3.142	0.63%	333.0	6.19	0.90							

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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	E1	1.03		0.64	0.66																					
E1	MH1					0.66	10	5.00	7.00	4.61	Circular	18	0.012	1.365	1.767	0.16%	18.0	2.61	0.11							
	E2	0.28		0.43	0.12																					
E2	MH1					0.12	10	5.00	7.00	0.84	Circular	18	0.012	1.365	1.767	0.01%	24.0	0.48	0.84							
MH1	OUTFALL					0.78	10	5.00	7.00	5.46	Circular	24	0.012	2.938	3.142	0.05%	278.0	1.74	2.67							
	F1	3.91		0.52	2.03																					
F1	MH3					2.03	10	5.00	7.00	14.23	Circular	18	0.012	1.365	1.767	1.57%	31.0	8.05	0.06							
	F2	2.93		0.35	1.03																					
F2	MH3					1.03	10	5.00	7.00	7.18	Circular	18	0.012	1.365	1.767	0.40%	31.0	4.06	0.13							
MH3	OUTFALL					3.06	10	5.00	7.00	21.41	Circular	18	0.012	1.365	1.767	3.54%	324.0	12.12	0.45							

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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	G1	1.91		0.36	0.69																					
G1	G2					0.69	10	5.00	7.00	4.81	Circular	15	0.012	0.841	1.227	0.47%	26.0	3.92	0.11							
	G2	0.79		0.44	0.35																					
G2	MH					1.04	10	5.00	7.00	7.25	Circular	18	0.012	1.365	1.767	0.41%	43.0	4.10	0.17							
	G3	1.8		0.36	0.65																					
G3	G4					0.65	10	5.00	7.00	4.54	Circular	15	0.012	0.841	1.227	0.42%	21.0	3.70	0.09							
	G4	0.37		0.54	0.20																					
G4	MH					0.85	10	5.00	7.00	5.93	Circular	18	0.012	1.365	1.767	0.27%	25.0	3.36	0.12							
MH	MH2					1.88	10	5.00	7.00	13.18	Circular	24	0.012	2.938	3.142	0.29%	305.0	4.20	1.21							
	G5	0.25		0.9	0.23																					
G5	MH2					0.23	10	5.00	7.00	1.58	Circular	18	0.012	1.365	1.767	0.02%	24.0	0.89	0.45							
MH2	OUTLET					2.11	10	5.00	7.00	14.76	Circular	24	0.012	2.938	3.142	0.36%	125.0	4.70	0.44							
	H1	0.8		0.59	0.47																					
H1	OUTFALL					0.47	10	5.00	7.00	3.30	Circular	18	0.012	1.365	1.767	0.08%	93.0	1.87	0.83							
	I1	0.42		0.4	0.17																					
I1	OUTFALL					0.17	10	5.00	7.00	1.18	Circular	18	0.012	1.365	1.767	0.01%	42.0	0.67	1.05							

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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	J1	0.07		0.48	0.03																					
J1	J2					0.03	10	5.00	7.00	0.24	Circular	18	0.012	1.365	1.767	0.00%	26.0	0.13	3.26							
	J2	0.29		0.6	0.17																					
J2	OUTFALL					0.21	10	5.00	7.00	1.45	Circular	18	0.012	1.365	1.767	0.02%	373.0	0.82	7.56							
	K1	0.05		0.61	0.03																					
K1	K2					0.03	10	5.00	7.00	0.21	Circular	12	0.012	0.464	0.785	0.00%	18.0	0.27	1.10							
	K2	0.48		0.57	0.27																					
K2	K3					0.30	10	5.00	7.00	2.13	Circular	18	0.012	1.365	1.767	0.04%	184.0	1.20	2.55							
	K4	0.18		0.62	0.11																					
K4	K3					0.11	10	5.00	7.00	0.78	Circular	18	0.012	1.365	1.767	0.00%	66.0	0.44	2.49							
	K3	0.34		0.60	0.20																					
K3	K5					0.62	10	5.00	7.00	4.34	Circular	18	0.012	1.365	1.767	0.15%	120.0	2.45	0.81							
	K5	0.55		0.74	0.41																					
K5	K6					1.03	10	5.00	7.00	7.19	Circular	18	0.012	1.365	1.767	0.40%	93.0	4.07	0.38							
	K6	0.15		0.71	0.11																					
K6	K7					1.13	10	5.00	7.00	7.93	Circular	18	0.012	1.365	1.767	0.49%	188.0	4.49	0.70							
	K7	0.19		0.78	0.15																					
K7	MH-OUT					1.28	10	5.00	7.00	8.97	Circular	18	0.012	1.365	1.767	0.62%	56.0	5.08	0.18							
	K12	3.55		0.36	1.28																					
K12	K14					1.28	10	5.00	7.00	8.95	Circular	15	0.012	0.841	1.227	1.63%	322.0	7.29	0.74							

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STORM SEWER DESIGN (10yr. Storm)

Job No. 2006041200
Sheet

PROJECT: Eastport Area
LOCATION: Annapolis, Maryland
CATEGORY: Storm Drain Analysis

	By	Date
Computed	JLA	11/01/07
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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	K13	2.51		0.35	0.88																					
K13	K14					0.88	10	5.00	7.00	6.15	Circular	18	0.012	1.365	1.767	0.29%	25.0	3.48	0.12							
	K14	0.97		0.42	0.41																					
K14	MH2					2.56	10	5.00	7.00	17.95	Circular	24	0.012	2.938	3.142	0.54%	279.0	5.71	0.81							
	K11	2.14		0.36	0.77																					
K11	K10					0.77	10	5.00	7.00	5.39	Circular	15	0.012	0.841	1.227	0.59%	25.0	4.40	0.09							
	K10	0.64		0.33	0.21																					
K10	MH2					0.98	10	5.00	7.00	6.87	Circular	18	0.012	1.365	1.767	0.36%	311.0	3.89	1.33							
MH2	K9					3.55	10	5.00	7.00	24.82	Circular	24	0.012	2.938	3.142	1.03%	250.0	7.90	0.53							
	K9	1.27		0.57	0.72																					
K9	MH-OUT					4.27	10	5.00	7.00	29.89	Circular	24	0.012	2.938	3.142	1.49%	127.0	9.51	0.22							
	K8	0.85		0.62	0.53																					
K8	MH-OUT					0.53	10	5.00	7.00	3.69	Circular	18	0.012	1.365	1.767	0.11%	92.0	2.09	0.73							
MH-OUT	OUTFALL					6.08	10	5.00	7.00	42.54	Circular	24	0.012	2.938	3.142	3.02%	10.0	13.54	0.01							

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PROJECT: Eastport Area
LOCATION: Annapolis, Maryland
CATEGORY: Storm Drain Analysis

	By	Date
Computed	JLA	11/01/07
Checked		

STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	L1	0.16		0.76	0.12																					
L1	L3					0.12	10	5.00	7.00	0.85	Circular	15	0.012	0.841	1.227	0.01%	101.0	0.69	2.43							
	L3	0.07		0.60	0.04																					
L3	L2					0.16	10	5.00	7.00	1.15	Circular	15	0.012	0.841	1.227	0.03%	56.0	0.93	1.00							
	L2	0.09		0.58	0.05																					
L2	OUTFALL					0.22	10	5.00	7.00	1.51	Circular	15	0.012	0.841	1.227	0.05%	135.0	1.23	1.83							
	M1	1.02		0.37	0.38																					
M1	M2					0.38	10	5.00	7.00	2.64	Circular	15	0.012	0.841	1.227	0.14%	26.0	2.15	0.20							
	M2	0.37		0.47	0.17																					
M2	OUTFALL					0.55	10	5.00	7.00	3.86	Circular	18	0.012	1.365	1.767	0.12%	167.0	2.18	1.27							
	N1	1.61		0.55	0.89																					
N1	OUTFALL					0.89	10	5.00	7.00	6.20	Circular	18	0.012	1.365	1.767	0.30%	170.0	3.51	0.81							

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PROJECT: Eastport Area
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CATEGORY: Storm Drain Analysis

	By	Date
Computed	JLA	11/01/07
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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	O1	4.13		0.32	1.32																					
O1	MH					1.32	10	5.00	7.00	9.25	Circular	18	0.012	1.365	1.767	0.66%	37.0	5.24	0.12							
	O2	4.16		0.37	1.54																					
O2	MH					1.54	10	5.00	7.00	10.77	Circular	18	0.012	1.365	1.767	0.90%	24.0	6.10	0.07							
MH	MH2					2.86	10	5.00	7.00	20.03	Circular	24	0.012	2.938	3.142	0.67%	326.0	6.37	0.85							
	O3	3.27		0.39	1.28																					
O3	O4					1.28	10	5.00	7.00	8.93	Circular	18	0.012	1.365	1.767	0.62%	28.0	5.05	0.09							
	O4	0.19		0.9	0.17																					
O4	MH2					1.45	10	5.00	7.00	10.12	Circular	18	0.012	1.365	1.767	0.79%	24.0	5.73	0.07							
MH2	MH3					4.31	10	5.00	7.00	30.15	Circular	30	0.012	5.330	4.909	0.46%	378.0	6.14	1.03							
	O5	2.08		0.42	0.87																					
O5	MH3					0.87	10	5.00	7.00	6.12	Circular	18	0.012	1.365	1.767	0.29%	28.0	3.46	0.13							
	O6	0.46		0.57	0.26																					
O6	O7					0.26	10	5.00	7.00	1.84	Circular	18	0.012	1.365	1.767	0.03%	18.0	1.04	0.29							
	O7	0.73		0.53	0.39																					
O7	MH3					0.65	10	5.00	7.00	4.54	Circular	30	0.012	5.330	4.909	0.01%	20.0	0.93	0.36							
MH3	OUTFALL					5.83	10	5.00	7.00	40.81	Circular	30	0.012	5.330	4.909	0.84%	10.0	8.31	0.02							

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PROJECT: Eastport Area
LOCATION: Annapolis, Maryland
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	By	Date
Computed	JLA	11/01/07
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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	P1	1.21		0.51	0.62																					
P1	MH					0.62	10	5.00	7.00	4.32	Circular	15	0.012	0.841	1.227	0.38%	25.0	3.52	0.12							
	P2	0.80		0.43	0.34																					
P2	MH					0.34	10	5.00	7.00	2.41	Circular	15	0.012	0.841	1.227	0.12%	18.0	1.96	0.15							
MH	MH3					0.96	10	5.00	7.00	6.73	Circular	18	0.012	1.365	1.767	0.35%	30.0	3.81	0.13							
	P3	0.74		0.44	0.33																					
P3	MH3					0.33	10	5.00	7.00	2.28	Circular	18	0.012	1.365	1.767	0.04%	29.0	1.29	0.37							
MH3	MH64					1.29	10	5.00	7.00	9.01	Circular	18	0.012	1.365	1.767	0.63%	324.0	5.10	1.06							
	P4	0.82		0.57	0.47																					
P4	MH64					0.47	10	5.00	7.00	3.27	Circular	18	0.012	1.365	1.767	0.08%	20.0	1.85	0.18							
MH64	MH20					1.75	10	5.00	7.00	12.28	Circular	18	0.012	1.365	1.767	1.17%	297.0	6.95	0.71							
	P5	1.24		0.35	0.43																					
P5	MH20					0.43	10	5.00	7.00	3.04	Circular	18	0.012	1.365	1.767	0.07%	16.0	1.72	0.16							
	P6	0.18		0.37	0.07																					
P6	MH20					0.07	10	5.00	7.00	0.47	Circular	18	0.012	1.365	1.767	0.00%	21.0	0.26	1.33							
MH20	P8					2.25	10	5.00	7.00	15.78	Circular	24	0.012	2.938	3.142	0.42%	247.0	5.02	0.82							
	P7	2.24		0.34	0.76																					
P7	P8					0.76	10	5.00	7.00	5.33	Circular	18	0.012	1.365	1.767	0.22%	21.0	3.02	0.12							
	P10	2.48		0.34	0.84																					
P10	P9					0.84	10	5.00	7.00	5.90	Circular	18	0.012	1.365	1.767	0.27%	20.0	3.34	0.10							

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PROJECT: Eastport Area
LOCATION: Annapolis, Maryland
CATEGORY: Storm Drain Analysis

	By	Date
Computed	JLA	11/01/07
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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	P9	1.57		0.42	0.66																					
P9	P8					1.50	10	5.00	7.00	10.52	Circular	18	0.012	1.365	1.767	0.86%	19.0	5.95	0.05							
	P8	0.80		0.33	0.26																					
P8	MH					4.78	10	5.00	7.00	33.48	Circular	30	0.012	5.330	4.909	0.57%	31.0	6.82	0.08							
	P12	2.20		0.42	0.92																					
P12	P13					0.92	10	5.00	7.00	6.47	Circular	18	0.012	1.365	1.767	0.32%	37.0	3.66	0.17							
	P13	0.39		0.36	0.14																					
P13	MH69					1.06	10	5.00	7.00	7.45	Circular	18	0.012	1.365	1.767	0.43%	58.0	4.22	0.23							
	P11	1.35		0.48	0.65																					
P11	MH69					0.65	10	5.00	7.00	4.54	Circular	18	0.012	1.365	1.767	0.16%	34.0	2.57	0.22							
MH69	P14					1.71	10	5.00	7.00	11.99	Circular	24	0.012	2.938	3.142	0.24%	378.0	3.82	1.65							
	P14	0.31		0.38	0.12																					
P14	MH					1.83	10	5.00	7.00	12.81	Circular	30	0.012	5.330	4.909	0.08%	663.0	2.61	4.23							
MH	OUTFALL					6.61	10	5.00	7.00	46.29	Circular	30	0.012	5.330	4.909	1.09%	82.0	9.43	0.14							

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PROJECT: Eastport Area
LOCATION: Annapolis, Maryland
CATEGORY: Storm Drain Analysis

	By	Date
Computed	JLA	11/01/07
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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	Q1	0.35		0.36	0.13																					
Q1	Q2					0.13	10	5.00	7.00	0.88	Circular	18	0.012	1.365	1.767	0.01%	17.0	0.50	0.57							
	Q2	1.28		0.37	0.47																					
Q2	Q3					0.60	10	5.00	7.00	4.20	Circular	18	0.012	1.365	1.767	0.14%	18.0	2.38	0.13							
	Q4	1.31		0.35	0.46																					
Q4	Q3					0.46	10	5.00	7.00	3.21	Circular	18	0.012	1.365	1.767	0.08%	14.0	1.82	0.13							
	Q3	2.02		0.34	0.69																					
Q3	MH					1.74	10	5.00	7.00	12.21	Circular	24	0.012	2.938	3.142	0.25%	401.0	3.89	1.72							
	Q5	0.93		0.37	0.34																					
Q5	MH					0.34	10	5.00	7.00	2.41	Circular	18	0.012	1.365	1.767	0.04%	39.0	1.36	0.48							
	Q6	2.11		0.34	0.72																					
Q6	MH					0.72	10	5.00	7.00	5.02	Circular	18	0.012	1.365	1.767	0.19%	23.0	2.84	0.13							
MH	MH-OUT					2.81	10	5.00	7.00	19.64	Circular	24	0.012	2.938	3.142	0.64%	378.0	6.25	1.01							
	Q7	0.46		0.38	0.17																					
Q7	Q8					0.17	10	5.00	7.00	1.22	Circular	15	0.012	0.841	1.227	0.03%	32.0	1.00	0.53							
	Q8	1.16		0.36	0.42																					
Q8	MH-OUT					0.59	10	5.00	7.00	4.15	Circular	18	0.012	1.365	1.767	0.13%	187.0	2.35	1.33							
MH-OUT	OUTFALL					3.40	10	5.00	7.00	23.79	Circular	30	0.012	5.330	4.909	0.29%	137.0	4.85	0.47							

APPENDIX

7.2 100-YEAR STORM DRAIN ANALYSIS

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STORM SEWER DESIGN (100yr. Storm)

Job No. 2009015000
Sheet

PROJECT: Eastport Area
LOCATION: Annapolis, Maryland
CATEGORY: Storm Drain Analysis

	By	Date
Computed	JLA	08/06/10
Checked		

STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	A1	1.69		0.33	0.56																					
A1	A2		1.69			0.56	100	5.00	10.00	5.58	Circular	15	0.012	0.841	1.227	0.63%	33.0	4.55	0.12							
	A2	0.51		0.27	0.14																					
A2	A3		2.20			0.70	100	5.12	10.00	6.95	Circular	15	0.012	0.841	1.227	0.98%	50.0	5.67	0.15							
	A3	0.22		0.67	0.15																					
A3	OUTFALL		2.42			0.84	100	5.27	10.00	8.43	Circular	15	0.012	0.841	1.227	1.45%	117.0	6.87	0.28							

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PROJECT: Eastport Area
LOCATION: Annapolis, Maryland
CATEGORY: Storm Drain Analysis

	By	Date
Computed	JLA	08/06/10
Checked		

STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	B1	0.53		0.40	0.21																					
B1	MH9		0.53			0.21	100	5.00	10.00	2.12	Circular	15	0.012	0.841	1.227	0.09%	41.0	1.73	0.40							
	B1A	0.71		0.42	0.30																					
B1A	MH9					0.30	100	5.00	10.00	2.98	Circular	18	0.012	1.365	1.767	0.07%	35.0	1.69	0.35							
MH9	MH5					0.51	100	5.00	10.00	5.10	Circular	18	0.012	1.365	1.767	0.20%	157.0	2.89	0.91							
	B3	2.08		0.43	0.89																					
B3	MH5					0.89	100	5.00	10.00	8.94	Circular	18	0.012	1.365	1.767	0.62%	19.0	5.06	0.06							
	B2	1.27		0.34	0.43																					
B2	MH5					0.43	100	5.00	10.00	4.32	Circular	18	0.012	1.365	1.767	0.14%	9.0	2.44	0.06							
MH5	B4					1.33	100	5.00	10.00	13.26	Circular	30	0.012	5.330	4.909	0.09%	271.0	2.70	1.67							
	B4	1.79		0.29	0.52																					
B4	B6					1.85	100	5.00	10.00	18.45	Circular	30	0.012	5.330	4.909	0.17%	280.0	3.76	1.24							
	B6	1.67		0.37	0.62																					
B6	MH14					2.46	100	5.00	10.00	24.63	Circular	30	0.012	5.330	4.909	0.31%	46.0	5.02	0.15							
	B5	1.28		0.38	0.49																					
B5	B7					0.49	100	5.00	10.00	4.86	Circular	18	0.012	1.365	1.767	0.18%	22.0	2.75	0.13							
	B7	1.21		0.38	0.46																					
B7	MH14					0.95	100	5.00	10.00	9.46	Circular	18	0.012	1.365	1.767	0.69%	25.0	5.35	0.08							
MH14	MH3					3.41	100	5.00	10.00	34.09	Circular	30	0.012	5.330	4.909	0.59%	232.0	6.95	0.56							
	B9	1.58		0.35	0.55																					
B9	MH3					0.55	100	5.00	10.00	5.53	Circular	18	0.012	1.365	1.767	0.24%	19.0	3.13	0.10							

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STORM SEWER DESIGN (100yr. Storm)

Job No. 2009015000
Sheet

PROJECT: Eastport Area
LOCATION: Annapolis, Maryland
CATEGORY: Storm Drain Analysis

	By	Date
Computed	JLA	08/06/10
Checked		

STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	B8	0.99		0.35	0.35																					
B8	MH3					0.35	100	5.00	10.00	3.47	Circular	18	0.012	1.365	1.767	0.09%	14.0	1.96	0.12							
	B10	0.23		0.42	0.10																					
B10	MH3					0.10	100	5.00	10.00	0.97	Circular	15	0.012	0.841	1.227	0.02%	148.0	0.79	3.13							
MH3	OUTFALL					4.41	100	5.00	10.00	44.06	Circular	30	0.012	5.330	4.909	0.98%	719.0	8.97	1.34							

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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	C1	0.8		0.57	0.46																					
C1	C2					0.46	100	5.00	10.00	4.56	Circular	15	0.012	0.841	1.227	0.42%	21.0	3.72	0.09							
	C2	1.7		0.57	0.97																					
C2	MH8					1.43	100	5.00	10.00	14.25	Circular	15	0.012	0.841	1.227	4.13%	28.0	11.61	0.04							
	C3	1.54		0.62	0.95																					
C3	MH8					0.95	100	5.00	10.00	9.55	Circular	15	0.012	0.841	1.227	1.86%	45.0	7.78	0.10							
MH8	C5					2.38	100	5.00	10.00	23.80	Circular	30	0.012	5.330	4.909	0.29%	151.0	4.85	0.52							
	C4	0.28		0.54	0.15																					
C4	C5					0.15	100	5.00	10.00	1.51	Circular	18	0.012	1.365	1.767	0.02%	48.0	0.86	0.93							
	C5	0.24		0.66	0.16																					
C5	C6					2.69	100	5.00	10.00	26.89	Circular	30	0.012	5.330	4.909	0.37%	226.0	5.48	0.69							
	C7	1.79		0.59	1.06																					
C7	C6					1.06	100	5.00	10.00	10.56	Circular	18	0.012	1.365	1.767	0.86%	42.0	5.98	0.12							
	C6	0.16		0.49	0.08																					
C6	OUTFALL					3.82	100	5.00	10.00	38.24	Circular	36	0.012	8.658	7.069	0.28%	104.0	5.41	0.32							

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PROJECT: Eastport Area
LOCATION: Annapolis, Maryland
CATEGORY: Storm Drain Analysis

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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	D1	0.09		0.33	0.03																					
D1	D2					0.03	100	5.00	10.00	0.30	Circular	18	0.012	1.365	1.767	0.00%	41.0	0.17	4.07							
	D2	0.04		0.35	0.01																					
D2	MH6					0.04	100	5.00	10.00	0.44	Circular	18	0.012	1.365	1.767	0.00%	369.0	0.25	24.87							
	D3	0.58		0.36	0.21																					
D3	MH4					0.21	100	5.00	10.00	2.09	Circular	18	0.012	1.365	1.767	0.03%	29.0	1.18	0.41							
MH4	MH6					0.21	100	5.00	10.00	2.09	Circular	18	0.012	1.365	1.767	0.03%	226.0	1.18	3.19							
MH6	MH1					0.25	100	5.00	10.00	2.53	Circular	24	0.012	2.938	3.142	0.01%	344.0	0.80	7.13							
	D4	3.63		0.35	1.27																					
D4	D5					1.27	100	5.00	10.00	12.71	Circular	18	0.012	1.365	1.767	1.25%	18.0	7.19	0.04							
	D5	1.66		0.43	0.71																					
D5	D6					1.98	100	5.00	10.00	19.84	Circular	18	0.012	1.365	1.767	3.04%	24.0	11.23	0.04							
	D6	0.54		0.67	0.36																					
D6	MH1					2.35	100	5.00	10.00	23.46	Circular	18	0.012	1.365	1.767	4.25%	31.0	13.28	0.04							
	D7	0.28		0.64	0.18																					
D7	MH1					0.18	100	5.00	10.00	1.79	Circular	18	0.012	1.365	1.767	0.02%	23.0	1.01	0.38							
MH1	OUTFALL					2.78	100	5.00	10.00	27.78	Circular	24	0.012	2.938	3.142	1.29%	333.0	8.84	0.63							

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CATEGORY: Storm Drain Analysis

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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	E1	1.03		0.64	0.66																					
E1	MH1					0.66	100	5.00	10.00	6.59	Circular	18	0.012	1.365	1.767	0.34%	18.0	3.73	0.08							
	E2	0.28		0.43	0.12																					
E2	MH1					0.12	100	5.00	10.00	1.20	Circular	18	0.012	1.365	1.767	0.01%	24.0	0.68	0.59							
MH1	OUTFALL					0.78	100	5.00	10.00	7.80	Circular	24	0.012	2.938	3.142	0.10%	278.0	2.48	1.87							
	F1	3.91		0.52	2.03																					
F1	MH3					2.03	100	5.00	10.00	20.33	Circular	18	0.012	1.365	1.767	3.19%	31.0	11.51	0.04							
	F2	2.93		0.35	1.03																					
F2	MH3					1.03	100	5.00	10.00	10.26	Circular	18	0.012	1.365	1.767	0.81%	31.0	5.80	0.09							
MH3	OUTFALL					3.06	100	5.00	10.00	30.59	Circular	18	0.012	1.365	1.767	7.23%	324.0	17.31	0.31							

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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	G1	1.91		0.36	0.69																					
G1	G2					0.69	100	5.00	10.00	6.88	Circular	15	0.012	0.841	1.227	0.96%	26.0	5.60	0.08							
	G2	0.79		0.44	0.35																					
G2	MH					1.04	100	5.00	10.00	10.35	Circular	18	0.012	1.365	1.767	0.83%	43.0	5.86	0.12							
	G3	1.8		0.36	0.65																					
G3	G4					0.65	100	5.00	10.00	6.48	Circular	15	0.012	0.841	1.227	0.85%	21.0	5.28	0.07							
	G4	0.37		0.54	0.20																					
G4	MH					0.85	100	5.00	10.00	8.48	Circular	18	0.012	1.365	1.767	0.56%	25.0	4.80	0.09							
MH	MH2					1.88	100	5.00	10.00	18.83	Circular	24	0.012	2.938	3.142	0.59%	305.0	5.99	0.85							
	G5	0.25		0.9	0.23																					
G5	MH2					0.23	100	5.00	10.00	2.25	Circular	18	0.012	1.365	1.767	0.04%	24.0	1.27	0.31							
MH2	OUTLET					2.11	100	5.00	10.00	21.08	Circular	24	0.012	2.938	3.142	0.74%	125.0	6.71	0.31							
	H1	0.8		0.59	0.47																					
H1	OUTFALL					0.47	100	5.00	10.00	4.72	Circular	18	0.012	1.365	1.767	0.17%	93.0	2.67	0.58							
	I1	0.42		0.4	0.17																					
I1	OUTFALL					0.17	100	5.00	10.00	1.68	Circular	18	0.012	1.365	1.767	0.02%	42.0	0.95	0.74							
	J1	0.07		0.48	0.03																					
J1	J2					0.03	100	5.00	10.00	0.34	Circular	18	0.012	1.365	1.767	0.00%	26.0	0.19	2.28							
	J2	0.29		0.6	0.17																					
J2	OUTFALL					0.21	100	5.00	10.00	2.08	Circular	18	0.012	1.365	1.767	0.03%	373.0	1.17	5.29							

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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	K1	0.05		0.61	0.03																					
K1	K2					0.03	100	5.00	10.00	0.31	Circular	12	0.012	0.464	0.785	0.01%	18.0	0.39	0.77							
	K2	0.48		0.57	0.27																					
K2	K3					0.30	100	5.00	10.00	3.04	Circular	18	0.012	1.365	1.767	0.07%	184.0	1.72	1.78							
	K4	0.18		0.62	0.11																					
K4	K3					0.11	100	5.00	10.00	1.12	Circular	18	0.012	1.365	1.767	0.01%	66.0	0.63	1.74							
	K3	0.34		0.60	0.20																					
K3	K5					0.62	100	5.00	10.00	6.20	Circular	18	0.012	1.365	1.767	0.30%	120.0	3.51	0.57							
	K5	0.55		0.74	0.41																					
K5	K6					1.03	100	5.00	10.00	10.27	Circular	18	0.012	1.365	1.767	0.81%	93.0	5.81	0.27							
	K6	0.15		0.71	0.11																					
K6	K7					1.13	100	5.00	10.00	11.33	Circular	18	0.012	1.365	1.767	0.99%	188.0	6.41	0.49							
	K7	0.19		0.78	0.15																					
K7	MH-OUT					1.28	100	5.00	10.00	12.81	Circular	18	0.012	1.365	1.767	1.27%	56.0	7.25	0.13							
	K12	3.55		0.36	1.28																					
K12	K14					1.28	100	5.00	10.00	12.78	Circular	15	0.012	0.841	1.227	3.32%	322.0	10.42	0.52							
	K13	2.51		0.35	0.88																					
K13	K14					0.88	100	5.00	10.00	8.79	Circular	18	0.012	1.365	1.767	0.60%	25.0	4.97	0.08							
	K14	0.97		0.42	0.41																					
K14	MH2					2.56	100	5.00	10.00	25.64	Circular	24	0.012	2.938	3.142	1.10%	279.0	8.16	0.57							

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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	K11	2.14		0.36	0.77																					
K11	K10					0.77	100	5.00	10.00	7.70	Circular	15	0.012	0.841	1.227	1.21%	25.0	6.28	0.07							
	K10	0.64		0.33	0.21																					
K10	MH2					0.98	100	5.00	10.00	9.82	Circular	18	0.012	1.365	1.767	0.74%	311.0	5.56	0.93							
MH2	K9					3.55	100	5.00	10.00	35.46	Circular	24	0.012	2.938	3.142	2.10%	250.0	11.28	0.37							
	K9	1.27		0.57	0.72																					
K9	MH-OUT					4.27	100	5.00	10.00	42.69	Circular	24	0.012	2.938	3.142	3.04%	127.0	13.59	0.16							
	K8	0.85		0.62	0.53																					
K8	MH-OUT					0.53	100	5.00	10.00	5.27	Circular	18	0.012	1.365	1.767	0.21%	92.0	2.98	0.51							
MH-OUT	OUTFALL					6.08	100	5.00	10.00	60.78	Circular	24	0.012	2.938	3.142	6.16%	10.0	19.34	0.01							

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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	L1	0.16		0.76	0.12																					
L1	L3					0.12	100	5.00	10.00	1.22	Circular	15	0.012	0.841	1.227	0.03%	101.0	0.99	1.70							
	L3	0.07		0.60	0.04																					
L3	L2					0.16	100	5.00	10.00	1.64	Circular	15	0.012	0.841	1.227	0.05%	56.0	1.33	0.70							
	L2	0.09		0.58	0.05																					
L2	OUTFALL					0.22	100	5.00	10.00	2.16	Circular	15	0.012	0.841	1.227	0.09%	135.0	1.76	1.28							
	M1	1.02		0.37	0.38																					
M1	M2					0.38	100	5.00	10.00	3.77	Circular	15	0.012	0.841	1.227	0.29%	26.0	3.08	0.14							
	M2	0.37		0.47	0.17																					
M2	OUTFALL					0.55	100	5.00	10.00	5.51	Circular	18	0.012	1.365	1.767	0.23%	167.0	3.12	0.89							
	N1	1.61		0.55	0.89																					
N1	OUTFALL					0.89	100	5.00	10.00	8.86	Circular	18	0.012	1.365	1.767	0.61%	170.0	5.01	0.57							

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STORM SEWER DESIGN (100yr. Storm)

Job No. 2009015000
Sheet

PROJECT: Eastport Area
LOCATION: Annapolis, Maryland
CATEGORY: Storm Drain Analysis

	By	Date
Computed	JLA	08/06/10
Checked		

STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	O1	4.13		0.32	1.32																					
O1	MH					1.32	100	5.00	10.00	13.22	Circular	18	0.012	1.365	1.767	1.35%	37.0	7.48	0.08							
	O2	4.16		0.37	1.54																					
O2	MH					1.54	100	5.00	10.00	15.39	Circular	18	0.012	1.365	1.767	1.83%	24.0	8.71	0.05							
MH	MH2					2.86	100	5.00	10.00	28.61	Circular	24	0.012	2.938	3.142	1.37%	326.0	9.11	0.60							
	O3	3.27		0.39	1.28																					
O3	O4					1.28	100	5.00	10.00	12.75	Circular	18	0.012	1.365	1.767	1.26%	28.0	7.22	0.06							
	O4	0.19		0.9	0.17																					
O4	MH2					1.45	100	5.00	10.00	14.46	Circular	18	0.012	1.365	1.767	1.62%	24.0	8.19	0.05							
MH2	MH3					4.31	100	5.00	10.00	43.07	Circular	30	0.012	5.330	4.909	0.94%	378.0	8.77	0.72							
	O5	2.08		0.42	0.87																					
O5	MH3					0.87	100	5.00	10.00	8.74	Circular	18	0.012	1.365	1.767	0.59%	28.0	4.94	0.09							
	O6	0.46		0.57	0.26																					
O6	O7					0.26	100	5.00	10.00	2.62	Circular	18	0.012	1.365	1.767	0.05%	18.0	1.48	0.20							
	O7	0.73		0.53	0.39																					
O7	MH3					0.65	100	5.00	10.00	6.49	Circular	30	0.012	5.330	4.909	0.02%	20.0	1.32	0.25							
MH3	OUTFALL					5.83	100	5.00	10.00	58.30	Circular	30	0.012	5.330	4.909	1.72%	10.0	11.88	0.01							

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PROJECT: Eastport Area
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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	P1	1.21		0.51	0.62																					
P1	MH					0.62	100	5.00	10.00	6.17	Circular	15	0.012	0.841	1.227	0.78%	25.0	5.03	0.08							
	P2	0.80		0.43	0.34																					
P2	MH					0.34	100	5.00	10.00	3.44	Circular	15	0.012	0.841	1.227	0.24%	18.0	2.80	0.11							
MH	MH3					0.96	100	5.00	10.00	9.61	Circular	18	0.012	1.365	1.767	0.71%	30.0	5.44	0.09							
	P3	0.74		0.44	0.33																					
P3	MH3					0.33	100	5.00	10.00	3.26	Circular	18	0.012	1.365	1.767	0.08%	29.0	1.84	0.26							
MH3	MH64					1.29	100	5.00	10.00	12.87	Circular	18	0.012	1.365	1.767	1.28%	324.0	7.28	0.74							
	P4	0.82		0.57	0.47																					
P4	MH64					0.47	100	5.00	10.00	4.67	Circular	18	0.012	1.365	1.767	0.17%	20.0	2.65	0.13							
MH64	MH20					1.75	100	5.00	10.00	17.54	Circular	18	0.012	1.365	1.767	2.38%	297.0	9.93	0.50							
	P5	1.24		0.35	0.43																					
P5	MH20					0.43	100	5.00	10.00	4.34	Circular	18	0.012	1.365	1.767	0.15%	16.0	2.46	0.11							
	P6	0.18		0.37	0.07																					
P6	MH20					0.07	100	5.00	10.00	0.67	Circular	18	0.012	1.365	1.767	0.00%	21.0	0.38	0.93							
MH20	P8					2.25	100	5.00	10.00	22.55	Circular	24	0.012	2.938	3.142	0.85%	247.0	7.18	0.57							
	P7	2.24		0.34	0.76																					
P7	P8					0.76	100	5.00	10.00	7.62	Circular	18	0.012	1.365	1.767	0.45%	21.0	4.31	0.08							
	P10	2.48		0.34	0.84																					
P10	P9					0.84	100	5.00	10.00	8.43	Circular	18	0.012	1.365	1.767	0.55%	20.0	4.77	0.07							

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PROJECT: Eastport Area
LOCATION: Annapolis, Maryland
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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
		A	ΣA	C	CA	ΣCA		T_c	I	Q		D	n	C	A	S_f	L	V_f	TIME	INVERT ELEVATION		S	V	Q		
FROM	TO	AREA (AC)	AREA (AC)	RUNOFF COEF.			DESIGN STORM (YRS)	TIME OF CONC. (MIN)	RAINFALL INTENS (IN/HR)	QUANTITY (CFS)	TYPE	SIZE (IN)	MANN-INGS COEF		AREA SF	FRICTION SLOPE (%)	LENGTH (FT)	VELOC (FT/SEC)	IN PIPE (MIN)	UPPER (FT)	LOWER (FT)	ACTUAL SLOPE (%)	FULL FLOW VELOCITY (FT/SEC)	CAPACITY (CFS)	PIPE TYPE	
	P9	1.57		0.42	0.66																					
P9	P8					1.50	100	5.00	10.00	15.03	Circular	18	0.012	1.365	1.767	1.74%	19.0	8.50	0.04							
	P8	0.80		0.33	0.26																					
P8	MH					4.78	100	5.00	10.00	47.83	Circular	30	0.012	5.330	4.909	1.16%	31.0	9.74	0.05							
	P12	2.20		0.42	0.92																					
P12	P13					0.92	100	5.00	10.00	9.24	Circular	18	0.012	1.365	1.767	0.66%	37.0	5.23	0.12							
	P13	0.39		0.36	0.14																					
P13	MH69					1.06	100	5.00	10.00	10.64	Circular	18	0.012	1.365	1.767	0.88%	58.0	6.02	0.16							
	P11	1.35		0.48	0.65																					
P11	MH69					0.65	100	5.00	10.00	6.48	Circular	18	0.012	1.365	1.767	0.32%	34.0	3.67	0.15							
MH69	P14					1.71	100	5.00	10.00	17.12	Circular	24	0.012	2.938	3.142	0.49%	378.0	5.45	1.16							
	P14	0.31		0.38	0.12																					
P14	MH					1.83	100	5.00	10.00	18.30	Circular	30	0.012	5.330	4.909	0.17%	663.0	3.73	2.96							
MH	OUTFALL					6.61	100	5.00	10.00	66.13	Circular	30	0.012	5.330	4.909	2.22%	82.0	13.47	0.10							

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STRUCT. NO		DRAINAGE AREA		RUNOFF							PIPE															REMARKS
FROM	TO	A AREA (AC)	ΣA AREA (AC)	C RUNOFF COEF.	CA	ΣCA	DESIGN STORM (YRS)	T_c TIME OF CONC. (MIN)	I RAINFALL INTENS (IN/HR)	Q QUANTITY (CFS)	TYPE	D SIZE (IN)	n MANN-INGS COEF	C	A AREA SF	S_f FRICTION SLOPE (%)	L LENGTH (FT)	V_f VELOC (FT/SEC)	TIME IN PIPE (MIN)	INVERT ELEVATION UPPER (FT)	INVERT ELEVATION LOWER (FT)	S ACTUAL SLOPE (%)	V FULL FLOW VELOCITY (FT/SEC)	Q CAPACITY (CFS)	PIPE TYPE	
	Q1	0.35		0.36	0.13																					
Q1	Q2					0.13	100	5.00	10.00	1.26	Circular	18	0.012	1.365	1.767	0.01%	17.0	0.71	0.40							
	Q2	1.28		0.37	0.47																					
Q2	Q3					0.60	100	5.00	10.00	6.00	Circular	18	0.012	1.365	1.767	0.28%	18.0	3.39	0.09							
	Q4	1.31		0.35	0.46																					
Q4	Q3					0.46	100	5.00	10.00	4.59	Circular	18	0.012	1.365	1.767	0.16%	14.0	2.59	0.09							
	Q3	2.02		0.34	0.69																					
Q3	MH					1.74	100	5.00	10.00	17.45	Circular	24	0.012	2.938	3.142	0.51%	401.0	5.55	1.20							
	Q5	0.93		0.37	0.34																					
Q5	MH					0.34	100	5.00	10.00	3.44	Circular	18	0.012	1.365	1.767	0.09%	39.0	1.95	0.33							
	Q6	2.11		0.34	0.72																					
Q6	MH					0.72	100	5.00	10.00	7.17	Circular	18	0.012	1.365	1.767	0.40%	23.0	4.06	0.09							
MH	MH-OUT					2.81	100	5.00	10.00	28.06	Circular	24	0.012	2.938	3.142	1.31%	378.0	8.93	0.71							
	Q7	0.46		0.38	0.17																					
Q7	Q8					0.17	100	5.00	10.00	1.75	Circular	15	0.012	0.841	1.227	0.06%	32.0	1.42	0.37							
	Q8	1.16		0.36	0.42																					
Q8	MH-OUT					0.59	100	5.00	10.00	5.92	Circular	18	0.012	1.365	1.767	0.27%	187.0	3.35	0.93							
MH-OUT	OUTFALL					3.40	100	5.00	10.00	33.99	Circular	30	0.012	5.330	4.909	0.59%	137.0	6.92	0.33							