Storm Water Management Model

Horse Run Ditch East Watershed MDPU

Master Drainage Plan

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Chesapeake VIRGINIA
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URS
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Horse Run Ditch East Watershed MDPU

Chesapeake, VA

URS Nos. 11658002

Executive Summary

Engineers from the City of Chesapeake (City) and URS Corporation (URS) have completed a drainage study of the Horse Run Ditch East Watershed ("Horse Run Watershed") using the Storm Water Management Model (SWMM) computer program.

The analytical procedure is based on computing localized flood volumes resulting from design rainfall events such as the 2-, 5-, 10-, 25-, 50- and 100-year storms. The watershed is analyzed using modeling configurations to quantify flooding associated with both existing and future watershed conditions.

The maximum computed water surface elevation at each modeled node, and peak computed discharge at each modeled link are presented in Appendices C and D, respectively, for existing and future conditions.

This study, in part, was conducted in conjunction with the *Copeland Drive Area Drainage Study*. The final report for the Copeland Drive Area (delivered to the City in August 2011) used results from the SWMM models to conclude findings in relation to the need for an alternate drainage outlet between the Bells Mill Creek and Horse Run watersheds. In short, it was determined that a connection between watersheds would worsen the flooding conditions along certain areas of Horse Run Ditch while the Bells Mill Creek Watershed would receive no benefits during a 10-year storm and very little benefit during a 50-year storm, provided that improvements be made to the Copeland Drive detention basin as detailed elsewhere in this report.

Locations along Horse Run Ditch East downstream of Battlefield Blvd are experiencing flooding during the 50-year storm event. Improvements were made to this channel in the mid-1990's, at which time the design standards were not as stringent as they are today. In July 2010, the City revised their *Public Facilities Manual* (PFM) to require protection from a 50-year storm for any locations receiving runoff from more than 300 acres of contributing drainage.

In order to reduce or eliminate flooding along Horse Run Ditch East downstream of Battlefield Blvd, it would be necessary to either expand the width of the channel for the entire length and/or create retention/detention facilities along the ditch or at locations upstream of Battlefield Blvd. Due to possible land acquisition issues and the extreme expense of such an undertaking, these options are not feasible at this time, and thus are not recommended. It is recommended, that in the event of future construction or redevelopment within this watershed, that the City should require the developer to supply drainage

improvements such as, enlarged drainage channels, detention facilities, etc. Such improvements would help to reduce, if not eliminate, the flooding along Horse Run Ditch East so that eventually this ditch can accommodate the 50-year storm.

One important caveat to keep in mind is that the system, as modeled for this study, assumes a well-maintained system. Debris, sediment, pipe collapses and other maintenance issues can cause very real flooding that must be addressed. In this respect, this study highlights *capacity* issues rather than *maintenance* issues (which are best resolved from inspection or citizen reports). There is good reason to create the models in this manner. If poor maintenance conditions are modeled, the capacity problems could easily be masked to the extent that public funds could be spent unnecessarily.

FEMA flood insurance studies and rate maps are the definitive source of floodplain limits and elevations. The SWMM models developed for this drainage study are specific design scenarios based on 2-, 5-, 10-, 25-, 50-, and 100-year rainfall events—THEY ARE NOT TO BE CONSTRUED AS INDICATIVE OF EXPECTED WATER SURFACE ELEVATIONS FOR THE PURPOSES OF FLOODPLAIN MANAGEMENT AND/OR INSURANCE REQUIREMENTS. The SWMM models developed for this study could be adapted for use in the National Flood Insurance Program and submitted to FEMA for approval, but until they are subjected to that process the published flood insurance studies and rate maps remain fully in effect.

Background

The Horse Run Watershed is located in central Chesapeake and encompasses approximately 898 acres. This watershed is nestled between Bells Mill Watershed to the west and Cooper's Ditch Watershed to the south and east. Runoff from the Horse Run Watershed discharges to the north into the Albemarle and Chesapeake Canal.

The Horse Run Watershed was delineated into 47 subcatchments in order to compute and distribute runoff throughout the entire watershed. Overall, this watershed is well developed with few vacant lots available for future development. This study addresses existing drainage and stormwater issues, as well as expected future conditions. The Horse Run SWMM model has 87 nodes and over 94 links, providing sufficient detail and modeling resolution for master drainage planning purposes. The components of the Horse Run Watershed were combined with the previously modeled Bells Mills Creek Watershed to encompass a total of 208 subcatchments, 412 nodes, and 443 links. This combination allows the analysis of flows across watershed boundary lines, to both the Bells Mill Creek Watershed as well as the Horse Run Watershed. While there is currently not an intended connection between the two watersheds, as the water surface elevation (WSE) rises in the vicinity of Caleb Drive, it will naturally "spill" over from one watershed to the other.

A previous drainage study, *Channel Improvements to Horserun Ditch East*, was completed in August 1987 by Gannett Fleming Corddry & Carpenter. The study recommendations included replacing the culverts under Battlefield Boulevard and Briarfield Drive as well as creating a paved channel along the Horse Run Ditch East. With some modifications to the 1987 study recommendations, culvert replacements under both roads were implemented, as well as a large portion of the Horse Run channel was paved.

In addition to the previous study, the City of Chesapeake provided URS with multiple plan sets for projects within the subject watershed—most of which have been implemented as designed.

The City of Chesapeake surveyed selected points in the subject watershed at the request of URS. These selected survey points are presented in Appendix B. The City also provided URS with GIS-related

topographic data. URS utilized these four main sources—previous study, plan sets, survey data, and GIS data, to compile channel and infrastructure information, such as invert elevations, pipe type and size, and channel characteristics, throughout the subject watershed.

Also, Engineers from the City and URS completed a comprehensive Master Drainage Plan Update (MDPU) of the Bells Mill Creek Watershed in 2009. This study was based on extensive computer modeling using the EPA's Storm Water Management Model (SWMM). Engineers conducted field investigations and City Surveyors collected critical surveying to support the study. The entire effort was documented in the *Bells Mill Creek Watershed MDPU* report completed in April 2009, and revised January 29, 2010.

One particular problem that was specifically addressed was flooding in the Copeland Drive area. An existing detention basin (node 743) has become overgrown with trees and vegetation. This area has become fully developed, with a fairly complex system of detention and retention basins, ditches and culverts, designed to convey stormwater runoff to a downstream outfall through Bells Mill Creek. The Bells Mill Creek SWMM modeling clearly indicated that flows are backing up into the existing detention area, and that some sort of backflow prevention device—such as a duckbill check valve—would be required in conjunction with improved storage in the existing detention basin. In addition, it was stated that an alternate outfall to the east along the Horse Run Ditch might also provide flooding relief to the Copeland Drive area. However, it was unknown at that time what effect providing alternate outfalls to the east would have on the Horse Run Ditch East, as well as the rest of the Horse Run Watershed.

A draft report for the study of the Copeland Drive area was issued to the city in April 2011 that outlined alternatives to the basin west of Copeland Drive (Node 743). Two of the four modeled options of this study included the creation of an additional outfall to the east for this basin. The April 2011 draft report recognized that a definitive solution, regarding the additional east ditch outfall, could not be made until the completion of the Horse Run Watershed MDPU. Therefore, this study, with options from the Copeland Drive study in mind, incorporated the "best fit" alternative for the outfall of the basin (Node 743).

In early August 2011, the modeling for Horse Run had been completed and was therefore analyzed for the completion of the Copeland Drive Study. Several scenarios were modeled, including one that incorporated the creation of a ditch to the east of Caleb Drive, thus allowing additional drainage from the Copeland Drive area to travel east through the Horse Run Watershed. In short, it was determined that by opening the ditch to the east of Caleb Drive, flooding conditions along certain areas of Horse Run Ditch were worsened while the Bells Mill Creek Watershed did not receive significant benefits. The *Copeland Drive Area Drainage Study* recommended that the basin (743) be dredged to increase the storage capacity, and that measures be taken at the outfall of the pond that would deter downstream flows from entering the pond. It was also determined that making a connection between the two watersheds, by opening the ditch east of Caleb Drive, is not recommended. Refer to the *Copeland Drive Area Drainage Study*, dated August 2011, for additional information.

Methodology

The engineering methodology applied in this study is summarized in a separate document, submitted by URS to the City of Chesapeake in April of 2005, entitled *Master Drainage Plan Methodology*. SWMM modeling is typically used for relatively large-scale studies. It is not generally intended to be used as a design tool for individual projects, due to its complexity and data requirements. Its strength lies in the application of very advanced hydrologic and hydraulic routing computational routines, fed with data from a geographic information system (GIS) and from plans for future roadway and parcel development projects.

This Master Drainage Plan Report presents the findings of the application of this methodology to the subject watershed.

Treatment of Nodal Flooding

The issue of how to handle nodal flooding is important when using or interpreting any rainfall-runoff model, including SWMM. Loosely speaking, nodal flooding occurs when a computed water surface elevation exceeds the maximum defined depth at a point in the system (referred to as a "node").

In previous versions of SWMM (Versions 4.x and earlier), the water leaving the node was treated as an "escape" from the system. However, the treatment of nodal flooding was enhanced in SWMM Version 5 by introducing "nodal ponding" and "nodal surcharge" capabilities. The new nodal ponding option allows the modeler to specify a constant "ponding area" over which nodal surcharges are stored as they escape from the node, then released back into the system as water surface elevations recede. This nodal ponding capability can produce more reliable water surface elevation computations due to the re-introduction of nodal flooding volumes and their continued downstream routing through the drainage system.

The option to compute nodal ponding in SWMM necessitates an approach to treat or develop the ponding area for each node, subject to two considerable limitations. First, the ponding area increases with depth, and in fact at some depth the ponded volume will actually combine with other nearby nodes such that deciding which node has what portion of the surface flooding becomes arbitrary at best. Secondly, it is not feasible to spend the time performing elaborate delineations at each node to compute a constant ponding area that is approximate at best, requires judgment regarding how much area to assign to which node, and ultimately varies with depth. In many locations, the situation is further complicated—when stormwater flows up and out of the ground, it runs down a gutter or downhill flow path to some other location.

SWMM is a one-dimensional model—it can only compute flow depth, discharge and related properties along one-dimensional lines through the drainage network. It cannot compute lateral variations in the flow (such as can be accomplished with two-dimensional surface-flow models). Even if it were possible to precisely compute the ponding area at each node, we are still limited by the use of a one-dimensional model. It is difficult to determine a ponding area with accuracy when the computed water surface elevation exceeds the ground elevation. The problem is further complicated by the difficulty in determining the nominal "ground elevation" in a one-dimensional model.

URS has developed an approach to handle nodal flooding using SWMM Version 5, which we are using on many similar studies. The approach used is to divide the total watershed area by the number of modeling nodes to develop an average ponding area, which is then applied to all nodes that are not directly modeled as storage nodes. This approach is simple, but effective, and because the surface

flooding is re-introduced into the drainage system as flood levels decrease, it gives a reliable basis upon which to compute water surface elevations in these models.

While this approach was applied to the Horse Run SWMM model as a rule of thumb, the nodes around Copeland Drive and Caleb Drive received a more detailed delineated area to represent their respective ponding areas. Because these areas are under high scrutiny, this additional level of detail was applied to produce more detailed and 'accurate' computations of the hydraulic grade line (HGL) above ground.

Vertical Datum

Unless specifically stated otherwise, the **North American Vertical Datum of 1988 (NAVD88)** was used throughout this study.

Modeling Configurations

Several scenario models were conducted in a trial and error effort to determine if the permanent connection between watersheds will be beneficial. After much analysis and discussion with City staff, the final two scenarios that are outlined in this report and described below are Scenario 1 (Existing Hydraulics and Existing Hydrology), and Scenario 2 (Existing Hydraulics, with some future improvements, and Future Hydrology). Additionally, Scenario 2alt is also described below. Originally Scenario 2 was 2a and Scenario 2alt was 2b reflecting the trial-and-error processes used to evaluate the need for a permanent connection east of Caleb Drive. Once the City decided which Scenario 2 to use, they were renamed to Scenario 2 and Scenario 2alt to be consistent. After the completion of Scenarios 1 and 2, URS and the City determined that a Scenario 3 model (future improvements) would not be necessary. In lieu of the Scenario 3, URS made recommendations (recorded elsewhere in this report) for drainage improvements during future development throughout the watershed as a whole.

Scenario 1 Existing watershed hydrology with the drainage system configured as it existed in 2011. Channels are modeled using their existing (2011) conditions as well. This is the "Scenario 1" model. The City of Chesapeake requested certain plan sets be considered as 'existing' because they have been approved prior to the start of this study. The following plan sets and studies, provided by the City, are accounted for in the existing conditions model:

1. Hall Manor Subdivision
2. Meadow Woods
3. Renovations to Great Bridge Middle School South
4. 1986 Road Bond Referendum Group D Battlefield BLVD. S. And Cedar Road and Intersection Improvements - Contract B
5. Horse Run Ditch, East Drainage Improvements
6. Chesapeake Colony Estates
7. Chesapeake Colony Estates, Sections 2B & 2C
8. Great Bridge Retail LLC
9. Chesapeake Colony, (Section One, Lots 14-22)
10. Briarwood (Sections Two and Three)
11. Project 0168-131-103,RW-201,C-501 - Battlefield Blvd
12. Great Bridge Professional Bldg.
13. Johnstowne Square
14. Wilson Village Shopping Center
15. Wilson Heights South (Section 1)
16. Commerce Bank Rite-Aid Pharmacy

17. Apartments for Hearndon Construction Co.
18. Kingsbridge Apartments (Section Two)
19. Wilson Heights South (Sec. 2 - 5) Road and Drainage Plan
20. Wilson Heights South (Sec. 1 - 5) Sewer Plan
21. Horse Run Ditch, Phase III
22. Copeland Drive Outfall Ditch Regrading
23. Site Plan of Great Bridge Marketplace
24. Albemarle Dr. Pipe Replacement (As-Builts)
25. Intracoastal Waterway Albemarle Chesapeake Canal
26. Great Bridge Intra-Coastal Waterway
27. Great Bridge Crossing
28. Briarwood Meadows, Sec 2 & 3
29. Briarwood Meadows
30. Johnstown Road, Contract 1, As-Builts
31. Apostles Lutheran Church

Scenario 2 Future watershed hydrology with the added future drainage system as it is anticipated by the City. For the most part, channels and conduits are configured as they exist in 2011, however, the addition of improvements to the Copeland Basin (node 743) have been added to this scenario. This is the "Scenario 2" model. This scenario will show the flooding effects of the existing drainage system (with the added future improvements in place) due to future land use development. The following improvements, as recommended in the Bells Mills Creek Watershed MDPU (January 2010) as well as the Copeland Drive Area Drainage Study (August 2011), have been added to this Scenario 2:

1. A perimeter berm to the west of the Copeland Drive basin (node 743),
2. A check valve at the outfall of the basin (node 743) that will prevent downstream flows from entering the basin, and
3. Dredging the basin, including clearing out the trees and regrading the basin bottom to an elevation of 4.5 feet, with 2(H):1(V) side slopes.

Scenario 2alt This Scenario is similar to Scenario 2 with the exception of merging the two watersheds by creating a readily accessible and permanent connection between the two. In Scenario 2, the intended watershed division location was the east side of Caleb Drive (node 1020). In Scenario 2alt, the new watershed division was located on the east side of Copeland Drive (node 1000). From nodes 1000 to 1030 positive drainage to the east was created, reversing the nominal direction of flow (flow is determined by head differential not channel invert elevations) between nodes 1000 and 1010, increasing the pipe sizes under Caleb Drive (nodes 1010 to 1020), and creating a proposed 5-foot bottom ditch from nodes 1020 to 1030. After analyzing the results from the connection as compared to no connection at all, the City decided to eliminate this option all together.

Tables E-1 and E-2 (see Appendix E) shows the comparison between all three Scenarios for the 10- and 50-year storm events respectively. During the 10-year storm there is virtually no benefit to the west (Bells Mill Creek) of the proposed connection (Scenario 2alt) while areas to the east (Horse Run Ditch) are made worse. For the 50-year storm there exists some relief for the Bells Mill Creek Watershed when applying the proposed connection, however, by creating this connection, significant flooding now occurs in the Horse Run Watershed at the connection point (node 1030), as well as increased flooding in the vicinity of node

1085. Overall, it is unfavorable to propose a permanent intended connection between the two watersheds due to the worsening effects it would have in the Horse Run Watershed.

Modeling Results

The maximum computed water surface elevations at each modeled node and computed peak discharge at each modeled link are presented in Appendices C and D, respectively, for existing and future conditions.

Stable SWMM runs were obtained for all modeling scenarios. Continuity errors ranged from low to very low. URS engineers used PCSWMM to review dynamic hydraulic grade line results, checking the hydraulic routing for potential stability problems or any type of flow anomaly. This QA/QC procedure aids in producing reliable modeling results.

Boundary conditions (water surface elevations) at the downstream outfall were specified by the City of Chesapeake, Department of Public Works, as stated in the *Public Facilities Manual*. In all cases, for all return periods, the hydraulic boundary condition for the Horse Run Watershed outfall was modeled as a constant water surface elevation of 2.3 feet (NAVD88) in the Albemarle and Chesapeake Canal.
The GIS analysis prepared in support of this modeling indicates that the Horse Run Watershed will increase from **32.39** to **34.09** percent imperviousness in the future, as indicated in Figures 3 and 4. The procedures used to determine this increase are explained in the *Master Drainage Plan Methodology* (April 2005) report submitted previously. This increase in impervious cover produces greater volumes of stormwater runoff, which have been incorporated into the future conditions models.

During the process of determining imperviousness, URS engineers, with agreement from City engineers, visually adjusted the percentage of impervious of each subbasin based on aerial imagery. This step is necessary because the City currently does not have imperviousness mapped in its GIS.

Figures 8 and 9 depict street and property flooding volumes for the 10- and 50-year design storm events. The histograms are not drawn to any scale, but they are proportional, and serve to graphically identify where flooding can be expected under each modeling configuration.

The City does not have to ‘fix’ all of the flooding represented by the histograms in the figures. Areas such as woodlands, deep ravines, large open spaces, ball fields and parks, and along railroad rights of way often do not require improvements unless there is a specific reason to construct them. It is also important to bear in mind that a 50-year design storm is an extreme event, and that small neighborhood drainage systems are typically not required to accommodate 50-year storms.

Flooding complaints, particularly those in residential neighborhoods, often result from maintenance problems such as a clogged pipe or debris in a ditch. In considering whether or not drainage improvements might be required to correct an *existing* deficiency, the model results should indicate a flooding problem, and there should be some flooding history to support the need for improvements. If both of these conditions are not met, then the system maintenance should be reviewed or the preliminary computer models should be carefully scrutinized.

It is also important to understand when reviewing these results that there can be low-lying structures in the watershed that have finished floor elevations below the maximum water surface elevations computed in the SWMM models. In order to estimate whether or not a particular structure will be subject to flooding for a given storm condition, maximum hydraulic grade line elevations in the vicinity should be checked against the finished floor elevation.

As with all models of this size and complexity there is a great deal of detailed information required. Because it is not feasible to collect *all* of the required data, in some locations it is necessary to make educated guesses about inverts and pipe and channel dimensions and geometries. Where future designs and studies will be based on these models, engineers are strongly encouraged to field-verify all items that may critically impact their designs.

The maximum computed water surface elevations at each model node are presented in Appendix C for both existing and future condition scenarios. The blue shading in Tables C-1 and C-2 indicates locations where the maximum computed water surface meets or exceeds the ground elevation for that node. Many of these nodal flooding locations are very small quantity or short duration events. In these SWMM 5 models, the volume of water leaving the node during flooding is computed and summarized for continuity purposes (which allows for a reasonable accounting of flood volume at the node) *and the flooded water is re-introduced into the model for subsequent downstream routing*, as explained in the Treatment of Nodal Flooding section above. If flooding occurs at a choke point in the system, downstream (or nearby) nodes may have computed maximum water surface elevations less than what can actually be expected due to the volume of water being 'held' upstream. With the introduction of Nodal Ponding in SWMM 5, this phenomenon is of less concern than it was in older versions of SWMM. Where computed water surface elevations exceed the ground elevation in these models, water surface elevations in the vicinity should be considered 'approximate'. The main purpose of this ponding approach is to account for local flooding volumes and re-introduce stored water back into the drainage system as water surface elevations recede.

The figures that indicate nodal flood volumes in this report have been filtered so that nodal flood volumes less than 10,000 cubic feet are not represented (because less than 10,000 cubic feet of flooding cannot be practically discerned on the ground—it simply appears as heavy runoff or sheet flow in most cases). Tables C-1 and C-2 have not been filtered at all; where nodal flooding is indicated in many cases the duration and quantity of flooding can be very minor.

The PCSWMM modeling platform contains a very helpful dynamic hydraulic grade line tool that allows the user to view animations of the computed water surface elevations. This dynamic hydraulic grade line tool takes input from a digital interface file at *a specified sampling interval*, for example every 3 minutes in these models. The SWMM routing computations are performed at one-second (or so) intervals, and the output file contains summary information based on *every* time step. If the dynamic hydraulic grade line tool is used to view the results the user should bear in mind that it is based on a sample (one out of every 180 seconds), and therefore the 'peak' values listed by the dynamic hydraulic grade line tool are peaks as sampled using a three-minute interval. The SWMM output data on the other hand contains a summary of the *exact* peak values. The SWMM output file summaries were used to prepare Tables C-1, C-2, D-1, and D-2, as well as the flooding figures in this report.

The modeling results presented in this report are based on the assumption that the drainage and stormwater systems will be well maintained. If debris builds up to block drainage structures, or channels are allowed to fill with silt, flooding will likely be more severe than computed and represented in this report. Debris can be a significant problem in natural channel outfall systems, and should be monitored carefully to ensure that these systems function properly. Likewise, heavy buildup of vegetation can significantly worsen local flooding. Channels that are relatively free from vegetation problems in the winter months can have significantly less conveyance capacity in the summer months. Depending on the type of plant growth, the change in conditions can be dramatic.

FEMA flood insurance studies and rate maps are the definitive source of floodplain limits and elevations in all cases. The SWMM models developed for this drainage study are specific design scenarios based on 2-, 5-, 10-, 25-, 50-, and 100-year rainfall events—THEY ARE NOT TO BE CONSTRUED AS INDICATIVE OF EXPECTED WATER SURFACE ELEVATIONS FOR THE PURPOSES OF

FLOODPLAIN MANAGEMENT AND/OR INSURANCE REQUIREMENTS. The SWMM models developed for this study could be adapted for use in the National Flood Insurance Program and submitted to FEMA for approval, but until they are subjected to that process, the published flood insurance studies and rate maps remain fully in effect.

Master Drainage Plan Improvements

The City of Chesapeake utilizes a 320-acre threshold for candidate Master Drainage Facility (MDF) improvements. If a project services less than 320 acres, it will generally not be constructed as part of the City's Master Drainage Plan.

In analyzing the SWMM models, the flooding locations in Horse Run having at least 320 acres of contributing drainage area are along Horse Run Ditch East downstream of Battlefield Blvd. This ditch is has over 1,700 linear feet of concrete-lined, 20+ foot bottom widths, followed by another 2,000 linear feet of 40+ foot bottom widths of earthen ditch before discharging into the Albemarle and Chesapeake Canal. Improvements were made to this channel in the mid-1990's, at which time the design standards were not as stringent as they are today. In July 2010, the City revised their *Public Facilities Manual* (PFM) so as to require protection from a 50-year storm for any locations receiving runoff from more than 300 acres of contributing drainage. Additional information regarding the City's drainage requirements can be found in Chapter 5 of the PFM – July 2010 Revision.

In order to reduce or eliminate the flooding along Horse Run Ditch East downstream of Battlefield Blvd, it would be necessary to either expand the width of the channel for the entire length and/or create retention/detention facilities along the ditch or at locations upstream of Battlefield Blvd. Due to possible land acquisition issues and the extreme expense of such an undertaking these options are not feasible at this time, and thus are not recommended. It is recommended, that in the event of future construction or re-construction within this watershed, that the City should require the developer to supply drainage improvements such as, enlarged drainage channels, detention facilities, etc. Such improvements would help to reduce, if not eliminate, the flooding issues along Horse Run Ditch East so that eventually this ditch can accommodate the 50-year storm.

Master Drainage Plan Caveats

One important caveat to keep in mind is that the system, as modeled for this study, assumes a well-maintained system. Debris, sediment, pipe collapses and other maintenance issues can cause very real flooding that must be addressed. In this respect, this study highlights *capacity* issues rather than *maintenance* issues (which are best resolved from inspection or citizen reports). There is good reason to create the models in this manner. If poor maintenance conditions are modeled, the capacity problems could easily be masked to the extent that public funds could be spent unnecessarily.

These models should also be useful for obtaining starting hydraulic grade line elevations for design purposes on smaller development projects, and for designing stormwater management BMPs on specific sites. URS is providing the models completed for this study to the City in the hope that future engineering efforts will build upon this effort.

Contact Information

Mr. Sam Sawan, PE (757.382.6101) served as the project manager for the City of Chesapeake on this project. Mr. John Paine, PE, PH, CFM was the project manager for URS. The modeling evaluations and report were produced by Stephanie Hood, PE. Quality Assurance and Quality Control (QA/QC) was provided by John Paine, PE, Fred Whitley, PE, and Hai Tran, PE. Additional production assistance was provided by Libby Ludwig (757.873.0559).