Storm Water Management Model

Deep Creek Watershed MDPU

Chesapeake, VA

URS No. 11656365

May 2006

Executive Summary

Engineers from the U.S. Army Corps of Engineers, City of Chesapeake and URS Corporation have completed a drainage study of the Deep Creek Watershed using the Storm Water Management Model (SWMM) computer program. This master drainage plan update (MDPU) began in 2005 and was completed in 2006.

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. Drainage improvement alternatives are carefully evaluated with respect to their potential impact to the entire watershed. The improvement alternatives are then given further consideration based on construction feasibility and financing constraints, with the focus on the entire watershed rather than on a few individual components. The advantage of this approach is that the entire drainage system can be evaluated on a consistent, system-wide basis.

The process of identifying candidate drainage improvement projects is based on trial-and-error modeling techniques. The watershed is analyzed using anticipated future land use and imperviousness, and locations and volumes of computed flooding are identified in the modeling.

After analyzing existing and potential problems in this watershed, URS has identified eight specific projects that can alleviate future flooding in the subject watershed. Four of the eight projects are not considered Master Drainage Facilities (MDF's) due to their contributing area being less than 320 acres. Preliminary cost opinion computations, provided in a separate Cost Appendix, indicate that the four Master Drainage Facilities are financially feasible. These projects can be carried forward as Capital Improvements Projects with some assurance that the impacts on the watershed as a whole have already been adequately considered. Portions of some projects can probably be constructed as part of private development initiatives with little or no cost to the City.

There are many combinations of drainage improvements that can be evaluated in any watershed. While a substantial effort has been applied to develop this study, it is by no means exhaustive. The intent of this undertaking was not only to develop sound alternatives for watershed improvements, but also to leave the

underlying data files and computer models so that they can be used in a straightforward manner in the future.

The peak computed water surface elevations at each modeled node are presented in Appendix C for existing conditions and future conditions.

Portions of this watershed associated with roadway or development projects have been evaluated by the City over the past several years. Some studies have been completed to address specific problems as described elsewhere in this report. The modeling conducted as part of this Master Drainage Plan Update incorporates the previously prescribed improvements where possible, either directly or with modifications. In some cases, previously recommended improvements can be eliminated, as detailed later in this report.

As part of the cost sharing agreement between the City of Chesapeake and the U.S. Army Corps of Engineers, improvements to the Deep Creek watershed must include features that provide valuable habitat restoration or creation opportunities that may also provide ancillary flood damage reduction benefits. This study was authorized by Resolution of the Committee of Transportation and Infrastructure of the U.S. House of Representatives, Docket 2674, Dismal Swamp and Dismal Swamp Canal, Chesapeake, Virginia, adopted 22 May 2002, which states in part "…*to determine whether modifications to the existing project are advisable to address flooding problems, environmental restoration and protection, and related water resources needs in the vicinity of the Dismal Swamp Canal in Chesapeake, Virginia.*"

The City of Chesapeake worked closely with URS to develop restoration and protection concepts that could be applied in this watershed to enhance environmental resources. These conceptual improvements were reviewed with Norfolk District Corps of Engineers staff, who also offered ideas for implementation of a wetland and riparian habitat corridor. After field screening, Corps staff identified one potential environmental protection and restoration project that can be used to meet the requirements of Docket 2674. This project involves constructing a wetland and riparian habitat corridor.

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

URS was directed by the City of Chesapeake and the U.S. Army Corps of Engineers to conduct a watershed study on the area of Deep Creek watershed covering approximately 8,850 acres. Portions of the Dismal Swamp were added to the model to address run-on from heavy storm events, bringing the total modeled watershed area up to 13,095 acres.

The Deep Creek Watershed is bordered on the west and part of the south by the Great Dismal Swamp. Runoff from the watershed discharges into Deep Creek, which runs east to west, and its tributaries. Deep

Creek ultimately drains to the northeast corner of the watershed into the Southern Branch of the Elizabeth River.

The watershed was delineated into approximately 150 subbasins in order to distribute point sources for inflow throughout the entire watershed. The Deep Creek Watershed is made up largely of Low Density Residential, Rural, and Conservation landuses and contains several large, undeveloped tracts of land that are expected to be developed in the future. This study addresses existing drainage and storm water issues, as well as expected future conditions.

Throughout the years several drainage studies have been completed within the Deep Creek watershed. These studies consist of both master drainage studies as well as local neighborhood studies. The following are studies that have been conducted since 1984. A brief outline of each study has been given in order to explain the purpose of that study and its respective improvement recommendations. While some have been implemented, not all of the recommendations have been constructed as of the completion of this Deep Creek MDPU. The original studies should be reviewed to extract specific data and/or to view figures and modeling results.

The Galberry Road Study by Gannett Fleming Corddry & Carpenter was conducted in June of 1984. This study includes 3,648 acres that drain into Deep Creek and its tributaries. Flooding at several locations throughout the system led to the following recommendations based on future landuse conditions:

1. Replace existing pipes under Old Mill Road, along main channel, with triple 4’ x 8’ box culverts.
2. Place additional triple 72-inch pipes under railroad parallel to double 6’ x 6’ box culverts.
3. Replace existing pipe under Bass Lane with double 54-inch pipes.
4. Place additional 24-inch pipe under Galberry Road (north most crossing) parallel to existing pipe.
5. Replace existing pipe under Galberry Road with double 48-inch pipes.
6. Reset invert elevations of existing pipes and place additional 42-inch pipe under the east and west bound lanes of I-64.
7. Replace existing pipe under Galberry Road (just south of railroad) with double 54-inch pipes.
8. Place additional 54-inch pipe under Yadkin Road parallel to existing pipes.

The Deep Creek Study by Gannett Fleming Corddry & Carpenter was conducted in July of 1984. This study includes 1,920 acres that drain into Deep Creek and its tributaries. Several drainage deficiencies were found during this study and the following recommendations were made based on future landuse conditions:

1. Replace the double 60-inch pipes under Old Mill Road at Windermere with double 6’ x 6’ box culverts.
2. Place 1250-lf of additional 54-inch pipe in the area of Strawberry Acres West.
3. Place an additional 42-inch pipe under the east and west bound lanes of I-64 in the area of Strawberry Acres West.
4. Make improvements to various ditch systems throughout the watershed.

The Deep Creek Locks Area Study by Gannett Fleming Corddry & Carpenter was conducted in June of 1985. This study includes 480 acres that drain into Deep Creek just north of the Dismal Swamp Canal locks. Several drainage deficiencies were found during this study and the following recommendations were made based on future landuse conditions:

1. Replace the 4.9’ x 3.2’ box culvert under Cedar Road with double 5’ x 4’ box culverts.
2. Construct a new 11.3 acre detention pond with outfall ditch South of Cedar Road.

The Gilmerton Canal, Oak Manor Area Study by Gannett Fleming Corddry & Carpenter, was conducted in May of 1985 and later revised in June of 1987. Upon the completion of this study, it was determined that deficiencies existed within the watershed centered around the single 6’ x 6’ box culvert under I-64 and Firman Avenue along the Gilmerton Canal. While this structure is adequate for passing a 25-year storm event without overtopping the roadways, the pinching at this location cause significant upstream flooding. As a result of these findings, it was recommended that a second 6’ x 6’ box culvert be placed parallel to the existing one.

The Shell Road Study by Gannett Fleming Corddry & Carpenter, July 1987, is an earlier version of the Flagg Road Study conducted in May 2000 by the City of Chesapeake. The 2000 study reported flooding in this area due to: inadequate downstream ditches/pipes, increased development, and poor maintenance of the drainage facility. Several suggestions were made to improve the drainage outfall system to accommodate future landuse conditions and included to following:

1. Increasing pipe sizes through Plummer Plantation, Woodlake Forest and Industco Corp.
2. Add an additional 60-inch RCP under Shell Road.
3. Widen ditches in the areas of Industco Corp and downstream of Hoyt Drive.

As an alternative to drainage outfall improvements, a 7.0-acre basin was recommended. It was also recommended that an interim solution be devised to clean the drainage outfall.

The Elmwood Landing Study which included 127 homes experience flooding on average of once a year. The flooding was primarily caused by excess runoff from adjacent cultivated fields and wooded areas. More extensive flooding occurred during the hurricane Dennis, Floyd and Irene storm events. Short- and long-term recommendations were made in light of this study, as described below.

<u>Short Term:</u>

1. Provide a 6,000-lf berm/ditch system along the southeastern and western boundaries to prevent the adjacent excess runoff from entering Elmwood.
2. Clear and grub the Elmwood Landing channel.
3. Establish a second outlet from the lake in Elmwood Landing.

<u>Long Term:</u>

4. Constructing a 5,000-lf, 20-ft bottom width channel to route 918 acres away from the Windermere Tributary.
5. Install three additional 60-inch RCPs at the Windermere Tributary/Old Mill Road crossing.
6. Clear and grub the Weiss Lane channel of Windermere Tributary.

The Yadkin Road Drainage Study by Robert P. Morrisette, Jr., P.E. was completed in January of 2000. This study started along Yadkin Road, north of Norfolk & Southern Railroad, west of George Washington Hwy. and continues south of the railroad, under Galberry road and discharges to a major outfall under Old Mill Road. Several channel and structure deficiencies were found along this route which prompted the following proposed improvements:

1. Along Yadkin Road, north of the railroad, widen the channels to 7’ upstream and 10’ downstream. Replace the existing driveway culverts with double 43” x 68” pipes upstream and 53” x 83” pipes downstream.
2. In addition to the existing pipes place double 54” concrete pipes under Yadkin Road and Railroad.

3. Widen ditch from railroad to Galberry Road to a 15-ft bottom width.
4. In addition to the existing pipes place double 48” x 76” concrete pipes under Galberry Road.
5. Widen the channel downstream of Galberry Road to a 25-ft bottom width until reaching junction of the major outfall (approx 1250 lf). At this point widen the channel to a 50-ft bottom width to Old Mill Road.
6. Remove the temporary bridge for the borrow pit access road.
7. Replace the existing pipes under Old Mill Road with triple 8’ x 4’ box culverts.

Several of the recommendations from the previous studies have been completed prior to the commencement of URS’ 2006 Deep Creek MDPU. The following improvements reflect the previous recommendation or a modified version of the previous recommendation:

1. Under Old Mill Road at Windermere, the double 60” pipes were replaced with a new 23-ft wide by 6-ft deep arch structure.
2. Under Cedar Road, east of the locks, the 4.9’ x 3.2’ box culverts were replaced with triple 48” pipes.
3. A 1.8 acres detention pond was constructed south of Cedar Road, east of the locks, and outfalls just upstream of the new triple 48” pipe (Cedar Road) crossing.
4. Two lakes were constructed in the northern portion of the Shell Road Study area to help alleviate flooding throughout that system.
5. The Weiss Lane channel of Windermere Tributary was cleaned and widened to a 10-ft bottom width.

The City of Chesapeake provided URS with several plan sets for projects within the subject watershed, some of which have been approved for construction but have not yet been completed. As directed by the City, URS modeled these as existing conditions. While some of these developments were not expected to be complete by the end of this study, they were considered “Existing Conditions” because the approval of the project assures its near-future development. 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 three main sources—plan sets, survey data, GIS data as well as the previously discussed drainage studies to extract channel and infrastructure information, such as inverts, pipe type and size(s), and channel characteristics, throughout the subject watershed.

Furthermore, the City provided to URS several plan sets to be considered in the future conditions. These plans are still in the design phase and have not received an approval prior to the commencement of this study. Therefore the future conditions models consist of the future hydrology (reflecting the City’s 2005 Adopted Land Use and Transportation Plans as applied to the Deep Creek Watershed), the projected future development (as outlined by the future plan sets), and the recommended improvements identified by URS, described elsewhere in this report.

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 Update Report presents the findings of the application of this methodology to the subject watershed.

Modeling Configurations

Three modeling configurations—Existing Hydraulics with Existing Hydrology, Existing Hydraulics with Future Hydrology, and Future Hydraulics with Future Hydrology—were developed for this study as described below.

Scenario 1 Existing watershed hydrology with the drainage system configured as it existed in 2006. Channels are modeled using their existing (2006) 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 is a list of plan sets and studies, provided by the City, that were used in the existing conditions model (the list includes completed past studies, projects that have been constructed as well as approved projects not yet constructed):

1. Arland Community
2. Buchanan Property
3. Cedar Rd.
4. Chesapeake Middle Schools - Cedar Road Site
5. Colony Manor Drainage Improvements
6. Deep Creek Elementary School Additions & Alterations
7. Deep Creek Lock Study
8. Deep Creek Meadows Master Drainage Map
9. Deep Creek Meadows - Phase One
10. Deep Creek Meadows - Phase Two
11. Deep Creek Middle School
12. Deep Creek Middle School Additions & Alterations
13. Deep Creek Study
14. Elmwood Landing Drainage Improvements (Bertram St. Culvert)
15. Elmwood Landing Drainage Improvements (Old Mill Rd. Crossing)
16. Elmwood Landing Study
17. Faith Alive Church of God
18. Flagg Road Drainage
19. Flagg Road Drainage Study
20. Galberry Road Borrow Pit
21. Galberry Road Study
22. George Washington Hwy Culvert Crossing/Lambert Trail Culvert Crossing
23. Glen Eagle
24. Great Dismal Swamp Restoration Bank
25. In-Town Lakes Facilities
26. King's Gate
27. Martin Johnson Rd. Drainage Improvement
28. Mayberry Meadows
29. Mill Creek
30. Mill Creek Harbor
31. Miller's Run

32. Miller's Run Sections 3 & 4
33. Oak Manor Area Study
34. Old Mill Road Drainage Improvements
35. Olde Mill Run
36. Olde Mill Run - Phase Two
37. Rivers Edge
38. Route 17, GWH – Deep Creek
39. Seventeen North
40. Shell Road Study
41. Ship's Crossing
42. Ships Landing
43. Ships Point
44. Southern Pines Borrow Pit - Phase One
45. Sunray Area Drainage Improvement
46. Sunray Area Drainage Improvements - Phase One
47. Washington Manor/Yakin Rd. Drainage Study
48. Windrose Farms
49. Woods of Deep Creek

Scenario 2 Future watershed hydrology with the drainage system configured as it existed in 2006. Channels are modeled using their existing (2006) conditions as well. This is the "Scenario 2" model. This scenario will show the flooding effects of the existing drainage system due to future landuse expansion. In other words, if no improvements are made to the current drainage system and the remainder of the watershed is constructed as described by the City's 2005 Adopted Land Use Plan, these are the locations and volumes of flooding that can be expected.

Scenario 3 Future watershed hydrology with the future drainage system configuration as envisioned by the City of Chesapeake and URS. This is the "Scenario 3" model. This scenario incorporates the drainage from scenarios 1 and 2 along with any future plans previously identified by the City. In addition, this scenario includes recommendations from URS to help eliminate flooding on a master drainage facility level (i.e. areas of flooding serviced by 320 acres or greater). The following is a list of plan sets, provided by the City, that were added to the future conditions model:

1. Cavalier Park Fleet Fueling Facility
2. Billie R. Todd Property
3. Galberry Road Culvert Improvements
4. Eady's Landing
5. Seventeen East
6. Southern Pines
7. Southern Pines Borrow Pit - Future

The recommended improvements should largely eliminate flooding at key locations, where feasible, in the future conditions. These improvements were developed during this study, are highlighted in Figure 10, and specifically include the following projects:

1. Sunray Area Drainage Improvements
2. Upper Deep Creek Channel Improvements

3. Borrow Pit Storm Water Improvements
4. Colony Manor Drainage Improvements
5. Galberry Road Area Drainage Improvements
6. Yadkin Road Drainage Improvements
7. Weiss Lane Channel Improvements
8. Oak Manor Area Channel Improvements

This configuration depicts future conditions with strategic drainage and storm water improvements in place. Additional details and descriptions regarding the improvements are presented elsewhere in this report. Cost opinions are presented in a separate Cost Appendix.

Modeling Results

Stable RUNOFF and EXTRAN runs were obtained for all modeling scenarios. EXTRAN continuity errors ranged from low to very low.

Boundary conditions (water surface elevations) at the downstream outfall were set in accordance with Chapter 5, Section Q of the City of Chesapeake Public Facilities Manual (July 2001 Edition). In all cases, for all return periods, the hydraulic boundary condition was modeled as a constant water surface elevation of 3.55 feet (NAVD88).

The GIS analysis prepared in support of this modeling indicates that the Deep Creek watershed will increase from **17.85** to **23.80** 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 storm water runoff, which have been incorporated into the future conditions models.

Figures 8, 9, and 11 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 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 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 computer models should be carefully checked.

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. For example the maximum computed water surface elevation (CWSE) at Node 158 appears to be higher than the ground surrounding the house to the northwest. As a result of further survey or field inspection it may be determined that there is no direct access for the flooding waters at Node 158 to reach this property. Areas such as this may require additional field verification to evaluate the impacts of flooding nodes on adjacent properties.

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 peak 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 through C-3 indicates locations where the maximum computed water surface meets or exceeds the ground elevation for the node. Many of these nodal flooding locations are very small quantity or short duration events. In the SWMM EXTRAN 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) *but the flooded water is not re-introduced into the model for subsequent routing*. If flooding occurs at a choke point in the system, downstream nodes may have computed maximum water surface elevations less than what can actually be expected due to the volume of water being 'held' upstream. At nodes in Tables C-1 and C-2 where this phenomenon is probably occurring the maximum computed water surface is indicated in ***bold, red, italic*** type. The patterns of flooding can appear to be somewhat counter-intuitive due to the complexity of hydraulic routing. For example, a given node can flood for the 10-year event, but not for the 25-year event. This could be due to computed upstream flooding, or it could be due to the timing of flooding along other hydraulic pathways.

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 EXTRAN routing computations are performed at one-second intervals, and the EXTRAN output (*.out) 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 EXTRAN output data on the other hand contains a summary of the *exact* peak values. The EXTRAN output file summaries are used to prepare Tables C-1 and C-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 storm water 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.

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.

Back-to-Back Storms Analysis

The City of Chesapeake has flood storage requirements regarding back-to-back storms. Simply stated, detention and retention facilities must recover a substantial portion of the available flood storage 48 hours after a 10-Year Type II design storm event begins. A special SWMM analysis was constructed and run to produce the results indicated in Table D-1. As shown in the table, all of the storm water basins in the watershed should recover flood storage capacity adequately within 48 hours after the onset of a 10-year Type II storm, and all of them have excess storage capacity above the peak 10-year water surface elevation.

The City's back-to-back storm analysis requirements are not well understood in the consulting community, and have not been consistently applied from project to project. The ultimate intent is to produce good detention and retention facility designs that can recover a reasonable amount of flood storage capacity so that flood damage can be avoided if one severe storm is followed shortly by another.

The development of specific back-to-back storm evaluation criteria is problematic for several reasons. First, back-to-back 10-year (for example) storms comprise a hydrologic design event that has a return period well beyond 10-years, and designs to accommodate such an event can be very expensive to construct, or to retrofit. Secondly, the City's current criteria—to recover 90-percent of the peak storage capacity used 24 hours after the cessation of a 10-year design rainfall—does not address how much of the total storage capacity is being used, or how much total capacity is available at the beginning of the second storm.

For example, a large lake could have a relatively small outlet, designed to slowly release runoff (to avoid downstream flooding while reducing the need for significant downstream channel and culvert improvements). Such a design would recover the peak storage volume being used relatively slowly, and might not strictly meet the 90-percent-recovery criterion. Yet if the computed rise in the lake is relatively small, then only a small portion of the lake's total storage capacity is being used. For example the lake at Node 186 has a 57-acre surface at its proposed normal pool elevation, which provides a very large storage potential. The lake discharges through a small outlet which does not allow the lake to recover much of its peak 10-year flood storage volume 48 hours after the 10-year design storm begins, however at the peak 10-year water surface elevation, only 17 percent of this lake's total storage capacity is being used.

For the design of stormwater basins that serve small parcels or land areas, the computation and analysis of back-to-back design storms can be an expensive and complicated process. However in the context of a Master Drainage Plan analysis, once a SWMM model has been constructed, it is a relatively straightforward matter to directly analyze back-to-back design storms. Master Drainage Plan updates completed recently for the City include 2-, 5-, 10- 25-, 50-, and 100-year 24-hour design storm analyses. A 72-hour design hyetograph, consisting of two 24-hour design storms separated by a 24-hour period of no rainfall, could be incorporated into the engineering design requirements for large developments, and into the Master Drainage Plan analyses themselves. The effects of flooding from back-to-back storms could be analyzed directly in these contexts.

Based on our analyses of many ponds and lakes in several large watershed studies in Chesapeake, URS recommends that the City reevaluate its back-to-back storm criteria. The City could simplify the criteria while accomplishing the goal of better flood protection by requiring that:

1. All storm water detention and retention basins serving more than 320 acres must be analyzed using the City's 72-hour design hyetograph, which is two back-to-back 10-year NRCS Type II 24-Hour hyetographs separated by 24 hours of no rainfall.
2. The maximum computed water surface in the detention or retention basin must not exceed the lowest ground elevation adjacent to the basin when using this design storm.

These two requirements would be in addition to the City's other applicable criteria, including requirements for 50-year and 100-year design analyses. Much debate could occur over using back-to-back *10-year* storms, however the City could adopt this criterion and see how it impacts proposed basins.

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. Such is the case at Node 160. Although there is excessive future flooding at this node, the contributing land area is not greater than 320 acres. In addition, this area is subject to future development in which the developers are responsible for handling post-development runoff.

Eight specific projects were conceived and incorporated into the modeling during the course of this study, four of which are not considered MDF improvements due to their contributing areas being less than 320 acres. These projects are by no means exhaustive, but they seem to provide a reasonable amount of flooding relief at reasonable costs. All of the projects appear to be feasible from a preliminary planning standpoint, but issues such as future wetlands delineations and the ability to successfully acquire rights-of-way or parcels of land may necessitate some modifications as these projects move forward. The eight projects are shown in Figure 10 and are included in the future modeling scenario. Refer to Figures 6, 7, and 10 of this report to find node and link numbers and to view the locations of improvements that are referenced in the following project summaries.

1. Sunray Area Drainage Improvements

This project is estimated to cost approximately **$2,135,640 million** in 2006 dollars, if constructed after surrounding land improvements are in place. If constructed as part of adjacent development projects, the cost to the City could be reduced significantly.

Improvements within the Sunray Area will increase the conveyance of storm water as well as provide extra storage to alleviate flooding as seen at Nodes 158 and 174 (Figures 8 and 9) due to excessive runoff. Recommended improvements to this area include:

1. From Nodes 164 to 172: Widen the channel bottom to 20-ft with side slopes equal to 2H:1V.
2. From Nodes 174 to 172: Place a new 48-in RCP (with a 1-ft vertical offset from the ditch invert at both ends) parallel to the existing 60-in CMP.
3. From Nodes 172 to 200: Widen the channel bottom to 20-ft with side slopes equal to 2H:1V.
4. From Nodes 196 to 774: Widen the channel bottom to 19-ft.
5. From Nodes 774 to 228: Widen the channel bottom to 20-ft.
6. From Nodes 228 to 229: Clean a grub channel bottom.

7. From Nodes 229 to 238: Place 40-lf of new 48-in RCP. Invert in at 2.9 (NAVD88) and invert out at 2.7 (NAVD88).

2. Upper Deep Creek Channel Improvements

This project is estimated to cost approximately **$2,684,603 million** in 2006 dollars, if constructed after surrounding land improvements are in place. If constructed as part of adjacent development projects, the cost to the City could be reduced.

While improvements to the upper portion of the Deep Creek channel will help to better convey storm water as well as provide extra storage to alleviate flooding, the total elimination of flooding is not feasible due to low contours in the area of Node 288. Recommended improvements to this area include:

1. Node 238: Lower ditch invert to 2.7 (NAVD88).
2. Node 248: Lower ditch invert to 2.6 (NAVD88).
3. From Nodes 238 to 248: Place a new 48-in steel pipe (at new ditch inverts) parallel to the existing double 5-ft x 6-ft box culverts under the Norfolk Southern Railroad.
4. Node 280: Lower ditch invert to 1.6 (NAVD88).
5. From Nodes 248 to 280: Widen the channel bottom to 30-ft with side slopes equal to 2H:1V. Re-grade channel bottom to new channel inverts.
6. Node 284: Lower ditch invert to 0.8 (NAVD88).
7. From Nodes 280 to 284: Widen the channel bottom to 40-ft with side slopes equal to 2H:1V. Re-grade channel bottom to new channel inverts.
8. Node 286: Lower ditch invert to 0.7 (NAVD88).
9. From Nodes 284 to 286: Regrade under bridge opening to new channel inverts.
10. From Nodes 286 to 288: Widen the channel bottom to 30-ft with side slopes equal to 2H:1V. Re-grade channel bottom to new channel inverts.
11. From Nodes 288 to 314: The existing channel is to be left un-touched below the 1.7 (NAVD 88) elevation. Both the east and west banks receive a 25-ft bench at the 1.7 elevation. At the end of each bench create a side slope of 2H:1V to tie into existing grade. The top width of this improved channel increases from 50 feet to 100 feet.
12. From Nodes 314 to 316: Replace all existing pipes with double 6-ft x 10-ft box culverts.

3. Borrow Pit Storm Water Improvements

This project is estimated to cost approximately **$845,026** in 2006 dollars, if constructed after surrounding land improvements are in place. If constructed as part of adjacent development projects, the cost to the City could be reduced.

The borrow pit lake is located to the south of Norfolk Southern Railroad and to the west of the upper portion of the main Deep Creek channel and is represented by Node 290. Currently this lake is a retention basin that mostly services undeveloped surrounding areas. The use of this lake to help retain future storm water runoff from developed parcels upstream is a wise use of existing floodplain storage. In addition, the Norfolk District Corps of Engineers has labeled this site, along with its outfall, as a potential wetland and riparian habitat corridor as described elsewhere in this report. Recommended improvements to this area include:

1. Node 776: Lower ditch invert to 4.3 (NAVD88).
2. From Nodes 774 to 776: Place new double 60-in steel pipes under theNorfolk Southern Railroad. Invert in at 4.4 (NAVD88) and invert out at 4.3 (NAVD88).

3. From Nodes 776 to 290: Construct a new 550-lf, 6-ft deep channel with a bottom width of 25 feet and side slopes of 2H:1V to discharge into the existing borrow pit lake. Starting ditch invert at 4.3 (NAVD88) to 4.0 (NAVD88).
4. From Nodes 290 to 292 (borrow pit lake outfall): Widen the channel bottom to 15-ft.

4. Colony Manor Drainage Improvements

The contributing upstream area for this project does not equal or exceed 320 acres and therefore is not considered a master drainage improvement. For this reason, this project does not contain a cost opinion; however, the City has requested that URS provide a recommendation for improvements to this area due to a continuing effort to relieve excessive flooding. The existing outfall for Colony Manor, illustrated in Figure 6, provides a connection from Nodes 198 to 228. The runoff generated from this area is currently carried under the Norfolk Southern Railroad at Node 238. Due to heavy flows from newly developed properties upstream, it is recommended that the connection linking Colony Manor to Node 238 be broken. A new outfall for Colony Manor has been devised to adequately convey future runoff. As seen in Figure 7, the new outfall breaks away from its original path just downstream of Node 220. Traveling south, the outfall intersects the Sunray Area main ditch before crossing under the Norfolk Southern Railroad at a new crossing 3,800 feet west of the existing railroad crossing. Changes in the model were made to the upper portion of this area that include opening all the ditches and pipe structures to equal that of a channel with a bottom width ranging from 25 feet to 55 feet. This was done to ensure the release of blocked runoff so that the downstream improvements could be made with the consideration of “all” future upstream runoff. The City is aware that the upper portion of this system is not adequate to handle the future runoff and will require future developments to make improvements that will properly convey future storm water runoff. Recommended improvements to this area include:

1. From Nodes 770 to 772: Construct a 1,200-lf, 4.5-ft deep channel with a bottom width of 50 feet and side slopes of 2H:1V to discharge into the future lake. Starting ditch invert at 7.4 (NAVD88) to 7.0 (NAVD88).
2. From Nodes 772 to 774 (future lake outfall): Construct a 5-ft deep channel with a bottom width of 50 feet and side slopes of 2H:1V. Starting ditch invert at 7.0 (NAVD88) to 6.0 (NAVD88).

5. Galberry Road Area Drainage Improvements

The contributing upstream area for this project does not equal or exceed 320 acres and therefore is not considered a master drainage improvement. For this reason, this project does not contain a cost opinion; however, the City has requested that URS provide a recommendation for improvements to this area due to a continuing effort to relieve excessive flooding. Recommended improvements to this area include:

1. From Nodes 240 to 242: Place an additional 42-in RCP parallel to the existing 42-in RCP.
2. From Nodes 244 to 246: Replace existing 24-in RCP with double 48-in RCPs.
3. Node 236: Lower ditch invert to 3.7 (NAVD88).
4. From Nodes 232 to 236: Widen the ditch bottom to 6-ft. Re-grade channel bottom to new channel inverts.
5. From Nodes 236 to 254: Place new double 48-in RCPs (at new ditch inverts) parallel to the existing 36-in RCP.
6. From Nodes 254 to 238: Widen the ditch bottom to 10-ft with side slopes equal to 2H:1V. Re-grade ditch bottom to new channel inverts.

6. Yadkin Road Drainage Improvements

The contributing upstream area for this project does not equal or exceed 320 acres and therefore is not considered a master drainage improvement. For this reason, this project does not contain a cost opinion; however, the City has requested that URS provide a recommendation for improvements to this area due to a continuing effort to relieve excessive flooding. Along Yadkin Road between Nodes 260 and 262, the existing condition is a series of 36-in culverts under industrial business entrances connected by open ditches. In the future conditions model this section was modified to reflect a continuous open channel with a bottom width of 15 feet. This was done to ensure the passage of “all” future storm water runoff so that it can be considered when making recommendations to downstream channels and crossings. Future driveway culverts along this section will need to be sized to accommodate this design. Recommended improvements to this area include:

1. Node 260: Lower ditch invert to 8 (NAVD88).
2. From Nodes 260 to 262: Widen the ditch bottom to 15-ft with side slopes equal to 2H:1V. Re-grade channel bottom to new channel inverts.
3. Node 262: Lower ditch invert to 7.5 (NAVD88).
4. From Nodes 262 to 266: Widen the channel bottom to 30-ft. Re-grade channel bottom to new channel inverts.
5. Node 268: Lower channel invert to 6.7 (NAVD88).
6. From Nodes 266 to 268: Place new double 60-in RCPs (at new ditch inverts) parallel to existing double 36-in RCPs.
7. From Nodes 268 to 270: Widen the channel bottom to 25-ft. Re-grade channel bottom to new channel inverts.
8. From Nodes 270 to 272: Replace existing double 24-in RCPs with triple 4-ft x 8-ft box culverts.
9. From Nodes 272 to 280: Widen the channel bottom to 20-ft. Re-grade channel bottom to new channel inverts.

7. Weiss Lane Channel Improvements

This project is estimated to cost approximately **$563,315** in 2006 dollars, if constructed after surrounding land improvements are in place. If constructed as part of adjacent development projects, the cost to the City could be minimal or insignificant.

Improvements to the channel adjacent to Weiss Lane will better help the conveyance of storm water as well as providing extra storage to alleviate flooding as seen at Node 438 (Figures 8 and 9) due to excessive runoff. Recommended improvements to this area include:

1. From Nodes 438 to 440: Widen the channel bottom to 14-ft with side slopes equal to 1.8H:1V. Re-grade channel bottom to maintain a continuous slope and positive drainage in the downstream direction.
2. From Nodes 440 to 442: Lower the upstream and downstream flow line inverts by clearing soil material from the bottom of both 4-ft x 8-ft box culverts.
3. From Nodes 442 to 456: Widen the channel bottom to 14-ft with side slopes equal to 1.8H:1V. Re-grade channel bottom to maintain a continuous slope and positive drainage in the downstream direction.
4. From Nodes 444 to 448: Place an additional 48-in RCP parallel to the existing 48-in RCP.
5. From Nodes 448 to 450: Widen the channel bottom to 10-ft.

6. From Nodes 450 to 452: Place an additional 48-in RCP parallel to the existing 48-in RCP.

8. Oak Manor Area Channel Improvements

The contributing upstream area for this project does not equal or exceed 320 acres and therefore is not considered a master drainage improvement. For this reason, this project does not contain a cost opinion; however, the City has requested that URS provide a recommendation for improvements to this area due to excessive flooding onto a single resident's property. This flooding is represented at Node 646 (Figures 8, 9, and 11). While improvements to the outfall at this location have helped to reduce the flooding, the low bank on the west side does not allow for total flooding reduction. Recommended improvements to this area include:

1. From Nodes 650 to 658: The existing ditch is to be left un-touched below the 1.7 (NAVD 88) elevation. Both the east and west banks receive an 8.5-ft bench at the 1.7 elevation. At the end of each bench create a side slope of 2H:1V to tie into existing grade. The top width of this improved channel increases from 32.5 feet to 49.5 feet.
2. From Nodes 658 to 730: The existing ditch is to be left un-touched below the 1.7 (NAVD 88) elevation. The north bank receives a 17-ft bench at the 1.7 elevation. At the end of the bench create a side slope of 2H:1V to tie into existing grade. Due to close, adjacent proximity to I-64, the south bank needs to receive a vertical retaining wall to contain this 8.5-ft deep channel. The top width of this improved channel increases from 41.0 feet to 45.5 feet.

During a previous Gilmerton Canal Subbasin / Oak Manor Area Study, it was recommended that additional 6-ft x 6-ft box culverts be placed parallel to the existing 6-ft x 6-ft box culverts along the Gilmerton Canal under I-64 and Firman Avenue. During the URS 2006 Deep Creek Study, it was determined that the placement of these additional 6-ft x 6-ft box culverts yields no benefits and relieved no excess flooding. In addition, the canal upstream of the I-64 crossing has sufficient storage available in which to handle excess runoff from high volume flows without adversely impacting adjacent properties or overtopping I-64.

The goal of this type of study is not to relive *all* flooding, but rather to identify Master Drainage Facility improvements that can be feasibly constructed. It is also important to consider that neighborhood and commercial parcel drainage and storm water systems are neither required nor designed to accommodate flooding from extreme events such as the 50-year storm.

Environmental Restoration and Protection Opportunities

As part of the cost sharing agreement between the City of Chesapeake and the U.S. Army Corps of Engineers, improvements to the Deep Creek watershed must include features that provide valuable habitat restoration or creation opportunities that may also provide ancillary flood damage reduction benefits. This study was authorized by Resolution of the Committee of Transportation and Infrastructure of the U.S. House of Representatives, Docket 2674, Dismal Swamp and Dismal Swamp Canal, Chesapeake, Virginia, adopted 22 May 2002, which states in part "…*to determine whether modifications to the existing project are advisable to address flooding problems, environmental restoration and protection, and related water resources needs in the vicinity of the Dismal Swamp Canal in Chesapeake, Virginia.*"

There are five categories under which potential restoration opportunities are evaluated: scarcity, connectivity, special species status, plan recognition, and self-sustainability.

The City of Chesapeake worked closely with URS to develop restoration and protection concepts that could be applied in this watershed to enhance environmental resources. The most practical opportunities involve benching of drainage outfall ditches and channels, using the typical channel sections presented in Figure 12. These conceptual improvements were reviewed with Norfolk District Corps of Engineers staff, who also offered ideas for implementation of wetland and riparian habitat corridors. After discussing these ideas at several meetings between the City of Chesapeake, the Norfolk District and URS, technical staff from the District visited the candidate sites, and further pared the list of potential improvement projects based on the five requirements noted above. After field screening, Corps staff identified one potential environmental protection and restoration project, as shown in Figure 13.

The project that holds potential for further study is a passageway for threatened and endangered (T&E) species to travel from the Great Dismal Swamp and into the subject watershed through a wetland and riparian habitat corridor. This corridor facilitates access because it is sufficiently wide to encourage animals to travel through it from the 60-acre borrow pit lake (Node 290) to intersect at an upper portion of the Southern Branch of the Elizabeth River (Node 288). Studies have shown that the corridor must be wide enough that animals will not see predators or they won't use it. This corridor could be graded and planted with wetlands vegetation while providing positive drainage towards the ultimate outfall. In addition, it would be most feasible to construct this wetlands area utilizing the least number of land parcels. The re-creation of wetlands will restore this corridor area to be more like the original land cover (Dismal Swamp) conditions that existed before development activities began.

Several other potential benching projects were considered, but when field examined by the Corps these candidate sites were found to be in relatively good shape and did not meet the five requirements for one or more reasons. For example, benching a farmer's ditch does not provide connectivity for T&E species if there is no potential habitat at the upstream end of the ditch. The selected project should meet all of the five requirements used in the Corps evaluation process.

Contact Information

Mr. Sam Sawan, PE (757.382.6101) served as the project manager for the City of Chesapeake on this project. Mr. Mark Mansfield, Chief Planning and Policy Branch; Mr. Bryant Wilkins, Project Manager; Mr. Tom Yancey, Senior Technical Reviewer; Mr. Walter Trinkala, Engineering Technical Specialist; Mr. Greg Steele, Planning Technical Team Leader; and Ms. Deborah Painter, Environmental Technical Specialist represented the Corps of Engineers, Norfolk District. Mr. Michael Barbachem, PE, DEE, CFM (757.499.4224) was the project manager for URS. The modeling evaluations and report were produced by Hai Tran, EIT, Stephanie Hood, EIT, William K. Walker, PE, CFM, and John Paine, PE, PH, CFM (757.873.0559).