VOLUME II

ELLERBE CREEK
WATERSHED MANAGEMENT
IMPROVEMENT PLAN

Prepared for

City of Durham

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Prepared for

City of Durham

May 2010

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1. INTRODUCTION

Clean water is important to all of us. The City of Durham (City) wants to keep our creeks, rivers, and lakes safe for recreational activities, aquatic species, and ultimately, drinking water. As a result of decades of growth and development, these bodies of water have been affected by flooding, erosion, land development and road construction, littering, landscaping and lawn care, and other activities. To protect our creeks, rivers, and lakes, we must protect and maintain the health of our watersheds - those land areas and their network of creeks that convey stormwater runoff to a common body of water.

The City realizes the importance of protecting our natural resources, which includes the ways in which we protect and enhance our creeks, rivers and lakes. The City launched the Ellerbe Creek Watershed Management Improvement Plan (WMIP) at the end of 2007 as a way to proactively address changes the City is making to comply with water quality regulations, to improve the health of the Ellerbe Creek, and create value for neighborhoods in the watershed.

The Ellerbe Creek Watershed, as shown on Figure 1-1, covers 37-square miles with approximately half of the watershed inside the Durham city limits. Ellerbe Creek has two main tributaries, South Ellerbe Creek and Goose Creek, and drains into Falls Lake and the Neuse River, both of which have been identified as nutrient sensitive waters. Nitrogen, phosphorus, and bacteria and excess sediment in the watershed are of particular concern. Since 1998, Ellerbe Creek from its headwaters to Falls Lake has been on the North Carolina Department of Environment and Natural Resources (NC DENR) 303(d) list as impaired for ecological/biological integrity. This indicates that the aquatic habitat and water quality conditions cannot support a healthy population of native aquatic species. Ellerbe Creek is also expected to be added to the 303(d) list as impaired for water contact recreation due to violations of the water quality standard for fecal coliform bacteria.

Protecting and improving the water quality and aquatic health of Ellerbe Creek is a primary goal of the City. The purpose of the Watershed Management Improvement Plan (WMIP) is to provide the City with the necessary information and tools to accomplish this goal by:

- Assessing current stream and watershed conditions;
- Identifying existing water quality problems;
- Engaging the stakeholders through a public involvement program;
- Identifying high-value stream and riparian areas where protection and preservation is critical;
- Developing a Riparian Area Management Plan for publicly-maintained riparian areas;
- Evaluating the feasibility and benefits of better site design techniques and low impact development (LID) practices;
- Evaluating the existing and projected future water quality conditions in the watershed;
- Identifying effective pollution control measures to minimize the water quality impacts from point source and non-point source control measures; and
- Developing the recommended water quality improvement plan for the Ellerbe Creek Watershed to enable the City to meet its goals for water quality and watershed health.

1.1 Organization of the WMIP

The Watershed Management Improvement Plan (WMIP) is organized into three volumes:

1. **Volume I – Executive Summary**. A brief document that describes the project goals, the watershed evaluation methods, the water quality improvement measures that were evaluated, the results for each watershed improvement scenario, the recommendations, and next steps for implementing the WMIP. This is the only volume that contains the specific high-priority stormwater BMP retrofits, new stormwater BMPs, and stream restoration and stabilization projects recommended in the WMIP for the Ellerbe Creek Watershed.
2. **Volume II – Watershed Management Improvement Plan**. The main report that summarizes the overall approach used to evaluate the Ellerbe Creek Watershed, the data used to complete the watershed characterization, the development and application of the watershed modeling tools, the water quality improvement measures that were evaluated, the results for each watershed improvement scenario, and the recommendations for the WMIP.
3. **Volume III – Technical Appendices**. Series of memoranda prepared throughout the project that describe in more detail the technical approach used to complete the watershed characterization, develop the watershed modeling tools, and evaluate each watershed improvement scenario.

2. WATERSHED IMPROVEMENT PROGRAM

2.1 Recommended Watershed Improvement Program

In order to improve water quality and watershed function within the Ellerbe Creek Watershed, the WMIP recommends watershed management strategies to minimize the water quality impacts from point sources and non-point sources of pollution. The priority for implementing the strategies is listed below followed by a brief overview of each watershed management strategy:

1. **Coordinate with the City's Department of Water Management to implement point source controls.** Prioritize the on-going sanitary sewer rehabilitation and replacement program within the Ellerbe Creek Watershed and upgrade the nutrient control technology at the North Durham WRF. Both of these improvements represent the most cost-effective methods to significantly reduce the impacts from point sources in the Ellerbe Creek Watershed.
2. **Improve Stormwater Quality.** Implement high-priority stormwater quality projects consisting of retrofits to existing stormwater BMPs and construction of new stormwater quality BMPs.
3. **Improve Stream Health.** Implement high-priority stream restoration and stabilization projects to reduce erosion and excessive sedimentation and improve the aquatic health of Ellerbe Creek and its tributaries, with an initial focus on South Ellerbe Creek and Goose Creek.
4. **Implement the Riparian Area Management Plan.** Excessive stream bank erosion; trash and other debris getting into streams and riparian buffers; and encroachment and clearing of riparian buffers are common and visible problems along many Durham streams. The Riparian Area Management Plan (RAMP) has been prepared to address the current maintenance practices within riparian buffers on publicly-owned property, utility easements, and greenway corridors along Ellerbe Creek and its tributaries. Re-establishing the riparian buffers on publicly-owned property is important for protecting stream stability, water quality and ecological functions.
5. **Acquire or preserve the high-priority riparian buffers and new BMP sites identified in the Critical Area Protection Plan.** The Critical Area Protection Plan (CAPP) plan focuses on acquiring sites that are the most ecologically intact and those that have important features and functions, such as preserving high-quality aquatic and terrestrial habitats, floodwater storage, and creating recreational and educational opportunities for local residents.

A more detailed description of the management strategies is provided below. A specific list of the high-priority water quality projects is provided in Table ES-5 and a summary of the total cost of the recommended WMIP is tabulated in Table ES-4 in Ellerbe Creek WMIP Volume I: Executive Summary.

2.2 Implement Point Source Controls

The highest-priority recommendation to improve water quality within the watershed is to apply additional point source controls by eliminating sanitary sewer overflows (SSOs), removing illicit connections, and upgrading nutrient control technology at the North Durham Water Reclamation Facility (WRF). Over 180 SSOs were recorded by the City in the Ellerbe Creek Watershed from 1999 to 2007. Approximately 85 percent of the SSOs and illicit connections could be removed through the City's on-going sanitary sewer rehabilitation and replacement program at an estimated cost of $18 to $22 million.

Further reductions in nutrient loads to Ellerbe Creek can be achieved by upgrading the nutrient control technology at the North Durham WRF, which discharges into Ellerbe Creek near the city limits. By implementing best available technology for nutrient removal, the average annual load of total nitrogen from the North Durham WRF could be reduced by 8 percent and by 66 percent for total phosphorus. The estimated cost for nutrient control upgrades at the North Durham WRF is $38 to $42 million.

Table 2-1 presents the estimated pollutant load reduction (in percent) in Ellerbe Creek expected at the city limits and at the confluence with Falls Lake based on implementation of the point source controls.

Table 2-1. Estimated Pollutant Reduction for Point Source Controls

Summary Point	Total Nitrogen Reduction	Total Phosphorus Reduction	Sediment Reduction	Fecal Coliform Reduction
City Limits	4%	20%	0%	59%
Falls Lake	4%	19%	0%	57%

Includes both SSO reductions and implementation of nutrient BAT at the North Durham WRF

2.3 Improve Stormwater Quality

To protect water quality, the City's Stormwater Performance Standards for Development requires nearly all new development and redevelopment sites (with very limited exceptions) to provide on-site stormwater quality BMPs to remove nutrients and sediment from the stormwater runoff. These stormwater quality BMPs provide retention of stormwater runoff and water quality improvement, typically by settling the pollutants, prior to discharge to the downstream stormwater drainage system or creek. The level of pollutant removal is dependent on both the type of BMP (e.g., typically, treatment wetlands have a higher nutrient removal than a dry pond), and the area available to accommodate the BMP to meet the water quality design parameters.

Almost 80 percent of the Ellerbe Creek Watershed has already been developed. The majority of the development occurred prior to adoption of the stormwater performance standards that are now in place. However, the Neuse Basin Rules including buffers, nitrogen controls, and 1-year peak flow control have been in place throughout the watershed since 2001; and Water Supply Overlay requirements covering a portion of the watershed requiring 85 percent TSS removal have been in place since 1994. Although the City's stormwater performance standards will help minimize the further degradation of water quality in Ellerbe Creek resulting from new development and redevelopment, it has a limited affect on runoff from existing developed areas. A major focus of the WMIP has been to find cost-effective measures to improve the stormwater quality of developed areas. Two approaches to meet this goal are identifying retrofits to existing stormwater BMPs to improve their water quality benefits and find locations where new BMPs can be integrated into the existing drainage system to treat these areas.

To identify these opportunities, field crews visited each of the existing stormwater BMPs in the watershed to evaluate potential retrofit options. A total of 48 existing sites were visited, and of those, 27 provide retrofit opportunities to improve the BMP's water quality benefits. In addition to visiting the existing BMP sites, 59 potential sites were visited to assess the location's feasibility to integrate new stormwater BMPs to improve the stormwater runoff of developed areas. The field crews found 46 of the 59 sites to hold potential for new stormwater BMPs.

Each of these retrofit opportunities and new BMPs sites were evaluated and prioritized based on their water quality benefits, costs, and other evaluation criteria described in Section 8.2. Based on the results of this evaluation, the high-priority BMP retrofits and new BMPs should be implemented based on their water quality efficiency (i.e., costs per pound of pollutant removed), overall score for the evaluation criteria, and ability to acquire the land. The recommended high-priority stormwater quality projects are provided in Table ES-5 in the Ellerbe Creek WMIP Volume I: Executive Summary.

2.4 Improve Stream Health

Streams provide many functions that affect watershed condition including water storage and supply, water and sediment transport, habitat for aquatic species, and recreational opportunities (e.g. canoeing and fishing) for local residents. Degradation of stream function can often lead to a decline in water quality, degradation of instream habitat, and loss of aquatic species diversity.

To inventory the stream system and evaluate its existing conditions, field crews assessed approximately 35-miles of Ellerbe Creek and its tributaries. The field crews documented the stream quality based on the stream stability, condition of aquatic habitat, observed water quality problems, and the quality of the riparian buffer based on vegetation composition, density, and width. In general, Ellerbe Creek and its tributaries rated “fair” and “poor” quality based on these indicators of stream health. The primary indicators of degraded stream quality within the Ellerbe Creek Watershed consist of bank erosion; sedimentation of the stream bed; the presence of trash and/or debris within the stream channel; the lack of instream habitat features; and the loss of riparian vegetation or the lack of riparian buffers.

The field crews also identified opportunities for stream restoration and stabilization projects to improve water quality and watershed health on 28 miles of the 35 miles that were assessed. In order to facilitate the restoration of the Ellerbe Creek Watershed, these stream restoration and stabilization projects should be implemented based on water quality efficiency, overall prioritization score, and the ability to acquire the land or negotiate conservation easements. The three areas of focus for stream restoration and stabilization are:

1. South Ellerbe Creek;
2. Goose Creek; and
3. Main channel of Ellerbe Creek downstream of Roxboro Road.

The specific high-priority stream restoration and stabilization projects, along with preservation of the high-quality stream reaches, are provided in Table ES-5 in the Ellerbe Creek WMIP Volume I: Executive Summary.

2.5 Implement Riparian Area Management Plan

The lack of riparian buffers, eroding stream banks, and dumping of pollution and trash are common and visible problems along Ellerbe Creek and other streams within Durham. Riparian buffers are vitally important for protecting stream banks and shorelines from erosion and pollution, dissipating high-energy flows during storms, and providing fish and wildlife habitat. Vegetated buffers of any width are better than no buffers and are important for protecting stream stability, water quality, and ecological functions.

The Riparian Area Management Plan (RAMP), available as a separate report from the WMIP, contains riparian buffer management recommendations targeted for City-owned and maintained property that should be followed by management, design, and maintenance staff when planning and designing new infrastructure and facilities; improving existing facilities; or performing maintenance on water and sanitary sewer lines and easements, parks and recreation facilities, stormwater and flood control projects, roads, and public works facilities. The RAMP contains the following recommendations:

- Vegetation maintenance guidelines and strategies for City staff along greenway trails, sanitary sewer and water easements, streams, and parks;
- Water quality and ecological benefits of the proposed riparian area management procedures;

- Invasive species management plan; and
- Planning and design guidance for managers and engineers.

The City will be moving forward in a cooperative manner with the other departments affected to effectively implement the recommendations contained in the RAMP on all City-owned and maintained property within the Ellerbe Creek watershed.

2.6 Implement the Critical Area Protection Plan

The Critical Area Protection Plan was developed for Ellerbe Creek to identify high-(water quality) value properties to purchase and preserve. These are typically undeveloped properties that contain forested riparian buffers located along the main channel of Ellerbe Creek or its tributaries. Protecting these critical areas can significantly improve water quality, prevent pollutants from entering the stream, protect valuable habitat, and provide recreational opportunities. Critical areas for protection were identified using 17 site selection criteria such as existing site conditions, water quality and ecological benefits, and connectivity to other protected natural resources. Site characteristics from each candidate site were gathered from a number of resources, including: (1) Ellerbe Creek Local Watershed Plan; (2) the Durham Trails Master Plan; (3) the Falls Lake Initiative Conservation Plan; (4) land use data provided by the City; and (5) supplemental information obtained during the stream inventory. Based on the watershed evaluation, seven high-priority areas in the watershed were identified where the City should focus initial efforts at acquisition and protection of these critical areas:

1. Headwaters of Ellerbe Creek;
2. Unnamed tributary to Ellerbe Creek just south of the intersection of US 70 and US 15;
3. Ellerbe Creek in the vicinity of Guess Road and Murray Avenue;
4. Goose Creek near Camden Avenue;
5. Unnamed tributary to Goose Creek near US 7;
6. Unnamed tributary to Goose Creek in the most eastern part of the Goose Creek subwatershed; and
7. Unnamed tributary to Ellerbe Creek just downstream of the confluence with Goose Creek.

In addition to the high-quality riparian areas in the areas listed above, the City should move forward with acquisition of all recommended new BMP sites. This would prevent development of these sites and preserve the opportunity to implement these stormwater quality BMPs at a future date. The specific parcels for the critical riparian areas and recommended new BMP sites are provided in the Critical Area Protection Plan, which is provided in Appendix M of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

3. PUBLIC INFORMATION

One primary objective of the project was to engage City staff and interested stakeholders to assist with developing the WMIP through a public involvement program. This was accomplished through a series of technical meetings, public workshops, and a City-hosted project website.

3.1 Technical Workshops

Technical workshops were held with City staff throughout the duration of the project. These meetings were used to facilitate discussion and consensus on key technical aspects of the project, including field assessment protocols and data collection methods; water quality evaluation methods and pollutant loading rates; selection and prioritization of evaluation criteria; and development and application of the GIS-based water quality model. These technical workshops allowed City staff to review and discuss the following topics:

- Stream and riparian buffer field assessment protocols and stormwater BMP survey methods;
- Land-use based pollutant export coefficients to generate pollutant loads for sediment, total nitrogen, total phosphorus, and fecal coliform bacteria; and assign pollutant removal efficiencies for each of these parameters for stormwater BMPs and stream restoration projects;
- Watershed modeling and software specifications for the GIS-based water quality evaluation tool;
- Weighting factors to the evaluation criteria used to assess the effectiveness of potential watershed improvement projects;
- Watershed characterization and selection of the five pilot study areas;
- Results of the pilot study area analyses and the Riparian Area Management Plan;
- Training on the GIS-based water quality evaluation tool;
- Results of the water quality modeling and evaluate the effectiveness of the ten watershed improvement scenarios; and
- Draft Ellerbe Creek Watershed Management Improvement Plan.

3.2 Public Involvement

3.2.1 Public Workshops

Three public workshops were held at key points in the project to engage interested stakeholders, including concerned property owners, environmental groups, and the general public. A summary of the information presented at each public workshop is described below.

Public Workshop – April 2, 2008. The first workshop was scheduled to coincide with a monthly meeting of the Environmental Affairs Board (EAB). A brief overview of the goals and schedule for the Ellerbe Creek WMIP was provided, followed by a question and answer period for EAB members, City staff, and the general public. After the EAB meeting, the City held two breakout sessions for interested stakeholders. The two breakout sessions focused on the results of the stormwater BMP and stream field inventories, and an initial discussion and prioritization of the evaluation criteria for each watershed improvement project. The attendees were provided comment sheets to solicit feedback on the goals of the project, and the formulation of the evaluation criteria and prioritization process for individual watershed improvement projects.

Public Workshop – October 22, 2008. The second workshop presented the Evaluation Criteria, including scoring range and weighting factors for each of the 14 factors used for evaluation. In addition, the draft Critical Area Protection Plan was presented, which identified areas within the watershed that should be targeted for preservation. Finally, the stakeholders were provided with a description of the five selected pilot study areas and the watershed analyses methods, which included an overview of the Watershed Improvement Planning (WIP) Tools model.

Public Workshop – November 19, 2009. The third public workshop provided a summary of the watershed evaluation, including a description of the potential water quality improvement projects and stormwater management measures that were evaluated, the water quality goals established for the watershed, the results of each watershed management scenario, and the preliminary recommendations for the WMIP. The final Critical Area Protection Plan, Riparian Area Management Plan, and Better Site Design and Low Impact Development Report were also presented to the stakeholders.

3.2.2 WMIP Website

A project website hosted by the City was implemented to provide the general public with schedule updates, field work activities, and project milestones. The WMIP brochures, press releases, and presentations from the public workshops were also posted to the website. The website is currently located at this address: http://www.ci.durham.nc.us/departments/works/stormwater_ellerbe.cfm.

3.2.3 WMIP Brochures

Four-page brochures were assembled in advance of each public workshop to provide a status report on the WMIP and the results of our watershed analyses. The brochures were made available on the WMIP website and distributed to the attendees at each public workshop. A copy of each brochure may be found in Appendix A of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

3.3 Regulatory Agency Coordination

Upon City acceptance of the Ellerbe Creek Watershed Management Improvement Plan, regulatory meetings will be held with appropriate agencies to discuss the recommendations. The City is also negotiating changes to the current maintenance practices for Ellerbe Creek that require the City to maintain it as a flood control channel. These existing maintenance practices are in conflict with the City's goals to improve the water quality, stream health, and watershed function of Ellerbe Creek.

4. WATERSHED CHARACTERIZATION

4.1 Overview of Ellerbe Creek Watershed

The Ellerbe Creek Watershed, which covers 37 square miles, is predominately urbanized. Approximately half of the watershed, including the majority of the headwaters, lies within the City limits. The main channel of Ellerbe Creek flows west to east with South Ellerbe Creek and Goose Creek as its two major tributaries. I-85 passes through the watershed and Ellerbe Creek cuts back and forth across the interstate numerous times. As shown on Figure 4-1, the southern border of the watershed is defined closely by the Durham Freeway (NC 147). Junction Road defines the eastern boundary of the watershed within the City limits. Three roads, Carver Street, Old Oxford Road and Hamlin Road stretch along the northern boundary of the watershed. The western boundary traces its way through Duke Forest's Durham Division lands.

Ellerbe Creek drains to Falls Lake and the Neuse River, both of which have been identified as nutrient sensitive waters. Nitrogen, phosphorus, and excess sediment in the watershed are of particular concern. Since 1998, Ellerbe Creek from its headwaters to Falls Lake has been on the North Carolina Department of Environment and Natural Resources (NC DENR) 303(d) list as impaired for ecological/biological integrity. This is an indicator that the aquatic habitat and water quality conditions cannot support a healthy population of native aquatic species. Ellerbe Creek is also expected to be added to the 303(d) list as impaired for water contact recreation due to violations of the water quality standard for fecal coliform bacteria.

The focus of the watershed characterization is to describe the watershed characteristics (e.g., hydrology, soils, land use, and water quality), that influenced the watershed analyses, the evaluation of the watershed improvement projects, and the final recommendations in the WMIP. For a more comprehensive summary of the watershed characteristics, refer to the Ellerbe Creek Watershed Characterization Report included in Appendix C of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

4.2 Data Inventory

The watershed characterization is based on GIS data obtained from the City of Durham and state agencies, and on information available from previous watershed studies, such as the Ellerbe Creek Local Watershed Plan developed by the North Carolina Ecosystem Enhancement Program (NCEEP). The City maintains a comprehensive GIS data library that contains detailed information used to develop the WMIP, including data such as:

- Existing land use
- Future land use projected in 2025
- Ambient water quality monitoring data
- Parcel boundaries
- Hydrography
- Floodplains
- Impervious cover
- Soil types

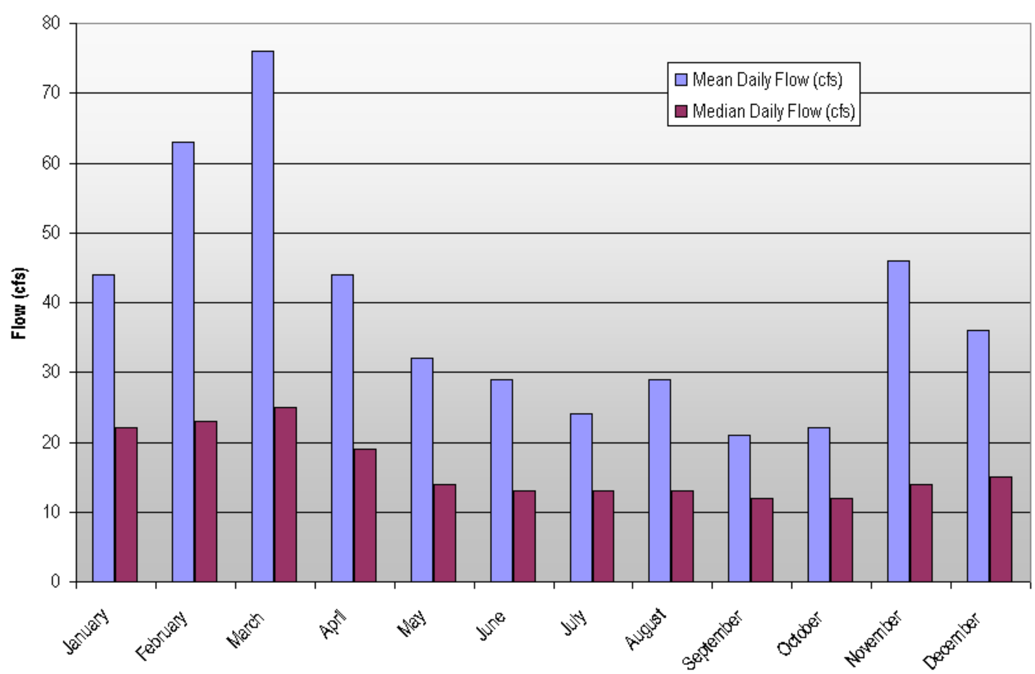
Additional data provided by other state agencies, such as the digital elevation model provided by the North Carolina Department of Transportation (NCDOT), were used to supplement the City's GIS database to complete the watershed characterization. A comprehensive list of GIS-based and other data obtained for the WMIP and its source may be found in Appendix J of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

4.3 Hydrology

Understanding the drainage patterns and conveyance network (e.g., pipes, ditches, stream channels, ponds, etc.) and the observed stream flows in Ellerbe Creek is important to assess the effect of existing development on the network of open channels and seasonal base flows, which in turn affects water quality and accessibility of aquatic habitat. The Ellerbe Creek watershed stretches from its confluence with Falls Lake to its headwaters in the Duke Forest, 5.5 miles west of downtown Durham. I-85 roughly bisects the watershed into northern and southern sections. Ellerbe Creek drains roughly 25 square miles of forested headwater and lowland areas with the highly urbanized downtown business district located in the center of the watershed. The total stream system, including unnamed tributaries, is approximately 132 miles. This includes both perennial and intermittent tributaries. Stormwater runoff is conveyed to this stream system by over 9 miles of stormwater drainage pipes. Based on this drainage network and the local topography, the watershed was divided into 33 smaller subwatersheds, as shown on Figure 4-2.

Ellerbe Creek is a United States Geologic Survey (USGS) gaged stream. The USGS gage station #02086849 is located approximately 1.2 miles upstream of Falls Lake just east of the Red Mill Road Bridge over Ellerbe Creek, as shown on Figure 4-3. At this location, the gage monitors approximately 22 square miles, or 90 percent, of the watershed area. Currently, the station records the stream flow and depth. The average annual flow is 44 cubic feet per second (cfs), while the median flow is 22 cfs, as shown on Figure 4-4. Average monthly flows range from a high of 76 cfs in March to a low of 21 cfs in September. Pollution problems are typically more physically noticeable during the drier summer and early fall months. During these periods, any SSOs or increased loadings from the North Durham WRF would make up a higher percentage of the overall flow in Ellerbe Creek.

Figure 4-4
Flow Data for USGS Gage Station 02086849 on Ellerbe Creek



4.4 Geology and Soils

Soil type and its underlying geology affect several aspects of watershed function and health, including erodibility of soils and the resulting sedimentation in streams, and the soil's capacity to infiltrate rainfall and stormwater runoff. The Ellerbe Creek watershed lies mainly within the Triassic Basin with its upper headwaters located in the Carolina Slate Belt. Triassic Basin soils originated from freshwater sediment that washed down from upland areas. These soils are erodible, which causes sedimentation to be the primary water quality impairment in many Triassic Basin streams. Triassic Basin soils are also characterized as poorly drained with very little porosity and very low permeability, which results in low infiltration rates of rainfall.

One effect of the low permeability soils is the low base flow conditions found during the summer due to reduced shallow groundwater flow available to feed streams between rain events. The poor infiltration rates that are characteristic of Triassic Basin soils also greatly reduce the applicability of stormwater management techniques that promote infiltration, such as infiltration basins and several better site design or low impact development (LID) practices, while greatly increasing the volume requirements of detention-based stormwater BMPs such as ponds and wetlands.

Human impacts on the soil have compounded the problems associated with Triassic Basin soils. Much of the historic topsoil has been lost to past agricultural practices or compacted by urban development, further reducing the infiltration capacity and increasing the amount of urban stormwater runoff generated.

Hydrologic soil groups have been established by the National Resource Conservation Service (NRCS) to represent ambient soil infiltration rates and water storage capacities:

- **Group A** soils have high infiltration rates, low runoff potential, and are primarily well-drained sandy soils;
- **Group B** soils have moderate infiltration rates, moderate runoff potential, and consist primarily of moderate to well drained soils such as loams;
- **Group C** soils have low infiltration rates, moderately high runoff potential, and are typically sandy clays or clay loams; and
- **Group D** soils also have low infiltration rates, high runoff potential, are clays or contain a clay pan layer near the surface, or consist of shallow soils over bedrock (urban complex and gullied areas are typically classified as Group D soils as well).

There are no Group A soils within the Ellerbe Creek watershed. Just over 10 percent of the Ellerbe Creek watershed has Group B soils while over 15 percent has Group C soils. The majority of the watershed is classified as Group D soils and Urban Complex. Figure 4-5 shows the hydrologic soil groups within the Ellerbe Creek watershed.

4.5 Floodplain

Ellerbe Creek's high percentage of impervious area makes it prone to flooding problems, especially within the highly urbanized center of the watershed. To reduce property damage caused by flooding the City regulates floodplain development through their Flood Damage Protection Standards. These standards were developed in conjunction with the update of floodplain mapping. In spring 2006, the Federal Emergency Management Agency (FEMA) issued new floodplain studies and 100-year floodplain maps for the City and County of Durham, as shown on Figure 4-6. Through a Cooperative Technical State Agreement with FEMA, the North Carolina Floodplain Mapping Program (NCFMP) has assumed responsibility for the review and maintenance of Flood Insurance Rate Maps (FIRMs) for the state. Currently, the NCFMP is in the process of their review and update of the FIRMs for the City and County of Durham, which is referred to as their MapMod effort. This MapMod effort includes the restudy of the hydrologic and hydraulic conditions of the detailed study areas within the Ellerbe Creek watershed. The state estimates preliminary FIRMs for the Durham City/County MapMod effort to be released in Spring 2011 and to become effective in early 2012.

Although Figure 4-6 shows many areas of the watershed within the 100-year floodplain, there are several locations where structural flooding and damage occurs often: (1) upstream of the confluence of Ellerbe Creek with South Ellerbe Creek near Northgate Park and Acadia Street and (2) downstream of the confluence of Ellerbe and South Ellerbe Creeks at the Roxboro Road/I-85 interchange and surrounding commercial areas.

4.6 Land Use

Existing land use conditions and future land use trends typically have the most significant effect on water quality and watershed health. The type of land use and its development density affects the extent of impervious areas, the amount of stormwater runoff and pollutant loads, and the direct impacts to streams and wetlands (e.g., filling and channelization of stream channels and wetlands, removal of forested riparian buffers). Durham County actively maintains existing land use data as part of their parcel-based property database and has defined a complex series of land use codes to cover a broad range of land use types and activities. The complex series of land use codes were simplified into ten general land use types, as shown on Figure 4-7. Since roads are not included in the parcel-based land use data, the road right-of-ways were added as an eleventh land use type to account for their impervious areas and pollutant loads. The eleven land use types used in the Ellerbe Creek watershed are listed below:

- Commercial
- High Density Residential (12-60 units/acre)
- Medium Density Residential (6-12 units/acre)
- Low Density Residential (2-6 units/acre)
- Very Low Density Residential (< 2 units/acre)
- Vacant (existing land use condition only)
- Agriculture Row Cropping
- Industrial
- Institutional
- Parks and Open Space
- Roadways

Future land use data for the watershed are developed and maintained by the City and County Planning Departments. The future land use data, as shown on Figure 4-8, are based on the planned full build-out that is forecast to occur by the year 2025. In order to evaluate land use trends and their potential effect on water quality and watershed health, the future land use data were merged into the same ten land use categories as the existing land use data with the exception that the vacant land use is not applicable under the future land condition. With both existing and future land use conditions based on the same land use categories, a comparative analysis of existing and future conditions could be used to estimate the affect of full build-out on water quality and watershed health.

The existing land uses within the Ellerbe Creek watershed are predominately dense urban residential and commercial inside the City limits with more semi-rural residential areas closer to Falls Lake. The western portion of the watershed is largely low density residential intermixed with industrial and commercial developments. The central portion represents the most intensely developed land within the watershed. This area contains the older residential neighborhoods, the downtown business district, a dense road network, and many notable landmarks, including Duke's East Campus, the School of Science and Math, Northgate Park, the county stadium, North Pointe Shopping Center, and the Museum of Life and Science. The eastern portion of the watershed contains a combination of industrial, commercial, and new residential development. This area will likely experience the most development pressures in the future because it contains large areas of land available for development.

The majority of the Ellerbe Creek watershed is already heavily developed, however, as noted above there are large tracks of undeveloped land that are expected to develop into low or medium density residential. The most influential land use changes are forecast to occur in the eastern portion of the watershed (i.e., subwatersheds 28 to 33), while in-fill develop will occur primarily in the areas north of I-85. The broad forested riparian areas owned by the USACE along the lower portion of Ellerbe Creek will continue to be preserved; however, all the remaining undeveloped land throughout the watershed is expected to be developed leading to additional water quality stress on both Ellerbe Creek and Falls Lake. Additional details of the land use data may be found in Appendix D of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

Figures 4-9 and 4-10 indicate the changes in expected land use over the next 25 years. Most notably, the agricultural lands in the watershed are expected to develop.

Figure 4-9. Existing Land Use

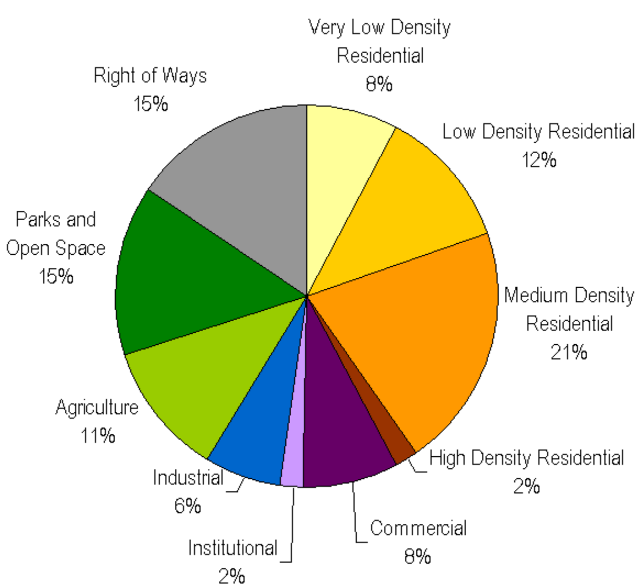
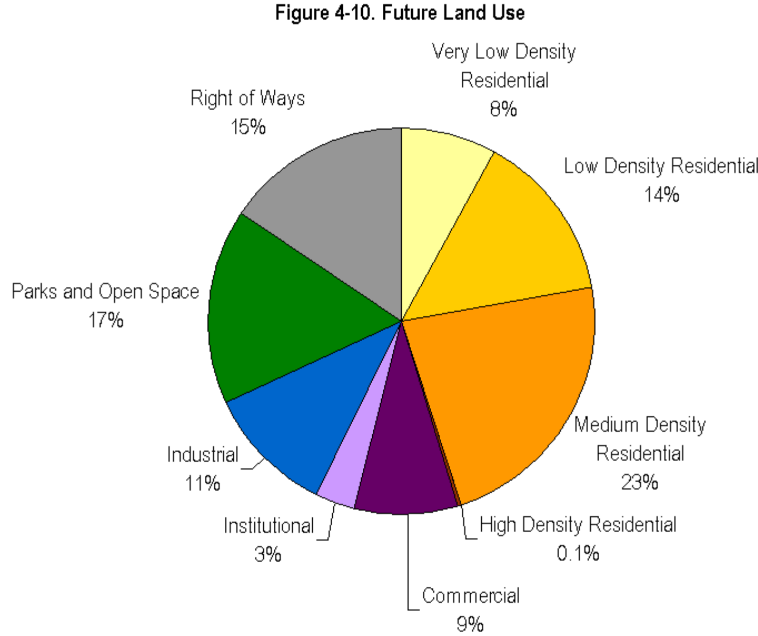


Figure 4-10. Future Land Use



4.7 Water Quality

Water quality is an important indication of the health of an ecosystem. Ellerbe Creek is classified as a nutrient sensitive water. Since 1998, Ellerbe Creek from its headwaters to Falls Lake has been on the North Carolina Department of Environment and Natural Resources (NC DENR) 303(d) list as impaired for ecological/biological integrity. This is an indicator that the aquatic habitat and water quality conditions can not support a healthy population of native aquatic species. Ellerbe Creek is also expected to be added to the 303(d) list as impaired for water contact recreation due to violations of the water quality standard for fecal coliform bacteria. Multiple factors have led to watershed and stream degradation. These include:

- Development within the watershed without adequate erosion control and stormwater treatment measures implemented both during and post-construction;
- Fill or encroachment in the natural floodplain;
- Loss of forested riparian buffers; and

- Historic(USACE) and on-going stream modifications and loss of wetlands.

This section presents the water quality analysis to date, including examination of the land use-based pollutant loadings for existing and future conditions and analysis of the City's ambient water quality monitoring data collected over the last 4 years.

4.7.1 City Water Quality Monitoring Data

Monthly ambient water quality data is available from January 2004 through December 2007 for 11 water quality monitoring stations located in the Ellerbe Creek watershed. The locations of the monitoring stations are shown on Figure 4-11. Fecal coliform data was available and evaluated at all 11 monitoring sites. Due to limited available data at 5 monitoring stations (EL7.9EC, EL7.1SEC, EL5.6EC, EL8.1GC, and EL1.9EC), these sites were only evaluated for total nitrogen, total phosphorus, and total suspended solids.

Table 4-1 presents the average concentrations for each of the selected water quality parameters. While the data allows for evaluation of some spatial and temporal trends, evaluation of wet weather effects are limited. Wet weather tends to drive pollutant loading in urban environments through stormwater runoff and combined and sanitary sewer overflows. The City's ambient monitoring program is not focused on characterizing wet weather flows, and while rainfall for the previous 72 hours was recorded at the time of water quality sampling, a limited number of water quality samples corresponded with significant amounts of rainfall or higher flows. Therefore, conclusions regarding wet weather impacts based upon the City's ambient data were not drawn at this time. Additional details and analyses of the water quality data may be found in Appendix C of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

Table 4-1. Ellerbe Creek Water Quality Monitoring Stations Average Concentrations

Station	Description	Subwatershed Location	Total Nitrogen (mg/L)	Total Phosphorus (mg/L)	Total Suspended Solids (mg/L)	Fecal Coliform (cfu/100mL)
EL10.7EC	Ellerbe Creek Headwaters	4	-	-	-	3579
EL8.2EC	Ellerbe Creek Headwaters	10	0.9	0.1	14	1792
EL7.9EC	Ellerbe upstream of South Ellerbe	11	0.9	0.1	22	1783
EL8.5SEC	South Ellerbe Creek Headwaters	8	-	-	-	7814
EL7.6SECT	Tributary to South Ellerbe Creek	13	-	-	-	5329
EL7.1SEC	South Ellerbe Creek near Ellerbe Creek	15	1.0	0.1	12	2346
EL5.6EC	Ellerbe upstream of Goose Creek	17	0.8	0.1	16	2158
EL8.1GC	Goose Creek Headwaters	18	1.4	0.1	56	8035
EL5.5GC	Goose Creek near Ellerbe Creek	25	-	-	-	3914
EL5.0EC	Ellerbe downstream of Goose Creek	26	1.1	0.1	14	4577
EL1.9EC	Ellerbe Creek near USGS Gage	31	3.0	0.2	13	1770

4.7.2 Sanitary Sewer Impacts

The North Durham Water Reclamation Facility (WRF) is located off East Club Boulevard upstream of the City's ambient water quality monitoring station, EL1.9EC. The WRF has a permitted capacity of 20 million gallons per day (mgd). Examination of the City's water quality data collected at monitoring station EL1.9EC indicates that the WRF has some impact on the overall nitrogen loading from the Ellerbe Creek watershed to Falls Lake. The City provided the Discharge Monitoring Report (DMR) data for the North Durham WRF (NC0023841) for the period from January 2004 through September 2007, which included discharge data for total nitrogen, total phosphorus, and total suspended solids. The City also provided 2007 DMR data for fecal coliform. Analysis of the North Durham WRF discharges is provided in Section 7.7.

City Stormwater Services has documented sanitary sewer overflows (SSOs) in the Ellerbe Creek watershed from 2001 through 2006. While many have no overflow volume recorded, several were major SSOs causing spills that exceeded 40,000 gallons. Examination of the fecal coliform monitoring data suggests that SSOs have a significant impact on water quality throughout the watershed. The City's ambient monitoring data shows higher levels of fecal coliform in the upper and middle portions of the Ellerbe Creek watershed, with the higher levels recorded in the portion of the watershed with a sanitary sewer collection system. Analysis of recorded SSOs is provided in Section 7.7.

The goal of the WMIP is to provide the City with the necessary planning tool to help restore watershed health and function to Ellerbe Creek and its headwaters and create educational and recreational opportunities throughout the watershed. Stream restoration projects and new and/or retrofit BMP projects will improve water quality within the watershed by reducing sediment and nutrients from stormwater runoff. However, implementation of BMPs or stream restoration projects may be ineffective at achieving reductions of the current fecal coliform concentrations in Ellerbe Creek unless sanitary sewer leaks and overflow events are corrected. A key element in restoring stream function to Ellerbe Creek will involve City departments working together to develop an aggressive plan for resolving the SSOs and leaking sewers within the watershed.

5. STORMWATER SYSTEM INVENTORY AND ASSESSMENT

5.1 Introduction

The three primary objectives of the stormwater system inventory were: (1) examine and assess existing stormwater quality best management practices for retrofit opportunities to improve their water quality treatment performance; (2) locate appropriate sites for new stormwater quality BMPs; and (3) inventory the stormwater drainage system to support the hydraulic and water quality modeling described in Section 7 and Section 8. These objectives were achieved through the implementation of GIS-based desktop analysis and field inventories. The desktop analysis consisted of locating existing BMPs, locating potential new BMP sites, and pre-screening potential new BMPs for feasibility based on site constraints and conflicts. The field inventory employed field crews to complete a detailed evaluation of existing stormwater BMPs and to confirm the feasibility of new sites for potential stormwater quality BMPs. Traditional survey crews were also employed to capture data on the piped conveyance systems and stream channels to allow for the detailed hydraulic and water quality evaluations presented in Section 7.

Forty-eight existing stormwater BMPs and 59 potential new stormwater quality BMP sites were identified through the desktop analysis, as shown on Figure 5-1. The results of the field assessments and inventories are presented in this section. A more detailed summary of the GIS-based desktop analysis and field inventories for stormwater quality BMPs can be found in Appendix B of the Ellerbe Creek WMIP Volume 3: Technical Appendices .

5.2 Field Inventory and Assessment

The existing stormwater BMPs identified during the desktop analysis were evaluated by field crews for a number of site factors that would affect the feasibility of retrofit opportunities to improve stormwater treatment, including:

- Confirming the type of stormwater BMP
- Verifying that the BMP meets current city and state design standards
- Evaluating the site to confirm the BMP meets current construction standards
- Identifying the potential retrofits appropriate for the BMP type
- Performing a constructability review for each potential retrofit:
  - Potential conflicts with known utilities (e.g., water, power, telecommunications, and sanitary sewer)
  - Access for construction and long-term maintenance
  - Encroachment onto adjacent properties
  - Environmental impacts and permits required
- Evaluating the water quality performance (i.e., pollutant removal efficiency) of the existing BMP

For each potential new BMP site, field crews visited the site to confirm the information collected during the GIS-based desktop evaluation and to verify the results of the pre-screening process. The field crews also collected adequate site data to support development of a conceptual design to estimate the water quality benefits of each new BMP using the hydraulic and water quality models described in Section 7. The field crews assessed the following factors at each new BMP site:

- Existing site conditions (e.g., vacant, forested)
- Appropriate BMP types for each potential new BMP site (e.g., more than one BMP type may be feasible at each site)
- Area available for the new BMP
- Drainage area characteristics
- Constructability, which included the following:
  - Potential conflicts with known utilities (e.g., water, power, telecommunications, and sanitary sewer)
  - Access for construction and long-term maintenance
  - Identification of and number of property owners involved
  - Environmental impacts and permits required

The results of the field assessment and inventory were documented on field datasheets and stored in a GIS geodatabase. The results and a description of the BMP opportunities are summarized below.

5.3 Retrofit Opportunities for Existing Stormwater BMPs

The 48 existing BMPs consist of 19 dry ponds, 10 wet ponds, three constructed wetlands, one pocket wetland, one bioretention area, 11 sand bed filters, two underground storage facilities, and one vegetated swale. Of the 48 existing BMPs inventoried, 27 provide retrofit opportunities to improve their water quality performance.

The two most common retrofit opportunities are:

- Convert an existing dry pond into a wet pond or constructed wetland
- Modify the outlet structure to increase the water quality detention volume of the BMP

The two most common reasons a BMP was not recommended for a water quality retrofit were:

- Inadequate site area was available to expand the existing BMP (i.e. the volume or surface area of the BMP could not be expanded due to site constraints, utility conflicts, or property ownership issues).
- Additional stormwater runoff could not be routed into the existing BMP (i.e. the site is located near a drainage boundary, or there would be a high cost associated with diverting additional stormwater runoff to the BMP).

The location of each existing BMP that provides a water quality retrofit opportunity can be found on Figure 5-2.

5.4 Potential New Stormwater BMPs

Of the 59 new BMP sites identified during the desktop analysis, 46 sites were found to be suitable based on the results of the field assessment. Of the potential new BMPs, the majority of the potential new BMPs (21 sites) were suitable for a constructed wetland. The remaining new BMP sites consisted of 11 wet ponds, two pocket wetlands, seven bioretention areas, and five other BMP types.

The three most common reasons the field crews did not recommend a site for a new BMP were:

- Conflicts with other utilities, such as existing sanitary sewers, water mains, or overhead power lines, were observed that restricts access and limits the area required to provide adequate treatment volume.
- Inadequate area available for the new BMP, typically due to constraints by adjacent property ownership.
- Environmental impacts were considered too severe, such as the site contained a healthy, mature forest, or the site contains a valuable riparian buffer.

The locations of each potential new stormwater quality BMP can be found on Figure 5-3.

5.5 Summary

Several issues may be encountered when plans are made to retrofit a BMP including ownership and maintenance responsibilities, achieving one design goal while possibly having to sacrificing another design goal, and the loss of developable or desired land. Coordination and communication become important between private owners and governing agencies when retrofit possibilities are examined and executed. Retrofit opportunities for existing BMPs and potential new BMPs should also be designed and implemented with consideration to any stream restoration or stabilization projects within the watershed. Summaries of the retrofit opportunities for existing and potential new BMPs in South Ellerbe Creek, Goose Creek, and Ellerbe Creek are included below. Each summary discusses potential retrofit opportunities for the existing and potential new BMPs identified in their respective watersheds on Figure 5-1.

South Ellerbe Creek has an approximate two square mile drainage area that is densely developed primarily with single family residential parcels typically smaller then a ¼ acre. These lots were developed prior to the City enacting stormwater control requirements. This area is served by four existing BMPs, one of which was found to have retrofit potential. Possible improvements to the health of South Ellerbe Creek can be achieved by installing additional new BMPs. The field inventory identified eitght potential new BMP sites along South Ellerbe Creek that can provide treatment of runoff that is not currently managed.

Goose Creek drains an area of approximately 2.4 square miles that is similar in average parcel size and land uses to South Ellerbe Creek. Goose Creek was also developed prior to the City enacting stormwater control requirements; however, as a result of redevelopment projects, six small-scale BMPs have been installed to address localized stormwater runoff from individual developments. There are no large-scale BMPs that treat stormwater in Goose Creek. Of the six existing BMPs, four were recommended for retrofits. These retrofits focused on increasing the BMPs detention volume through redesign of the control structure or increasing the BMP's size. Due to limited availability of land, only six potential new BMP sites were identified during the field inventory. These BMPs were identified to capture and treat runoff from small tributaries or adjacent buildings and parking areas.

Ellerbe Creek is surrounded by a diverse mix of residential, commercial, industrial, agriculture, and open space areas. There are 38 existing BMPs located in this watershed; 22 of these sites were found to have retrofit potential. The improvements to the retrofit BMPs include redesigning control structures, increasing the BMPs' size, or converting it to a different BMP type in order to increase water quality benefits. In several cases, flood control storage capabilities may be sacrificed to achieve additional water quality benefits. The field inventory identified 32 potential new BMP sites that could treat runoff from land uses not currently managed. Public land was targeted first because of land availability and to avoid ownership issues. In most cases, public areas offered more room to treat larger areas of runoff from development or tributaries. Other potential new BMPs on private lands were identified to treat more localized, residential and commercial runoff.

6. STREAM INVENTORY AND ASSESSMENT

6.1 Introduction

The goals of the stream inventory and assessment were to characterize existing stream and riparian conditions and to identify opportunities for stream and riparian restoration projects to improve water quality and watershed health. The primary objectives of the stream assessment were to:

- Identify and characterize the quality of each stream reach;
- Characterize bank stability and erosion potential;
- Recognize water quality issues and identify pollution sources;
- Assess problems (e.g., exposed pipes) associated with public utilities within the stream corridors;
- Categorize opportunities for stream and riparian restoration projects; and
- Find high-quality stream and riparian areas appropriate for preservation.

Stream assessment data were collected at two levels of detail depending on the level of priority assigned to the stream by the City prior to initiating field work. Both surveys were conducted through "stream walks", where field crews walked in the stream bed or along the banks in order to collect the required data. The stream inventory and evaluation was used for subsequent evaluation and prioritization of recommended stream and riparian restoration projects and the preservation of critical stream and riparian areas.

Level 1 Surveys were focused on the tributaries of Ellerbe Creek. The surveys were relatively rapid and focused on the assessment of stream bank erosion, stability of public utilities within the stream corridor, and the identification of potential pollution sources. Restoration opportunities and high quality stream reaches and riparian areas that could be preserved were also identified during the Level 1 field surveys. A detailed description of data collection efforts for the Level 1 Survey, including the field datasheets, may be found in Appendix B of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

Level 2 Surveys were performed primarily along the main stem of Ellerbe Creek. Level 2 surveys required more comprehensive data collection effort that involved the additional assessment of stream habitat condition and geomorphic classification. The stream habitat assessment protocol required data collection on several stream attributes including channel stability, channel sediment deposition, physical habitat (e.g. presence of riffles and pools, and substrate composition), water quality, riparian habitat conditions, and biological indicators (e.g. diversity of the macroinvertebrate community). Restoration opportunities and high quality stream reaches and riparian areas that could be preserved were also identified. A detailed description of data collection efforts for the Level 2 Surveys, including field datasheets, may be found in Appendix B of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

6.2 Preliminary Stream Assessment Findings

During the stream inventory, field crews walked approximately 35 miles of stream; Level 1 assessments were performed on 28 miles (80 percent) and Level 2 assessments were performed on 7 miles (20 percent), as shown on Figure 6-1. For both the Level 1 and Level 2 surveys, field crews divided the stream channels into individual reaches based on changes in stream characteristics (e.g. bank height, bank erosion) or riparian buffer characteristics (e.g. vegetation composition, density, width). The results of the stream assessment for bank erosion, pollution sources, stream quality, and restoration opportunities are presented below. A more detailed summary of the stream inventory is provided in Appendix B of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

6.2.1 Erosion Potential

Stream bank erosion was assessed on all Level 1 and Level 2 reaches using qualitative criteria as described in the United States Environmental Protection Agency's (USEPA) Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers. Common field indicators of erosion along the main stem of Ellerbe Creek and its headwaters included unvegetated banks, exposed tree roots, and areas of "raw" or exposed soil. Bank failure or slumping over an entire reach was less common, however this condition was observed in localized areas along the streams. Four categories of erosion were used to describe the percentage of the stream bank affected by erosion: Excellent (<5 percent), Good (5 to 30 percent), Fair (30 to 60 percent) and Poor (60 to 100 percent). Figure 6-2 depicts the percentage of stream reaches that fell within each erosion category for the Level 1 surveys while Figure 6-3 depicts the percentage of stream reaches for the Level 2 surveys. The majority of both Level 1 and Level 2 reaches were rated "Fair", which means the banks along those reaches are moderately unstable and have a high potential for erosion during moderate to high flow conditions. There were no reaches along the main stem of Ellerbe Creek that received a rating of excellent.

Figure 6.2 Percentage for Erosion Potential - Level 1

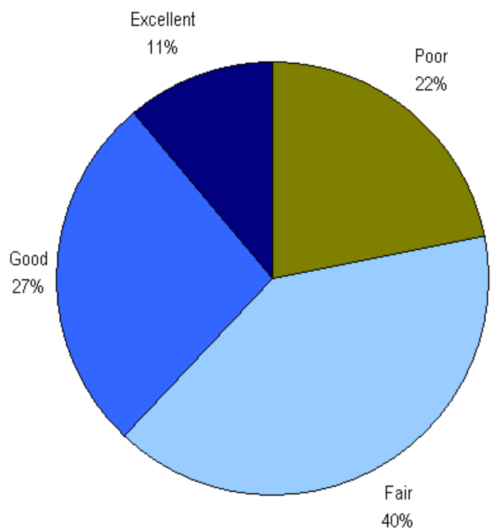
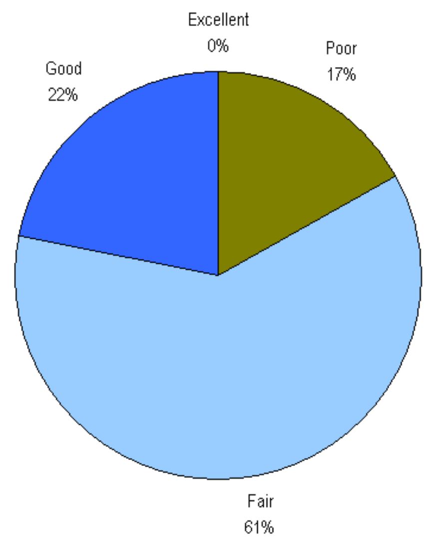


Figure 6.3 Percentage for Erosion Potential - Level 2



6.2.2 Pollution Sources

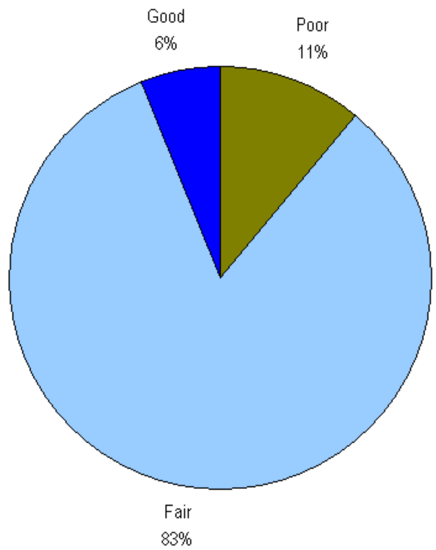
In order to more accurately describe potential water quality problems within the watershed, field crews recorded potential sources of pollution including the presence of potential illicit discharges, erosion and sediment control violations, and dumping activities. An illicit discharge is defined as the discharge of pollutants or non-stormwater materials to storm sewer systems through improper connections to the system by overland flow or direct dumping. Very few signs of potential illicit discharges (e.g., dry weather flow, staining of pipes) were observed within the watershed. The most common sources of pollution were the presence of garbage and/or debris in the stream bed along South Ellerbe Creek and Goose Creek.

6.2.3 Stream Quality

Stream Quality was assessed using the Rapid Stream Assessment Technique (RSAT) developed by the Center for Watershed Protection. The RSAT rates stream conditions using four categories, which are defined by the total number of points a stream receives: Excellent (42 to 50 points), Good (30 to 41 points), Fair (16 to 29 points), and Poor (<16 points). A detailed description stream quality assessment may be found in Appendix B of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

The RSAT was performed on all Level 2 reaches; the results are depicted on Figure 6-4. None of the Level 2 reaches scored within the excellent category. Characteristics of an excellent stream include minimal bank erosion, low riffle embeddedness, a large number of deep pools, a diverse combination of riffle, run, pool habitat, a diverse substrate composition, a diverse macroinvertebrate composition (i.e. mayflies, caddisflies, and stoneflies), and a mature riparian buffer. The majority of the reaches surveyed within the watershed scored in the "fair" category. Characteristics of a "fair" stream include 50 to 70 percent of the bank affected by erosion, relatively high riffle embeddedness, a low to moderate number of deep pools, the riffle substrate dominated by sand and gravel, observations of pollution tolerant macroinvertebrates, (e.g., caddisflies and snails), and a riparian area predominately wooded, but with major localized gaps.

Figure 6.4 Stream Quality Conditions – Percentage of Level 2



6.2.4 Restoration Opportunities

Restoration opportunities were categorized based on the 6 definitions developed by the USACE in their stream mitigation guidelines for North Carolina:

- **Restoration** involves the conversion of an unstable, altered, or degraded stream corridor, including adjacent riparian buffers and floodplain, to its natural condition. The stable physical dimensions to the stream (i.e., dimension, pattern, and profile) as well as biological and water quality functions are restored.
- **Enhancement Level I** includes improvements to the stream channel and riparian zone that restore channel stability, water quality and stream ecology. Channel dimension and profile are typically addressed, but restoration of channel pattern is typically not feasible.
- **Enhancement Level II** includes activities that augment channel stability, water quality and stream ecology but fall short of restoring both dimension and profile as well as channel pattern.
- **Stream Bank Stabilization** involves the stabilization of an eroding stream bank. Stabilization techniques include (1) the use of materials like root wads and log crib structures, (2) sloping stream banks and (3) revegetating the riparian zone.
- **Preservation** involves the protection of ecologically important streams and is generally done in perpetuity through the implementation of appropriate legal and physical mechanisms. Preservation can include the protection of upland buffer areas adjacent to the stream necessary to ensure protection or enhancement of the overall stream.

- **Buffer Restoration** includes all activities in the riparian zone to restore a native forested buffer with a minimum width of 50 feet from the top of bank, including tree planning and invasive species removal.

The proposed restoration category for each stream reach is presented on Figure 6-5. The restoration categories are based on location and/or feasibility, potential water quality improvements, and public education and outreach opportunities.

6.3 Summary of Restoration Opportunities

Streams provide many functions that affect watershed conditions including water storage and supply, water and sediment transport, habitat for aquatic and terrestrial species and recreational opportunities (e.g. canoeing and fishing). Degradation of stream function can often lead to a decline in water quality, an increase in sediment loads and embedded substrate and a loss of instream habitat and species diversity. Primary indicators of degraded stream quality within the Ellerbe Creek Watershed include bank erosion and sedimentation; the presence of trash and/or debris within the stream channel; the lack of instream habitat features; and the loss of riparian vegetation or the lack of riparian buffers. The combined data collected in the Level 1 and Level 2 surveys enables the identification of several restoration opportunities throughout the watershed that could restore stream function and protect water quality throughout the watershed. Brief summaries of restoration opportunities for streams within South Ellerbe Creek, Goose Creek, and Ellerbe Creek are included below.

South Ellerbe Creek stream reaches are primarily suitable for Bank Stabilization and Enhancement Level I activities. Buffer restoration activities were only identified along a small portion of the streams surveyed. Restoration activities are limited due to the extensive development and its encroachment within the riparian area as the streams are often confined by relatively narrow or non-existent buffers. Bank erosion ranged from poor to good, with adjacent development and the loss of riparian vegetation contributing to the problems identified within the South Ellerbe Creek Watershed.

Goose Creek stream reaches are suitable for a more diverse mix of restoration opportunities, which included Restoration, Enhancement Level II, Bank Stabilization, and Buffer Restoration activities. A large amount of trash, debris, and fill material were observed along most of Goose Creek and its tributaries. Continued and concentrated stream clean-up activities would increase the aesthetic view of these streams and would contribute to water quality improvements. Enhancement Level II activities along the eastern tributary of Goose Creek were identified due to the relatively high level of bank erosion. Field indicators suggest that erosion problems are a result of increased surface runoff from upstream development.

Ellerbe Creek main stem has been channelized and is currently maintained according to flood control standards established in cooperation with the USACE. Stream quality for the majority of the main stem of Ellerbe Creek was rated poor due to the lack of riffle-pool complexes, instream habitat features, woody debris, and biological diversity. This is directly related to the on-going maintenance activities for flood conveyance. The City is in the process of negotiating changes to these maintenance practices to improve the water quality and aquatic habitat conditions of Ellerbe Creek. Due to controls on development within the floodplain, the main stem of Ellerbe Creek provides the opportunity for stream restoration activities, which will need to be balanced with the flood control requirements. Along the tributaries to Ellerbe Creek, a diverse mix of opportunities is available, including Restoration, Enhancement Level 2, Buffer Restoration, and Preservation. Bank erosion along these streams ranged from good to poor. However, the restoration of these tributaries will be challenging due to existing land use practices (e.g. golf courses and urban development).

ELLERBE CREEK WATERSHED MANAGEMENT IMPROVEMENT PLAN

7. WATERSHED EVALUATION

7.1 Introduction

The goal of the Ellerbe Creek WMIP is to improve water quality and restore watershed function. This goal will be achieved by implementing an effective water quality improvement plan to meet specific water quality goals. To ensure that effective watershed improvement projects were identified, a watershed-specific geodatabase was built to organize and process the City's existing GIS data and the data collected during the field inventories. Computer models were used as the foundation for evaluating projects; analyzing the hydrologic, hydraulic, and water quality characteristics of the watershed; and estimating the water quality benefits of watershed improvement projects and stormwater management measures. The integration of the watershed geodatabase and the watershed evaluation models is shown in Figure 7-1.

Watershed Geodatabase

A comprehensive watershed-specific geodatabase was built upon the following data:

- GIS data (from City of Durham, NCDOT, etc.) and results of spatial analyses; and
- Field inventories of BMPs, stormwater infrastructure, and streams.

Extensive spatial analyses were completed using information contained in the geodatabase to characterize the watershed and to provide input data for the watershed evaluation tools. All of this data is stored in the comprehensive watershed geodatabase.

Watershed Evaluation Models

1. PCSWMM.NET, a variation of the U.S. Environmental Protection Agency (EPA) Storm Water Management Model (SWMM) developed by Computational Hydraulics Institute, was applied to perform the following evaluations:

- Watershed-scale hydrologic and hydraulic evaluation of the Ellerbe Creek watershed;
- Detailed hydraulic analysis of the five pilot study areas (described in further detail in Section 7.3);
- Conceptual design of retrofits to existing stormwater BMPs or installation of new stormwater BMPs to evaluate their water quality and hydrologic benefits;
- Water quality and hydrologic benefits of low impact development (LID) practices;
- Water quality benefits of street sweeping; and
- Potential flood improvement measures to eliminate or reduce observed flooding problems.

2. Watershed Improvement Planning Tools Model (WIP Tools Model), a planning level GIS-based model developed by Brown and Caldwell, was applied to assess the following conditions:

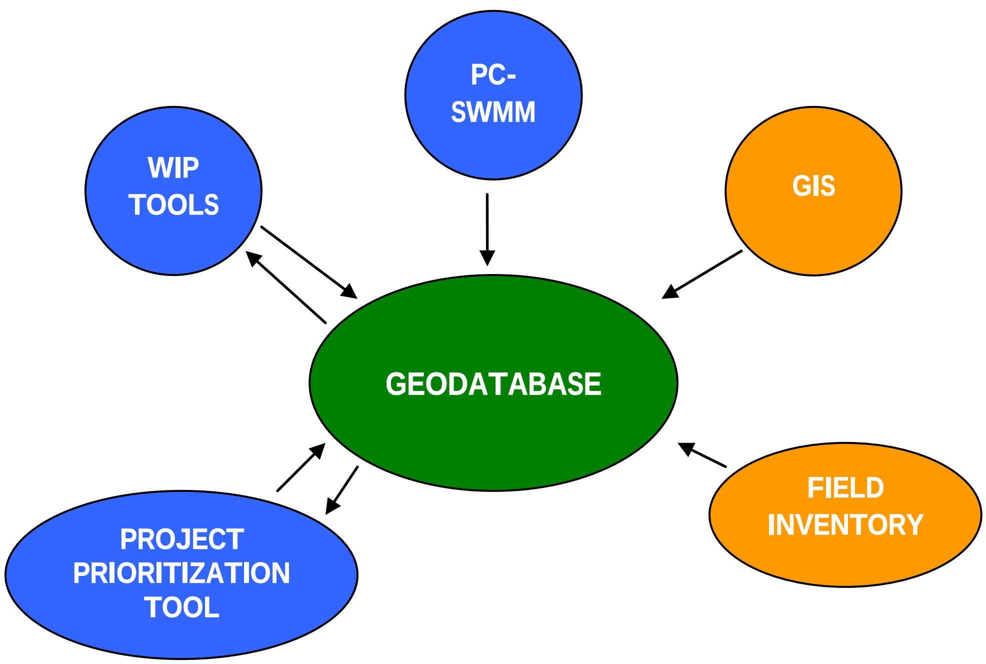
- Watershed-wide water quality conditions under existing and future land use conditions;
- Water quality benefits of retrofits to existing stormwater BMPs, new stormwater BMPs, and stream restoration and stabilization projects; Better Site Design and Low Impact Development techniques; stormwater performance standards for new development and redevelopment; and point source controls; and
- Development and evaluation of multiple watershed improvement scenarios that combine non-point source and point source control measures.

3. Project Prioritization Tool, an spreadsheet-based tool developed by Brown and Caldwell, was applied to determine the following:

- Costs for new stormwater BMPs, retrofits to existing BMPs, and stream restoration and stabilization projects;
- Assign evaluation scores and prioritize individual projects based on the prioritization criteria presented in Section 8.2; and
- Develop cost estimates for various watershed improvement scenarios.

Methods used to develop the PCSWMM model are further discussed in Section 7.4. Methods used to develop the WIP Tools Model for the Ellerbe Creek Watershed are detailed in Section 7.5. Methods to develop the appropriate input data for the Ellerbe Creek Watershed into the Project Prioritization Tool are discussed in Section 7.6.

Figure 7-1. Integration of the Watershed Geodatabase and Evaluation Models



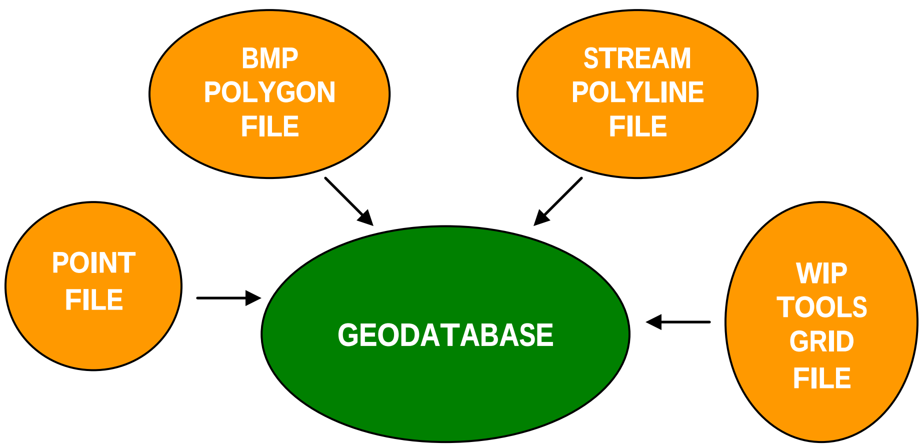
7.2 Project Geodatabase

The Project Geodatabase contains all of the watershed specific data compiled for the Ellerbe Creek Watershed. The Project Geodatabase, as shown in Figure 7-2, is a compilation of four GIS files which are joined based on the Project ID (Proj_ID column heading).

- **Point File** containing all of the BMP (both existing and new) and Stream Project points. Most of the information in the Point File was obtained during the BMP and stream field inventories. Information includes project type, BMP type and category, Stream type and category, proposed project type, project description, BMP retrofit information, stream erosion score and bank height, notes, photo references, cost factors, and evaluation scores.

- **BMP Polygon File** containing all of the GIS analysis and PCWMM data for the BMPs including land use, area, proposed project dry and wet volumes, ownership, number of parcels impacted, PIN numbers, floodplain information, and tax values.
- **Stream Polyline File** containing all of the GIS analysis and PCSWMM data for the Stream Projects including land use, ownership, number of parcels affected, PIN numbers, tax values, floodplain, and greenway information.
- **WIP Tools GRID File** containing all of the information required to run WIP Tools or generated in WIP Tools including BMP and Stream existing and proposed pollutant removal efficiencies; existing and proposed channel protection discharges; required water quality, 1-year, and 10-year volumes; drainage area; impervious cover; WIP Tool Scenarios for BMP and Stream projects (True/False fields for individual projects); and pollutant loads and reductions based on the Single Project Scenario.

Figure 7-2. Geodatabase Components



The four Project Geodatabase file components were developed from multiple sources:

- BMP Field Inventory
- Stream Field Inventory
- GIS spatial analysis of existing City and County data including watershed and City boundaries, impervious area, floodway mapping, NWI wetlands, hydrology, existing and future land use, parcels, roadways, greenways, topography, and water, sewer, and stormwater infrastructure
- WIP Tools Model results
- Project Prioritization Tool results
- Direct data entry

Additional details on the Project Geodatabase development may be found in Appendix J of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

7.3 Pilot Study Areas

The Ellerbe Creek Watershed was originally delineated into 33 smaller subwatersheds. Of these subwatersheds, five pilot study areas (PSAs) were identified for detailed hydrologic, hydraulic, and water quality modeling of BMPs, stream restoration projects, and other stormwater quality measures (e.g., Better Site Design and LID techniques, stormwater performance standards for new development/redevelopment). Once the detailed modeling was completed, the hydrologic, hydraulic, and water quality benefits could be extrapolated to the other subwatersheds based on similarities to the five PSAs.

The following criteria were used to select representative subwatersheds throughout the Ellerbe Creek basin: (1) mix of land use types (existing and future); (2) number and type of existing BMPs; (3) flow dynamics (piped vs. open channel); (4) percentage of impervious area; (5) retrofit and new BMP opportunities; (6) and stream restoration and stabilization opportunities.

The recommended PSAs were Subwatersheds 1, 8, 17, 24 and 30, as shown on Figure 7-3. These areas were selected because they are representative of the conditions found throughout the entire watershed. The five recommended PSAs are spread across the watershed and range from the western most headwaters (Subwatershed 1) to the eastern lowlands area (Subwatershed 30). Each subwatershed has a unique mix of land use types including areas that are highly urbanized with built-out conditions to largely undeveloped areas, as described below:

- Subwatershed 1 contains the headwaters of Ellerbe Creek; diverse land use types; opportunity for growth; and abundance of existing BMPs and potential for new BMPs.
- Subwatershed 8 represents the headwaters of South Ellerbe Creek; typical of the highly developed central portion of the watershed; includes Duke East Campus and Walltown Park; and has several opportunities for stream restoration and BMP sites.
- Subwatershed 17 located centrally in the northern half of the watershed; beginning to see development of vacant land into residential homes and local parks; and potential for new BMPs and a BMP retrofit opportunity.
- Subwatershed 24 represents a tributary of Goose Creek that is primarily low density residential and agricultural land; no existing BMPs in the subwatershed; great potential for new BMPs and stream restoration projects.
- Subwatershed 30 located in the lower portion of Ellerbe Creek that is still under the City's jurisdiction; beginning to see the conversion of agricultural land into residential neighborhoods; provides good opportunities to install new BMPs and preserve high-quality streams and their riparian corridors.

Each of the remaining 28 subwatersheds were assigned to a PSA that most closely matches the conditions found within each subwatershed and the types of potential water quality and stream restoration projects that are available. The PSA to subwatershed assignments are listed in Table 7-1. The application of the PSAs in analyzing the watershed improvement scenarios is described in Section 8.8. More detailed information on the PSAs, including the Pilot Study Area Fact Sheets, may be found in Appendices B and J of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

Table 7-1. Pilot Study Area to Subwatershed Assignments

Pilot Study Area	Similar Subwatersheds
1	4, 5, 10, 23, 26, 27
8	6, 7, 12, 13, 14, 15, 16, 18, 19, 20, 22
17	3, 9
24	2, 11, 21, 25, 29
30	28, 31, 32, 33

7.4 PCSWMM

PCSWMM.NET, a modified version of the EPA's SWMM developed by the Computation Hydraulics Institute, is a comprehensive and versatile tool that allows both water quantity and water quality analyses for watersheds comprised of a complex, interconnected system of open channels, closed conduits, roadways, constructed stormwater management facilities and BMPs. The PCSWMM model was used to evaluate the potential new and retrofit BMPs within the PSAs as well as provide detailed information for stream restoration and stabilization projects within the Ellerbe Creek Watershed.

The modeling methods for the detailed PSAs and the watershed-wide model are outlined in the following sections. Additional details on the PCSWMM model development and methods may be found in Appendices G and H of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

7.4.1 Approach

PCSWMM was used for preliminary sizing and determining the available water quality treatment volume for retrofits to existing stormwater BMPs and proposed new stormwater BMPs. The PCSWMM networks for the pilot study areas and the watershed-wide model are shown in Figure 7-4. In the PSAs, the potential retrofits to existing BMPs and the proposed new BMPs were modeled. The base stream network includes all stream segments with at least 40-acres of drainage, which is also the basis for the network in WIP Tools. Additional stream and pipe segments leading up to existing or potential new BMPs were included in the PCSWMM model. Also, pipes greater than 24-inches in diameter significant to hydraulic routing and routing through downstream BMPs and culverts at major road crossings were included.

This watershed-wide model was constructed at the catchment level and was linked by open channels or pipes. The majority of the 33 subwatersheds within the Ellerbe Creek watershed were further subdivided into approximately 89 catchments. Several subwatersheds, such as numbers 12 and 21, were not subdivided into smaller catchments due to their size and land use distribution within the subwatershed.

Most of the watershed-wide model was constructed with open channel sections based on the FEMA floodplain model or LiDAR data where available. Open channel sections, in most cases, were defined as one reach representative of the catchment. For longer reaches such as through subwatershed 23, multiple stream segments were used.

7.4.2 Model Development

The Ellerbe Creek Watershed PCSWMM model is comprised of the following major components:

- Precipitation data;
- Rainfall loss (infiltration) model (this model can estimate the volume of runoff, given the precipitation, land cover, and soil properties of the watershed);
- Direct runoff model (this model accounts for overland flow, storage, and energy losses as water runs off a watershed and into the stream channels);
- Hydrologic and hydraulic routing models (combined these models account for storage and energy flux as water moves through stream channels); and
- Hydraulic components models (open and closed conduits as well as natural channels, storage/treatment units or BMPs, headwalls, manholes, and weirs for various flow regimes).

Three design storms were simulated with PCSWMM for both existing and future land use conditions: (1) the City's water quality event; (2) the 10-year, 24-hour storm; and (3) the 25-year, 24-hour storm.

7.4.3 Model Validation

The output data of hydrologic and hydraulic models (H&H models), such as PCSWMM, have uncertainty based on the methods used in the model and the reliability of the model input data. Validation of H&H models to measured flow data or values generated by empirical equations based on watershed characteristics (e.g., drainage area, impervious cover) is typically used to improve the reliability and usefulness of the model. Typically, the initial runoff volumes and peak discharges generated by the H&H models are compared directly to historical flow data, when available, or values generated by an empirical method, such as the USGS regression equations for North Carolina. Once a comparison is made, key variables in the H&H models are adjusted to produce comparable results. This iterative process is called model validation. For the Ellerbe Creek Watershed model, initial adjustments to the model input data were focused on matching runoff volumes, with additional adjustments made to match peak flows.

Typically validation includes historical data from USGS stream gages and monitoring sites. Ellerbe Creek watershed has one USGS gage station (#2086849) and it is located in the downstream portion of the watershed near Falls Lake, as shown on Figure 7-4. The measured data for this station were reviewed and no suitable historical storm events were found to allow for validation; therefore, runoff volumes generated by the simple method and peak discharges generated by the USGS regression equations were used to validate the watershed-scale PCSWMM model.

In order to sample a range of conditions and locations, eight locations were selected to serve as model validation points, as shown on Figure 7-4:

- At the outlet of the PSAs 1, 8, 17, and 24;
- South Ellerbe Creek near its confluence with Ellerbe Creek;
- Goose Creek near its confluence with Ellerbe Creek;
- Main stem of Ellerbe Creek in the middle of the watershed at Roxboro Street; and
- USGS gage location located near Falls Lake.

Since the WIP Tools Model uses the simple method for volume estimates and the USGS regression equations for peak flows, it was used to generate the runoff volume for the City's water quality design storm and peak discharges for the 2-year and 10-year storm events to serve as the basis for validation of the results from the PCSWMM model.

Several factors influence the volume of runoff generated in the PCSWMM model, but one of the primary factors is the percentage of impervious area. To validate the water quality runoff volumes, this parameter was selected for calibration. Based on the initial model results, the runoff volumes in the PCSWMM model appeared to be too low, so the percentage of impervious area in each catchment was increased by a value of 1.2 (which equals a 20-percent increase in the initial estimates of impervious percentage) to yield the best results.

As with runoff volume, many parameters can affect the peak discharge. One of these parameters is the catchment width, which is difficult to derive. Since this parameter contains uncertainty, it is often selected as a model validation parameter. Based on the initial model results, the peak discharges in the PCSWMM model appeared to be too high, so the catchment width was reduced by a factor of 0.2 to yield the best results. Additional details on the validation of the PCSWMM model may be found in Appendices G and H of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

7.5 WIP Tools

The WIP Tools is a grid based GIS model used to evaluate hydrological and water quality conditions and aids in the development of Watershed Improvement Plans. WIP Tools is deployed as an extension in ArcMap. After installation, enabling the extension adds a toolbar to the interface. Spatial analyst must also be engaged in order to use WIP Tools. WIP Tools works in a systematic manner starting at the first menu item and then continuing down the menu list. One of the outputs of the WIP Tools extension are maps that can be used to define areas of high pollutant loads and how proposed projects could reduce these loads. A digital elevation model (DEM) grid provides the topographic basis for a model. In addition to grid data, polygon data for land use (or impervious cover) and lakes and point data for stream inventory data collection points and proposed projects are required inputs. About two dozen grids representing a variety of physical parameters (e.g., cumulative drainage area, runoff volume, sediment load) are created during an analysis. Several line themes are also generated during a study, these represent streams, cumulative impervious cover, and pollutant loads.

The information derived from this method and modeling approach is used to guide the strategy for selecting and prioritizing water quality improvement projects. One of the primary benefits of WIP Tools is the ability to select the projects that provide the best cost benefit and are in the area of need based on physical conditions in the watershed. WIP Tools also allows for the development and analysis of multiple proposed watershed improvement scenarios. The multiple scenarios provide the ability to select the plan most suitable to the meet the objectives of the Watershed Management Improvement Plan.

Additional details on the WIP Tools Model development and methods may be found in Appendix I of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

7.5.1 Model Development

The inputs to the WIP Tools Model for the Ellerbe Creek Watershed include the following:

- **Drainage Network.** Based upon a digital elevation model (DEM), the standard ESRI D8 flow direction algorithm is used to develop a flow direction raster which is then accumulated to develop the cumulative drainage area raster for the watershed. DEMs generally reflect the ground surface, but not the underlying stormwater pipe network. Therefore, the base DEM for Ellerbe Creek Watershed, developed from LIDAR data provided by the North Carolina Flood Plain Mapping program, was modified to reflect the constructed stormwater drainage network based on GIS data obtained from the City. The process used is call DEM reconditioning and uses a selected polyline file to modify the DEM. The polyline file used for Ellerbe Creek Watershed is a combination of the stormwater pipe and stormwater channels GIS files.
- **Impervious Cover.** The basis of the impervious cover used in the model is a polygon vector file developed from 2007 impervious area data provided by the City. The analysis performed by the model uses raster data in order to fully describe the study area in a continuous manner. In order to better characterize the impervious surface a smoothing method is used to obtain values that are between 0 to 100 percent in grid cells that contain some impervious area but are not completely impervious.
- **Hydrology.** Peak discharges and runoff volumes are required to evaluate watershed conditions and to appropriately design and size BMP and stream restoration projects. Since the WIP Tools Model characterizes the study area in a continuous manner, the hydrology parameters are also developed as rasters and allow the user to readily obtain information throughout the watershed. The water quality volume, 1-year and 10-year volumes, and the 2-year and 25-year peak discharges are calculated for each BMP and Stream Project using WIP Tools.
- **Pollutant Production and Transport.** The formulations for pollutant production and transport are generalized to address both conservative (i.e., nitrogen, phosphorus, and sediment) and non-conservative

(i.e., fecal coliform bacteria) constituents where 1st order growth or decay is applicable. Multi-constituent interaction and more complex production and transport relationships are not supported. In the analyses presented herein, upland pollutant production is calculated using pollutant specific loading rates for specified land use types. In addition, each constituent has a potential stream production component. For example, stream production of sediment is estimated based upon streambank and streamflow characteristics, which specify streambank erodibility and streamflow erosivity. For the other pollutants of interest (i.e., nitrogen, phosphorus, and fecal coliform), the stream transport of the pollutants is achieved using a similar stream production (or decay) formulation.

- **Watershed Improvement Scenarios.** The WIP Tools Model provides for the development of a baseline conditions model and multiple watershed improvement scenarios. The baseline conditions model reflects existing or future land use prior to the implementation of any stormwater quality project. The WIP Tools Model may then be used to evaluate the benefits of existing stormwater quality BMPs and current stream conditions. For each watershed improvement scenario, the user may select non-point source or point source projects or measures to implement. The WIP Tools Model was then used to evaluate alternative watershed improvement scenarios in the PSAs and ten watershed-wide improvement scenarios.

7.5.2 WIP Tools Users Guide

This User's Guide includes sections on Getting Started, Using the Tool, Analysis Methodologies and Grid-based GIS modeling. The User's Guide was provided under separate cover with the WIP Tools Application.

7.6 Land Use-based Pollutant Loading Rates

One important component of the input data for the WIP Tools Model is the land use-based pollutant export coefficients used to generate the average annual pollutant loads and yields within the watershed. The pollutant export coefficients for total nitrogen (TN), total phosphorus (TP), sediment, and fecal coliform for each land use type are presented in Table 7-2. Coefficients for total nitrogen, total phosphorus, and sediment are presented in pounds per acre per year (lbs/ac/yr). Fecal coliform is presented in colony forming units per acre per year (cfu * 10^9/ac/yr).

The land use-based export coefficients for total nitrogen, total phosphorus, and sediment are based on local and regional monitoring data, including the following:

- Upper Neuse Site Evaluation Tool (Tetra-Tech 2006);
- WATERSHEDSS pollutant budget estimation form developed by the Water Quality Group at North Carolina State University (Osmond et al 1995);
- Neuse River nutrient rules (NCAC 1998); and
- Jordan Lake TMDL Watershed Model (Tetra-Tech 2003).

Fecal coliform loading rates are based upon USGS Water Resources Investigations Report 99-4180 "Relation of land use to streamflow and water quality at selected sites in the City of Charlotte and Mecklenburg County, North Carolina" (Bales et. al 1999).

It should be noted that the export coefficients result from various constituent transport mechanisms. For example, nitrogen has significant surface water and groundwater delivery pathways to local streams whereas phosphorus loading from groundwater sources is usually quite limited. To an extent, nitrogen exports from a watershed, and even more strongly phosphorus exports, are linked to the sediment exports. The expected sediment export due to soil erosion from a given area depends upon a number of factors beyond the soil properties. These factors include the rainfall intensities in the region, soil cover and land management practices, and slope. Fecal coliform may be delivered by surface runoff or by groundwater discharges from areas that have poorly performing septic systems or leaking/failing sanitary sewers.

Table 7-2. Ellerbe Creek Watershed Pollutant Export Coefficients				
Land Use Type	TN (lbs/ac/yr)	TP (lbs/ac/yr)	Sediment (lbs/ac/yr)	Fecal Coliform (cfu*10^9 /ac/yr)
Residential				
High Density	8.6	0.7	600	9.1
Medium Density	4.7	1	200	9.1
Low Density	2.4	0.3	50	6.9
Very Low Density	1.2	0.2	40	6.9
Commercial	13.9	1.7	860	2.7
Institutional	4.2	0.7	100	9.1
Industrial	9.4	0.8	750	2.7
Agriculture				
Animal Operations	35.0	2.5	1000	75
Row Cropping/Pasture	7.5	1.1	200	8.7
Parks and Open Space	1.8	0.2	35	7.9
Roads and Right-of-Way	9.3	1.7	980	2.7

These pollutant export coefficients are multiplied by the area of each land use type to generate the long-term, average annual pollutant load from each land use type. Pollutant loading results for the existing and future land use conditions as well as the watershed management scenarios evaluated to improve water quality are presented in Section 8 of this Report.

7.7 Point Source Pollutant Loading Rates

To accurately assess the water quality conditions in Ellerbe Creek and the overall pollutant loads from Ellerbe Creek into Falls Lake, an estimate of the pollutant contribution from the sanitary sewer collection system and the North Durham Water Reclamation Facility is required for total nitrogen, total phosphorus, sediment, and fecal coliform. The pollutant loads for these four parameters from the sanitary sewer collection system are based on recorded sanitary sewer overflows, leaky sanitary sewers, and illicit connections in the Ellerbe Creek watershed.

The City has provided documentation of the sanitary sewer overflows (SSOs), leaky sanitary sewers, and illicit connections in the Ellerbe Creek Watershed investigated by City staff from 1999 through 2007. For the WIP Tools Model, the collective pollutant load from the sanitary sewer collection system was consolidated into 10 point sources, as shown on Figure 7-5. The annual pollutant loads assigned to the 10 point sources in the WIP Tools Model are documented in Table 7-3.

Table 7-3. Point Source Loads from the Sewer Collection System					
Point Source ID	Volume (gal/yr)	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Sediment (lbs/yr)	Fecal Coliform (cfu^9/yr)
PS-Sub2	12,300	4.1	1.0	74	2,330
PS-Sub8	578,100	193	48	3,473	109,403
PS-Sub11	3,500	1.2	0.3	21	665
PS-Sub14	8,600	2.9	0.7	52	1,624
PS-Sub17	34,100	11.4	2.8	205	6,451
PS-Sub18	19,900	6.7	1.7	120	3,774
PS-Sub20	40,900	13.6	3.4	246	7,739
PS-Sub21	13,400	4.5	1.1	81	2,537
PS-Sub24	14,300	4.8	1.2	86	2,703
PS-Sub26	11,600	3.9	1.0	70	2,200

The pollutant loads from the North Durham WRF are based on monitoring data provided by the City's Water Department. The average effluent concentrations and average annual pollutant loads for total nitrogen, total phosphorus, sediment, and fecal coliform are documented in Table 7-4. These are based on the average effluent concentrations and the current average daily flow rate of 8.4-million gallons per day. The pollutant load from the North Durham WRF is represented as a separate point source load, as shown on Figure 7-5.

Table 7-4. North Durham WRF Annual Pollutant Loads		
Pollutant	Average Effluent Concentration	Average Annual Load
Total Nitrogen	3.3-mg/L	83,200-lbs/yr
Total Phosphorus	0.4-mg/L	8,360-lbs/yr
Sediment	5.8-mg/L	137,800-lbs/yr
Fecal Coliform	45-cfu/100mL	12,740-cfu*10^9/yr

7.8 BMP Pollutant Removal Efficiencies

Table 7-5 presents the average annual BMP removal efficiencies that were applied in the WIP Tools Model to calculate pollutant load reductions for each existing and proposed stormwater quality BMP. These removal efficiencies were estimated for all stormwater quality BMPs that meet the design criteria established by the City of Durham Stormwater Services and the design criteria contained in the North Carolina BMP Design Manual.

Table 7-5. Average Annual Pollutant Removal Efficiencies for BMPs (in Percent)

BMP Type	Pollutant Removal (%)			
	Total Nitrogen	Total Phosphorus	Sediment	Fecal Coliform
Dry Pond (Peak Shaver)	1	5	50	10
Enhanced Dry Pond	5	10	55	15
Extended Detention Dry Pond[1]	15	20	70	20
Wet Pond	25	40	80	50
Constructed and Pocket Wetlands	35	40	70	50
Sand Filter	20	45	80	40
Enhanced Sand Filter with Peat/Sand	35	45	80	40
Bioretention Area	40	60	80	60
Vegetated Swale	10	20	60	20

[1]Release the stormwater runoff from a one-inch storm event between 2 and 5 days.

The removal efficiencies presented in Table 7-5 represent the average removal efficiencies for specific stormwater BMP categories. The removal efficiencies for existing BMPs may have been reduced based on the results of the BMP inventory and assessment. For example, if the existing BMP does not have adequate storage volume to contain the stormwater runoff resulting from the City's water quality design storm, then the removal efficiency was reduced accordingly.

For proposed new BMPs within the five PSAs, the removal efficiency was determined upon the results of a detailed hydraulic analysis using the PCSWMM model. The detailed evaluation verified that adequate storage volume, detention times, peak discharge rates, and other important design factors outlined in the City and State BMP design manuals were met in order to assign the removal efficiencies presented in Table 7-5. If one or more of the design criteria could not be met at the proposed new BMP site, then the removal efficiencies were reduced accordingly.

For the water quality evaluation of new stormwater BMPs located outside of the five PSAs, the BMPs were assigned the average annual pollutant removal efficiency listed in Table 7-5. Additional information on BMP pollutant removal efficiencies and assignments may be found in Appendix F of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

Once the stream restoration and stabilization projects are implemented, Ellerbe Creek and its tributaries also have the ability to remove pollutants and improve overall water quality. To account for these water quality benefits in the WIP Tools Model, pollutant removal efficiencies for stream restoration and stabilization projects have been assigned for each water quality parameter:

- Stream Preservation, Restoration, Enhancement Levels 1 and 2, and Stabilization:
  - Total Nitrogen removal of 0.02 pounds per linear foot (lbs/lf)
  - Total Phosphorus removal of 0.004 lbs/lf
  - Sediment removal of 2.25 lbs/lf
  - No Fecal coliform removal assigned
- Buffer Restoration: No pollutant removal assigned

The pollutant removal efficiencies are included in a GIS geodatabase that generates the input data for the WIP Tools Model. The WIP Tools Model allows the user to alter the pollutant removal efficiencies on a project by project basis. Additional information on stream project pollutant removal efficiencies and assignments may be found in Appendix F of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

ELLERBE CREEK WATERSHED
MANAGEMENT IMPROVEMENT PLAN

8. WATERSHED IMPROVEMENT SCENARIOS AND RESULTS

8.1 Introduction

One of the objectives of the Ellerbe Creek Watershed Management Implementation Plan is to develop watershed-wide scenarios and alternatives to improve the water quality of Ellerbe Creek and the overall health of the watershed. To develop the watershed-wide scenarios, PCSWMM and the WIP Tools Models were used to evaluate potential solutions and their combinations. Parameters identified for evaluation in this plan were total nitrogen (TN), total phosphorus (TP), sediment, and fecal coliform (FC).

BMP and Stream projects were evaluated individually using PCSWMM, WIP Tools, and the Project Prioritization Tool. The evaluation criteria that drove the ranking of the projects are discussed in Section 8.2. The criteria were developed after several public workshops and meetings with the City.

The WIP Tools Model generated pollutant loads throughout the watershed and pollutant reductions were summarized at key points within the watershed. Each watershed improvement scenario was evaluated based on its pollutant reduction and cost to meet specific watershed goals. The following water quality goals were used in evaluating the scenarios (or alternatives):

- **Total Nitrogen.** 7.5 lb/ac/yr based on the Interim Strategy for Falls Lake, which represents a 40 percent reduction of the existing (based on 2006 data) total nitrogen yield from the Ellerbe Creek Watershed at the city limits
- **Total Phosphorus.** 0.38 lbs/ac/yr based on the Interim Strategy for Falls Lake, which represents a 77 percent reduction of the existing (based on 2006 data) total nitrogen yield from the Ellerbe Creek Watershed at the city limits
- **Sediment.** 1,600 lbs/ac/yr based on field studies relating healthy aquatic communities to sediment yields in streams in the northern Piedmont region of Georgia
- **Fecal Coliform.** 5.1 cfu x 10^9/ac/yr based on meeting the 200 cfu/100mL water quality standard for North Carolina and the average annual flow measured by the USGS

A brief overview of the watershed improvement scenarios, and their results and costs are presented in Section 8.3.

8.2 Prioritization Criteria

When developing a WMIP, a sound approach must be employed to evaluate and prioritize potential projects. One method of evaluation is the development of prioritization criteria. The prioritization criteria cover a range of considerations that are important in the implementation of a potential watershed improvement project. The criteria may include items such as constructability of the project; water quality and environmental benefits; permitting issues; public benefits and acceptance; and capital and long-term maintenance costs. By applying the criteria in a systematic method each potential project may be objectively evaluated and compared.

Table 8-1 outlines the prioritization criteria that were applied to each potential project for the WMIP. There are 14 criteria that are divided into six categories. Each criterion has a score range from 0 to 5, with 0 representing no benefit and 5 showing substantial benefits. In addition, Table 8-1 lists the weighting factor for each criterion. The weighting factor allows certain prioritization criteria to given higher priority over other criteria based on local watershed conditions or goals of the watershed improvement plan. Each potential project was assigned a score for each criterion and then the criterion score was multiplied by the weighting factor. The sum of these calculations is the project evaluation score.

Table 8-1. Proposed Prioritization Criteria

Category	Criteria	Score Range	Weighting Factor	Score x Weighting Factor
Water Quality Treatment				
	Nitrogen	0 – 5	2.5	0 – 12.5
	Phosphorus	0 – 5	1	0 – 5
	Sediment	0 – 5	2.5	0 – 12.5
	Fecal Coliform	0 – 5	1	0 – 5
Habitat and Biological Integrity				
	Habitat/Biology	0 – 5	3	0 – 15
Stream Bank Protection				
	Stream Bank Protection	0 – 5	2	0 – 10
Community Enhancement				
	Property Protection	0 – 5	1	0 – 5
	Property Owner and Neighborhood Acceptance	0 – 5	1	0 – 5
	Public Education	0 – 5	2	0 – 10
Implementation Issues				
	Property Ownership	0 – 5	1	0 – 5
	Accessibility for Construction and O&M	0 – 5	1	0 – 5
	City Program Compatibility	0 – 5	0.5	0 – 2.5
	Permitting/Adverse Environmental Impacts	0 – 5	0.5	0 – 2.5
Public Safety and Public Property				
	Public Safety and Public	0 – 5	1	0 – 5
Project Evaluation Score				0 – 100

A brief description of each prioritization criteria is included below. Additional details on the prioritization criteria, including specific scoring guidance for each criterion and equations, may be found in Appendix K of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

8.2.1 Water Quality Criteria

Four water quality parameters are considered in the project evaluation process. These include total nitrogen, total phosphorus, sediment, and fecal coliform. The project specific estimate of pollutant removal is based on the pounds of pollutant removed divided by the present value of the project's estimated life-cycle cost (where present value equals the estimated costs of planning, design, permitting, construction, and 20 years of operation and maintenance of the project). The following equation was used to calculate the project specific pollutant removal efficiency for both BMP and stream projects:

*Pollutant Removal Efficiency (units/year per dollar) = (Treatment Area Pollutant Loading (units/year) * Average Annual Removal Efficiency) / Present Value of the Estimated Project Life-Cycle Cost*

The average annual pollutant removal (lbs/year or cfu/year) for each project was assessed using the WIP Tools Model. Thresholds for cost per pound of pollutant removed were used to score the projects. Based upon the range of pollutant removal efficiencies for the BMP and stream projects estimated by the initial results from the WIP Tools Model, the following cost thresholds were used to assign the water quality score for each project:

- Total Nitrogen: $50,000 per pound
- Total Phosphorus: $200,000 per pound
- Sediment: $100 per pound
- Fecal Coliform: $50,000 per cfu*$10^9$

8.2.2 Habitat and Biological Integrity Criteria

Habitat assessments are often performed to better understand the biological integrity of a stream. A good habitat assessment does not directly imply healthy biota; however, the habitat quality is considered an indicator of the biological integrity.

BMP Projects. Development of a watershed greatly increases the storm-induced flows for a stream and often destroys habitat. Providing detention lessens the flow and thus protects the habitat. The length of channel protected was used to evaluate BMPs and was defined as the point downstream of the BMP where the 1-year peak discharge after installation of the BMP is equal to the 1-year discharge at the BMP prior to installation.

Stream Projects. Scoring of this criterion is based on how well a project could improve the aquatic habitat conditions. Scores were calculated based on results of the Rapid Stream Assessment Technique (RSAT) as a percentage of a maximum score of 60 or the Level 1 Bank Stability rating for each reach, which indicates the ability of the proposed project to improve overall aquatic habitat conditions. The closer the RSAT score was to 60, the lower the project benefits since the stream already has relatively good habitat conditions and a lower level of potential improvement.

Riparian Buffer Restoration Projects. Riparian buffers also benefit water quality, habitat, and biological integrity. Therefore, these projects were assigned a habitat and biological integrity score between 0 and 5 based upon the potential width of the restored vegetated buffer.

8.2.3 Stream Bank Protection Criteria

Stream bank protection, as the name implies, is scored based upon the ability of the BMP or stream project to provide protection for stream banks.

BMP Projects. BMPs in the Neuse River Basin are required to detain the runoff generated by the 1-year, 24-hour storm volume for a period of 24 hours. Stream bank protection scores were assigned based on a minimum of a 1-year storm volume retention and were scaled downward to volumes retaining the water quality storm (1 inch of rainfall in 24 hours).

Stream Projects. Restoration projects received a score based on the project length.

8.2.4 Community Enhancement Criteria

A major factor in implementing any capital improvement project is the public perception, benefit, and acceptance of the proposed project. The following section indicates how scores are calculated for BMP and stream projects for property protection, property owner and neighborhood acceptance, and public education.

8.2.4.1 Property Protection

BMP Projects. By detaining stormwater, a BMP can reduce the flood peak and thus provide flood protection to downstream property. If a BMP had adequate volume to detain the 10-year runoff volume, it was eligible to receive credit for property protection.

Stream Restoration Projects. Scoring of this criterion was based on how well a project would reduce the immediate threat of erosion along adjacent properties. Scores were calculated based on erosion conditions observed during the stream assessment and the ability of the proposed project to reduce any erosion threats.

Riparian Buffer Restoration. Since riparian buffer restoration projects typically result in protection of the floodplain and limit development close to the creek, all riparian buffer restoration projects receive a score of 2 for property protection.

8.2.4.2 Property Owner and Neighborhood Acceptance

BMP Projects. Previous experience indicates that commercial or industrial areas are often more accepting of proposed stormwater related projects while residential areas present more opposition. As a result, the score for BMP projects for this factor was based on the land use of the property where the proposed BMP is located. The land use was determined using GIS data.

Stream Restoration Projects. Restoration projects in and along streams are usually considered aesthetically pleasing and can protect adjacent property. Therefore, it is assumed that stream restoration and stabilization projects are more readily accepted by the surrounding community and were assigned a score of 4.

8.2.4.3 Public Education

All projects located on school property or within existing public parks and open space receive a maximum score of 5. If the project was the first of its kind within a 1-mile radius and was observable by the general public, it received a maximum score of 5. If the project has little direct public education benefit, but improves the overall site aesthetics, it received a maximum score of 4.

8.2.5 Implementation Criteria

The implementation issues component focuses on four areas that play into the successful completion of a proposed retrofit to an existing BMP, a proposed new BMP, or stream restoration or stabilization project. These factors include property ownership, city program compatibility, permitting/adverse environmental impacts, and accessibility for construction and operation and maintenance. All factors with the exception of permitting/adverse environmental impacts are uniform for both BMP and Stream projects.

8.2.5.1 Property Ownership

If the project site consists of multiple parcels, then it is assumed that it would be more difficult to implement than a project consisting of fewer parcels. However, if the property is owned by the City, then property ownership is not considered a constraint. Therefore, publicly-owned properties received higher scores.

8.2.5.2 City Program Compatibility

Another consideration is the compatibility of a proposed project with other, non-stormwater related, City programs. Compatible programs include Greenways programs or revitalization plans. Projects were also scored based on compatibility with watershed objectives.

8.2.5.3 Accessibility for Construction and Operation and Maintenance (O&M)

The accessibility of the site from an existing road or parking lot for initial construction and long-term operation and maintenance activities was evaluated during the field visit. Projects were scored based upon how accessible the site was by both foot and vehicle.

8.2.5.4 Permitting/Adverse Environmental Impacts

BMP Projects. The environmental impact of the BMP has a direct relationship with an ability to implement the project. A project with significant adverse environmental impact (even if only a temporary impact) may result in extensive permitting, which may increase the cost and extend the time schedule for a project.

Upland BMPs are assumed to have little adverse environmental impact as they will not interfere with wetlands or floodplains. Each project site was evaluated to determine if it is within a 100-year floodplain. Also, the National Wetlands Inventory (NWI) mapping of wetlands compiled by the federal government was compared with project locations. It is assumed that any project located within a NWI wetland would have significant environmental impact and should be preserved rather than changed to include a BMP and was therefore assigned a score of 0.

Stream Restoration and Buffer Restoration Projects. The majority of stream projects would have only minimal short-term impacts during construction and long-term positive impacts on stream habitat and water quality. Therefore, all stream restoration projects received a high score. All riparian buffer restoration projects also received a high score.

8.2.6 Public Safety and Public Property Criteria

Flood detention, culvert replacements, bank stabilization and other projects may provide direct protection to public safety and public property. Projects which have no direct benefits upon public safety or public property are assigned a score of 0. Projects which prevent street flooding or other damage to public property for design events from the 10-year storm to the 25-year storm were assigned a range of scores from 0 to 5.

8.3 Project Prioritization Tool

The Project Prioritization Tool is a macro-based Excel spreadsheet that performs several functions, including calculating project costs, project evaluation scores, proposed BMP pollutant removal efficiencies, and proposed channel protection discharges.

Project costs are calculated for BMPs based on small, medium, or large projects. Small projects are defined as those that are smaller than 10,000 cubic feet while large projects exceed 75,000 cubic feet. Approximately 17 percent of the proposed new BMPs or retrofits to existing BMPs fell into the small category, while 47 percent were medium-sized, and 36 percent were large-sized projects. The Project Prioritization Tool provides several tabs where the end-user may alter quantities and unit costs for BMP retrofits, new BMPs, and stream projects.

Project prioritization or evaluation scores are calculated in the Project Prioritization Tool based on the results of the detailed PCSWMM analyses, the stream and BMP field inventories, the project costs (specifically for the water quality score), and the Single Project Scenario in WIP Tools. The Single Project Scenario generates the pollutant reduction achieved by each project as though it were implemented individually and not part of a series of water quality projects. This is used in conjunction with the project cost to determine the water quality score. The prioritization criteria including six categories (water quality treatment, habitat and biological integrity, stream bank protection, community enhancement, implementation issues, and public safety), are further described in Section 8.2.

8.3.1 Application of the Project Prioritization Tool

The Project Prioritization Tool is the end-user of the Project Geodatabase. It is through the Project Geodatabase that all the information from the PCSWMM analyses, the BMP and stream field inventories, and the Single Project Scenario WIP Tool results are stored. The results of all these tools are incorporated into the Project Geodatabase for use in the Project Prioritization Tool.

The results of the prioritization scores were used to determine the most water quality efficient projects within each PSA. These results determined the pollutant removal efficiencies assigned to the remainder of the watershed to evaluate the effectiveness of implementing new regional BMPs, stream restoration projects, and retrofitting existing BMPs. The results of this evaluation are documented in Section 8.4.

The total project prioritization scores were used to determine the high-priority water quality improvement projects WMIP and the implementation year. The Project Prioritization Tool also has the function to estimate the total present value cost of the project based on the year the project is recommended in the WMIP (i.e., cost escalation factor if the project is implemented several years in the future).

8.3.2 Integration with WIP Tools Model

As noted earlier, the Project Prioritization Tool calculates the proposed BMP pollutant removal efficiencies and proposed channel projection discharges. These are calculated based on the required water quality and 1-year storage volume and the actual volumes the proposed BMPs provide. The required water quality and 1-year volumes are initially calculated in the WIP Tools Model and incorporated into the project geodatabase. The project geodatabase is imported into the Project Prioritization Tool where the new efficiencies and discharges are calculated (e.g., the actual volumes were derived from GIS and PCSWMM evaluations and are previously incorporated into the project geodatabase). The new BMP pollutant removal efficiencies and channel protection discharges are exported out of the Project Prioritization Tool to the WIP Tools grid file (discussed in Section 7.2). The new WIP Tools Grid file is used to run the Single Project Scenario in WIP Tools to generate the individual pollutant reduction achieved by each project. This integration of the Project Prioritization Tool results back into the WIP Tool is only done once in the course of a project. All other watershed scenario results from WIP Tools are included in the project geodatabase and used in the Project Prioritization Tool to calculate overall costs of the watershed scenarios.

8.4 Watershed Scenarios

Ten watershed improvement scenarios were evaluated to assess the effectiveness of stormwater quality BMPs, stream restoration and stabilization projects, other non-point source management practices, and point source controls on improving water quality and watershed function within the Ellerbe Creek watershed. The water quality benefits of many of the scenarios presented in this section are tabulated at 12 summary points distributed at key locations throughout the watershed, as shown on Figure 8-1:

- PSA 1: located at the outlet of Pilot Study Area 1;
- PSA 8: located at the outlet of Pilot Study Area 8;
- South Ellerbe Creek: located on South Ellerbe Creek just upstream of its confluence with Ellerbe Creek;
- Murray Avenue: located on the main channel of Ellerbe Creek at Murray Avenue;

- Roxboro Road: located on the main channel of Ellerbe Creek at Roxboro Road;
- PSA 17: located at the outlet of Pilot Study Area 17;
- PSA 24: located at the outlet of Pilot Study Area 24;
- Goose Creek Tributary: located at the downstream end of the western tributary of Goose Creek;
- Goose Creek: located on Goose Creek just upstream of its confluence with Ellerbe Creek;
- City Limits: located on the main channel of Ellerbe Creek at the City limits;
- USGS: located on the main channel of Ellerbe Creek at the USGS monitoring station; and
- Falls Lake: located on the main channel of Ellerbe Creek at its discharge point into Falls Lake.

The results at these summary points are reported as a "pollutant yield," which equals the total annual pollutant load divided by the cumulative drainage area at that location. Pollutant yield is expressed as pounds per acre per year (lbs/ac/yr) for total nitrogen, total phosphorus, and sediment; and as colony forming units per acre per year (cfux10^9/ac/yr) for fecal coliform. Additional details on the WIP Tools Scenarios and Results may be found in Appendix L of the Ellerbe Creek WMIP Volume 3: Technical Appendices.

8.5 Scenario 1 – Baseline Conditions

Scenario 1 represents the pollutant yield without the effect of existing stormwater BMPs and proposed watershed improvement projects. This scenario does not include the water quality benefits of any existing stormwater BMPs or the effect of high-quality stream reaches (designated for preservation). Results for the baseline conditions scenario were generated using both existing and future land use conditions. This scenario provides a mechanism for the City to demonstrate the water quality improvements achieved by the existing stormwater BMPs by comparing the results to Scenario 2. Results for the baseline conditions at the 12 summary points distributed throughout the watershed are presented in Table 8-2.

Table 8-2. Results for Scenario 1: Baseline Conditions

Summary Points	Drainage Area (acres)	Total Nitrogen		Total Phosphorus		Sediment		Fecal Coliform	
		Existing Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Existing Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Existing Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Existing Yield (cfu x 10^9 /ac/yr)	Future Yield (cfu x 10^9 /ac/yr)
PSA 1	655	6.4	5.9	0.9	0.7	710	730	3.8	3.2
PSA 8	497	8.2	8.6	1.3	1.4	2,660	2,680	223.9	223.7
South Ellerbe Creek	1,814	7.8	7.9	1.2	1.3	2,870	2,850	64.6	64.6
Murray Avenue	3,370	5.7	5.7	0.9	0.9	1,240	1,240	5.1	5.1
Roxboro Road	5,815	6.3	6.3	1.0	1.0	1,910	1,900	23.7	23.7
PSA 17	405	5.1	5.3	0.9	1.0	600	610	21.5	21.7
PSA 24	506	5.9	5.4	0.9	0.6	1,690	1,740	10.9	9.7
Goose Creek Tributary	2,875	7.0	7.2	1.1	1.1	3,730	3,750	9.9	9.5
Goose Creek	4,162	6.6	7.0	1.0	1.0	3,000	3,050	9.0	8.4
City Limits	13,057	12.6	12.7	1.6	1.6	2,240	2,260	15.5	15.3
USGS	14,188	11.9	11.9	1.5	1.5	2,180	2,190	14.5	14.3
Falls Lake	16,252	11.0	10.8	1.4	1.4	2,000	2,010	12.7	12.5

It should be noted that in some cases the yields under future land use conditions are smaller than existing land use conditions. This is caused by two factors: (1) the detailed parcel-based existing land use information and (2) the nature of the Future Land Use Plan. The existing land use data provided by Wake County is parcel based, while the future land use data provided the City's Planning Department identifies larger, multiparcel areas that are expected to contain similar land uses 20-years in the future. Since the future land use plan developed by the City is less detailed, it would result in small decreases in pollutant yields if implemented. For instance, in PSA 24, the existing land use is a mixture of low and medium density residential, commercial, and industrial land uses as well as parks and open space. The future land use plan calls for converting the subwatershed to primarily low density residential and industrial land uses with some parks and open space. The corresponding pollutant export coefficients associated with the future land use plan are lower overall than the export coefficients associated with the existing land uses. Therefore, if this conversion occurs, then loading from PSA 24 would be decreased. If the future land use plan does not occur as anticipated, the total pollutant loads (lbs/yr) and pollutant yields (lbs/ac/yr) under future conditions are underestimated in the WIP Tools Model.

8.6 Scenario 2 – Existing BMPs and Stream Conditions

Scenario 2 represents the pollutant yields based on the existing watershed and stream conditions while taking into account the water quality benefits of all existing BMPs and high-quality stream reaches. No BMP retrofits, new BMPs, stream restoration and stream stabilization projects, or other stormwater management measures are included in this scenario. The water quality benefits of 45 existing BMPs and 20 high-quality stream reaches recommended for preservation are included in this scenario. The 45 existing BMPs consist of:

- 14 wet ponds
- 18 dry pond peak shavers
- 3 constructed wetlands
- 2 pocket wetlands
- 8 sand filters

A breakdown of these projects by subwatershed is provided in Table 8-3. Twenty-seven of these existing BMPs are recommended for retrofit to improve their water quality performance. The water quality benefits associated with these 27 retrofit opportunities along with the new BMPs and stream restoration projects are assessed in Scenario 3 – Stormwater Quality BMP and Stream Restoration Projects.

Table 8-3. Number of Existing BMPs in Scenario 2

Subwatershed	Stream Preservation	Wet Ponds	Dry Pond Peak Shaver	Constructed Wetland	Pocket Wetland	Sand Filter
1	1	-	6	-	2	1
2	1	1	-	-	-	-
3	-	-	1	-	-	-
4	2	4	-	-	-	-
8	-	-	-	-	-	1
9	-	1	-	-	-	-
10	2	-	3	-	-	3
11	2	1	-	1	-	-
12	1	-	-	-	-	-
13	1	-	-	-	-	-
14	-	-	-	-	-	1
16	-	1	-	-	-	-
17	1	1	1	-	-	-
18	-	-	2	1	-	-
20	-	-	1	-	-	-
22	-	-	1	-	-	-
23	-	3	-	-	-	-
26	1	-	-	-	-	1

Table 8-3. Number of Existing BMPs in Scenario 2						
Subwatershed	Stream Preservation	Wet Ponds	Dry Pond Peak Shaver	Constructed Wetland	Pocket Wetland	Sand Filter
27	2	-	-	-	-	1
28	6	-	-	-	-	-
30	-	1	1	1	-	-
31	-	1	2	-	-	-
Total	20	14	18	3	2	8

Results for Scenario 2. The results for the existing conditions scenario under existing and future land use conditions are summarized below in Table 8-4 and Table 8-5. At the City limits, the 45 existing BMPs and high-quality stream reaches reduce the total pollutant load by less than 2 percent for all four water quality parameters: 0.4 percent for total nitrogen, 0.6 percent for total phosphorus, 0.3 percent for sediment, and 1.6 percent for fecal coliform. This is due to the fact that, when combined together, the 45 existing BMPs treat stormwater runoff from only 1,100 acres, which is less than 2 percent of the watershed. Since such a small portion of the watershed is affected by the existing BMPs, the water quality thresholds outlined in Section 8.1 are exceeded for each of the four water quality parameters under this scenario.

Table 8-4. Results for Scenario 2: Existing BMPs and Stream Conditions										
Summary Points	Drainage Area (acres)	Total Nitrogen		Total Phosphorus		Sediment		Fecal Coliform	
		Existing Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Existing Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Existing Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Existing Yield (cfu x 10^9 /ac/yr)	Future Yield (cfu x 10^9 /ac/yr)
PSA 1	655	6.2	5.8	0.9	0.7	680	700	3.8	3.2
PSA 8	497	8.2	8.6	1.3	1.4	2,650	2,670	223.9	223.6
South Ellerbe Creek	1,814	7.8	7.9	1.2	1.3	2,860	2,850	64.5	64.5
Murray Avenue	3,370	5.7	5.6	0.9	0.8	1,230	1,220	5.1	5.0
Roxboro Road	5,815	6.3	6.2	1.0	1.0	1,900	1,890	23.6	23.6
PSA 17	405	5.0	5.3	0.9	1.0	590	610	21.5	21.7
PSA 24	506	5.9	5.4	0.9	0.6	1,690	1,740	10.9	9.7
Goose Creek Tributary	2,875	7.0	7.2	1.1	1.1	3,720	3,750	9.8	9.5
Goose Creek	4,162	6.6	7.0	1.0	1.0	2,990	3,050	9.0	8.3
City Limits	13,057	12.5	12.6	1.6	1.6	2,230	2,250	15.5	15.6
USGS	14,188	11.8	11.9	1.5	1.5	2,170	2,180	14.5	14.5
Falls Lake	16,252	11.0	10.8	1.4	1.3	1,990	2,000	12.7	12.7

Table 8-5. Pollutant Reduction Provided by Existing BMPs under Future Land Use					
Summary Points	Drainage Area (acres)	Reduction in Pollutant Yield (%)			
		Nitrogen	Phosphorus	Sediment	Fecal Coliform
PSA 1	655	3%	4%	4%	1%
PSA 8	497	<1%	<1%	<1%	-
South Ellerbe Creek	1,814	1%	1%	<1%	-
Murray Avenue	3,370	1%	1%	1%	1%
Roxboro Road	5,815	1%	2%	1%	<1%
PSA 17	405	1%	1%	1%	-
PSA 24	506	-	-	-	-
Goose Creek Tributary	2,875	<1%	<1%	<1%	<1%
Goose Creek	4,162	<1%	<1%	<1%	<1%
City Limits	13,057	<1%	1%	<1%	2%
USGS	14,188	1%	1%	<1%	2%
Falls Lake	16,252	<1%	1%	<1%	2%

8.7 Scenario 3 – Identified Stormwater Quality BMP and Stream Restoration Projects

Scenario 3 represents the pollutant yield based on implementation of the potential watershed improvement projects identified during the stream and BMP field surveys under future land use conditions. This includes all 165 potential projects identified during the BMP and stream field inventories described in Section 5 and Section 6. The projects consist of stormwater BMP retrofits, new stormwater BMPs, and stream restoration and stabilization projects. This scenario also includes the water quality benefits provided by the remaining existing BMPs (not recommended for retrofit) and from high-quality stream reaches recommended for preservation that were evaluated in Scenario 2.

This scenario does not represent a comprehensive list of potential watershed improvement projects. The field inventories were concentrated in the five PSAs; therefore identification of potential projects outside of these five subwatersheds was limited. Scenario 4 – Pilot Study Areas analyzes the water quality benefits of applying the potential projects found in the PSAs throughout the entire watershed.

Results for Scenario 3. The results for pollutant yields under future land use conditions are tabulated below in Table 8-6. The reductions in pollutant yield compared to Scenario 2 (Existing BMPs and Stream Conditions) for each parameter are summarized in Table 8-7. At the City limits, the potential watershed improvement projects reduce the total pollutant load by up to 15 percent for all four water quality parameters: 3 percent for total nitrogen, 5 percent for total phosphorus, 16 percent for sediment, and 2 percent for fecal coliform. The stormwater BMP retrofit and new BMP projects still treat a small percentage of the watershed, which results in a limited reduction in pollutant yield for total nitrogen, total phosphorus, and fecal coliform. The sediment yield is reduced by a greater amount since this scenario includes the stream restoration and stabilization projects on 37 miles of Ellerbe Creek and its tributaries that were identified during the field inventory.

Even with the addition of the potential watershed improvement projects, the conclusion drawn from this scenario is similar to Scenario 2; the water quality thresholds outlined in Section 8.1 are exceeded for each of the four water quality parameters under this scenario. The total estimated cost to implement Scenario 3 is approximately $134-million. A breakdown of cost by project type is provided in Table 8-8.

Table 8-6. Results for Scenario 3: All Potential Projects

Summary Points	Drainage Area (acres)	Total Nitrogen	Total Phosphorus	Sediment	Fecal Coliform
		Future Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Future Yield (cfu x 10^9 /ac/yr)
PSA 1	655	4.6	0.6	440	2.8
PSA 8	497	7.9	1.2	2,200	223.1
South Ellerbe Creek	1,814	7.6	1.2	2,460	64.2
Murray Avenue	3,370	5.0	0.8	1,020	4.4
Roxboro Road	5,815	5.8	0.9	1,620	23.1
PSA 17	405	5.2	1.0	590	21.6
PSA 24	506	4.9	0.5	1,250	9.6
Goose Creek Tributary	2,875	6.8	1.0	3,160	9.4
Goose Creek	4,162	6.6	0.9	2,520	8.3
City Limits	13,057	12.2	1.5	1,890	15.3
USGS	14,188	11.5	1.4	1,850	14.3
Falls Lake	16,252	10.4	1.3	1,710	12.5

Table 8-7. Pollutant Reduction Provided by Scenario 3 under Future Land Use

Summary Points	Drainage Area (acres)	Reduction in Pollutant Yield (%)			
		Nitrogen	Phosphorus	Sediment	Fecal Coliform
PSA 1	655	20%	20%	37%	13%
PSA 8	497	8%	12%	18%	<1%
South Ellerbe Creek	1,814	4%	6%	14%	1%
Murray Avenue	3,370	10%	10%	16%	13%
Roxboro Road	5,815	8%	9%	14%	2%
PSA 17	405	2%	3%	3%	1%
PSA 24	506	10%	15%	28%	1%
Goose Creek Tributary	2,875	5%	6%	16%	1%
Goose Creek	4,162	5%	7%	17%	1%
City Limits	13,057	3%	5%	16%	2%
USGS	14,188	3%	4%	15%	2%
Falls Lake	16,252	3%	4%	15%	2%

Table 8-8. Cost Estimates: Scenario 3

Project Type	Number of Projects	Cost in Millions (2009)
Stream Restoration		$88.31
Enhancement Level I	17	$23.31
Enhancement Level II	20	$15.24
Restoration	33	$39.12
Stabilization	6	$5.07
Buffer Restoration	16	$4.72
Preservation	20	$0.85
New BMPs		$35.87
Wet Ponds	8	$9.38
Extended Dry Detention	6	$4.47
Constructed Wetlands	9	$20.55
Pocket Wetlands	3	$1.47
BMP Retrofits		$9.61
Wet Ponds	12	$5.89
Extended Dry Detention	10	$2.65
Constructed Wetlands	1	$0.22
Pocket Wetlands	3	$0.75
Sand Filters	1	$0.10
Total	165	$133.78

8.8 Scenario 4 – Pilot Study Areas

Scenario 4 takes the results of detailed evaluations of BMP retrofits, new BMPs, and stream restoration and stabilization projects in each pilot study area (PSA) and applies it to the entire watershed. This scenario also includes the water quality benefits provided by the remaining existing BMPs (not recommended for retrofit) and from high-quality stream reaches recommended for preservation that were evaluated in Scenario 2.

The five PSAs were selected because they are representative of the conditions found throughout the entire watershed. The five PSAs are spread across the watershed and range from the western most headwaters (Subwatershed 1) to the eastern lowlands area (Subwatershed 30). Each subwatershed has a unique mix of land use types including areas that are highly urbanized to largely undeveloped areas, as described below:

- **Subwatershed 1** contains the headwaters of Ellerbe Creek; diverse land use types; opportunity for growth; and abundance of existing BMPs and potential for new BMPs.
- **Subwatershed 8** represents the headwaters of South Ellerbe Creek; typical of the highly developed central portion of the watershed; includes Duke East Campus and Walltown Park; and several opportunities for stream restoration and BMP sites.
- **Subwatershed 17** located centrally in the northern half of the watershed; beginning to see development of vacant land into residential homes and local parks; and potential for new BMPs and a BMP retrofit opportunity.
- **Subwatershed 24** represents a tributary of Goose Creek that is primarily low density residential and agricultural land; no existing BMPs in the subwatershed; great potential for new BMPs and stream restoration projects.

- **Subwatershed 30** located in the lower portion of Ellerbe Creek that is still under the City's jurisdiction; beginning to see the conversion of agricultural land into residential neighborhoods; provides good opportunities to install new BMPs and preserve high-quality streams and their riparian corridors.

The first step in this scenario was to determine the overall pollutant removal efficiency within each PSA based on the potential projects identified during the field surveys. Each potential project was modeled in WIP Tools and analyzed as a stand-alone project based on its efficiency (i.e., water quality benefits per dollar spent). Only the projects within each PSA that were defined as "efficient" (water quality scores greater than 50 percent of the total possible water quality score of 35) were selected as "feasible" and used to determine the overall pollutant removal efficiency for that PSA. From this evaluation, a set of recommended projects was identified for each PSA. The results of this screening process in Step 1 in each PSA are:

- Subwatershed 1:
  - 5 BMP retrofits, 5 new BMPs, and 1 stream restoration project are recommended
  - 2 BMP retrofits are not recommended
- Subwatershed 8:
  - 1 new BMP and 3 stream restoration projects are recommended
- Subwatershed 17:
  - 3 new BMPs are recommended
  - 2 BMP retrofits are not recommended
- Subwatershed 24:
  - 1 new BMP and 6 stream restoration project are recommended
  - 2 BMP retrofits are not recommended
- Subwatershed 30:
  - 1 new BMP and 1 stream restoration projects are recommended

In Step 2, each of the remaining 28 subwatersheds were assigned to a PSA that most closely matches the conditions found within each subwatershed and the types of potential water quality and stream restoration projects that are available. The PSA to subwatershed assignments are listed in Table 8-9 and shown on Figure 8-1.

Table 8-9. Pilot Study Area to Subwatershed Assignments

PSA	Similar Watersheds
1	4, 5, 10, 23, 26, 27
8	6, 7, 12, 13, 14, 15, 16, 17, 18, 19, 20, 22
17	3, 9
24	2, 11, 21, 25, 29
30	28, 31, 32, 33

In Step 3, the water quality benefits of the recommended projects were extrapolated to the remaining subwatersheds to estimate the overall effectiveness for the Ellerbe Creek watershed. The pollutant load reductions based on implementing the recommended projects in each PSA, when compared to Scenario 2, are tabulated in Table 8-10.

Table 8-10. Load Reductions Based on Recommended Projects

PSA	Total Nitrogen (lbs/yr)	Total Phosphorus (lbs/yr)	Sediment (lbs/yr)	Fecal (cfu x 10^9/yr)
1	736 (20%)	92 (20%)	166,963 (37%)	279 (13%)
8	330 (8%)	78 (12%)	234,685 (18%)	263 (<1%)
17	49 (3%)	11 (3%)	6,676 (3%)	48 (<1%)
24	278 (10%)	47 (15%)	246,475 (28%)	43 (1%)
30	See note	See note	See note	See note

Note: Although one new BMP and one stream restoration project provide efficient removal of pollutants in PSA 30, no overall pollutant reduction was assigned to PSA 30 or the similar subwatersheds listed in Table 8-9. PSA 30 and its similar subwatersheds are primarily undeveloped, so the likely approach to meeting water quality goals in these areas is through implementation of the City's Stormwater Performance Standards for Development which require on-site water quality BMPs for all new development and significant redevelopment. This approach is captured in Scenario 5 – Stormwater Performance Standards for Development.

To apply the benefits of the recommended projects in each PSA to the remaining subwatersheds, these projects were removed from the WIP Tools Model and the pollutant export coefficients were adjusted until equivalent pollutant load reductions to those in Table 8-10 were achieved. This approach was employed since the specific locations of most potential projects are unknown at this time in the remaining subwatersheds. The percent reduction in export coefficients to achieve the load reductions (shown in Table 8-10 for each PSA) is presented in Table 8-11. These reductions were applied to each corresponding subwatershed as noted in Table 8-9.

Table 8-11. Reduction in Pollutant Export Coefficients to Match Load Reductions Based on Recommended Projects

PSA	Total Nitrogen	Total Phosphorus	Sediment	Fecal
1	20%	20%	60%	15%
8	15%	15%	75%	13%
17	3%	30%	3%	1%
24	10%	15%	90%	1%
30	-	-	-	-

Results for Scenario 4. The results for pollutant yield under future land use conditions are tabulated below in Table 8-12. The reductions in pollutant yield compared to Scenario 2 (Existing BMPs and Stream Conditions) for each parameter are summarized in Table 8-13. Based on the preliminary cost estimates of the recommended projects prepared for each PSA, the total cost for Scenario 4 may equal $220 to $260 million, which results in an 8 percent reduction of pollutant yield for total nitrogen, a 10 percent reduction for total phosphorus, a 24 percent reduction for sediment, and a 3 percent reduction for fecal coliform at the City limits. Even with the more comprehensive treatment of stormwater runoff throughout the watershed achieved by this scenario, the conclusion is similar to Scenarios 2 and 3; the water quality thresholds outlined in Section 8.1 are exceeded for all four water quality parameters. However, the 24 percent reduction in sediment yield indicates that the combination of stormwater BMPs to treat the upland sources of sediment and the stream restoration/stabilization projects can provide a significant reduction in the sediment load.

Table 8-12. Results for Scenario 4: Pilot Study Areas					
Summary Points	Drainage Area (acres)	Total Nitrogen	Total Phosphorus	Sediment	Fecal Coliform
		Future Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Future Yield (cfu x 10^9/ac/yr)
PSA 1	655	4.6	0.6	430	2.7
PSA 8	497	7.4	1.2	2,230	223.0
South Ellerbe Creek	1,814	6.9	1.1	2,350	64.1
Murray Avenue	3,370	4.6	0.7	910	4.5
Roxboro Road	5,815	5.3	0.8	1,500	23.1
PSA 17	405	5.1	1.0	590	21.6
PSA 24	506	4.9	0.5	1,390	9.7
Goose Creek Tributary	2,875	5.8	0.9	2,800	9.0
Goose Creek	4,162	5.8	0.8	2,260	7.9
City Limits	13,057	11.6	1.4	1,720	15.2
USGS	14,188	10.9	1.3	1,700	14.1
Falls Lake	16,252	9.9	1.2	1,570	12.4

Table 8-13. Pollutant Reduction Provided by Scenario 4 under Future Land Use					
Summary Points	Drainage Area (acres)	Reduction in Pollutant Yield (%)			
		Nitrogen	Phosphorus	Sediment	Fecal Coliform
PSA 1	655	21%	20%	38%	15%
PSA 8	497	14%	14%	16%	<1%
South Ellerbe Creek	1,814	13%	13%	18%	1%
Murray Avenue	3,370	17%	18%	26%	11%
Roxboro Road	5,815	15%	16%	21%	2%
PSA 17	405	3%	3%	3%	<1%
PSA 24	506	9%	14%	20%	1%
Goose Creek Tributary	2,875	19%	20%	25%	6%
Goose Creek	4,162	17%	20%	26%	5%
City Limits	13,057	8%	10%	24%	3%
USGS	14,188	8%	10%	22%	3%
Falls Lake	16,252	8%	10%	22%	3%

8.9 Scenario 5 – Stormwater Performance Standards for Development

The WIP Tools Model results under Scenario 5 are based on the implementation of the City's Stormwater Performance Standards for Development, Sections 70-736 and 70-737 (effective on March 17, 2009), and the State of North Carolina Regulations 15A NCAC 02B (effective on April 28, 2009). The Stormwater Performance Standards for Development require on-site water quality treatment for sediment and nutrients for all (with very few exceptions) new development and redevelopment projects that exceed 1-acre for single-family residential, detached, duplex, or recreational land uses; and that exceed 0.5 acres for other land use types in the Neuse River Basin. The Stormwater Performance Standards for Development state that total suspended solids must be reduced by 85 percent for both new development and redevelopment projects that meet the site thresholds (i.e., percentage of impervious area) to trigger this requirement. As stated in State Code 15A NCAC 02B, "local governments shall use a nitrogen export standard of 3.6-pounds/acre/year, determined by the Environmental Management Commission as 70 percent of the average collective nitrogen load for the 1995 non-urban land uses..." as the allowable pollutant yield for total nitrogen. Developers are required to install stormwater BMPs sufficient to meet the sediment and nitrogen performance standards required in these regulations.

Based on the land use data provided by the City, we identified parcels classified as vacant or undeveloped under existing land use conditions that exceed 1 acre in size. As these were converted to their future land use designation, we made the following reductions to the pollutant export coefficients for new development areas to account for the on-site stormwater quality controls:

- **Sediment.** Export coefficients for all land use types were reduced by 85 percent to comply with the City's Stormwater Performance Standards for Development.
- **Total Nitrogen.** Export coefficients were reduced to 3.6-lb/ac/yr to comply with City's Stormwater Performance Standards for Development, Sections 70-736 and 70-737 (effective on March 17, 2009), and the State of North Carolina Regulations 15A NCAC 02B (effective on April 28, 2009); pollutant yields for low density residential, very low density residential, and parks and open space land use type remained unchanged since the yields from these three land use types are less than 3.6-lbs/ac/yr.
- **Total Phosphorus.** Export coefficients were reduced 5 percent more than the nitrogen export coefficients to account for the higher efficiencies that are typically achieved for total phosphorus by stormwater BMPs than for total nitrogen; pollutant yields for low density residential, very low density residential, and parks and open space land use remained unchanged since the yields from these three land use types are less than 0.38 lbs/ac/yr.
- **Fecal Coliform.** Export coefficients for all land use types were reduced by 25 percent based on typical water quality benefits of on-site BMPs.

The City also identified nine areas within the watershed that are expected to undergo significant redevelopment. The areas consist of portions of the core downtown business district in Subwatershed 14 and Subwatershed 19, and smaller areas of redevelopment in Subwatersheds 5, 6, 8, 9, 18, and 19. The City's Stormwater Performance Standards for Development state that the nitrogen control standard for redevelopment must "reduce the nitrogen load by 40 percent from the nitrogen load that existed on March 19, 2001." The phosphorus reduction coefficient was set at 5 percent higher than the nitrogen export coefficient to account for the higher efficiencies that are typically achieved for total phosphorus by stormwater BMPs than for total nitrogen. The City's Stormwater Performance Standards for Development also state that the total suspended solids load must be reduced by 85-percent. As these areas were converted to their future land use designation, the pollutant export coefficients for these redevelopment areas were reduced by the following percentages to account for on-site stormwater quality controls:

- Total Nitrogen = 40 percent
- Total Phosphorus = 45 percent
- Sediment = 85 percent
- Fecal Coliform = 15 percent

In total, approximately 3,300 acres (20 percent) of the watershed within the City limits and 2,100 acres (13 percent) of the watershed outside the City limits may be affected by the State regulations and the City's Stormwater Performance Standards for Development.

Results for Scenario 5. The results for pollutant yield under future land use conditions are tabulated below in Table 8-14. The reductions in pollutant yield compared to Scenario 2 (Existing BMPs and Stream Conditions) for each parameter are summarized in Table 8-15. Implementation of the State regulations and the City's Stormwater Performance Standards for Development is expected to result in a 5 percent reduction of pollutant yield for total nitrogen, a 5 percent reduction for total phosphorus, a 3 percent reduction for sediment, and a 1 percent reduction for fecal coliform at the City limits. The costs to achieve these benefits are primarily borne by private development; therefore, we did not estimate the City's administrative costs for implementing Scenario 5. Since only 20 percent of the watershed may be subjected to these regulations, the water quality thresholds outlined in Section 8.1 are exceeded for each of the four water quality parameters under this scenario. These results indicate that due to the small percentage of future development area, the City's Stormwater Performance Standards for Development will need to be combined with the watershed improvement projects and other non-point source and point source control measures to meet the water quality thresholds.

Table 8.14. Results for Scenario 5: Stormwater Performance Standards for Development

Summary Points	Drainage Area (acres)	Total Nitrogen	Total Phosphorus	Sediment	Fecal Coliform
		Future Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Future Yield (cfu x 10^9/ac/yr)
PSA 1	655	5.0	0.7	620	3.1
PSA 8	497	7.5	1.3	2,560	223.3
South Ellerbe Creek	1,814	7.0	1.1	2,740	64.3
Murray Avenue	3,370	5.3	0.8	1,190	4.9
Roxboro Road	5,815	5.8	0.9	1,840	23.5
PSA 17	405	4.9	0.8	550	21.3
PSA 24	506	4.6	0.6	1,650	9.6
Goose Creek Tributary	2,875	6.6	1.0	3,690	9.3
Goose Creek	4,162	6.2	0.9	2,970	8.2
City Limits	13,057	12.1	1.5	2,190	15.4
USGS	14,188	11.3	1.4	2,130	14.3
Falls Lake	16,252	10.3	1.3	1,950	12.6

Table 8-15. Pollutant Reduction Provided by Scenario 5 under Future Land Use

Summary Points	Drainage Area (acres)	Reduction in Pollutant Yield (%)			
		Nitrogen	Phosphorus	Sediment	Fecal Coliform
PSA 1	655	12%	5%	11%	2%
PSA 8	497	12%	7%	4%	<1%
South Ellerbe Creek	1,814	12%	9%	4%	<1%
Murray Avenue	3,370	6%	7%	3%	3%
Roxboro Road	5,815	8%	8%	3%	1%
PSA 17	405	8%	19%	9%	2%
PSA 24	506	16%	7%	5%	1%
Goose Creek Tributary	2,875	8%	7%	2%	2%
Goose Creek	4,162	11%	7%	3%	2%
City Limits	13,057	4%	5%	3%	1%
USGS	14,188	4%	5%	3%	1%
Falls Lake	16,252	5%	5%	3%	1%

8.10 Scenario 6 – Better Site Design Techniques

Better Site Design aims to mitigate the impacts to land and water from development activities. Approaches to better site design emphasize the integration of site design and planning techniques with low impact development measures that conserve the natural areas and hydrologic functions of a site. Important factors impacting better site design include:

- Land use
- Soil characteristics such as permeability
- Depth to groundwater

- Ground slope

Only 20 percent of the Ellerbe Creek watershed is undeveloped or expected to undergo a significant redevelopment, which limit the opportunity to use better site design as a tool to improve water quality. Other factors also limit the effectiveness of better site design techniques. For example, most of the soils found within the watershed have low permeability or have been highly modified during development, and as such, impacts the rate at which water can infiltrate. Higher infiltration rates are necessary for effective and efficient LID measures. In addition, if the groundwater table is less than 3 feet from the surface, infiltration is also greatly reduced. Slopes of less than 5 percent are also generally required to implement effective LID measures. A significant portion of Durham and much of the Ellerbe Creek watershed has ground slopes that average greater than 5 percent.

Based on its watershed characteristics, LID measures recommended for implementation within the Ellerbe Creek watershed included both structural and non-structural practices. A brief description of each LID measure noted in Table 8-16 is included below.

Table 8-16. LID Practices Recommended

Structural	Non-Structural
Bioretention	Cluster development
Permeable pavement	Minimization of disturbed area
Green roofs	Sensitive area preservation
Green streets (including alleys)	
Native vegetation	
Capture and reuse (cisterns, rain barrels)	

Bioretention are usually small areas placed in parking lots or near other highly impervious areas that use chemical, biological and physical properties of plants, microbes and soils to remove pollutants from stormwater runoff.

Permeable pavement is porous pavement through which stormwater can infiltrate into the soil or be stored below the pavement; thereby both treating and reducing stormwater runoff.

Green roofs include planting vegetation on rooftops to reduce runoff and absorb heat. Studies conducted by N.C. State University have shown that green roofs can retain up to 60 percent of rainfall.

Green streets is a term referring to practices that reduce the impervious area and/or treat runoff from transportation rights-of-way. Green streets help reduce the impact of paved streets, particularly in residential areas. When combined with vegetated swales or bioretention techniques, water quality treatment can be provided. Green streets can also provide public safety benefits by helping reduce vehicle speeds.

Native vegetation can be retained or re-established in development landscaping to reduce the need for supplemental irrigation and fertilizers, and promote infiltration.

Capture and reuse techniques such as cisterns and rain barrels may be implemented to reduce runoff. Water can be stored to use for irrigation or other outdoor needs.

Cluster development/minimization of disturbed area includes placing houses closer together on smaller lots, while reserving more open space in the overall land development area. Cluster development is particularly suitable for reducing the amount of impervious area generated by new development; minimizing disturbed areas preserves vegetation, which preserves rainfall interception, and helps maintain the existing infiltration capacity of soils by minimizing soil compaction.

Sensitive area preservation includes identifying and preserving stream buffers, steep slope areas, wetlands, and forested areas. These sensitive areas help retain natural water flow, reduce erosion, and promote infiltration.

Results for Scenario 6. PSA 1 was evaluated for better site design and implementation of both structural and non-structural LID measures. Several scenarios were evaluated including baseline (no LID implementation), likely LID, implementing LID practices aggressively across the watershed, aggressive runoff reduction, and a combination of both aggressive LID implementation and runoff reduction measures. Each scenario was based on future land use conditions. The reduction in effective impervious area and in stormwater runoff from implementing each of the LID scenarios is summarized in Table 8-17.

Table 8-17. LID Results for PSA 1

LID Scenario	Effective Impervious Area*	Runoff Volume (MG)
Baseline (Existing Land Use)	32%	24
Likely (Future Land Use)	30%	23
Implement LID Aggressively (Future Land Use)	25%	20
Aggressive Runoff Reduction (Future Land Use)	28%	22
Both Aggressive Implementation and Runoff Reduction	20%	18

**Reductions in effective impervious area are based on a combination of infiltration/retention of stormwater runoff and reduced impervious area.*

The Likely LID Scenario assumes the moderate application of LID measures with a moderate level of effectiveness at runoff reduction. As shown in Table 8-17, it can be used to mitigate the effect of future development on runoff volume. This is the most reasonable scenario for implementation within the City based on the City's Stormwater Performance Standards for Development. Estimated costs for implementing this scenario are shown in Table 8-18.

Table 8-18. Estimated Costs for Implementing Likely LID Scenario

LID Practice	Estimated Reduction in Impervious Area (%)	Estimated Cost
Permeable Pavement	55%	$5,259,000
Rain Barrels	10%	$375,000
Cisterns	10%	$41,000
Green Roofs	35%	$2,688,000
Green Streets	22%	$18,479,000

Additional information on better site design and LID implementation practices for the City may be found in the Better Site Design: A Review of Low Impact Development Practices and Recommendations for Implementation in the City of Durham provided under separate cover.

8.11 Scenario 7 – Proprietary Stormwater Quality BMPs

Proprietary BMPs are becoming increasingly common in highly urbanized areas where open space to expand or construct new BMPs is limited, and piped stormwater drainage systems limit the feasibility of traditional BMPs such as ponds or wetlands. There are a wide-variety of proprietary BMPs on the market, including devices that focus on nutrient removal in addition to sediment and debris, such as the StormFilter or Filtera units. The intent of this scenario is to determine the cost-effectiveness of retrofitting highly urbanized areas with proprietary BMPs or application of these types of stormwater BMPs as on-site controls during redevelopment. The results for Scenario 7 are based on use of a typical stormwater proprietary device under future land use conditions in comparison to Scenario 2 (Existing BMPs and Stream Conditions).

Based on the layout of the existing storm drainage system, approximately 75 percent of each PSA could be retrofitted with proprietary BMPs. Based upon the percentage of road right-of-ways, it was assumed that one proprietary BMP unit could treat approximately 0.3 acres in PSA 8, and treat 0.5 acres in PSAs 1, 17, and 24. The percentage of these four PSAs that could be treated by proprietary BMPs is provided in Table 8-19. Due to the rural and undeveloped nature of PSA 30 and its similar watersheds, proprietary BMPs were not applied in those areas as a retrofit option. Based on performance data provided by the manufacturer, proprietary BMP units can typically achieve the following average water quality treatment efficiencies: (1) 35 percent removal of total nitrogen, (2) 45 percent removal for total phosphorus, (3) 85 percent removal of sediment, and (4) and 65 percent removal for fecal coliform.

Table 8-19. Proprietary BMPs Applied to Pilot Study Areas

Pilot Study Area	Watershed Area (ac)	Proprietary BMP Treatment Area (ac)	Percent of Watershed Treated	Acres Treated	Number of Units Required
1	650	0.5	19%	122	244
8	500	0.3	23%	113	375
17	390	0.5	19%	73	146
24	510	0.5	19%	96	191

Just as in Scenario 4, the percentage of each PSA that could be treated by proprietary BMPs was applied to the subwatersheds which most closely resembled each PSA (see Table 8-9), with the exception of PSA 30 and its similar subwatersheds. Based on this assumption, stormwater runoff from approximately 2,540 acres (16 percent of the watershed) could be treated with proprietary BMPs.

To treat 2,540 acres, approximately 6,680 proprietary BMP units would be required. Based on an average purchase price per unit of $11,000, the total estimated capital cost would be $73.5 million. Assuming a range of installation costs from 40 to 50 percent, the total cost for installing these units is approximately $103 to $110 million.

Results for Scenario 7. The reduction in annual pollutant load under future land use conditions for proprietary BMPs are tabulated below in Table 8-20. Implementation of proprietary BMPs are expected to result in a 5 percent reduction of pollutant yield for total nitrogen, a 7 percent reduction for total phosphorus, a 13 percent reduction for sediment, and a 10 percent reduction for fecal coliform at the City limits. Although the proprietary BMPs are efficient at removing pollutants, their use is limited to older, developed neighborhoods that have no prior stormwater management measures in place. These results indicate that the proprietary BMPs will need to be combined with the watershed improvement projects and other non-point source and point source control measures to meet the water quality thresholds.

Table 8-20. Proprietary BMPs Pollutant Removal Estimates				
Item	Total Nitrogen	Total Phosphorus	Sediment	Fecal Coliform
Falls Lake Summary Point Loads (from Scenario 2, Existing Conditions, Future Land Use)	174,800-lbs/yr	21,920-lbs/yr	32,555,560-lbs/yr	206,870*109-cfu/yr
Falls Lake Summary Point Unit Loads (from Scenario 2, Existing Conditions, Future Land Use)	10.8-lbs/ac/yr	1.3-lbs/ac/yr	2003-lbs/ac/yr	12.7*109-cfu/yr
Pollutant Reduction	9,570-lbs	1,540-lbs	4,329,650-lbs	21,040*109-cfu/yr
Percent Pollutant Removal	5%	7%	13%	10%
Cost per Pound or 109 cfu	$11,000 to $12,000	$67,000 to $72,000	$24 to $25	$4,900 to $5,300

The estimated costs provide above do not include maintenance. Maintenance for the first year or second year is typically included with the purchase price. However, after the initial maintenance period, City staff would need to continue to contract maintenance with the manufacturer or perform the once to twice yearly maintenance on each unit themselves. If City staff maintained the 6,680 units twice a year, it would likely require the purchase of new equipment and hiring of additional staff to conduct the maintenance. Four two-person crews would have to visit 10 to 15 units per day in order to inspect each proprietary BMP twice per year.

8.12 Scenario 8 – Point Source Controls

Scenario 8 evaluates the benefits of sanitary sewer rehabilitation and replacement in areas with older sanitary sewer pipes, and the installation of best available technology (BAT) for nutrient control at the North Durham Water Reclamation Facility (WRF). Point source loads for each water quality parameter under existing land use conditions include 10 points sources that represent the water quality impacts from older sanitary sewer pipes (e.g., sanitary sewer overflows, leaks, and spills) based on data provided by the City. These point sources are located in Subwatersheds 2, 8, 11, 14, 17, 18, 20, 21, 24, and 26. A separate point source was created to represent the discharge from the North Durham WRF.

Under Scenario 8, it was assumed that 85 to 100 percent of the discharges of wastewater from the sanitary sewer collection system into Ellerbe Creek are removed through the City's on-going sanitary sewer replacement and rehabilitation program, and that implementation of BAT for nutrients at the North Durham WRF reduces the average annual concentrations to from 3.3 mg/l to 3.0 mg/l for total nitrogen, and from 0.4 mg/l to 0.2 mg/l for total phosphorus. No additional BMP retrofits, new BMPs, or stream projects are included in this scenario in order to assess the water quality benefits of reducing point sources from the sanitary sewer collection system and the North Durham WRF within the Ellerbe Creek Watershed.

Results for Scenario 8. The results for pollutant yield under future land use conditions are tabulated below in Table 8-21. The percent reductions compared to existing conditions Scenario 2 (Existing BMPs and Stream Conditions) for each parameter are summarized in Table 8-22. We have estimated the total cost for sanitary sewer rehabilitation equal to $18- to $22-million, and nutrient control upgrades to the North Durham WRF equal to $38 to $42 million, for a total cost ranging from $56 to $60 million for the point source controls. Implementation of point source reductions are expected to result in a 4 percent reduction of pollutant yield for total nitrogen, a 20 percent reduction for total phosphorus, no significant reduction (< 1 percent) for sediment, and a 59 percent reduction for fecal coliform at the City limits. The City's on-going sewer replacement and rehabilitation program and the installation of improved nutrient controls at the North Durham WRF represent cost-effective measures to significantly reduce the pollutant yield for total phosphorus (20 percent) and fecal coliform (59 percent).

Table 8-21. WIP Tools Results for Scenario 8: Point Source Load Reductions					
Summary Points	Drainage Area (acres)	Total Nitrogen	Total Phosphorus	Sediment	Fecal Coliform
		Future Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Future Yield (cfu x 10^9 /ac/yr)
PSA 1	655	5.8	0.7	700	3.2
PSA 8	497	8.2	1.3	2,660	27.6
South Ellerbe Creek	1,814	7.8	1.2	2,850	10.8
Murray Avenue	3,370	5.6	0.8	1,230	4.5
Roxboro Road	5,815	6.2	1.0	1,890	6.5
PSA 17	405	5.3	1.0	610	6.6
PSA 24	506	5.4	0.6	1,740	5.6
Goose Creek Tributary	2,875	7.2	1.1	3,750	5.1
Goose Creek	4,162	7.0	1.0	3,050	4.8
City Limits	13,057	12.1	1.3	2,250	6.4
USGS	14,188	11.4	1.2	2,180	6.1
Falls Lake	16,252	10.3	1.1	2,000	5.4

Table 8-22. Pollutant Reduction Provided by Scenario 8 under Future Land Use					
Summary Points	Drainage Area (acres)	Reduction in Pollutant Yield (%)			
		Nitrogen	Phosphorus	Sediment	Fecal Coliform
PSA 1	655	<1%	<1%	<1%	<1%
PSA 8	497	4%	6%	<1%	88%
South Ellerbe Creek	1,814	1%	2%	<1%	83%
Murray Avenue	3,370	<1%	<1%	<1%	12%
Roxboro Road	5,815	1%	1%	<1%	73%
PSA 17	405	1%	1%	<1%	70%
PSA 24	506	<1%	<1%	<1%	42%
Goose Creek Tributary	2,875	<1%	<1%	<1%	46%
Goose Creek	4,162	<1%	<1%	<1%	42%
City Limits	13,057	4%	20%	<1%	59%
USGS	14,188	4%	20%	<1%	58%
Falls Lake	16,252	4%	20%	<1%	57%

8.13 Scenario 9 – Combination of Non-Point Source Controls

Scenario 9 combines the efforts of Scenarios 4, 5, and 7 by examining the benefits of cost-effective non-point source control measures: (1) BMP retrofits, new BMPs, and stream restoration projects; (2) implementing the City's Stormwater Performance Standards for Development and state regulations; (3) and retrofitting highly developed areas with proprietary BMPs. The total area within each subwatershed that could be treated by proprietary BMPs (from Scenario 7) was revised to ensure that these areas were not also treated by new BMPs (from Scenario 4), thereby reducing the likelihood of double-counting pollutant reductions and overestimating the effectiveness of these combined non-point source control measures.

Results for Scenario 9. The results for pollutant yield under future land use conditions are tabulated below in Table 8-23. The reductions in pollutant yield compared to Scenario 2 (Existing BMPs and Stream Conditions) for each parameter are summarized in Table 8-24. The total estimated cost to implement Scenario 9 is $320 to $370 million. Implementation of these water quality measures are expected to result in a 13 percent reduction of pollutant yield for total nitrogen, a 16 percent reduction for total phosphorus, a 25 percent reduction for sediment, and an 6 percent reduction for fecal coliform at the City limits. Even with this combination of non-point source controls, the water quality thresholds outlined in Section 8.1 are exceeded for all four water quality parameters. This indicates that meeting the water quality thresholds will also require implementation of the point source controls described in Scenario 8.

Table 8-23. WIP Tools Results for Scenario 9: Combined Non-Point Source Controls

Summary Points	Drainage Area (acres)	Total Nitrogen	Total Phosphorus	Sediment	Fecal Coliform
		Future Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Future Yield (cfu x 10^9 /ac/yr)
PSA 1	655	4.2	0.5	410	2.6
PSA 8	497	6.2	1.0	2,200	222.3
South Ellerbe Creek	1,814	5.8	0.9	2,280	63.5
Murray Avenue	3,370	4.3	0.6	880	4.2
Roxboro Road	5,815	4.7	0.7	1,470	22.7
PSA 17	405	4.5	0.9	520	20.8
PSA 24	506	4.0	0.4	1,390	9.0
Goose Creek Tributary	2,875	5.1	0.8	2,780	8.4
Goose Creek	4,162	4.9	0.7	2,240	7.4
City Limits	13,057	11.0	1.3	1,700	14.7
USGS	14,188	10.3	1.3	1,670	13.7
Falls Lake	16,252	9.4	1.1	1,550	12.0

Table 8-24. Pollutant Reduction Provided by Scenario 9 under Future Land Use

Summary Points	Drainage Area (acres)	Reduction in Pollutant Yield (%)			
		Nitrogen	Phosphorus	Sediment	Fecal Coliform
PSA 1	655	27%	25%	42%	18%
PSA 8	497	28%	26%	18%	1%
South Ellerbe Creek	1,814	27%	26%	20%	2%
Murray Avenue	3,370	23%	23%	28%	16%
Roxboro Road	5,815	24%	25%	22%	4%
PSA 17	405	14%	14%	14%	4%
PSA 24	506	26%	28%	20%	8%
Goose Creek Tributary	2,875	30%	31%	26%	12%
Goose Creek	4,162	30%	31%	27%	12%
City Limits	13,057	13%	16%	25%	6%
USGS	14,188	13%	16%	23%	6%
Falls Lake	16,252	13%	15%	23%	6%

8.14 Scenario 10 – Combined Non-Point Source and Point Source Controls

Scenario 10 combines the non-point source pollutant reduction efforts included in Scenario 9 (watershed improvement projects, proprietary BMPs, and implementing the City's Stormwater Performance Standards for Development) with the water quality benefits of the City's on-going sewer replacement and rehabilitation program and the nutrient control improvements to the North Durham WRF presented in Scenario 8.

Results for Scenario 10. The results for pollutant yield under future land use conditions are tabulated below in Table 8-25. The reductions in pollutant yield compared to Scenario 2 (Existing BMPs and Stream Conditions) for each parameter are summarized in Table 8-26. The total estimated cost for implementing all of the components of Scenario 10 is $376 to $430 million. Implementation of these water quality measures are expected to result in a 33 percent reduction of pollutant yield for total nitrogen, a 36 percent reduction for total phosphorus, a 24 percent reduction for sediment, and a 65 percent reduction for fecal coliform at the City limits. By combining point-source controls and non-point source controls, significant water quality improvement can be reached (i.e., a 24% to 65% reduction in pollutant yield at the City limits), even though the goals established for the Ellerbe Creek Watershed for each parameter are not met.

The water quality threshold for total phosphorus (0.38-lbs/ac/yr) will be difficult to reach; it is higher than the pollutant export coefficients for 9 of the 12 land use types found in Ellerbe Creek, as shown in Table 7-2. To meet this water quality threshold, controls will have to be implemented to reduce total phosphorus at the source, or new treatment technologies will need to be developed to improve the performance of stormwater BMPs at phosphorus removal.

Table 8-25. WIP Tools Results for Scenario 10: Combined Non-Point and Point Source Controls

Summary Points	Drainage Area (acres)	Total Nitrogen	Total Phosphorus	Sediment	Fecal Coliform
		Future Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Future Yield (lbs/ac/yr)	Future Yield (cfu x 10^9 /ac/yr)
PSA 1	655	4.2	0.5	410	2.6
PSA 8	497	5.8	0.9	2,190	26.4
South Ellerbe Creek	1,814	5.7	0.9	2,280	9.7
Murray Avenue	3,370	4.3	0.6	880	3.7
Roxboro Road	5,815	4.7	0.7	1,470	5.6
PSA 17	405	4.5	0.8	520	5.7
PSA 24	506	4.0	0.4	1,390	4.9
Goose Creek Tributary	2,875	5.0	0.8	2,780	4.0
Goose Creek	4,162	4.8	0.7	2,240	3.9
City Limits	13,057	8.5	1.0	1,700	5.5
USGS	14,188	8.0	1.0	1,670	5.3
Falls Lake	16,252	7.4	0.9	1,550	4.7

Table 8-26. Pollutant Reduction Provided by Scenario 10 under Future Land Use

Summary Points	Drainage Area (acres)	Reduction in Pollutant Yield (%)			
		Nitrogen	Phosphorus	Sediment	Fecal Coliform
PSA 1	655	27%	25%	42%	18%
PSA 8	497	32%	32%	18%	88%
South Ellerbe Creek	1,814	28%	28%	20%	85%
Murray Avenue	3,370	23%	23%	28%	28%
Roxboro Road	5,815	25%	25%	22%	76%
PSA 17	405	15%	15%	14%	74%
PSA 24	506	26%	29%	20%	50%
Goose Creek Tributary	2,875	30%	31%	26%	58%
Goose Creek	4,162	30%	32%	27%	54%
City Limits	13,057	33%	36%	25%	65%
USGS	14,188	32%	35%	23%	64%
Falls Lake	16,252	31%	34%	23%	63%

8.15 Summary

Efforts to improve water quality in Ellerbe Creek have been underway for several decades. Restoring the water quality and watershed function of Ellerbe Creek will take decades and require a considerable commitment in funds and staff time by the City. Although the watershed goals may not be realized immediately, the results of the watershed scenarios indicate that a significant improvement in water quality and watershed function can be achieved over time. The results of the watershed evaluations are presented in Table 8-27. The total estimated cost of each watershed improvement scenario as well as the anticipated reduction in pollutant yield at the City limits is also presented.

The highest-priority water quality improvement measure is to implement further point source controls within the watershed through the City's ongoing sewer rehabilitation and replacement program and upgrades to the nutrient control technology at the North Durham WRF (to meet the Phase 1 Falls Lake reductions). When these point-source controls are combined with the non-point controls (Scenario 10), significant water quality improvement can be reached (i.e., a 24% to 65% reduction in pollutant yield) even though the water quality goals are not met. The next steps towards achieving the City's long-term water quality goals for Ellerbe Creek are provided in Section 9.

Table 8-27. Summary of Watershed Improvement Scenarios 3 through 10					
Scenario	Pollutant Yield at the City Limits (% Reduction from Scenario 2 – Existing BMPs and Stream Conditions)				Cost (millions)
	Nitrogen (lb/ac/yr)	Phosphorus (lb/ac/yr)	Sediment (lb/ac/yr)	Fecal Coliform (10^9 cfu/ac/yr)	
Scenario 3: Identified Stormwater Quality BMP and Stream Restoration Projects	12.2 (3%)	1.5 (6%)	1,890 (16%)	15.3 (2%)	$130
Scenario 4: Pilot Study Area Evaluations Projected onto Entire Watershed	11.6 (8%)	1.4 (13%)	1,720 (24%)	15.2 (3%)	$220 - $260
Scenario 5: Stormwater Performance Standards for Development	12.1 (4%)	1.5 (6%)	2,190 (3%)	15.4 (1%)	Private
Scenario 7: Proprietary Stormwater Quality Devices	12.0 (5%)	1.4 (13%)	1,960 (13%)	14.0 (10%)	$103 - $110
Scenario 8: Point Source Controls for Sewer Collection System and North Durham Water Reclamation Facility*	12.1 (4%)	1.3 (19%)	2,250 (0%)	6.4 (59%)	$56 - $60*
Scenario 9: Combined Non-Point Source Controls (Scenarios 4, 5, 6, and 7)	11.0 (13%)	1.3 (19%)	1,700 (24%)	14.7 (6%)	$320 - $370
Scenario 10: Combined Point and Non-Point Source Controls (Scenarios 4 through 8)	8.5 (33%)	1.0 (38%)	1,700 (24%)	5.5 (65%)	$376 - $430
Water Quality Goals	7.5	0.38	1,600	5.1	

Note: Pollutant yields are based on future land use conditions projected in 2025. The water quality goals are described on page 8-1.

**Costs for North Durham Water Reclamation Facility include only those costs to meet the proposed Stage 1 Falls Lake reductions.*

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9. NEXT STEPS

The City has been undertaking efforts to protect water quality in Ellerbe Creek for several decades, and will continue those programs. Implementing all of the recommendations of the WMIP will take decades and require a considerable commitment in funds and staff time by the City. The costs shown do not reflect the cost of this additional staffing and resources. The following initial program is recommended as the next steps towards achieving the City's long-term water quality goals for Ellerbe Creek:

1. **Coordinate with the City's Department of Water Management to implement $60 million in point source controls.** Prioritize the on-going sanitary sewer rehabilitation and replacement program within the Ellerbe Creek Watershed and upgrade the nutrient control technology at the North Durham WRF (to meet the Phase 1 Falls Lake reductions). Both of these improvements represent the most cost-effective methods to significantly reduce the impacts from point sources in the Ellerbe Creek Watershed.
2. **Complete the Stormwater Utility Rate Study (currently underway) to determine the annual funding level that will be available based on the existing and projected stormwater utility fee structures.** The results of the rate study should allow the City to determine the annual funding available to implement the watershed improvement projects (e.g., stormwater BMP retrofits, new BMPs, stream restoration and stabilization project).
3. **Implement $49 million in High-Priority Water Quality Improvement Projects for the Ellerbe Creek Watershed** consisting of the stormwater BMP retrofits, new stormwater BMPs, and stream restoration and stabilization projects based on the City's ability to purchase the property or negotiate easements, overall project prioritization score, and available funding. These high-priority projects are identified in the Executive Summary to the WMIP.
4. **Implement the Riparian Area Management Plan.** Excessive stream bank erosion; trash and other debris getting into streams and riparian buffers; and encroachment and clearing of riparian buffers are common and visible problems along many Durham streams. The Riparian Area Management Plan (RAMP) has been prepared to address the current maintenance practices within riparian buffers on publicly-owned property, utility easements, and greenway corridors along Ellerbe Creek and its tributaries. Re-establishing the riparian buffers on publicly-owned property is important for protecting stream stability, water quality and ecological functions.
5. **Acquire or preserve the high-priority riparian buffers and new BMP sites valued at $60 million identified in the Critical Area Protection Plan.** The plan focuses on acquiring sites that are the most ecologically intact and those that have important features and functions, such as preserving high-quality aquatic and terrestrial habitats, floodwater storage, and creating recreational and educational opportunities for local residents.

Application to Falls Lake

The Ellerbe Creek WMIP was developed concurrently with the draft Falls Lake rules. While it was not explicitly designed to address the Falls Lake rules, the WMIP does provide a blueprint to move toward the nutrient reduction goals in the draft Falls Lake rules. The additional resources needed to implement the WMIP do not reflect the resources needed to implement the Falls Lake rules. An evaluation for additional resources, including staffing, will be needed when the rules are finalized.

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10. SUPPLEMENTAL REPORTS

10.1 Better Site Design

As part of the WMIP, an evaluation of better site design techniques and low impact development (LID) practices was conducted. The results of this evaluation are documented in the Better Site Design: A Review of Low Impact Development Practices and Recommendations for Implementation in the City of Durham, which is available as a separate report from the WMIP. A brief overview of the report is included below.

The Better Site Design and LID Report presents several assessments and technical evaluations designed to provide information to the City of Durham regarding the potential use of LID. The following LID-related assessments are documented in the report:

- General recommendations of LID practices for the City of Durham
- Identification of target Ellerbe Creek subwatersheds for LID implementation
- Evaluation of the hydrologic benefits of LID implementation in Pilot Study Area 1 in the Ellerbe Creek watershed
- Review of LID ordinances from other municipalities and recommendations for LID ordinance implementation in Durham

The LID practices considered for Durham included both nonstructural and structural techniques and are noted in Table 10-1. Nonstructural techniques are those that deal with overall site design or construction practices, while structural techniques are physical elements that are engineered to provide a specific function related to maintaining or mimicking natural hydrology.

Table 10-1. LID Practices Evaluated

Structural	Non-Structural
Bioretention	Cluster development
Infiltration practices	Minimization of disturbed area
Permeable pavement	Minimization of soil compaction
Green roofs	Sensitive area preservation
Green streets (including alleys)	
Native vegetation	
Capture & reuse (cisterns, rain barrels)	
Soil amendments	

Based on the results of the LID evaluations, several LID practices were recommended for implementation within the City of Durham. These LID practices are noted in Table 10-2.

Table 10-2. Recommended LID Practices

LID Practice	Rationale for Recommendation
Cluster development	Cluster development is particularly suitable for reducing the amount of impervious area generated by new development.
Minimization of disturbed area	This measure helps maintain the existing infiltration capacity of soils by minimizing soil compaction; minimizing disturbed areas also preserves vegetation, which preserves rainfall interception.
Sensitive area preservation	Protection of wetlands, steep slopes, and wooded areas will help retain natural flow paths, reduce erosion, and promote interception and infiltration.
Bioretention	Bioretention can be implemented on a range of scales and in a variety of land use settings to capture stormwater for infiltration and treatment.
Infiltration practices	Infiltration practices are recommended for areas of Durham with type "B" soils that may allow these practices to function without significant soil modification or amendments. A detailed evaluation of local site conditions should be performed to verify soil types, as well as depth to groundwater.
Permeable pavement	Permeable pavement can help reduce the effective impervious area of paved portions of the site even where the infiltration capacity of underlying soils is limited, particularly for low intensity precipitation events. As with infiltration practices, permeable pavement will only be effective where underlying soils can infiltrate rainwater or where subpavement drainage is incorporated into the design.
Green roofs	Green roofs can be implemented on commercial and industrial development and will reduce runoff, while providing other water quality benefits.
Green streets (including alleys)	Green streets help reduce the impact of paved streets, particularly in residential areas. When combined with vegetated swales, or bioretention techniques, water quality treatment can be provided. Green streets can also provide public safety benefits by helping reduce vehicle speeds.
Native vegetation	The use of native vegetation in development landscaping will reduce the need for supplemental irrigation, fertilizers, and promote infiltration.
Capture & reuse (cisterns/rain barrels)	Directing roof runoff to on-site storage for slow release can be implemented on a range of scales and in any type of land use. Smaller rain barrels can be used for houses, while larger cisterns or roof storage can be used for commercial or industrial development to offset the effect of roof tops.

A detailed analysis of LID implementation was conducted on pilot study area (PSA) 1. Results of the detailed hydrologic analysis of implementing LID within PSA 1 are documented in Section 8.10 of this report. Several additional subwatersheds (Subwatersheds 21, 24, 25, 27, 31, and 33) were identified as good opportunities to implement Better Site Design and LID as development occurs. These subwatersheds are located in the lower reaches of Ellerbe Creek, some of which are outside the existing City limits.

Finally, local land development ordinances are currently the most common way of promoting LID implementation. Ordinances from these communities were evaluated for their application to the City of Durham: (1) Huntersville, North Carolina; (2) Stafford County, Virginia; (3) Chesterfield County, Virginia; and (4) Fauquier County, Virginia. Recommendations for modifications to City of Durham Ordinances to promote the use of better site design and LID techniques are presented in the report.

10.2 Critical Area Protection Plan

This Critical Area Protection Plan (CAPP) provides a systematic method for evaluating undeveloped or forested parcels throughout the watershed to identify high-value properties that if acquired or protected would yield cost-effective watershed protection and improvement benefits. Watershed protection benefits include: (1) preservation of intact habitats and (2) maintenance of existing riparian functions and values, such as nutrient assimilation and floodwater storage. Watershed improvement benefits include: (1) stabilizing eroded stream channels, (2) reducing sediment and pollutant loading, (3) reducing flood damage, (4) improving aquatic and riparian habitats, (5) recovering fish and wildlife species and/or habitat, and (6) creating recreational and educational opportunities. Critical area protection planning focuses on sites that are most ecologically intact and those that have features and functions considered environmentally important. High-value sites must include stream frontage, be privately-owned lands, and be worth preserving in their current condition. Other aspects of the WMIP address methods for restoring degraded stream reaches and overall watershed health. A brief overview of the CAPP is provided below.

The first step to identify CAPP sites was to establish the site selection criteria. Development of the site selection criteria was guided by professional experience; documents from City, County, State, and regional planning sources and the Ellerbe Creek Watershed Association (ECWA); and the Watershed Characterization and Assessment Report prepared during development of the WMIP. These resources shaped the site selection criteria and provided insights into the particular problems and priorities within the Ellerbe Creek watershed. Several Upper Neuse River Basin Association (UNRBA) critical protection area plans and the North Carolina Natural Heritage Program's Conservation Planning Tool were also reviewed for any methods, procedures, or spatial data suggestions they might offer.

The second step was to locate potential CAPP sites and characterize them using a geographic information system (GIS), including tax parcel data, aerial photography, hydrology, topography, land use/land cover data, sanitary sewer line and greenway corridor mapping, national wetland inventory data, and floodplain mapping layers. Based on the results of the GIS analyses, each parcel received a prioritization score.

Finally, to qualify as a CAPP site, a property needed to meet the following two standards: (1) first, it needed to have scored well on its own merits, and (2) it needed to have the ability to serve as a keystone property around which larger protection corridors or areas might be built in the coming years. The goal of the CAPP is not to create isolated protected areas throughout the watershed, but rather to establish a network of protected sites that might ultimately weave themselves into the fabric of the City.

The watershed evaluation identified 324 high-value sites; 228 of these are within the city limits. Based on the large number of sites that qualify as high-value, seven high-priority areas in the watershed were identified where the City should focus initial efforts at acquisition and protection of these critical riparian areas:

1. Headwaters of Ellerbe Creek
2. Tributary to Ellerbe Creek just south of the intersection of US 70 and US 15
3. Ellerbe Creek in the vicinity of Guess Road and Murray Avenue
4. Goose Creek near Camden Avenue
5. Tributary to Goose Creek near US 70
6. Tributary to Goose Creek in the most eastern part of the Goose Creek subwatershed
7. Tributary to Ellerbe Creek just downstream of the confluence with Goose Creek

These seven critical areas and the specific high-priority parcels within these areas are provided in the Critical Area Protection Plan, which can be found in Appendix M of the Ellerbe Creek WMIP Volume 3: Technical Appendices. In addition to the high-quality riparian areas in the areas listed above, the City should also move forward with acquisition of all recommended new BMP sites to prevent development of these sites in order to preserve the opportunity to implement stormwater quality BMPs at a future date.

10.3 Riparian Area Management Plan

The land adjacent to ditches, streams, rivers, wetlands, ponds, lakes, and reservoirs are called "riparian buffers." Riparian buffers are vitally important for protecting stream banks and shorelines from erosion and pollution, dissipating high-energy flows during storms, and providing fish and wildlife habitat. Vegetated buffers of *any* width are better than no buffers and can be important for protecting stream stability, water quality and ecological functions. Currently, there are many riparian areas in Durham where vegetated buffers do not exist or are not protected, including unmapped streams, ephemeral channels and ditches, and lands that were cleared or developed prior to the current regulations protecting riparian buffers were enacted.

The lack of riparian buffers, eroding stream banks, and dumping of pollution and trash are common and visible problems along many Durham streams. The Riparian Area Management Plan (RAMP) has been prepared to address the current maintenance practices within riparian buffers on city-owned property, utility easements, and greenway corridors along Ellerbe Creek and its tributaries. The RAMP contains riparian buffer management recommendations targeted for City-owned property that should be followed by management, design, and maintenance staff when planning and designing new infrastructure and facilities; improving existing facilities; or performing maintenance on water and sanitary sewer lines and easements, parks and recreation facilities, stormwater and flood control projects, roads, and public works facilities.

The purpose of the RAMP is to further educate City planning, design, and maintenance staff on ways to address water quality impacts during maintenance or construction activities near or in riparian buffers. These recommendations are written to apply to riparian buffers on ephemeral, intermittent, or perennial streams on all publicly-maintained land; and pre-existing development and on-going maintenance activities are exempt from current riparian buffer regulations.

To understand the current maintenance practices performed on publicly-owned property, several City-owned properties and utility easements were visited to document current management and maintenance practices within the riparian buffers. In many cases, the field visits revealed mowing and clearing of trees and other woody vegetation along riparian areas, typically stopping at the top of the stream bank. These current maintenance practices are one of the many causes of the widespread stream bank erosion and reduced water quality found in the Ellerbe Creek watershed. With these simple changes to these current maintenance practices and simple changes in design, construction, and management of public facilities and infrastructure, the City can have a positive impact on the water quality and ecological functions of the City's streams.

The recommendations in the RAMP to improve the quality of the riparian buffers on publicly-owned land fell into five categories:

- Maintenance Recommendations
- Riparian Buffer Restoration
- Design Modifications
- Pollution Avoidance
- Public Education and Involvement

Maintenance Recommendations covers such topics as protecting existing forested riparian buffers; converting heavily-maintained areas into forested riparian buffers; revising mowing practices and techniques; protecting woody vegetation and roots in riparian buffers; preserving leaf litter; minimizing the use of herbicides for vegetation control along stream banks or in drainage ditches; protecting in-stream habitat for fish and wildlife, and creating better habitat for terrestrial wildlife.

Riparian Buffer Restoration covers techniques and species that can be used to restore native shrubs and trees to create a forested riparian buffer that will regenerate naturally. A forested buffer of any width along a stream bank, even just a few feet, will be beneficial to stream bank stability and ecological functions. Re-vegetating stream buffers will likely save on maintenance costs and reduce property damage in the long-term.

Design Structure Maintenance covers design techniques that protect riparian buffers from the impacts of development and stormwater runoff, such as the use of level spreaders to better disperse stormwater into riparian buffers to control erosion.

Pollution Avoidance covers topics such as proper cleanup of oil and fuel spills, and the flushing of potable water lines that contain chlorine or chloramines. For example, potable water used in vehicle washing, pavement washing, and hydrant flushing should be de-chlorinated prior to discharge into nearby streams; or only discharged during high stream flows.

Public Education and Involvement recommends installing signs along riparian buffers to educate the public about the importance and benefits of the riparian buffers. The City of Durham Public Works Department has a "Natural Plant Area" sign with a "No Mow" symbol that can be posted along the outer edges of protected buffers on public lands. Once riparian buffers are located and identified, the boundaries of the buffer to be protected (whether regulated or not) should have these signs posted in strategic locations to also remind staff to avoid land clearing and mowing in those areas.

The Riparian Area Management Plan, which is available as a separate report from the WMIP, should be considered preliminary. Many of the recommendations are shown on the two-page Fact Sheets created for distribution to the City maintenance personnel. Each of the City departments that have maintenance responsibilities within riparian buffers will need to review the RAMP and provide feedback. The RAMP will also need to be updated over time as modifications are made to the current regulations on riparian buffers and unforeseen situations arise within the City of Durham.