Upper Salem Creek Watershed Master Plan

City of Winston-Salem

October 2010

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Certification

I hereby certify that this Upper Salem Creek Watershed Master Plan for the City of Winston-Salem was prepared by me or under my direct supervision.

Signed, sealed, and dated this 28 day of October 2010.

By: ______________________

Ronald A. Geiger, PE

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LIST OF FIGURES AND CHARTS/ILLUSTRATIONS

FIGURES

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MASTER PLAN UPDATES

The City of Winston Salem, since the early 1990's prepared Watershed Master Plans for each of their 15 watersheds that encompass the jurisdictional area of the City's drainage system. These Master Plan documents were delivered to the City for their use in a hard copy paper format. The City has prepared updates to these documents to reflect the growth in the city storm water system as well as the growth in the development of the city. Increased development may create additional problems to the drainage system thereby impacting the residents of Winston Salem.

The purpose of this document is to update the previous Master Plan Documents with current and future land use conditions, updated water quality estimates, and current storm drainage conveyance systems, and assess the previously identified recommended Capital Improvement Project areas. Updates to these recommendations are included. Furthermore, this document will be developed as a "Virtual Master Plan" where it will be housed electronically by the City with the data and information on improvements accessed via links embedded into the document. Geographical data associated with the city storm water system will be contained in the City's GIS Geodatabase, and accessed through the hyperlinks.

Alternative improvement options were not revisited as part of this update, rather the recommendations were assessed to determine if adjustments were necessary due to a change in land use, which in turn would generate a different hydrologic runoff condition.

PROJECT GOALS

The goals of the Upper Salem Creek Watershed Master Plan are threefold. First, the Master Plan includes a comprehensive update of the existing municipal separate storm sewer systems (MS4) inventory. Second, the Master Plan identifies areas of existing and potential future flooding based on existing and projected development patterns. And third, the Master Plan assesses the impacts of storm water discharges on the water quality of the region's streams.

Traditionally, MS4s have developed in a haphazard fashion associated principally with roadway drainage. Storm water conveyance structures were designed and constructed by diverse groups such as the developers, North Carolina Department of Transportation (NCDOT), and the City of Winston-Salem (City) Streets Department. A central repository of storm water conveyance structures has never been maintained. Therefore, a principal goal of this Master Plan is to develop a complete inventory of the MS4 system. To this end, **Section 2.4.3** discusses the condition of the MS4 system within the Upper Salem Creek watershed. The reader is referred to the Storm Water Division for more detailed information including a storm water structure database inventory.

This Master Plan addresses the existing and projected flooding within the Upper Salem Creek watershed. The mainstem of the Upper Salem Creek watershed has been included in previous Federal Emergency Management Agency (FEMA) studies. While FEMA Flood Insurance Studies are the official regulatory document for floodplain identification within Winston-Salem, they are lacking in three areas: 1) they are based on very coarse hydrologic information, 2) they do not include drainage areas smaller than 1 square mile, and 3) they do not consider the impacts of future development patterns. This Master Plan addresses these deficiencies by using more detailed hydrologic techniques as discussed in **Sections 3.3.1** and **3.4.1**. Additionally, the detailed analysis within the City limits has been extended to areas as small as, or smaller than, 50 acres. Therefore, while not regulatory, the floodplains delineated in **Figure 6-3** in **Section 6** are a more accurate representation of expected floodplains for planning purposes. Lastly, the floodplain delineation noted above includes considerations of future development patterns for the build-out land use conditions in addition to an analysis of current conditions.

This Master Plan also addresses water quality within the Upper Salem Creek watershed. One driver behind development of the City's Storm Water Management Program, of which this Master Plan is one component, is the United States Environmental Protection Agency's (USEPA) discharge permit requirements for MS4 systems. This Master Plan calculates expected maximum and Event Mean Concentrations (EMCs) for pollutants typically associated with urban runoff. **Section 4** provides general recommendations regarding suitable Best Management Practices (BMPs) that could be employed within the Upper Salem Creek watershed. However, because recommendations of BMPs is not a watershed-specific objective, formal implementation of a BMP program is deferred until Master Plans have been completed for all Salem Creek watersheds.

WATER QUALITY ISSUES

The results presented in **Section 4** identify EMC and maximum concentration values for the non-point source constituents modeled in this Master Plan for the existing and future land use conditions. North Carolina action levels were used to evaluate the model results and determine which pollutants exceed the action level criteria for in stream concentrations. In the Upper Salem Creek watershed, Copper (Cu) EMC and maximum concentrations were found to be above the action level in both land use scenarios and maximum concentrations for Zinc (Zn) was found to be above the action level both land use scenarios. This information is summarized in **Table 4.2-3.**

RECOMMENDED PROGRAM

The recommended program for Upper Salem Creek consists of 19 improvements with a total estimated cost of $28,919,000. Of the 19 recommended improvements, 10 fall under the control of the City of Winston-Salem with a total estimated cost of $16,781,000. These 10 City improvements are broken into buyout of flooded properties ($254,300) and capital improvement projects ($16,526,700). The remaining nine improvements consists of three roadway improvements that fall under the control of NCDOT roadway with an estimated total capital cost of $11,629,00 and six stream bank erosion repairs/restoration with an estimated total capital cost of $508,500. Improvement locations are referenced by their improvement codes in **Figure 1-1**. The following tables give a brief description of each improvement and the associated cost as referenced by the improvement code**.** **Table ES-1** describes all structural flooding improvements, **Table ES-2** includes the prioritized list of all roadway overtopping improvements in the City of Winston-Salem program, and **Table ES-3** describes all roadway overtopping improvements in the NCDOT/Private program.

1.1 PROJECT AUTHORITY

The City of Winston-Salem is preparing this Master Plan under authority to protect the public welfare as granted through the City Charter and in response to requirements contained within the City's Storm Water National Pollutant Discharge Elimination System (NPDES) permit.

1.2 PROJECT BACKGROUND

Urban drainage and flood control is one of the oldest areas of Public Works. Prior to the advent of city-wide water and sewer systems, municipalities had been draining land and removing storm water from street surfaces. Winston-Salem was fortunate to develop at or near the headwaters of streams rather than in low-lying floodplains. Therefore, the upstream drainage areas were too small to produce widespread regional flooding. Thus, drainage and flood control consisted principally of curbside catchbasins and culvert pipes to convey storm water to the nearest natural channel.

Urban development within a watershed generally results in an increase in the percent impervious, i.e., more hard surfaces, with a concurrent increase in runoff associated with any given storm event. Therefore, stream channels and culverts that were adequate prior to urbanization may become inadequate as the watershed develops. This results in more frequent stream channel flooding and backwater flooding from undersized culverts. The City of Winston-Salem addresses these problems as funds would allow, through street and drainage improvement projects. However, funding did not allow a comprehensive evaluation of all of the drainage problems and interrelationships within the City, or even individual watersheds.

The 1987 Amendments to the Clean Water Act recognized urban runoff as a major contributor to the Nation's water quality problem. Thereafter, storm water issues became as closely allied with water quality issues as they had been previously associated with flood control. In other words, *quality* became as important as *quantity*.

The 1987 Amendments required medium and large municipal MS4 systems to obtain NPDES permits for their storm water discharges. Winston-Salem met the definition of a medium sized municipality (population 100,000 to 250,000). The NPDES permit application process consisted of two parts. The Part 1 NPDES application was submitted May 16, 1992, and the Part 2 NPDES application was submitted May 17, 1993.

The Part 1 NPDES application consisted of a review of the City's legal authority, identification of known major storm sewer outfalls, discharge characterization based on rainfall records and dry weather pollutant screening, a description of a proposed wet weather sampling program, a description of existing management programs and, lastly, a description of available fiscal resources. The Part 1

NPDES application determined that the City had some, but not all, of the legal authority necessary to implement the USEPA mandated program. Specifically, the elements of a potential storm water program were dispersed among several City departments, and that funding was inadequate to meet the overall program requirements. Additionally, the Part 1 NPDES application highlighted the lack of a comprehensive inventory of storm water facilities.

The Part 2 NPDES application carried the Part 1 NPDES application a step further. It included specific legal authorities needed, an inventory of all major industrial storm water dischargers, presentation of pollutant wet weather sampling results, development of a storm water management plan, and recommendations for a funding vehicle. The Part 2 NPDES application led to creation of the City's Storm Water Utility in 1994. The most important aspect of the Part 2 NPDES application as it pertains to this Master Plan was the development of the proposed Storm Water Management Program.

The City's Storm Water Management Program has five major components: 1) master planning, 2) pollutant monitoring, 3) facility inventory, 4) illicit connection investigation and control, and 5) public education. This Master Plan partially fulfills the first and third requirements of the Storm Water Management Program. Recently the City has had their NPDES permit updated to include various additional elements that are included under Phase II of the NPDES program which targeted smaller municipal governments (i.e. those less than 100,000 population and other select entities), and includes focus on water quality recover plans, TMDLs, additional water quality measures for pollutants of concern. To meet the needs of NPDES Phase II, the City includes in their program the following measures:

- Public Education/Awareness
- Public Outreach/Involvement
- Illicit Discharge Detection and Elimination
- Construction Site Runoff Controls
- Post Construction Site Runoff Controls
- Good Housekeeping of Municipal Facilities

1.3 PROJECT GOALS AND OBJECTIVES

1.3.1 General

The goal of the Upper Salem Creek Watershed Master Plan is to provide a comprehensive evaluation of flood control and water quality issues within the watershed. This goal will be met within the constraints of the authority of the City MS4 system.

The objectives of the study are threefold. First, the Master Plan includes a comprehensive update of the existing municipal separate storm sewer systems (MS4) inventory. Second, the Master Plan identifies areas of existing and potential future flooding based on existing and projected development patterns. And third, the Master Plan assesses the impacts of storm water discharges on the water quality of the region's streams.

1.3.2 Storm Sewer Inventory

Traditionally, MS4s have developed in a haphazard fashion associated principally with roadway drainage. Storm water conveyance structures were designed and constructed by diverse groups such as the developers, North Carolina Department of Transportation (NCDOT), and the City of Winston-Salem Streets Department. A central repository of storm water conveyance structures has never been maintained. Therefore, a principal goal of this Master Plan was to develop a complete inventory of the MS4 system.

A detailed field survey of storm sewer facilities was completed. Global Positioning Satellite (GPS) surveys of all identifiable storm sewer structures were made. Where buildings and/or leaf cover prevented GPS survey location, the facilities were located by conventional ground survey techniques using a total station. Following the GPS location, a second "sweep" of the watershed was made to attribute the type and condition of each located structure. From this information, a Geographical Information System (GIS) coverage was made for the storm sewer system. Using ArcView, City staff can highlight any storm sewer structure and call up an attribute table that contains pertinent information on the structure. Additionally, the attribute tables can be queried to show all structures meeting certain conditions. The reader is referred to the Storm Water Division within the City's Streets Department for more detailed information including a 1" = 200' scale mapping and storm water structure database inventory.

It is important to note that the storm sewer inventory only includes structures within the City's MS4 system. The City defines its MS4 system as those structures within City Rights-of-Way. Specifically, this excludes systems wholly within private property such as large private storm sewer systems at shopping malls and industrial facilities. Unless otherwise noted in the Illicit Discharge Ordinance. Where a storm sewer structure originates on public right-of-way but then leaves the public right-of-way and crosses private property, the entire structure was located, if possible.

However, in cases where the end of the structure was obscured, behind a private fence, etc., only that portion of the structure on public right-of-way was located and attributed.

1.3.3 Flood Control and Drainage

This Master Plan addresses existing and projected flooding within the Upper Salem Creek watershed. The mainstem of the Upper Salem Creek watershed has been included in previous FEMA studies. While FEMA flood insurance studies are the official regulatory document for floodplain identification within Winston-Salem, they are lacking in three areas: 1) they are based on very coarse hydrologic information, 2) they do not include drainage areas smaller than 1 square mile, and 3) they do not consider the impacts of future development patterns. This Master Plan addresses these deficiencies by using more detailed hydrologic techniques. Additionally, the detailed analysis within the City limits has been extended to areas as small as, or smaller than, 50 acres. Therefore, while not regulatory, the floodplains delineated in this Master Plan are a more accurate representation of expected floodplains for planning purposes. Lastly, the floodplain delineation noted above includes considerations of future development patterns in addition to an analysis of current conditions.

Specifically, this Master Plan identifies the expected future hydrology for the watershed considering reasonable land use changes based on expected population growth. For the present time and the future build-out land use conditions, the 10-, 25-, 50-, and 100-year flood events were investigated. Problems were identified for the existing system without any improvements at the present flows. Alternatives were evaluated and solutions recommended based on the future flows.

Tables in Section 5 highlight current and expected flows and flood elevations for the 10-, 25-, 50-, and 100-year events for existing, present and future land use conditions at critical locations within the Upper Salem Creek watershed. This information for all modeled nodes is presented in the Appendix. This information is of critical use in evaluating future developments within the watershed. As long as future flows and flood elevations are below the predicted flows and elevations, then the capacity of the improved overall system will be adequate through planning period.

1.3.4 Water Quality

This Master Plan also addresses water quality within the Upper Salem Creek watershed. As noted in the Executive Summary, one driver behind development of the City's Storm Water Management Program, of which this Master Plan is one component, is the USEPA's discharge permit requirements for MS4 systems.

For purposes of this Master Plan, expected maximum and Event Mean Concentrations (EMCs) for pollutants typically associated with urban runoff were calculated. The results presented in this Master Plan are based on land use buildup/washoff rates calibrated using the limited data collected during the Part 2 NPDES application. Because of this, HDR urges extreme caution in applying these results and recommends that they be considered Order-of-Magnitude estimates of expected water quality. Ongoing watershed monitoring efforts as an independent element of the City's Storm Water Management Program should be used to validate the results presented in the individual watershed master plans.

Section 4 makes general recommendations regarding suitable BMPs that could be employed within the Upper Salem Creek watershed. However, formal recommendation for implementation of a BMP program is deferred until Master Plans have been completed for all Salem Creek watersheds.

SECTION 2 - WATERSHED DESCRIPTION

2.1 GENERAL

The Upper Salem Creek watershed is located in the east-central vicinity of the Winston-Salem municipal limits, which includes downtown Winston-Salem. The watershed extends upstream toward the northeast, from the confluence of Upper Salem Creek and Peters Creek to Salem Lake. The watershed measures approximately 7.0 square miles, with all of the drainage area being contained within the Winston-Salem municipal limits. The drainage area is roughly bounded by sections of Hutton and Broad Streets on the west, Salisbury Ridge Road and Waughtown Street on the south, Salem Lake Road on the east, and sections of Old Greensboro Road and Dr. Martin Luther King, Jr. Drive on the north.

2.2 PHYSICAL CHARACTERISTICS

2.2.1 Topography

Topography of a watershed refers to the characteristics and features of the land surface, such as slope and channel width. The slope of a watershed influences the rate at which precipitation falling on the land surface will be conveyed to the outlet point of the watershed. All other parameters considered equal, as the slope of a watershed increases, the faster the water travels to the outlet point. Although there can be a great deal of variation in slope magnitude and direction within a watershed, there are two main slope values of particular interest—average overland slope and average channel slope. Overland slope gives an indication of how fast runoff will travel on the land surface to a drainage channel, and channel slope relates how quickly the runoff will be routed to the outlet point of the watershed. Watersheds in the Piedmont area typically have a much steeper overland slope than channel slope.

Elevation measurements and slope calculations were performed using the Geographic Information System (GIS). HDR obtained attributed digital contour data, based on 1997 ortho-rectified aerial photography from the City-County Planning Board. From this data, a digital terrain model (DTM) was constructed in GIS for slope and other topological calculations.

The Upper Salem Creek watershed is characterized by typical Piedmont terrain. The land is relatively steep, with an average terrain slope of about 10 percent. The overall slope of the main channel is approximately 0.2 percent. Elevation in the watershed ranges from 727 ft. NAVD at the confluence of Upper Salem Creek and Peters Creek to 966 ft. NAVD in the upper ranges of the watershed.

2.2.2 Soil Types

The types of soils present in a watershed have a significant impact on the amount of runoff a given storm will produce for modeling purposes, the different soil types were grouped by their texture as loam soil, sandy loam soil, and loamy sand soil. In general, one would expect that loamy sand soil would have the best infiltration capacity, followed by sandy loam soil, and lastly, by loam soil.

Information on the soil types and characteristics in the Upper Salem Creek watershed was compiled by developing a digital soils database in GIS. Soil survey maps published by the Soil Conservation Service (SCS) were digitized and scanned into GIS, and then all the soil polygons were attributed with the soil symbols shown on the maps. This information was then combined with another database to obtain symbol, series, and texture for each soil polygon. Table 2.2-1 shows the relative representation and general hydrologic characteristics for the different soil series found in the Upper Salem Creek watershed.

The Upper Salem Creek drainage basin consists of over 10 different soil types, of which the Chewacla and Pacolet series account for about 83 percent of the total watershed area. For modeling purposes, the different soil types were grouped by their texture as loam soil, sandy loam soil, or loamy sand soil. The majority of the watershed consists of sandy loam soils, which are generally located in the upland areas of the watershed. There is a significant amount of loam soil located along stream channels and other bodies of water, while the presence of loamy sand soil is minor.

2.2.3 Natural Drainage Systems

The drainage system in the Upper Salem Creek watershed consists of both natural channel and closed conduit sections. The total length of the drainage system modeled is approximately 22.2 miles,

The majority of the storm water conveyance system consists of open channels. Of the total 22.2 miles of conveyance length modeled, 14.8 miles are open channels consisting of major creeks and tributaries. Although 18 tributaries in the Upper Salem Creek watershed were modeled, Upper Salem Creek is the only major creek.

2.3 ENVIRONMENTAL CHARACTERISTICS

Biological monitoring, or bioassessment, is a cost-effective way to determine water quality problems since biological communities reflect general ecological integrity. Biological communities change due to the type and duration of pollutants within the water column. An understanding of those changes can be an effective way for the public to relate to water quality and pollution problems. Organisms living in streams are exposed to the aquatic environment during most, if not all, of their life. Each organism has certain requirements for sustaining growth and reproduction. By observing the types and abundance of the organisms present, a trained investigator can accurately determine the predominant environmental conditions within the stream. By combining bioassessment with traditional chemical analyses, a more robust water quality assessment can be obtained.

The United States Environmental Protection Agency (USEPA) Rapid Bioassessment Manual – EPA/444/4/89/001 (Plafkin *et al.* 1989), examines existing biotic communities in addition to water chemistry to determine stream health. In 1999, eight sites (SU1-SU8) within the Upper Salem Creek watershed were examined for fish populations, aquatic insects, freshwater mussels, and other organisms that live in the stream (Figure 2-4). Additional water quality parameters, including temperature, dissolved oxygen, total dissolved solids, conductivity, and elemental water chemistry were recorded. Riparian vegetation, siltation, bed load conditions, litter presence, stream bank conditions, and channel stability were also examined at each site. A review of these issues assisted in determining and prioritizing urban water quality Best Management Practices (BMPs) improvements within each watershed for the 2002 Final Upper Salem Watershed Master Plan (2002 Master Plan). All eight sites were re-sampled in March of 2009. This section will provide a comparison of the 1999 and 2009 results.

The Upper Salem Creek watershed covers an area of approximately 4,450 acres (6.95 square miles) and extends from the base of Salem Lake dam to an area immediately north of Interstate 40. A portion of the watershed is contained within the city limits and has been extensively urbanized, with large residential and commercial areas. Upper Salem Creek receives flow from Brushy Fork Creek, Berry Branch, Cloverleaf Branch, and four unnamed tributaries.

Riparian areas within the project area were typical of those found in urban watersheds and ranged from relatively disturbed to very disturbed. Riparian vegetation has been removed to accommodate residential and commercial developments. Riparian buffer widths varied from narrow corridors of 0 to 10 feet to broad corridors greater than 50 feet. Woody species were dominated by early succesional species that included box elder (*Acer negundo*), sycamore (*Platanus occidentalis*), red maple (*Acer rubrum*), sweetgum (*Liquidambar styraciflua*), river birch (*Betula nigra*), and black cherry (*Prunus serotina*). Non-native invasive species were present throughout and included Chinese privet (*Ligustrum sinense*), multiflora rose (*Rosa multiflora*), Japanese honeysuckle (*Lonicera japonica*), English ivy (*Hedera helix*), and Nepal grass (*Microstegium vimineum*).

A survey of the fish community was conducted at all eight sites previously surveyed in 1999. Sampling techniques were based on the USEPA Rapid Bioassessment Protocol V (RBP V) (Plafkin et al 1989). Each sampling reach was approximately 100 meters in length. Electo-fishing all available habitats took 60 to 90 minutes at each sampling site. All available fish were released after being identified and counted.

Results were calculated using the North Carolina Index of Biological Integrity (NCIBI). The NCIBI was developed for assessing a stream's biological integrity by examining the structure and health of its fish community using the cumulative assessment of 12 parameters or metrics. These 12 metrics are grouped into five categories that include species richness and composition, indicator species, trophic function, abundance and conditions, and reproductive function. Sites may then be compared by their index values for the relative impact of pollution (Table 2.3-1).

The 2009 fish assessment revealed that fish communities and number of species collected had some variation from the 1999 sampling. The integrity class remained "Poor" with an average score of 23. Fish communities were dominated by omnivorous and insectivorous fish exhibiting intermediate to high tolerance to pollution. The highback chub (*Hybopsis hypsinotus*) was the only intolerant species collected within the watershed at sites, SU2, SU7, and SU8. The majority of the fish collected were insectivores. Creek chubs (*Semotilus atromaculatus*) and redbreast sunfish (*Lepomis auritis*) were found at every site and were the only species observed at sites SU5 and SU6, respectively. The brown bullhead (*Ameiurus nebulosus*) was the only omnivorous species collected at site SU7. Largemouth bass (*Micropterus salmoides*) and flathead catfish (*Pylodictis olivaris*) were the only piscivores collected within the watershed. Many of these sites supported populations of salamanders as noted on the Field Data Sheets located in Appendix. Chart 2.3.1 summarizes the 1999 and 2008 NCIBI scores for the Upper Salem Creek watershed.

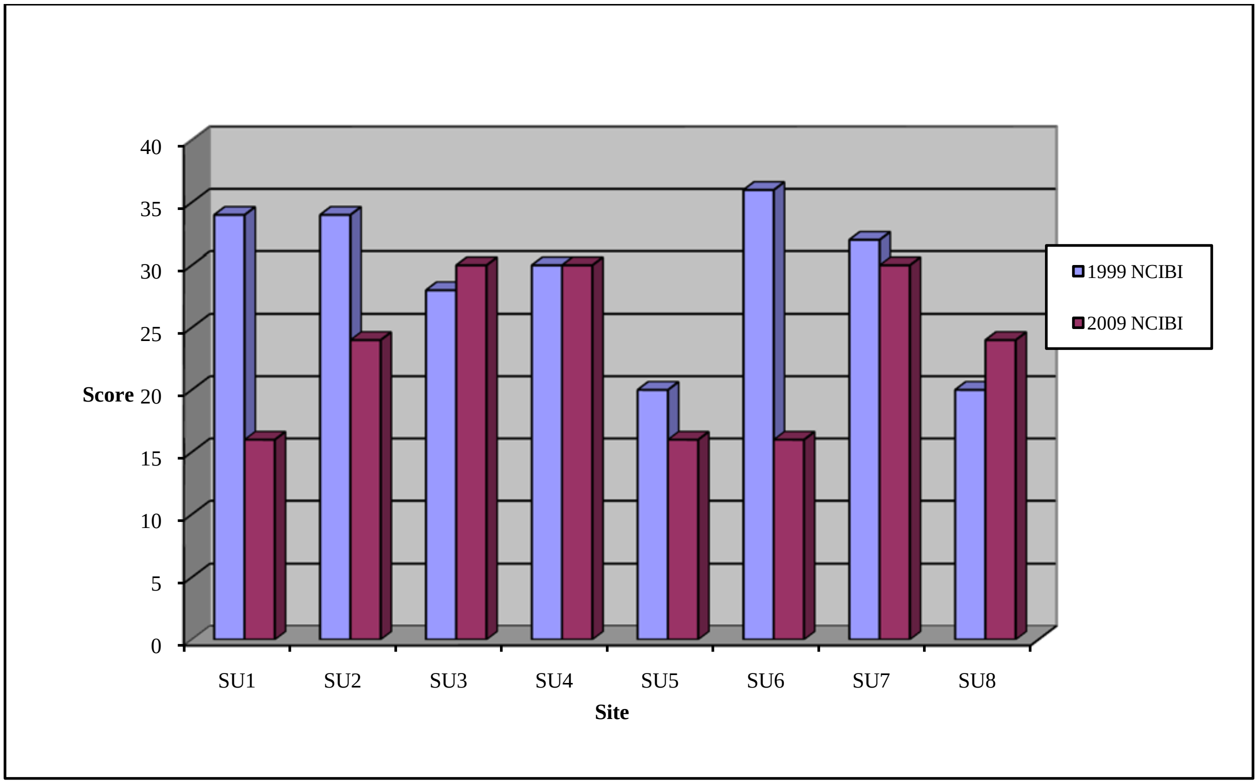

Chart 2.3-1 IBI Scores for Upper Salem Creek Watershed

There were some differences in the numbers and species caught in the comparison years. Most notably, fish were caught at sites SU5 and SU9 where no species were collected during the 1999 assessment. In 2009, the NCIBI scores have declined at five of the eight sampling sites and can attributed to the decrease of species diversity and number of individuals collected between sampling periods.

The 2009 field assessments revealed that all sites have poor to fair instream habitat and have been adversely impacted by the surrounding urbanized area as indicated by the presence of garbage, debris, erosion, and sedimentation. Variability between sites and sampling events may be due to seasonal variations, habitat degradation, and the ongoing drought conditions this region has been experiencing. Consistent, continued monitoring will improve the analysis of the watershed's biological integrity.

Benthic macroinvertebrates were surveyed in conjunction with fish and physio-chemical sampling at the eight sites. Sampling techniques were based on the USEPA Rapid Bioassessment Manual - EPA/444/4-89-001, Bioassessment Protocol I (RBP I) (Plafkin et al 1989). RBP I is a screening technique that involves documentation of the benthic faunal community and generates a limited amount of data. The components of the benthic macroinvertebrate community that are commonly used to evaluate water quality are the EPT taxa. The EPT taxa include species belonging to the insect orders Ephemeroptera (mayflies), Plecoptera (stoneflies), and Tricoptera (caddisflies). These orders are generally the least tolerant to water pollution and therefore are very useful indicators of water quality.

EPT taxa were present at all sites; however the relative abundance and species diversity were variable. EPT taxa collected consisted of fairly tolerant species including hydropsychid caddisflies and heptageniid mayflies. SU1, SU4, and SU7 sites had the greatest diversity and abundance of EPT taxa.

The presence of tolerant organisms including Oligochaeta (aquatic worms) and Diptera (flies) indicated some degree of water quality impairment typical of urban watersheds. The Asiatic clam (*Corbicula fluminea*), an invasive non-native mollusk, was found at four sites (SU1, SU3, SU4, SU7). This nuisance species multiplies rapidly and has been known to colonize and damage municipal and industrial water facilities. Ultimately it may additionally cause detriment to native species. Sites that exhibited the most favorable habitat had the most diverse and abundant macroinvertebrate assemblages. Benthic macroinvertebrate data are included in Appendix on the Field Data Sheets.

Water chemistries and physical attributes were sampled in conjunction with the bioassessment. Field meters were used for measuring *in-situ* chemical and physical characteristics. Chemical constituents were detected using a LaMotte Water Pollution Detection Kit I (Model Am-22) using comparators and direct titration methods. Two parameters, total dissolved solids (TDS) and carbon dioxide, were measured at a North Carolina Division of Water Quality (NCDWQ) certified lab.

Water chemistry results revealed the presence of pollutants that are typically found in urban watersheds that include extensive residential and commercial development (Table 2.3-2). The 2009 sampling indicated elevated nutrient levels including nitrate and phosphate within the watershed. The strong presence of periphyton at sites SU5, SU6, and SU7 can be a biological indicator of nutrient enrichment. Although, SU1 had the lowest dissolved oxygen levels, it did not fall below EPA Freshwater Criteria or NCDWQ Class C standards. All sites exhibited consistent pH levels ranging from 6.9 to 7.4. SU5 experienced the greatest impairment, recording high conductivity, ammonia, nitrate, and phosphate values.

Results from the Inductively Coupled Plasma Atomic Emission Spectroscopy Analysis (ICP) analysis of water samples for the eight sampling locations provided evidence of impairment by metals and other elements (Table 2.3-3). All eight sites exceeded NCDWQ Standard Class C standards for silver (Ag), cadmium (Cd), lead (Pb), and selenium (Se). Trace amounts of nickel (Ni) and zinc (Zn) were present in all samples. Very little to no amount was present in 1999.

Metals including cadmium, lead, iron, and zinc present within the Upper Salem Creek watershed have a relatively high density and are toxic, highly toxic or poisonous at low concentrations. These metals can be dangerous because they bioaccumulate. Bioaccumulation is an increase in the concentration of a chemical in a biological organism over time, compared to the chemical's concentration in the environment. Compounds accumulate in organisms when these chemicals are absorbed and stored more quickly than they can be metabolized or excreted.

The 2009 ICP analysis revealed the presence of metals and other constituents throughout the watershed. All sampling locations contained elevated levels as compared to the 1999 samples. No particular pattern can be identified at this time due to lack of long-term continuous water quality sampling data

2.4 URBAN DEVELOPMENT CHARACTERISTICS

2.4.1 Population and Land Use

Land use is a critical element for storm water planning. It impacts both the quantity and quality of water being routed through storm water systems and natural channels. The effect land use has on water quantity is generally linked to the amount of impervious area there is for a particular land use category. The more impervious area a tract of land has, the faster the water will be routed to the storm sewer system or channel, due to the loss of infiltration into the ground and lower surface roughness of the land. In general, an area with a high percentage of impervious area will have a quicker time to peak flow, and peak higher, than a similar area with a lower percentage impervious. The effect land use has on water quality is driven by the type of activities a particular land use defines. For example, the runoff from industrial land use would have much different water quality characteristics than runoff from agricultural land use. The industrial runoff would likely contain more heavy metals and toxic substances, whereas the agricultural runoff would likely contain high nutrients and suspended solids.

The scope of this project was to model storm water quantity and quality for the present day and the future "built-out" conditions so a land use database containing information for these scenarios had to be created. The present day and the future "built-out" conditions land uses are shown in Figure 2-4 and Figure 2-5, respectively. Although, there was no comprehensive land use plan already available, the county tax parcel database served as a starting point. The first step in developing a land use database was to devise a land use scheme. A scheme containing 13 different land use groups, developed by HDR, is shown in Table 2.4-1. Next, land use codes in the county tax parcel database were assigned to an HDR land use group, as shown in Table 2.4-2.

Land use classifications in Upper Salem Creek range from undeveloped to high density manufacturing, with the majority of the watershed being classified as roads and pavement, light density single-family residential, and undeveloped land uses. The breakdown of land use within the Upper Salem Creek watershed for present and future years is shown in Table 2.4-3.

2.4.2 Existing Water and Sewer Utilities

The geographic location and distribution of the existing water and sewer utility systems are of concern in a watershed master plan, mainly with respect to potential flood and water pollutant reduction strategies. Once the existing hydrologic and hydraulic conditions are assessed for a given storm event, the engineer investigates potential solutions to alleviate problem areas. Most proposed solutions require some construction and/or excavation, especially construction of a detention basin. The location of water and sewer lines should be considered since they are very expensive to move, and thus may cause the proposed solution to not be economically feasible.

Information describing geographic location and lengths of water and sewer lines was generated in GIS. The water and sewer systems were obtained in a GIS file format from the Winston-Salem Utilities Department, and then combined with existing watershed and municipal boundaries to compute summary statistics.

A total of approximately 87.2 miles of existing water lines run through the Upper Salem Creek watershed, all of which are within the Winston-Salem municipal limits. The water system is densely distributed throughout the watershed, with the exception of areas adjacent to the I-40 and Highway 52 interchanges, and a few large undeveloped tracts in the eastern section of the watershed.

The existing sewer system contains approximately 54.0 miles of sewer lines, all of which are within the municipal limits. The sewer system has a similar distribution to that of the water system, except in the eastern half of the watershed and less developed areas around Reynolds Park Road and Butler Street where it is sparser.

2.4.3 Municipal Separate Storm Sewer System

The purpose of a municipal storm sewer system is to efficiently route storm water runoff within a watershed, in order to minimize unwanted flooding, roadway overtopping, and environmental degradation. It is important to have an inventory of the storm sewer system for storm water modeling, among other issues such as structure maintenance and effective urban planning. For modeling purposes, the storm sewer system helps to define watershed and subwatershed boundaries, as well as hydraulic properties associated with channels, culverts, and pipes. The surveyed storm sewer system inventory is presented in Figure 2-6.

The model was to only include pipes with a diameter of 36 inches and greater, or pipes that drained more than 50 acres. The total length of modeled closed conduits, such as culverts and storm drainage piping, is approximately 24.3 miles. There were a total of 285 closed conduits included in the model, comprised of 244 circular and arch pipes, and 41 box culverts and bridges.

The municipal storm sewer system is comprised of both line structures and point structures. Line structures consist of storm sewer pipes and culverts, whereas point structures include catchbasins, drop inlets, manholes, junction boxes, and bridges (center point). A storm sewer inventory was recently collected for the Upper Salem Creek watershed. The inventory included all structures inside the right-of-way within the Winston-Salem municipal limits. The Upper Salem Creek watershed has 4,506 line structures and 3,701 point structures, for a total of 8,207 structures. About 99 percent of the storm sewer system is comprised of circular pipes and catchbasins. Table 2.4-4 shows a summary of the storm sewer structures in the Upper Salem Creek watershed.

3.1 MODEL OBJECTIVES

3.1.1 General

A key element of the master planning process is selection of a predictive hydrologic and hydraulic model of the watershed, and the natural and man-made storm drainage system. The model should be capable of analyzing control strategies for watershed master planning, evaluating Best Management Practices, predicting flooding potential, evaluating existing facilities, and designing proposed facilities.

Early in the master planning process, HDR evaluated several commonly used models. HDR developed a comparative evaluation matrix for the selection of a hydraulic model for use in the Upper Salem Creek watershed Master Plan. Table 3.1-1 shows the technical capabilities of the various candidates for hydrologic and hydraulic models. The primary objectives of the computer model selection and evaluation were:

- To identify current computer software available, appropriate for use in the analysis of drainage systems.
- To identify the technical requirements for system modeling and determine the criteria for model selection.
- To develop a comparative matrix to assist in the evaluation of technical capabilities and performance for identified model options.

Table 3.1-1 *Technical Capabilities of Candidate Hydrologic and Hydraulic Models*								
Model Function	**Model Name**	**Hydrograph Generation and Routing**	**Analysis of Existing Storm Drains**	**Channel Routing (Detention/ Retention)**	**Quality Routing**	**Water Surface Profiles**	**Surcharge Modeling**	**Adaptability to Land Use Variations**
Quantity	Advanced ICPR	X		X				X
	HEC-1	X	X	X				X
	HEC-2					X		X
	HECWRC	Flood Frequency Analysis						
	HYDRA	X	X					X
	ILLUDAS /ILUDRAIN	X	X	X				X
	POND-2	Routing		X				X
	QUICK TR-55	X		X				X
	SYNOP	Data Analysis						
	TR-20	X	X	X				X
	Water Works	X	X	X		X	X	X
Quantity & Quality	HSPF	X	X	X	X			X
	STORM	X			X			X
	SWMM	X	X	X	X		X	X
	P-8	X	X	X	X			X

3.1.2 Model Selection Criteria

HDR utilized the existing XP-SWMM models from the original Master Plan activity for this update. The functional capabilities of this model can be seen in Table 3.1-2.

Table 3.1-2

Functional Capabilities of Candidate Hydrologic and Hydraulic Models

Model Function	Model Name	Degree Of Complexity				Menu Driven	Model Category	Documentation	Output Display	Tech. Support
		Routing	Calibration	Data Req'd	Gen'l					
Quantity	Advanced ICPR	M	M	M	M	yes	event	good	excellent	good
	HEC-1	L	L	L	L	yes	event	excellent	good	excellent
	HEC-2	-	L	L	L	yes	event	excellent	good	excellent
	HECWRC	-	L	L	L	-	event	good	good	good
	HYDRA	L	M	M	M	yes	event	excellent	good	excellent
	ILLUDAS/ ILUDRAIN	H	M	H	H	-	event	good	good	good
	POND-2	L	L	L	L	yes	event	excellent	excellent	excellent
	QUICK TR-55	L	L	L	L	-	event	good	excellent	good
	SYNOP	-	-	-	L	-	event/cont	good	good	fair
	TR-20	L	L	L	L	-	event	good	good	good
	Water Works	L	L	M	M	yes	event	good	excellent	excellent
Quality & Quantity	HSPF	M	H	H	H	-	event/cont	fair	fair	fair
	STORM	L	L	M	M	-	cont.	good	fair	good
	SWMM	H	M	H	H	-	event/cont	excellent	good	good
	P-8	M	M	M	M	-	event	poor	fair	none

XP-SWMM is a commercially enhanced version of the public domain SWMM model. XP-SWMM is a comprehensive mathematical model capable of computing runoff, analyzing sanitary and storm sewer networks, and modeling treatment of pollutants.

XP-SWMM has a diverse array of routines for computing runoff, analyzing sanitary and storm sewer networks, and modeling treatment of sewage and pollutants. The program can generate hydrographs and mix them with runoff pollutants, sediment, and sewage. The program will develop runoff hydrographs from rain or snowfall. These hydrographs can then be added into the stormwater conveyance system at storm sewer junctions. The storm sewer network analysis takes into account hydrograph attenuation and displacement, in-conduit storage, downstream control effects, flow reversal, surcharge, pressure flow, branches, loops, pumps, weirs, and regulators. XP-SWMM can employ land use and population statistics to estimate the rate of sewage transport in a sewer system. For network analysis, the user may choose from 13 pre-programmed conduit shapes, or define its own.

3.2 MODEL DESCRIPTION

The XP-SWMM model is a commercially enhanced version of the USEPA SWMM model. The original SWMM model was developed from 1969-1971 by a team of contractors including Metcalf & Eddy, the University of Florida, and Water Resources Engineers under contract to the USEPA. The original SWMM program was substantially enhanced by the addition of a transport model known as EXTRAN. The original EXTRAN model was developed by Water Resources Engineers in 1973 as the WRE Transport Model. In 1974, the USEPA acquired the model and incorporated it into SWMM as the EXTRAN block. Water Resources Engineers was purchased by Camp Dresser and McKee (CDM) in 1980. In the mid-80’s CDM enhanced the EXTRAN block to model natural channels with arbitrary cross-sections.

XP-SWMM consists of four basic modules (referred to hereinafter as blocks) each of which is both supported by, and supports, the other blocks. The four blocks: 1) runoff, 2) transport, 3) EXTRAN, and 4) storage/treatment, are in turn supported by shell program blocks that provide input information, editing, plotting, statistical, and combination functions. The “XP” enhancement is a windows-based graphical pre- and post-processor. Illustration 3.2-1 shows the basic schematic layout for XP-SWMM. Each of the four major blocks is generally discussed in the following paragraphs. More detailed explanations of the runoff block and EXTRAN block are included in Sections 3.3.1 and 3.4.1, respectively.

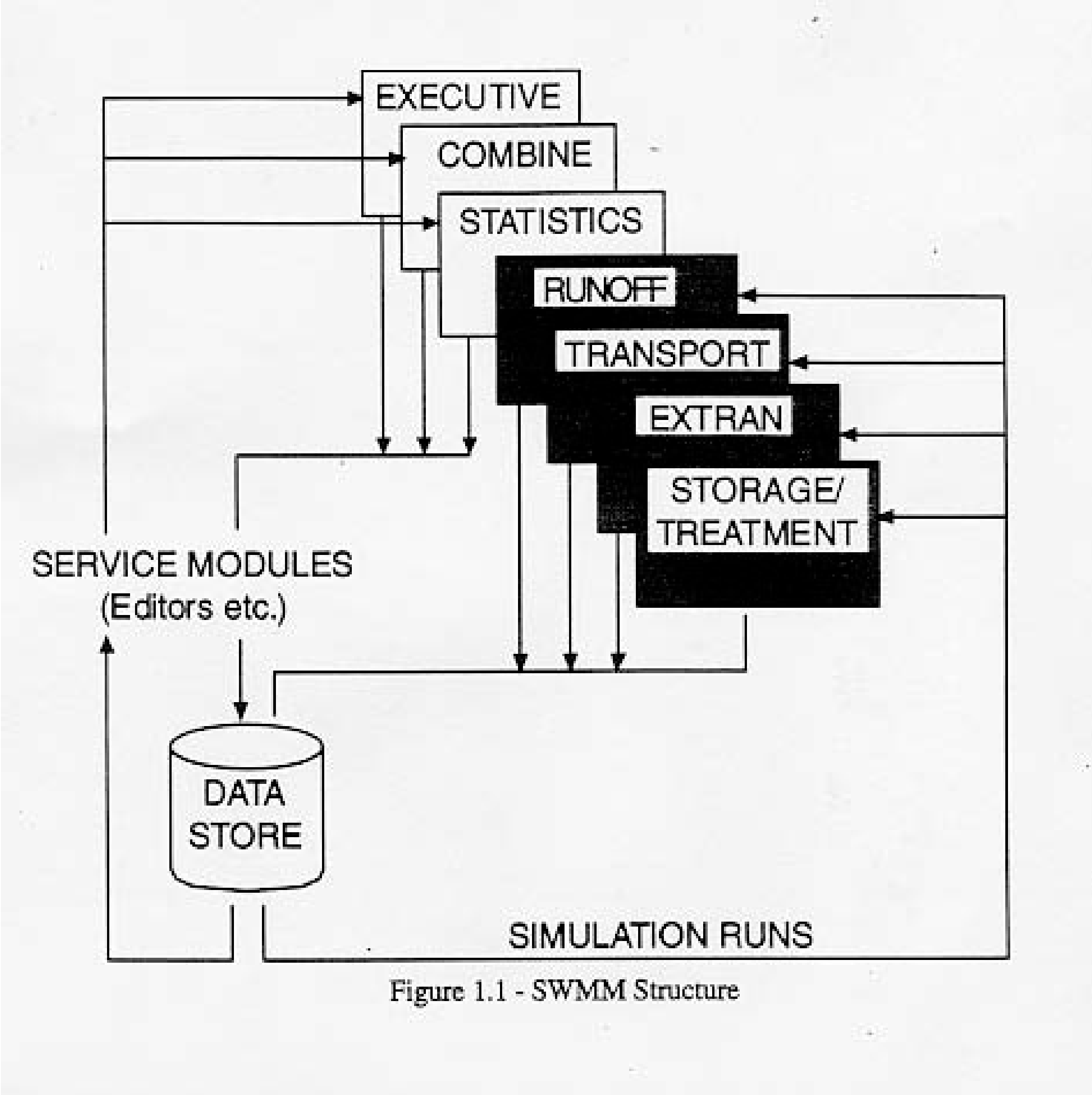

Illustration 3.2-1 ***SWMM Model Schematic Structure (source: XP-SWMM Training Workshop, Seattle Washington, 1974)***

The runoff block is the hydrologic element of the XP-SWMM model. The runoff block calculates the hydrograph for surface runoff and ground-water infiltration. For the purpose of this Master Plan, only surface runoff was considered. The model can be run as an event-specific hydrograph generator, or as a long-term continuous time series simulation. The model offers two options for hydrograph calculation: 1) traditional SCS curve number methodology, and 2) non-linear overland flow routing using Manning's equation. The runoff block also provides limited hydrograph routing using non-linear reservoir routing. The routing assumes that the water surface profile is parallel to the channel invert. Reverse flow and backwater effects are not modeled.

The transport block is an extension of the non-linear reservoir routing contained in the runoff block. It uses non-linear kinematic wave routing to simulate cascading (sequential) conduit flow. The transport block can only simulate reverse flow and backwater effects within one reach. It has limited ability to handle surcharged flow. Excess flow is stored in the upstream storage node until conduit capacity is restored. The transport model is also used to route pollutants generated within the runoff block. It is the only pollutant routing technique available within XP-SWMM. In this Master Plan, the transport block was used only for pollutant routing.

The EXTRAN block is the primary routing tool within XP-SWMM. It is a full dynamic wave routing program. Reverse flow, backwater effects, flow diversion and looping, tidal and transitions between subcritical and supercritical flow are accommodated. EXTRAN solves the St. Venant equations at each time step. While EXTRAN is a powerful tool, it requires considerable computing power and is very unstable.

Selection of proper starting parameters must be made with great care to ensure that the model converges. A significant benefit of EXTRAN is that it models the flow attenuation observed in the real world as flow is retarded at undersized culverts, etc. Traditionally, the downstream discharge hydrograph routed using a full dynamic wave routing technique will be lower than a hydrograph routed using reservoir or kinematic wave routing.

The storage/treatment block is a tool for the simulation of wastewater treatment processes. It has applications in combined sewer studies where sanitary and storm flows are carried in the same sewer. Additionally, it may be possible to simulate Best Management Practices, but only as it relates to plain sedimentation. The storage and treatment block was not used in this Master Plan.

3.3 HYDROLOGIC MODEL

3.3.1 General

As noted earlier, XP-SWMM's runoff block can be used in one or two modes. The first mode uses SCS methodology. When the SCS method is used, the model functions similarly to HEC-1 and uses inputs for the SCS curve number, time of concentration, storm duration, depression storage, and shape factors. Antecedent moisture conditions are accounted for through adjustments to the runoff curve number. The advantage of the SCS methodology is that it converges quickly, resulting in a very stable model. Additionally, the input parameters are more commonly known and understood, resulting in easier applications. The disadvantage is that the results are not as accurate as for non-linear routing, and differing land uses can only be accounted for via the runoff curve number. In the Upper Salem Creek Master Plan, SCS methodology was used.

The second mode uses Manning's equation, a non-linear runoff routing that is a more precise method to calculate runoff. The overland flow from the pervious and impervious portions of the watershed sub-basin are calculated separately and summed at the sub-basin outlet. The non-linear method replaces the SCS curve number with soil infiltration parameters. In the Middle Salem Creek Master Plan Update, Manning's methodology was not used.

The entire contributing drainage area for the Upper Salem Creek watershed was delineated using the USGS (U.S. Geological Survey) Quadrangle Maps (scale: 1″ = 200′), 2-foot contour maps of the City of Winston-Salem (scale: 1″ = 200′), 2-foot contour maps of the County of Forsyth (scale: 1″ = 400′), and aerial photographs taken in 1997 (scale: 1″ = 200′). The entire drainage area was then sub-delineated to include all the major outlet locations and drainage structures serving over a 50-acre limitation within the City limit. A total of 156 sub-basins were delineated with areas ranging from 0.2 acres to 156 acres. Within the City limit, a 50-acre limit applies. However, drainage areas outside of the City limit were delineated based on the reasonable outlet locations. Within the City limits, a 50-acre limit applies. However, drainage areas outside of the City limits were delineated based on the reasonable outlet locations.

All the delineated sub-basins were digitized and converted into a GIS format to be prepared for the runoff block requirements. Basin delineation is shown in Figure 3-1. Initially, basin-wide hydrologic data was generated in GIS by creating the pertinent thematic layers, such as impervious areas, land uses, soil groups, basin widths, and contours. Once this was complete, spatial overlays were constructed in GIS to compute the specific hydrologic parameters required by the runoff block. The hydrologic parameters are summarized in Appendix, Subcatchment Hydrologic Parameters.

3.3.2 Hydrologic Parameters

Runoff block in XP-SWMM computes a basin runoff hydrograph using the selected hydrograph method in conjunction with given rainfall data. Among five hydrograph generation techniques available in runoff block, the SWMM Runoff Non-Linear Reservoir Method was utilized. The SCS Unit Hydrograph Method was not used because all of the sub-basins were within Winston-Salem City limits.

For sub-basin hydrograph generation calculation, the following hydrologic parameters are required:

1. Area in acres.
2. Imperviousness by percent – The impervious areas must be hydraulically (directly) connected to the drainage system. If the imperious area is included in the Runoff Curve Number, imperviousness will be set at 0%.
3. Width in feet – A good estimate for the width is the area of the sub-basin divided by the average path length of overland flow.
4. Slope in ft/ft – The sub-basin slope should reflect the average slope along the pathway of overland flow to outlet locations.
5. Runoff Curve Number (CN) – The major factors that determine CN are the hydrologic soil group, cover type, treatment, hydrologic condition, and antecedent runoff condition.

6. Time of concentration in minutes – Time for runoff to travel from the hydraulically most distant point of the watershed to a point of interest within the watershed.
7. Peak Rate Factor – A typical Piedmont terrain Unit Hydrograph shape factor is 484.
8. Initial abstraction – The initial abstraction from the precipitation may be represented as the total depth of precipitation that is lost, or as a percentage of the amount of total precipitation. In this Master Plan, the latter method was used and set equal to 20 percent.

The 24-hour rainfall depths for the 10-, 25-, 50-, and 100-year storm event shown in Table 3.3-1 were based on the Drainage Criteria and Design Manual of the City of Winston-Salem, December 1995. The hydrograph for each basin was developed using a 10-minute time increment interval with the SCS Type-II rainfall distribution. The runoff peak flows are summarized in Appendix, Subcatchment Runoff Peaks.

Table 3.3-1
Upper Salem Creek Watershed
24-Hour Total Rainfall Depths

Storm Frequency	Rainfall Depth (Inches)
10-year	5.1
25-year	5.6
50-year	6.3
100-year	7.2

3.3.3 Model Validation

Model calibration was set during the original model development for this watershed and therefore was not performed again during the update process. However, the model results were compared with the original model results that used a different hydrology method to understand where model sensitivity occurred and to provide a reasonableness check on the results. Gage data is not available throughout the City's watershed, and therefore the lack of real-time data will influence the model results. The City is in the process of obtaining flow data at various locations, and this data will be used to perform additional calibration and possible model parameter adjustments in the near future.

3.3.4 Present and Future Runoff

A hydrologic analysis was performed for the present land use and for future build-out land use conditions. The peak discharge for the Upper Salem Creek 100-year storm are shown in Table 3.3-3 and Table 3.3-4 showing the peak discharge at the downstream study limit of Upper Salem Creek.

3.4 HYDRAULIC MODEL

3.4.1 General

The primary flow routing program within XP-SWMM is EXTRAN. EXTRAN is an extremely powerful flow routing system. It can handle dendritic (branch-like) or looped and divided flow paths. This ability to handle divided flows is particularly applicable to storm sewer system modeling. It allows piped systems to be modeled under surcharged and overflowing conditions. The flow which cannot be conveyed within the conduit system is divided and routed overland to a node farther downstream. In simpler models, the excess flow is simply "lost" from the system.

For the majority of flow cases, EXTRAN calculates nodal water surface elevations using the St. Venant equations for gradually varied one-dimensional flow. The St. Venant equations are non-linear hyperbolic partial differential equations with unknown or, at best, unwieldy direct solutions. EXTRAN uses a discrete numerical solution to converge on a solution based on user-defined upstream and downstream boundary conditions and initial starting conditions. Because of this iteration, the model is somewhat unstable and subject to non-convergence problems.

Because supercritical flow is not gradually varied, the St. Venant equations are not valid for flow in this system. Therefore, EXTRAN uses kinematic wave routing when the flow is known to be in the supercritical range. EXTRAN makes this determination by verifying: 1) a positive flow direction (in a downstream direction), 2) water surface slope is greater than the channel or conduit slope, and 3) the kinematic flow as determined by Manning's equation is less than the flow calculated by the dynamic St. Venant equations.

A notable difference between EXTRAN routing and HEC-2 routing pertains to channel cross-section. EXTRAN uses a constant cross-section for each channel or conduit. Therefore, node locations must be selected with care to ensure that the upstream and downstream reaches where the cross-sections are cut are representative of the channel or conduit between the nodes. HEC-2, on the other hand, uses cross-sections cut at the nodes.

Because of the complexity associated with the EXTRAN model, the reader is referred to the USEPA SWMM and XP-SWMM guidance manuals for a more extensive discussion on the theory behind the model.

3.4.2 Model Schematic

XP-SWMM dynamically routes storm water through open channels and/or closed conduits. Hydraulic routing through conveyance and drainage systems requires a mathematical framework from which numerical calculations can take place. XP-SWMM uses a link-node concept to idealize real-world systems. This concept requires that the drainage system be represented by a network of nodes or junctions and links or reaches. A node is a discrete location in the drainage system where conservation of mass or continuity is maintained. Links are the connections between nodes and are used to transfer or convey water through the drainage system. The following general guidelines were used to locate nodes in the Upper Salem Creek schematic:

1. A node should be placed upstream and downstream of structures, such as culverts, weirs, etc.

2. All ponds and lakes should be specified as storage nodes.

3. A node should be located at all channel junctions.

4. A node is required at any downstream boundary.

5. A node should be located where the channel geometry changes abruptly.

6. A node should be placed where the channel bed slope changes abruptly.

7. A node should be located where major surface inflow enters to the conveyance system.

By following the general guidelines, a schematic diagram of the Upper Salem Creek conveyance system was developed as shown in schematic Figure 3.1. Beginning from the confluence with Peters Creek and going upstream to Salem Lake, nodes on the main channel of Upper Salem Creek were specified by the node name "SC" followed by a number, starting with 5 and proceeding in increments of 5. For example, the first node of the main channel is SC005, the second is SC010, and so on. This naming convention was used as a first cut, and allowed for the placement of nodes between reaches if additional nodes were deemed necessary. An example of this would be the placement of a new node between SC015 and SC020 with the name SC017. Tributaries for all three sub-basins of Salem Creek (Lower, Middle and Upper) were named alphabetically proceeding up the mainstem from Clemmonsville Road. Therefore, the first tributary of Upper Salem Creek was named the "O" branch, the second the "P" branch, and so on. As tributaries branched, another letter was added alphabetically. An example would be a small minor tributary off the "T" branch could be named the "TA" branch.

3.4.3 Model Calibration

Model calibration was performed during the original Master Plan efforts.

3.4.4 Existing and Proposed Condition, Present and Future Study Results

Present and future land use condition model runs were completed for the 10-, 25-, 50-, and 100-year storm events, for existing and proposed storm sewer systems. For existing and proposed hydraulic conditions using present and future land use condition, summary tables have been created and are attached in the Appendix. The summary tables report peak flow, maximum velocity, and maximum water surface elevation for the modeled storm events. The graphic representation of water surface profiles can be found in Figure 6-2 which includes the following segments.

- Upper Salem Creek (STA. 0-26000)
- Tributary R/RB (STA. 0-5000)
- Cloverleaf Branch, Tributary T (STA. 0-3500)
- Stadium Branch, Tributary V (STA. 0-4500)
- Tributary W (STA. 0-8500)
- Berry Branch, Tributary X (STA. 0-95000)

A summary of results for all modeled locations can be found in the Appendix in the following figures:

- Existing Hydraulic Conditions
  - Maximum Water Surface Elevation
  - Maximum Flows and Velocities
  - Water Surface Profiles
- Proposed Hydraulic Conditions
  - Maximum Water Surface Elevation
  - Maximum Flows and Velocities
  - Water Surface Profiles

Tables 3.4-1 and Table 3.4-2 summarize the 10-, 25-, 50-, and 100-year discharge and water surface elevations (WSEL) for the present and future land use conditions at selected locations. In general, the selected locations are the confluence and roadway crossings of major tributaries.

SECTION 4 – ESTIMATION OF NON-POINT SOURCES AND RECOMMENDED CONTROLS

4.1 MODEL DEVELOPMENT

A major component of the Part 2 NPDES Storm Water permit was the estimation of annual watershed pollutant loads and EMCs. Loading refers to the total pounds of a particular pollutant that wash off the watershed into downstream watercourses. The EMC is the average concentration of the pollutant expressed in concentration units of milligram per liter (mg/l). The EMC is equal to the total pounds of pollutants divided by the total runoff volume, multiplied by the required unit conversion factors. It is important to note that the EMC is not a measured value, and is merely representative of the average value for the pollutant. For any given storm event, the concentration may be significantly higher than the EMC for certain periods during the runoff event.

During development of the Part 2 NPDES Storm Water permit application, three representative storm events were sampled from six watersheds representing different land use makeups. The storm water samples were analyzed for 12 pollutants, including: biochemical oxygen demand, cadmium, chemical oxygen demand, copper, lead, total and Kjeldahl nitrogen, dissolved and total phosphorus, dissolved and suspended solids, and zinc.

The results from the Part 2 NPDES Storm Water permit application sampling were used to calibrate the P-8 Urban Catchment model. The P-8 model has been previously discussed in Section 3.1.2. The P-8 model was calibrated to the measured storm events with loading parameters developed for five land use categories: 1) light density residential, 2) medium density residential, 3) high density residential, 4) heavy business, and 5) light industrial. These five categories were determined to be representative of all the land uses within the City. The calibrated P-8 model was used to determine annual loading estimates for each watershed for each pollutant based on the land use distribution within each watershed. At that time, pollutant loading estimates were made only for the portion of a watershed lying within the City limits.

For the Master Plan, the water quality capabilities of the runoff and transport blocks of XP-SWMM were utilized.

For master planning, it is desirable to know the EMC value for the entire watershed. In practice, pollutants recognize no political boundary. Therefore, it is necessary to estimate watershed-wide pollutant loadings including contributions from unincorporated areas. The water quality components of XP-SWMM were calibrated from the P-8 modeling results for Fiddlers Creek. Specifically, the wash-off coefficients for each pollutant for each land use category for the XP-SWMM water quality rating curves were adjusted for the inside City sub-basins until the predicted total annual pollutant loading from Fiddlers Creek matched the P-8 results. These calibrated coefficients for each pollutant for each land use were then used to determine annual loadings for the entire watershed, including unincorporated areas.

4.2 MODEL RESULTS

The water quality simulation model was run for present land use conditions, 2007, and future build-out land use development conditions. The model results for the 12 parameters are provided in the tables. Annual pollutant loading estimates are summarized in Table 4.2-1. Table 4.2-2 provides the EMC and the event concentrations that are exceeded 10 percent (highest value) and 90 percent (lowest value) of the time additionally, for pollutants where the North Carolina Division of Water Quality has established action levels, these levels are indicated on the charts.

Overall, the quality of the runoff during storm events is typical of discharges from an urbanized area. Copper (Cu) and zinc (Zn) are the only metals that exceeded State action levels. The on-going monitoring work should carefully evaluate copper and zinc to see if the elevated levels are responsible for any deleterious effects on stream aquatic life. A summary of the results are found in Table 4.2-3

4.3 EVALUATION OF BEST MANAGEMENT PRACTICES

4.3.1 General Information

One major component of managing storm water runoff is the implementation of BMPs. BMPs are operational techniques and/or structural facilities that can dramatically improve the quality of storm water runoff. Operational BMPs reduce the opportunity for pollution to come into contact with storm water runoff, whereas structural BMPs collect, concentrate, and/or treat runoff. The costs to implement operational and/or structural BMPs are usually significantly less than the costs associated with remediating damage resulting from inadequate storm water management. Operational BMPs are much more economical and simplistic, so they should generally be considered before structural BMPs.

When selecting any type of BMP, non-technical issues, as well as technical issues, should be considered. Technical issues vary with individual BMPs, but broadly deal with site feasibility, design considerations, and/or pollutant removal efficiencies. Technical issues are generally more involved for structural BMPs than operational BMPs, and are discussed in greater depth in later sections. Non-technical issues deal with the economic, regulatory, and public aspects of selecting a BMP. These issues, among others, include federal, state, and local regulations; real and perceived receiving water problems; economic feasibility of BMP being considered; and public acceptance of BMP being considered.

Additionally, implementation of BMPs, particularly operational BMPs, is generally done on a City-wide basis rather than specific to any one watershed. Therefore, the following discussion presents information that may be considered in adopting a City-wide BMP program rather than specific for this watershed. Upon completion of all specific watershed Master Plans, the City may elect to review the entire issue of BMP implementation.

4.3.2 Operational BMPs

The goal of operational BMPs is to prevent pollutants from coming in contact with storm water by controlling the pollutants at their source. For this reason, operational BMPs are often referred to as source control BMPs. Operational BMPs are non-structural controls generally associated with management practices that reduce contact between storm water and pollutants. The effectiveness of operational BMPs is often highly dependent on site-specific conditions, due to the high variability in pollutant source conditions; thus it is difficult to generate general removal efficiencies. Source controls for urban areas can be grouped into the following general categories:

- Public education.
- Street/storm drain system maintenance.
- On-site materials management.
- Planning and regional management.
- Illicit/accidental controls.

Public education can be one of the most economical and effective pollution control strategies. The goal of public education is to change the way the public manages many of the constituents that end up in storm water runoff through awareness. The methods in which many household products are used and disposed of, such as automotive fluids, cleaners, and fertilizers, can have a profound effect on the quantities of these substances that come into contact with storm water, and thus on the water quality of receiving waters. Many methods are available for increasing public education, including radio/television advertisements, mailings, public meetings, and others. Although public education is one of the simplest means of affecting storm water quality, its effectiveness is highly variable and may be hard to directly measure.

Street and storm drain maintenance refers to the removal of pollutants from street surfaces and the periodic cleaning of storm drainage structures. This control may reduce the quantity of pollutants, most notably sediment, entering the storm sewer system. Examples of this type of pollution control include street sweeping, catchbasin cleaning, curb and gutter cleaning, and road and bridge maintenance.

On-site materials management deals with the practice of use, storage, and disposal of substances that could pollute storm water runoff. There are many specific pollution controls for materials management; however, they can be generalized into three groups:

- Altering the activity to minimize generation of potential pollutants.
- Covering pollutant sources, thus reducing their contact with precipitation and runoff.

- Containing/segregating the activity containing source of pollutants from other activities, so pollutants may be handled and disposed of separately.

Examples of on-site materials management include storing materials inside or under cover on paved surfaces, minimizing storage and handling of hazardous materials, secondary containment to reduce leakage, and choosing safer alternative products.

Planning and regional management refers to practices by local governments aimed at reducing pollutants in storm water on a regional basis, especially those loadings from new development areas. Land use controls and floodplain management practices are the typical mechanisms for this type of pollution control. Examples of planning and regional management include buffers and setback from all water bodies, zoning ordinances for open areas, regulations for sediment control measures in new developments, and use of vegetated natural channels.

Illicit and accidental control BMPs can be used to reduce introduction of pollutants to storm sewer systems through illegal or accidental activities. These activities are often related, because a responsible party may not even be aware of the detrimental impacts of an illegal or accidental discharge to the storm sewer system. Examples of illicit and accidental controls include detection, removal, and enforcement system for illegal connections/dumping through inspections or source testing; public notices; and accidental spill information boards/hotlines.

4.3.3 Structural BMPs

The goal of structural BMPs is to reduce non-point source pollution by collecting, concentrating, and treating storm water runoff. Unlike operational BMPs, which are often simply techniques for source control, structural BMPs are physical structures that are strategically located within a watershed. In comparison with non-structural BMPs, structural BMPs involve higher capital cost, more complexity, and required maintenance but they do provide a higher assurance in treatment because they are mechanistic and continually operating. Overall, structural BMPs are most applicable to developing and redeveloping areas, since construction/implementation costs are less and site location is easier. With NPDES Phase II regulation qualifying new development and redevelopment are required to have structural BMPs as part of their overall post construction storm water runoff control.

General Structural BMP Considerations

Structural BMPs are strategically located and designed to maximize their beneficial impact on storm water quality for an area, and to minimize implementation and operational costs. This benefit/cost feasibility analysis for selecting a structural BMP can be grouped into five general categories:

- Physical suitability
- Hydrologic conditions

- Pollutant characteristics and removal capabilities
- Environmental and aesthetic factors
- Operational factors

Physical suitability of a site refers to the technical feasibility criteria related to physical conditions, such as topography, required land area, contributing drainage area, soil types, and water availability. Physical suitability is often one of the first considerations when selecting a structural BMP, since it is not feasible or possible to change many of the factors, and it can dramatically affect the usefulness of a given BMP.

Hydrologic criteria focus on the hydrologic characteristics for a given design storm event, such as storm water runoff volume, distribution, and peak discharge. It should be noted that the concepts in designing water quality controls are different than those for water quantity controls. The highest concentrations of pollutants are often found in the beginning of storms, often referred to as the "first flush" stage. In this stage, built-up pollutants are being washed off the land surface and potential dilution effects are negligible. Thus, water *quality* controls are designed for smaller, more frequent storms, whereas water *quantity* controls focus on larger, less frequent storms, which cause flooding and other damage.

Pollutant characteristics and removal capacities refer to the water quality of the storm water runoff entering a structure, and the effectiveness of that BMP in removing those pollutants. Generally, the pollutants of consideration are sediment, nutrients, oxygen demand, trace metals, and bacteria. Table 4.3-1 provides a summary of removal efficiencies for selected structural BMPs. Through additional research, the removal efficiencies may be changed based on readily available data.

Environmental and aesthetic factors refer to the impacts a structural BMP would have on the environment and how it would affect the aesthetics of the area. Examples of environmental and aesthetic factors include maintenance of low flows for aquatic life, streambank erosion, recreational benefits, and community acceptance.

Operational factors are mainly concerned with the amount and type of maintenance a given structural BMP requires. Generally, structural BMPs have a passive design, meaning that there is no active operation of mechanical or chemical equipment. However, almost all structural BMPs require periodic cleaning and maintenance to keep them working efficiently.

Environmental and aesthetic factors refer to the impacts a structural BMP would have on the environment and how it would affect the aesthetics of the area. Examples of environmental and aesthetic factors include maintenance of low flows for aquatic life, streambank erosion, recreational benefits, and community acceptance.

Operational factors are mainly concerned with the amount and type of maintenance a given structural BMP requires. Generally, structural BMPs have a passive design, meaning that there is no active operation of mechanical or chemical equipment. However, almost all structural BMPs require periodic cleaning and maintenance to keep them working efficiently.

Table 4.3-1
Upper Salem Creek Watershed
Comparison of Pollutant Removal Efficiencies of Structural BMPs

Best Management Practice	Suspended Sediment (%)	Total Phosphorous (%)	Total Nitrogen (%)	Bacteria (%)
Bioretention	85	45	35	High
Storm Water Wetlands	85	35	40	Med
Wet Detention Basin (Wet Pond)	85	40	25	Med
Sand Filter	85	45	35	High
Filter Strip	25-40	35	20	Med
Grassed Swale	35	20	20	Low
Restored Riparian Buffer	60	35	30	Med
Infiltration Devices	85	35	30	High
Dry Extended Detention Basin	50	10	10	Med
Permeable Pavement System	0	0	0	Low
Rooftop Runoff Management	0	0	0	Low

Source: NC DNER Stormwater BMP Manual, 2007

Overview of Specific Structural BMPs

A brief explanation of the types of structural BMPs listed in Table 4.3-1and their primary modes of operation is provided here.

Detention controls consist of dry extended detention basins, which completely drain out between storm events, and wet detention basins (wet ponds), which maintain a designed level of water between storm events. In addition, storm water wetlands are detention facilities that have additional construction and biological requirements, but often provide increased pollutant removal. The primary mechanism for pollutant removal for these structural BMPs is sedimentation. Wet ponds provide additional removal through physical and biochemical processes, such as reduction in bottom sediments and increased vegetative growth that occur along the outer permanent pool. In addition to good pollutant removal, detention facilities can also provide reduction in peak runoff flows.

Detention controls are most applicable where relatively large tracts of land are available, such as parks and industrial facilities.

Conveyance-driven structural BMPs are measures that treat storm water runoff as it flows across the landscape. Swales are shallow, vegetated, mildly sloped channels that convey storm water runoff. They are designed for low velocity flows during small storms to allow infiltration of storm water into the swale bottom, and filtration and biological uptake of pollutants into the vegetative cover, collectively referred to as biofiltration. Swales are applicable in most mildly sloping areas due to their relatively low space, cost, and maintenance requirements.

Filter strips are similar to swales, except they do not have side slopes, thus runoff is spread evenly through the filter strip area as sheet flow rather than through small channels. Filter strips most commonly refer to grassed areas however, restored riparian buffers operate in the same manner except with a mix of grasses, trees and shrubs. They are less effective given the difficulty in maintaining sheet flow. Treatment, cost, maintenance, and applicability are similar to those of swales.

Infiltration type structural BMPs include bioretention, infiltration devices and sand filters. These systems treat storm water runoff by filtering flow through an engineered media and in some situations by exfiltrating flow to in-situ soil. These systems consist of a structure or trench filled with a filter media such as sand or gravel, which allows percolation. Infiltration devices only work with porous soils, favorable site geology, and proper ground-water conditions. Infiltration devices are generally not effective in the Winston-Salem area due to the predominantly clayey soil types. Additionally, their use may violate ground-water protection rules. Bioretention systems incorporate vegetation into the engineering media at the surface to provide additional removal through vegetative uptake and biochemical fixation. Bioretention systems are typically linear with a semi-permeable linear and are under-drained to facilitate full emptying of the system within a desired duration.

Sand filters operate in the same manner as infiltration devices and bioretention except that they are almost always lined with an impervious liner, filled solely with sand, and lack vegetation. Sand filters are effective measures in capturing sediments and oils and grease. However, they do come with high complexities of design and maintenance costs.

Lastly, permeable pavement and rooftop runoff management systems are adaptations to typically impervious surfaces to provide greater runoff and storm water quality control. Permeable pavements allow for the infiltration and temporary storage of runoff from previously impervious surfaces at low intensity and volume storms. Where in-situ soils have high infiltration rates, the storm water can be exfiltrated otherwise and an under drain and downstream control devices may be needed. Rooftop runoff management systems harbor low intensity and volume storms within an engineering media and system on rooftops. The media filters the rainfall for pollutants and stores the rainfall for evaporation and evapotranspiration when vegetation is also provided. These systems need care engineering and design to work properly and sustain their intended design life.

4.4 STRUCTURAL BMP RETROFITTING

4.4.1 General Information

The implementation of structural BMPs is effective at minimizing non-point source pollution for urbanizing areas; however, for the City much of the municipal limits have been developed prior to these Phase II regulations requiring structural BMPs on new qualifying development. While these previously developed areas are not required to have post construction controls they still contribute significant non-point source pollution contributing to violation of water quality standards. Therefore, a retrofitting strategy may be employed to locate structural BMPs where existing stormwater controls are present or opportunities for construction of new facilities can be implemented. The City is embracing this strategy as part of the Master Plan where it needs to implement a WQRP as part of a TMDL.

4.4.2 Retrofitting Strategy and Methodology

Retrofitting opportunities for structural BMPs offer a spectrum of activities for meeting various goals and objectives. For the Master Plan, the City and HDR identified a strategic process for identifying and evaluating potential structural BMPs. The process is outlined here:

1. Develop Retrofitting Goals
2. Determine Evaluation Criteria
3. Perform Desktop Analysis
4. Perform Retrofit Reconnaissance
5. Evaluate and Screen Retrofits
6. Develop Conceptual Designs
7. Model Conceptual Design Hydraulics and Water Quality

In determining goals of the retrofitting process the WQRP served as the overarching guidance. From the WQRP and discussions with City staff the retrofitting goals for the Master Plan include:

- Focus on structural BMPs that maximize bacteria control and treatment
- Location of structural BMPs in regional settings to maximize stormwater volume collection
- Location of structural BMPs on public property to maintain public access for maintenance and minimize land acquisition
- Location of structural BMPs away from jurisdictional wetlands and streams and high hazard dams to minimize permitting requirements.

__Evaluation Criteria__

In order to screen multiple retrofit opportunities within an objective framework, several evaluation criteria were established. The basis for these evaluation criteria was determined through guidance from the Center for Watershed Protection's series titled Urban Watershed Restoration and discussions with City staff. In particular, Manual Three Urban Stormwater Retrofit Practices was utilized in determining criteria and defining metrics to be calculated for evaluation. Table 4.4-1 lists the criteria that were established.

Table 4.4-1
Middle Salem Creek Watershed
BMP Retrofit Opportunity Evaluation Criteria

Evaluation Criteria	Basis of Metric
Ownership Type	• Public • Private Commercial • Private Residential
Acceptance of Significant Drainage	• Drainage Area
Future Growth Impact	• Present Imperviousness • Future Imperviousness
Pollutant Loading Impact	• Pollutant Load Relative Ranking
Ability to Treat First Flush	• Water Quality Volume • Preferred BMP Design Depth
Treatability of Pollutant of Concern	• BMP Efficiency
Permitting Involvement	• Dam Permit Required • Wetland Permit Required • Stream Impacts Permit Required

Desktop Analysis and Site Reconnaissance

A desktop analysis was performed to identify quickly existing structural BMPs as well as potential sits for new BMPs within the City's MS4 for Middle Salem Creek watershed. The City maintains a database of existing structural BMPs that require annual inspection. This database served as a baseline for evaluating existing BMPs. From this database all existing structural BMPs were identified for site reconnaissance despite their ability in possibly meeting the retrofit goals. Site reconnaissance was necessary to understand better the physical and operational qualities of these existing facilities.

For potential new BMP locations a spatial analysis was performed to filter through open sites in order to appropriately identify potential locations roughly meeting retrofitting goals. The two most important characteristics in recognizing potential locations are the sites capacity to receive concentrated runoff and its ability to provide enough ground space for treatment. Therefore, this process first identified publicly owned parcels, such as schools, parks, municipal facilities, and excessive or abandoned right-of-ways. In addition to this subset, parcels depicting open space downstream and next to pipes with diameters equal to or greater than 24" where identified. Pipes of this diameter were determined to provide enough runoff capacity to support the financial implementation of a newly-constructed, structural BMP. Finally, a visual desktop inspection of the entire Middle Salem Creek watershed was performed to identify any other open sites that may have potential for retrofitting but may require significant piping of stormwater to bring runoff to the site. From this analysis several sites were to be identified for site reconnaissance.

Each site in the Desktop Analysis was visited in the field where a quick determination was made to further investigate and document its feasibility. If a site was determined to possess minimal feasibility then a Retrofit Reconnaissance Investigation form was completed documenting the physical description of the site and drainage area, existing stormwater management practices, proposed retrofit, site constraints, sketch, design and delivery notes, and initial feasibility and construction considerations. The data collected on the forms was used in filling out evaluation criteria and making subjective determinations of the feasibility. In addition, photographs were taken to further document the details identified in the form. A number of sites with the potential for a retrofit or system of retrofits were documented. Table 4.4-2 and Figure 4-1 identify these sites.

Evaluation and Screening of Retrofits

With a subset of retrofit opportunities identified and site inspection data documented, the evaluation criteria and their associated metrics were tabulated. The tabulation of the evaluation criteria was performed utilizing basic calculations, subjective assessment, the North Carolina BMP design standards and GIS datasets and processes. For example Schuler's Simple Method was employed to calculate both the water quality volume as well as the fecal coliform pollutant loading rate. Subjective assessment and the Retrofit Reconnaissance Investigation forms were used to populate permitting impacts and determine a preferred BMP type for the facility. Subsequently, the North Carolina BMP design standards were referenced for hydraulic loading depth of the water quality volume and removal efficiency for various BMP types. GIS datasets were utilized in determining existing and future impervious coverage, ownership type, and drainage areas.

Once the evaluation criteria metrics were populated each criterion was partitioned into three classifications based on the range and distribution of the metric data. These classifications allowed for a range of scoring values to be assigned for the screening process. The Middle Salem Creek Master Plan is one of five total, City master plans contributing to the Salem Creek watershed. Since the WQRP makes no distinction about subwatershed or locally referenced goals within the watershed, it was determined that a watershed-wide basis screening process be administered within Salem Creek. Therefore, the retrofit opportunities from all contributing Master Plans were screened collectively. The retrofit opportunities for structural BMPs identified in Middle Salem Creek are listed in the following section.

Conceptual Plan Design and Modeling

Section to be completed once screening and selection of all BMP retrofit opportunities in Salem Creek has been finalized.

5.1 CRITERIA AND METHODOLOGY

5.1.1 General

Investigations of structural flooding, roadway overtopping, and channel erosion were conducted for present and future land use development conditions. Runoff from the existing and future conditions was routed through the existing channels, culverts, and storm drains. Therefore improvements identified in the original Master Plan Document were evaluated for the Present (land use conditions) flows and the Future (build-out land use conditions) flows.

5.1.2 Structural Flooding

A delineation of a 100-year floodplain was created in ArcGIS® using the existing conveyance elements and the year 2020 land use and runoff estimates. Using the GIS building structures layer, aerial photography, and the 100-year floodplain, flooded structures were initially identified by visual inspection. A field investigation of the identified structures was made to determine if the structure was a residence, place of business, shed, or other non-habitable structure. If the structure was determined to be a shed or a non-habitable structure, the identified location was considered a non-problem area. If the identified location was considered a potential problem area, the approximate finished floor elevation and basement finished floor elevation (if applicable) were determined. Finished floor elevations were surveyed with a level using catchbasin and manhole rim elevations as benchmarks determined in the recent storm sewer inventory. It is important to note that the finished floor elevations presented are approximate and are intended for use in this Master Plan only. If the basement was not a finished basement, the basement elevation was not recorded and the ground level floor was considered the lowest finished floor elevation. These finished floor elevations were compared to the floodplain elevation as the last step in the determination of structural flooding problem identification.

5.1.3 Roadway Overtopping

Roadway overtopping was estimated for the 10-, 25-, 50- and 100-year storm events. Roadway crest elevations were determined from the North Carolina Floodplain Mapping Program May 2007 Lidar, the associated 2007 NC DOT 2-foot contours, and from storm sewer inventory point structure rim elevations. A majority of the roadway crest elevations at creek and tributary crossings were identified on the contour maps with spot elevations. If spot elevations were not available, ArcView coverage was utilized to obtain catchbasin rim elevations at crossing locations to approximate roadway crest elevations. If spot elevation and GIS information could not supply the crest elevations, they were determined by interpolation between roadway contours at crossing locations. In summary, the crest elevations were obtained by the following methods listed in order of preference:

1. Spot elevations from 2-foot contour maps.
2. Catchbasin rim elevations from ArcView coverage.

3. Interpolation between roadway contours from 2-foot contour maps.

Roadways adjacent to or crossing the storm drain system were classified as residential, collector, arterial, or freeway. Because roadway classifications were not available and for the purposes of this Master Plan only, the affected roadways were classified by the HDR team using the following general definitions:

- Residential – interior streets in subdivisions and residential areas.
- Collector – streets that direct subdivision and residential traffic to arterial roadways.
- Arterial – major streets directing collector traffic to other collector streets and freeways.
- Freeway – U.S. designated Interstate Highway.

The roadway overtopping criteria are summarized below in Table 5.1-1. In this table, the Design Storm is the flood event the culvert or storm sewer must pass to meet the criteria. For example, a residential roadway cannot flood in the 10-year storm to meet the criteria but may flood in the 25-year storm.

Table 5.1-1
Roadway Overtopping Design Storms

Roadway Classification	Design Storm
Residential	10-year
Collector	25-year
Arterial	50-year
Freeway	100-year

5.1.4 Channel Erosion

For this study, channel erosion problem locations were identified using a combination of model output review and field investigations. Model output was reviewed to identify the open channels with velocities greater than 5 feet per second (fps) during the 10-year storm. The 5 fps criteria are considered the erosive velocity for streambed material consisting of silts with sand and fine gravel. A visual inspection of the identified high velocity channels was made to determine the channel bed characteristics and to identify visible signs of channel erosion. A channel that did not show visible signs of erosion and/or had bed material that would withstand higher velocities was omitted from the problem identification list.

5.2 PROBLEM IDENTIFICATION

Flooding problems are present throughout the watershed. There are a few locations where clusters of buildings flood, but, for the most part, flooding is spread out in isolated areas throughout the watershed along tributaries and the mainstem.

Problem identification began with a revisit of the previous problem areas identified to validate the presence and magnitude of the problem. In addition, new problem areas were investigated according to the criteria established in the original Master Plan.

5.2.1 Structural Flooding

The structural flooding problem locations are shown on Figure 5.1, Problem Identification Map. This is a GeoPDF file, items on the map are able to reveal critical attributes when selected with the Object Data tool in Adobe Reader. The Problem Identification Map includes a map symbol indicating the storm in which the structure floods as well as the problem location code. The problem location code is comprised of a two-letter watershed identification (SU), an “S” indicating structural, and a location number. For example, a structure flooded in the Upper Salem Creek watershed could have the following problem location code: SUS5. It is important to note that this system does not rank the problem locations in order of importance.

Information, along with approximate flooded depths, problem identification number, and location description, is summarized in Table 5.2-1. The last column in this table refers to the location of problem solution alternatives and cost estimates in subsequent tables.

5.2.2 Roadway Overtopping

The roadway overtopping problem locations are shown on Figure 5.1, Problem Identification Map. The Problem Identification Map includes a map symbol indicating the storm in which the roadway does not meet the specified criteria as well as the problem location code. The problem location code is comprised of a two-letter watershed identification (SU), an “R” indicating roadway, and a location number. As with the structure location code, this system does not rank the problem locations in order of importance.
The roadway overtopping problem locations are summarized in Tables 5.2-2, Table 5.2-3, and Table 5.2-4. For clarity, the tables have been separated by roadway classification.

There are no freeways with overtopping problems in the Upper Salem Creek Watershed.

5.2.3 Channel Erosion > 5 Feet Per Second (fps) @ 10-Year Storm

Channel erosion problem locations were identified if the natural channel Model link velocity during the 10-year storm event exceeded 5 feet per second (> 5 fps) or if field observations revealed badly eroded channel banks. The channel erosion problem locations are shown on Figure 5.1, Problem Identification Map. The Problem Identification Map includes a map symbol indicating the velocity of the problem channel during a 10-year storm as well as the problem location code. The problem location code is comprised of a two-letter watershed identification (SU), a "V" indicating velocity, and a location number. As with the structure and roadway location codes, this system does not rank the problem locations in order of importance.

The channel erosion problem locations are summarized below in Table 5.2-5. Previous limited field investigation indicated these channel segments show visible signs of erosion and have channel bed materials consisting of sand, fine gravel, and loam soil characteristics. Caution should be exercised along with further field confirmation prior to implementing any improvements in these areas. There can be fluctuation in the model results that may indicate areas of potential erosion, while the actual ground conditions (both soils and vegetation) will show stable channel reaches.

5.3 ALTERNATIVE EVALUATION

5.3.1 General

Alternatives

Alternatives were considered during the original Master Plan development. This Master Plan update did not revisit the options considered, rather it focused on the effect the land use pattern and drainage system growth had on the selected recommended improvement (preferred alternative) option.

Alternative Summaries

Monetary benefits for structural flooding were determined using an adaptation of the Newark4 Flood Damage Assessment Model. The Newark4 model produces annual benefits to solving structural flooding problems based on tax value and flooded depth. The annual benefits were translated into present worth benefits using a 100-year planning period and the March 2000 Federal Discount Interest Rate of 8.2 percent. These present worth benefits were used to develop benefit/cost ratios for structural flooding alternatives. The input parameters (structure finished floor elevation and water surface elevations for the 10-, 25-, 50-, and 100-year storms) are listed in Table 5.2-1.

As previously noted in Section 5.2.2, some of the roadway problems also result in structural flooding due to backwater from the undersized pipes or box culverts. Also previously noted, in some cases the roadway crest elevation is higher than the finished floor elevation of an adjacent structure that has flooding problems identified in this report. With this in mind, the solution of a roadway overtopping problem can reduce the structural flooded depth significantly. Conversely, the solution of a structural flooding problem in many cases resolves the identified roadway overtopping problem. Therefore, solutions to structural flooding can also include the benefit of resolution of roadway overtopping solutions.

Costs

A cost estimate is defined by the American Association of Cost Engineers (AACE) as an evaluation of the cost of the element for a project or effort with an agreed-upon scope. Of the three types of estimates noted by the AACE, costs developed for this Master Plan are considered Order-of-Magnitude estimates. Order-of Magnitude estimates generally do not require a preliminary design and are used for feasibility studies, selection of alternative designs, budgeting, and/or construction forecasting. Typically, Order-of-Magnitude estimates have an expected accuracy of 50 percent more than and 30 percent less than the actual construction costs.

Conceptual Order-of-Magnitude level cost estimates were developed for each alternative using NCDOT bid tab sheets, Site Work and Landscape Costs Data, by R.S. Means, and previous projects to determine unit costs. The cost estimates include a 20 percent contingency for potential construction items not quantified and a 30 percent contingency for engineering, administrative, fiscal, or legal fees, and are represented in 2010 dollars. Benefit/Cost (B/C) ratios were developed for the structural flooding alternatives and are also noted in the alternative summaries.

Ranking

In the development of alternative solutions, each alternative for a particular problem was ranked against the other alternatives for that problem. In many cases and mostly in roadway overtopping problems, only one conceptual alternative was identified and investigated: replacing an existing culvert with one having a greater hydraulic capacity. In general, the alternative that provided the greatest benefit for the least cost was the alternative of choice for that problem. This includes the alternatives that provided solutions to one or more problem locations or problem categories. Other factors considered in the ranking of alternatives were environmental and social impacts. The environmental impacts include potential loss of aquatic habitat and increase in pollution concentrations in creeks and streams. Social impacts include visual aesthetics, reliability of the solution, and potential conflicts with current City policy. These factors were slightly more difficult to quantify than the benefit/cost components but were used to select the preferred alternative when other alternatives were close, based on benefit/cost comparisons alone. The project ranking was not modified as part of the Master Plan Updates.

5.3.2 Development of Alternative Solutions

Problems and Problem Clusters are illustrated below depicting the original alternative number from the initial master plan. This alternative was evaluated for the development of an updated recommendation or possibly removed based on updated modeling. Tables have been updated and renumbered to be sequential. The Summary Table cross referencing the problems, schematic nodes, solutions, and other pertinent information is enclosed in Appendix.

Proposed Solution for Problem SUR04

Residential roadway Haled Street, east of Lomond Street overtops during 10-year storm. The 42-inch and 48-inch pipe sections are not sufficient to convey 10-year storm flow under the residential street.

Alternative 1 as described in Table 5.3-1 is included in the recommended plan and is hereafter referred to as Program Item SU-1.

Proposed Solution to Problem SUR59

Seventh and One Half Street is a residential roadway, which overtops in the 10-year storm. The existing pipe system does have a sufficient capacity to convey safely the 10-year storm flow.

Alternative 1 as described in Table 5.3-2 prevents the residential roadway overtopping. Therefore, Alternative 1 is recommended and included in the recommended plan and is hereafter referred to as Program Item SU-2. However, the City may consider no action because this is a dead end street and the parking lot exit has an alternative exit on Martin Luther King Drive.

Proposed Solution to Problem Cluster SUR32, SUR33, and SUS18

The problem cluster starts at First Street between Shady Avenue and Poplar Street and extends downstream to the low point in Brookstown Avenue underneath the Business I-40 bridge. Two residential streets overtop and flooding occurs in the lowest level of three residential structures on the south side of First Street. The existing storm sewer system extends under private property from First Street to Brookstown Avenue. The system is undersized, causing water to overtop First Street, backup through a private drop inlet in the parking lot behind 620 First Street, and overtop the storm sewer system at the low point in Brookstown Avenue.

Alternative 1 as described in Table 5.3-3 prevents residential roadway overtopping and structural flooding with a lower capital cost, but requires pipe system construction in addition to a looped relief system on First Street to Brookstown and reconnects under I-40 Bridge. Therefore, Alternative 1 is recommended and included in the recommended plan and is hereafter referred to as Program Item SU-3.

Proposed Solution to Problem Cluster SUR11, SUS16, and SUR63

A 3.5-ft x 3.7-ft elevated arch culvert extending from Holly Avenue to Second Street between Poplar and Brookstown overtops, flooding the basement level of a multi-family residential structure in the 10- through 100-year storms.

Increase existing system and install a looped relief system on West Fourth Street and reconnect on to other side of parking garage. Cross Holly Avenue and continue south to end of parking lot. The existing 36-inch pipe under parking deck is maintained. The alternative prevents overtopping of the residential and collector roads and structural flooding. Therefore, Alternative 1 as described in Table 5.3-4 is included in the recommended plan and is hereafter referred to as Program Item SU-4.

Proposed Solution to Problem Cluster SUR25 through SUR29

Old Salem Road overtops from south of Brookstown to Academy Streets during the 10- and 25-year design storms.

Alternative 1 as described in Table 5.3-5 prevents overtopping of the collector roadway, Old Salem Road. Therefore, Alternative 1 is included in the recommended plan and is hereafter referred to as Program Item SU-5.

Proposed Solution to Problem SUR53

The overtopping of Peters Creek Parkway occurs during the 50-year storm and is a result of the water surface being above the current overtopping elevation of Peters Creek Parkway. .

Alternative 1 as described in Table 5.3-6 prevents the overtopping of the collector roadway, Peters Creek Parkway by creating an earthen beam along Salem Creek and the east side of the road to increase the overtopping elevation to 746 feet NAVD 88. Therefore, Alternative 1 is included in the recommended plan and is hereafter referred to as Program Item SU-6.

Problem Cluster SUS01 through SUS10 (Table 5.3-7)

The flooding of eight structures along Peters Creek Parkway and four structures along Hutton Street and Salem Valley (private road) is the result of constriction of Salem Creek by the Peters Creek Parkway Bridge and backwater from Peters and Salem Creeks. The structural flooding occurs during the 10- through 100- year storm events.

The studied solutions for alleviating the structural flooding included building a floodwall and buying and razing the properties. However, analysis of these solutions proved to be economically not feasible, therefore, no improvement is recommended.

Problem Cluster SUR35, SUR36, SUR37, SUR56, SUR58 and SUS14 (Table 5.3-8)

This cluster includes potential flooding of a commercial structure immediately south of the Main Street Bridge during the 10- through 100-year storms. Collector roadways, Main Street and Waughtown Street overtop during the 10- and 25-year storms.

This area is located on the low ground in the Salem Creek floodplain. The improvements of the storm drainage systems are not feasible due to the backwater effect of Salem Creek. No improvement is recommended.

Proposed Solution to Problem Cluster SUR42 through SUR46

Three collector roadways (Fourth, Fifth, and Seventh Streets west of Linden Street) overtop in the 10- through 25-year storm events. A by-pass system is proposed to route overtopping flow into pipes underneath the right-of-way of Fifth Street, Linden and Third Street.

Alternative 1 as described in Table 5.3-9 prevents overtopping of the three collector roadways. Therefore, Alternative 1 is included in the recommended plan and is hereafter referred to as Program Item SU-9.

Proposed Solution to Problem Cluster SUS26 through SUS28

Eight residential structures along Alder, Liberia, Pitts, and Humphrey Streets flood in the 10- through 100-year storm.

Alternative 1 as described in Table 5.3-10 requires the purchasing of the eight properties in the 100-year floodplain in the Main Street bridge area and raze them. Therefore, Alternative 1 is included in the recommended plan and is hereafter referred to as Program Item SU-10. However, the City may consider no action because the B/C ratio is estimated to be 0.4.

Proposed Solution to Problem Cluster SUR17, SUR18, and SUR40

Chestnut Street (residential roadway) at Fifth Street (collector roadway) intersection overtop in the 10- through 25-year storms. Existing pipes are replaced with larger pipes to accommodate the overtopping flow.

Alternative 1 as described in Table 5.3-11 prevents overtopping of the residential and collector roadways. Therefore, Alternative 1 is included in the recommended plan and is hereafter referred to as Program Item SU-11.

Proposed Solution to Problem Cluster SUR06 and SUR07

The cluster includes overtopping of sections of West Salem Avenue at Walnut Street, and Main Street and Old Salem Road circle interchange in the 10- and 25-year storms. Flooding is partially caused by constriction of Salem Creek by the Main Street and old railroad bridges. In addition, flow from undersized pipes in the Tarr Branch Tributary (Tributary R) contributes to the flooding. Business owners in the area claim that flow starts coming out of manhole lids whenever a moderately heavy rain event occurs. They believe most of the flooding is due to this undersized tributary system and not from Salem Creek itself (although most likely a backwater exasperates the problem).

Alternative 1 as described in Table 5.3-12 prevents the overtopping of the collector roadway. Improvements include keeping existing pipe system, adding RCBCs under West Salem Avenue and through the circle interchange, lowering inverts to meet cover requirements However, the solution is contains a high cost for a low benefit given the overtopping is less than 0.3 feet, thereby creating a low ranking. Alternative 1 is included in the recommended plan and is hereafter referred to as Program Item SU-12.

Proposed Solution to Problem SUR55

East Salem Avenue and northeast of circle interchange overtop in the 10-year storm. Create a berm and upsizing the existing system is improved with larger pipes that accommodate the overtopping flow.

Alternative 1 as described in Table 5.3-13 prevents overtopping of the residential roadways, East Salem Avenue. Therefore, Alternative 1 is included in the recommended plan and is hereafter referred to as Program Item SU-13.

Proposed Solution to Problem Cluster SUR01, SUR23, SUR24, and SUS13

The residential (Doune Street) and collector (Main Street) roadway overtopping and flooding of two structures in the area between Doune Street and Main Street are the result of inadequate pipe system capacity in Tributary Q as it passes under Main and Doune Streets. The problem is exacerbated by tailwater from Salem Creek downstream of Main Street. Structural flooding occurs during the 10- through 100-year storms, residential roadway overtopping in 10-year and collector roadway overtopping in 10- and 25-year storms.

Alternative 1 as described in Table 5.3-14 prevents the overtopping of the collector roadway and includes installation of a by-pass system along Main Street to intersection at Doune Street and continue heading northwest to the Creek. Therefore, Alternative 1 is included in the recommended plan and is hereafter referred to as Program Item SU-14.

Proposed Solution to Problem SUR54

Pipes in the area south of Business I-40 and west of Liberty Street are undersized, causing overtopping of Liberty Street and along the Liberty Strollway. Arterial roadway overtopping occurs during the 25- and 50-year storms.

Alternative 1 as described in Table 5.3-15 prevents the overtopping of the arterial roadway, Liberty Street. Therefore, Alternative 1 is included in the recommended plan and is hereafter referred to as Program Item SU-15.

6.1 COMPONENTS

6.1.1 City of Winston-Salem Program

City of Winton-Salem program items are shown on Figure 6.1 entitled "Recommended Program." For the Upper Salem Creek watershed, City program items are identified as SU-1 through SU-21. The numerical identifier does not rank the program item in order of importance. City proposed items include solutions to all identified roadway overtopping problems, structural flooding problems with B/C ratios greater than 0.5, and channel erosion problems affecting City utilities or drainage structures. The following subsections summarize the proposed solutions for the City. Section 5.3 provides additional details regarding the specific location, technical data, and implementation of each alternative.

The program developed for the City of Winston-Salem consists of all the recommended solutions for the Upper Salem Creek watershed which are located within the Winston-Salem city limits and would be an improvement which the City would have the authority to implement. The City of Winston-Salem program to eliminate roadway overtopping and structural flooding consists of the improvements SU-1 through SU-15 (ID codes SU-7 and SU-8 were not used). The program to eliminate channel erosion consists of the improvements SU-16 through SU-21. The total cost for all City proposed solutions is estimated at $28,919,000 (2010 dollars), which includes roadway overtopping, structural flooding, and channel erosion problem categories for tributary improvements, and improvements on the mainstem. The Summary Table cross referencing the problems, schematic nodes, solutions, and other pertinent information is enclosed in Appendix. The following is a summary of the City program costs by problem category:

Tributary Improvements

- Structural Flooding = $254,300
- Roadway Overtopping = $28,156,200
- Channel Erosion = $508,500

Proposed Solution SU-1 (Table 6.1-1)

Problem Location: Intersection of Haled Street and Lomond Street, extending East on Haled Street.

Problem Description: Residential roads overtop in the 10-year storm.

Selected Improvement: Standard pipe replacement and re-paving of roads.

Proposed Solution SU-2 (Table 6.1-2)

Problem Location: Seventh and One Half Street

Problem Description: Residential roadway overtopping in the 10-yr storm

Selected Improvement: Standard pipe placement and road re-paving. Consider no action because this is a dead end street and the parking lot has an alternative exit on Martin Luther King Drive

Proposed Solution SU-3 (Table 6.1-3)

Problem Location: First Street between Shady Avenue and Poplar Street. Brookstown Avenue underneath the Business I-40 Bridge.

Problem Description: Three residential structures flood in the 10- through 100-year storms. Sections of First Street and Brookstown Avenue overtop in the 10- through 25 year storms. The existing system cannot be improved because it runs under private property (and private structures). Therefore alternative include a loop around systems to relieve flow from the existing system.

Selected Improvement: Standard pipe replacement and road re-paving.

Proposed Solution SU-4 (Table 6.1-4)

Problem Location: West Forth Street, Holly Avenue and through the Intersection of Shady Boulevard and Second Street.

Problem Description: Overtopping of elevated arch culvert onto a residential and collector roadways (Holly Avenue and Second Street, respectively), structural flooding, and collapse of soil over storm sewer system in a residential backyard. The pipe system begins as a 3′.5x 3.7′ elevated arch culvert at Holly Street and ends as a 36-inch RCP northeast of First Street and Shady Boulevard with unknown locations of the pipe size transition.

Selected Improvement: Standard pipe replacement and road re-paving.

Proposed Solution SU-5 (Table 6.1-5)

Problem Location: Old Salem Road from South of Brookstown Avenue to Academy Street.

Problem Description: The 66-inch RCP extending under Old Salem Road overtops onto the collector roadway during the 10- and 25-year design storms.

Selected Improvement: Standard pipe replacement and road re-paving.

Proposed Solution SU-6 (Table 6.1 6)

Problem Location: Peters Creek Parkway.

Problem Description: Arterial road overtops in the 50-year storm.

Selected Improvement: Earthen berm construction.

Proposed Solution SU-9 (Table 6.1-9)

Problem Location: Fourth, Fifth, and Seventh Streets west of Linden Street

Problem Description: Three collector streets overtop in the 10- through 25-year storms.

Selected Improvement: Standard pipe replacement and road re-paving.

Proposed Solution SU-10

Problem Location: Alder, Liberia, Pitts, and Humphrey Streets, Salem Avenue east of Main Street

Problem Description: Structural and residential road flooding in the 10- through 100-year storm.

Selected Improvement: Purchasing of the eight properties and raze them.

Proposed Solution SU-11 (Table 6.1-11)

Problem Location: Chestnut Street between Fifth and Sixth Streets. Intersection of Fifth Street and Chestnut Street.

Problem Description: Chestnut Street north of Fifth Street overtops in the 10- through 100-year storms. The overtopping flow runs south to the intersection of Fifth and Chestnut Streets and ponds.

Selected Improvement: Standard pipe replacement and road re-paving.

Proposed Solution SU-12 (Table 6.1-12)

Problem Location: West Salem Avenue at Walnut Street, and Main Street and Old Salem Road circle interchange.

Problem Description: Collector road overtopping in the 10- and 25-year storms

Selected Improvement: Standard pipe replacement and road re-paving.

Proposed Solution SU-13 (Table 6.1-13)

Problem Location: East Salem Avenue and northeast of circle interchange.

Problem Description: Salem Avenue and northeast of circle interchange residential roadways overtop in the 10-year storm.

Selected Improvement: Construct a berm and the standard pipe replacement and road re-paving.

Proposed Solution SU-14 (Table 6.1-14)

Problem Location: Area between Doune Street and Main Street

Problem Description: Structural and residential, collector roadway flooding occur during the 10- through 100- year storms.

Selected Improvement: Install a by-pass system and Standard pipe replacement and road re-paving.

Proposed Solution SU-15 (Table 6.1-15)

Problem Location: Private Property along Liberty Strollway and Liberty Street under Business I-40 bridge.

Problem Description: Liberty Street and the U.S. Bankruptcy Court receive flood flows in the 10- through 100-year storms.

Selected Improvement: Standard pipe replacement and road re-paving.

6.2 RANKING SYSTEM

6.2.1 Structural Flooding Improvements

Remediation of structural flooding was ranked on the basis of the benefit/cost ratio. In the cases in which an improvement was found to also solve the roadway overtopping criteria, the cost difference between the cost for just correcting the roadway overtopping criteria and the cost for solving structural flooding was the cost applied in developing the benefit/cost ratio. The improvements that affect structural flooding are ranked in Table 6.2-1. Although it is atypical to recommend projects with a benefit/cost ratio less than 1.0, improvements with a benefit/cost ratio greater than 0.5 are considered acceptable in this study. FEMA regulations describe substantial damage as damage assessed to be equal to or exceed 50 percent of the present market value of the structure prior to flood damage. Therefore, if the ratio of the present value of avoiding annual property damage (benefit) to the property value buyout expense (cost) is greater than 0.5, the structure should be condemned, elevated, or moved.

6.2.2 Roadway Overtopping Improvements

Ranking of roadway overtopping improvements was based on the ranking of the roadway overtopping problems removed by the improvements. Roadway overtopping problems were ranked according to the type of roadway overtopped, the frequency of overtopping, and the depth of overtopping. Problems removed under the City of Winston-Salem Program improvements were separated from problems removed under the NCDOT/Private Program improvements. A roadway-overtopping matrix was developed (as seen in table 6.2-2) to group overtopping problems on a point system with the lower point value indicating higher importance of the overtopping problem. This table was based upon type of road and frequency of overtopping. Within these groupings, the problems were further ranked based upon the depth of overtopping, with the greater depth having the higher ranking. City of Winston-Salem program improvements are ranked in Table 6.2-3 and NCDOT/Private Program improvements are ranked in Table 6.2-4.

Table 6.2-2 ***City of Winston-Salem Program*** ***Roadway Overtopping Matrix***				
	Residential	**Collector**	**Arterial**	**Freeway**
10-year	10	8	5	1
25-year		9	6	2
50-year			7	3
100-year				4

6.2.3 Velocity Reduction/Protection Improvements

Velocity reduction/protection improvements were based on the field inspector's opinion as to the relative degree of erosive degradation of all channels that were field identified as having a degree of erosion worthy of attention. None of the identified channel improvements in Upper Salem Creek were grouped in the City of Winston-Salem program (Table 6.2-5).

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