NORTH BUFFALO CREEK

May 2026

Nine Element Watershed Management (9E) Plan

Contents

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INTRODUCTION

BACKGROUND AND OBJECTIVES

The North Buffalo Creek watershed is located within the City of Greensboro, North Carolina, and drains approximately 37 square miles of predominantly urbanized land characterized by residential, commercial, institutional, and transportation uses. As one of the most developed watersheds in the City of Greensboro (City), it contains a high density of impervious cover, altered drainage patterns, and modified stream channels. These conditions have resulted in increased stormwater runoff volumes, elevated peak flows, and reduced infiltration, all of which contribute to both flooding and water quality.

Water quality assessments conducted under the City's National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit identify North Buffalo Creek as impaired. Documented impairments include elevated fecal coliform bacteria, increased concentrations of nutrients (particularly nitrogen), the presence of metals such as zinc and copper, and overall degraded biological integrity within the stream system. As such, North Buffalo Creek is listed as an impaired waterbody on the State's 303(d) list. These impairments are typical of urban watersheds and reflect cumulative impacts from stormwater runoff and watershed development.

The primary causes of impairment within the watershed are associated with nonpoint source pollution driven by urbanization. Stormwater runoff from impervious surfaces transports pollutants such as nutrients, bacteria, metals, and sediments into receiving streams. Streambank erosion, identified through field assessments, contributes significant sediment loads and associated nutrient transport. Additionally, aging and undersized stormwater infrastructure can cause localized flooding and mobilize pollutants during storm events. Illicit discharges and potential sanitary sewer cross-connections may also contribute to elevated bacteria levels. Stakeholder input and historical observations further indicate that increased upstream development and changing hydrologic conditions have resulted in more frequent and severe flooding, hydrologic alteration, and water quality degradation.

The North Buffalo Creek Stormwater Master Plan (**Appendix A**) addresses these issues through a comprehensive evaluation of watershed conditions and proposes a range of flood control, stream restoration, and stormwater control measures intended to improve both hydraulic performance and water quality. Recommended management measures include constructed stormwater wetlands, wet ponds, level spreader-vegetated filter strips, streambank stabilization projects, and other nature-based stormwater retrofit strategies. The following sections of this report provide additional supporting information to supplement the North Buffalo Creek Stormwater Master Plan, including summaries of existing water quality monitoring efforts, public engagement activities, and how these components collectively address the requirements of a 9-Element Watershed Plan.

ADDITIONAL INFORMATION

STREAM MONITORING

The City of Greensboro maintains an established Water Quality Assessment and Monitoring Program (**Appendix B**) as part of its NPDES MS4 permit requirements (**Appendix C**). The purpose of this program is to monitor and assess stream conditions, identify pollutant sources, evaluate trends over time, and support the implementation and effectiveness of stormwater management practices. The monitoring program provides a critical foundation for understanding existing watershed conditions and guiding future management decisions.

The City of Greensboro has conducted routine water quality monitoring within the watershed and broader Cape Fear Basin for more than 20 years, providing a substantial dataset for evaluating long-term

watershed trends. The City currently operates a network of twenty monitoring sites distributed across major watersheds, including seven sites within the North Buffalo Creek watershed. Monitoring is conducted on a monthly basis using grab samples collected directly from the stream channel, with sampling designed to capture a range of hydrologic conditions over time. A comprehensive suite of water quality parameters is analyzed, including nutrients such as nitrogen and phosphorus, fecal coliform bacteria, total suspended solids and turbidity, metals such as copper and zinc, and general water quality indicators including dissolved oxygen, pH, conductivity, and temperature.

Results from the monitoring program indicate that North Buffalo Creek continues to exhibit characteristics consistent with urban stream impairment. Elevated bacteria levels suggest contributions from urban runoff and potential sanitary sources, while nutrient concentrations reflect inputs from fertilizers and other anthropogenic sources. Metals detected in the system are commonly associated with roadway runoff and urban surfaces. Biological assessments further indicate that the stream does not fully support its designated uses, reflecting the cumulative impacts of these stressors. These findings are consistent with statewide assessments and reinforce the need for continued implementation of watershed management strategies.

In addition to water quality sampling, the City utilizes rainfall and stream gage data to support hydrologic and hydraulic analyses, which are integral to understanding watershed response to storm events and informing project design. Moving forward, the City will continue its established monitoring program, including monthly sampling and ongoing data analysis, while maintaining flexibility to refine monitoring locations or parameters as needed. Future monitoring efforts will also support evaluation of implemented projects, including stormwater control measures and stream restoration efforts, and will be used to track progress toward improving water quality conditions within the watershed.

PUBLIC ENGAGEMENT

Public engagement has been a key component of both the North Buffalo Creek watershed study and the City’s broader stormwater management program. The City of Greensboro has actively involved stakeholders and the public throughout the planning process to ensure that local knowledge, concerns, and priorities are incorporated into watershed management decisions. The watershed planning effort involved coordination with local institutions and stakeholders, including universities, neighborhood representatives, and regional watershed organizations.

As part of the watershed study, the City conducted multiple public meetings and stakeholder engagement efforts, including meetings in 2020, 2022, and 2023. These meetings provided opportunities to present project goals, share modeling results, and discuss potential alternatives, while also soliciting feedback from residents, property owners, and other stakeholders. Public input played a significant role in identifying areas of concern, particularly related to flooding frequency, infrastructure performance, and changes in watershed conditions over time. Stakeholders consistently emphasized the need for improved understanding of runoff sources, enhanced monitoring, and solutions that balance flood mitigation with environmental considerations.The City also developed an online Story Map to communicate watershed history, flooding concerns, study progress, and opportunities for community involvement

Beyond the watershed study, the City implements a comprehensive public education and outreach program as part of its MS4 permit. This program includes distribution of educational materials, participation in community events, and use of multimedia platforms to promote pollution prevention and stormwater awareness. The City regularly engages the public through workshops, volunteer programs, and outreach campaigns addressing topics such as litter prevention, pet waste management, fertilizer application, and household chemical disposal. These efforts are designed to reduce nonpoint source pollution by influencing behaviors at the individual and community levels and have reached thousands of residents annually through both in-person and digital engagement.

Looking forward, the City intends to continue and expand its public engagement efforts in conjunction with implementation of watershed projects. Additional opportunities exist to enhance engagement through more targeted outreach within the North Buffalo Creek watershed, including focused communication in high-priority areas, expanded volunteer monitoring or stewardship programs, and improved accessibility of project information through online platforms. These efforts will support sustained community involvement and help ensure long-term success of watershed management initiatives.

CONCLUSION

The North Buffalo Creek Stormwater Master Plan, when paired with this supplemental report, fulfills the intent of the Environmental Protection Agency's Nine Minimum Elements for watershed-based planning. The Master Plan provides a detailed technical foundation, including watershed characterization, hydrologic and hydraulic modeling, identification of critical areas, development of management measures, and prioritization of projects based on need and effectiveness.

This supplemental report enhances the Master Plan by explicitly documenting watershed impairments and their causes, summarizing the City's monitoring program and findings, and providing a comprehensive overview of public engagement efforts. Together, these components address key elements required for Section 319 funding eligibility, including identification of pollutant sources, link between impairments and management measures, and demonstration of ongoing monitoring and stakeholder involvement.

Collectively, the combined documents present a comprehensive and implementable watershed-based plan that addresses both water quantity and water quality challenges within the North Buffalo Creek watershed (**Appendix D**). The plan supports adaptive management through continued monitoring and community engagement and positions the City of Greensboro to effectively pursue and implement projects funded through the EPA Section 319 program.

APPENDIX A

APPENDIX A - GUIDE TO NINE MINIMUM ELEMENTS

This table serves as a quick reference quide to where the Environmental Protection Agengy (EPA) Nine Minimum Elements are discussed within this watershed management plans

EPA Nine Minimum Elements		Location in Plan	Additional Resources
1	**Identification of causes of impairment and pollutant sources or groups of similar sources that need to be controlled to achieve needed load reductions, and any other goals identified in the watershed plan.**	Causes of impairment and pollutant sources are identified in Sections 3 (pp. 13–16), 4 (pp. 22, 39, 68), 6.7 (p. 124), and 7 (pp. 129–139), including urban runoff, undersized infrastructure, and streambank erosion.	North Buffalo Creek is classified as Water Supply (WS-V) and Nutrient Sensitive Waters (NSW), North Buffalo Creek is designated as impaired under Section 303(d) of the Clean Water Act due to elevated levels of nutrients, turbidity, and fecal coliform bacteria, largely stemming from over a century of urban runoff and industrial legacy pollution.
2	**An estimate of the load reductions expected from management measures.**	Estimated load reductions are provided in Section 6.7 (pp. 124–128) and Section 7.4 (pp. 139–146), with supporting calculations in Appendix D, including reductions in nutrients and sediment from GSI, SCM retrofits, and streambank stabilization.	Estimated load reductions from proposed stormwater control measures were calculated using the NCDEQ SNAP Tool and include reductions in nutrients, sediment, and runoff associated with the recommended SCM retrofit and green stormwater infrastructure projects within the North Buffalo Creek watershed.
3	**A description of the nonpoint source management measures that will need to be implemented to achieve load reductoins, and a description of the critical areas in which those measures will be needed to implement this plan.**	Nonpoint source management measures are described in Sections 6 and 7 (pp. 88–146), including GSI, SCM retrofits, and streambank stabilization. Critical areas for implementation are identified in Sections 4.7–4.8 (pp. 67–68), Sections 6.1 and 6.4 (pp. 91–120), and Figure 1-1 (p. 3).	Nonpoint source management measures proposed for the North Buffalo Creek watershed include stormwater control measure retrofits, green stormwater infrastructure, and stormwater conveyance upgrades focused within identified critical areas experiencing water quality impairments throughout the watershed.
4	**Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.**	Estimated costs and financial needs are provided in Section 9 (pp. 153–156) and Section 1.7 (pp. 8–10), with detailed breakdowns in Appendix F. Technical requirements are described in Section 4 (pp. 17–83) and Appendix J, and implementation authorities are identified in Section 8 (pp. 146–148).	Please refer to the Preliminary Opinions of Probably Construction Cost in Section 9.
5	**An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.**	Public participation is incorporated through service request and community input data in Sections 3.1 (p. 13), 4.8 (p. 68), and 2.2 (p. 12).	The City of Greensboro developed the North Buffalo Creek Watershed Study website to inform the public of the timeline of the study and to allow for the public to provide public comment: https://storymaps.arcgis.com/stories/b10caa840bd54ab6af288d323f985390
6	**Schedule for implementing the nonpoint source management measures identified in this plan that is reasonably expeditious.**	Implementation sequencing is provided through project prioritization in Sections 5 (p. 83), 1.6 (p. 7), and 10 (pp. 157–159), with supporting detail in Appendix G.	Please refer to the Prioritization Results in Section 10.
7	**A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.**	Interim milestones are implied through project prioritization in Section 10 (pp. 157–159) and detailed in Appendix H.	Please refer to the Prioritization Results in Section 10.
8	**A set of criteria that can be used to determine whether load reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.**	Criteria for evaluating progress include pollutant reduction estimates in Section 6.7 (pp. 124–128) and system performance standards in Sections 1.2 and 2.3 (pp. 4 and 13), supported by baseline conditions in Section 4.7 (p. 39).	Progress toward achieving load reductions and water quality standards will be evaluated through reductions in bacteria, nutrients, metals, sediment, and turbidity, as well as observed improvements in biological integrity and stream stability within the North Buffalo Creek watershed.
9	**A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the established criteria.**	Monitoring components include stream gage data and model validation described in Sections 4.2 (p. 18) and 4.6 (pp. 33–38), with supporting data in Appendix D and Section 2.2 (p. 12).	The City of Greensboro performs monthly stream monitoring within the North Buffalo Creek watershed, including sampling for nutrients, fecal coliform bacteria, metals, sediment, dissolved oxygen, pH, conductivity, and other water quality indicators, along with rainfall and stream gage monitoring, to evaluate the effectiveness of implemented watershed projects and track long-term water quality trends.

APPENDIX B

Stormwater Master Plan - North Buffalo Creek

Prepared for:
City of Greensboro

January 29, 2025

Prepared by:
Stantec Consulting Services Inc.

Project/File:
175513006

Stantec Consulting Services Inc.

Rev	Description	Author	Date	Quality Check	Date	Independent Review	Date
0	Draft	Matthew Armstrong	01/24/25	Kevin Kubiak	01/31/25	Linda Pass	01/31/25
1	Address City Comments	Matthew Armstrong	02/18/25	Kevin Kubiak	02/18/25	Linda Pass	02/18/25

The conclusions in the Report titled Stormwater Master Plan - North Buffalo Creek are Stantec's professional opinion, as of the time of the Report, and concerning the scope described in the Report. The opinions in the document are based on conditions and information existing at the time the scope of work was conducted and do not take into account any subsequent changes. The Report relates solely to the specific project for which Stantec was retained and the stated purpose for which the Report was prepared. The Report is not to be used or relied on for any variation or extension of the project, or for any other project or purpose, and any unauthorized use or reliance is at the recipient's own risk.

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Acronyms / Abbreviations

AHP	Analytic Hierarchy Process
AMC	Antecedent Moisture Conditions
BEHI	Bank Erosion Hazard Index
BMP	Best Management Practice
CC	Climate Change
CFS	Cubic Feet per Second
CIP	Cast Iron Pipe
CIP	Capital Improvement Program
CLOMR	Conditional Letter of Map Revision
CMP	Corrugated Metal Pipe
CN	Curve Number
DEM	Digital Elevation Model
DIP	Ductile Iron Pipe
DSS	Data Storage System
EAMs	Enterprise Asset Management System
EPA	Environmental Protection Agency
ETJ	Extraterritorial Jurisdiction
EX	Existing
FB	Freeboard
FEMA	Federal Emergency Management Agency
FIRM	Flood Insurance Rate Map
FUT	Future
GIS	Geographical Information System
GPS	Global Positioning System
GSI	Green Stormwater Infrastructure
GSO	City of Greensboro
HEC-RAS	Hydraulic Engineering Center River Analysis System
HMS	Hydrologic Modeling System
HPC	Horsepen Creek
HSG	Hydrologic Soil Group
HY-8	Culvert Hydraulic Analysis and Design Program
IP	Individual Permit
LAG	Lowest Adjacent Grade
LF	Linear Feet
LiDAR	Light Detection and Ranging
LOMR	Letter of Map Revision
LOS	Level of Service
LU	Land Use
NAD	North American Datum
NAVD	North American Vertical Datum
NBC	North Buffalo Creek
NBC	North Buffalo Creek
NBS	Near Bank Shear Stress
NC	North Carolina
NCDEQ	North Carolina Department of Environmental Quality
NCDOT	North Carolina Department of Transportation
NCFMP	North Carolina Floodplain Mapping Program

NCFRIS	North Carolina Flood Risk Information System
NCWRC	North Carolina Wildlife Resources Commission
NEH	National Engineering Handbook
NLCD	National Land Cover Database
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWI	National Wetland Inventory
NWP	Nationwide Permit
OPCC	Opinion of Probable Construction Cost
PCN	Pre-Construction Notification
PCSWMM	Personal Computer Stormwater Management Model
PVC	Polyvinyl Chloride
RAS	River Analysis System
RCBC	Reinforced Concrete Box Culvert
RCP	Reinforced Concrete Pipe
SCM	Stormwater Control Measure
SCS	Soil Conservation Service
SEPA	State Environmental Policy Act
SHPO	State Historic Preservation Office
SHWT	Seasonally High-Water Table
SNAP	Stormwater Nitrogen and Phosphorus Tool
SWMM	Stormwater Management Model
SWMM-CAT	Stormwater Management Model Climate Adjustment Tool
SWMP	Stormwater Master Plan
TDN	Total Dissolved Nitrogen
TDP	Total Dissolved Phosphorous
TMDL	Total Maximum Daily Load
TOC	Time of Concentration
TS	Tropical Storm
TSS	Total Suspended Solids
UNC	University of North Carolina
USACE	United States Army Corps of Engineers
USFWS	United States Fish and Wildlife Service
VRS	Virtual Reference Station
WQ	Water Quality
WQV	Water Quality Volume
WSE	Water Surface Elevation
WSMP	Watershed Master Plan

1 Executive Summary

The City of Greensboro initiated a comprehensive stormwater planning program and engaged multiple consultant firms to develop watershed master plans. Kimley-Horn studied the Horsepen Creek watershed, McAdams studied the South Buffalo Creek watershed, and Stantec studied the North Buffalo Creek (NBC) watershed. Kimley-Horn also served as the program manager between the consultant teams to maintain consistency in approach and methodology of the watersheds.

The master plan program set forth several objectives for each watershed: (1) assess the watershed to identify issues related to flooding, water quality, and erosion; (2) formulate and prioritize infrastructure projects to reduce both the frequency and impact of floods; (3) conceptualize stream stabilization projects to reduce property damage risks along watercourses and decrease sediment deposition from erosion; and (4) recommend Stormwater Control Measures retrofit projects to improve water quality within the watershed. The following report focuses on the NBC watershed project specifically.

As part of this project, Stantec conducted a limited survey in the NBC watershed in support of modeling efforts; summary data is compiled in Table 1.1-1.

Table 1.1-1 Type of Survey Data Collected

System	Item surveyed	Number Collected
Primary	Road Crossing Structures	27
Primary	Storage Structures	4
Primary	Channel Cross-sections	75
Primary	Weir/Riser Spillway	1
Secondary	Storm Sewer Inlets	113
Secondary	Storm Sewer Manholes	152
Secondary	Pipe Inlets/Outlets	35
Secondary	Channel Cross-sections	43
Secondary	Weir/Riser Spillway	7
Primary and Secondary	Staff Gage Top Cap	17

The NBC watershed spans around 37 square miles and includes 33 square miles within the City's limits. Positioned in north central Greensboro, the NBC watershed drains from west to northeast. Key features within the watershed are UNC-Greensboro, NC A&T University, Greensboro College, a portion of the downtown central business district, Friendly Shopping Center, Hamilton and Buffalo lakes, Latham Park, and Revolution Mill. Watershed boundaries are generally marked by Norfolk Southern Railroad to the south, Muirs Chapel Road and Westridge Road to the west, Pisgah Church Road and Hicone Road to the north, and US Interstate Highway 785 to the east. As the City's most built-out watershed area, the watershed primarily features moderate-intensity residential uses, complemented by commercial and industrial areas.

1.1 Project Types

The NBC Stormwater Master Plan (SWMP) included identification of five (5) types of projects: Primary System and Secondary System flood control projects, Stream Bank Stabilization, Culvert Conditions Assessment, and Stormwater Control Measure retrofits. These projects were identified based on a variety of criteria that are presented in the sections and appendices that follow this Executive Summary. Figure 1-1 includes the locations of projects that have been identified as part of this study; brief descriptions of each project follow.

Reach Name	Trib/Reach ID
Jordan Branch	JB
Lake Hamilton	LH
Muddy Creek	MC
NBC (I-840 to N O'Henry)	NBC1
NBC (N O'Henry to W Wendover)	NBC2
NBC (W Wendover to South Holden)	NBC3
Philadelphia Lake	PL
Tributary A	NBC-TA
Unnamed Tributary (College Branch)	NBC-UT
Unnamed Tributary 1	JB-UT1
Unnamed Tributary 2	MC-UT2
Unnamed Tributary 3	NBC-UT3
Unnamed Tributary 4	NBC-UT4
Unnamed Tributary 5	TA-UT5
Unnamed Tributary 6	LH-UT6

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Legend

- Primary Streams
- Primary Alternatives (31)
- Secondary Alternatives (14)
- Bank Stabilization Projects (17)
- Culvert Condition Assessment Project
- SCM Projects (10)
- Watershed Boundary

0 2,000 4,000 8,000 Feet

(At original document size of 11x17)
1:48,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title
Projects Overview Map

Project Location:
City of Greensboro,
Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:
01/28/2025

Sheet No.
Figure 1-1

1.2 Flood Control Projects

Stantec utilized both City Geographical Information System (GIS) data and survey data collected to support modeling to evaluate the conveyance capacity and Level Of Service (LOS) of existing infrastructure. Two systems were evaluated: Primary and Secondary Systems. Primary Systems included culvert and bridge crossings along the streams within the watershed. Secondary systems consisted of closed pipe systems, small open channels/ditches, small ponds, and other similar infrastructure intended to drain roads, neighborhoods, and lawns. Secondary Systems ultimately discharge into the Primary System.

Various infrastructure elements within these types of systems were evaluated to determine if they meet LOS requirements established by the City in its 2008 *Storm Drainage Design Manual* (the "Manual"). REF _Ref175688656 \h Table 1.2-1 below summarizes the LOS requirements from the Manual. A LOS was adopted for private crossings for the purposes of the watershed studies and is also included in the table below.

Table 1.2-1 System Level of Service Criteria for Primary and Secondary Systems

Facility	Design Storm	Level of Service
Stormwater Collection System • 15" minimum diameter	10-year	10-year storm within the pipe (no pressurized flow except as permitted in the Manual)
	25-year	25-year storm below surface (grate/rim, etc.)
Roadway Culverts • HW/D ≤ 1.2 • No Structures inundated for 100-year storm • 12" Freeboard (from overtopping for culverts) culvert diameter <= 36" • 18" Freeboard (from overtopping for culverts, from low chord for bridges) culvert diameter > 36" and all bridges	25-year	Minor City Streets (Sub collector, Local and Residential Streets)
	50-year	Major City Streets (Thoroughfares, Major and Minor Collector Streets), NCDOT
	100-year	All Street Classifications Over Regulated Floodways
Greenways/Footbridges	n/a	No City standard applies
Private	n/a	No City standard applies

1.2.1 Primary Systems

The Primary System consisted of all Effective Federal Emergency Management Agency (FEMA) mapped streams within the watershed and one additional stream (Unnamed Tributary) which only had Preliminary FEMA mapping. It is important to note that there are now draft-preliminary models available for much of Greensboro. In general, the preliminary models were only used for reference except where additional structure survey was included. Unnamed Tributary does not have an effective FEMA Hydraulic Engineering Center - River Analysis System (HEC-RAS) model; therefore, the preliminary FEMA model was used as the starting point. Stantec acquired the effective and preliminary models for the Primary Systems and then assembled them into a three separate HEC-RAS 5.0.7 models for use on the project.

Survey data was collected for areas within the FEMA models in need of augmentation. Additional cross sections, roadway overtopping profiles, culvert data, and bridge data were collected at strategic locations. Cross sections were collected where review of the FEMA model indicated additional section density could improve overall model precision. For example, several areas along the streams were identified as having varying terrain from upstream and downstream sections. Therefore, additional survey and cross-sectional data were needed in those areas.

Hydrologic analysis was performed in the Hydraulic Engineering Center – Hydrologic Modeling System (HEC-HMS) version 4.6.1 using the 2019 North Buffalo Creek HEC-HMS model as a starting point. The HEC-HMS subbasins were developed to provide lateral inflows for the HEC-RAS hydraulic model. Several storages that were outside of the HEC-RAS model limits were included in the HEC-HMS model. Junctions were added to collect flow from the subbasins; however, junction results were not used for the HEC-RAS modeling. Curve Numbers (CN) were developed for each subbasin from the 2019 National Land Cover Database (NLCD) land use data, 2019 NLCD impervious data, and Soil Conservation Service (SCS) soil survey data. Stantec used HEC-HMS subbasin hydrographs to convert the steady state FEMA HEC-RAS model to unsteady state by connecting HMS Data Storage System (DSS) output files to the HEC-RAS models. Note that DSS files from the subbasins were input directly to the HEC-RAS model; no routing was performed within the primary stream channels in the HMS model.

The Primary System streams consisted of the following:

Table 1.2-2 Primary System Streams

Stream Name	Approximate Length, Feet
Jordan Branch	16,100
Lake Hamilton	7,200
Muddy Creek	19,000
North Buffalo Creek	61,600
Philadelphia Lake	14,700
Tributary A	9,400
Unnamed Tributary (College Branch)	5,600
Unnamed Tributary 1	4,000
Unnamed Tributary 2	6,600
Unnamed Tributary 3	2,900
Unnamed Tributary 4	3,800
Unnamed Tributary 5	9,000
Unnamed Tributary 6	3,200
Total	**163,200**

Within the Primary Systems, various culvert/bridge crossings were analyzed using the existing conditions HEC-RAS model to determine if they met the minimum LOS required within the city's design documentation. City-owned roadway crossings found to be deficient based on the LOS requirements were designated as needing a project to bring the location up to standards. Footbridges and crossings outside of the City's control (North Carolina Department of Public Transportation (NCDOT), private, railroads) were considered out of scope and not analyzed for a project alternative. Figure 1-1 shows Primary System crossings for which projects were proposed.

1.2.2 Secondary Systems

Stantec reviewed all city Enterprise Asset Management System (EAMs) data for the NBC watershed and the City's map entitled "Top 20 areas of Historically Observed Flooding in GSO." These data sources were compared with the City's GIS piping and ditch inventory to identify areas of concern to include in the secondary system analysis. Secondary system analysis, dissimilarly from the primary, provides hydraulic gradient and capacity of the piped system greater than or equal to a 15-inch diameter. Stantec filtered and manually categorized EAMs data entries to reports of stormwater flooding, erosion, sinkholes, or other surface water problems based on the problem description provided in the data.

Based on the EAMs and other city data, eight (8) systems were identified to analyze, which included over 350,000 linear feet of stormwater system, including pipes, culverts, ditches, and streams. Stantec met with the City's Project Manager to assess the identified systems and they concurred with the chosen systems. The full list of secondary systems considered and the reasons for selection are included within the main report. The areas that were identified for further analysis are primarily within residential areas that experience frequent flooding, as reported by the City. Figure 1-1 shows the Secondary Systems which were selected for evaluation and project development. A digital copy of the Secondary Systems is included in Appendix J. The following sections include summaries of each proposed project.

1.3 Culvert Condition Assessment Projects

Stantec reviewed the culvert inspection report and associated geodatabase (provided by the City) for culverts within the NBC watershed. The data was analyzed to identify culverts with a structural defect grade of 3, 4, or 5; of these culverts only defect grade 5 were scoped to be evaluated for a potential project if not already being evaluated as part of a Primary or Secondary System.

Of the two (2) defect code 5 projects, one crossing was located within a secondary system model. This location was modeled within the Personal Computer Stormwater Management Model (PCSWMM) as part of the secondary system.

The remaining culvert was modeled in the Culvert Hydraulic Analysis and Design Program (HY-8) Culvert Hydraulic Analysis Program using the reported dimensions and inverts. The hydrologic analysis was performed in HEC-HMS using the same data as the Primary System hydrologic analysis. The resulting flows were input into HY-8, where the design flow was set to the 25-year storm.

1.4 Stream Bank Stabilization Water Quality Projects

As part of the engineering field investigation, Stantec collected Bank Erosion Hazard Index (BEHI) data from 60 sites throughout the watershed. This information was then used to identify 17 bank stabilization and asset protection project alternative locations.

Of the stream miles that were assessed, 10 were measured moderate, 31 were measured high, 18 were measured very high, and 1 was measured extreme.

1.5 Stormwater Control Measure Water Quality Projects

Several SCM retrofit opportunities were identified in the North Buffalo Creek watershed based on data collected during the stream walks. However, during the review of the March 2012 CDM Smith report North Buffalo Creek Best Management Practice (BMP) Siting and Nutrient Reduction Strategy provided by the city, it was recognized that many of the possible SCM retrofit locations had already been analyzed in the report.

The 2012 analysis identified 289 candidate sites throughout the North Buffalo Creek watershed, 42 of which were determined to be suitable locations for BMPs. Of these 42 sites, 10 sites were selected for alternative development.

1.6 Project Prioritization

Development of the Prioritization method for the City of Greensboro (GSO) was performed by Kimley-Horn as part of their program management scope. Fifteen separate evaluation factors were incorporated with varying scoring criteria and factor weighting to facilitate development of project scores. The factors and a more detailed narrative on the prioritization development process can be found within the report. The prioritization criteria apply across all project types.

1.7 Overall Project Summary

Table 1.7-1 below presents the overall project summary for the NBC SWMP.

Table 1.7-1 Overall Project Summary

Project ID	Tributary	Project Name	Triggering / Selection Configuration	Proposed Configuration	OPCC	Score	Rank	Project Classification
NBC_JB_CULV_01	Jordan Branch	Martin Avenue	< 18" FB in 100-yr Event, HW/D > 1.2	(3) 13' x 7' Box Culvert	$2,497,000	351.8	3	Primary
NBC_JB_CULV_02	Jordan Branch	Murchie and Sharon	< 18" FB in 100-yr Event, HW/D > 1.2	(3) 13' x 7' Box Culvert	$5,746,000	273.2	22	Primary
NBC_JB_FB_01	Jordan Branch	Jordan Branch Floodplain Benching	WSEL Increase	Floodplain Benching	$10,948,000	--	--	Primary
NBC_JB-UT1_BEHI_01	Unnamed Tributary 1	Voss Avenue Streambank Stabilization	Sanitary sewer and property threatened by excessive erosion	BEHI 01 - Watershed Masterplan - North Buffalo Creek	$205,000	147.4	46	BEHI
NBC_JB-UT1_CULV_01	Unnamed Tributary 1	Martin Avenue	< 18" FB in 100-yr Event, HW/D > 1.2	(2) 8' x 8' Box Culvert	$2,414,000	359.6	2	Primary
NBC_JB-UT1_CULV_02	Unnamed Tributary 1	Cody Avenue	< 18" FB in 100-yr Event, HW/D > 1.2	(2) 10' x 7' Box Culvert	$2,051,000	230.2	30	Primary
NBC_LH_CULV_01	Lake Hamilton	North Holden Road	< 18" FB in 100-yr Event, HW/D > 1.2	(3) 12' x 7' Box Culvert	$3,873,000	223.7	33	Primary
NBC_LH_FB_01	Lake Hamilton	Lake Hamilton Floodplain Benching	WSEL Increase	Floodplain Benching	$7,675,000	--	--	Primary
NBC_LH_SCM_01	Lake Hamilton	Starmount Drive Constructed Stormwater Wetlands	--	Wetland	$3,102,954	136.6	31	SCM
NBC_LH_SCM_02	Lake Hamilton	Henderson Road Wet Pond	--	Wet Pond	$3,499,823	151.0	28	SCM
NBC_LH-UT6_BEHI_01	Unnamed Tributary 6	Kenbridge Court Streambank Stabilization	Loss of property threatened by excessive erosion	BEHI 17 - Watershed Masterplan - North Buffalo Creek	$610,000	128.0	61	BEHI
NBC_MC_BEHI_01	Muddy Creek	Autumn Drive Streambank Stabilization	Loss of property threatened by excessive erosion	BEHI 03 - Watershed Masterplan - North Buffalo Creek	$503,000	130.4	60	BEHI
NBC_MC_BRG_01	Muddy Creek	Phillips Avenue	< 18" FB in 100-yr Event	140' Span Bridge	$5,832,000	281.6	20	Primary
NBC_MC_CULV_01	Muddy Creek	White Street	< 18" FB in 100-yr Event, HW/D > 1.2	(3) 16' x 11.5' Box Culvert	$3,130,000	109.3	64	Primary
NBC_MC_CULV_02	Muddy Creek	East Bessemer	< 18" FB in 100-yr Event, HW/D > 1.2	(2) 14' x 9', (2) 14' x 8' Box Culvert	$5,097,000	345.4	5	Primary
NBC_MC_FB_01	Muddy Creek	Muddy Creek Floodplain Benching	< 18" FB in 100-yr Event, HW/D > 1.2	Floodplain Benching	$6,326,000	--	--	Primary
NBC_MC-UT2_BEHI_01	Unnamed Tributary 2	Jolson Street Streambank Stabilization	Roadway threatened by excessive erosion	BEHI 02 - Watershed Masterplan - North Buffalo Creek	$144,000	139.2	49	BEHI
NBC_MC-UT2_CULV_01	Unnamed Tributary 2	Phillips Avenue	< 18" FB in 100-yr Event, HW/D > 1.2	(3) 18' x 6.5' Box Culvert	$3,124,000	325.4	14	Primary
NBC_MC-UT2_CULV_02	Unnamed Tributary 2	Textile Drive	< 18" FB in 100-yr Event, HW/D > 1.2	(3) 10' x 7.5' Box Culvert	$1,999,000	318.8	15	Primary
NBC_MC-UT2_FB_01	Unnamed Tributary 2	Unnamed Trib 2 Floodplain Benching	WSEL Increase	Floodplain Benching	$657,000	--	--	Primary
NBC_NBC2_BEHI_01	NBC2	Roseland Street Streambank Stabilization	Loss of property threatened by excessive erosion	BEHI 06 - Watershed Masterplan - North Buffalo Creek	$2,216,000	114.8	62	BEHI
NBC_NBC2_BEHI_02	NBC2	Fairview Street Streambank Stabilization	Overhead electric utility tower threatened by excessive erosion	BEHI 05 - Watershed Masterplan - North Buffalo Creek	$410,000	137.8	53	BEHI
NBC_NBC2_BRG_01	NBC2	Yanceyville Street	< 18" FB in 100-yr Event	140' Span Bridge	$13,064,000	330.5	12	Primary
NBC_NBC2_BRG_02	NBC2	North Elm Street	< 18" FB in 100-yr Event, HW/D > 1.2	312' Span Bridge	$9,704,000	339.3	9	Primary
NBC_NBC2_BRG_03	NBC2	Cridland Road	< 18" FB in 100-yr Event, HW/D > 1.2	220' Span Bridge	$4,797,000	330.8	11	Primary
NBC_NBC2_FB_01	NBC2	Latham Park Floodplain Benching	< 18" FB in 100-yr Event, HW/D > 1.2	Floodplain Benching	$13,505,000	314.0	16	Primary
NBC_NBC2_SCM_01	NBC2	Latham Road Constructed Stormwater Wetland	--	Wetland	$1,182,526	131.6	32	SCM
NBC_NBC3_BEHI_01	NBC3	Hill Street Streambank Stabilization	Overhead electric utility tower threatened by excessive erosion	BEHI 07 - Watershed Masterplan - North Buffalo Creek	$492,000	134.6	58	BEHI
NBC_NBC3_BEHI_02	NBC3	Benjamin Parkway Streambank Stabilization	Overhead electric utility tower threatened by excessive erosion	BEHI 09 - Watershed Masterplan - North Buffalo Creek	$480,000	139.2	50	BEHI
NBC_NBC3_BEHI_03	NBC3	Campus Drive Streambank Stabilization	Sanitary sewer threatened by excessive erosion	BEHI 12 - Watershed Masterplan - North Buffalo Creek	$457,000	136.8	54	BEHI
NBC_NBC3_BEHI_04	NBC3	West Wendover Avenue Streambank Stabilization	Loss of property threatened by excessive erosion	BEHI 15 - Watershed Masterplan - North Buffalo Creek	$277,000	112.0	63	BEHI
NBC_NBC3_BEHI_05	NBC3	Green Valley Road Streambank Stabilization	Overhead electric utility tower threatened by excessive erosion	BEHI 16 - Watershed Masterplan - North Buffalo Creek	$371,000	153.0	42	BEHI
NBC_NBC3_BRG_01	NBC3	Battleground Avenue	< 18" FB in 100-yr Event	160' Span Bridge	$6,472,000	313.4	17	Primary

Project ID	Tributary	Project Name	Triggering / Selection Configuration	Proposed Configuration	OPCC	Score	Rank	Project Classification
NBC_NBC3_BRG_02	NBC3	West Smith Street	< 18" FB in 100-yr Event	115' Span Bridge	$4,762,000	348.6	4	Primary
NBC_NBC3_SCM_01	NBC3	East Lake Drive Constructed Stormwater Wetland	--	Wetland	$956,316	149.0	29	SCM
NBC_NBC3_SCM_02	NBC3	East Lake Drive Level Spreader - Vegetated Filter Strip	--	LS-VFS	$321,249	93.6	35	SCM
NBC_NBC3_SCM_03	NBC3	West Radiance Drive Level Spreader - Vegetated Filter Strip	--	LS-VFS	$190,185	103.2	34	SCM
NBC_NBC3_SCM_04	NBC3	Mimosa Drive Level Spreader - Vegetated Filter Strip	--	LS-VFS	$138,234	103.2	33	SCM
NBC_NBC3_SCM_05	NBC3	West Wendover Avenue Constructed Stormwater Wetlands	--	Wetland	$1,276,616	152.8	27	SCM
NBC_NBC3_SCM_06	NBC3	Ashland Drive Constructed Stormwater Wetlands	--	Wetland	$1,463,928	156.0	26	SCM
NBC_NBC-TA_BEHI_01	Tributary A	Gracewood Drive Streambank Stabilization	Loss of property threatened by excessive erosion	BEHI 13 - Watershed Masterplan - North Buffalo Creek	$147,000	144.8	48	BEHI
NBC_NBC-TA_SCM_01	Tributary A	Benjamin Parkway Wet Pond	--	Wet Pond	$1,270,153	139.2	30	SCM
NBC_NBC-UT_BEHI_01	Unnamed Tributary	Eugene Court Streambank Stabilization	Commercial property / structures threatened by excessive erosion	BEHI 08 - Watershed Masterplan - North Buffalo Creek	$319,000	138.0	52	BEHI
NBC_NBC-UT_CULV_01	Unnamed Tributary	Hill Street	< 18" FB in 100-yr Event, HW/D > 1.2	(2) 12' x 6.5', (2) 12' x 5.5' Box Culvert	$3,568,000	248.0	26	Primary
NBC_NBC-UT_CULV_02	Unnamed Tributary	West Smith Street	< 18" FB in 100-yr Event, HW/D > 1.2	(4) 10' x 6.5' Box Culvert	$3,637,000	344.0	7	Primary
NBC_NBC-UT_CULV_03	Unnamed Tributary	Guilford Avenue	< 18" FB in 100-yr Event, HW/D > 1.2	(3) 20' x 5' Box Culvert	$13,832,000	230.6	29	Primary
NBC_NBC-UT3_CULV_01	Unnamed Tributary 3	Latham Road	< 18" FB in 100-yr Event, HW/D > 1.2	(3) 13' x 6' Box Culvert	$2,845,000	294.0	19	Primary
NBC_NBC-UT3_CULV_02	Unnamed Tributary 3	Briarcliff Road	< 18" FB in 100-yr Event, HW/D > 1.2	(3) 8' x 6' Box Culvert	$2,451,000	164.5	39	Primary
NBC_NBC-UT3_CULV_03	Unnamed Tributary 3	Cleburne Street	< 18" FB in 100-yr Event, HW/D > 1.2	(1) 12' x 5', (2) 12' x 4' Box Culvert	$4,000,000	236.0	28	Primary
NBC_NBC-UT4_BEHI_01	Unnamed Tributary 4	Mimosa Drive Streambank Stabilization	Sanitary sewer and roadway threatened by excessive erosion	BEHI 11 - Watershed Masterplan - North Buffalo Creek	$535,000	136.0	56	BEHI
NBC_NBC-UT4_BEHI_02	Unnamed Tributary 4	Mayflower Drive Streambank Stabilization	Sanitary sewer and roadway threatened by excessive erosion	BEHI 10 - Watershed Masterplan - North Buffalo Creek	$224,000	134.8	57	BEHI
NBC_NBC-UT4_CULV_01	Unnamed Tributary 4	West Friendly Avenue	< 18" FB in 100-yr Event, HW/D > 1.2	(4) 14' x 7' Box Culvert	$3,765,000	338.0	10	Primary
NBC_NBC-UT4_CULV_02	Unnamed Tributary 4	South Josephine Boyd Street	< 18" FB in 100-yr Event, HW/D > 1.2	(4) 12' x 8' Box Culvert	$6,179,000	345.2	6	Primary
NBC_PL_BEHI_01	Philadelphia Lake	East Cone Boulevard Streambank Stabilization	Loss of property threatened by excessive erosion, partially exposed sanitary sewer crossing	BEHI 04 - Watershed Masterplan - North Buffalo Creek	$680,000	155.4	41	BEHI
NBC_PL_CULV_01	Philadelphia Lake	East Cone Boulevard	< 18" FB in 100-yr Event, HW/D > 1.2	(3) 17' x 9' Box Culvert	$6,464,000	219.4	35	Primary
NBC_PL_CULV_CON_01	Philadelphia Lake	Elkhart Drive and Dellwood Drive	Condition assessment 5	(1) 5' x 8' Box Culvert	731000	271.3	23	CCA
NBC_PL_FB_01	Philadelphia Lake	Philadelphia Lake Floodplain Benching	WSEL Increase	Floodplain Benching	$2,638,000	--	--	Primary
NBC_SUB3_PIPE_01	Subbasin 3	Benjamin Parkway	< 10-year event within the pipe (no pressurized flow)	2 FT Dia Pipe	$831,000	167.5	38	Secondary
NBC_SUB6_CULV_01	Subbasin 6	Mayflower Drive	< 18" FB in 50-yr Event, HW/D > 1.2	(2) 8' x 5.5' Box Culvert	$1,658,000	330.1	13	Secondary
NBC_SUB6_CULV_02	Subbasin 6	Warren Street/Wright Avenue	25-year event above surface (grate/rim, etc.)	(2) 8.5' x 5' Box Culvert	$1,971,000	302.1	18	Secondary
NBC_SUB6_PIPE_01	Subbasin 6	Storm Sewer Area 1	< 10-year event within the pipe (no pressurized flow)	6.5 FT Dia Pipe	$514,000	223.0	34	Secondary
NBC_SUB8_CULV_01	Subbasin 8	Parkway Street	< 10-year event within the pipe (no pressurized flow)	(2) 8' x 6.5', (1) 8' x 7' Box Culvert	$9,902,000	275.2	21	Secondary
NBC_SUB8_PIPE_01	Subbasin 8	Florence Street	< 10-year event within the pipe (no pressurized flow)	2.5 FT Dia Pipe	$626,000	259.4	25	Secondary
NBC_SUB8_PIPE_02	Subbasin 8	North Elm Street	< 10-year event within the pipe (no pressurized flow)	4 FT Dia Pipe	$314,000	228.2	31	Secondary
NBC_SUB8_PIPE_03	Subbasin 8	West Fisher Avenue	< 10-year event within the pipe (no pressurized flow)	2 FT Dia Pipe	$336,000	216.2	36	Secondary
NBC_SUB8_PIPE_04	Subbasin 8	Church Street	< 10-year event within the pipe (no pressurized flow)	3 FT Dia Pipe	$717,000	268.8	24	Secondary
NBC_SUB9_CULV_01	Subbasin 9	Baseball Field	<18" FB in 100-yr Event, HW/D > 1.2	(2) 13' x 7.5' Box Culvert	$2,840,000	371.8	1	Secondary
NBC_SUB9_PIPE_01	Subbasin 9	Salem and Stewart	< 10-year event within the pipe (no pressurized flow)	2 FT Dia Pipe	$1,458,000	245.0	27	Secondary
NBC_SUB9_PIPE_02	Subbasin 9	North Morrow	25-year event above surface (grate/rim, etc.)	2.5 FT Dia Pipe	$211,000	227.1	32	Secondary

Project ID	Tributary	Project Name	Triggering / Selection Configuration	Proposed Configuration	OPCC	Score	Rank	Project Classification
NBC_SUB9_PIPE_03	Subbasin 9	Bellemeade Street	< 10-year event within the pipe (no pressurized flow)	1.25 FT Dia Pipe	$69,000	214.8	37	Secondary
NBC_SUB9_PIPE_04	Subbasin 9	East Washington Street	< 10-year event within the pipe (no pressurized flow)	1.5 FT Dia Pipe	$484,000	341.7	8	Secondary
NBC_TA-UT5_BEHI_01	Unnamed Tributary 5	Cascade Drive Streambank Stabilization	Partially exposed sanitary sewer crossing, loss of property threatened by excessive erosion	BEHI 14 - Watershed Masterplan - North Buffalo Creek	$908,000	146.8	47	BEHI
				Total:	**$208,093,985**			

2 Introduction and Background

The City of Greensboro initiated a comprehensive stormwater planning program and engaged multiple consultant firms to develop watershed master plans. Kimley-Horn studied the Horsepen Creek watershed, McAdams studied the South Buffalo Creek watershed, and Stantec studied the North Buffalo Creek watershed. Stantec was assigned the North Buffalo Creek watershed due to our previous work within the North Buffalo Creek (NBC) basin (GSO Contract 2020-5074).

The master plan program set forth several objectives for each watershed: (1) assess the watershed to identify issues related to flooding, water quality, and erosion; (2) formulate and prioritize infrastructure projects to reduce both the frequency and impact of floods; (3) conceptualize stream stabilization projects to reduce property damage risks along watercourses and decrease sediment deposition from erosion; and (4) recommend SCM retrofit projects to improve water quality within the watershed. The following report focuses on the North Buffalo Creek watershed project specifically.

2.1 Project Description

This project evaluated four different types of systems: Primary System, Secondary System, Culvert Condition Assessments, SCMs, and stream stabilization. Primary Systems are FEMA mapped streams, including City-owned crossings such as bridges and culverts. All City-owned Primary System crossings that were determined to have LOS deficiencies based on existing condition modeling results were identified for further study. Secondary Systems include closed pipes and smaller open channels that feed into the Primary System. These systems were selected based on a review of City EAMs data, the City's map entitled "Top 20 areas of Historically Observed Flooding in GSO," and in collaboration with City staff. SCMs are water quality measures to treat stormwater runoff across the basin. SCM retrofit opportunities were identified via a desktop and field screening process that considered property ownership and drainage area composition. Stream stabilization projects protect structure foundations, utilities, and other assets, as well as reduce sediment loads in streams. Opportunities for these projects were also identified via a desktop and field screening process that considered property ownership, bank erosion, and proximity to utilities.

2.2 Data Sources

This project utilized data from a variety of sources. The major data elements and sources are catalogued below:

Table 2.2-1 Data Sources

Description	Source
City-wide storm drainage infrastructure	City GIS inventory
Parcel data, buildings data	Guilford County GIS data
FEMA HEC-RAS models, stream centerlines, effective floodplains	NFRIS website
FEMA HEC-HMS models	Provided directly by NCFMP
City boundary	NCOneMap.com
National Land Cover Dataset	https://www.mrlc.gov/
Zoning Data	City GIS data
EAMs stormwater service request data	City GIS data
Critical infrastructure	Countywide excel file
LiDAR used for surface modeling	NC Spatial Data Download
Survey data for Primary System model augmentation and Secondary System models	Field survey provided by JC Waller & Associates, PC
City streets and classifications	City street centerlines GIS data
NBC USGS gage data (precipitation and streamflow)	https://waterdata.usgs.gov/nc/nwis/rt
Repetitive loss structures	City GIS data
Greenways	City GIS data
City culvert inspections	City GIS data
City stormwater CIP projects	City data
Soils data	Web Soil Survey
NOAA 3rd Quartile Atlas 14 Volume 2, 6-Hour duration, 10% distribution	https://hdsc.nws.noaa.gov/pfds/pfds_temporal.html
1-Day Observed Precipitation spatial data	NOAA and NWS
Structure As-Builts	City data
Channel Manning's N values	FHWA Hydraulic Design Series No. 4
Unnamed Tributary structure data	FEMA (preliminary HEC-RAS model)
High Water Marks	Community comments
Curve Numbers per Land Use	Greensboro Strom Drainage Design Manual (2008) and Guildford County Drainage Report (2002)
2-year peak discharges	USGS StreamStats

2.3 Design Standards and Criteria

Unless otherwise noted, the following LOS requirements are from the GSO's 2008 *Storm Drainage Design Manual* (the "Manual"). The standards were used to evaluate the performance of the Primary and Secondary Systems in this SWMP.

Table 2.3-1 System Level of Service Criteria for Primary and Secondary Systems

Facility	Design Storm	Level of Service
Stormwater Collection System • 15" minimum diameter	10-year	10-year storm within the pipe (no pressurized flow except as permitted in the Manual)
	25-year	25-year storm below surface (grate/rim, etc.)
Roadway Culverts • HW/D ≤ 1.2 • No Structures inundated for 100-year storm • 12" Freeboard (from overtopping for culverts) culvert diameter <= 36" • 18" Freeboard (from overtopping for culverts, from low chord for bridges) culvert diameter > 36" and all bridges	25-year	Minor City Streets (Sub collector, Local and Residential Streets)
	50-year	Major City Streets (Thoroughfares, Major and Minor Collector Streets), NCDOT
	100-year	All Street Classifications Over Regulated Floodways
Greenways/Footbridges	n/a	No City standard applies
Private	n/a	No City standard applies

3 Existing Watershed Conditions

3.1 Resident Service Request Data

As part of initial data collection, the City provided stormwater service request data from the City EAMs system. This data consisted of various types of service requests, including flooding, erosion, cave-ins, debris or blockage of stormwater structures, and issues with stormwater ponds. Due to the large volume of service request data, Stantec focused on service requests that have occurred since January 1, 2011 (4525 requests). Table 3.1-1 below summarizes the types of service requests present within the NBC watershed.

Table 3.1-1 Service Requests within the NBC Watershed

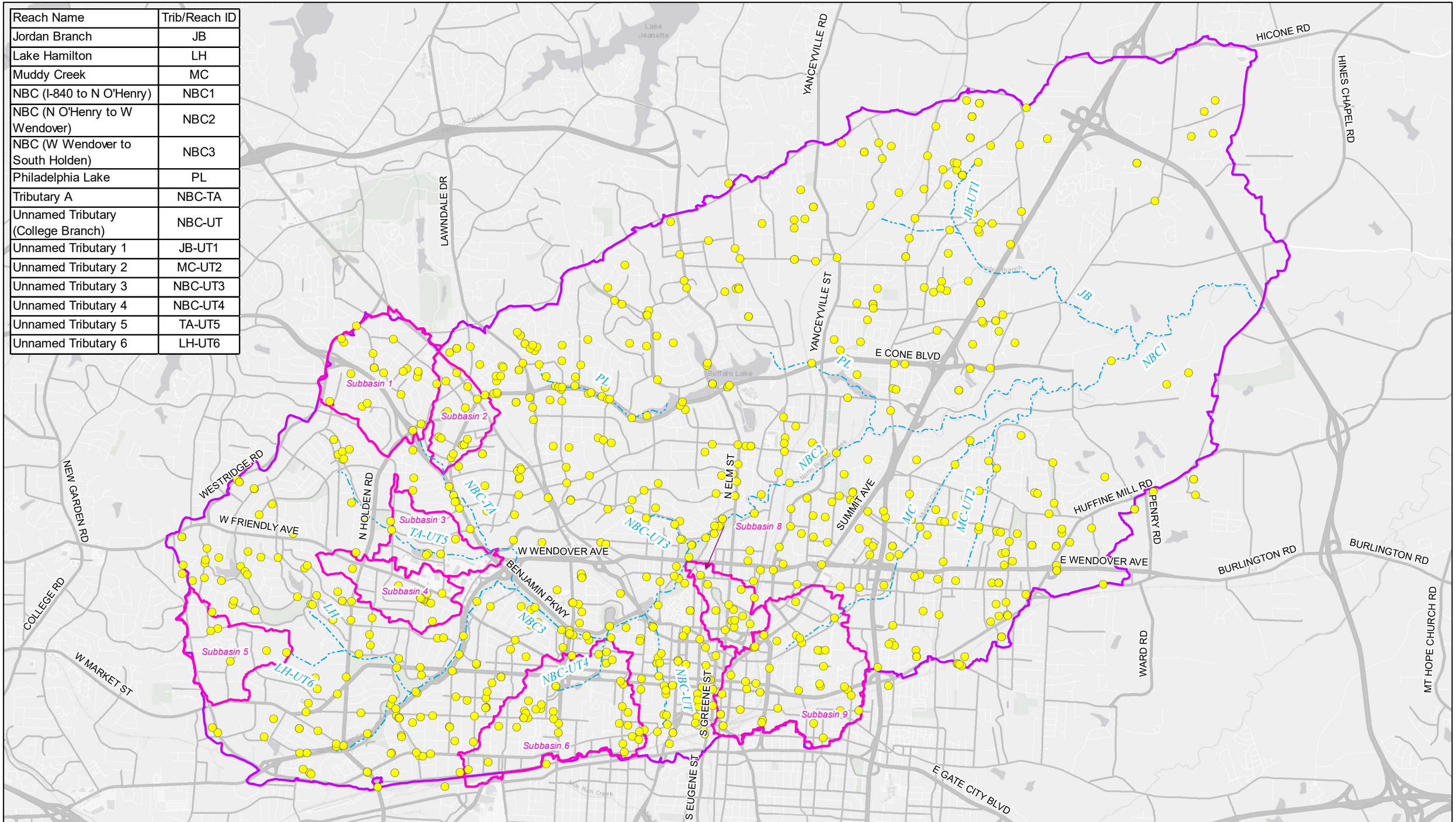
Cause Description	Cause Code	Number of Requests
SWM - Weather	SWM006	4
Standing Surface Water	SR002	1
Storm Water Maintenance-Blockage	SW007	81
Storm Water Maintenance-Flash Flood (Inundated)	SW009	90
Storm Water Maintenance-Not Applicable*	SW020	219
Storm Water Maintenance-Sediment	SW003	139
Storm Water Maintenance-Structure Failure	SW019	259

** excluded "No Action Taken" and "Refer to other Department."*

Figure 3-1 shows the spatial distribution of the various service requests within the watershed. There are certain areas where service requests are concentrated; these areas were reviewed as possible systems

to be evaluated as “Secondary Systems”. Selection of Secondary Systems is discussed further in Section 4.8. In addition to helping identify Secondary Systems, the EAMs data was useful in validation for the Primary System models.

Reach Name	Trib/Reach ID
Jordan Branch	JB
Lake Hamilton	LH
Muddy Creek	MC
NBC (I-840 to N O'Henry)	NBC1
NBC (N O'Henry to W Wendover)	NBC2
NBC (W Wendover to South Holden)	NBC3
Philadelphia Lake	PL
Tributary A	NBC-TA
Unnamed Tributary (College Branch)	NBC-UT
Unnamed Tributary 1	JB-UT1
Unnamed Tributary 2	MC-UT2
Unnamed Tributary 3	NBC-UT3
Unnamed Tributary 4	NBC-UT4
Unnamed Tributary 5	TA-UT5
Unnamed Tributary 6	LH-UT6



Stantec
One West Fourth Street, Suite 820
Winston-Salem, North Carolina
27101-3818
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N

Legend
- Stream Centerline
- EAM Service Requests
- Secondary System Boundaries
- Watershed Boundary

0 2,000 4,000 8,000 Feet

(At original document size of 11x17)
1:48,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title
Spatial Distribution of Service Requests

Project Location:
City of Greensboro,
Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:
08/05/2024

Sheet No.
Figure 3-1

3.2 Watershed Characteristics

The North Buffalo Creek watershed spans around 37 square miles and includes 33 square miles within the City's limits. Positioned in north central Greensboro, the NBC watershed drains from west to northeast. Key features within the watershed are UNC-Greensboro, NC A&T University, Greensboro College, a portion of the downtown central business district, Friendly Shopping Center, Hamilton and Buffalo lakes, Latham Park, and Revolution Mill. Watershed boundaries are generally marked by Norfolk Southern Railroad to the south, Muirs Chapel Road and Westridge Road to the west, Pisgah Church Road and Hicone Road to the north, and US Interstate Highway 785 to the east. As the City's most built-out watershed area, the watershed primarily features moderate-intensity residential uses, complemented by commercial and industrial areas.

Existing Land Use (LU) within the watershed was determined based on the 2019 National Land Cover Dataset (NLCD). Refer to Appendix A for the LU map. The following LU areas were identified within the NBC watershed:

Table 3.2-1 NBC NLCD Watershed LUs

NLCD Gridcode	NLCD LU Designation	Area, Acres	Area, Percentage
11	Open Water	93.2	0.4%
21	Developed, Open Space	6,873.0	28.9%
22	Developed, Low Intensity	7,285.4	30.6%
23	Developed, Medium Intensity	4,062.3	17.1%
24	Developed, High Intensity	2,183.0	9.2%
31	Barren Land	14.0	0.1%
41	Deciduous Forest	1,827.2	7.7%
42	Evergreen Forest	127.8	0.5%
43	Mixed Forest	159.2	0.7%
52	Shrub/Scrub	208.4	0.9%
71	Grassland/Herbaceous	159.2	0.7%
81	Pasture/Hay	705.8	3.0%
82	Cultivated Crops	47.6	0.2%
90	Woody Wetlands	26.9	0.1%
95	Emergent Herbaceous Wetlands	0.4	0.002%
	Totals	**23,773**	**100%**

The land uses in the watershed range from undeveloped farmland and forests in the most eastern corner of the watershed to densely developed downtown areas in the central, southern part of the watershed. Most of the watershed along the north and west consists of low-density, suburban developments.

Soil type within the watershed is another major hydrologic characteristic. Refer to Appendix A for the watershed Soil Map. Each soil type is described below; note that combination soils (B/D and C/D) were assumed to be the higher runoff potential, but only constituted around 5% of the watershed. Open water areas were assigned to soil group “D”.

- Group A—Soils in this group have low runoff potential when thoroughly wet. Water is transmitted freely through the soil.
- Group B—Soils in this group have moderately low runoff potential when thoroughly wet. Water transmission through the soil is unimpeded.
- Group C—Soils in this group have moderately high runoff potential when thoroughly wet. Water transmission through the soil is somewhat restricted.
- Group D—Soils in this group have high runoff potential when thoroughly wet. Water movement through the soil is restricted or very restricted.

Table 3.2-2 North Buffalo Creek Hydraulic Soil Group (HSG) Distribution

HSG	Area, Square Miles	% of Watershed
A	1.9	5%
B	12.6	34%
C	16.5	44%
D	6.2	17%
Total	**37.1**	**100%**

4 Existing Conditions Analysis

4.1 Field Surveying Data Collection

Collection of field survey data was conducted in support of hydraulic modeling tasks. Surveying was accomplished using a combination of Global Positioning System (GPS) and conventional surveying. The following specifications were used for data collected:

- Elevations meet the posted standards of the North Carolina (NC) Virtual Reference Station (VRS) network
- All survey work shall be “Class A” surveying standard and performed in compliance with the Standards of Practice for Land Surveying in North Carolina as defined for GIS surveys
- The horizontal datum is the North American Datum (NAD) 83
- The coordinate system is North Carolina State Plane 3200
- The vertical datum is the North American Vertical Datum (NAVD) 88
- The unit of measurement is the US Survey Foot

Primary system survey was collected at structures that did not have current or sufficient survey data in the existing FEMA HEC-RAS models and at representative cross-sections along each river reach. Channel cross-section survey was collected for the primary purpose of capturing the below-water portion of the channel that is not captured in LiDAR data. The channel cross-section data collected also provided data to guide the selection of appropriate channel Mannings n values. Survey was not collected for all model cross-sections due to constraints of time and cost. Structure survey data was collected to determine the size, shape, material, and other hydraulic properties of structure openings and embankments. Structure survey data was not collected where infrastructure was entirely underwater, buried, or where it was

determined that the survey data included in the existing FEMA models was sufficient. In cases where infrastructure was underwater or buried, as-builts were obtained from the GSO or reasonable assumptions were made based on visible components of the structure. Table 4.1-1 shows the type of data collected for each type of system.

Table 4.1-1 Type of Survey Data Collected

System	Item surveyed	Number Collected
Primary	Road Crossing Structures	27
Primary	Storage Structures	4
Primary	Channel Cross-sections	75
Primary	Weir/Riser Spillway	1
Secondary	Storm Sewer Inlets	113
Secondary	Storm Sewer Manholes	152
Secondary	Pipe Inlets/Outlets	35
Secondary	Channel Cross-sections	43
Secondary	Weir/Riser Spillway	7
Primary and Secondary	Staff Gage Top Cap	17

4.2 Stream Stage Gages

Stream stage gages were installed in select locations throughout the North Buffalo Creek, South Buffalo Creek, and Horsepen Creek (HPC) watersheds. Each of the three consultant teams selected gage locations for their assigned watershed based on ease of installation and maintenance, site safety and access, and at major structures at creek crossings. Stantec worked with a subconsultant, Taylor Engineering, to construct and install gages at each location. High water level at each gage was checked following target storm events. The gages consisted of a wooden staff installed inside a polyvinyl chloride (PVC) pipe with holes drilled to allow water into the bottom of the pipe and loose cork particles hand-placed at the bottom of the PVC tube. During rain events, the cork inside the pipe would rise with the water and stick to the wooden staff at the high water mark. After the high water receded, the staff was removed and the height of the cork on the wood stick was measured. The cork height measurement was translated into a water surface elevation using the surveyed elevation of the gage.

The targeted storm event for stage gage data collection was approximately the 99-percent-annual-chance streamflow event (streamflow with a 1-year return period). Using USGS gages within each watershed, the team set email alerts through the USGS WaterAlert website for automatic notification when the peak flows in the watershed exceeded the 1-year peak discharge. Following the storm event, the height data was collected, converted to a high water mark elevation and distributed to the teams for use in validating their Primary System models. Data was collected from 12 gages for 8 storms in North Buffalo Creek, 6 gages for 6 storms in Horsepen Creek, and 5 gages for 8 storms in South Buffalo Creek. Some storms were more concentrated over one watershed than the others so not all gages recorded data. The gage locations and high water level results, including precipitation data for the storms, are included in Appendix D.

4.3 Engineering Field Investigation

Field investigations were completed to collect supplemental information required for modeling analysis, project evaluations, and to gain a better understanding of overall watershed characteristics and conditions. The field investigations included physically walking approximately 40 miles of Primary and Secondary System creeks to document the condition of outfalls, utility crossings, streambanks, bridges, and other creek crossing structures. General comments on observed water quality and other features of the watershed were recorded and photographed. The information collected during the stream walks was used to inform the existing conditions model and project alternatives development.

The stream walk data was collected using ArcGIS Field Maps. Existing spatial features of the watershed were input into the map including open channels, utilities, storm drains, and roads. Stantec developed forms for each type of feature anticipated to be encountered during the field walks. Observations for each of the following types of features were collected:

- Utility crossings
- Structures
- Tributaries
- Storm outfalls
- General comments
- Bank Erosion Hazard Index (BEHI)

In each form, Stantec recorded general observation notes and captured geolocated photos for each observation. The collected notes and photos are included in the project geodatabase delivered to the city. Appendix K includes maps of the collected data and photograph logs of features throughout the watershed.

The collected BEHI data was used to evaluate potential project locations for asset protection and bank stabilization alternatives, discussed in further detail below. Stantec also utilized the stream walk water quality issue observations to help develop the Green Stormwater Infrastructure (GSI) project alternatives for the North Buffalo Creek watershed.

The data collected during the stream walks also helped the city identify some immediate maintenance and water quality concerns within the watershed. The Stantec team noticed discoloration and a foul odor while walking a reach of North Buffalo Creek near the Friendly Shopping Center. The team notified the city, who was able to quickly identify and repair a damaged sewer manhole that allowed sewage to discharge into the stream. On another occasion, Stantec encountered a sewer cleanout overflow near Unnamed Tributary 2 and once again notified the City to quickly resolve the issue.

4.4 Primary System Identification

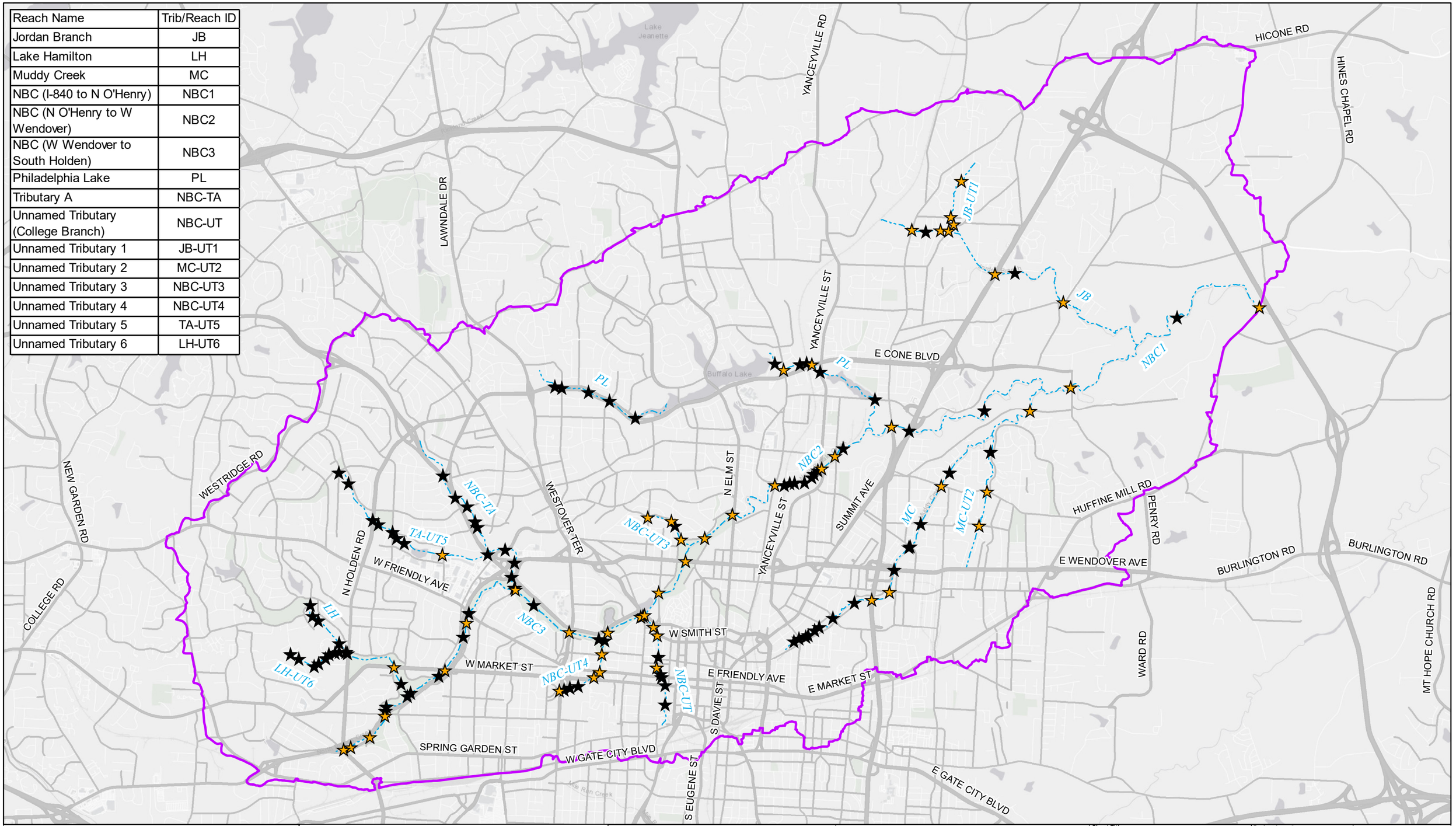
The Primary System consisted of all Effective FEMA mapped streams within the watershed and one additional stream (Unnamed Tributary) which only had Preliminary FEMA mapping. The Primary System streams consisted of the following:

Table 4.4-1 Primary System Streams

Stream Name	Approximate Length, Feet
Jordan Branch	16,100
Lake Hamilton	7,200
Muddy Creek	19,000
North Buffalo Creek	61,600
Philadelphia Lake	14,700
Tributary A	9,400
Unnamed Tributary (College Branch)	5,600
Unnamed Tributary 1	4,000
Unnamed Tributary 2	6,600
Unnamed Tributary 3	2,900
Unnamed Tributary 4	3,800
Unnamed Tributary 5	9,000
Unnamed Tributary 6	3,200
Total	**163,200**

Within the Primary Systems, various culvert/bridge crossings were analyzed using the existing conditions HEC-RAS model to determine if they met the minimum LOS required within the city's design documentation. City-owned roadway crossings found to be deficient based on the LOS requirements were designated as needing a project to bring the location up to standards. Footbridges and crossings outside of the City's control (NCDOT, private, railroads) were considered out of scope and not analyzed for a project alternative. Figure 4-1 shows Primary System crossings which were analyzed and the crossings that did not meet the City's required LOS.

Reach Name	Trib/Reach ID
Jordan Branch	JB
Lake Hamilton	LH
Muddy Creek	MC
NBC (I-840 to N O'Henry)	NBC1
NBC (N O'Henry to W Wendover)	NBC2
NBC (W Wendover to South Holden)	NBC3
Philadelphia Lake	PL
Tributary A	NBC-TA
Unnamed Tributary (College Branch)	NBC-UT
Unnamed Tributary 1	JB-UT1
Unnamed Tributary 2	MC-UT2
Unnamed Tributary 3	NBC-UT3
Unnamed Tributary 4	NBC-UT4
Unnamed Tributary 5	TA-UT5
Unnamed Tributary 6	LH-UT6



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Legend

- Primary Streams
- Primary System Crossings
- Primary System Crossings - LOS Not Met
- Watershed Boundary

0 2,000 4,000 8,000 Feet

(At original document size of 11x17)
1:48,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title

Primary System Analysis Map

Project Location:

City of Greensboro,
Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:

08/05/2024

Sheet No.

Figure 4-1

4.5 Primary System Analysis Methodology

4.5.1 Hydrology

Hydrologic analysis was performed in HEC-HMS version 4.6.1 using the 2019 North Buffalo Creek HEC-HMS model as a starting point. The HEC-HMS subbasins were developed to provide lateral inflows for the HEC-RAS hydraulic model. Several storages that were outside of the HEC-RAS model limits were included in the HEC-HMS model. Junctions were added to collect flow from the subbasins; however, junction results were not used for the HEC-RAS modeling.

Subbasins were delineated using two-foot contours and a raster terrain file. Basin splits along each stream were placed at a 10 to 20 percent increase in drainage area, at ponds or lakes in line with the stream, and at significant (large abutments) structures crossing the stream. Subbasins were initially delineated using only the topographic data, and subsequently refined using the city storm sewer data to identify any areas where storm sewers carried flow across natural watershed divides.

Curve Numbers were developed for each subbasin from the 2019 -NLCD-land use data, 2019 NLCD impervious data, and SCS soil survey data, shown in Section 3.2. Table 4.5-1 below shows the relationship between the NLCD data and the CNs based on the Guilford County Drainage Report (Source 1) and the GSO Storm Drainage Design Manual (Source 2).

Table 4.5-1 NLCD Land Cover and Curve Number Assignments

NLCD Land Cover Classification	NC Assigned Land Use/Treatment	Curve Number by Soil Group				Source
		A	B	C	D	
Deciduous Forest	Wood or forest land - Thin Strand - poor cover, no mulch	45	66	77	83	1
Developed, High Intensity	Urban Districts: Commercial and business	89	92	94	95	2
Developed, Low Intensity	Residential: 1/2 acre lot	54	70	80	85	2
Developed, Medium Intensity	Residential: 1/4 acre lot	61	75	83	87	2
Developed, Open Space	Open Space: Fair Condition (grass cover 50 to 75%)	49	69	79	84	2
Evergreen Forest	Wood or forest land - Thin Strand - poor cover, no mulch	45	66	77	83	1
Hay/Pasture	Pastureland - fair condition	49	69	79	84	1
Mixed Forest	Wood or forest land - Thin Strand - poor cover, no mulch	45	66	77	83	1
Open Water		100	100	100	100	
Woody Wetlands	Open Space: Poor Condition (grass cover <50%)	68	79	86	89	2
Cultivated Crops	Cultivated land - without conservation	72	81	88	91	1
Barren Land	Open Space - Poor Condition (grass cover <50%)	68	79	86	89	2
Emergent Herbaceous Wetlands	Open Water	100	100	100	100	
Grassland/Herbaceous	Pastureland - fair condition	49	69	79	84	1
Shrub/Scrub	Open Space: Fair Condition (grass cover 50 to 75%)	49	69	79	84	2
1-Guilford County Drainage Report						
2-City of Greensboro Storm Drainage Design Manual						

The table below shows CNs computed prior to adjustments made during the model validation process, as described later in this document.

Table 4.5-2 Watershed Existing CNs

Description	Existing
Area Weighted Average	79.1
Maximum	94
Minimum	61

Residential adjustments were applied to account for differences in the assumed percent impervious range between the NLCD categories of low- and medium-intensity residential (Gridcodes 22 and 23 and Curve Number categories of ½-acre and ¼-acre residential lots). For NLCD Gridcodes 22 and 23, the NLCD

percent impervious data and soils data was used to determine an adjusted CN value based on Table 4.5-3.

Table 4.5-3 Curve Number Residential Adjustments

Curve Number Lookup	>65% impervious	38% to 64% Impervious	30% to 37% Impervious
Soil Type A	77	61	57
Soil Type B	85	75	72
Soil Type C	90	83	81
Soil Type D	92	87	86

The maximum increase in CN was 16 and there were no decreases resulting from the residential adjustments. The average increase, excluding polygons that had an increase of 0, was 4.23. 30.6% of the polygons, representing 24.3% of the total area, had an increase in CN value due to the residential adjustments.

Five storages were included in the HMS modeling. Storage curves were derived from LiDAR terrain data. Outlet dimensions were determined from survey data, or from City data.

Stantec delineated two longest flow paths for each subbasin to develop time of concentration values. A spreadsheet was used to perform the Time of Concentration (TOC) calculations for each subbasin. The TOC spreadsheet inputs included the longest flow path, the 50-percent-annual chance event (2-year return period) flows, pipe diameters for pipe flow path segments, channel bottom widths, Mannings N values for the flow path segments, and elevations at the upstream and downstream ends of the flow path segments.

Flow paths were divided into sheet flow, shallow concentrated flow, and concentrated flow (pipe flow or channel flow), and ponds per the National Engineering Handbook (NEH) Part 630 Chapter 15. Multiple pipe flow, channel flow, and pond segments were split out if there were multiple ponds, channels, or storm sewer segments along the flow path.

- Isolated culverts were not considered to be separate pipe flow segments (were left as part of the channel flow length) since they have minimal impact on the 2-year flow.
- Ponds were not included in the time of concentration calcs. (TOC = 0 for pond segments)
- Open channel segments were split at confluences and/or wherever a single cross-section would not be representative of the entire reach.
- Sheet Flow was considered to be the first 100 feet and the city minimum of 10 minutes was used if the calculated Sheet Flow TOC was less than 10 minutes.
- Shallow concentrated flow distance was determined from the end of sheet flow to the first clear channel in the Digital Elevation Model (DEM), or when the flow entered the storm sewer system.

The 2-year flows were determined from StreamStats for each flow path segment and were used in estimating velocities and determining time of concentration for each flow path segment. Some flow path segment drainage areas had “impermeable” or “developed” parameters that were outside of the limits of

the regression equations. In these situations, the parameters were adjusted to be within the limit and the flows were recalculated for that drainage area.

Manning's n values for open channels were set as shown below for the TOC calculations:

- Grass lined swale 0.040
- Small Streams in upstream reaches, forested and non-forested 0.035
- Modeled Tributaries to North Buffalo Creek 0.030
- North Buffalo Creek 0.025

Pipe diameters and lengths used in the TOC calculations for pipe flow segments were derived from the city storm sewer data. A length-averaged diameter was calculated for each pipe flow segment using an excel spreadsheet and was used as the input diameter for the TOC calculations. Pipe Manning's n values were assumed to be 0.013, for reinforced concrete pipe.

Elevations were extracted from the DEM at the upstream and downstream end of each flow path segment. These elevations along with the flow path segment lengths were used to calculate the slope of each flow path segment. These slopes were used along with the Mannings n values, segment type, and 2-year flows to calculate the flow velocity for each segment during the 2-year event. The flow path length divided by the velocity was used to determine the time of concentration. The flow path that resulted in longest TOC was then converted to a lag time and input into the HMS model.

The HMS model included a total of 88 subbasins that were utilized in the HEC-RAS model. Table 4.5-4 shows other hydrologic parameters at the watershed scale; more detailed hydrologic information on each subbasin is included in the Appendix B.

Table 4.5-4 Overall Watershed Hydrologic Parameters

Description	Time of Concentration, Minutes	Area, Acres
Average	18.3	265.2
Maximum	43.1	1983.9
Minimum	4.3	4.5

Stantec used HEC-HMS subbasin hydrographs to convert the steady state FEMA HEC-RAS model to unsteady state by connecting HMS DSS output files to the HEC-RAS models. Note that DSS files from the subbasins were input directly to the HEC-RAS model; no routing was performed within the primary stream channels in the HMS model.

ArcGIS tools were also used to develop hydrologic basin parameters including SCS CN, time of concentration, lag time, and percent imperviousness. Refer to Section 4.6.4 for a summary of all hydrologic scenarios created for analysis and run results performed in HEC-HMS.

During this analysis, Antecedent Moisture Conditions were assumed to be average conditions.

4.5.1.1 Rainfall

SCS Type II storm distribution was used to evaluate performance of alternatives because this is the design storm required by the Manual and to yield more conservative designs.

NOAA Atlas 14 3rd quartile 10% rainfall distributions for the 2-Year, 10-Year, 25-Year, 50-Year, and 100-Year 6-hr storms were also used in the HMS model. Rainfall depths were based on the values used in the previous model (GSO Contract 2020-5074) and are shown in Table 4.5-5. These depths are 0.03 to 0.04 inches lower than the 6-hour rainfall depths published by the program manager on 6/12/2023. Since the North Buffalo Creek watershed HEC-HMS and HEC-RAS models were completed, reviewed, and calibrated before 6/12/2023 and the differences are minor, the 6-hr rainfall depths were not updated to exactly match the values used in the other watersheds.

Rainfall depths for each storm event were obtained from NOAA Atlas 14 data, as obtained from NOAA's website in 2021. Table 4.5-5 shows the rainfall depths used for this SWMP.

Table 4.5-5 Depth-Duration-Frequency

Duration, year	2	5	10	25	50	100	500
24-Hour Rainfall, inches	3.41	4.25	4.91	5.8	6.5	7.22	8.97
6-Hour Rainfall, inches	2.41	--	3.46	4.05	4.51	4.98	--

4.5.1.2 Results

Results from the hydrologic analysis for each of the subbasins is provided in Appendix B. Since the HEC-RAS model for this project is unsteady, the routing along the hydraulic components was performed within HEC-RAS. HEC-RAS version 5.0.7 was used as it is the most stable version of the HEC-RAS 5.0 series. Within the RAS model, there are over 800 locations along the Primary System at which peak flows are continuously modeled and reported (cross sections, culvert crossings, bridges, etc.).

4.5.2 Hydraulics

One-Dimensional (1D) unsteady HEC-RAS models were developed to incorporate the hydrologic modeling output from HEC-HMS. Effective FEMA HEC-RAS models were utilized as the starting point for development of the models utilized within the SWMP effort. It is noted that there are now draft-preliminary models available for much of Greensboro. In general, the preliminary models were only used for reference except where additional structure survey was included. Unnamed Tributary does not have an effective FEMA HEC-RAS model; therefore, the preliminary FEMA model was used as the starting point. Stantec acquired the effective and preliminary models for the Primary Systems and then assembled them into a three separate HEC-RAS 5.0.7 models for use on the project. As described in Section 4.1, survey data was collected for areas within the FEMA models in need of augmentation. Additional cross sections, roadway overtopping profiles, culvert data, and bridge data were collected at strategic locations. Cross sections were collected where review of the FEMA model indicated additional section density could improve overall model precision. For example, several areas along the streams

were identified as having varying terrain from upstream and downstream sections. Therefore, additional survey and cross-sectional data were needed in those areas.

Model parameters, including boundary conditions, geometry updates including bridges and cross-sections, model stability, and model validation will be discussed in the following sections.

4.5.2.1 Application of Existing Land Use Hydrology

The unsteady flow rates were incorporated into the hydraulic model by linking the output Data Storage System (DSS) files from the hydrologic results for each of the evaluated storm events. The available options for boundary conditions to link the DSS file to the hydraulic model included uniform lateral inflow, lateral inflow, and flow hydrograph. Based on the hydrologic model, a total of 119 flow boundary conditions were applied to the unsteady flow data file and required the use of two of the boundary condition types. The following decision model was used to apply the flows to select boundary types:

- Flow Hydrograph – this type of boundary condition was only utilized at the top of a reach or just downstream of a stream junction. This boundary condition applies flow between the user defined cross-section and the next adjacent cross-section downstream. Subbasins whose outflow began at the top of the delineated stream centerline from the preliminary FEMA models were applied to the stream as a flow hydrograph boundary condition.

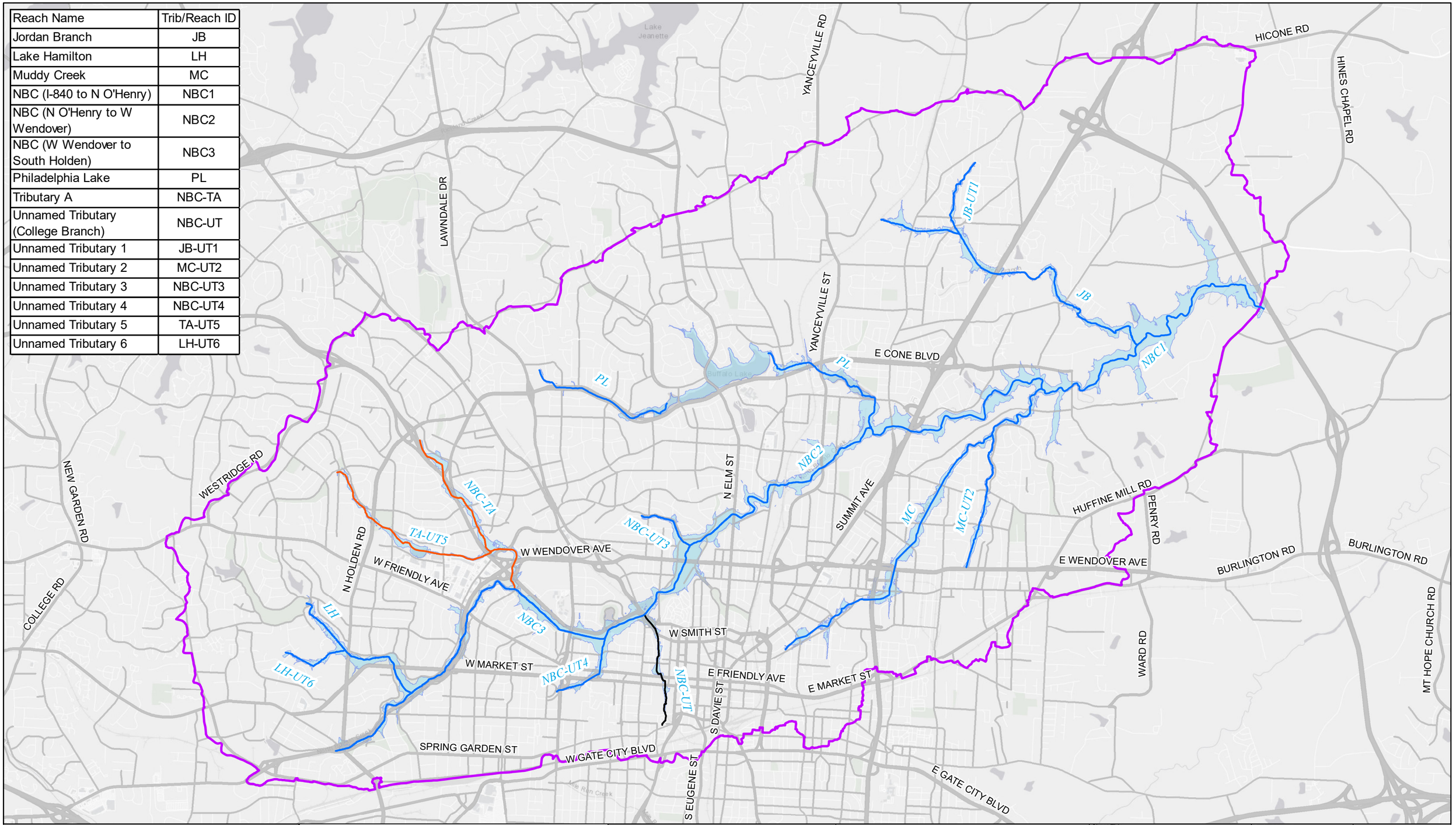
- Lateral Inflow – this type of boundary condition is similar to the flow hydrograph boundary condition where flow is applied between the user defined cross-section and the next adjacent cross-section downstream. This boundary condition was used for all other subbasins.

Lateral inflows were initially assigned along the stream centerline near the upstream side of the HEC-HMS subbasin the flows were calculated from. The flow assignments were then updated based on where significant structures crossed the stream to ensure that each structure was seeing an appropriate amount of flow. Flow multipliers were used to split a single inflow into multiple inflows in situations where a subbasin flow needed to be input partially upstream and partially downstream of a structure. Minimum flows were set for most inflows to maintain model stability, and all inflows were set up to pull data directly from the HMS DSS.

4.5.2.2 Existing Conditions Model Geometry

1D unsteady HEC-RAS models were developed for North Buffalo Creek and 12 tributaries. The models were first developed as individual models which were refined until they were stable. Most of the tributaries were then combined into a single model with the North Buffalo Creek mainstem. However, due to the bridges located very near their confluence with North Buffalo Creek, Tributary A and Unnamed Tributary could not be combined with the mainstem model. Tributary A was combined with its tributary, Unnamed Tributary 5, in a separate model. Unnamed Tributary did not have any tributaries and was left as an individual model. Figure 4-2 shows the spatial extents of the three separate Primary System models that were developed.

Reach Name	Trib/Reach ID
Jordan Branch	JB
Lake Hamilton	LH
Muddy Creek	MC
NBC (I-840 to N O'Henry)	NBC1
NBC (N O'Henry to W Wendover)	NBC2
NBC (W Wendover to South Holden)	NBC3
Philadelphia Lake	PL
Tributary A	NBC-TA
Unnamed Tributary (College Branch)	NBC-UT
Unnamed Tributary 1	JB-UT1
Unnamed Tributary 2	MC-UT2
Unnamed Tributary 3	NBC-UT3
Unnamed Tributary 4	NBC-UT4
Unnamed Tributary 5	TA-UT5
Unnamed Tributary 6	LH-UT6



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Legend
- North Buffalo Creek Combined Model Centerline
- Tributary A Combined Model Centerline
- UnnamedTributary Combined Model Centerline
- Watershed Boundary
- SCS II - 1-percent-annual-chance inundation

0 2,000 4,000 8,000 Feet

(At original document size of 11x17)
1:48,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title
Primary System Model Footprints

Project Location:
City of Greensboro,
Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:
08/05/2024

Sheet No.
Figure 4-2

When models were unable to be combined due to structures near the confluence, the downstream boundary of the tributary model was set to the stage timeseries from the upstream mainstem cross-section. When the mainstem stage values were lower than the tributary channel bottom, a minimum elevation was used to maintain a reasonable downstream depth. In some instances, the peak value of the mainstem stage timeseries was lower than normal depth for the tributary. A normal depth downstream boundary condition was applied in these situations since the mainstem stage was not controlling the tributary flow depth.

Model geometries were developed and updated from existing FEMA model geometries. Cross-section layouts were updated as necessary and channel survey was incorporated into the model. The channel geometry of the upstream and downstream structure cross sections was leveraged from the existing FEMA models where survey was not collected. Channel geometry for the upstream and downstream structure cross sections of all culverts was updated so that the channel was completely below and outside of the culvert on all sides. Culverts located partially behind or beneath channel geometry led to model instabilities.

Channel survey data was applied to non-survey cross-sections through interpolation or by adjusting the invert to maintain changes in the channel slope. Preliminary FEMA models were released during the project timeline, survey from those models was incorporated into the unsteady models where applicable. Overbank geometry was extracted from the project DEM.

Initial channel Manning's N values were assigned based on survey data and Table 12 of the FHWA Hydraulic Design Series No. 4, while initial overbank Manning's N values were determined from land use categories as shown in Table 4.5-6. Composite Left and Right overbanks values were assigned using the Stantec Mannings N Python Tool. Values from the tool were then adjusted as needed based on aerial imagery.

Table 4.5-6 Manning's N Values Assigned to Land Use Types

Class/Value	Classification/Description	Assigned Manning's n Value
Water		
11	**Open Water** - areas of open water, generally with less than 25% cover or vegetation or soil.	0.030
Developed		
21	**Developed, Open Space** - areas with a mixture of some constructed materials, but mostly vegetation in the form of lawn grasses. Impervious surfaces account for less than 20% of total cover. These areas most commonly include large-lot single-family housing units, parks, golf courses, and vegetation planted in developed settings for recreation, erosion control, or aesthetic purposes.	0.040
22	**Developed, Low Intensity** - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 20% to 49% percent of total cover. These areas most commonly include single-family housing units.	0.100
23	**Developed, Medium Intensity** - areas with a mixture of constructed materials and vegetation. Impervious surfaces account for 50% to 79% of the total cover. These areas most commonly include single-family housing units.	0.080
24	**Developed High Intensity** - highly developed areas where people reside or work in high numbers. Examples include apartment complexes, row houses and commercial/industrial. Impervious surfaces account for 80% to 100% of the total cover.	0.150
Barren		
31	**Barren Land (Rock/Sand/Clay)** - areas of bedrock, desert pavement, scarps, talus, slides, volcanic material, glacial debris, sand dunes, strip mines, gravel pits and other accumulations of earthen material. Generally, vegetation accounts for less than 15% of total cover.	0.025
Forest		
41	**Deciduous Forest** - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species shed foliage simultaneously in response to seasonal change.	0.100
42	**Evergreen Forest** - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. More than 75% of the tree species maintain their leaves all year. Canopy is never without green foliage.	0.120
43	**Mixed Forest** - areas dominated by trees generally greater than 5 meters tall, and greater than 20% of total vegetation cover. Neither deciduous nor evergreen species are greater than 75% of total tree cover.	0.100
Shrubland		
52	**Shrub/Scrub** - areas dominated by shrubs; less than 5 meters tall with shrub canopy typically greater than 20% of total vegetation. This class includes true shrubs, young trees in an early successional stage or trees stunted from environmental conditions.	0.100
Herbaceous		
71	**Grassland/Herbaceous** - areas dominated by gramanoid or herbaceous vegetation, generally greater than 80% of total vegetation. These areas are not subject to intensive management such as tilling, but can be utilized for grazing.	0.0350
Planted/Cultivated		
81	**Pasture/Hay** - areas of grasses, legumes, or grass-legume mixtures planted for livestock grazing or the production of seed or hay crops, typically on a perennial cycle. Pasture/hay vegetation accounts for greater than 20% of total vegetation.	0.030
82	**Cultivated Crops** - areas used for the production of annual crops, such as corn, soybeans, vegetables, tobacco, and cotton, and also perennial woody crops such as orchards and vineyards. Crop vegetation accounts for greater than 20% of total vegetation. This class also includes all land being actively tilled.	0.035
Wetlands		
90	**Woody Wetlands** - areas where forest or shrubland vegetation accounts for greater than 20% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.	0.120
95	**Emergent Herbaceous Wetlands** - Areas where perennial herbaceous vegetation accounts for greater than 80% of vegetative cover and the soil or substrate is periodically saturated with or covered with water.	0.070

Source: National Land Cover Database 2011 (2011)

When available, structures were updated using survey data. Otherwise, data from the existing models and/or city data was used. Road embankment geometries were extracted from the DEM. City data was used to determine entrance and exit coefficients as well as chart and scale numbers for culverts.

Blocked obstructions were applied to any areas that should not be inundated because of high terrain but were lower than the peak Water Surface Elevation (WSE). Ineffective areas were applied upstream and downstream of bridges to effect only events that did not overtop the structure and were also applied to capture flow expansions and contractions. Blocked areas and ineffective areas were also applied at confluences to approximate the area blocked by water from the other stream.

The drop structure upstream of Marston Road on Philadelphia Lake was modeled as a weir with width equal to the perimeter of the riser. Survey data could not be obtained for the culvert under the Marston Road as it is entirely submerged on both sides of the road, so the outlet pipe was estimated to have the same flow area as the riser to be conservative. An excel spreadsheet was used to calculate the hydraulics of the structure under different flow conditions and determine if modeling the structure as a weir was appropriate. Before model calibration, the calculations showed that the structure operates under weir flow conditions up to the 100-year 24-hour SCS Type II event, therefore modeling the structure as a weir was considered appropriate. The structure was re-assessed after calibration to determine if it needed to be modeled as a rating curve or if the weir method was sufficient. After calibration, peak flows decreased along the upstream portion of Philadelphia Lake and the weir method of modeling the structure was sufficient for up to the 500-year 24-hour SCS Type II event, the largest event being modeled.

4.5.2.3 Unsteady Model Stability

The unsteady models were not stable during initial runs and required extensive refinement to develop stable model results. Stantec's effort to develop the hydraulic models was iterative and was unique per reach and section of stream. The following methods were used, generally in order of progressive implementation, to develop stable hydraulic models:

1. Run base model using inflow hydrographs and small baseflows from multiple boundary conditions per reach (individual, disconnected models for each tributary and the main stem).

    a. Cross-section HTab parameters were set to have a starting elevation 0.5 foot above the channel minimum elevation and an increment of 0.5 foot. The number of points was increased as necessary to cover the entire cross-section. Structure HTab curves were examined for structures with stability issues to determine if a lack of refinement in the curve may be causing the issue. The number of points on the curves and the number of submerged curves were increased if needed. The maximum discharge calculated on the curves was set between 10,000 and 25,000 cfs.

    b. Interpolated cross-sections were added to the model to improve stability where the stream had steep channel slopes.

    c. Ineffective Flow Areas were further defined upstream and downstream of structures to avoid abrupt changes in flow conveyance area.

d. Channel geometry for cross-sections 2 and 3 of all culverts was updated so that the channel was completely below and outside of the culvert on all sides.

2. Combine stabilized reaches into a single combined watershed scale model using junctions by incorporating one tributary at a time, stabilizing, and then adding the next tributary.

   a. Included updates to structure hydraulic table parameters on the tributaries where tailwater conditions raised headwater elevations.

3. Lake Hamilton Reach 1 bridge 4164 had significant instabilities across the bridge for 50 YR Climate Change, 100 YR Climate Change, 500 YR Climate change, 100 YR Future Conditions, and 500 YR Future Conditions plans. This area was a persistent problem area with model instabilities frequently arising during the model development process. Attempts to resolve the current issues did not result in significant change. Since these are the only events impacted, they were left as-is.

4. North Buffalo Reach 9 Culvert 85200 - 500 Year Climate Change plan has an inverse WSE slope across the structure. This seemed to be caused by some instability in the culvert. Attempts to resolve the issue did not have a significant impact or worsened the condition. Since only one event is impacted, this area was left as-is.

5. On Unnamed Tributary 1, the July 2019 event simulation initially resulted in some peak discharges < 1 cfs. A minimum flow of 1 cfs was applied at every inflow on Unnamed Tributary 1 to maintain model stability.

4.5.2.4 Model Control Parameters

Model control for unsteady-state models includes Manning's roughness, computational interval (timestep), model duration, and computation options and tolerances. Table 4.5-7 specifies the model control parameters that were utilized. Model timestep was set to 1 minute for all models.

Table 4.5-7 Hydraulic Model Control Parameters

Parameter	Value	Description
Smallest Timestep	1 minute	The minimum simulation time interval chosen for achieving precise hydraulic computations in the model.
Model Duration	24 hours	The total simulation period, specifically set to encompass the entirety of SCS Type II 24-hour storm events, capturing both peak flow and receding limb.
Theta	0.6	A coefficient adjusting the weighting of temporal terms in the solution algorithm.
Maximum Number of Iterations	40	The cap on the iteration count per time step, ensuring the model's convergence within reasonable computational efforts.

4.6 Primary System Model Validation

This section outlines the model validation and parameter adjustment process for the Primary System HEC-HMS and HEC-RAS models. The process incorporates a multi-faceted review using various data sources, including USGS gage data, local service request data, staff gage data, and anecdotal feedback. The validation and adjustment procedures attempt to have the model simulations closely represent observed WSE and peak flows, particularly during significant storm events.

4.6.1 Staff Gages

As discussed in Section 4.2, Staff gage data was collected by Stantec. Within the NBC watershed, "cork-float" style staff gages were installed at twelve locations to assist with model validation. Table 4.6-1 shows the locations at which staff gages were installed.

Table 4.6-1 NBC Staff Gage Locations

Gage#	Gage Location	Stream
1	McKnight Mill Road	Jordan Branch
2	East Cone Blvd	Philadelphia Lake
3	Lafayette Avenue	Philadelphia Lake
4	Larkspur Drive	Unnamed Tributary 2
5	Phillips Avenue	Muddy Creek
6	Hobbs Road	Unnamed Tributary 5
7	Pembroke Road	Unnamed Tributary 5
8	Green Valley Road	Tributary A
9	Fairmont Street	Unnamed Tributary 4
10	West Market Street	Lake Hamilton
11	Fairview Street	North Buffalo Creek
12	Cridland Road	North Buffalo Creek

Stantec collected WSE data following strategic rainfall events during project execution. Tables 4.6-2 and 4.6-3 show the rainfall events dates and precipitation depths at the USGS NBC Church Street and Westover Terrace gages.

Table 4.6-2 Staff Gage Reading Rainfall Events – Church Street (USGS-02095271)

Event No.	Date	Total Precipitation, Inches	Duration, hrs	Average Intensity, in/hr	Peak Intensity, in/hr	Peak Flow, cfs
1	3/8/2022	1.17	14.00	0.08	0.31	755
2	3/31/2022	0.92	4.50	0.20	0.62	1,050
3	4/18/2022	1.53	7.25	0.21	0.36	1,090
4	5/24/2022	1.51	19.25	0.08	0.36	459
5	7/13/2022	1.02	4.25	0.24	0.74	900
6	7/21/2022	0.73	1.25	0.58	0.71	956
7	6/20/2023	1.26	40.00	0.03	0.32	1,170
8	1/9/2024	2.50	13.00	0.19	1.09	3,300

Table 4.6-3 Staff Gage Reading Rainfall Events – Westover Terrace (USGS-02095181)

Event No.	Date	Total Precipitation, Inches	Duration, hrs	Average Intensity, in/hr	Peak Intensity, in/hr	Peak Flow, cfs
1	3/8/2022	1.17	14.00	0.08	0.32	547
2	3/31/2022	0.83	4.75	0.17	0.56	920
3	4/18/2022	1.41	7.25	0.19	0.37	772
4	5/24/2022	1.18	19.00	0.06	0.27	352
5	7/13/2022	1.05	5.00	0.21	0.90	827
6	7/21/2022	0.99	1.25	0.79	0.96	1,000
7	6/20/2023	2.87	40.00	0.07	0.76	1,450
8	1/9/2024	2.82	14.00	0.20	1.12	2,390

The procedure for use of staff gage data was to develop a Bulletin 17C peak flow statistical analysis in HEC-SSP for the nearest USGS gage within the watershed in order to determine the return period of each storm event (2-, 10-year, etc.) based on the USGS gaged peak flow for the event. Based on the determined frequency storm event, model WSE results at the location of the staff gage are then compared to the field readings for validation purposes.

The collected events in NBC were significantly below the 2-year flow except the 01/09/2024 event. Since the highest frequency event modeled in the SWMP is the 2-year event, the first 7 events provided a floor for validation purposes.

4.6.2 Initial Validation Efforts

Initial efforts focused on validating model results against observed data for three significant storm events, Hurricane Florence (September 16, 2018), Hurricane Michael (October 10, 2018), and a July 31, 2019 storm. The rainfall data was obtained from the USGS gage data download website for the five gages shown in Table 4.6-4.

Table 4.6-4 USGS Gages Used to Obtain Calibration Storm Event Data

USGS Gage Data	USGS Gage Name	Short Name
02095500	North Buffalo Creek Near Greensboro, NC	Rankin Gage
02095271	North Buffalo Creek at Church Street at Greensboro, NC	Church Gage
02095181	North Buffalo Creek at Westover Terrace at Greensboro, NC	Westover Gage
0209399200	Horsepen Creek at US 220 Near Greensboro, NC	Horsepen Gage
02094659	South Buffalo Creek Near Pomona	South Buffalo Gage

Three of the gages, Rankin, Church, and Westover, were on North Buffalo Creek. The other two were close enough to influence the watershed. The Westover gage failed to collect data during the July 2019 storm event, so the NOAA spatial rainfall data was used to scale the rainfall hyetograph from the South Buffalo Gage and create a hyetograph for the Westover Gage.

HEC-HMS runs were developed for each of the three storms using Thiessen polygons to assign a gage to each subbasin in the HMS model. These gage assignments were then updated as needed based on

NOAA spatial rainfall data. This update was most impactful for the July 2019 event, which, according to the NOAA spatial rainfall distribution, experienced four times as much rainfall in the immediate vicinity of the Westover gage compared to the surrounding area. Therefore, the number of subbasins assigned the Westover gage was adjusted to better match the NOAA spatial data.

Based on the NOAA spatial rainfall data, it was also observed that several basins in the Church Gage area of influence were shown as having either 2 inches or 2.5 inches of rainfall instead of the 3.06 inches recorded at the gage for the July 31, 2019 event. Basins in the Rankin Gage area of influence with rainfall of 2 inches instead of the 0.97 inches recorded at the gage were also noted.

During calibration, excessive model flow volume was observed at the Rankin Gage on North Buffalo Creek downstream of these basins on July 31, 2019. A scaled rainfall timeseries was created for these basins to better represent the actual volume of rainfall and correct the flow volume issues. The July 31, 2019 rainfall distributions from Church Gage and Rankin Gage were scaled to a cumulative rainfall based on the NOAA spatial precipitation grid, and the scaled distribution was applied to the basins shown having lower or higher rainfall than what was recorded at the gage.

4.6.3 Model Adjustments

Calibration of the HMS and RAS models was performed using WSE, discharge, and volume data from the three gages on North Buffalo Creek, shown in Table 4.6-5. USGS measures WSE at each of these gages and calculates discharge and volume from rating curves. USGS developed the rating curves based on intermittent field measurements of discharge as well as the WSE. The events used in model calibration occurred in September 2018, October 2018, and July 2019. The largest discharge ever field measured by USGS, to develop the rating curve, occurred during the October 2018 event. July 2019 was a larger event than the October 2018 event, falling on the extrapolated portion of the USGS gage rating curve; therefore, the July 2019 peak discharge and streamflow volume data is considered to be less reliable that the 2018 events.

July 2019 and October 2018 were the calibration events, and September 2018 was used as a check. July 2019 was the storm of record; however, the Westover Gage only recorded data through part of the July 2019 event. The peak WSE at the Westover gage was not captured during the July 2019 event. Priority was given to matching the models to the October 2018 and September 2018 events at the Westover gage.

Table 4.6-5 USGS Gages Used for North Buffalo Model Calibration

USGS Gage Data	USGS Gage Name	Short Name
02095500	North Buffalo Creek Near Greensboro, NC	Rankin Gage
02095271	North Buffalo Creek at Church Street at Greensboro, NC	Church Gage
02095181	North Buffalo Creek at Westover Terrace at Greensboro, NC	Westover Gage

Curve Numbers and lag times were adjusted in the HEC-HMS model and Manning's N values were adjusted in the HEC-RAS models to match the peak WSE, streamflow volumes, peak discharge, and

overall hydrograph shapes of the gage data. Model data was pulled from the cross-section closest to the gage on the same side of the bridge or structure where the gages were located.

Since no USGS gages were located on the tributaries to North Buffalo Creek, a RAS controller spreadsheet was created to extract WSE and flow hydrograph data from the HEC-RAS DSS files at cross-sections upstream and downstream of confluences. This data was used to determine the impacts of changes in the tributary hydrograph on the mainstem hydrograph. Using the spreadsheet helped to determine when to increase or decrease the tributary lag times and Manning's n values to help match the mainstem gage data.

Measurements from staff gages installed on each tributary were also used to calibrate the HEC-RAS models. The largest storm that occurred in Greensboro over the duration of the staff gage data collection period was approximately a two-year recurrence interval, or 50% annual chance, event. This data was used to perform a final pass of model calibration on the tributaries of North Buffalo Creek.

Once calibrations were complete, the City's feedback was obtained for any roads that were shown to be overtopped during the level of service design event for that road crossing. The City personnel present at the meeting had 25 years of collective experience, so any roads that did not have observed overtopping from the City's feedback were considered to not flood in at least the 25-year event. This feedback was compared to the lowest event overtopping each roadway, and further refinements in Mannings values, Curve Numbers, and Time of Concentration were made based on the results.

A summary of the adjusted CN values for each subbasin is included in Table 4.6-6 below. A maximum lag time of 50 minutes was used for the calibration adjustments. Refer to Appendix B for more detailed tables pertaining to the hydrologic analysis.

Table 4.6-6 Watershed Existing CNs post-Validation

	Existing
Area Weighted Average	80.6
Maximum	99.4
Minimum	61.6

4.6.4 Baseline Storm Selection and Final Validation

To address the City-wide model validation challenges, the NOAA 3rd Quartile Atlas 14 Volume 2, 6-hour duration, 10% rainfall distribution was considered for use as the baseline evaluation storm. The rainfall distribution curve is included in Appendix B. The consultant teams reviewed rainfall data for 3 different storm events at 4 different gages within HPC, North Buffalo Creek, and South Buffalo Creek and determined that the general pattern of rainfall across the watersheds more closely matches the NOAA event as opposed to the SCS event. Table 4.6-7 below summarizes all hydrologic model scenarios run in HEC-HMS as part of the model evaluation. Table 4.6-8 presents the final validation results at the USGS gages. Figure 4-3 compares NOAA, SCS, and actual rainfall distributions, demonstrating that NOAA more

closely represents area rainfall patterns. It is noted that the rainfall events shown have been scaled to allow for comparison of curve shape across events of varying duration.

Table 4.6-7 Hydrologic Model Scenarios

Rainfall Distribution	Modeled Storm Events	LU(s)
SCS Type II	2-, 10-, 25-, 50-, 100-, 500-year current, and climate change	Existing and Future
NOAA 3rd Quartile Atlas 14 Volume 2, 6-Hour duration, 10% distribution	25-, 50-, 100-year current	Existing and Future
Storm Specific rainfall record	Hurricane Florence, Hurricane Michael, and July 31, 2019	Existing

Table 4.6-8 Final Validation Storm Event WSE Comparisons

Event Name	Event Date	USGS Gage Number	USGS Gage Peak WSE	HEC-RAS Peak WSE	Comparison
Hurricane Florence	September 16, 2018	02095181	747.7	748.2	+0.5
Hurricane Florence	September 16, 2018	02095271	734.7	735.0	+0.3
Hurricane Florence	September 16, 2018	02095500	692.9	692.8	-0.1
Hurricane Michael	October 10, 2018	02095181	747.7	747.8	+0.1
Hurricane Michael	October 10, 2018	02095271	734.5	734.8	+0.3
Hurricane Michael	October 10, 2018	02095500	692.0	692.3	+0.3
Unnamed Rainfall Event	July 31, 2019	02095181	750.0	750.0	0.0
Unnamed Rainfall Event	July 31, 2019	02095271	736.0	736.0	0.0
Unnamed Rainfall Event	July 31, 2019	02095500	690.1	690.5	+0.4

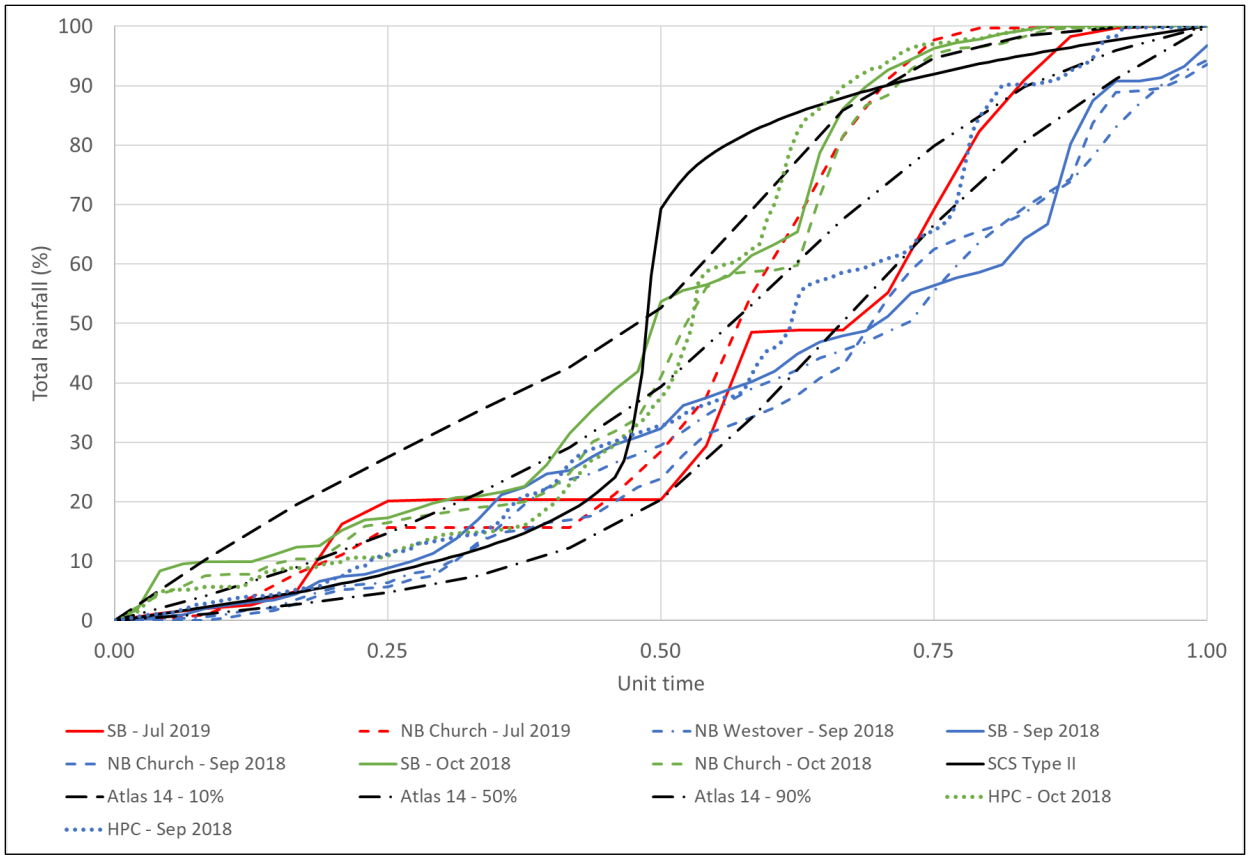


Figure 4-3 Total Rainfall (%) vs. Unit Time

4.6.5 Staff Gage 01/09/2024 Results Comparison

In general, NOAA-storm based project model results compared well to the event USGS gage readings. WSE results were collected at only eight staff gages, with field notes indicating gage failure at two of the eight. Results at four of the gage locations were less than one-foot different between the model and the readings, while two more were within two feet. Table 4.6-9 presents the results comparison at the various gage locations along the Primary System models.

Table 4.6-9 Staff Gage 1/9/2024 Event Comparison with 10-Year Model Results

Gage	Event WSE	Model WSE Upstream of Crossing	Model WSE Downstream of Crossing
USGS Gage 02095181	748.3	746.6	746.0
USGS Gage 02095271	734.3	733.4	733.1
USGS Gage 02095500	692.2	692.9	691.4
Staff Gage JB_1	710.5*	713.4	710.4
Staff Gage MC_1	728.9	729.4	728.8
Staff Gage UN2_1	720.2	719.9	719.5
Staff Gage PA_1B	729.8	731.5	731.1

Gage	Event WSE	Model WSE Upstream of Crossing	Model WSE Downstream of Crossing
Staff Gage PA_1A	777.4	774.5	774
Staff Gage UN4_1	741.6*	745.2	745.2
Staff Gage NBTA_2	N/A	766.2	766.0
Staff Gage UN5_1B	776.8	779.6	779.5
Staff Gage UN5_1A	799.0	796.9	796.9
** Measurement based on debris line*			

It is important to note that there are limitations to this comparison methodology as follows.

- It is not uncommon for there to be areal variations in rainfall depth across a watershed of this size, which would not be reflected in the model results but would be in the varying staff gage locations. This creates potential inconsistency in results comparisons from one gage to the next.
- Differences in duration / intensity of storms is a significant factor in watershed response that is not accounted for: the NOAA distribution is a 6-hour event, while the collected events vary in duration and intensity.
- The method of determining storm frequency is based on flow data, whereas the rainfall depths used for modeling a specific storm frequency event (to which the gage data will be compared) are based on statistical analysis of rainfall data.

4.7 Primary System Existing Results

4.7.1 Hydraulic Results

4.7.1.1 Existing LU Peak Discharges

As shown in Section 4.4, thirteen (13) streams were evaluated in the Primary System model. A summary of the maximum peak flow rates from the existing LU analysis for each of the reaches is provided in Table 4.7-1. As described earlier, the hydraulic routing for the hydrologic flows was evaluated directly in HEC-RAS. As such, it is noted that maximum peak flows within a stream are impacted by hydraulic constraints and downstream surcharging, which in some cases may reduce peak flows, particularly in a tributary near the confluence with the NBC main stem. Effectively, the maximum flows of the streams may not occur at the points of confluence of the tributaries; tabular model data shows that these max flow values often occur several crossings upstream of confluence points, outside the hydraulic influence of the adjoining stream. Additionally, attenuation along the stream can cause flows to fluctuate up and down. In an unsteady model, flows do not always continually increase moving downstream as they would in a steady model.

Table 4.7-1 NOAA 3rd Quartile Max Peak Flows per Evaluated Stream (Existing LU)

Stream Name	Stream ID	25-year, cfs	50-year, cfs	100-year, cfs	Sept 16, 2018 Hurricane Florence, cfs	Oct 11, 2018 Hurricane Michael, cfs	July 30, 2019, cfs	FEMA Existing 100-Year, cfs
Jordan Branch	JB	1,266	1,457	1,655	776	893	523	1,783
Lake Hamilton	LH	718	864	1,025	979	628	998	2,367
Muddy Creek	MC	2,592	2,848	3,204	1,656	1,977	1,440	4,013
NBC (I-840 to N O'Henry)	NBC1	8,224	9,433	10,522	7,588	7,323	5,945	11,460
NBC (N O'Henry to W Wendover)	NBC2							
NBC (W Wendover to South Holden)	NBC3							
Philadelphia Lake	PL	1,319	1,609	1,956	1,529	1,145	984	3,500
Tributary A	NBC-TA	1,533	1,959	2,122	1,667	1,662	2,328	2,935
Unnamed Tributary (College Branch)	NBC-UT	639	721	794	401	642	796	2,077
Unnamed Tributary 1	JB-UT1	283	335	383	132	180	112	758
Unnamed Tributary 2	MC-UT2	670	776	839	473	505	574	1,328
Unnamed Tributary 3	NBC-UT3	521	603	683	369	461	879	1,865
Unnamed Tributary 4	NBC-UT4	789	886	979	516	828	923	1,883
Unnamed Tributary 5	TA-UT5	473	670	701	595	535	652	1,578
Unnamed Tributary 6	LH-UT6	323	383	443	449	227	342	1,214

Using the results from the NOAA 6-hour storms, Table 4.7-2 summarizes the peak flows at primary crossings. The table presents the magnitude of flows through hydraulic structures along the main stem of NBC and its tributaries. Fluctuations in flow values are due to changes in attenuation and hydraulic restrictions moving down the system.

Table 4.7-2 NOAA Peak Flows through Primary Structures

Crossing	Crossing Station	25-Year Peak Flow, cfs	50-Year Peak Flow, cfs	100-Year Peak Flow, cfs
Jordan Branch (JB)				
Summit Avenue	14577	423	490	552
Irwin Street	13942	463	536	603
Murchie St and Sharon Ave	13245	517	604	683
Martin Avenue	12855	515	603	683
US 29	9884	1004	1161	1317
Private Crossing	8874	1114	1286	1454

Crossing	Crossing Station	25-Year Peak Flow, cfs	50-Year Peak Flow, cfs	100-Year Peak Flow, cfs
McKnight Mill Road	5076	1190	1371	1555
Lake Hamilton (LH)				
Kemp Road East	7106	178	228	284
Golf Course Bridge	6430	262	330	405
Golf Course Bridge	6091	262	330	404
Sam Snead Drive	4698	260	327	403
Golf Course Bridge	4183	555	674	822
North Holden Road	4100	555	674	822
West Market Street	1593	697	834	990
Arboretum Greenway	690	694	830	985
Arboretum Greenway	84	695	825	995
Muddy Creek (MC)				
Footbridge	18473	364	407	450
Yanceyville Street	18267	364	407	450
Footbridge	17895	432	484	536
Baseball Stadium	17824	432	484	536
Footbridge	17386	432	484	536
Boyd Street	17160	432	484	536
Sullivan Street	16293	876	983	1092
East Lindsay Street	15050	969	1087	1206
US 29	14190	1075	1206	1336
East Bessemer Avenue	13180	1269	1421	1572
East Wendover Avenue	12243	1403	1571	1737
Pipe Crossing	10878	1552	1734	1914
Gatewood Avenue	10844	1552	1734	1914
Textile Drive	9662	1674	1872	2070
Phillips Avenue	7701	1733	1924	2176
Footbridge	6961	1837	2041	2312
White Street	1326	2410	2661	2983
North Buffalo Creek				
NBC3 (West Wendover to South Holden)				
South Holden Road	85720	382	438	492

Crossing	Crossing Station	25-Year Peak Flow, cfs	50-Year Peak Flow, cfs	100-Year Peak Flow, cfs
Ramp to West Wendover Avenue	85342	456	521	581
West Wendover Avenue	84329	500	557	603
West Wendover Avenue	83207	568	634	690
Arboretum Greenway	82813	568	634	690
Arboretum Greenway	82612	574	634	690
Arboretum Greenway	81459	775	872	961
Ramp to West Wendover Avenue	79800	1458	1703	1931
West Market Street	79391	1459	1703	1931
West Wendover Avenue	77643	1542	1805	2040
Ramp to West Wendover Avenue	76984	1541	1805	2042
West Friendly Avenue	76502	1732	2035	2302
North Elam Avenue	73430	3309	3995	4462
Footbridge	72338	3302	4007	4483
North Josephine Boyd Street	70280	3553	4279	4893
Lake Daniel Greenway	68918	3470	4148	4724
Garland Drive	68297	3728	4402	4999
West Smith Street	66600	3978	4682	5309
Atlantic Yadkin Greenway	66460	3978	4682	5309
Battleground Avenue	66390	3976	4683	5307
Hill Street	65129	4100	4833	5436
NBC2 (North O'Henry to West Wendover)				
West Wendover Avenue	63123	4018	4747	5469
Cridland Road	61494	4161	4877	5601
North Elm Street	59880	4090	4794	5452
North Church Street	56163	4174	4861	5490
Railroad	55660	4166	4858	5481
Abandoned Railroad	55308	4162	4857	5478
Footbridge	55099	4159	4856	5474
Footbridge	54688	4157	4867	5479
Footbridge	54194	4151	4866	5474
Revolution Mill Building	54076	4150	4866	5474
Revolution Mill Building	53804	4149	4866	5475

Crossing	Crossing Station	25-Year Peak Flow, cfs	50-Year Peak Flow, cfs	100-Year Peak Flow, cfs
Yanceyville Street	53550	4147	4863	5469
Fairview Street	52751	4194	4905	5530
Abandoned Railroad	52191	4192	4901	5528
Summit Avenue	49184	5319	6222	7210
NBC1 (I-840 to O'Henry)				
US 29	48409	5326	6217	7197
Footbridge	43874	5433	6303	7288
Ralph C Johnson Lane	37979	7097	8071	8981
Rankin Mill Road	24647	7952	9145	10286
Philadelphia Lake (PL)				
West Cone Boulevard	18829	157	195	234
Dellwood Drive	18483	157	194	234
Elkhart Drive	17216	305	376	450
Lafayette Avenue	16190	358	442	529
West Cone Boulevard	14738	376	462	555
St. Jude Street	7090	684	895	1119
North Church Street	6514	695	911	1182
Private Crossing	5712	713	930	1178
Railroad	5411	808	1061	1322
East Cone Boulevard	5118	1095	1355	1784
Yanceyville Street	4656	1093	1355	1771
Sixteenth Street	1512	1300	1592	1930
Tributary A (NBC-TA)				
Joseph M Bryan Boulevard	7493	673	795	920
Joseph M Bryan Boulevard	6270	783	921	1063
West Cornwallis Drive	5483	847	991	1141
Footbridge	4645	892	1024	1195
Pembroke Road	4403	891	1024	1194
Green Valley Road	2555	1281	1647	1785
West Wendover Avenue	1481	1535	1934	2111
Benjamin Parkway	790	1534	1932	2112
Lake Daniel Greenway	95	1539	1949	2111

Crossing	Crossing Station	25-Year Peak Flow, cfs	50-Year Peak Flow, cfs	100-Year Peak Flow, cfs
Unnamed Tributary (NBC-UT) (College Branch)				
Abandoned Railroad	4566	192	222	237
West Market Street	3687	300	339	370
West Friendly Avenue	3226	300	335	369
Abandoned Railroad	3039	300	335	369
Guilford Drive	2705	372	420	463
Abandoned Railroad	2115	372	420	463
West Smith Street	1157	473	535	589
Hill Street	713	640	720	792
Unnamed Tributary 1 (JB-UT1)				
Voss Avenue	2876	126	149	174
Cody Avenue	916	281	327	375
Martin Avenue	552	278	322	374
Unnamed Tributary 2 (MC-UT2)				
Textile Drive	4584	542	611	681
Phillips Avenue	2935	573	645	716
Larkspur Drive	874	669	755	839
Unnamed Tributary 3 (NBC-UT3)				
Cleburne Street	2659	307	353	399
Briarcliff Road	1509	342	394	445
Footbridge	1205	518	600	682
Latham Road	524	471	559	646
Unnamed Tributary 4 (NBC-UT4)				
South Josephine Boyd Street	3712	354	400	446
Footbridge	3471	354	404	446
Footbridge	3186	509	572	639
Footbridge	2783	508	584	637
West Market Street	2457	507	574	635
West Friendly Avenue	1580	693	778	860
Fairmont Street	767	744	828	891
Lake Daniel Greenway	128	590	643	691

Crossing	Crossing Station	25-Year Peak Flow, cfs	50-Year Peak Flow, cfs	100-Year Peak Flow, cfs
Unnamed Tributary 5 (TA-UT5)				
Forest Hill Drive	9146	161	199	239
Footbridge	8367	296	365	437
North Holden Road	6358	295	363	435
Bicentennial Garden	5966	373	458	548
Hobbs Road	5259	373	457	545
Bog Garden	4885	468	568	671
Bog Garden	4400	453	547	645
Pembroke Road	2551	429	568	632
Benjamin Parkway	482	469	666	693
Unnamed Tributary 6 (LH-UT6)				
Waycross Drive	2981	220	260	302
Golf Course Bridge	2714	230	273	317
Golf Course Bridge	2492	230	273	316
Footbridge	1692	324	385	450
Golf Course Bridge	1457	324	406	449
Golf Course Bridge	1033	323	386	448
Golf Course Bridge	799	323	384	449
Golf Course Bridge	497	323	384	449
Golf Course Bridge	293	323	383	443

4.7.1.2 LOS Evaluation

As discussed in Section 4.6, it was determined that the NOAA storms would be utilized to determine LOS within the Primary System. After reevaluating the system using the NOAA storm, results were better aligned with the City's knowledge of flood frequency at various locations across the City. The LOS criteria are presented in Section 2.3; each crossing within the Primary System was evaluated on this basis.

It was also determined that crossings which currently do not cross the floodway in the effective FEMA maps but do in the draft-preliminary FEMA maps would be evaluated based on the floodway requirement (100-year design storm) presented in Section 2.3. Within NBC, this meant that every crossing must meet the 100-year design storm criteria, as all Primary System streams include floodway in the draft-preliminary maps.

Table 4.7-3 presents the results of the LOS evaluation for the Primary System crossings analyzed as part of the project. Note that due to project criteria regarding ownership of the facilities discussed earlier in this document, not all crossings that violate LOS will have a project proposed.

Table 4.7-3 Primary System Crossing LOS Results (Existing LU, NOAA Storm)

Crossing	Stream	Owned By	LOS Requirement, year	Existing Infrastructure	Meets LOS?
Jordan Branch (JB)					
Summit Avenue	Jordan Branch	State	100 YR	(1) 8'x6' Box Culvert	No
Irwin Street	Jordan Branch	City	100 YR	(2) 11'x6' Box Culverts	Yes
Murchie St and Sharon Ave	Jordan Branch	City	100 YR	(2) 11'x6' Box Culverts	No
Martin Avenue	Jordan Branch	City	100 YR	(2) 6' Circular Culverts	No
US 29	Jordan Branch	State	100 YR	(2) 9'x8' Box Culverts	No
Private Crossing	Jordan Branch	Private	n/a	51' Span Bridge	n/a
McKnight Mill Road	Jordan Branch	State	100 YR	(2) 8'x5' Box Culverts	No
Lake Hamilton (LH)					
Kemp Road East	Lake Hamilton	City	100 YR	(2) 10'x5' Box Culverts	Yes
Golf Course Bridge	Lake Hamilton	Private	n/a	25' Span Bridge	n/a
Golf Course Bridge	Lake Hamilton	Private	n/a	23' Span Bridge	n/a
Sam Snead Drive	Lake Hamilton	Private	n/a	(1) 12'x5.2' Box Culvert	n/a
Golf Course Bridge	Lake Hamilton	Private	n/a	(2) 10'x5' Box Culverts	n/a
North Holden Road	Lake Hamilton	City	100 YR	(2) 11.7'x6' Box Culverts	Yes
West Market Street	Lake Hamilton	State	100 YR	(2) 10'x6' Box Culverts	No
Arboretum Greenway	Lake Hamilton	City	n/a	39' Span Bridge	n/a
Arboretum Greenway	Lake Hamilton	City	n/a	(2) 3.5' Circular Culverts	n/a
Muddy Creek (MC)					
Footbridge	Muddy Creek	Unknown	n/a	35' Span Bridge	n/a
Yanceyville Street	Muddy Creek	City	100 YR	(2) 11'x5' Box Culverts	Yes
Footbridge	Muddy Creek	Unknown	n/a	30' Span Bridge	n/a
Baseball Stadium	Muddy Creek	Unknown	n/a	(1) 12'x5' Box Culvert	n/a
Footbridge	Muddy Creek	Unknown	n/a	38' Span Bridge	n/a
Boyd Street	Muddy Creek	City	100 YR	(2) 13'x5.5' Elliptical Culverts	Yes
Sullivan Street	Muddy Creek	City	100 YR	(3) 10'x6.5' Box Culverts	Yes
East Lindsay Street	Muddy Creek	City	100 YR	(3) 14'x7.5' Box Culverts	Yes
US 29	Muddy Creek	State	100 YR	(2) 10'x10' Box Culverts	No
East Bessemer Avenue	Muddy Creek	City	100 YR	(3) 11'x8' Box Culverts	No
East Wendover Avenue	Muddy Creek	State	100 YR	(3) 11'x8' Box Culverts	Yes
Gatewood Avenue	Muddy Creek	City	100 YR	(3) 11'x8' Box Culverts	Yes
Textile Drive	Muddy Creek	City	100 YR	(4) Box Culverts: 11'x10'; 9'x10'; 8.8'x10'; 9'x9	Yes
Phillips Avenue	Muddy Creek	City	100 YR	44' Span Bridge	No
Footbridge	Muddy Creek	Unknown	n/a	52' Span Bridge	n/a
White Street	Muddy Creek	City	100 YR	(3) 12'x10.5' Box Culverts	No

Crossing	Stream	Owned By	LOS Requirement, year	Existing Infrastructure	Meets LOS?
North Buffalo Creek (NBC)					
NBC3 (West Wendover to South Holden)					
South Holden Road	North Buffalo Creek	State	100 YR	(1) 10'x6.4' Box Culvert	No
Ramp to West Wendover Avenue	North Buffalo Creek	State	100 YR	(1) 9'x5' Box Culvert	No
West Wendover Avenue	North Buffalo Creek	State	100 YR	(1) 6.36'x6' Box Culvert	No
West Wendover Avenue	North Buffalo Creek	State	100 YR	(1) 10'x7' Box Culvert	No
Arboretum Greenway	North Buffalo Creek	City	n/a	35' Span Bridge	n/a
Arboretum Greenway	North Buffalo Creek	City	n/a	30' Span Bridge	n/a
Arboretum Greenway	North Buffalo Creek	City	n/a	28' Span Bridge	n/a
Ramp to West Wendover Avenue	North Buffalo Creek	State	100 YR	(2) Box Culverts: 12'x10'; 17'x10'	Yes
West Market Street	North Buffalo Creek	State	100 YR	35' Span Bridge	No
West Wendover Avenue	North Buffalo Creek	State	100 YR	(2) 12'x10' Box Culverts	Yes
Ramp to West Wendover Avenue	North Buffalo Creek	State	100 YR	(2) 12'x9' Box Culverts	No
West Friendly Avenue	North Buffalo Creek	City	100 YR	(1) 37.7'x16.75' Arch Culvert	Yes
North Elam Avenue	North Buffalo Creek	City	100 YR	57' Span Bridge	No
Footbridge	North Buffalo Creek	Unknown	n/a	107' Span Bridge	n/a
North Josephine Boyd Street	North Buffalo Creek	City	100 YR	85' Span Bridge	No
Lake Daniel Greenway	North Buffalo Creek	City	n/a	76' Span Bridge	n/a
Garland Drive	North Buffalo Creek	City	100 YR	Arch Bridge: (4) 14' Openings; (1) 50' Opening	No
West Smith Street	North Buffalo Creek	City	100 YR	75' Span Bridge	No
Atlantic Yadkin Greenway	North Buffalo Creek	City	n/a	55' Span Bridge	n/a
Battleground Avenue	North Buffalo Creek	City	100 YR	49' Span Bridge	No
Hill Street	North Buffalo Creek	City	100 YR	87' Span Bridge	No
NBC2 (N O'Henry to West Wendover)					
West Wendover Avenue	North Buffalo Creek	State	100 YR	126' Span Bridge	No

Crossing	Stream	Owned By	LOS Requirement, year	Existing Infrastructure	Meets LOS?
Cridland Road	North Buffalo Creek	City	100 YR	69' Span Bridge	No
North Elm Street	North Buffalo Creek	City	100 YR	77' Span Bridge	No
North Church Street	North Buffalo Creek	State	100 YR	110' Span Bridge	No
Railroad	North Buffalo Creek	Private	n/a	Arch Bridge: (3) 24' Openings	n/a
Abandoned Railroad	North Buffalo Creek	Private	n/a	163' Span Bridge	n/a
Footbridge	North Buffalo Creek	Private	n/a	75' Span Bridge	n/a
Footbridge	North Buffalo Creek	Private	n/a	240' Span Bridge	n/a
Footbridge	North Buffalo Creek	Private	n/a	83' Span Bridge	n/a
Revolution Mill Building	North Buffalo Creek	Private	n/a	Arch Structure (1) 150' Span Opening	n/a
Revolution Mill Building	North Buffalo Creek	Private	n/a	Arch Structure (3) 11' Opening; (1) 43' Opening	n/a
Yanceyville Street	North Buffalo Creek	City	100 YR	90' Span Bridge	No
Fairview Street	North Buffalo Creek	City	100 YR	79' Span Bridge	No
Abandoned Railroad	North Buffalo Creek	Private	n/a	164' Span Bridge	n/a
Summit Avenue	North Buffalo Creek	State	100 YR	76' Span Bridge	No
NBC1 (I-840 to O'Henry)					
US 29	North Buffalo Creek	State	100 YR	(2) 30'x21' Culverts	Yes
Footbridge	North Buffalo Creek	Unknown	n/a	104' Span Bridge	n/a
Ralph C Johnson Lane	North Buffalo Creek	City	100 YR	267' Span Bridge	No
Rankin Mill Road	North Buffalo Creek	State	100 YR	137' Span Bridge	No
Philadelphia Lake (PL)					
West Cone Boulevard	Philadelphia Lake	City	100 YR	(1) 12'x6' Box Culvert	Yes
Dellwood Drive	Philadelphia Lake	City	100 YR	(2) 6' and 1 (5') Circular Culverts	Yes
Elkhart Drive	Philadelphia Lake	City	100 YR	(2) 10.5'x5.5' Box Culverts	Yes
Lafayette Avenue	Philadelphia Lake	City	100 YR	(2) 10.5'x5.5' Box Culverts	Yes
West Cone Boulevard	Philadelphia Lake	City	100 YR	(3) 10'x7' Box Culverts	Yes
St. Jude Street	Philadelphia Lake	City	100 YR	(3) 13'x7' Box Culverts	Yes
North Church Street	Philadelphia Lake	State	100 YR	(3) 10'x7' Box Culverts	No

Crossing	Stream	Owned By	LOS Requirement, year	Existing Infrastructure	Meets LOS?
Private Crossing	Philadelphia Lake	Private	n/a	(2) 21.5'x7.5' Arch Culverts	n/a
Railroad	Philadelphia Lake	Private	n/a	(1) 12' Circular Culvert	n/a
East Cone Boulevard	Philadelphia Lake	City	100 YR	(3) 13'x7' Box Culverts	No
Yanceyville Street	Philadelphia Lake	City	100 YR	(3) 12'x8' Box Culverts	Yes
Sixteenth Street	Philadelphia Lake	City	100 YR	60' Span Bridge	Yes
Tributary A (NBC-TA)					
Joseph M Bryan Boulevard	Tributary A	State	100 YR	(2) 8'x9' Box Culverts	Yes
Joseph M Bryan Boulevard	Tributary A	State	100 YR	(2) 8'x9' Box Culverts	Yes
West Cornwallis Drive	Tributary A	City	100 YR	(2) 10'x7' Box Culverts	Yes
Footbridge	Tributary A	Unknown	n/a	37' Span Bridge	n/a
Pembroke Road	Tributary A	City	100 YR	(2) 8'x9' Box Culverts	Yes
Green Valley Road	Tributary A	City	100 YR	(3) 12'x8' Box Culverts	Yes
West Wendover Avenue	Tributary A	State	100 YR	(3) 10'x8' Box Culverts	Yes
Benjamin Parkway	Tributary A	City	100 YR	(3) 9'x11.1' Box Culverts	Yes
Lake Daniel Greenway	Tributary A	City	n/a	44' Span Bridge	n/a
Unnamed Tributary (NBC-UT) (College Branch)					
Abandoned Railroad	Unnamed Tributary	Private	n/a	9' Span Bridge	n/a
West Market Street	Unnamed Tributary	State	100 YR	(1) 10'x5' Box Culvert	Yes
West Friendly Avenue	Unnamed Tributary	City	100 YR	167' Span Bridge	Yes
Abandoned Railroad	Unnamed Tributary	Private	n/a	9' Span Bridge	n/a
Guilford Drive	Unnamed Tributary	City	100 YR	(1) 10'x4' Box Culvert	No
Abandoned Railroad	Unnamed Tributary	Private	n/a	18' Span Bridge	n/a
West Smith Street	Unnamed Tributary	City	100 YR	(2) 8.5'x5.5' Box Culverts	No
Hill Street	Unnamed Tributary	City	100 YR	(2) 10'x5.5' Box Culverts	No
Unnamed Tributary 1 (JB-UT1)					
Voss Avenue	Unnamed Tributary 1	City	100 YR	(1) 4' Circular Culvert	No
Cody Avenue	Unnamed Tributary 1	City	100 YR	(1) 11.4'x5.8' Box Culvert	No
Martin Avenue	Unnamed Tributary 1	City	100 YR	(1) 7' Circular Culvert	No
Unnamed Tributary 2 (MC-UT2)					

Crossing	Stream	Owned By	LOS Requirement, year	Existing Infrastructure	Meets LOS?
Textile Drive	Unnamed Tributary 2	City	100 YR	(1) 12'x6' Box Culvert	No
Phillips Avenue	Unnamed Tributary 2	City	100 YR	(1) 15.5'x5.1' Box Culvert	No
Larkspur Drive	Unnamed Tributary 2	City	100 YR	(2) 12'x6' Box Culvert	Yes
Unnamed Tributary 3 (NBC-UT3)					
Cleburne Street	Unnamed Tributary 3	City	100 YR	(1) 8.5'x4' Box Culvert	No
Briarcliff Road	Unnamed Tributary 3	City	100 YR	(2) 8'x5' Box Culverts	No
Footbridge	Unnamed Tributary 3	Unknown	n/a	31' Span Bridge	n/a
Latham Road	Unnamed Tributary 3	City	100 YR	(2) 9'x5' Box Culverts	No
Unnamed Tributary 4 (NBC-UT4)					
South Josephine Boyd Street	Unnamed Tributary 4	City	100 YR	(1) 9'x6' Box Culvert	No
Footbridge	Unnamed Tributary 4	Unknown	n/a	28' Span Bridge	n/a
Footbridge	Unnamed Tributary 4	Unknown	n/a	31' Span Bridge	n/a
Footbridge	Unnamed Tributary 4	Unknown	n/a	30' Span Bridge	n/a
West Market Street	Unnamed Tributary 4	State	100 YR	(1) 12'x6' Box Culvert	No
West Friendly Avenue	Unnamed Tributary 4	City	100 YR	(2) 10'x6' Box Cuvlerts	No
Fairmont Street	Unnamed Tributary 4	City	100 YR	56' Span Bridge	No
Lake Daniel Greenway	Unnamed Tributary 4	City	n/a	43' Span Bridge	n/a
Unnamed Tributary 5 (TA-UT5)					
Forest Hill Drive	Unnamed Tributary 5	City	100 YR	(1) 8' Circular Culvert	Yes
Footbridge	Unnamed Tributary 5	Unknown	n/a	18' Span Bridge	n/a
North Holden Road	Unnamed Tributary 5	City	100 YR	(1) 12'x7' Box Culvert	Yes
Bicentennial Garden*	Unnamed Tributary 5	City	n/a	21' Span Bridge	n/a
Hobbs Road	Unnamed Tributary 5	City	100 YR	(2) 14.3'x5' Box Culvert	Yes
Bog Garden*	Unnamed Tributary 5	City	n/a	25' Span Bridge	n/a

Crossing	Stream	Owned By	LOS Requirement, year	Existing Infrastructure	Meets LOS?
Bog Garden*	Unnamed Tributary 5	City	n/a	27' Span Bridge	n/a
Pembroke Road	Unnamed Tributary 5	City	100 YR	(2) 11.6'x5.45' Box Culvert	No
Benjamin Parkway	Unnamed Tributary 5	City	100 YR	(2) 8.65'x9' Box Culvert	Yes
Unnamed Tributary 6 (LH-UT6)					
Waycross Drive	Unnamed Tributary 6	City	100 YR	(1) 9'x6' Box Culvert	Yes
Golf Course Bridge	Unnamed Tributary 6	Private	n/a	19' Span Bridge	n/a
Golf Course Bridge	Unnamed Tributary 6	Private	n/a	31' Span Bridge	n/a
Footbridge	Unnamed Tributary 6	Private	n/a	18' Span Bridge	n/a
Golf Course Bridge	Unnamed Tributary 6	Private	n/a	35' Span Bridge	n/a
Golf Course Bridge	Unnamed Tributary 6	Private	n/a	23' Span Bridge	n/a
Golf Course Bridge	Unnamed Tributary 6	Private	n/a	28' Span Bridge	n/a
Golf Course Bridge	Unnamed Tributary 6	Private	n/a	21' Span Bridge	n/a
Golf Course Bridge	Unnamed Tributary 6	Private	n/a	28' Span Bridge	n/a

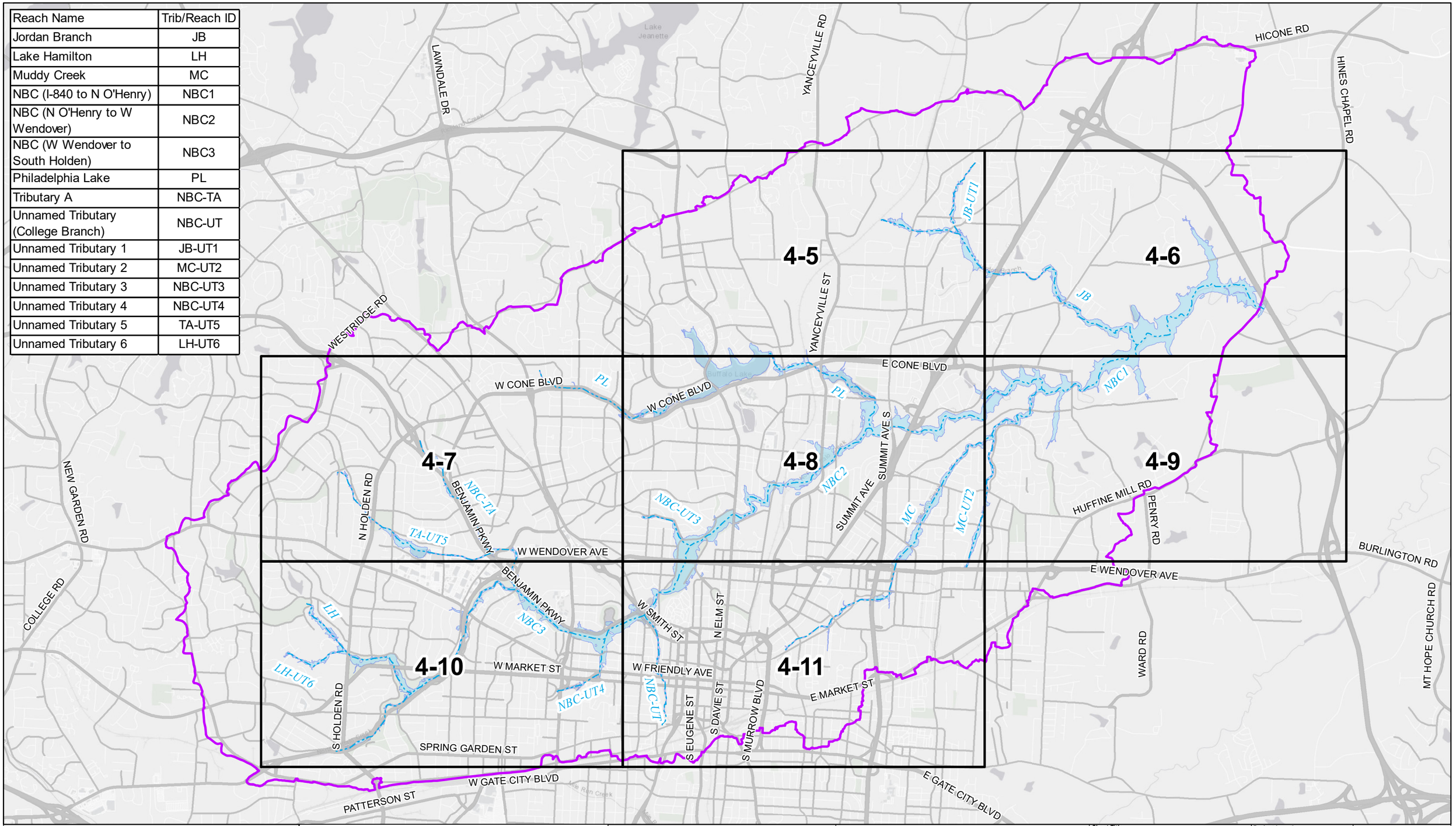
* Assessed as Greenway/Footbridge

4.7.1.3 25-Year and 100-Year Floodplain Plots

Floodplain plots were developed for the 25-year and 100-year events based on the NOAA 3rd Quartile, Atlas 14 Volume 2, 6-hour duration, 10% rainfall distribution existing conditions models. Floodplains were developed for each of the tributaries and along the main stem. Some minor adjustments and cleanup were required along the boundaries. No universal trend emerged when compared to FEMA maps, but as shown in Table 4.7-2, SWMP 100-year NOAA peak flows were generally lower than FEMA 100-year flows. (Note that FEMA flows were taken at the downstream end of each tributary and would receive the full tributary drainage area, whereas the SWMP model flows at the downstream end were impacted / reduced by tailwater from NBC).

The objective of the figures below is to provide a comparison between the SWMP 25- and 100-year NOAA floodplains with the 100-year FEMA floodplain. In addition, the figures demonstrate the impacted parcels in the NOAA floodplains. These parcels may differ from the parcels identified by FEMA for insurance purposes. FEMA impacted parcels and structures are still the legal basis on which the flood risk is determined.

Reach Name	Trib/Reach ID
Jordan Branch	JB
Lake Hamilton	LH
Muddy Creek	MC
NBC (I-840 to N O'Henry)	NBC1
NBC (N O'Henry to W Wendover)	NBC2
NBC (W Wendover to South Holden)	NBC3
Philadelphia Lake	PL
Tributary A	NBC-TA
Unnamed Tributary (College Branch)	NBC-UT
Unnamed Tributary 1	JB-UT1
Unnamed Tributary 2	MC-UT2
Unnamed Tributary 3	NBC-UT3
Unnamed Tributary 4	NBC-UT4
Unnamed Tributary 5	TA-UT5
Unnamed Tributary 6	LH-UT6



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Legend
- Primary System Inundation Index (Figure number)
- Primary Streams
- NOAA 1%-annual-chance inundation
- Watershed Boundary

0 2,000 4,000 8,000 Feet

(At original document size of 11x17)
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Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

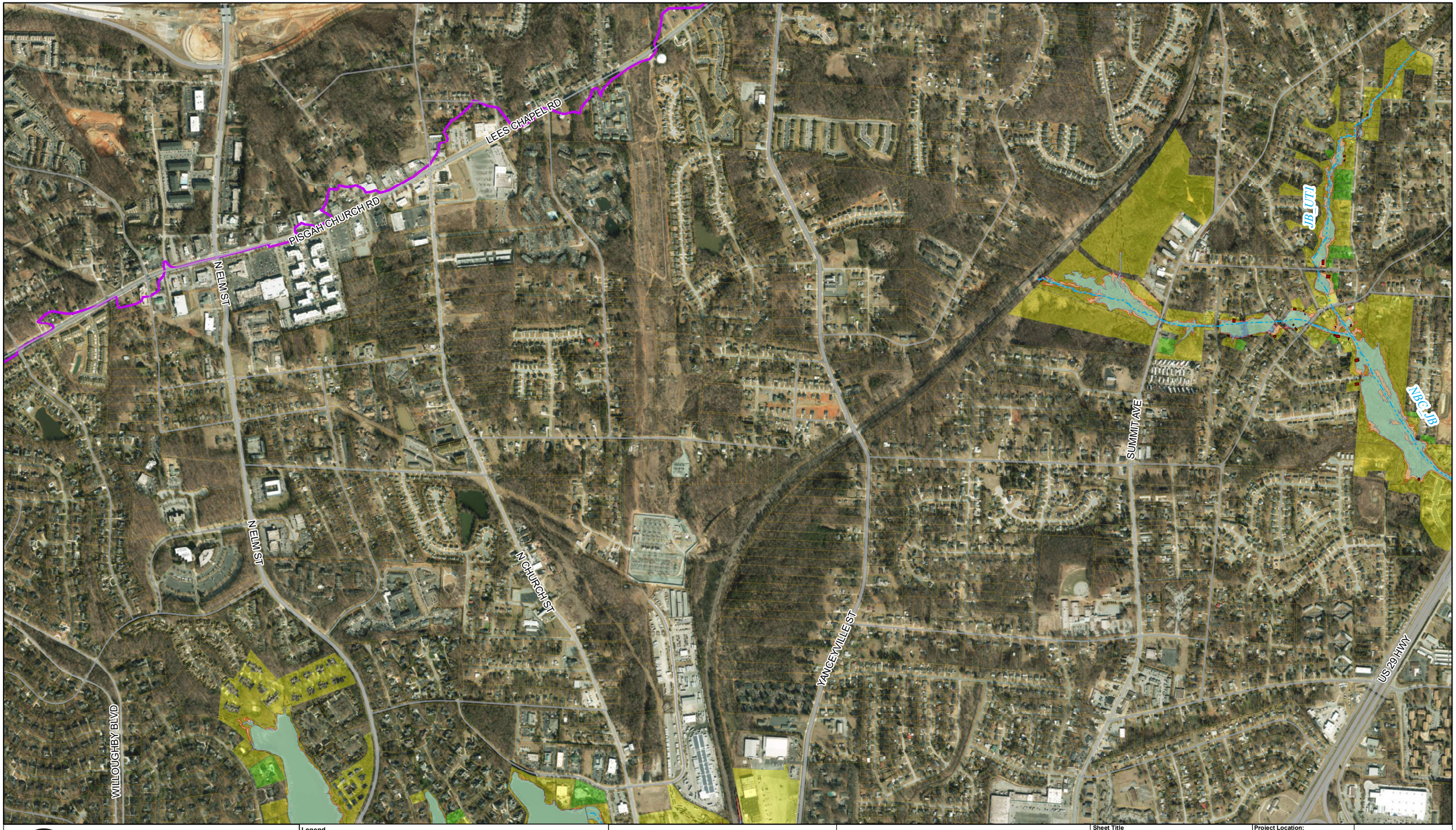
Sheet Title
Primary System Existing Landuse NOAA Floodplains Index

Project Location:
City of Greensboro, Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:
08/05/2024

Sheet No.
Figure 4-4



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Legend

- Primary Streams
- Structures At-Risk
- 4%-annual-chance inundation
- 1%-annual-chance inundation
- FEMA Effective 1%-annual-chance inundation
- Impacted Parcels - 4% & 1%-annual-chance
- Impacted Parcels - 1%-annual-chance
- Parcel data
- Watershed Boundary

0 500 1,000 2,000 Feet

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1:12,000

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Sheet Title
Primary System Existing Landuse NOAA Floodplains

Project Location:
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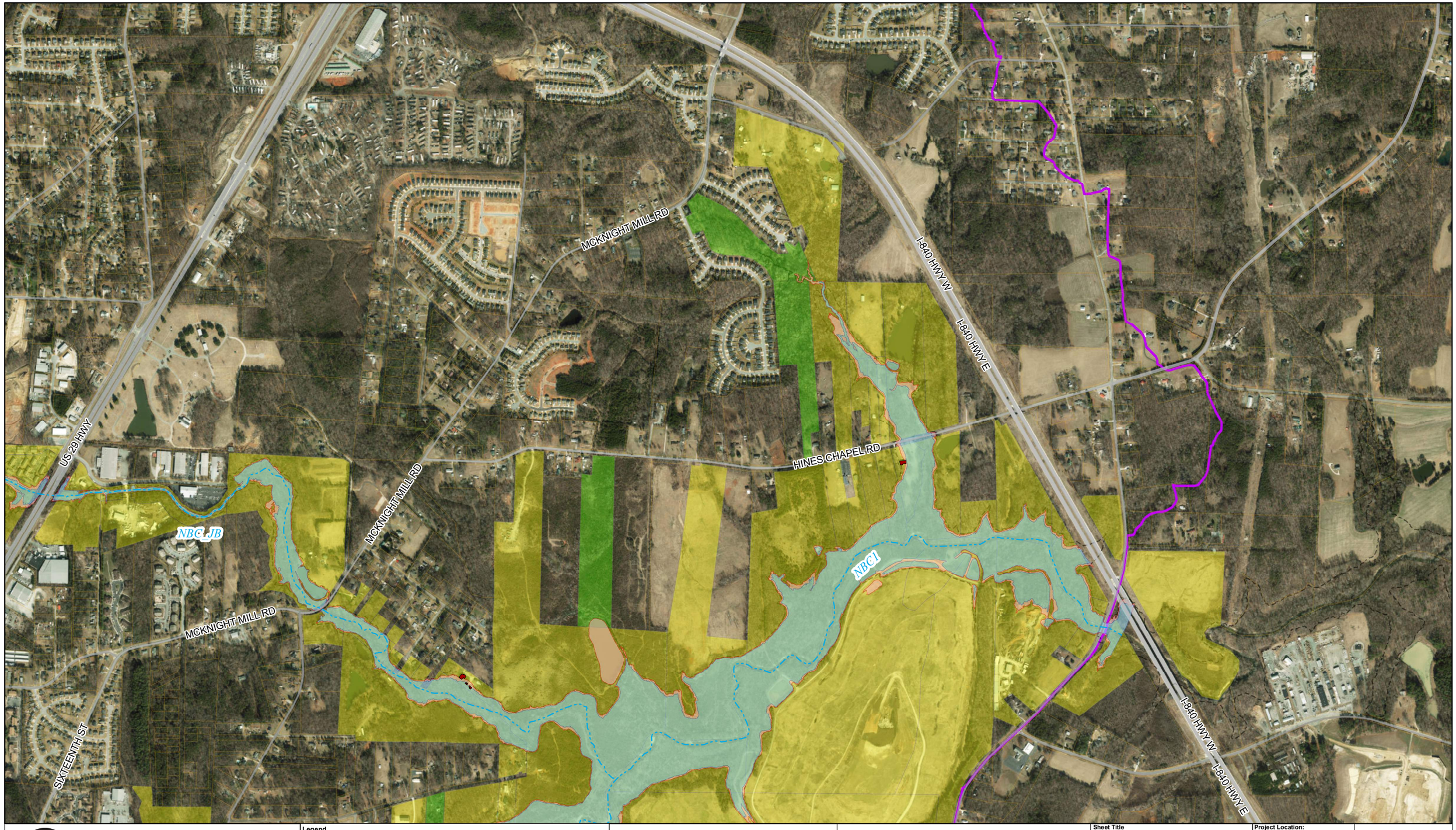
Date:
08/09/2024

Sheet No.
Figure 4-5



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- Impacted Parcels - 1%-annual-chance
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0 500 1,000 2,000 Feet

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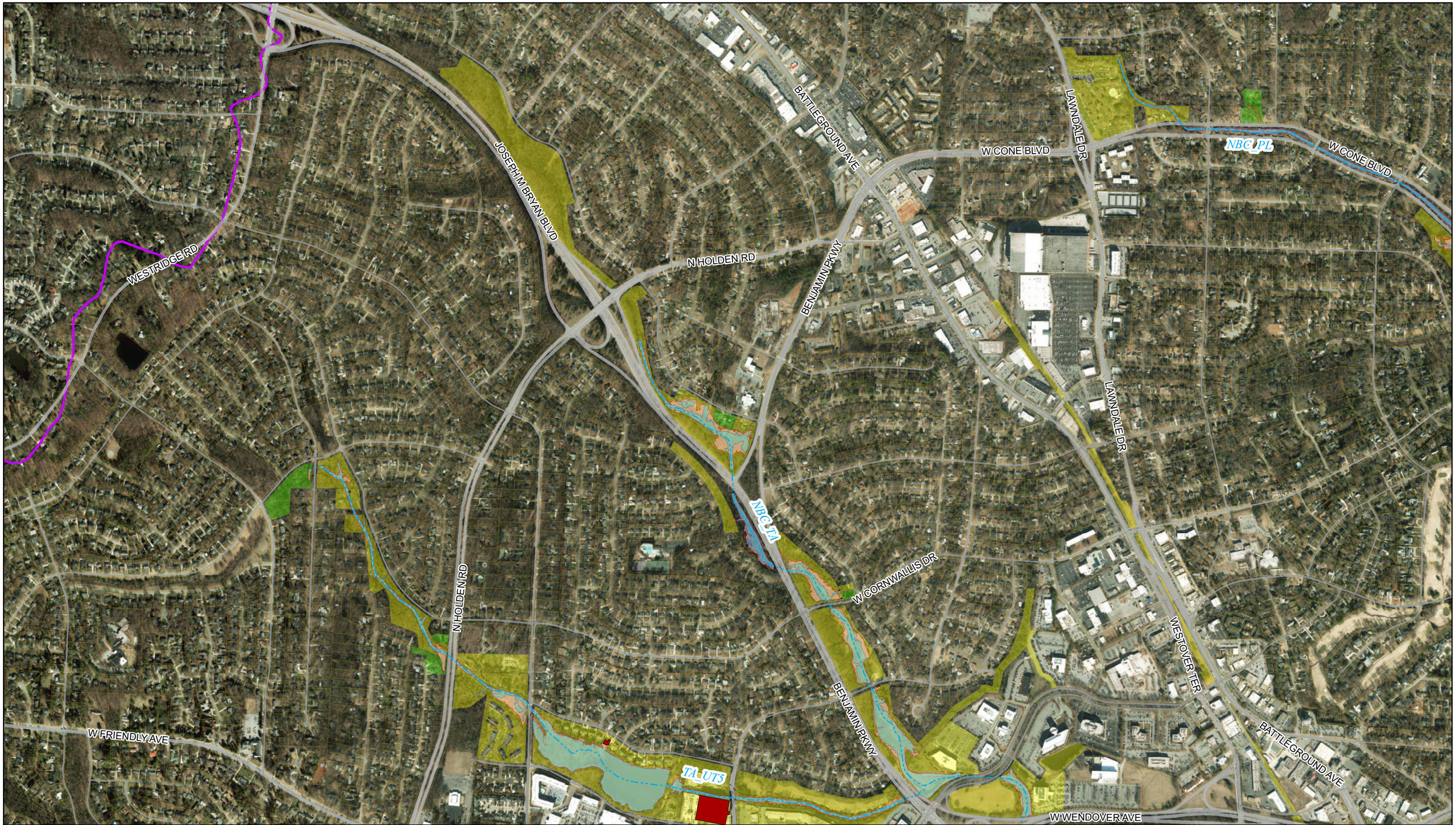
Figure 4-6



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- Impacted Parcels - 1%-annual-chance
- Parcel data
- Watershed Boundary

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Stormwater Master Plan - North Buffalo Creek

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Primary System Existing Landuse NOAA Floodplains

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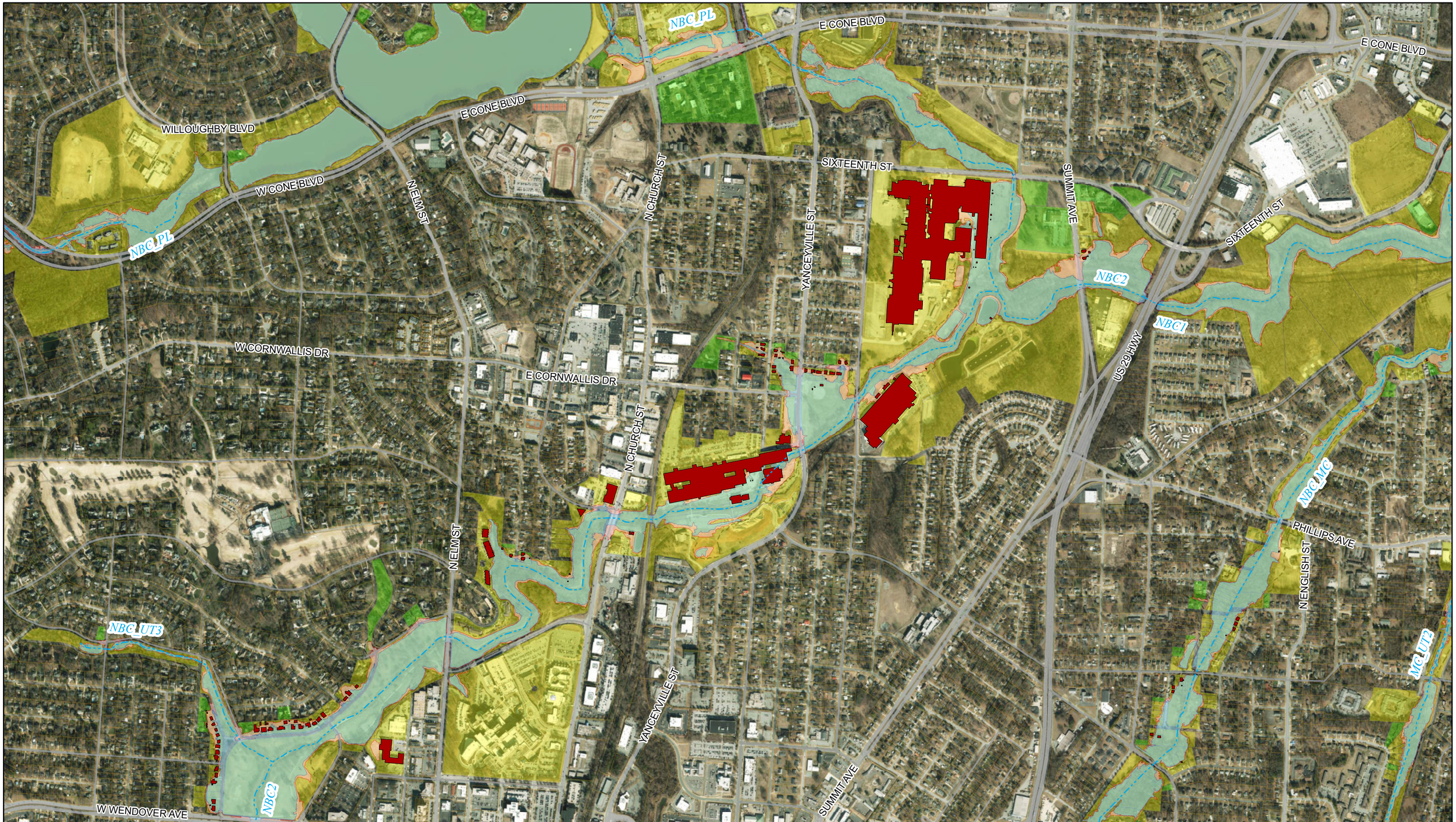
Figure 4-7



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- FEMA Effective 1%-annual-chance inundation
- Impacted Parcels - 4% & 1%-annual-chance
- Impacted Parcels - 1%-annual-chance
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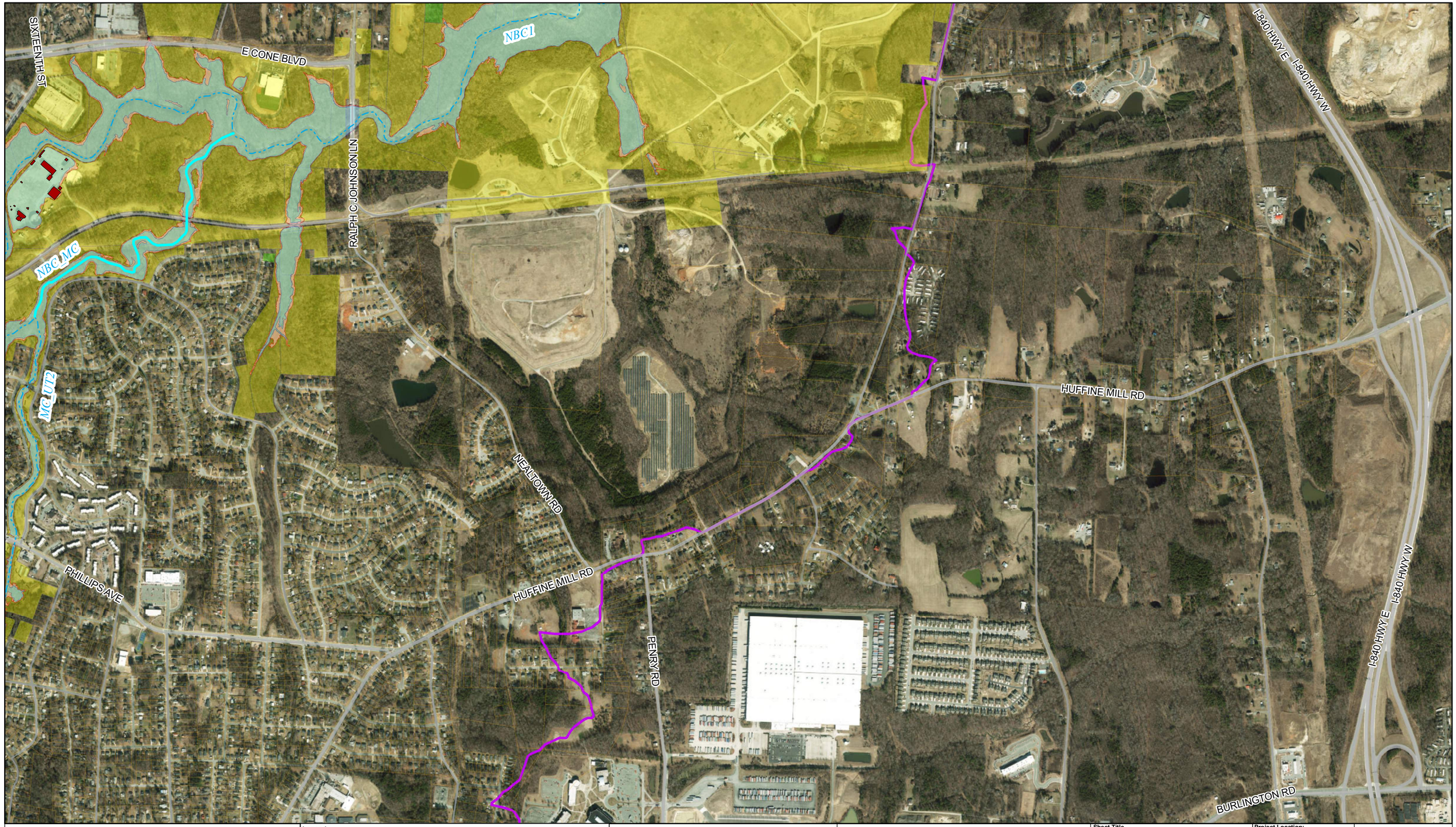

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- Impacted Parcels - 4% & 1%-annual-chance
- Impacted Parcels - 1%-annual-chance
- Parcel data
- Watershed Boundary

0 500 1,000 2,000 Feet

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Stormwater Master Plan - North Buffalo Creek

Sheet Title

Primary System Existing Landuse NOAA Floodplains

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Figure 4-9

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- Structures At-Risk
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- 1%-annual-chance inundation
- FEMA Effective 1%-annual-chance inundation
- Impacted Parcels - 4% & 1%-annual-chance
- Impacted Parcels - 1%-annual-chance
- Parcel data
- Watershed Boundary

0 500 1,000 2,000 Feet

(At original document size of 11x17)
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Primary System Existing Landuse NOAA Floodplains

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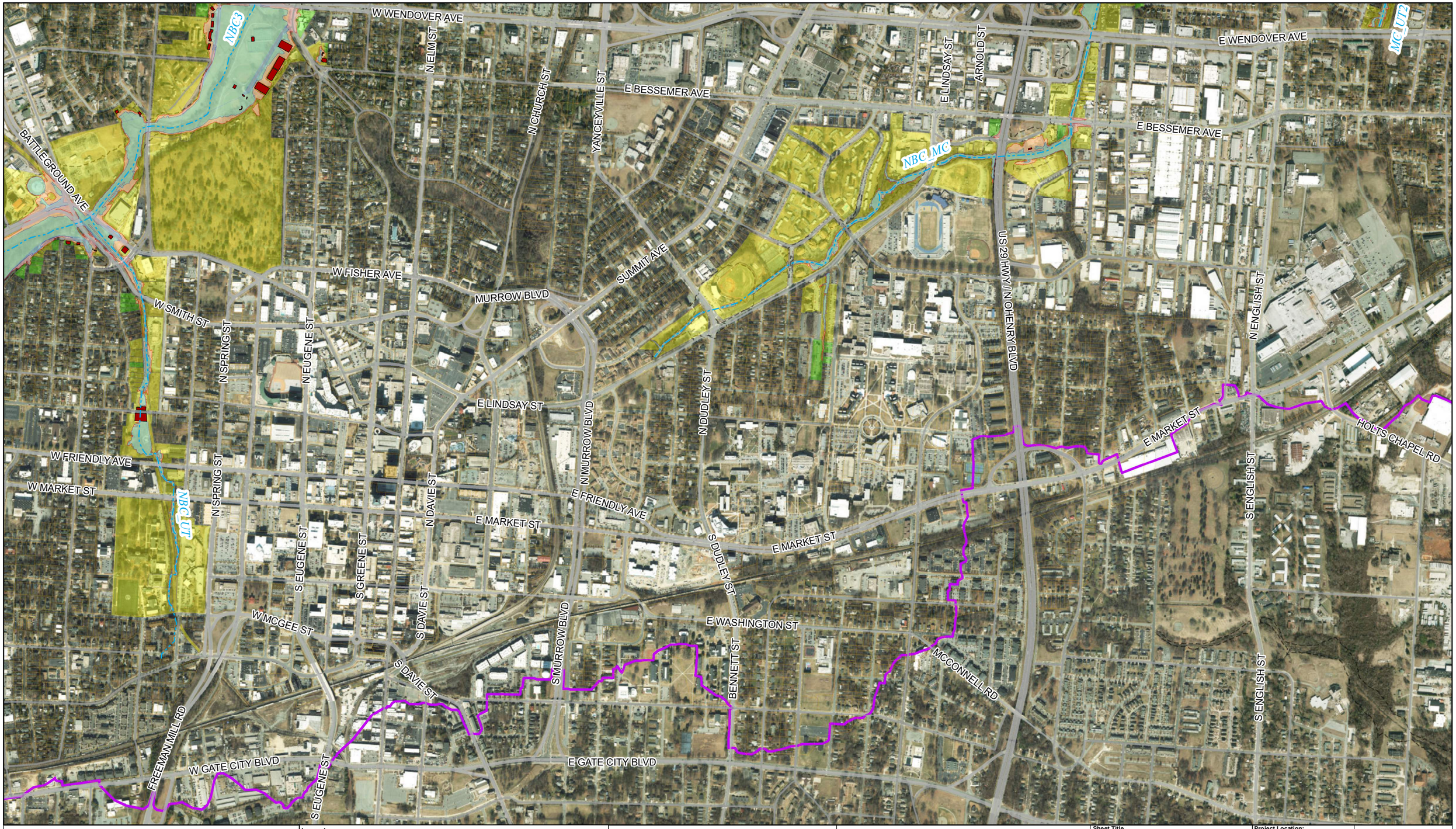

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- Primary Streams
- Structures At-Risk
- 4%-annual-chance inundation
- 1%-annual-chance inundation
- FEMA Effective 1%-annual-chance inundation
- Impacted Parcels - 4% & 1%-annual-chance
- Impacted Parcels - 1%-annual-chance
- Parcel data
- Watershed Boundary

0 500 1,000 2,000 Feet

(At original document size of 11x17)
1:12,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title

Primary System Existing Landuse NOAA Floodplains

Project Location:

City of Greensboro,
Guilford County, North Carolina

Prepared by MIA on 2024-08-03
Reviewed by SM on 2024-08-20

Date:

08/09/2024

Sheet No.

Figure 4-11

4.7.1.4 At-Risk Structures

At-Risk Structures are defined as a structure whose footprint falls partially or totally within a floodplain plotted based on the SWMP NOAA HEC-RAS model (see above figures). This determination is made by plotting floodplains based on model results and comparing the floodplain polygons with building polygons to identify intersections between these two layers. Table 4.7-4 summarizes the at-risk structures in the NBC watershed based on the existing LU NOAA 100-year storm event model results. Table 4.7-5 summarizes the at-risk structures in the NBC watershed based on the future LU NOAA 100-year storm event model results. The lists may not be complete at recognizing all structures in the watershed, as they are only those adjacent to modeled Primary System streams.

Table 4.7-4 25- and 100-Year At-Risk Structures (NOAA Existing Storm)

Address	25-year at-risk structure	100-year at-risk structure
Jordan Branch (JB)		
3601 Country Ridge Road		X
3703 Martin Avenue	X	X
3709 Martin Avenue	X	X
3714 Martin Avenue		X
3499 Murchie Street		X
3500 Murchie Street	X	X
2906 Nabors Road	X	X
3707 Redor Street	X	X
3702 Sharon Avenue	X	X
3336 Spring Street	X	X
Muddy Creek (MC)		
1415 Elmer Street	X	X
1503 Elmer Street		X
1505 Elmer Street	X	X
1507 Elmer Street		X
1706 Fairbrother Street		X
1708 Fairbrother Street	X	X
1506 Headquarters Drive		X
1314 Joyce Street	X	X
1316 Joyce Street		X
1810 Phillips Avenue	X	X
1804 Textile Drive	X	X
1806 Textile Drive	X	X
510 Yanceyville Street		X
North Buffalo Creek (NBC)		
NBC3 (West Wendover to South Holden)		
1013 Battleground Avenue	X	X
600 E Lake Drive	X	X
808 E Lake Drive		X
899 Grayland Street	X	X

Address	25-year at-risk structure	100-year at-risk structure
213 Green Valley Road		X
215 Green Valley Road		X
217 Green Valley Road		X
1000 Hill Street	X	X
2215 Mimosa Drive	X	X
616 N Mendenhall Street		X
411 Parkway Street	X	X
322 W Bessemer Avenue		X
1500 W Lake Drive		X
1502 W Lake Drive		X
1504 W Lake Drive		X
601 W Wendover Avenue	X	X
701 W Wendover Avenue	X	X
901 Wharton Street	X	X
NBC2 (N O'Henry to West Wendover)		
1301 Carolina Street		X
1700 Fairview Street		X
2420 Fairview Street	X	X
1103 Latham Road	X	X
1105 Latham Road	X	X
1111 Latham Road	X	X
1113 Latham Road	X	X
1115 Latham Road	X	X
1307 Latham Road	X	X
1309 Latham Road	X	X
1311 Latham Road	X	X
1317 Latham Road	X	X
1319 Latham Road	X	X
1321 Latham Road	X	X
1323 Latham Road	X	X
1325 Latham Road	X	X
1327 Latham Road		X
1401 Latham Road		X
1403 Latham Road	X	X
1405 Latham Road		X
2204 Maple Street	X	X
2208 Maple Street	X	X
2210 Maple Street	X	X
2213 Maple Street		X
2214 Maple Street		X
2215 Maple Street		X
2217 Maple Street		X
1514 N Church Street		X
1517 N Church Street		X
1909 N Church Street		X
1600 Roseland Street	X	X
1601 Roseland Street	X	X
1602 Roseland Street		X

Address	25-year at-risk structure	100-year at-risk structure
1603 Roseland Street	X	X
406 Shelton Street	X	X
2300 Summit Avenue	X	X
2302 Summit Avenue	X	X
130 Sunset Circle	X	X
134 Sunset Circle	X	X
1200 Water Street	X	X
1202 Water Street		X
1204 Water Street		X
1206 Water Street	X	X
1208 Water Street		X
1210 Water Street	X	X
1211 Water Street		X
1213 Water Street		X
2005 Yanceyville Street	X	X
2007 Yanceyville Street	X	X
2200 Yanceyville Street	X	X
2207 Yanceyville Street	X	X
2209 Yanceyville Street		X
NBC1 (I-840 to N O'Henry)		
3242 Hines Chapel Road		X
2199 White Street	X	X
Philadelphia Lake (PL)		
2420 Fairview Street	X	X
2701 N Church Street		X
Tributary A (NBC-TA)		
1000 Benjamin Parkway		X
Unnamed Tributary (NBC-UT)		
Unnamed Tributary		
501 Guilford Avenue	X	X
Unnamed Tributary 1 (JB-UT1)		
1801 Allyson Avenue	X	X
1809 Cody Avenue		X
1812 Cody Avenue		X
3720 Martin Avenue	X	X
4418 Voss Avenue	X	X
Unnamed Tributary 3 (NBC-UT3)		
1212 Briarcliff Road		X
401 Hammel Road	X	X
403 Hammel Road	X	X
405 Hammel Road	X	X
407 Hammel Road		X
1201 Latham Road		X
1203 Latham Road	X	X

Address	25-year at-risk structure	100-year at-risk structure
1205 Latham Road	X	X
1207 Latham Road	X	X
1301 Latham Road		X
1305 Latham Road		X
Unnamed Tributary 4 (NBC-UT4)		
301 E Lake Drive		X
1211 W Friendly Avenue		X
1213 W Friendly Avenue		X
1300 W Market Street		X
1308 W Market Street	X	X
1310 W Market Street	X	X
1312 W Market Street		X
Unnamed Tributary 5 (TA-UT5)		
1107 Hobbs Road		X
3003 Starmount Farms Drive		X

Table 4.7-5 25- and 100-Year At-Risk Structures (NOAA Future Storm)

Address	25-year at-risk structure	100-year at-risk structure
Jordan Branch (JB)		
3601 Country Ridge Road		X
3703 Martin Avenue	X	X
3709 Martin Avenue	X	X
3714 Martin Avenue		X
3499 Murchie Street		X
3500 Murchie Street	X	X
2906 Nabors Road	X	X
3707 Redor Street	X	X
3702 Sharon Avenue	X	X
3336 Spring Street	X	X
Muddy Creek (MC)		
1415 Elmer Street	X	X
1503 Elmer Street		X
1505 Elmer Street	X	X
1507 Elmer Street		X
1706 Fairbrother Street		X
1708 Fairbrother Street	X	X
1506 Headquarters Drive		X
1314 Joyce Street	X	X
1316 Joyce Street		X
1810 Phillips Avenue	X	X
1804 Textile Drive	X	X
1806 Textile Drive	X	X

Address	25-year at-risk structure	100-year at-risk structure
510 Yanceyville Street		X
North Buffalo Creek (NBC)		
NBC3 (West Wendover to South Holden)		
1013 Battleground Avenue	X	X
600 E Lake Drive	X	X
808 E Lake Drive		X
899 Grayland Street	X	X
213 Green Valley Road		X
215 Green Valley Road		X
217 Green Valley Road		X
1000 Hill Street	X	X
2215 Mimosa Drive	X	X
616 N Mendenhall Street		X
411 Parkway Street	X	X
322 W Bessemer Avenue		X
1500 W Lake Drive		X
1502 W Lake Drive		X
1504 W Lake Drive		X
601 W Wendover Avenue	X	X
701 W Wendover Avenue	X	X
901 Wharton Street	X	X
NBC2 (N O'Henry to West Wendover)		
1301 Carolina Street		X
1700 Fairview Street		X
2420 Fairview Street	X	X
1103 Latham Road	X	X
1105 Latham Road	X	X
1111 Latham Road	X	X
1113 Latham Road	X	X
1115 Latham Road	X	X
1307 Latham Road	X	X
1309 Latham Road	X	X
1311 Latham Road	X	X
1317 Latham Road	X	X
1319 Latham Road	X	X
1321 Latham Road	X	X
1323 Latham Road	X	X
1325 Latham Road	X	X
1327 Latham Road		X
1401 Latham Road		X
1403 Latham Road	X	X
1405 Latham Road		X
2204 Maple Street	X	X
2208 Maple Street	X	X
2210 Maple Street	X	X
2213 Maple Street		X
2214 Maple Street		X
2215 Maple Street		X

Address	25-year at-risk structure	100-year at-risk structure
2217 Maple Street		X
1514 N Church Street		X
1517 N Church Street		X
1909 N Church Street		X
1600 Roseland Street	X	X
1601 Roseland Street	X	X
1602 Roseland Street		X
1603 Roseland Street	X	X
406 Shelton Street	X	X
2300 Summit Avenue	X	X
2302 Summit Avenue	X	X
130 Sunset Circle	X	X
134 Sunset Circle	X	X
1200 Water Street	X	X
1202 Water Street		X
1204 Water Street		X
1206 Water Street	X	X
1208 Water Street		X
1210 Water Street	X	X
1211 Water Street		X
1213 Water Street		X
2005 Yanceyville Street	X	X
2007 Yanceyville Street	X	X
2200 Yanceyville Street	X	X
2207 Yanceyville Street	X	X
2209 Yanceyville Street		X
NBC (I-840 to N O'Henry)		
3242 Hines Chapel Road	X	X
2199 White Street	X	X
Philadelphia Lake (PL)		
2420 Fairview Street	X	X
2701 N Church Street		X
Tributary A (NBC-TA)		
1000 Benjamin Parkway		X
Unnamed Tributary (NBC-UT)		
501 Guilford Avenue	X	X
Unnamed Tributary 1 (JB-UT1)		
1801 Allyson Avenue	X	X
1809 Cody Avenue		X
1812 Cody Avenue		X
3720 Martin Avenue	X	X
4418 Voss Avenue	X	X
Unnamed Tributary 3 (NBC-UT3)		
1212 Briarcliff Road		X
401 Hammel Road	X	X

Address	25-year at-risk structure	100-year at-risk structure
403 Hammel Road	X	X
405 Hammel Road	X	X
407 Hammel Road		X
1201 Latham Road		X
1203 Latham Road	X	X
1205 Latham Road	X	X
1207 Latham Road	X	X
1301 Latham Road		X
1305 Latham Road		X
Unnamed Tributary 4 (NBC-UT4)		
301 E Lake Drive		X
1211 W Friendly Avenue		X
1213 W Friendly Avenue		X
1300 W Market Street		X
1308 W Market Street	X	X
1310 W Market Street	X	X
1312 W Market Street		X
Unnamed Tributary 5 (TA-UT5)		
1107 Hobbs Road		X
3003 Starmount Farms Drive		X

4.7.1.5 Primary System Existing Condition Results

As shown in Table 4.7-6, a total of 137 crossings were evaluated as part of the Primary System analysis. There were a variety of types of crossings included within the watershed. LOS compliance was determined based on the table shown in Section 2.3. The city street classification had no bearing on LOS requirement in this watershed because the floodway provision applied (based on draft-preliminary FEMA maps), therefore the 100-year design storm applied to all city crossings.

Table 4.7-6 Crossings Evaluated within the NBC Watershed

Facility Type	Crossings	LOS Deficient
State Maintained (NCDOT)	25	17
Major/Minor Road	61	32
Greenway/Footbridge	25	n/a
Private	26	n/a
Total	**137**	**49**

A listing of city-owned crossings which did not meet their applicable LOS is provided below. Additional information on alternatives developed for each crossing is included in Section 6.1 Primary System Projects.

• Battleground Avenue • Briarcliff Road • Cleburne Street • Cody Avenue • Cridland Road • East Bessemer Avenue • East Cone Boulevard • Fairmont Street • Fairview Street • Garland Drive • Guilford Drive • Hill Street – North Buffalo Creek • Hill Street – Unnamed Tributary • Latham Road • Martin Avenue – Jordan Branch • Martin Avenue – Unnamed Tributary 1	• Murchie Street & Sharon Avenue • North Elam Avenue • North Elm Street • North Josephine Boyd Street • Pembroke Road • Phillips Avenue – Muddy Creek • Phillips Avenue – Unnamed Tributary 2 • Ralph C Johnson Street • South Josephine Boyd Street • Textile Drive • Voss Avenue • West Friendly Avenue • West Smith Street – North Buffalo Creek • West Smith Street – Unnamed Tributary • White Street • Yanceyville Street

4.7.2 Special Risk Areas

City Ordinance Section 27-22 requires that new development sites within the City that increase the net built-upon area of the site by more than 400 square feet or that result in a change to the predevelopment drainage patterns must minimize off-site flooding, drainage and erosion problems. The City has further implemented a policy that for areas of known flooding, additional detention can be required as part of the development review process.

This SWMP evaluation included a comparison of runoff produced based upon existing and future LUs to determine if future LU changes (development) in undeveloped areas of the watersheds would result in additional LOS deficiencies at City maintained road crossings. Procedures used to establish CNs in the future condition are described in Section 4.5.1. The NOAA distribution was utilized for this comparison since the model validation process described in Section 4.6.4 established it as the rainfall distribution which best correlated to Primary System storm response. The procedure to identify special risk areas is as follows:

1. Compare the NOAA distribution existing LU model results to the NOAA distribution future LU model results and identify locations where a stream crossing meets City design standards in existing conditions but not in the future conditions.

2. Within areas that qualify under Criteria 1 (if any), identify locations of increased flooding risk to houses and businesses when comparing the existing and future conditions. Comparison shall be performed for both the 25-year and the 100-year events. “Increased flooding risk” is defined as when primary residences or businesses intersect the flood elevation in the future conditions but not in existing conditions.

Within the NBC watershed, this comparison was conducted, and it was determined that one new LOS deficiency occurred in the future conditions; however, no buildings were impacted. Since Criteria 1 and 2 were not met, no areas were designated as Special Risk Areas. This result aligns with the findings that most areas of the watershed, except for areas in the Jordan Branch drainage basin, are already fully developed and experience little or no increase in runoff between the existing conditions and future conditions analyses. .

4.7.3 Other Policy Considerations

In recent years, the trend of tearing down small, older homes and rebuilding large, highly impervious structures has continued to grow. The city is experiencing this in several areas, including within each of its three major watersheds (Horsepen Creek, North Buffalo Creek, and South Buffalo Creek). Currently, the City has no means to require these lots to offset peak flow increases generated as a result of new built upon area. During community outreach meetings, Stantec received resident feedback that these scenarios have created issues at various locations within the watershed.

This trend has been addressed in some nearby municipalities, including the City of Raleigh. In 2016, City of Raleigh implemented code text changes (TC-02-16) to curtail the increases in runoff associated with these types of teardowns. The Raleigh code includes impervious surface limitations and empowers the city to require stormwater controls if analyses show downstream impact of a certain magnitude. While it is beyond the scope of this SWMP to study this scenario in detail, the city may wish to conduct a future analysis that would assess the potential small scale and cumulative impact of teardowns and the potential ways this issue may be addressed. Such a study would include both a quantitative analysis of changes in runoff over time and a qualitative benchmarking review of how other North Carolina municipalities have addressed this scenario.

4.8 Secondary Systems Analysis and Results

4.8.1 System Identification

Stantec reviewed all city EAMs data for the NBC watershed and the City's map entitled "Top 20 areas of Historically Observed Flooding in GSO." These data sources were compared with the City's GIS piping and ditch inventory to identify areas of concern to include in the secondary system analysis. Secondary system analysis, dissimilarly from the primary, provides hydraulic gradient and capacity of the piped system greater than or equal to a 15-inch diameter. Stantec filtered and manually categorized EAMs data entries to reports of stormwater flooding, erosion, sinkholes, or other surface water problems based on the problem description provided in the data.

Based on the EAMs and other city data, eight (8) systems were identified to analyze, which included over 350,000 linear feet (LF) of stormwater system, including pipes, culverts, ditches, and streams. Stantec met with the City's Project Manager to assess the identified systems and they concurred with the chosen systems.

The full list of secondary systems considered and the reasons for selection are included in Section 4.8.4. The areas that were identified for further analysis are primarily within residential areas that experience frequent flooding, as reported by the city. These areas include:

- Subbasin 1 – Joseph M Bryan Boulevard, 58,000 LF of stormwater system
- Subbasin 2 – North Holden Road, 25,000 LF of stormwater system
- Subbasin 3 – Greensboro Botanical Gardens, 27,500 LF of stormwater system and retention basin at the botanical garden
- Subbasin 4 – Edgewater Drive, 19,500 LF of stormwater system
- Subbasin 5 – Montrose Drive, 23,500 LF of stormwater system
- Subbasin 6 – UNC Greensboro, 80,000 LF of stormwater system directly inflowing to South Branch of North Buffalo Creek
- Subbasin 7 – See below note.
- Subbasin 8 – Fisher Park, 21,000 LF of stormwater system flows into North Buffalo Creek at West Wendover Avenue
- Subbasin 9 – NC A&T State, 99,000 LF of stormwater system discharging to Muddy Creek by East Lindsay Street

  **Note: Subbasin 7 – Greensboro College was initially included in secondary system discussions with the city; however, this reach has as Preliminary FEMA study, so it was converted to a Primary System analysis.*

4.8.2 Hydrology

The Personal Computer Stormwater Management Model (PCSWMM) was selected to model the secondary systems. PCSWMM utilizes the EPA-SWMM engine, which is a free public domain software. Environmental Protection Agency – Stormwater Management Model (EPA-SWMM) uses the kinematic wave or dynamic wave approach. The kinematic wave approach converts a drainage area to an equivalent rectangular cascading plane with a separate runoff response from the pervious and impervious areas. The dynamic wave routing methodology, which was utilized for secondary system modeling, solves the complete one-dimensional Saint Venant flow equations, including continuity and momentum for conduits and a volumetric continuity at nodes. Dynamic wave routing provides accurate results, and it can represent pressurized flow, as well as account for backwater, entrance and exit losses, and channel storage.

4.8.2.1 Subbasin Parameters

Subbasin infiltration was estimated using the EPA-SWMM's Curve Number methodology. Curve numbers were developed based on primary modeling land use results, weighted by subbasin boundaries. The methodology followed to develop curve number values is discussed in more detail in Section 4.5.

Runoff flow rates from each subbasin are calculated using the following parameters:

- Subbasin Area:
    - Subbasin area was delineated using state-available LiDAR, contours, and up-to-date imagery. Subbasin outlets were defined by the downstream end of the subcatchment where rainfall runoff could enter the system (i.e., surface inlet).
- Subbasin Flow Length:
    - The overland flow lengths were determined using the same LiDAR and contours as for subbasin area. One to three flow lengths were delineated per subbasin in order to determine a longest overland flowpath, from the upstream most boundary to the outlet with the subbasin. The longest returned flowpath was input as the subbasin flow length.
- Subbasin Width:
    - The subbasin width is calculated by dividing the subbasin area with the length of overland flow. This property was automatically calculated by SWMM.
- Basin Slope:
    - PCSWMM calculates the basin slope along the flowpath based on the LiDAR. The slope is applied in the Manning's equation to estimate the rate of flow leaving each subbasin. Where the PCSWMM was unable to return a slope, they were hand calculated using LiDAR elevations and the flow length.
- Percent Impervious:
    - The percent impervious for each subbasin was zero, as impervious surfaces were already accounted for within the curve number because the Primary System curve number data was utilized.
- Manning's n-Values for Pervious and Impervious Areas:
    - Manning's n values are specified for pervious and impervious areas because the runoff from those areas is calculated separately in SWMM (if Percent impervious is utilized). Stantec did not utilized Percent impervious; however, the Manning's n value for all impervious surfaces was set to 0.01. The Manning's n values for pervious surfaces were set to 0.1.

- Subarea Routing and Percent Routed:
    - SWMM subcatchments are divided into pervious and impervious sub areas (if Percent impervious is utilized). Infiltration can occur in the upper soil zone of the pervious sub area but not impervious area. There are three choices for internal routing of runoff between pervious and impervious sub areas:
        - IMPERVIOUS – a percentage of the runoff from the pervious area is directed to the impervious area
        - PERVIOUS – a percentage of the runoff from the impervious area is directed to the pervious area
        - OUTLET – runoff from each sub area is routed directly to the outlet.
    - Based on the decision that the curve number accounted for impervious areas within the subbasin, Stantec utilized Outlet Routing.
- Depression Storage:
    - Depression storage includes surface ponding. This rainfall loss is in addition to soil infiltration and is not converted to runoff. Impervious depression storage for all subbasins was set to 0.05, while pervious depression storage was modified to closer match HEC-HMS. Additional information is included in Section 4.8.4.

4.8.2.2 Rainfall

The existing stormwater networks were evaluated using five storm events: 2-, 5-, 10-, 25-, and 50-year. To maintain consistency between the primary and secondary models, the NOAA 3rd Quartile Atlas 14 Volume 2, 6-hour duration, 10% rainfall distribution was used to evaluate the existing conditions for each of the secondary systems, while the proposed system was designed in accordance with the SCS Type II rainfall distribution. Copies of the PCSWMM models have been provided digitally in Appendix J.

4.8.3 Hydraulics

Junctions in PCSWMM represent inlets, manholes, confluences, and culvert beginnings and ends. The naming convention for junctions matches the City's GIS nomenclature and identifies the type of node structure (i.e. INL for inlet). Invert and rim elevations were input for each junction based on available GIS data from the City of Greensboro. Stantec was provided survey data from JC Waller & Associates for structures required for modeling with no available data. If survey was unable to verify a node, LiDAR was used for rim elevations and inverts were assumed based on surrounding survey information. All junctions that were interpolated are marked as such in the model.

If a manhole was flooding in the existing condition, the stormwater was captured by either modeling localized storage or an overland flow. An overland flow represented the flow captured in curb and gutter systems and was connected from the flooding inlet to the next downstream inlet.

Conduits in PCSWMM represent both open channels, such as ditches or swales, and closed systems, such as pipes and culverts. Open channels are modeled with a trapezoidal cross-section based on survey data or an irregular cross-section from LiDAR data. Pipe and culvert data, including the inverts, size, and material, are from City data or provided by survey. Similar to junctions, the pipes and culverts follow the City GIS nomenclature.

In EPA-SWMM hydraulics routing, the head loss is modeled in links rather than nodes. Entrance, exit, and other losses are entered for each conduit where a transition from open or closed channel occurs. Pipe entrance losses were assumed based on the HEC-RAS Hydraulic Reference Manual. Entrance losses are 0.5, which assumes a square-cut end of the pipe. Exit losses were assumed from the same reference at 1.0, which is a conservative value for sudden expansion of flow.

4.8.4 Secondary System Validation

The model input parameters (flow length, drainage area, curve number, Manning's n and basin slope) were developed utilizing the same source data and methodologies as the primary system models. In order to validate the Secondary System models, Stantec compared the PCSWMM model results to the Primary System HEC-HMS and then revisited model parameters when significant differences were observed. Table 4.8-1 includes the validation comparison results.

EPA SWMM utilizes a modified version of the CN method and known to generate more runoff volume than the same areas in HEC-HMS. While we did expect some increase in volume because the SWMM models are not using areal reduction factors, the differences exceeded our expectations. To force the SWMM models runoff volumes closer to the HMS model, Stantec utilized SWMM guidance document information to hardcode the initial abstraction from the CN method into the Dstore Perv attribute.

The Dstore Perv attribute was updated based on the following:

$$\text{Dstore Perv (in.)} = (((1000/CN)-10)*0.2)/2$$

Table 4.8-1 Post-Validation PCSWMM and HEC-HMS Comparisons

		NOAA Atlas 14 3rd Quartile 6-hr 25-yr
Subbasin ID	**Subbasin Name**	**% of HEC-HMS Peak Flow Outlet**
1	Joseph M Bryan Blvd	98%
2	North Holden Rd	110%
3	Greensboro Botanical Gardens	115%*
4	Edgewater Dr	87%
5	Montrose Dr	98%
6	UNC Greensboro	121%*
8	Fisher Park	106%
9	NC A&T State	104%*

** % of HEC-RAS peak flow outlet*

Figures 4-12 through 4-19 in the following sections show the subbasins, conduits, and junctions within the systems analyzed. LOS deficiencies were determined according to Section 2.3 and the City's 2008 Storm Drainage Design Manual, based on the surcharging of the pipes.

4.8.4.1 Secondary System - Joseph M Bryan Boulevard (Subbasin 1)

The Joseph M Bryan Boulevard subbasin is approximately 550 acres and contains approximately 33 EAMs stormwater service request points. It is one of two points (with North Holden Road) draining to the Gracewood Park tributaries on Gracewood Drive. Four historic flooding points from previous studies fall within this area.

4.8.4.2 Secondary System - North Holden Road (Subbasin 2)

The North Holden Road subbasin is approximately 225 acres and contains 22 EAMs stormwater service request points. It is one of two points (with Joseph M Bryan Boulevard) draining to the Gracewood Park tributaries on Gracewood Drive. Two historic flooding points from previous studies fall within this area.

4.8.4.3 Secondary System - Greensboro Botanical Gardens (Subbasin 3)

The Greensboro Botanical Gardens subbasin is approximately 260 acres and contains nearly 7 EAMs stormwater service request points. This area drains the wetlands and large retention pond at the outlet of the gardens, as well as a portion of Friendly Center. Nine historic flooding points from previous studies fall within this area.

4.8.4.4 Secondary System - Edgewater Drive (Subbasin 4)

The Edgewater Drive subbasin is approximately 280 acres and contains over 19 EAMs stormwater service request points. This area is south of the Greensboro Botanical Gardens and drains a portion of Friendly Center. Four historic flooding points from previous studies fall within this area.

4.8.4.5 Secondary System - Montrose Drive (Subbasin 5)

The Montrose Drive subbasin is approximately 310 acres and contains 7 EAMs stormwater service request points. This area drains to the tributary at the Starmount Forest Country Club and contains one historically observed flooding location, near the intersection of Montrose Drive and Mercury Drive. No historic flooding points from previous studies fall within this area.

4.8.4.6 Secondary System - University of North Carolina (UNC) Greensboro (Subbasin 6)

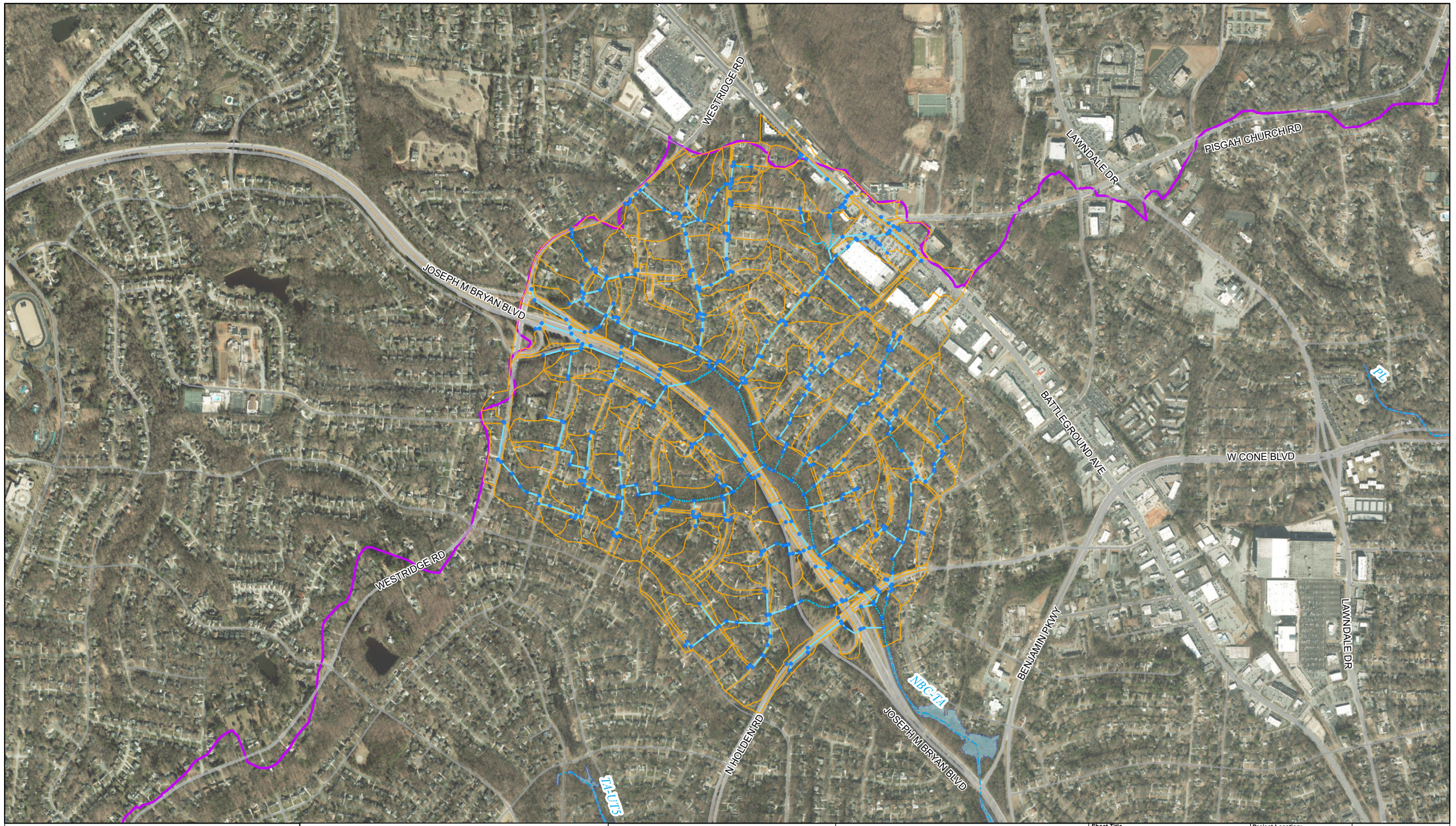
The UNC Greensboro subbasin is approximately 700 acres and contains 60 EAMs stormwater service request points. This area drains a majority of the university, beginning north of Oakland Avenue. The outlet of the subbasin ties directly into North Buffalo Creek. Eight historic flooding points from previous studies fall within this area.

4.8.4.7 Secondary System - Fisher Park (Subbasin 8)

The Fisher Park subbasin is approximately 190 acres and contains 20 EAMs stormwater service request points. This area drains to North Buffalo Creek at Latham Park. Two historic flooding points from previous studies fall within this area.

4.8.4.8 Secondary System - NC A&T State (Subbasin 9)

The NC A&T State subbasin is approximately 780 acres and contains 66 EAM stormwater service request points. This area drains to Muddy Creek, upstream of Joyce Street. No historic flooding points from previous studies fall within this area.



Stantec
One West Fourth Street, Suite 820
Winston-Salem, North Carolina
27101-3818
www.stantec.com

N

Legend

- Primary Streams
- Model Junctions
- Closed conduit
- Open Channel
- Subcatchment Boundaries
- Watershed Boundary
- Primary System - NOAA 1%-annual-chance inundation

0 500 1,000 2,000 Feet

(At original document size of 11x17)
1:12,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title
Secondary System
Subbasin 1 - Joseph M Bryan Blvd

Project Location:
City of Greensboro,
Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:
08/09/2024

Sheet No.
Figure 4-12

Stantec
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N

Legend

- Primary Streams
- Model Junctions
- Closed conduit
- Open Channel
- Subcatchment Boundaries
- Watershed Boundary
- Primary System - NOAA 1%-annual-chance inundation

0 300 600 1,200 Feet

(At original document size of 11x17)
1:7,200

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title

Secondary System
Subbasin 2 - North
Holden Road

Project Location:

City of Greensboro,
Guilford County, North Carolina

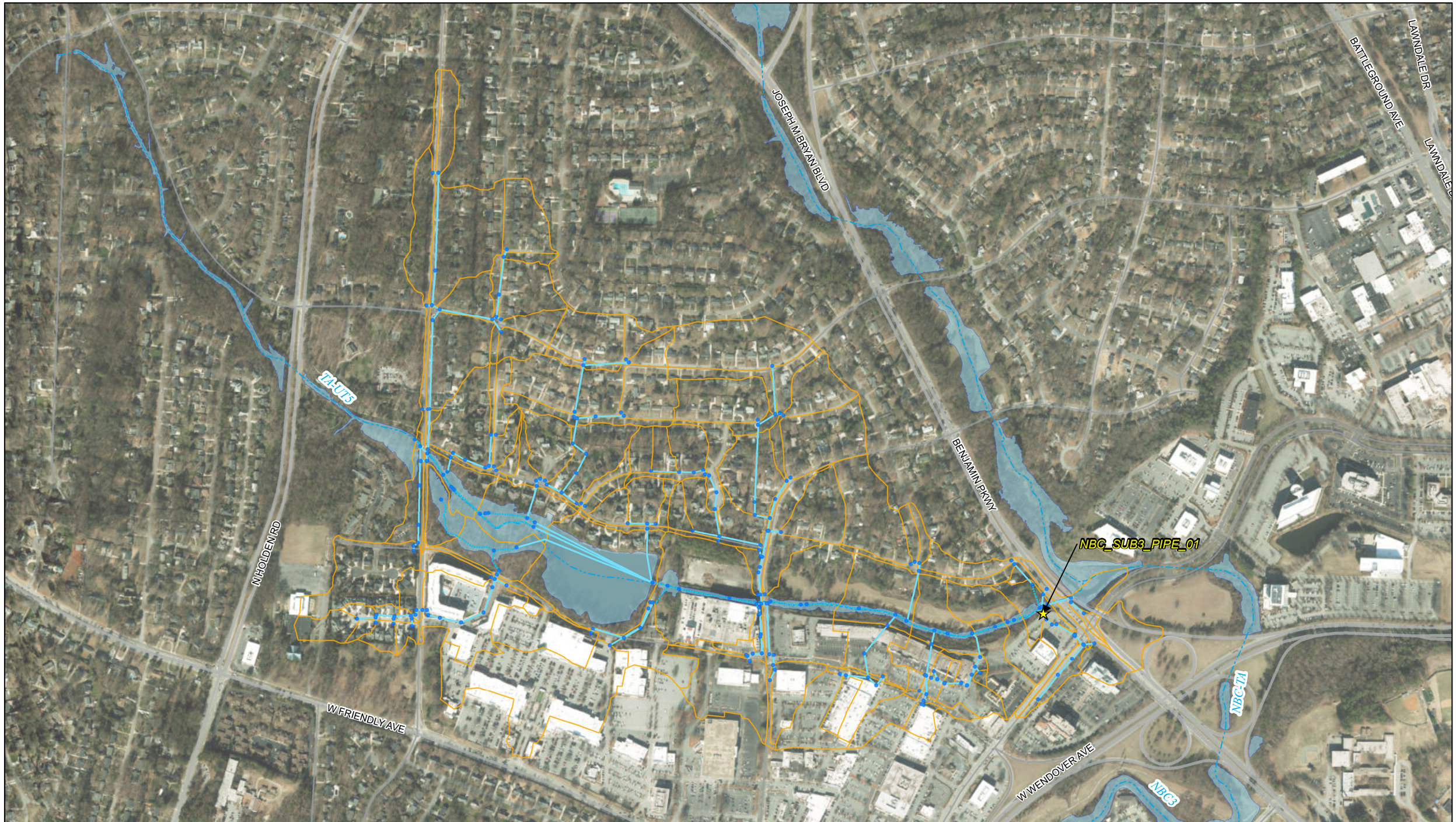
Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:

08/09/2024

Sheet No.

Figure 4-13



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Legend

- Primary Streams
- Model Junctions
- Closed conduit
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- Secondary Alternatives
- Watershed Boundary
- Primary System - NOAA 1%-annual-chance inundation

0 300 600 1,200 Feet

(At original document size of 11x17)
1:7,200

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title
Secondary System
Subbasin 3 - Greensboro Botanical Gardens

Project Location:
City of Greensboro,
Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:
08/09/2024

Sheet No.
Figure 4-14

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- Primary Streams
- Model Junctions
- Closed conduit
- Open Channel
- Subcatchment Boundaries
- Watershed Boundary
- Primary System - NOAA 1%-annual-chance inundation

0 250 500 1,000 Feet

(At original document size of 11x17)
1:6,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title

Secondary System
Subbasin 4 - Edgewater Drive

Project Location:

City of Greensboro,
Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:

08/09/2024

Sheet No.

Figure 4-15

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- Primary Streams
- Model Junctions
- Closed conduit
- Open Channel
- Subcatchment Boundaries
- Secondary Alternatives
- Watershed Boundary
- Primary System - NOAA 1%-annual-chance inundation

0 300 600 1,200 Feet

(At original document size of 11x17)
1:7,200

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title

Secondary System
Subbasin 5 - Montrose Drive

Project Location:

City of Greensboro,
Guilford County, North Carolina

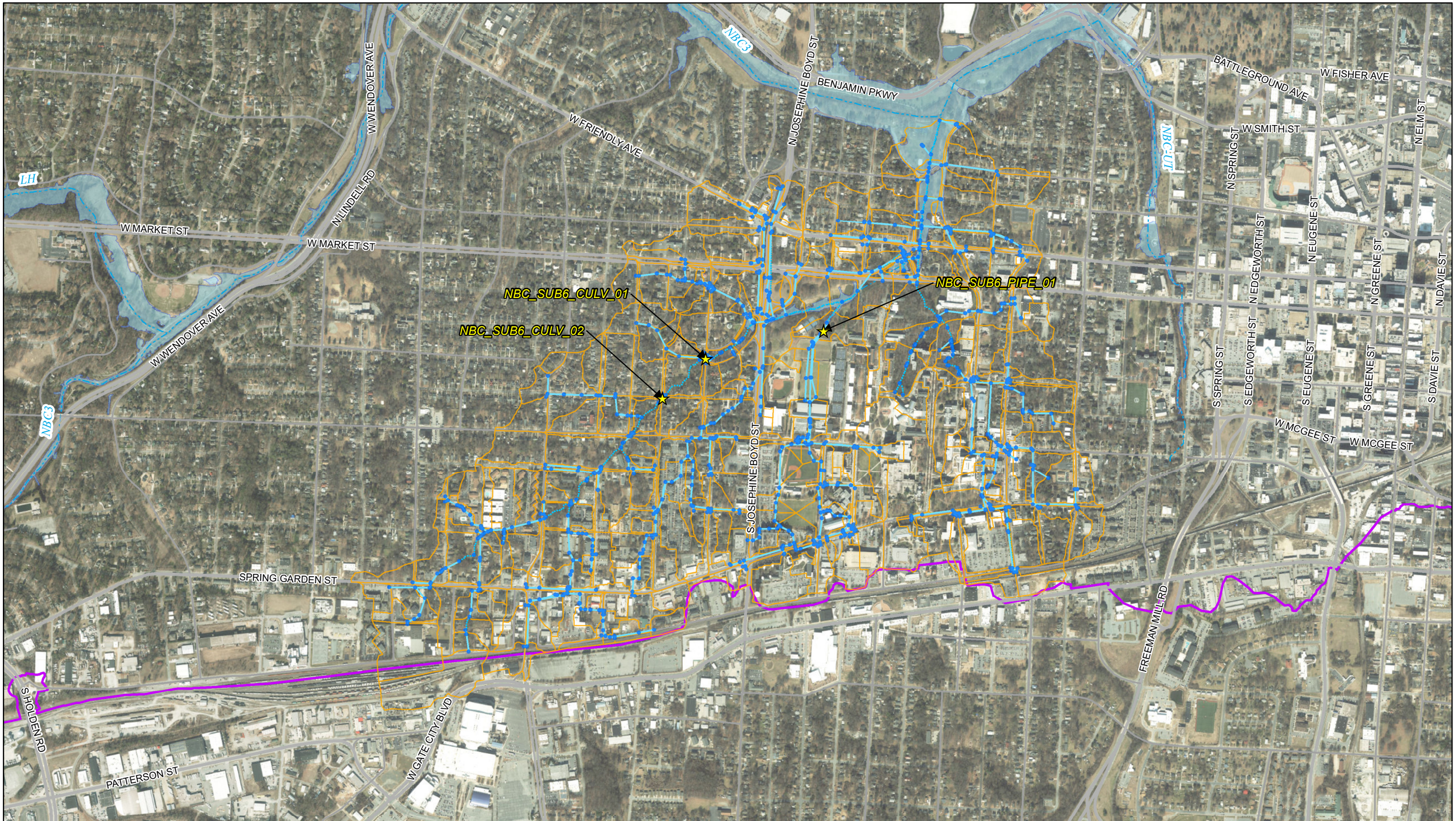
Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:

08/09/2024

Sheet No.

Figure 4-16



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Legend

- Primary Streams
- Model Junctions
- Closed conduit
- Open Channel
- Subcatchment Boundaries
- Secondary Alternatives
- Watershed Boundary
- Primary System - NOAA 1%-annual-chance inundation

0 500 1,000 2,000 Feet

(At original document size of 11x17)
1:12,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title

Secondary System
Subbasin 6 - UNC
Greensboro

Project Location:

City of Greensboro,
Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:

08/09/2024

Sheet No.

Figure 4-17

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- Primary Streams
- Model Junctions
- Closed conduit
- Open Channel
- Subcatchment Boundaries
- Secondary Alternatives
- Watershed Boundary
- Primary System - NOAA 1%-annual-chance inundation

0 250 500 1,000 Feet

(At original document size of 11x17)
1:6,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

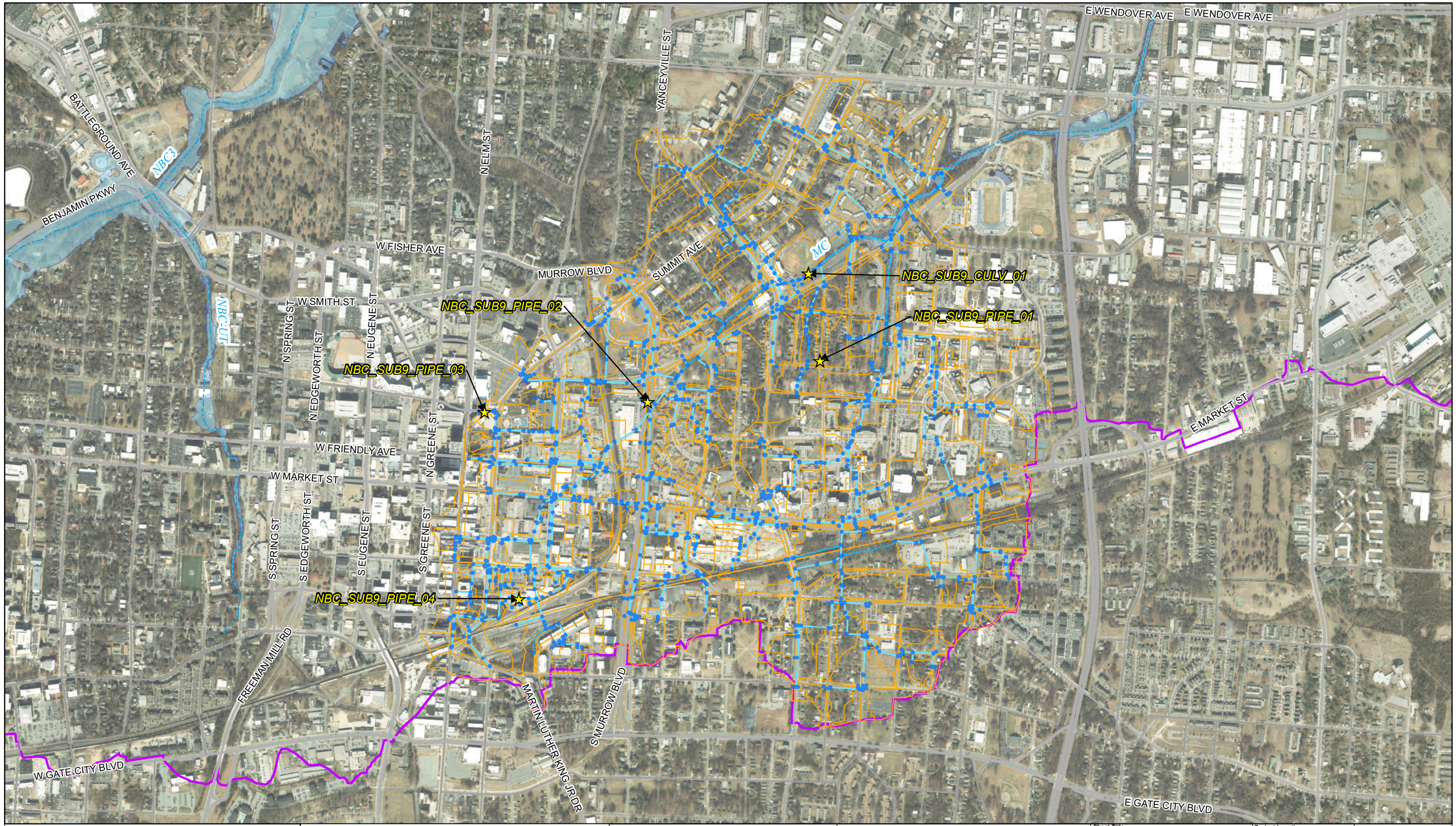
Sheet Title
Secondary System
Subbasin 8 - Fisher Park

Project Location:
City of Greensboro,
Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:
08/09/2024

Sheet No.
Figure 4-18



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- Primary Streams
- Model Junctions
- Closed conduit
- Open Channel
- Subcatchment Boundaries
- Secondary Alternatives
- Watershed Boundary
- Primary System - NOAA 1%-annual-chance inundation

0 500 1,000 2,000 Feet

(At original document size of 11x17)
1:12,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title
Secondary System
Subbasin 9 - NC A&T State

Project Location:
City of Greensboro,
Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:
08/09/2024

Sheet No.
Figure 4-19

5 Scoring Methodology

Development of the Prioritization method for GSO was performed by Kimley-Horn as part of their program management scope. The activities summarized below were performed by Kimley-Horn unless otherwise noted.

Prioritization methods from several municipalities were reviewed as part of developing prioritization criteria for the city. References included:

- Stormwater project prioritization criteria from the City of Raleigh, NC
- Stormwater prioritization criteria from the City of Greenville, NC
- Stormwater prioritization criteria and methodology from the City of Virginia Beach, VA
- Stream restoration project prioritization criteria from the City of Greensboro, NC

Municipalities such as Virginia Beach and Raleigh had in-depth and multi-tiered prioritization. A significant amount of information for each project was required to develop the project rankings, which was mostly found through modeling or detailed calculations. However, the goal of the GSO's prioritization was to apply SWMP developed criteria to all of their stormwater projects moving forward. Some of the projects would be identified outside of the master plan for which models would not be available. Therefore, a more simplified approach was taken, and a prioritization spreadsheet was developed that merged several concepts of the various criteria methodologies together.

Instead of scoring scales ranging from one to ten, the initial scoring scale for the city ranged from zero to five. Similarly, one set of criteria was identified for city instead of multiple criteria tiers and included 14 criteria:

- Severity of Structure Flooding
- Severity of Street Flooding
- Emergency Access Flooding
- Flood-Resolution Efficacy
- Project in Socially Vulnerable Areas
- Project in Economic Development Corridor or Growth Tier Areas
- Open Channel - Erosion Control
- Permitting and Compliance
- Water Quality Enhancements
- Constructability
- Operation and Maintenance
- Land Acquisition/ Available Easements
- Grant Funding
- Multi-Department Benefits

The scoring spreadsheet also included definitions for each criteria listed above and more detail in the scoring scale descriptions, which can be seen in Appendix G. Kimley-Horn met with the city in July 2023 to discuss the initial set of criteria to establish that the prioritization could apply to all stormwater projects. The city provided input including removing some criteria and adding others, updating definitions and scoring descriptions, and creating categories to distinguish between the types of prioritization criteria.

With the City's input, the criteria grew to four categories with 14 total criteria:

Health and Safety

- Severity of Structure Flooding
- Severity of Street Flooding
- Emergency Access Flooding
- General Public Safety and Benefit
- Flood-Resolution Efficacy

Environmental

- Open Channel - Erosion Control
- Permitting and Compliance
- Water Quality Enhancements

Implementation

- Constructability
- Operation and Maintenance
- Project Age
- Land Acquisition/ Available Easements

Financial

- Grant Funding
- Secondary Benefits

The next step in developing the prioritization was to determine the weight, or relative importance, assigned to each criterion. Based on the research and Kimley-Horn's experience with other municipalities, holding a workshop to gather stakeholder input is a best practice. A workshop ensures that all stakeholders are engaged and participating. Kimley-Horn led the Master Planning Prioritization Workshop with the City on September 21, 2023. The city attendee list is included below:

- Dave Phlegar – Stormwater Management Division Manager
- Jana Stewart – Water Resources Engineering Manager
- Johnnie Hill – Water Resource Engineering Supervisor
- Virginia Spillman – Senior Water Resources Manager
- Jason Millington – Stormwater Construction Projects Coordinator
- Blake Strumbel – Stormwater Construction Projects Coordinator

Each City attendee was provided an online survey through Menti that utilized the Analytical Hierarchy Process (AHP). The AHP is a specific methodology that simplifies the decision-making process by comparing individual criterion through a series of multiple "pairwise" or "side-by-side" comparisons. The process is a best practice for determining the relative importance of criteria. The weighting for each

question was based on a sliding scale. The scale ranged from 0, which meant the two criteria being compared were “equally important” to 4, which meant a particular criterion was “extremely important” when compared to the other. A few examples of pair-wise questions are included below.

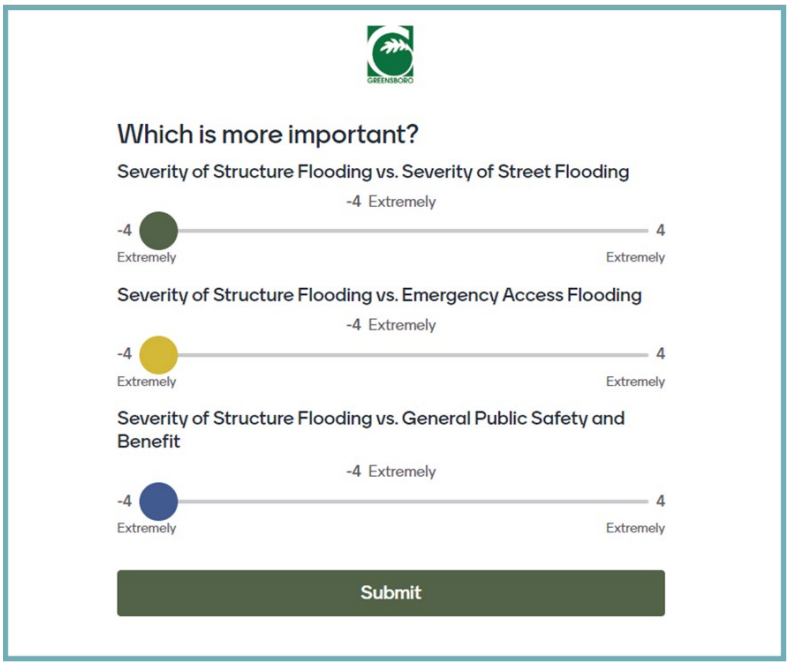


Figure 5-1 Sliding Scale Survey Example

During a break in the workshop, the results of the survey were pulled into the AHP tool that converted the city input into percentages or weights. A screenshot from the tool is shown below.

	Seve...	Seve...	Emer...	Gene...	Flood...	Open...	Perm...	Wate...	Cons...	Oper...	Proje...	Land ...	Gran...	Multi...
Sever...	1	3	1/3	1/9	6	1/4	1/3	1/2	6	1/3	1/3	1/3	1	4
Sever...	1/3	1	1/2	1/9	1	3	5	1/3	6	3	1/3	3	7	2
Emer...	3	2	1	1/9	1/2	1	1	1/3	3	5	3	1/3	1	3
Gene...	9	9	9	1	9	9	9	9	9	9	9	9	9	9
Flood...	1/6	1	2	1/9	1	1	3	5	1	1	5	3	7	5
Open...	4	1/3	1	1/9	1	1	1	7	4	2	3	1	1	2
Permi...	3	1/5	1	1/9	1/3	1	1	3	1/3	1/5	1/3	1/3	3	1/2
Wate...	2	3	3	1/9	1/5	1/7	1/3	1	1	1/2	1/3	1	1/4	1
Const...	1/6	1/6	1/3	1/9	1	1/4	3	1	1	1/7	3	1/3	1/3	2
Oper...	3	1/3	1/5	1/9	1	1/2	5	2	7	1	1/5	1	1	1/3
Proje...	3	3	1/3	1/9	1/5	1/3	3	3	1/3	5	1	1	2	1/5
Land ...	3	1/3	3	1/9	1/3	1	3	1	3	1	1	1	3	3
Grant...	1	1/7	1	1/9	1/7	1	1/3	4	3	1	1/2	1/3	1	1/5
Multi-...	1/4	1/2	1/3	1/9	1/5	1/2	2	1	1/2	3	5	1/3	5	1

Figure 5-2 AHP Tool

The tool provided the ability to show “real-time” results from the workshop survey. The results showed that the city prioritized the Health and Safety criteria category by giving the category a collective weight of 73.5%. The Environment category received 12.3% of the weight, Implementation had 10.8%, and Financial had 3.4%.

The city agreed with the initial weights that resulted from the workshop. However, there were a few modifications the city wanted to implement. One of the more significant discussion topics was about the best way to incorporate the project cost into scoring. The city did not want to implement a full benefit-cost analysis for the watershed projects and future City projects. Ultimately, an additional criterion for Project Cost was created with a 5% weight. The finalized prioritization process had four categories with 15 total criteria with the following weights:

Table 4.8-1 Final Criteria Weights

Criteria Description	Percent
Health and Safety	**69.8%**
• Severity of Structure Flooding	11.4%
• Severity of Street Flooding	11.7%
• Emergency Access Flooding	20.0%
• General Public Safety and Benefit	18.2%
• Flood-Resolution Efficacy	8.5%
Environmental	**11.8%**
• Open Channel - Erosion Control	4.6%
• Permitting and Compliance	2.8%
• Water Quality Enhancements	4.4%
Implementation	**10.2%**
• Constructability	5.6%
• Operation and Maintenance	1.8%
• Project Age	1.2%
• Land Acquisition/ Available Easements	1.6%
Financial	**8.2%**
• Grant Funding	1.6%
• Secondary Benefits	1.6%
• Project Cost	5.0%

Another adjustment from the workshop was to generate a normalized score to create a better comparison between different types of projects, such as a stream project versus a primary flood mitigation project. Each project received a raw score and a normalized score with the normalized score only accounting for the applicable criteria of the project. For instance, a stream restoration project that did not mitigate flooding had an “N/A” for several of the Health and Safety criteria instead of scoring zero. Those criteria were removed from the project’s total score. Effectively, the stream and SCM projects had smaller denominators with the normalized score.

The Horse Pen Creek (HPC) watershed was used to test the prioritization. Using the normalized scoring, eight of the top ten projects were stream stabilization projects. Most of the primary and secondary system projects were ranked in the lowest quartile. Comparatively, three of the top ten projects were stream stabilizations when using the raw scores. The other top ten projects were primary or secondary system projects.

The city and consultant team reviewed the results and agreed that the normalized score skewed the results in favor of stream and SCM projects. The normalized scores bypassed the usefulness of the

criteria weights. The primary and secondary projects should score higher because they were addressing flood safety concerns, which are highly weighted criteria. The normalization process removes these heavily weighted criteria from some projects, allowing them to rise above projects with these factors included. Through this process of developing and testing a normalization process, it was determined that the weighting developed by the project team was already serving to create the desired comparison outcomes. Therefore, score normalization was not used to rank projects in the city.

Changes to the prioritization protocol made during project execution have been tracked in a Change Log. Several of the modifications were from the workshop as noted above. Other modifications occurred as the matrix evolved with different consultants and City use. The log and dates are included in Table 4.8-2 below.

Table 4.8-2 Change Log for Prioritization Matrix

Change(s)	Date/Version
Revised "Severity of Street Flooding" to remove reference to LOS. This one is meant to measure how badly the street floods, which does not always align with LOS, which includes other factors such as HW/D.	11.2023
Revised "Emergency Access Flooding" to include a distance from critical infrastructure. Projects receive 1 point for addressing an LOS concern and being within 0.5 miles from a critical infrastructure, 3 points for mitigating flooding on the street and being within 0.5 miles, and 5 points for mitigating flooding on the street and being within 1000 feet.	01.2024
Added language for "Flood-Resolution Efficacy" to say "no adverse downstream impacts are anticipated, or the impacts are considered acceptable."	01.2024
Revised "Water Quality Enhancements" to include ranges of nitrogen removal cost. Projects receive 1 point for removing nitrogen at a rate >$100,000/lb. N, 3 points at a rate between $50,000 - $80,000/lb. N, and 5 points at a rate of <$30,000/lb. N removed.	01.2024
Adjusted "Project Cost" brackets to be 0 points for costs >$10M, 1 point for costs between $6-10M, 3 points for costs between $3-4M, 5 points for costs <$1M.	01.2024
Strikethrough normalized scores. Kimley-Horn, the city, and consultant teams concluded that the normalized scores were de-emphasizing the score weights, especially those in Health & Safety. Normalized scores will be kept track of for further comparison, but projects will be ranked based on the raw score.	01.2024
Revised definition of "Emergency Access Flooding" to denote which types of street centerlines are considered City evacuation routes (Freeway, Major and Minor).	02.2024

After finalizing the criteria, Kimley-Horn held a workshop on February 7, 2024, for the city and consultant team. The workshop had three overall goals: (1) help create consistent scoring among the City and consultants, (2) provide references for scoring, and (3) answer any outstanding questions.

Kimley-Horn demonstrated using the prioritization spreadsheet with examples from HPC. Projects, such as streams or SCMs, have consistent scores in certain categories. For instance, grant funding opportunities for stream restoration projects are nearly always scored as a five out of five due to the number of funding opportunities for stream projects.

While it was not possible to review every project nuance in 90 minutes, a few reoccurring nuances were discussed. For example, stream projects that mitigate erosion near an exposed at-risk utility score higher in the General Public Safety and Benefit criterion.

Several tools, such as websites, shapefiles, and other City data were reviewed and shared with the consultant team to assist with streamlining the prioritization process. Using the same resources should also help create consistency in scoring between the watersheds and with future City projects.

6 Flood Control Alternatives Analysis

6.1 Primary System Projects

The goal of the existing conditions analysis within the Primary System was to identify locations which do not meet the required LOS, as outlined in Section 2.3, based on the NOAA distribution storm event.

NCDOT crossings, greenway and private bridges, railroads, and private drives were excluded from potential project locations since those locations would also not be considered for a City CIP project. There was one exception to this approach: 1) if a water surface increase requiring mitigation due to a proposed improvement could be mitigated by proposing a project at one of these locations.

After the identification of City crossings that did not meet the applicable design standards, an alternative was developed at each location to maximize the LOS (ideally meeting the City's design guidance). WSE increases related to the proposed projects were evaluated on a case-by-case basis to determine if mitigation was needed. While each situation was unique, general criteria utilized to determine if a WSE increase should be mitigated are shown in Table 6.1-1.

WSE increases were compared using the SCS Type II Future Conditions model and the SCS Type II Future Conditions Alternatives models. When a WSE increase requiring mitigation was identified, increases were either mitigated through floodplain benching and channel modifications.

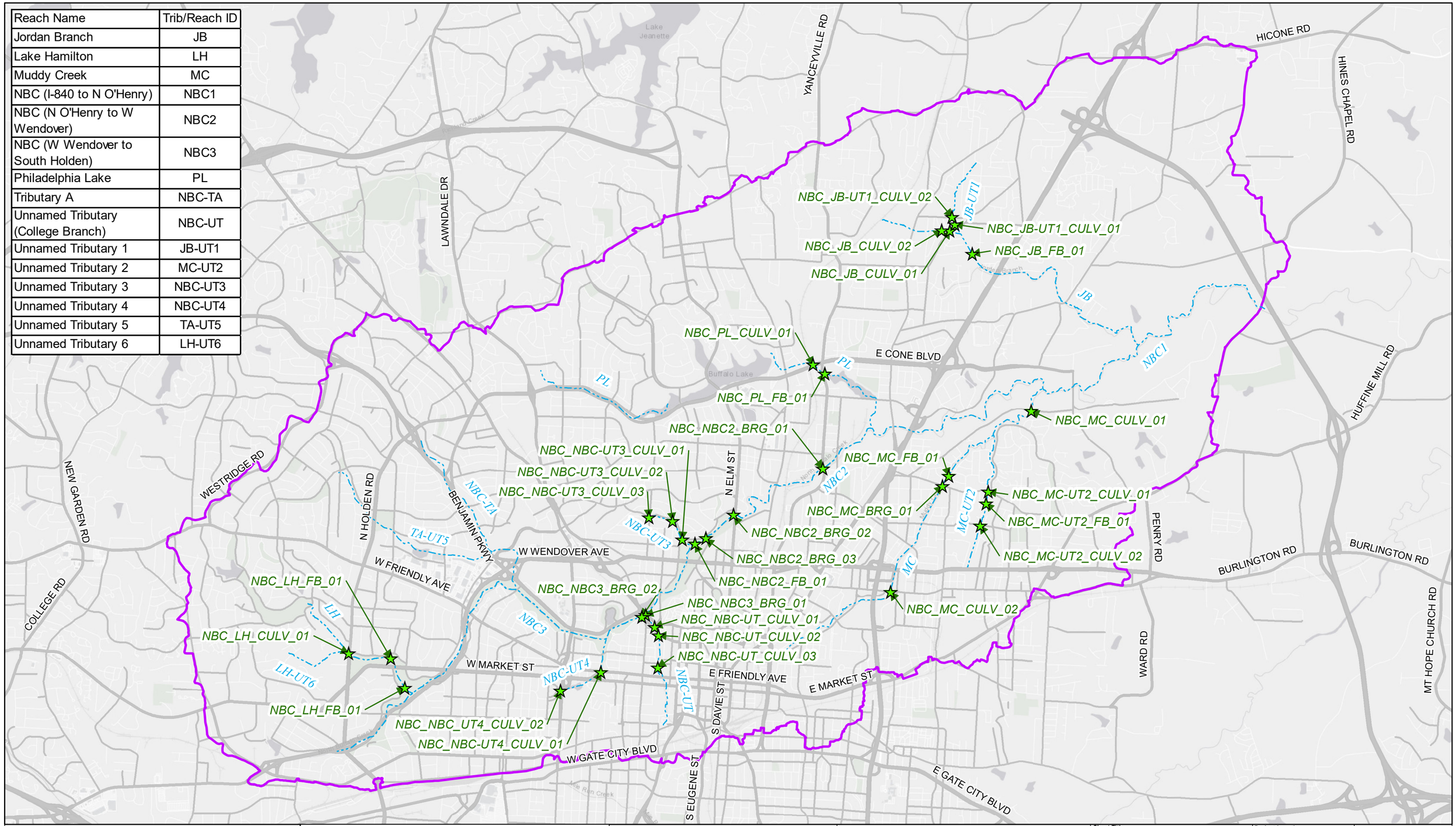
Table 6.1-1 100-Year WSE Increase Mitigation Criteria

Scenario	Approach
WSE increase brings new structure into 100-year floodplain	Mitigate WSE increase
WSE increase causes additional flooding on existing structure (increased depth)	Mitigate WSE increase
WSE increase causes LOS violation at downstream crossing	Mitigate WSE increase
WSE increase affects non-vacant private property	Case-by-case evaluation, if minor and not impacting structure, typically no WSE mitigation
WSE increase affects vacant private property	No mitigation
WSE increase affects City owned or encumbered private property	No mitigation

The City's design guidance states that the design of the improvements should be based on the SCS Type II rainfall distribution. Therefore, improvements were developed based on this storm event. Note that if a

new location was identified as not meeting LOS upon incorporation of the SCS Type II distribution, that location did not have a project proposed since crossing deficiencies were determined based on the NOAA distribution.

Reach Name	Trib/Reach ID
Jordan Branch	JB
Lake Hamilton	LH
Muddy Creek	MC
NBC (I-840 to N O'Henry)	NBC1
NBC (N O'Henry to W Wendover)	NBC2
NBC (W Wendover to South Holden)	NBC3
Philadelphia Lake	PL
Tributary A	NBC-TA
Unnamed Tributary (College Branch)	NBC-UT
Unnamed Tributary 1	JB-UT1
Unnamed Tributary 2	MC-UT2
Unnamed Tributary 3	NBC-UT3
Unnamed Tributary 4	NBC-UT4
Unnamed Tributary 5	TA-UT5
Unnamed Tributary 6	LH-UT6



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Legend

- Primary Streams
- Primary Alternatives
- Watershed Boundary

0 2,000 4,000 8,000 Feet

(At original document size of 11x17)
1:48,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title

Primary System Project Location Map

Project Location:

City of Greensboro,
Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date: 08/05/2024

Sheet No. Figure 6-1

Primary system flood control alternatives were developed for road crossings not meeting level-of-service (LOS). Initial LOS assessments were performed using NOAA 3rd Quartile 10% distribution storm events, since this distribution is a better match for actual rain events occurring in the City of Greensboro. The alternative designs were developed using the SCS Type II, 24-hour distribution with future land uses per City design guidelines.

Only crossings owned by the city were considered for alternatives development, and no alternatives were developed for footbridges, trails, or golf course bridges. Thirty-three structures were flagged for alternatives development and, during the prioritization meeting with the city, nine of those locations were determined to not need alternatives developed. This left a total of twenty-four structures for which to develop alternatives. An initial estimate of the sizing for each alternative location was developed using HY-8 to streamline the process. Inverts were assumed to remain the same and the opening height was either not increased from existing or was sized to maintain at least 3 ft of cover for culverts. Once initial estimates were developed, the designs were analyzed in the HEC-RAS models to ensure adequate performance and refined if needed. Each alternative was analyzed in a scenario with only that one structure improved and all other structures modeled as existing conditions. An additional HEC-RAS scenario was created that included all of the alternatives in one model to ensure that cumulative upstream improvements did not cause additional structure level of service failures.

Water surface elevation increases resulting from the design alternatives were mitigated with floodplain benching. Floodplain benching was recommended only in areas where water surface elevation increases impacted structures or privately-owned property.

The analysis of each structure is summarized below along with a description of the existing structure and the proposed structure if applicable.

6.1.1 North Buffalo Creek (I-840 to North O'Henry)

The Rankin Mill Road crossing on North Buffalo Creek consists of an approximately 137 foot span bridge. The crossing does not meet LOS. However, no alternatives were developed since it is state-owned.

The Ralph C Johnson Lane crossing on North Buffalo Creek consists of an approximately 267 foot span bridge. The city-owned structure does not meet LOS because it does not have enough freeboard. No alternatives were developed based on direction from the city during the initial prioritization meeting.

6.1.2 Jordan Branch

The McKnight Mill Road crossing on Jordan Branch consists of two 8 foot by 5 foot box culverts. This crossing does not meet LOS and no alternatives were developed since it is a state-owned crossing.

US 29 is a state-owned road crossing on Jordan Branch that consists of two 9 foot by 8 foot box culverts. This crossing does not meet LOS, but no alternatives were developed since it is a state-owned roadway.

The completion of the Jordan Branch floodplain benching project will mitigate the anticipated WSE increase for upstream primary system design alternatives and is intended to be completed in conjunction

with those pertinent primary system design alternatives. The project is downstream of the culvert upgrades projects on Martin Avenue at Jordan Branch, Martin Avenue at Unnamed Tributary 1, Murchie Street and Sharon Avenue, and Cody Avenue.

Table 6.1-2 NBC_JB_FB_01 Jordan Branch Floodplain Benching

Jordan Branch Floodplain Benching 01	**Jordan Branch**	**NBC_JB_FB_01**
Description	**Criteria/Result**	
Existing Configuration	Existing grade	
LOS Requirement	Maintain WSEL	
Triggering Criteria	WSEL Increase	
Proposed Configuration	Floodplain benching	
Prioritization Score	Scored with upstream projects	
OPCC	$10,948,000	
Notes/Comments	Mitigates the anticipated WSEL increase for upstream primary system design alternative(s): NBC_JB_CULV_01, NBC_JB-UT1_CULV_01, NBC_JB_CULV_02, NBC_JB-UT1_CULV_02.	

The Martin Avenue crossing on Jordan Branch is a city-owned crossing consisting of two 6-foot diameter circular culverts. The current structure does not meet LOS. The proposed structure is three 13 feet by 7 feet concrete box culverts, set 1 foot below the existing channel to allow for fish passage. Waterline and sanitary sewer conflicts were identified based on available City GIS data. See alternative figures in Appendix E for other information on conflicts, easements, or other design notes.

Table 6.1-3 NBC_JB_CULV_01 Martin Avenue

Martin Avenue Culvert 01	**Jordan Branch**	**NBC_JB_CULV_01**
Summary	**Criteria/Result**	
Roadway Classification	Collector	
Existing Configuration	(2) 6' Circular Pipe	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(3) 13' x 7' Box Culvert	
Prioritization Score	357.4	
Opinion of Probable Construction Cost	$2,497,000	
Notes/Comments	10 buildings removed from the floodplain. Relocation of sanitary sewer, water main, and stormwater pipe.	

Murchie Street and Sharon Street intersect at their mutual crossing over Jordan Branch, this crossing consists of two 11 foot by 6 foot box culverts and does not meet LOS. Since it is a city-owned crossing, an improved crossing of three 13 foot by 7 foot concrete box culverts is proposed. The culverts will be placed one foot below the current streambed and allowed to fill with bed material to maintain fish passage. This proposed alternative only meets LOS if the downstream Martin Avenue crossing is also improved. Waterline and sanitary sewer conflicts were identified based on available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-4 NBC_JB_CULV_02 Murchie and Sharon

Murchie and Sharon Culvert 02	**Jordan Branch**	**NBC_JB_CULV_02**
Summary	**Criteria/Result**	
Roadway Classification	Residential	
Existing Configuration	(2) 11' x 6' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(3) 13' x 7' Box Culvert	
Prioritization Score	276.0	
Opinion of Probable Construction Cost	$5,746,000	
Notes/Comments	To be performed with Jordan Branch Floodplain Benching. Relocation of sanitary sewer, water main, and stormwater pipe.	

Summit Avenue is the most upstream modeled structure on Jordan Branch. This crossing consists of one 8 foot by 6 foot box culvert. The structure currently does not meet LOS requirements. However, no alternatives were developed since it is a state-owned road crossing.

6.1.3 Unnamed Tributary 1

The Martin Avenue crossing on Unnamed Tributary 1 consists of one 7 foot diameter circular culvert. The city-owned crossing does not meet LOS. The proposed structure consists of two 8 foot by 8 foot box culverts placed 1 foot below the channel invert to allow for fish passage. Waterline and sanitary sewer conflicts were identified based on the available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-5 NBC_JB-UT1_CULV_01 Martin Avenue

Martin Avenue Culvert 01	**Jordan Branch Unnamed Tributary 1**	**NBC_JB-UT1_CULV_01**
Summary	**Criteria/Result**	
Roadway Classification	Collector	
Existing Configuration	(1) 7' Circular Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(2) 8' x 8' Box Culvert	
Prioritization Score	365.2	
Opinion of Probable Construction Cost	$2,414,000	
Notes/Comments	1 building removed from the floodplain. This project is intended to be completed with Jordan Branch Floodplain Benching. Relocation of sanitary sewer, water main, and stormwater pipe.	

The Cody Avenue crossing on Unnamed Tributary 1 consists of one 11.4 foot by 5.8 foot box culvert. The city-owned structure currently meets LOS for the NOAA rainfall events. However, it will not meet LOS once the preliminary floodway becomes effective. Therefore, a proposed structure consisting of two 10

foot by 7 foot box culverts was developed. The culverts will be placed 1 foot below the channel invert to maintain fish passage. Waterline and sanitary sewer conflicts were identified based on the available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-6 NBC_JB-UT1_CULV_02 Cody Avenue

Cody Avenue Culvert 01	**Jordan Branch Unnamed Tributary 1**	**NBC_JB-UT1_CULV_01**
Summary	**Criteria/Result**	
Roadway Classification	Collector	
Existing Configuration	(1) 11.4' x 5.8' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(2) 10' x 7' Box Culvert	
Prioritization Score	235.8	
Opinion of Probable Construction Cost	$2,051,000	
Notes/Comments	To be performed with Jordan Branch Floodplain Benching. Relocation of sanitary sewer, water main, and stormwater pipe.	

Voss Avenue is the most upstream crossing modeled on Unnamed Tributary 1. The crossing consists of one 4 ft diameter circular culvert. The city-owned structure does not meet LOS. No alternatives were developed because the City already has a completed design that meets the preliminary Flood Insurance Rate Maps (FIRMs) LOS.

6.1.4 Muddy Creek

The White Street crossing on Muddy Creek consists of three 12 foot by 10.5 foot box culverts. The city-owned crossing does not meet LOS. The proposed alternative consists of three 16 foot by 11.5 foot box culverts placed 1 foot below the channel invert to allow for fish passage. Waterline conflicts were identified based on available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-7 NBC_MC_CULV_01 White Street

White Street Culvert 01	**Muddy Creek**	**NBC_MC_CULV_01**
Summary	**Criteria/Result**	
Roadway Classification	Collector	
Existing Configuration	(3) 12' x 10.5' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(3) 16' x 11.5' Box Culvert	
Prioritization Score	137.6	
Opinion of Probable Construction Cost	$3,130,000	
Notes/Comments	Tailwater issues from North Buffalo Creek are present. Relocation of water main and stormwater pipe.	

The completion of the Muddy Creek floodplain benching project will mitigate the anticipated WSE increase for upstream primary system design alternatives and is intended to be completed in conjunction with the pertinent primary system design alternative located at Phillips Avenue and Muddy Creek.

Table 6.1-8 NBC_MC_FB_01 Muddy Creek Floodplain Benching

Muddy Creek Floodplain Benching 01	**Muddy Creek**	**NBC_MC_FB_01**
Summary	**Criteria/Result**	
Existing Configuration	Existing grade	
LOS Requirement	Upstream crossing LOS	
Triggering Criteria	Tailwater condition	
Proposed Configuration	Floodplain benching	
Prioritization Score	Scored with upstream projects	
OPCC	$6,326,000.00	
Notes/Comments	Improves channel conveyance capacity during design event, eliminating tailwater conditions of upstream crossing, Phillips Avenue. Mitigates the anticipated WSEL increase for upstream primary system design alternative(s): NBC_MC_BRG_01	

The Phillips Avenue crossing on Muddy Creek is an approximately 44 foot span bridge owned by the city. The structure does not meet LOS. The proposed design is a 140 foot span bridge. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-9 NBC_MC_BRG_01 Phillips Avenue

Phillips Avenue Bridge 01	**Muddy Creek**	**NBC_MC_BRG_01**
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	44' Span Bridge	
LOS Requirement	18" FB in 100-yr Event	
Triggering Criteria	< 18" FB in 100-yr Event	
Proposed Configuration	140' Span Bridge	
Prioritization Score	287.2	
Opinion of Probable Construction Cost	$5,832,000	
Notes/Comments	1 building removed from the floodplain. Tailwater issues from NBC are present and are to be addressed by completing the project in conjunction with Muddy Creek Floodplain Benching. Relocation of water main and stormwater pipe.	

The East Bessemer Avenue crossing on Muddy Creek consists of three 11 ft by 8 ft box culverts. The city-owned structure does not meet LOS. An improved crossing consisting of two 14 ft by 9 ft box culverts and two 14 ft x 8ft box culverts. The culverts will be placed 1 ft below the channel invert to allow for fish passage. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-10 NBC_MC_CULV_02 East Bessemer

East Bessemer Culvert 02	Muddy Creek	NBC_MC_CULV_02
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	(3) 11' x 8' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(2) 14' x 9', (2) 14' x 8' Box Culvert	
Prioritization Score	353.9	
Opinion of Probable Construction Cost	$5,097,000	
Notes/Comments	Tailwater issues from State-owned East Wendover Avenue crossing are present. Relocation of water main and stormwater pipe.	

6.1.5 Unnamed Tributary 2

The Phillips Avenue crossing on Unnamed Tributary 2 consists of one 15.5 ft by 5.1 ft box culvert. The city-owned structure does not meet LOS. The proposed alternative consists of three 18 ft by 6.5 ft box culverts placed 1 ft below the channel invert. Waterline conflicts were identified based on the available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-11 NBC_MC-UT2_CULV_01 Philips Avenue

Philips Avenue Culvert 01	Unnamed Tributary 2	NBC_MC-UT2_CULV_01
Summary	**Criteria/Result**	
Roadway Classification	Minor	
Existing Configuration	(1) 15.5' x 5.1' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(3) 18' x 6.5' Box Culvert	
Prioritization Score	328.2	
Opinion of Probable Construction Cost	$3,124,000	
Notes/Comments	Relocation of water main, overhead electric utility, and stormwater pipe.	

The completion of the Unnamed Tributary 2 floodplain benching project will mitigate the anticipated WSE increase for upstream primary system design alternatives and is intended to be completed in conjunction with those pertinent primary system design alternatives located at Textile Drive.

Table 6.1-12 NBC_MC-UT2_FB_01 Unnamed Tributary 2 Floodplain Benching

Unnamed Tributary 2 Floodplain Benching 01	**Unnamed Tributary 2**	**NBC_MC-UT2_FB_01**
Summary	**Criteria/Result**	
Existing Configuration	Existing grade	
LOS Requirement	Maintain WSEL	
Triggering Criteria	WSEL Increase	
Proposed Configuration	Floodplain benching	
Prioritization Score	Scored with upstream projects	
OPCC	$657,000	
Notes/Comments	Mitigates the anticipated WSEL increase for upstream primary system design alternative(s): NBC_MC-UT2_CULV_02	

Textile Drive is the most upstream structure modeled on Unnamed Tributary 2. The crossing consists of one 12 ft by 6 ft box culvert. The City-owned structure currently meets LOS for the NOAA rainfall events. However, it will not meet LOS once the preliminary floodway for Unnamed Tributary 2 becomes effective. Therefore, a proposed alternative consisting of three 10 ft by 7.5 ft box culverts was developed. The culverts will be placed 1 ft below the channel invert to maintain fish passage. Waterline conflicts were identified based on the available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-13 NBC_MC-UT2_CULV_02 Textile Drive

Textile Drive	**Unnamed Tributary 2**	**NBC_MC-UT2_CULV_02**
Summary	**Criteria/Result**	
Roadway Classification	Collector	
Existing Configuration	(1) 12' x 6' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(3) 10' x 7.5' Box Culvert	
Prioritization Score	327.2	
Opinion of Probable Construction Cost	$1,999,000	
Notes/Comments	5 buildings removed from the floodplain. The project is to be completed in conjunction with Tributary 2 Floodplain Benching. Relocation of water main and stormwater pipe.	

6.1.6 Philadelphia Lake

The completion of the Philadelphia Lake floodplain benching project will mitigate the anticipated WSE increase for upstream primary system design alternatives and is intended to be completed in conjunction with those pertinent primary system design alternatives located at East Cone Boulevard and Philadelphia Lake.

Table 6.1-14 NBC_PL_FB_01 Philadelphia Lake Floodplain Benching

Philadelphia Lake Floodplain Benching	Philadelphia Lake	NBC_PL_FB_01
Summary	**Criteria/Result**	
Existing Configuration	Existing grade	
LOS Requirement	Maintain WSEL	
Triggering Criteria	WSEL Increase	
Proposed Configuration	Floodplain benching	
Prioritization Score	Scored with upstream projects	
OPCC	$2,638,000	
Notes/Comments	Mitigates the anticipated WSEL increase for upstream primary system design alternative(s): NBC_PL_CULV_01	

The East Cone Boulevard crossing on Philadelphia Lake consists of three 13 ft by 7 ft box culverts. The city-owned structure currently meets LOS for the NOAA rainfall events. However, it will not meet LOS once the currently preliminary regulated floodway becomes effective. Therefore, an improved crossing consisting of three 17 ft by 9 ft box culverts has been proposed based on the future LOS requirements. The culverts will be placed 1 ft below the channel invert to allow for fish passage. Waterline conflicts were identified based on available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-15 NBC_PL_CULV_01 East Cone Boulevard

East Cone Boulevard	Philadelphia Lake	NBC_PL_CULV_01
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	(3) 13' x 7' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(3) 17' x 9' Box Culvert	
Prioritization Score	239.2	
Opinion of Probable Construction Cost	$6,464,000	
Notes/Comments	Tailwater issues are present. The project to be completed in conjunction with Philadelphia Lake Benching. Relocation of water main and overhead electric utility.	

The North Church Street crossing on Philadelphia Lake consists of three 10 ft by 7 ft box culverts. The crossing does not meet LOS. However, no alternatives were developed since it is state-owned.

6.1.7 North Buffalo Creek (North O'Henry to West Wendover)

The Summit Avenue crossing on North Buffalo Creek consists of an approximately 76 ft span bridge. The structure does not meet LOS but is state-owned, so no alternatives were developed.

The Fairview Street crossing on North Buffalo Creek consists of an approximately 79 ft span bridge. The City-owned structure does not meet LOS. However, the LOS issues are due to backwater from the downstream US 29 crossing and are not due to the capacity of the bridge opening. Therefore, the existing structure is considered sufficient, and no alternatives were developed.

The Yanceyville Street crossing on North Buffalo Creek consists of an approximately 90 ft span bridge. The City-owned crossing does not meet LOS. The proposed design alternative is a 140 ft span bridge. Waterline and sanitary sewer conflicts were identified based on available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-16 NBC_NBC2_BRG_01 Yanceyville Street

Yanceyville Street	**North Buffalo Creek**	**NBC_NBC2_BRG_01**
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	90' Span Bridge	
LOS Requirement	18" FB in 100-yr Event	
Triggering Criteria	< 18" FB in 100-yr Event	
Proposed Configuration	140' Span Bridge	
Prioritization Score	336.1	
Opinion of Probable Construction Cost	$13,064,000	
Notes/Comments	Relocation of sanitary sewer, water main, and stormwater pipe. New greenspace area created.	

The North Church Street crossing on North Buffalo Creek consists of an approximately 110 ft span bridge. The structure does not meet LOS but is owned by the state, so no alternatives were developed.

The North Elm Street crossing on North Buffalo Creek consists of an approximately 77 ft span bridge. The City-owned bridge does not meet LOS.

Table 6.1-17 NBC_NBC2_BRG_02 North Elm Street

North Elm Street	**North Buffalo Creek**	**NBC_NBC2_BRG_02**
Summary	**Criteria/Result**	
Existing Configuration	77' Span Bridge	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	312' Span Bridge	
Prioritization Score	342.1	
OPCC	$9,704,000	
Notes/Comments	Part of the previous North Buffalo Creek Watershed Study scope. Relocation of sanitary sewer, water main, and stormwater pipe.	

The Cridland Road crossing on North Buffalo Creek consists of an approximately 69 ft span bridge. The City-owned structure does not meet LOS.

Table 6.1-18 NBC_NBC2_BRG_03 Cridland Road

Cridland Road	**North Buffalo Creek**	**NBC_NBC2_BRG_03**
Summary	**Criteria/Result**	
Existing Configuration	69' Span Bridge	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	220' Span Bridge	
Prioritization Score	333.6	
OPCC	$4,797,000	
Notes/Comments	Part of the previous North Buffalo Creek Watershed Study scope. Relocation of sanitary sewer, water main, and stormwater pipe.	

The completion of the Latham Park floodplain benching project will decrease WSE throughout the park. This project is a stand along project that is not necessary to mitigate any upstream primary system design alternatives.

Table 6.1-19 NBC_NBC2_FB_01 Latham Park Floodplain Benching

Latham Park Floodplain Benching	**North Buffalo Creek**	**NBC_NBC2_FB_01**
Summary	Criteria/Result	
Existing Configuration	Existing grade	
Most Restrictive Upstream LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Upstream Project Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	Floodplain benching	
Prioritization Score	316.8	
OPCC	$13,505,000	
Notes/Comments	Part of the previous North Buffalo Creek Watershed Study scope. Project increases available floodplain storage within Latham Park. Due to site limitations, WSEL improvements are most significant for events <50-year. Relocation of sanitary sewer, water main, and stormwater pipe	

6.1.8 Unnamed Tributary 3

The Latham Road crossing on Unnamed Tributary 3 consists of two 9 ft by 5 ft box culverts. The City-owned structure does not meet LOS. The proposed structure consists of three 13 ft by 6 ft box culverts placed 1 ft below the channel invert to maintain fish passage. Waterline conflicts were identified based on the available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-20 NBC_NBC-UT3_CULV_01 Latham Road

Latham Road	**Unnamed Tributary 3**	**NBC_NBC-UT3_CULV_01**
Summary	**Criteria/Result**	
Roadway Classification	Collector	
Existing Configuration	(2) 9' x 5' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(3) 13' x 6' Box Culvert	
Prioritization Score	316.6	
Opinion of Probable Construction Cost	$2,845,000	
Notes/Comments	Tailwater issues from North Buffalo Creek are present. Relocation of water main and stormwater pipe.	

The Briarcliff Road crossing on Unnamed Tributary 3 consists of two 8 ft by 5 ft box culverts. The City-owned crossing currently meets LOS for NOAA rainfall events. However, the structure will not meet LOS once the preliminary floodway becomes effective. Therefore, three 8 ft by 6 ft box culverts were proposed as an alternative based on the future LOS requirements. The culverts will be placed 1 ft below the channel invert to allow for fish passage. Waterline and sanitary sewer conflicts were identified based on the available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-21 NBC-UT3_CULV_02 Briarcliff Road

Briarcliff Road	**Unnamed Tributary 3**	**NBC_NBC-UT3_CULV_02**
Summary	**Criteria/Result**	
Roadway Classification	Residential	
Existing Configuration	(2) 8' x 5' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(3) 8' x 6' Box Culvert	
Prioritization Score	187.1	
Opinion of Probable Construction Cost	$2,451,000	
Notes/Comments	Tailwater issues from North Buffalo Creek are present. Relocation of sanitary sewer, water main, and stormwater pipe.	

Cleburne Street is the most upstream modeled crossing on Unnamed Tributary 3. The City-owned crossing consists of one 8.5 ft by 4 ft box culvert and does not meet LOS. The proposed alternative consists of two 12 ft by 4 ft box culverts and one 12 ft by 5 ft culvert placed with its invert 1 ft lower than the other two culverts. Due to bedrock channel in this area, the 12 ft by 5 ft culvert may be buried at a depth less than 1 ft below the existing channel invert for fish passage. Waterline, sanitary sewer, and underground electrical conflicts were identified based on the available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-22 NBC-UT3_CULV_03 Cleburne Street

Cleburne Street	**Unnamed Tributary 3**	**NBC_NBC-UT3_CULV_03**
Summary	**Criteria/Result**	
Roadway Classification	Collector	
Existing Configuration	(1) 8.5' x 4' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(1) 12' x 5', (2) 12' x 4' Box Culvert	
Prioritization Score	238.8	
Opinion of Probable Construction Cost	$4,000,000	
Notes/Comments	Tailwater issues are present and are to be addressed with local channel widening. Relocation of sanitary sewer, water main, and stormwater pipe.	

6.1.9 Unnamed Tributary

The Hill Street crossing on Unnamed Tributary consists of two 10 ft by 5.5 ft box culverts. The City-owned crossing does not meet LOS. The proposed alternative consists of two 12 ft by 5.5 ft box culverts placed at the channel invert and two 12 ft by 6.5 ft culverts placed 1 ft below the channel invert to maintain fish passage. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-23 NBC_NBC-UT_CULV_01 Hill Street

Hill Street	**Unnamed Tributary**	**NBC_NBC-UT_CULV_01**
Summary	**Criteria/Result**	
Roadway Classification	Collector	
Existing Configuration	(2) 10' x 5.5' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(2) 12' x 6.5', (2) 12' x 5.5' Box Culvert	
Prioritization Score	267.8	
Opinion of Probable Construction Cost	$3,568,000	
Notes/Comments	Backwater from North Buffalo Creek impacts structure. Relocation of stormwater pipe.	

The West Smith Street crossing on Unnamed Tributary consists of two 8.5 ft by 5.5 ft box culverts. The City-owned structure does not meet LOS. The proposed alternative consists of four 10 ft by 6.5 ft box culverts placed 1 ft below the channel invert to maintain fish passage. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-24 NBC_NBC-UT_CULV_02 West Smith Street

West Smith Street	Unnamed Tributary	NBC_NBC-UT_CULV_02
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	(2) 8.5' x 5.5' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(4) 10' x 6.5' Box Culvert	
Prioritization Score	346.8	
Opinion of Probable Construction Cost	$3,637,000	
Notes/Comments	Tailwater issues are present. Relocation of stormwater pipe.	

The Guilford Drive crossing on Unnamed Tributary consists of one 10 ft by 4 ft box culvert. The City-owned structure does not meet LOS. The proposed alternative consists of three 20 ft by 5 ft box culverts placed 1 ft below the channel invert to allow for fish passage. Waterline and sanitary sewer conflicts were identified based on available City GIS data, and two buildings located over the existing culvert will be purchased and demolished during the culvert replacement. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-25 NBC_NBC-UT_CULV_03 Guilford Avenue

Guilford Avenue	Unnamed Tributary	NBC_NBC-UT_CULV_03
Summary	**Criteria/Result**	
Roadway Classification	Collector	
Existing Configuration	(1) 10' x 4' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(3) 20' x 5' Box Culvert	
Prioritization Score	239.0	
Opinion of Probable Construction Cost	$13,832,000	
Notes/Comments	Tailwater issues are present due to lack of downstream channel conveyance. Relocation of sanitary sewer, water main, and stormwater pipe.	

The West Market Street crossing on Unnamed Tributary consists of one 10 ft by 5 ft box culvert, The crossing currently meets LOS for the NOAA rainfall events but will not meet LOS once the preliminary floodway becomes effective. However, no alternatives were developed since the structure is state-owned.

6.1.10 Unnamed Tributary 4

The Fairmont Street crossing on Unnamed Tributary 4 consists of an approximately 56 ft span bridge. The City-owned structure does not meet LOS due to backwater from North Buffalo Creek. The existing structure has sufficient capacity to meet LOS without backwater from North Buffalo Creek, so no alternatives were developed.

The West Friendly Avenue crossing on Unnamed Tributary 4 consists of two 10 ft by 6 ft box culverts. The City-owned structure currently meets LOS for the NOAA rainfall events. However, it will not meet LOS

once the preliminary floodway becomes effective. The proposed structure consists of four 14 ft by 7 ft box culverts placed 1 ft below the channel invert. Waterline conflicts were identified based on the available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-26 NBC_NBC-UT4_CULV_01 West Friendly Avenue

West Friendly Avenue	**Unnamed Tributary 4**	**NBC_NBC-UT4_CULV_01**
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	(2) 10' x 6' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(4) 14' x 7' Box Culvert	
Prioritization Score	360.6	
Opinion of Probable Construction Cost	$3,765,000	
Notes/Comments	Backwater from North Buffalo Creek creates tailwater at this crossing.	

The West Market Street crossing on Unnamed Tributary 4 consists of one 12 ft by 6 ft box culvert. The structure does not meet LOS. However, no alternatives were developed since it is state-owned.

South Josephine Boyd Street is the most upstream culvert modeled on Unnamed Tributary 4. The City-owned structure consists of one 9 ft by 6 ft box culvert. The structure currently meets LOS for the NOAA rainfall events but will not meet LOS once the preliminary floodway becomes effective. The proposed alternative for this structure consists of four 12 ft by 8 ft box culverts placed 1 ft below the channel invert to maintain fish passage. Waterline and sanitary sewer conflicts were identified based on the available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-27 NBC_NBC-UT4_CULV_02 South Josephine Boyd Street

South Josephine Boyd Street	**Unnamed Tributary 4**	**NBC_NBC-UT4_CULV_02**
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	(1) 9' x 6' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(4) 12' x 8' Box Culvert	
Prioritization Score	348.0	
Opinion of Probable Construction Cost	$6,179,000	
Notes/Comments	Eliminates overtopping of roadways and removes building from floodplain.	

6.1.11 North Buffalo Creek (West Wendover to South Holden)

The North Elam Avenue crossing on North Buffalo Creek consists of a 57 ft span bridge. The City-owned structure does not meet LOS because it does not have enough freeboard. No alternatives were developed based on direction from the City during the initial prioritization meeting.

A ramp to West Wendover Avenue crosses North Buffalo Creek on two 12 ft by 9 ft box culverts. The structure does not meet LOS but is state-owned, so no alternatives were developed.

The West Market Street crossing on North Buffalo Creek consists of an approximately 35 ft span bridge. The structure does not meet LOS but is state-owned. So, no alternatives were developed.

A West Wendover Avenue crossing on North Buffalo Creek consists of one 10 ft by 7 ft box culvert. The structure does not meet LOS but is state-owned, so no alternatives were developed.

A West Wendover Avenue crossing on North Buffalo Creek consists of one 6.36 ft by 6 ft box culvert. The structure does not meet LOS but is state-owned, so no alternatives were developed.

A ramp to West Wendover Avenue crosses North Buffalo Creek on a single 9 ft by 5 ft box culvert. The crossing does not meet LOS but is state-owned, so no alternatives were developed.

A West Wendover Avenue crossing on North Buffalo Creek consists of an approximately 126 ft span bridge. The state-owned structure does not meet LOS, but no alternatives were developed since it is owned by the state.

The Hill Street crossing on North Buffalo Creek consists of an approximately 87 ft span bridge. The city-owned structure does not meet LOS because it does not have enough freeboard. No alternatives were developed based on direction from the city during the initial prioritization meeting.

The Battleground Avenue crossing on North Buffalo Creek consists of an approximately 49 ft span bridge. The city-owned structure does not meet LOS. The proposed alternative consists of a 160 ft span bridge. Waterline and sanitary sewer conflicts were identified based on available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-28 NBC_NBC3_BRG_01 Battleground Avenue

Battleground Avenue	**North Buffalo Creek**	**NBC_NBC3_BRG_01**
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	49' Span Bridge	
LOS Requirement	18" FB in 100-yr Event	
Triggering Criteria	< 18" FB in 100-yr Event	
Proposed Configuration	160' Span Bridge	
Prioritization Score	319.0	
Opinion of Probable Construction Cost	$6,472,000	
Notes/Comments	Tailwater issues are present due to downstream channel depth. Utility relocations necessary.	

The West Smith Street crossing on North Buffalo Creek consists of an approximately 75 ft span bridge. The City-owned structure does not meet LOS. The proposed design alternative consists of a 115 ft bridge. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-29 NBC_NBC3_BRG_02 West Smith Street

West Smith Street	North Buffalo Creek	NBC_NBC3_BRG_02
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	75' Span Bridge	
LOS Requirement	18" FB in 100-yr Event	
Triggering Criteria	< 18" FB in 100-yr Event	
Proposed Configuration	115' Span Bridge	
Prioritization Score	354.2	
Opinion of Probable Construction Cost	$4,762,000	
Notes/Comments	Tailwater issues are present due to downstream channel depth. Relocation of stormwater pipe and overhead electric utility.	

The Garland Drive crossing on North Buffalo Creek consists of an arch bridge with four 14 ft openings and one 50 ft opening. The City-owned structure does not meet LOS because it does not have enough freeboard. No alternatives were developed based on direction from the City during the initial prioritization meeting.

The North Josephine Boyd Street crossing on North Buffalo Creek consists of an 85 ft span bridge. The City-owned structure does not meet LOS because it does not have enough freeboard. No alternatives were developed based on direction from the City during the initial prioritization meeting.

The South Holden Road crossing is the most upstream crossing modeled on North Buffalo Creek. The state-owned crossing consists of one 10 ft by 6.4 ft box culvert. The structure does not meet LOS, but no alternatives were developed since it is state-owned.

6.1.12 Tributary A

All crossings meet LOS for the NOAA rainfall events.

6.1.13 Unnamed Tributary 5

The Pembroke Road crossing consists of two 11.6 ft by 5.45 ft box culverts. The City-owned structure does not meet LOS because it does not have enough freeboard. No alternatives were developed based on direction from the City during the initial prioritization meeting.

6.1.14 Lake Hamilton

The West Market Street crossing on Lake Hamilton is a state-owned road crossing. The crossing consists of two 10 ft by 6 ft box culverts and does not meet LOS. Since the road is owned by the state, no alternatives were developed.

The completion of the Lake Hamilton floodplain benching project will mitigate the anticipated WSE increase for upstream primary system design alternatives and is intended to be completed in conjunction with those pertinent primary system design alternatives located at at North Holden Road and Lake Hamilton.

Table 6.1-30 NBC_LH_FB_01 Lake Hamilton Floodplain Benching

Lake Hamilton Floodplain Benching	Lake Hamilton	NBC_LH_FB_01
Summary	**Criteria/Result**	
Existing Configuration	Existing grade	
Most Restrictive Upstream LOS Requirement	Maintain WSEL	
Upstream Project Triggering Criteria	WSEL Increase	
Proposed Configuration	Floodplain benching	
Prioritization Score	Scored with upstream projects	
OPCC	$7,675,000	
Notes/Comments	Mitigates the anticipated WSEL increase for upstream primary system design alternative(s); NBC_LH_CULV_01	

The North Holden Road crossing on Lake Hamilton consists of two 11.7 ft by 6 ft box culverts. This structure currently meets LOS for the NOAA events. However, if current preliminary FEMA maps become effective and floodway is mapped on Lake Hamilton, the structure will be evaluated against the 100-year flood elevations and will no longer meet LOS. Therefore, an alternative was developed for this structure. The proposed crossing consists of three 12 ft by 7 ft box culverts placed 1 ft below the channel invert to allow for fish passage. Waterline conflicts were identified based on available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.1-31 NBC_LH_CULV_01 North Holden Road

North Holden Road	Lake Hamilton	NBC_LH_CULV_01
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	(2) 11.7' x 6' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(3) 12' x 7' Box Culvert	
Prioritization Score	226.5	
Opinion of Probable Construction Cost	$3,873,000	
Notes/Comments	To be completed in conjunction with the Lake Hamilton Floodplain Benching project. Relocation of sanitary sewer, water main, and stormwater pipe.	

6.1.15 Unnamed Tributary 6

All crossings meet LOS for the NOAA rainfall events.

6.2 Culvert Condition Assessment Projects

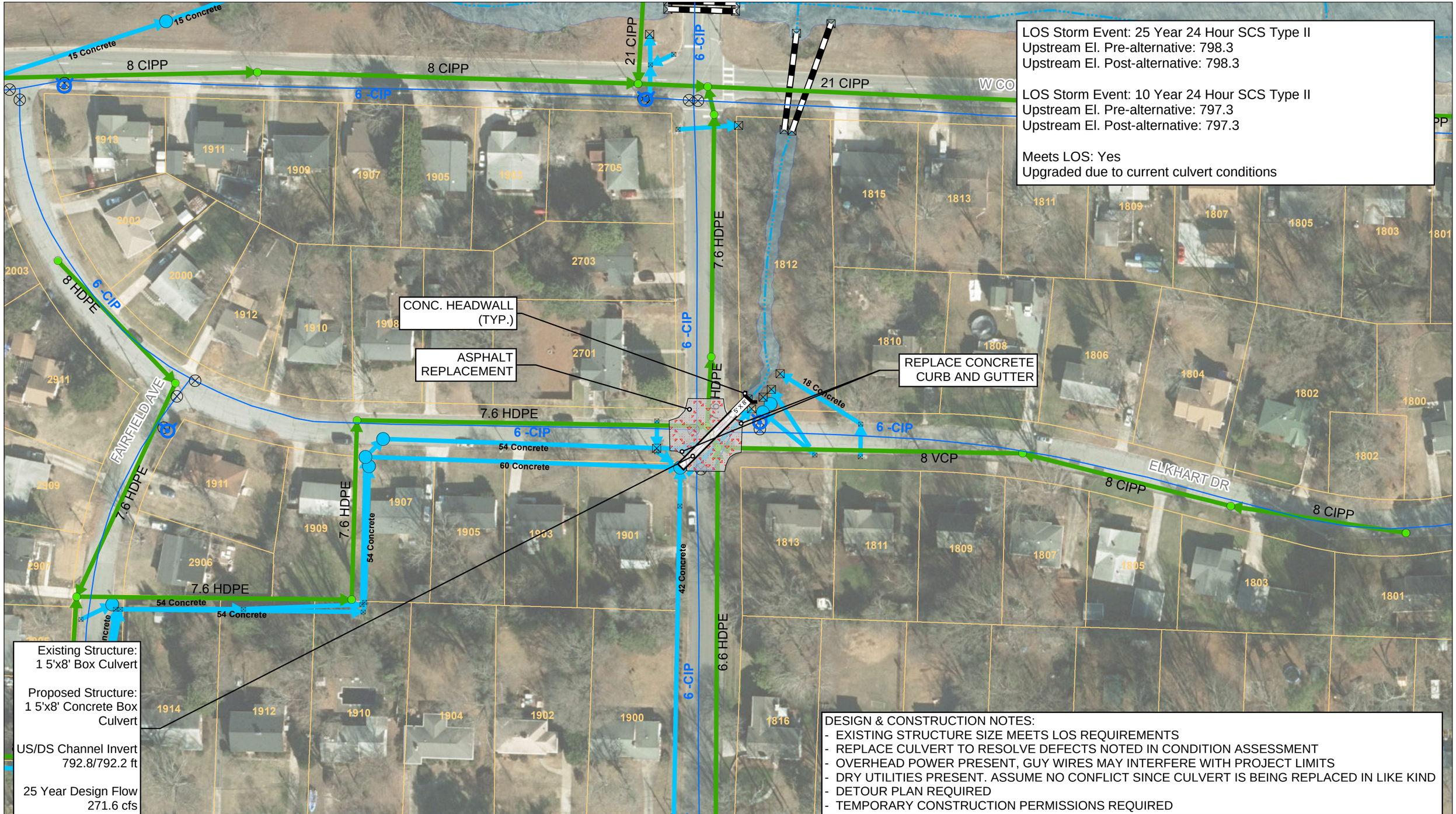
Starting in 2020, the City is working with other firms to inspect approximately 600 locations city-wide to evaluate overall culvert condition and identify structural problems. Stantec reviewed the culvert inspection report and associated geodatabase (provided by the City) for culverts within the NBC watershed. The data was analyzed to identify culverts with a structural defect grade of 3, 4, or 5; of these

culverts only defect grade 5 were scoped to be evaluated for a potential project if not already being evaluated as part of a Primary or Secondary System. In NBC, a total of 42 culverts met the structural defect grade for project evaluation: 40 with a defect code rating of 3, zero code 4, and two with a defect code rating of 5.

Of the two (2) defect code 5 projects, one crossing was located within a secondary system model. This location was modeled within PCSWMM as part of the secondary system.

The remaining culvert was as modeled in HY-8 Culvert Hydraulic Analysis Program using the reported dimensions and inverts. The hydrologic analysis was performed in HEC-HMS using the same data as the Primary System hydrologic analysis. The resulting flows were input into HY-8, where the design flow was set to the 25-year storm. This location was found to meet LOS in existing conditions; therefore, replacement of the culvert in-kind was developed.

Copies of the HY-8 model have been provided digitally in Appendix J. The conceptual figure is shown below in Figure 6-2 and included in Appendix E while the fact sheets are included in Appendix H, OPCC in Appendix F, and prioritization in Appendix G.



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LOS Deficient Locations

Priority
- High
- Medium
- Low
- Hydrants
- Water Valves

Water Mains
- 4-8"
- 10-27"
- 30"
- 36-60"
- Sewer Manhole
- Sewer Gravity

- Culvert
- StormMH
- Storm Pipe
- Storm Channels
- SCS II 1-Percent Annual Chance

N

0 50 100 Feet
(At original document size of 11x17)
1:1,000

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title
Culvert Conditions Assessment - Elkhart Drive and Dellwood Drive

File Name:
NBC_PL_CULV_CON_01

Project Location:
City of Greensboro, Guilford County, North Carolina

Date:
9/21/2023

Prepared by BN on 2023-07-19
Reviewed by MIA on 2023-09-07
Updated by AJB on 2023-09-20

Sheet No.
Figure 6-2

6.3 Previous CIP Projects

Stantec was provided a GIS database of stormwater projects which the City had already programmed for the next several years. The project scope included evaluation of City CIP projects in the same manner that similar projects were being evaluated within the SWMP scope. In the case of NBC, twenty-one CIPs were identified within the watershed. Table 6.3-1 below presents the CIP projects, their SWMP inclusion status, and the resulting SWMP Project Number/Name, if applicable.

Table 6.3-1 NBC Capital Improvement Projects

CIP ID	CIP Project Title	Project Category	NBC SWMP Incorporation	NBC SWMP Number	NBC SWMP Name
576	Green Street Water Garden	BMPs	Not incorporated into modeling because not along a primary stream or within the footprint of a secondary model. Impacts to 1%-annual-chance event are not anticipated.		
628	401 W Avondale Flood Hazard Minimization	Flood Damage Prevention	Not incorporated into modeling. Secondary model was provided to project consultant and was utilized for project design.		
629	1601 Roseland	Flood Damage Prevention	Not incorporated into modeling because not along a primary stream or within the footprint of a secondary model. Impacts to 1%-annual-chance event are not anticipated.		
630	1105 Latham Rd	Flood Damage Prevention	Not incorporated into modeling because not along a primary stream or within the footprint of a secondary model. Impacts to 1%-annual-chance event are not anticipated.		
635	Martin Avenue Culvert Replacement	Culverts and Bridges	Martin Avenue culvert has been assessed as part of Jordan Branch primary system alternatives.	NBC_JB_CULV_01	Jordan Branch - Martin Avenue
642	Downtown Greenway Phase 4 Storm Drainage Improvements	Pipe Systems	Not incorporated into modeling because not along a primary stream or within the footprint of a secondary model. Impacts to 1%-annual-chance event are not anticipated.		
662	Arboretum Stream Restoration Project	Stream Restoration	Incorporating the as-built terrain data did not impact the LOS of any road crossings and had no impacts on any of the proposed alternatives; therefore, the as-built terrain was not incorporated into the modeling.		
664	Woodmere Stream bank stabilization	Stream Restoration	Has been assessed as an asset/bank stabilization project.	NBC_MC_BEHI_01	Autumn Drive Streambank Stabilization

CIP ID	CIP Project Title	Project Category	NBC SWMP Incorporation	NBC SWMP Number	NBC SWMP Name
665	College Park Stream Stabilization	Stream Restoration	Has been assessed as an asset/bank stabilization project.	NBC-UT4_BEHI_02	Mayflower Drive Streambank Stabilization
666	Latham Park Stream Stabilization	Stream Restoration	Has been assessed as a floodplain benching project.	NBC_LH_FB_01	Latham Park Floodplain Benching
667	Downtown Greenway Phase 4 Stream Stabilization	Stream Restoration	Stantec did not assess LOS of the designed stream crossings (3 culverts & 1 bridge) because they are all greenway crossings; no City LOS criteria.		
670	Revolution Mill Stream Restoration	Stream Restoration	Not incorporated into modeling because the benefit gained by the floodplain benches was offset by the new boardwalk installed through the existing railroad bridge.		
674	Lake Daniel/North Buffalo Stream Bank Stabilization	Stream Restoration	Not incorporated into the modeling because Stantec confirmed that the improvements had no measurable impact on results of the LOS design event (1%-annual-chance).		
691	Cody - Voss Basin WQ BMP / Stream Alignment	BMPs	Not incorporated into the modeling because the project has not been constructed. Stantec reviewed the design documents and confirmed that the proposed design meets the required preliminary FIRMs LOS.		
728	Windshield Glass Outfall	Pipe Systems	Not incorporated into modeling because not along a primary stream or within the footprint of a secondary model. Impacts to 1%-annual-chance event are not anticipated.		
729	Fairview Wetland Pond	BMPs	Not incorporated into modeling because not along a primary stream or within the footprint of a secondary model. Impacts to 1%-annual-chance event are not anticipated.		
730	Chapman Street Storm Outfall Improvements	Pipe Systems	Not incorporated into modeling because not along a primary stream or within the footprint of a secondary model. Impacts to 1%-annual-chance event are not anticipated.		
731	Green Valley Stream Restoration	Stream Restoration	Has been assessed as an asset/bank stabilization project.	NBC3_BEHI_05	Green Valley Road Streambank Stabilization

CIP ID	CIP Project Title	Project Category	NBC SWMP Incorporation	NBC SWMP Number	NBC SWMP Name
732	Shady Lawn Storm Outfall Upgrade	Pipe Systems	Not incorporated into the modeling because the project has not been constructed. Stantec incorporated the design into a copy of the secondary model and confirmed that the proposed structures meet the City LOS.		
-8888	Prescott Street	Pipe Systems	Not incorporated into modeling because not along a primary stream or within the footprint of a secondary model. Impacts to 1%-annual-chance event are not anticipated after discussions with the design engineer.		
-8888	Rev Mill Trestle Removal	Stream Restoration	Not incorporated into modeling because the benefit gained by the trestle removal was offset by the new boardwalk installed through the existing railroad bridge.		

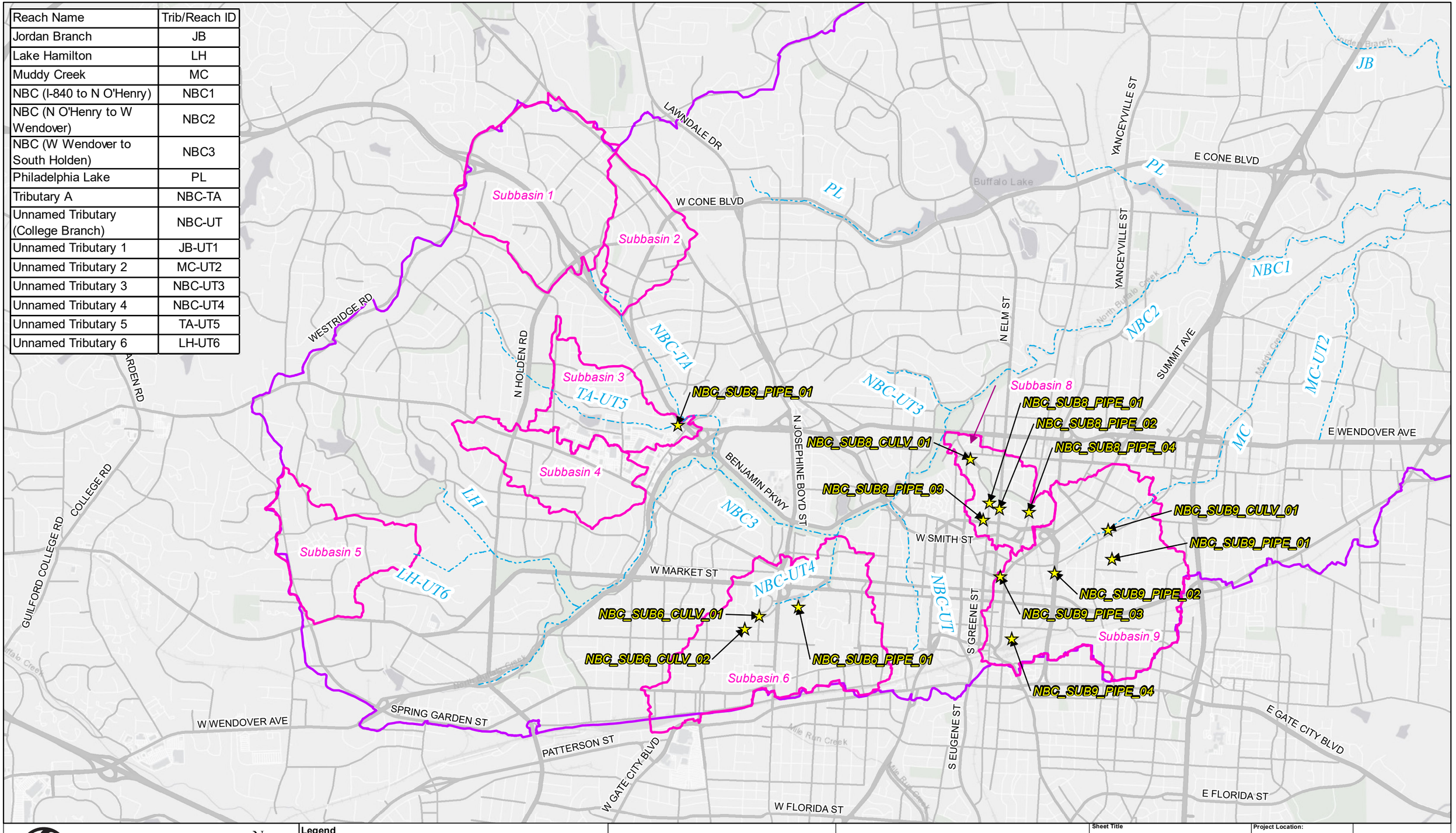
6.4 Secondary System Projects

Secondary System alternatives typically involve increasing conveyance capacity through larger pipe sizes, additional barrels, or alternative routes for stormwater conveyance to enhance overall system capacity. Similar to the Primary System, Secondary Systems face constraints such as private property encroachment, utility conflicts, and spatial limitations.

Detailed information, including existing system performance, system modeling limits, and explanations for detailed modeling, is provided in Section 4.8. The development of these alternatives aims to mitigate pipe surcharging during the 10-year storm event and mitigate surface flooding in the 25-year event. The pipes not meeting the required LOS were identified using the 10- and 25-year NOAA 3rd Quartile Atlas 14 Volume 2, 6-hour 10% distribution storm events. Similar to the Primary System, the proposed improvements address those pipes with LOS deficiencies and meet the LOS in the 10- and 25-year SCS Type II storm events. LOS deficiencies were not identified within Subbasins 1, 2, 4, and 5

The following sections provide details about each project and recommended alternatives. Figure 6-3 shows the location of the Secondary System projects; polygons represent the system analyzed and projects are located within the polygon areas. Conceptual figures are included in Appendix E and fact sheets are included in Appendix H to illustrate the proposed projects.

Reach Name	Trib/Reach ID
Jordan Branch	JB
Lake Hamilton	LH
Muddy Creek	MC
NBC (I-840 to N O'Henry)	NBC1
NBC (N O'Henry to W Wendover)	NBC2
NBC (W Wendover to South Holden)	NBC3
Philadelphia Lake	PL
Tributary A	NBC-TA
Unnamed Tributary (College Branch)	NBC-UT
Unnamed Tributary 1	JB-UT1
Unnamed Tributary 2	MC-UT2
Unnamed Tributary 3	NBC-UT3
Unnamed Tributary 4	NBC-UT4
Unnamed Tributary 5	TA-UT5
Unnamed Tributary 6	LH-UT6



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N

Legend
- Primary Streams
- Secondary Alternatives
- Secondary System Boundaries
- Watershed Boundary

0 1,500 3,000 6,000 Feet

(At original document size of 11x17)
1:36,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title
Secondary System Project Location Map

Project Location:
City of Greensboro, Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date:
08/05/2024

Sheet No.
Figure 6-3

6.4.1 Subbasin 3

Benjamin Parkway project alternative involves replacing a section of 18 in diameter concrete pipe discharging to a channel near the intersection of Benjamin Parkway and Green Valley Road. The upstream storm sewer system consists of 24 in diameter pipes, so the project pipe is being upsized to 24 in diameter concrete pipe. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.4-1 NBC_SUB3_PIPE_01 Benjamin Parkway

Benjamin Parkway	**Subbasin 3**	**NBC_SUB3_PIPE_01**
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	18" Pipe	
LOS Requirement	10-year event within the pipe (no pressurized flow)	
Triggering Criteria	< 10-year event within the pipe (no pressurized flow)	
Proposed Configuration	24" Pipe	
Prioritization Score	167.5	
OPCC	$831,000	
Notes/Comments	Upgrade existing stormwater pipe capacity with no utility relocation.	

6.4.2 Subbasin 6

Mayflower Drive project alternative involves upsizing and realigning the existing 7 ft by 4 ft box culvert under Mayflower Drive. The proposed structure consists of two 8 ft by 5.5 ft box culverts. The two culverts will be set 1 ft below the channel grade to allow for fish passage. The new alignment of the culverts will require adjustments to the storm sewer pipes connecting into the existing culvert. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.4-2 NBC_SUB6_CULV_01 Mayflower Drive

Mayflower Drive	**Subbasin 6**	**NBC_SUB6_CULV_01**
Summary	**Criteria/Result**	
Roadway Classification	Collector	
Existing Configuration	(1) 7' x 4' Box Culvert	
LOS Requirement	18" FB in 50-yr Event, HW/D < 1.2	
Triggering Criteria	< 18" FB in 50-yr Event, HW/D > 1.2	
Proposed Configuration	(2) 8' x 5.5' Box Culvert	
Prioritization Score	330.1	
OPCC	$1,658,000	
Notes/Comments	Relocation of sanitary sewer and stormwater pipe.	

Warren Street & Wright Avenue project alternative involves upsizing the existing 7’ by 4’ box culvert under the intersection of Warren Street and Wright Avenue. The proposed structure consists of two 8 ft by 5.5 ft box culverts and will be placed 1 ft below the channel invert to allow for fish passage. Conflicts were

identified between the proposed structure and existing waterlines, an existing fire hydrant, and storm sewer pipes connecting into the culvert based on available city GIS data. Adjustments to the conflicting infrastructure are shown in the alternative figure. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.4-3 NBC_SUB6_CULV_02 Warren Street/Wright Avenue

Warren Street/Wright Avenue	**Subbasin 6**	**NBC_SUB6_CULV_02**
Summary	**Criteria/Result**	
Roadway Classification	Residential	
Existing Configuration	(1) 7' x 4' Box Culvert	
LOS Requirement	25-year event below surface (grate/rim, etc.)	
Triggering Criteria	25-year event above surface (grate/rim, etc.)	
Proposed Configuration	(2) 8' x 5.5' Box Culvert	
Prioritization Score	302.1	
OPCC	$1,971,000	
Notes/Comments	Relocation water main and stormwater pipe.	

Storm Sewer Area 1 project alternative involves upsizing approximately 24 linear feet of 48 in concrete pipe north of the University of North Carolina Greensboro athletic fields. The existing pipe is being replaced with 78 in Reinforced Concrete Pipe (RCP). See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.4-4 NBC_SUB6_PIPE_01 Storm Sewer Area 1

Storm Sewer Area 1	**Subbasin 6**	**NBC_SUB6_PIPE_01**
Summary	**Criteria/Result**	
Roadway Classification	N/A	
Existing Configuration	48" Concrete Pipe	
LOS Requirement	10-year event within the pipe (no pressurized flow)	
Triggering Criteria	< 10-year event within the pipe (no pressurized flow)	
Proposed Configuration	78" Concrete Pipe	
Prioritization Score	223.0	
OPCC	$514,000	
Notes/Comments	Upgrade existing stormwater pipe capacity with no utility relocation.	

6.4.3 Subbasin 8

Parkway Steet project alternative involves replacement of various stormwater pipes and box culverts with larger capacity box culverts. The proposed starts at Fisher Park Circle and extends downstream to W Bessemer Avenue. See alternative figure for other information on conflicts, easements, or other design notes

Table 6.4-5 NBC_SUB8_CULV_01 Parkway Street

Parkway Street	**Subbasin 8**	**NBC_SUB8_CULV_01**
Summary	**Criteria/Result**	
Roadway Classification	Collector	
Existing Configuration	Various Box Culvert Sizes and 72" Pipe	
LOS Requirement	10-year event within the pipe (no pressurized flow)	
Triggering Criteria	< 10-year event within the pipe (no pressurized flow)	
Proposed Configuration	Various Box Culvert Sizes	
Prioritization Score	283.6	
OPCC	$9,902,000	
Notes/Comments	Upgrade existing culvert capacity and replace stormwater pipe with box culvert where applicable. Relocation of sanitary sewer, water main, and stormwater pipe.	

Florence Street project alternative involves upsizing approximately 512 linear ft of pipe near the intersection of Florence Street and Fisher Park Circle to 30 in RCP. The pipe extends under the intersection and overhead power line poles and a communications pedestal may be in conflict. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.4-6 NBC_SUB8_PIPE_01 Florence Street

Florence Street	**Subbasin 8**	**NBC_SUB8_PIPE_01**
Summary	**Criteria/Result**	
Roadway Classification	Residential	
Existing Configuration	15" and 24" Pipe	
LOS Requirement	10-year event within the pipe (no pressurized flow)	
Triggering Criteria	< 10-year event within the pipe (no pressurized flow)	
Proposed Configuration	30" Concrete Pipe	
Prioritization Score	259.4	
OPCC	$626,000	
Notes/Comments	Upgrade existing stormwater pipe capacity with no utility relocation.	

North Elm Street project alternative involves upsizing approximately 130 linear feet of 30 in. pipe under North Elm Street to 48 in. RCP. There is approximately 15 in. of clearance between the proposed storm pipe and the existing sanitary sewer based on available City GIS data. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.4-7 NBC_SUB8_PIPE_02 North Elm Street

North Elm Street	**Subbasin 8**	**NBC_SUB8_PIPE_02**
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	30" Pipe	
LOS Requirement	10-year event within the pipe (no pressurized flow)	
Triggering Criteria	< 10-year event within the pipe (no pressurized flow)	
Proposed Configuration	48" Concrete Pipe	
Prioritization Score	228.2	
OPCC	$314,000	
Notes/Comments	Upgrade existing stormwater pipe capacity with no utility relocation.	

West Fisher Avenue project alternative involves upsizing approximately 265 linear feet of pipe near the intersection of West Fisher Avenue and North Greene Street to 24 in RCP. The proposed pipe extends under West Fisher Avenue and may need adjustments to the inverts and slopes to avoid conflict with the existing 30 in PCCP waterline. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.4-8 NBC_SUB8_PIPE_03 West Fisher Avenue

West Fisher Avenue	**Subbasin 8**	**NBC_SUB8_PIPE_03**
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	15" and 18" Pipe	
LOS Requirement	10-year event within the pipe (no pressurized flow)	
Triggering Criteria	< 10-year event within the pipe (no pressurized flow)	
Proposed Configuration	24" Pipe	
Prioritization Score	216.2	
OPCC	$336,000	
Notes/Comments	Upgrade existing stormwater pipe capacity with no utility relocation.	

Railroad & Church Street project alternative involves upsizing approximately 465 linear feet of pipe near North Church Street and Leftwich Street. The proposed design consists of a 65 ft section of 36 in RCP under the railroad and approximately 400 ft of 36 in RCP draining away from the railroad and under North Church Street. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.4-9 NBC_SUB8_PIPE_04 Church Street

Church Street	**Subbasin 8**	**NBC_SUB8_PIPE_04**
Summary	**Criteria/Result**	
Roadway Classification	Minor	
Existing Configuration	24" Pipe	
LOS Requirement	10-year event within the pipe (no pressurized flow)	
Triggering Criteria	< 10-year event within the pipe (no pressurized flow)	
Proposed Configuration	36" Concrete Pipe	
Prioritization Score	268.8	
OPCC	$717,000	
Notes/Comments	Upgrade existing stormwater pipe capacity with no utility relocation.	

6.4.4 Subbasin 9

Baseball Field Culvert design alternative involves upsizing the existing 12 ft by 5 ft box culvert under World War Memorial Stadium near Yanceyville Street and East Lindsay Avenue. The proposed design consists of two 13 ft by 7.5 ft box culverts placed 1 ft below the channel invert to allow for fish passage. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.4-10 NBC_SUB9_CULV_01 Baseball Field

Baseball Field	**Subbasin 9**	**NBC_SUB9_CULV_01**
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	(1) 12' x 5' Box Culvert	
LOS Requirement	18" FB in 100-yr Event, HW/D < 1.2	
Triggering Criteria	<18" FB in 100-yr Event, HW/D > 1.2	
Proposed Configuration	(2) 13' x 7.5' Box Culvert	
Prioritization Score	377.4	
OPCC	$2,840,000	
Notes / Comments	This culvert is along Muddy Creek (primary system) but does not have a Primary LOS requirement because it is not a roadway crossing. Therefore, this culvert replacement was developed using Secondary system LOS requirements.	

Salem & Stewart design alternative involves diverting flow to a new 24 in and 36 in RCP storm sewer pipeline. The existing 18 in pipe discharging to an open channel north of Salem Street between Banks Street and Stewart Street will be abandoned in place with flowable fill. The proposed pipeline extends east along Salem Street then north along Stewart Street where it discharges to Muddy Creek. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.4-11 NBC_SUB9_PIPE_01 Salem and Stewart

Salem and Stewart	**Subbasin 9**	**NBC_SUB9_PIPE_01**
Summary	**Criteria/Result**	
Roadway Classification	Residential	
Existing Configuration	18" Pipe	
LOS Requirement	10-year event within the pipe (no pressurized flow)	
Triggering Criteria	< 10-year event within the pipe (no pressurized flow)	
Proposed Configuration	24" Concrete Pipe	
Prioritization Score	245.0	
OPCC	$1,458,000	
Notes/Comments	Upgrade existing stormwater pipe capacity with no utility relocation.	

North Morrow Boulevard design alternative involves open trench removal and replacement of a portion of the existing stormwater system near East Washington Street. The existing pipe will be upgraded to a larger pipe in addition to the installation of new stormwater system structures. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.4-12 NBC_SUB9_PIPE_02 North Morrow

North Morrow	**Subbasin 9**	**NBC_SUB9_PIPE_02**
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	18" Pipe	
LOS Requirement	25-year event below surface (grate/rim, etc.)	
Triggering Criteria	25-year event above surface (grate/rim, etc.)	
Proposed Configuration	30" Concrete Pipe	
Prioritization Score	227.1	
OPCC	$211,000	
Notes/Comments	Upgrade existing stormwater pipe capacity with no utility relocation.	

Bellemeade Street design alternative involves replacing an inlet and connection pipe along Bellemeade Street between North Elm Street and North Davie Street. The existing 15 in connection pipe will be abandoned in place and the proposed 15 in RCP pipe will connect into the storm sewer system at a downstream location to improve performance and reduce costs. See alternative figure for other information on conflicts, easements, or other design notes

Table 6.4-13 NBC_SUB9_PIPE_03 Bellemeade Street

Bellemeade Street	**Subbasin 9**	**NBC_SUB9_PIPE_03**
Summary	**Criteria/Result**	
Roadway Classification	Major	
Existing Configuration	15" Pipe	
LOS Requirement	10-year event within the pipe (no pressurized flow)	
Triggering Criteria	< 10-year event within the pipe (no pressurized flow)	
Proposed Configuration	Additional Inlet	
Prioritization Score	214.8	
OPCC	$69,000	
Notes/Comments	Construct new inlet, no utility relocation required.	

East Washington Street design alternative involves upsizing approximately 425 linear feet of 15 in pipe to 18 in RCP near East Washington Street and South Davie Street. See alternative figure for other information on conflicts, easements, or other design notes.

Table 6.4-14 NBC_SUB9_PIPE_04 East Washington Street

East Washington Street	**Subbasin 9**	**NBC_SUB9_PIPE_04**
Summary	**Criteria/Result**	
Roadway Classification	N/A	
Existing Configuration	15" Pipe	
LOS Requirement	10-year event within the pipe (no pressurized flow)	
Triggering Criteria	< 10-year event within the pipe (no pressurized flow)	
Proposed Configuration	18" Concrete Pipe	
Prioritization Score	341.7	
OPCC	$484,000	
Notes/Comments	Upgrade existing stormwater pipe capacity with no utility relocation.	

6.5 Future Land Use Considerations

Future land cover data was developed utilizing a combination of City zoning and NLCD data as follows: NLCD areas deemed undeveloped were converted to their developed LU based on the City's zoning layer. These areas included Barren Land, Cultivated Crops, Deciduous Forest, Evergreen Forest, Hay/Pasture, Grassland/Herbaceous, Mixed Forest, and Shrub/Scrub. From this updated future LU dataset, future CNs were computed. Table 6.5-1 includes the summary of future LU CNs for the watershed.

Table 6.5-1 Watershed Future CNs

	Future
Area Weighted Average	79.3
Maximum	94
Minimum	61

Since the exact locations of future developments are unknown, time of concentration values were held constant in the existing and future condition models. These values are included in Table 4.5-4 in Section 4.5.1.

The HMS model discussed in Section 4.5.1 was used to develop SCS Type II rainfall distribution runoff curves from each of the subbasins with the land cover adjustments for future conditions. The DSS output from this new HMS model was linked to the HEC-RAS geometry that was developed as described in Section 4.5.2 for the Primary System analysis.

The future conditions scenarios showed increased flows primarily in the eastern, currently undeveloped portions of the North Buffalo Creek. The western, upstream portion of the watershed is already heavily developed and saw little or no increase in discharges.

6.6 Climate Change Impact Assessment

The potential effects of CC were evaluated by altering rainfall depths to determine if alternatives proposed for both Primary Systems and Secondary Systems were still sufficient in CC rainfall scenarios. The following paragraphs detail modeling parameters and findings.

6.6.1 Climate Change Rainfall Depths

Impact of CC to rainfall depths was determined based on the SWMM-CAT 1.0 tool, which provides a set of location-specific adjustments derived from World Climate Research Programme global CC models. SWMM-CAT allows users to input a longitude-latitude or zip code and returns percentage-based adjustments to rainfall depth that are correlated to specific return periods. Two different projection periods (Near Term 2020-2049 and Far Term 2045-2074) and three different CC outcomes are included (Hot/Dry, Median, and Warm/Wet). The median outcome does not represent the average of the Hot/Dry and Warm/Wet outcomes, but rather, a separate model outcome. All Greensboro zip codes have the same rainfall depth near term adjustment results:

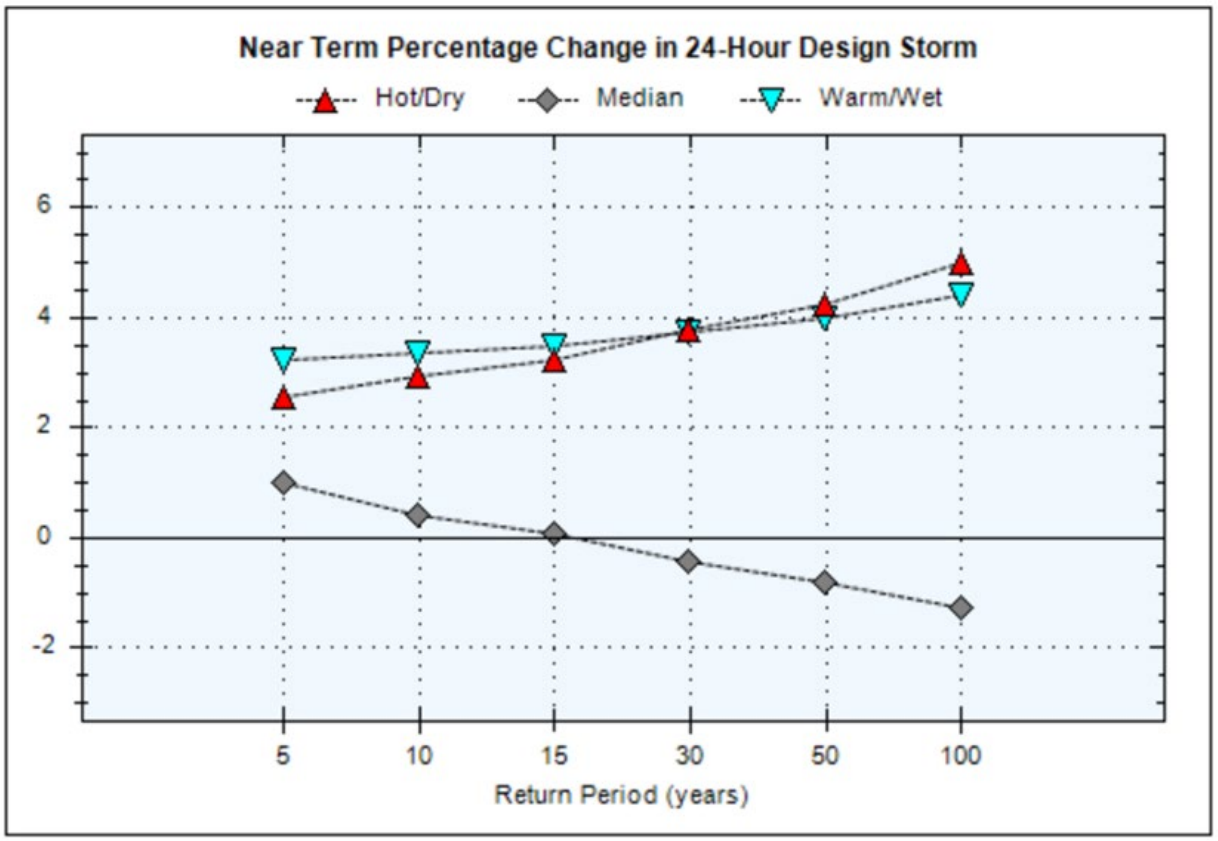


Figure 6-4 SWMM-CAT Output for Greensboro, NC

For the purposes of this study, Stantec used the highest adjustment value applicable for the return period under evaluation. Applicable adjustment values are shown below:

Table 6.6-1 CC Adjustment

Return Period, year	Rainfall Depth % Adjustment	Climate Change Outcome
2	+3.22*	Warm/Wet
10	+3.34	Warm/Wet
25	+3.66	Warm/Wet
50	+4.24	Hot/Dry
100	+4.97	Hot/Dry
500	+4.97**	Hot/Dry

**SWMM-CAT's lowest value is for the 5-year return period; that value will be used for the 2-year event*

*** SWMM-CAT's highest value is for the 100-year return period; that value will be used for the 500-year event*

6.6.2 Primary Systems

For Primary Systems, Stantec created hydrologic and hydraulic models accounting for adjusted rainfall depths to evaluate the effects of CC. Based on the hydraulic model used to develop alternatives based on the SCS Type II storm event, Stantec created a duplicate RAS model and linked the CC hydrology to the duplicate alternatives model in order to compare performance of alternatives between the two models. Table 6.6-2 below compares model results at the identified project locations both in the base alternatives model and in the described CC model.

Table 6.6-2 Climate Change Model Results Comparison (Primary)

Project Location	Proposed LOS	LOS Met in Climate Change Model?
Battleground Avenue	100-Year 24-Hour SCS Type II	No
Briarcliff Road		No
Cleburne Street		Yes
Cody Avenue		Yes
East Bessemer		No
East Cone Boulevard		No
Guilford Drive		No
Hill Street		No
Latham Road		No
Martin Avenue – Jordan Branch		No
Martin Avenue – Unnamed Tributary 1		Yes
Murchie Street & Sharon Avenue		Yes
North Holden Road		Yes
Phillips Avenue – Muddy Creek		No
Phillips Avenue – Unnamed Tributary 2		No
South Josephine Boyd Street		No
Textile Drive		Yes
West Friendly Avenue		No
West Smith Street – North Buffalo Creek		No
West Smith Street – Unnamed Tributary		No
White Street		No
Yanceyville Street		No

Climate Change models were developed using 1) future conditions land use and 2) rainfall depths adjusted for climate change shown in the table below. Climate change analysis was performed for the alternatives model, and the climate change analysis results were compared to the future conditions analysis results at each assessed structure.

6.6.3 Secondary Systems

The impact of CC to the Secondary Systems was quantified similarly to the Primary System evaluation; Stantec created a duplicate of the PCSWMM models used to evaluate alternatives, adjusted rainfalls by the appropriate percentages, and evaluated differences in WSE within the proposed Secondary System alternative. Table 6.6-3 shows locations within the Secondary System where the LOS is no longer met at an alternative location due to increased rainfall associated with CC.

Table 6.6-3 CC Model Results Comparison (Secondary)

System Name	Proposed LOS	LOS Met in CC Model?
Mayflower Drive	SCS Type II, 10-Year HGL in pipe, 25-Year HGL below surface	Yes
Warren Street & Wright Avenue		No
Storm Sewer Area 1		Yes
Florence Street		Yes
North Elm Street		No
Church Street		Yes
West Fisher Avenue		Yes
Parkway Street		No
Baseball Field		Yes
East Washington Street		No
North Murrow Boulevard		No
Salem & Stewart		Yes
Bellemeade Street		Yes
Benjamin Parkway		Yes

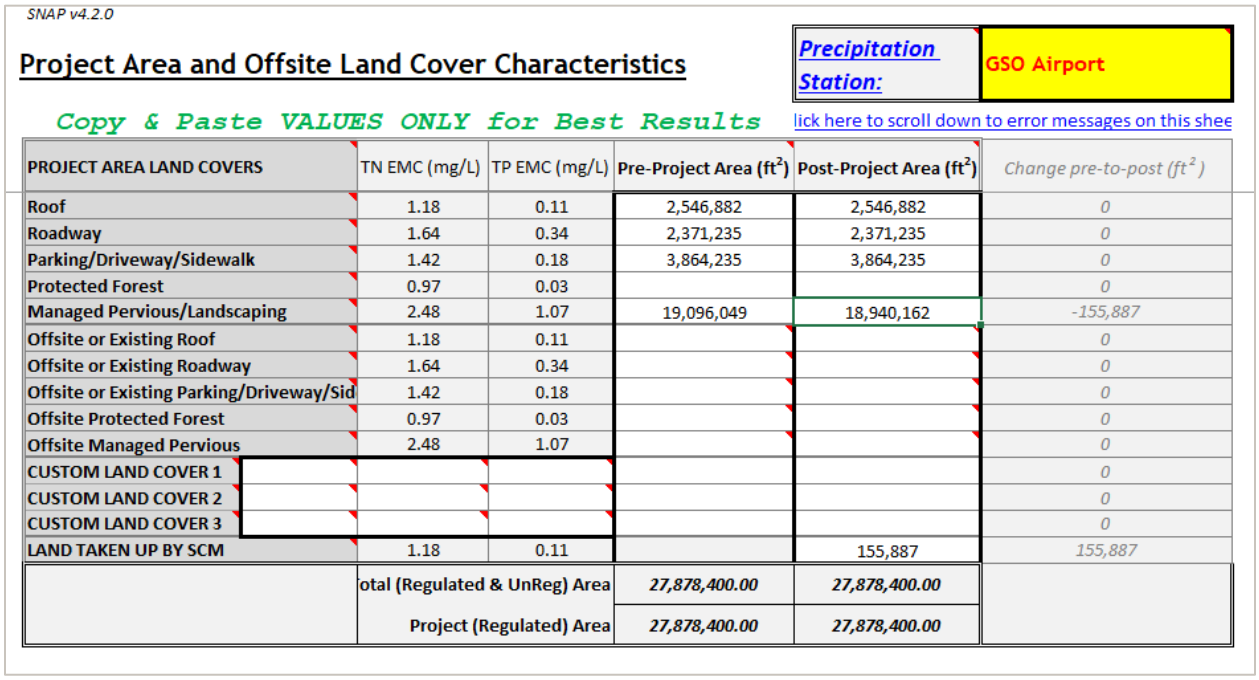
6.6.4 Climate Change Conclusion

Based on the analysis described above, CC does impact future performance of proposed alternatives. This assessment is intended to help the city determine if adjustments to the design approach based on CC predictions is warranted. It is noted that more recent versions of the SWMM-CAT (V1.1) tool have changed the downscaling process and the resultant percentage change in rainfall depths have been revised. In general, increases in depth are higher than in prior versions of SWMM-CAT. There are a number of ways to assess CC impact, but this study shows that further review and consideration is warranted as predicted rainfall continues to increase.

6.7 Green Stormwater Infrastructure Assessment

The goal of this analysis was to calculate the volume reduction benefits to the NBC watershed if runoff from certain LU types were routed through bioretention treatment. The results of the assessment could help demonstrate if a GSI City-wide initiative would help address flooding concerns. The city can use the results of the analysis to determine the investment benefits a GSI program could provide.

All GSI treatment methods for this analysis were assumed to be bioretention. Bioretention was chosen for this analysis due to it being a commonly used practice for treating roadway and parking lots. In addition to volume reduction, another benefit of the GSI treatment is the reduction of nutrients in the stormwater runoff. Volume and nutrient reduction benefits were estimated using the SNAP tool version 4.2.0. The SNAP tool inputs include the areas for three types of impervious surface (Roadway, Roof, and Parking/Sidewalk), the area of two types of pervious surfaces (managed pervious and protected forest), the GSI area, the hydrologic soil group, and the total area draining to the GSI. Limitations associated with use of the SNAP tool in this analysis were that land cover area was limited in both the allowed size of land area (1 square mile) and the defined land cover categories.



SNAP v4.2.0

Project Area and Offsite Land Cover Characteristics

Precipitation Station:	GSO Airport

Copy & Paste VALUES ONLY for Best Results

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PROJECT AREA LAND COVERS	TN EMC (mg/L)	TP EMC (mg/L)	Pre-Project Area (ft^2)	Post-Project Area (ft^2)	Change pre-to-post (ft^2)
Roof	1.18	0.11	2,546,882	2,546,882	0
Roadway	1.64	0.34	2,371,235	2,371,235	0
Parking/Driveway/Sidewalk	1.42	0.18	3,864,235	3,864,235	0
Protected Forest	0.97	0.03			0
Managed Pervious/Landscaping	2.48	1.07	19,096,049	18,940,162	-155,887
Offsite or Existing Roof	1.18	0.11			0
Offsite or Existing Roadway	1.64	0.34			0
Offsite or Existing Parking/Driveway/Sid	1.42	0.18			0
Offsite Protected Forest	0.97	0.03			0
Offsite Managed Pervious	2.48	1.07			0
CUSTOM LAND COVER 1					0
CUSTOM LAND COVER 2					0
CUSTOM LAND COVER 3					0
LAND TAKEN UP BY SCM	1.18	0.11		155,887	155,887
	otal (Regulated & UnReg) Area		27,878,400.00	27,878,400.00	
	Project (Regulated) Area		27,878,400.00	27,878,400.00	

Figure 6-5 SNAP Tool Land Cover Characteristics Tab

Due to the difficulty in definitively determining that forest areas within the watershed meet the criteria of being a protected forest area, all non-impervious area in the watershed was placed in the managed pervious category in the SNAP tool. 2019 NLCD impervious data was used to determine the total percent impervious for the NBC watershed. The total amount of impervious surface identified within the NBC Watershed was 6.89 sq miles.

To further break up the impervious areas into the specified SNAP categories, ratios of land cover were calculated based on an impervious data layer for the City of Raleigh. These Raleigh ratios shown in Table 6.7-1 were applied to the total impervious area calculated for the NBC Watershed to be used to approximate the land cover area for roof, roadway, and parking/driveway/sidewalk.

Table 6.7-1 Raleigh Impervious Layer Category Percentages

RALEIGH IMPERVIOUS DATA	
SNAP LU Categories	**% of Impervious Layer**
Parking/driveway/sidewalk	45%
Roadway	25%
Roof	30%

The NBC watershed is approximately 37 square miles in land area. To utilize the SNAP tool for this analysis within its limitations, the subbasin area was scaled down to 1 square mile and all LU areas were scaled down by the same factor. These scaled areas were input into the SNAP tool as pre-project area values. It was assumed that any constructed bioretention areas would be constructed in areas where LU is currently categorized as managed pervious/landscaping; therefore, an increase in bioretention area resulted in a decrease in managed pervious/landscaping within the SNAP tool LUs. Soil group B was assumed for this analysis Since approximately 1/3 of the watershed is group B it was assumed that the GSI areas can be strategically placed in locations with Group B soil or better. Each bioretention pond was assumed to be sized to 100% of the surface area required for the area drained (ponding depth assumed to be 12 inches). This resulted in bioretention areas that increased in size as the area treated assumption increased. The design volume of each bioretention cell was calculated using the simple method.

Twelve SNAP analyses were run based on treating runoff from various percentages of roadway and parking/driveway/sidewalk area. These percentages were 5, 10, 20, and 30%. Roof area was not included in this analysis as distributed practices are most often associated with roadways and parking lots.

Table 6.7-2, Table 6.7-3, and Table 6.7-4 show reduction results for various scenarios run through the SNAP tool.

- Annual Runoff % Change: percent difference between runoff volume pre-project and post-project after treatment has begun
- Total Volume Reduced: difference between runoff volume pre-project and post-project after treatment has begun
- Total Nitrogen % Change: percent difference between total nitrogen load leaving site pre-project and post-project after treatment has begun
- Total TN Removal: difference between total nitrogen load leaving site pre-project and post-project after treatment has begun.

Table 6.7-2 Reduction Results for Roadway Runoff Treatment

ROADWAY					
Total Estimated Area, sf		**87,475,153**	**(2008 sq. mi.)**		
% Treated	Area Treated, sf	Annual Runoff % Change	Total Volume Reduced, cf	Total Nitrogen % Change	Total TN removal (lb/yr)
5%	4,771,041	-0.78%	8,509,347	-1.07%	1,112
10%	9,542,083	-1.56%	17,018,694	-2.14%	2,225
20%	19,084,165	-3.11%	34,037,387	-4.29%	4,450
30%	28,626,248	-4.67%	51,056,081	-6.43%	6,674

Table 6.7-3 Reduction Results for Parking/Driveway/Sidewalk Runoff Treatment

PARKING LOTS, SIDEWALKS, ETC.					
Total Estimated Area, sf		**87,475,153**	**(2008 sq. mi.)**		
% Treated	Area Treated, sf	Annual Runoff % Change	Total Volume Reduced, cf	Total Nitrogen % Change	Total TN removal (lb/yr)
5%	7,775,030	-1.27%	13,867,084	-1.48%	1,534
10%	15,550,060	-2.54%	27,734,167	-2.96%	3,068
20%	31,100,121	-5.07%	55,468,334	-5.92%	6,136
30%	46,650,181	-7.61%	83,202,502	-8.87%	9,205

Table 6.7-4 Reduction Results for Combined Runoff Treatment

COMBINED					
Total Estimated Area, sf		**87,475,153**	**(2008 sq. mi.)**		
% Treated	Area Treated, sf	Annual Runoff % Change	Total Volume Reduced, cf	Total Nitrogen % Change	Total TN removal (lb/yr)
5%	12,546,071	-2.05%	22,376,430	-2.55%	2,647
10%	25,092,143	-4.09%	44,752,861	-5.10%	5,293
20%	50,184,286	-8.19%	89,505,721	-10.21%	10,586
30%	75,276,429	-12.28%	134,258,582	-15.31%	15,879

As expected, the more impervious surface treated, the higher the volume and nutrient reduction benefit. A more detailed analysis of which portions of the overall watershed and impervious surface cover may be feasible for treatment via distributed GSI measures would help better understand the overall benefit of a watershed-wide GSI retrofit program, however, this analysis reveals that large scale treatment strategies would be required to make significant reductions in overall runoff.

7 Stream and Water Quality Recommendations

This SWMP included a wide-ranging desktop and field review of properties and locations which may be suitable for bank stabilization and SCM construction. As part of the desktop review the City provided Stantec a copy of the comprehensive North Buffalo Creek BMP Siting and Nutrient Reduction Strategy report produced by CDM Smith in 2012 which outlined a watershed-wide SCM and BMP strategy.

7.1 Field Investigation and Bank Erosion Assessment

As part of the engineering field investigation, Stantec collected BEHI data from 60 sites throughout the watershed. This information was then used to identify 17 bank stabilization and asset protection project alternative locations.

Stantec developed a digital form of the BEHI worksheet developed by David Rosgen and team to collect data in field to use to develop BEHI scores in areas of interest. Copies of these forms are included in Appendix D. Stantec selected areas to evaluate based on the severity of erosion and the proximity of erosion to property, utilities, or other assets. The assessments included measuring bank height and angle, identifying soil composition, observing vegetation cover, and noting any signs of active erosion or instability. Photographic documentation was collected to support the BEHI scores and saved geospatially along the channel reach. Photos were intended to capture the general representation of the existing channel and capture areas of observed threatened utilities or areas of high erosion potential. The BEHI data collection process includes the following general steps: Site Location and Initial Observations: Records the precise location using GPS and makes initial observations of the streambank conditions, noting any visible signs of erosion, slumping, or bank undercutting. Measurement of Bank Attributes: Study Bank Height and Length:

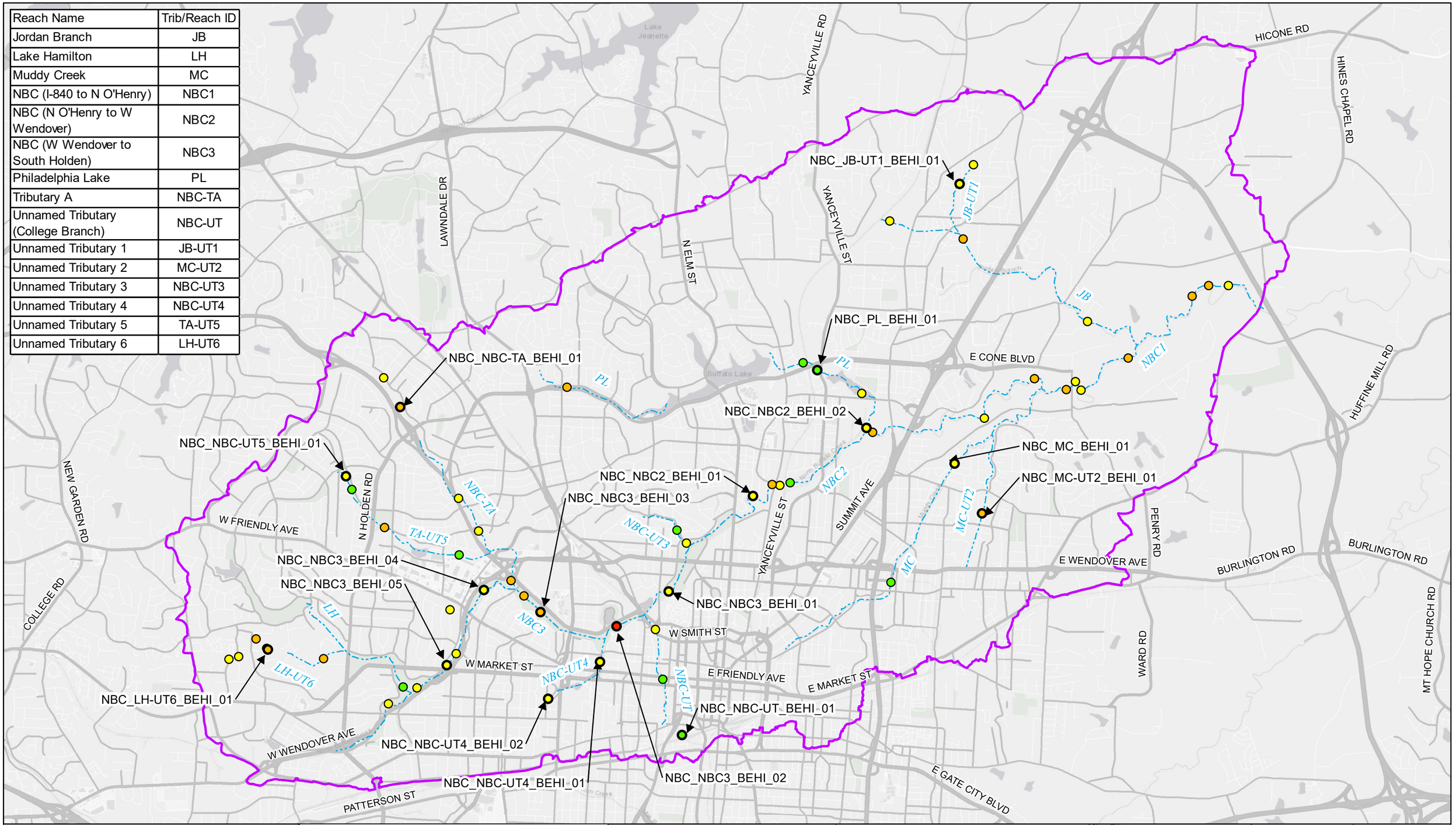
1. The vertical height from the toe (base) of the bank to the top was measured, along with the length of the eroding bank section.
    a. Bank Angle: The angle of the bank slope was visually estimated. Steeper angles typically indicate a higher erosion hazard.
    b. Bankfull Height: The vertical height from the toe (base) of the bank to the bankfull elevation of the channel.
2. Soil and Vegetation Assessment:
    a. Root Depth and Density: The depth and density of vegetative roots within the bank material were assessed.
    b. Bank Surface Protection: The type and extent of vegetative or artificial cover on the bank surface are evaluated.

3. Photographic Documentation: Photographs were taken to document bank conditions, erosion features, vegetation, and any relevant structures.

4. BEHI Scoring: Based on the collected data, each site is assigned a BEHI score according to established criteria, which categorizes the erosion hazard from low to extreme.

Of the stream miles that were assessed, 10 were measured moderate, 31 were measured high, 18 were measured very high, and 1 was measured extreme. Figure 7-1 shows the locations of all BEHI assessments evaluated in the field with the selected project alternative locations identified. It is color coded to note the BEHI score categories.

Reach Name	Trib/Reach ID
Jordan Branch	JB
Lake Hamilton	LH
Muddy Creek	MC
NBC (I-840 to N O'Henry)	NBC1
NBC (N O'Henry to W Wendover)	NBC2
NBC (W Wendover to South Holden)	NBC3
Philadelphia Lake	PL
Tributary A	NBC-TA
Unnamed Tributary (College Branch)	NBC-UT
Unnamed Tributary 1	JB-UT1
Unnamed Tributary 2	MC-UT2
Unnamed Tributary 3	NBC-UT3
Unnamed Tributary 4	NBC-UT4
Unnamed Tributary 5	TA-UT5
Unnamed Tributary 6	LH-UT6



Stantec
One West Fourth Street, Suite 820
Winston-Salem, North Carolina
27101-3818
www.stantec.com

N

Legend

- Bank Stabilization Project
- Primary Streams
- Watershed Boundary

BEHI RATING

- Extreme
- Very High
- High
- Moderate

0 2,000 4,000 8,000 Feet

(At original document size of 11x17)
1:48,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title

Bank Erosion Hazard Index (BEHI) Locations

Project Location:

City of Greensboro, Guilford County, North Carolina

Prepared by MIA on 2024-08-27
Reviewed by SM on 2024-08-28

Date: 08/14/2024

Sheet No. Figure 7-1

Figure 7-2 shows the distributions of the BEHI categories collected. The majority of BEHI assessments fall into the High or Very High category. One extreme erosion was noted.

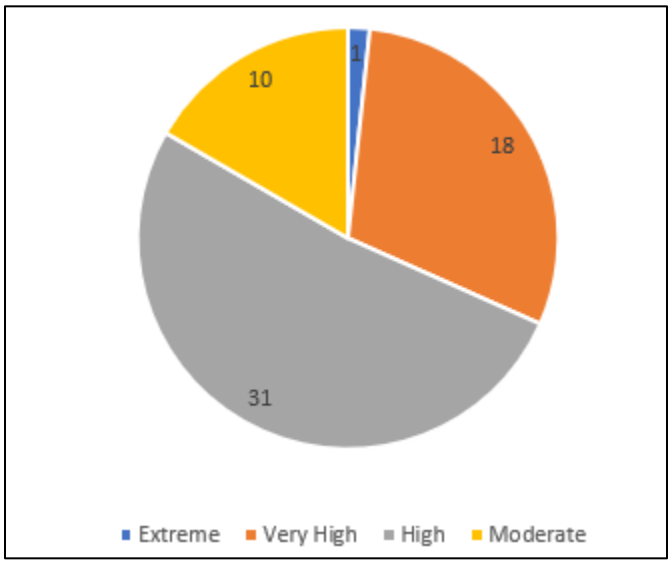


Figure 7-2 NBC BEHI Results Distribution

7.2 Site Selection

Locations were selected for bank stabilization project alternatives based on the data collected in the field during the engineering field investigations. During the field investigations, Stantec identified and evaluated 60 sites with bank erosion and determined a BEHI score and rating for each. From these 60 sites, 17 locations were selected for alternative development based on the following criteria:

- Bank erosion threatening property, infrastructure, utilities, etc.
- Site accessibility
- Severity of erosion
- Sites identified on the City's active CIP project list

7.3 Stream Bank Stabilization Recommendations

Opportunities to improve the bank and stream health throughout the watershed were identified during the Bank Stabilization Assessment. These opportunities are described in detail below.

7.3.1 Unnamed Tributary 1

Table 7.3-1 NBC_JB-UT1_BEHI_01 Voss Avenue Streambank Stabilization

Voss Avenue	**Unnamed Tributary 1**	**NBC_JB-UT1_BEHI_01**
Summary	**Criteria/Result**	
BEHI Rating	High - 31	
Existing Conditions	Eroded and unstable streambank	
Photo ID	JB-UT1_021	
Selection Criteria	Sanitary sewer and property threatened by excessive erosion	
Proposed Configuration	100LF Bank stabilization boulder wall	
Prioritization Score	150.2	
OPCC	$205,000	
Notes/Comments	Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

7.3.2 Muddy Creek

Table 7.3-2 NBC_MC_BEHI_01 Autumn Drive Streambank Stabilization

Autumn Drive	**Muddy Creek**	**NBC_MC_BEHI_01**
Summary	Criteria/Result	
BEHI Rating	High - 34	
Existing Conditions	Eroded and unstable streambank	
Photo ID	NBC-MC_019	
Selection Criteria	Loss of property threatened by excessive erosion	
Proposed Configuration	200LF Bank stabilization boulder wall and J-Hook rock vanes	
Prioritization Score	133.2	
OPCC	$503,000	
Notes/Comments	J-Hook vanes dissipate waterway energy. Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

7.3.3 Unnamed Tributary 2

Table 7.3-3 NBC_MC-UT2_BEHI_01 Jolson Street Streambank Stabilization

Jolson Street	**Unnamed Tributary 2**	**NBC_MC-UT2_BEHI_01**
Summary	Criteria/Result	
BEHI Rating	Very High - 43	
Existing Conditions	Eroded and unstable streambank	
Photo ID	MC-UT2_021	
Selection Criteria	Roadway threatened by excessive erosion	
Proposed Configuration	50LF Bank stabilization boulder wall, 60LF streambank grading	
Prioritization Score	142.0	
OPCC	$144,000	
Notes/Comments	Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

7.3.4 Philadelphia Lake

Table 7.3-4 NBC_PL_BEHI_01 East Cone Boulevard Streambank Stabilization

East Cone Boulevard	**Philadelphia Lakes**	**NBC_PL_BEHI_01**
Summary	Criteria/Result	
BEHI Rating	Moderate - 23	
Existing Conditions	Eroded and unstable streambank	
Photo ID	NBC-PL_026 and NBC-PL_027	
Selection Criteria	Loss of property threatened by excessive erosion, partially exposed sanitary sewer crossing	
Proposed Configuration	100LF Bank stabilization boulder wall	
Prioritization Score	155.4	
OPCC	$680,000	
Notes/Comments	Stabilize sanitary sewer crossing. Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

7.3.5 North Buffalo Creek (North O'Henry to West Wendover)

Table 7.3-5 NBC_NBC2_BEHI_01 Roseland Street Streambank Stabilization

Roseland Street	**North Buffalo Creek**	**NBC_NBC2_BEHI_01**
Summary	Criteria/Result	
BEHI Rating	High - 35	
Existing Conditions	Eroded and unstable streambank	
Photo ID	NBC2_035	
Selection Criteria	Loss of property threatened by excessive erosion	
Proposed Configuration	200LF Bank stabilization boulder wall and floodplain benching	
Prioritization Score	117.6	
OPCC	$2,216,000	
Notes/Comments	Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

Table 7.3-6 NBC_NBC2_BEHI_02 Fairview Street Streambank Stabilization

Fairview Street	**North Buffalo Creek**	**NBC_NBC2_BEHI_02**
Summary	Criteria/Result	
BEHI Rating	High - 36	
Existing Conditions	Eroded and unstable streambank	
Photo ID	NBC2_004	
Selection Criteria	Overhead electric utility tower threatened by excessive erosion	
Proposed Configuration	200LF Bank stabilization boulder wall and J-Hook rock vanes	
Prioritization Score	137.8	
OPCC	$410,000	
Notes/Comments	J-hook rock vanes dissipate waterway energy. Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

7.3.6 North Buffalo Creek (West Wendover to South Holden)

Table 7.3-7 NBC_NBC3_BEHI_01 Hill Street Streambank Stabilization

Hill Street	**North Buffalo Creek**	**NBC_NBC3_BEHI_01**
Summary	Criteria/Result	
BEHI Rating	High - 39	
Existing Conditions	Eroded and unstable streambank	
Photo ID	NBC3_006	
Selection Criteria	Overhead electric utility tower threatened by excessive erosion	
Proposed Configuration	250LF Bank stabilization boulder wall and floodplain benching	
Prioritization Score	137.4	
OPCC	$492,000	
Notes/Comments	Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

Table 7.3-8 NBC_NBC3_BEHI_02 Benjamin Parkway Streambank Stabilization

Benjamin Parkway	**North Buffalo Creek**	**NBC_NBC3_BEHI_02**
Summary	Criteria/Result	
BEHI Rating	Extreme - 57	
Existing Conditions	Eroded and unstable streambank	
Photo ID	NBC3_034	
Selection Criteria	Overhead electric utility tower threatened by excessive erosion	
Proposed Configuration	100LF Bank stabilization boulder wall and sandbar excavation	
Prioritization Score	139.2	
OPCC	$480,000	
Notes/Comments	Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

Table 7.3-9 NBC_NBC3_BEHI_03 Campus Drive Streambank Stabilization

Campus Drive	**North Buffalo Creek**	**NBC_NBC3_BEHI_03**
Summary	Criteria/Result	
BEHI Rating	Very High - 43	
Existing Conditions	Eroded and unstable streambank	
Photo ID	NBC3_062	
Selection Criteria	Sanitary sewer threatened by excessive erosion	
Proposed Configuration	150LF Bank stabilization boulder wall, slope stabilization anchors, and J-Hook rock vanes	
Prioritization Score	139.6	
OPCC	$457,000	
Notes/Comments	Slope stabilization achieved with anchors and geogrid. J-hook rock vanes dissipate energy in the waterway. Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

Table 7.3-10 NBC_NBC3_BEHI_04 West Wendover Avenue Streambank Stabilization

West Wendover Avenue	**North Buffalo Creek**	**NBC_NBC3_BEHI_04**
Summary	Criteria/Result	
BEHI Rating	High - 33	
Existing Conditions	Eroded and unstable streambank	
Photo ID	NBC3_062	
Selection Criteria	Loss of property threatened by excessive erosion	
Proposed Configuration	100LF Bank stabilization boulder wall, rehab existing stormwater outlet structures	
Prioritization Score	117.6	
OPCC	$277,000	
Notes/Comments	Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

Table 7.3-11 NBC_NBC3_BEHI_05 Green Valley Road Streambank Stabilization

Green Valley Road	**North Buffalo Creek**	**NBC_NBC3_BEHI_05**
Summary	Criteria/Result	
BEHI Rating	High - 39	
Existing Conditions	Eroded and unstable streambank	
Photo ID	NBC3_106	
Selection Criteria	Overhead electric utility tower threatened by excessive erosion	
Proposed Configuration	140LF Bank stabilization boulder wall	
Prioritization Score	155.8	
OPCC	$371,000	
Notes/Comments	Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

7.3.7 Unnamed Tributary

Table 7.3-12 NBC-UT_BEHI_01 Eugene Court Streambank Stabilization

Eugene Court	**Unnamed Tributary**	**NBC_NBC-UT_BEHI_01**
Summary	Criteria/Result	
BEHI Rating	Moderate - 28	
Existing Conditions	Eroded and unstable streambank	
Photo ID	NBC-UT_064	
Selection Criteria	Commercial property / structures threatened by excessive erosion	
Proposed Configuration	200LF Bank stabilization boulder wall	
Prioritization Score	138.0	
OPCC	$319,000	
Notes/Comments	Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

7.3.8 Unnamed Tributary 4

Table 7.3-13 NBC-UT4_BEHI_01 Mimosa Drive Streambank Stabilization

Mimosa Drive	**Unnamed Tributary 4**	**NBC_NBC-UT4_BEHI_01**
Summary	Criteria/Result	
BEHI Rating	High - 30	
Existing Conditions	Eroded and unstable streambank	
Photo ID	NBC-UT4_013	
Selection Criteria	Sanitary sewer and roadway threatened by excessive erosion	
Proposed Configuration	100LF Bank stabilization boulder wall	
Prioritization Score	136.0	
OPCC	$535,000	
Notes/Comments	Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

Table 7.3-14 NBC-UT4_BEHI_02 Mayflower Drive Streambank Stabilization

Mayflower Drive	**Unnamed Tributary 4**	**NBC_NBC-UT4_BEHI_02**
Summary	Criteria/Result	
BEHI Rating	High - 30	
Existing Conditions	Eroded and unstable streambank	
Photo ID	NBC-UT4_051	
Selection Criteria	Sanitary sewer and roadway threatened by excessive erosion	
Proposed Configuration	100LF Bank stabilization boulder wall	
Prioritization Score	134.8	
OPCC	$224,000	
Notes/Comments	Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

7.3.9 Tributary A

Table 7.3-15 NBC-TA_BEHI_01 Gracewood Drive Streambank Stabilization

Gracewood Drive	**Tributary A**	**NBC_NBC-TA_BEHI_01**
Summary	Criteria/Result	
BEHI Rating	Very High - 41	
Existing Conditions	Eroded and unstable streambank	
Photo ID	NBC-TA_070	
Selection Criteria	Loss of property threatened by excessive erosion	
Proposed Configuration	100LF Bank stabilization boulder wall	
Prioritization Score	144.8	
OPCC	$147,000	
Notes/Comments	Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

7.3.10 Unnamed Tributary 5

Table 7.3-16 TA-UT5_BEHI_01 Cascade Drive Streambank Stabilization

Cascade Drive	**Unnamed Tributary 5**	**NBC-TA-UT5_BEHI_01**
Summary	Criteria/Result	
BEHI Rating	High - 37	
Existing Conditions	Eroded and unstable streambank	
Photo ID	TA-UT5_075	
Selection Criteria	Partially exposed sanitary sewer crossing, loss of property threatened by excessive erosion	
Proposed Configuration	100LF Bank stabilization boulder wall, relocated sanitary sewer	
Prioritization Score	146.8	
OPCC	$908,000	
Notes/Comments	Sanitary sewer relocation. Nutrient removal including Nitrogen, Phosphorus, and suspended solids.	

7.3.11 Unnamed Tributary 6

Table 7.3-17 LH-UT6_BEHI_01 Kenbridge Court Streambank Stabilization

Kenbridge Court	**Unnamed Tributary 6**	**NBC_LH-UT6_BEHI_01**
Summary	Criteria/Result	
BEHI Rating	Very High - 43	
Existing Conditions	Eroded and unstable streambank	
Photo ID	LH-UT6_032	
Selection Criteria	Loss of property threatened by excessive erosion	
Proposed Configuration	70LF Bank stabilization boulder wall and slope stabilization anchors	
Prioritization Score	130.8	
OPCC	$610,000	
Notes/Comments	Nutrient removal including Nitrogen, Phosphorus, and suspended solids	

7.4 SCM Retrofit Recommendations

Locations were selected for SCM retrofit project alternatives based on the data collected in the field during the engineering field investigations and stream walks. Additionally, Stantec performed a review of the March 2012 CDM Smith report North Buffalo Creek BMP Siting and Nutrient Reduction Strategy provided by the city, it was recognized that many of the possible SCM retrofit locations had also been analyzed in the report. The 2012 analysis identified 289 candidate sites throughout the North Buffalo Creek watershed, 42 of which were determined to be suitable locations for BMPs. During the stream walks, Stantec observed conditions that generally agreed with the results of the 2012 analysis. Of these 42 sites, 10 sites were selected for alternative development based on the following criteria:

- City owned property and site accessibility
- Prescene of utilities and infrastructure
- Large drainage areas are preffered for cost effective nutrient removal
- Permitting requirements

The sizing parameters for the various BMPs were performed in accordance with the NCDEQ Stormwater Design Manual. Nutrient removal and volume reduction performance of each site was evaluated with the most current version of the Stormwater Nitrogen and Phosphorus Tool (SNAP). In addition to the 10 retrofit sites two more opportunities to improve water quality in the watershed were identified during the stream walks and are mentioned.

A potential opportunity identified during the stream walks occurred along an inflowing tributary to Muddy Creek. The storm sewer pipe near Salem Street and Laurel Street (west of NC A&T) showed a significant muddy discoloration and appeared to contain suspended sediment. While attempting to locate the source of the sediment, Stantec located a construction site upstream of the discharge location which appeared to have improper sediment control measures that were allowing sediment to leave the site and enter the storm sewer system. Once Stantec confirmed this sediment was the result of a temporary condition that was the responsibility of a private entity, no further analysis was performed by Stantec.

Next, a stream cleanup opportunity which will help improve the overall stream health and water quality conditions of North Buffalo Creek was identified. While performing stream walks near the area of the landfill, the Stantec team observed many discarded tires within the stream. The tires start near Ralph C. Johnson Road and extend downstream approximately 1.6 miles. The largest concentrations of tires were observed within the first 1,500 feet of the stream downstream of the Ralph C. Johnson crossing. The proximity of these concentrations of tires to the road and the walkability of the stream in this area makes it a desirable place to host a community outreach and education event. A cleanup event, which can be used to document compliance with minimum control measures 1 (Public outreach and education) and 2 (Public participation) of MS4 permits, is a low-cost way to attain beneficial results without large amounts of impacts to the stream. Depending on the number of volunteers and the ease of access to the landfill, additional cleanups could be scheduled to clean the remaining 1.6 miles of the reach where tires were observed. During these clean up events, volunteer assistance can be utilized to start live staking some of the banks of the stream to maintain good riparian vegetation and stream health in this reach.

The 10 identified retrofit sites and project opportunities aimed at improving water quality throughout the watershed are described in detail below.

Reach Name	Trib/Reach ID
Jordan Branch	JB
Lake Hamilton	LH
Muddy Creek	MC
NBC (I-840 to N O'Henry)	NBC1
NBC (N O'Henry to W Wendover)	NBC2
NBC (W Wendover to South Holden)	NBC3
Philadelphia Lake	PL
Tributary A	NBC-TA
Unnamed Tributary (College Branch)	NBC-UT
Unnamed Tributary 1	JB-UT1
Unnamed Tributary 2	MC-UT2
Unnamed Tributary 3	NBC-UT3
Unnamed Tributary 4	NBC-UT4
Unnamed Tributary 5	TA-UT5
Unnamed Tributary 6	LH-UT6

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N

Legend
- SCM Projects
- Primary Streams
- Watershed Boundary

0 2,000 4,000 8,000 Feet

(At original document size of 11x17)
1:48,000

Coordinate System: NAD 1983 StatePlane North Carolina FIPS 3200 Feet

The City of GREENSBORO

Stormwater Master Plan - North Buffalo Creek

Sheet Title
Stormwater Control Measure (SCM) Locations

Project Location:
City of Greensboro,
Guilford County, North Carolina

Prepared by MIA on 2024-08-03
Reviewed by SM on 2024-08-20
Updated by XXX on 2024-08-XX

Date:
01/27/2025

Sheet No.
Figure 7-3

7.4.1 North Buffalo Creek (North O'Henry to West Wendover)

Table 7.4-1 NBC_NBC2_SCM_01 West Wendover Avenue

West Wendover Avenue	North Buffalo Creek	NBC_NBC2_SCM_01
Summary	Criteria/Result	
Drainage Area Description	32.5-Acres, 77% impervious drainage area	
SCM Description	Stormwater wetland	
Treatment	55% of WQV treated. Reduction of 41.1% total Nitrogen and 35.6% total Phosphorus	
Pretreatment	Upstream forebay	
Photo ID	NBC3_082	
Prioritization Score	103.2	
OPCC	$138,234	

7.4.2 North Buffalo Creek (West Wendover to South Holden)

Table 7.4-2 NBC_NBC3_SCM_01 Henderson Road

Henderson Road	Lake Hamilton	NBC_NBC3_SCM_01
Summary	Criteria/Result	
Drainage Area Description	322-Acres, 16% impervious drainage area	
SCM Description	Stormwater wet pond	
Treatment	100% of WQV treated. Reduction of 33.9% total Nitrogen and 58.0% total Phosphorus	
Pretreatment	Upstream forebay	
Photo ID	N/A	
Prioritization Score	103.2	
OPCC	$190,185	

Table 7.4-3 NBC_NBC3_SCM_02 West Radiance Drive

West Radiance Drive	**North Buffalo Creek**	**NBC_NBC3_SCM_02**
Summary	Criteria/Result	
Drainage Area Description	21-Acres, 31% impervious drainage area	
SCM Description	Level spreader - vegetated filter strip	
Treatment	174% of WQV treated. Reduction of 45.7% total Nitrogen and 46.6% total Phosphorus	
Pretreatment	Forebay located upstream of SCM	
Photo ID	N/A	
Prioritization Score	93.6	
OPCC	$321,249	

Table 7.4-4 NBC_NBC3_SCM_03 East Lake Drive

East Lake Drive	**North Buffalo Creek**	**NBC_NBC3_SCM_03**
Summary	Criteria/Result	
Drainage Area Description	12.7-Acres, 27% impervious drainage area	
SCM Description	Level spreader - vegetated filter strip	
Treatment	237% of WQV treated. Reduction of 48.4% total Nitrogen and 51.8% total Phosphorus	
Pretreatment	Forebay located upstream of SCM	
Photo ID	N/A	
Prioritization Score	149	
OPCC	$956,316	

Table 7.4-5 NBC_NBC3_SCM_04 Mimosa Drive

Mimosa Drive	**North Buffalo Creek**	**NBC_NBC3_SCM_04**
Summary	Criteria/Result	
Drainage Area Description	12.4-Acres, 23% impervious drainage area	
SCM Description	Level spreader - vegetated filter strip	
Treatment	236% of WQV treated. Reduction of 49.1% total Nitrogen and 54.2% total Phosphorus	
Pretreatment	Forebay upstream of SCM	
Photo ID	NBC3_064	
Prioritization Score	131.6	
OPCC	$1,182,526	

Table 7.4-6 NBC_NBC3_SCM_05 Starmount Drive

Starmount Drive	**Lake Hamilton**	**NBC_NBC3_SCM_05**
Summary	Criteria/Result	
Drainage Area Description	151-Acres, 32% impervious drainage area	
SCM Description	Stormwater wetland	
Treatment	25% of WQV treated. Reduction of 38.8% total Nitrogen and 42.6% total Phosphorus	
Pretreatment	Upstream forebay	
Photo ID	NBC_LH_020	
Prioritization Score	156	
OPCC	$1,463,928	

Table 7.4-7 NBC_NBC3_SCM_06 Latham Road

Latham Road	**North Buffalo Creek**	**NBC_NBC3_SCM_06**
Summary	Criteria/Result	
Drainage Area Description	18-Acres, 23% impervious drainage area	
SCM Description	Stormwater wetland	
Treatment	100% of WQV treated. Reduction of 42.1% total Nitrogen and 46.0% total Phosphorus	
Pretreatment	Upstream forebay	
Photo ID	NBC2_050	
Prioritization Score	139.2	
OPCC	$1,270,153	

7.4.3 Tributary A

Table 7.4-8 NBC_NBC-TA_SCM_01 Ashland Drive

Ashland Drive	**North Buffalo Creek**	**NBC_NBC-TA_SCM_01**
Summary	Criteria/Result	
Drainage Area Description	65.2-Acres, 26% impervious drainage area	
SCM Description	Stormwater wetland	
Treatment	59% of WQV treated. Reduction of 52% total Nitrogen and 58.2% total Phosphorus	
Pretreatment	Upstream forebay	
Photo ID	NBC3_136	
Prioritization Score	152.8	
OPCC	$1,276,616	

7.4.4 Lake Hamilton

Table 7.4-9 NBC_LH_SCM_01 East Lake Drive

East Lake Drive	**North Buffalo Creek**	**NBC_LH_SCM_01**
Summary	Criteria/Result	
Drainage Area Description	9.4-Acres, 17% impervious drainage area	
SCM Description	Stormwater wetland	
Treatment	172% of WQV treated. Reduction of 42.1% total Nitrogen and 44.9% total Phosphorus	
Pretreatment	Upstream forebay	
Photo ID	NBC3_034	
Prioritization Score	136.6	
OPCC	$3,102,954	

Table 7.4-10 NBC_LH_SCM_02_Benjamin Parkway

Benjamin Parkway	Tributary A	NBC_LH_SCM_02
Summary	Criteria/Result	
Drainage Area Description	74.4-Acres, 42% impervious drainage area	
SCM Description	Stormwater wet pond	
Treatment	100% of WQV treated. Reduction of 28.3% total Nitrogen and 44.2% total Phosphorus	
Pretreatment	Upstream forebay	
Photo ID	N/A	
Prioritization Score	151	
OPCC	$3,499,823	

8 Anticipated Permitting

Projects such as those presented in this document often require local, state, and federal permits to be issued for various aspects of construction. Applicable permits that are typical for these types of projects are included in Table 8-1 below.

Table 8-1 Applicable Permit Types

Permit Type	Expected Applicable Project Type
Local site plan review (planning, zoning, land disturbance, post-construction stormwater, etc.)	Primary, Secondary, CCA, Stream, and SCM
Environmental Permitting: NCDEQ 401 Water Quality Certification, USACE Section 404 Permit, Jordan Lake Stream Buffers	Primary, Secondary, Stream, and SCM
NCDPS / FEMA Permitting: No-Rise Certification, or CLOMR	Primary, Secondary, Stream, and SCM
NCDEQ / DEMLR Erosion and Sediment Control Permitting (>1 acre disturbed)	Large Primary, larger Secondary, and Stream
NCDOT Encroachment Agreements	n/a

The following sections provide a more detailed discussion of each anticipated permit. Table 8.4-1 shows the anticipated permits for the proposed projects in the NBC Watershed.

8.1 Environmental Permitting

The USACE 404 Permit is a federal regulatory process managed by the USACE to ensure that construction projects comply with Section 404 of the Clean Water Act. This section requires permits for the discharge of dredged or fill material into U.S. waters, including wetlands. The permit process, originating from the Clean Water Act, involves a thorough evaluation of the potential impacts on aquatic resources and considers alternatives that would have less environmental impact. In North Carolina, the USACE works closely with state agencies to ensure that proposed projects meet both federal and state

water quality standards. The process includes interagency coordination and may require mitigation measures to offset environmental impacts.

The 401 Water Quality Certification is a state-level regulatory process ensuring that construction projects comply with the Clean Water Act's provisions. Originating from Section 401 of the Clean Water Act, this certification process mandates that any project requiring a federal permit, which might result in discharges into U.S. waters, obtains state approval to ensure adherence to water quality standards. In North Carolina, the DEQ implements this certification by reviewing project documents, assessing potential impacts on water bodies, and ensuring that mitigation measures are in place to protect water quality. The process requires implementation of BMPs to minimize environmental impacts.

Within the Jordan Lake watershed, disturbance of the riparian buffer (50’ landward of a jurisdictional stream) requires buffer disturbance authorization, which is also regulated by NCDEQ.

While specific permit coverage is at the discretion of the USACE, in general, construction activities associated with these project types would fall under one of several NWPs:

NWP #3: NWP3 is a general permit issued by the USACE to authorize maintenance activities for existing structures and fills in Waters of the US. This permit allows for the repair, rehabilitation, or replacement of previously authorized, currently serviceable structures or fills without the need for IPs, provided the activities have minimal environmental impact.

NWP #13: NWP13 authorizes bank stabilization activities necessary to prevent erosion and protect stream banks and shorelines. This permit covers activities such as the construction of revetments, bulkheads, and other stabilization structures, provided they have minimal adverse environmental effects. General limitations are work must be less than 500 feet of bank and less than 1 cubic yard fill per running foot of stream.

NWP #27: NWP27 authorizes activities for aquatic habitat restoration, enhancement, and establishment. NWP27 is most commonly used for stream and wetland restoration projects. This permit allows for projects such as the re-establishment of wetland and riparian areas, the creation of aquatic habitat features, and the enhancement of existing habitats. Applicants must demonstrate that their projects will provide functional uplift to the aquatic environment.

For projects with significant environmental impacts, an IP may be required. An IP is a specific authorization issued by the USACE for activities that do not qualify for NWPs due to their scale or potential environmental impact. These permits are typically required for projects that involve significant discharges into U.S. waters, including large-scale developments, extensive dredging, or substantial wetland impacts. The application process for an IP is comprehensive, requiring detailed project descriptions, EAs, and mitigation plans to minimize and offset impacts. Applicants must submit these documents to the USACE, which then conducts a thorough review, interagency consultations, and potentially public hearings.

The timeframe for obtaining an IP can vary widely, often taking a year, depending on the project's complexity and environmental sensitivity. Limitations on IPs are stringent, including strict adherence to

water quality standards, protection of endangered species, and compliance with historic preservation requirements.

8.2 NC Department of Public Safety Flood Plain Mapping (FEMA)

Coordination with FEMA is anticipated for projects that involve any work within the regulatory floodway. All primary streams studied in this report have mapped 1% annual chance flood hazard areas and are therefore regulated by FEMA. Projects within the FEMA regulatory floodway must either achieve a "no-rise" condition or submit for and acquire a FEMA approved CLOMR prior to local floodplain permit approvals. Projects within the FEMA floodway fringe may also require a CLOMR if certain conditions are met; therefore, those need to be assessed on a project-by-project basis. Most primary system projects are expected to achieve a "no-rise" condition. In some cases, significant lowering of the WSE associated with a project may also trigger a post-construction LOMR in conjunction with the pre-construction no-rise certification.

8.3 NC Department of Transportation Encroachment

Based on the City provided parcel and street centerline data it is not anticipated that any project within NBC will require an NCDOT encroachment agreement.

8.4 Land Disturbance / Erosion and Sedimentation Control

It is anticipated that all proposed projects for the NBC Watershed will require a land disturbance permit. Any project that disturbs over one acre requires a preconstruction notification to NCDEQ. Submittal and approval of a complete erosion control plan to NCDEQ is required as part of obtaining a land disturbance permit. Depending on project conditions, location, applying for a local grading permit may also be required. For this reason, a Land Disturbance permit is shown as applicable for all projects.

Table 8.4-1 Anticipated Permits Required for Proposed Projects

Project ID	Project	Tributary	FEMA No-Rise or CLOMR/ LOMR	404/401 NWP	404/401 IP	Land Disturbance
Primary System Projects						
NBC_JB_CULV_01	Martin Avenue	Jordan Branch	X	X	X	X
NBC_JB_CULV_02	Murchie and Sharon	Jordan Branch	X		X	X
NBC_JB_FB_01	Jordan Branch Floodplain Benching	Jordan Branch	X		X	X

Project ID	Project	Tributary	FEMA No-Rise or CLOMR/ LOMR	404/401 NWP	404/401 IP	Land Disturbance
NBC_JB-UT1_CULV_01	Martin Avenue	Unnamed Tributary 1	X	X		X
NBC_JB-UT1_CULV_02	Cody Avenue	Unnamed Tributary 1	X	X		X
NBC_LH_CULV_01	North Holden Road	Lake Hamilton	X	X	X	X
NBC_LH_FB_01	Lake Hamilton Floodplain Benching	Lake Hamilton	X		X	X
NBC_MC_BRG_01	Phillips Avenue	Muddy Creek	X		X	X
NBC_MC_CULV_01	White Street	Muddy Creek	X	X		X
NBC_MC_CULV_02	East Bessemer	Muddy Creek	X	X	X	X
NBC_MC_FB_01	Muddy Creek Floodplain Benching	Muddy Creek	X		X	X
NBC_MC-UT2_CULV_01	Phillips Avenue	Unnamed Tributary 2	X	X		X
NBC_MC-UT2_CULV_02	Textile Drive	Unnamed Tributary 2	X	X		X
NBC_MC-UT2_FB_01	Unnamed Tributary 2 Floodplain Benching	Unnamed Tributary 2	X		X	X
NBC_NBC2_BRG_01	Yanceyville Street	NBC2	X		X	X
NBC_NBC2_BRG_02	North Elm Street	NBC2	X	X		X
NBC_NBC2_BRG_03	Cridland Road	NBC2	X	X		X
NBC_NBC2_FB_01	Latham Park Floodplain Benching	NBC2	X		X	X
NBC_NBC3_BRG_01	Battleground Avenue	NBC3	X		X	X
NBC_NBC3_BRG_02	West Smith Street	NBC3	X		X	X
NBC_NBC-UT_CULV_01	Hill Street	Unnamed Tributary	X	X	X	X
NBC_NBC-UT_CULV_02	West Smith Street	Unnamed Tributary	X	X	X	X

Project ID	Project	Tributary	FEMA No-Rise or CLOMR/ LOMR	404/401 NWP	404/401 IP	Land Disturbance
NBC_NBC-UT_CULV_03	Guilford Avenue	Unnamed Tributary	X		X	X
NBC_NBC-UT3_CULV_01	Latham Road	Unnamed Tributary 3	X	X		X
NBC_NBC-UT3_CULV_02	Briarcliff Road	Unnamed Tributary 3	X	X		X
NBC_NBC-UT3_CULV_03	Cleburne Street	Unnamed Tributary 3	X		X	X
NBC_NBC-UT4_CULV_01	West Friendly Avenue	Unnamed Tributary 4	X	X	X	X
NBC_NBC-UT4_CULV_02	South Josephine Boyd Street	Unnamed Tributary 4	X		X	X
NBC_PL_CULV_01	East Cone Boulevard	Philadelphia Lake	X		X	X
NBC_PL_FB_01	Philadelphia Lake Floodplain Benching	Philadelphia Lake	X		X	X
Secondary System Projects						
NBC_SUB3_PIPE_01	Benjamin Parkway	Subbasin 3	X	X		X
NBC_SUB6_CULV_01	Mayflower Drive	Subbasin 6		X		X
NBC_SUB6_CULV_02	Warren Street/Wright Avenue	Subbasin 6		X		X
NBC_SUB6_PIPE_01	Storm Sewer Area 1	Subbasin 6		X		X
NBC_SUB8_CULV_01	Parkway Street	Subbasin 8				X
NBC_SUB8_PIPE_01	Florence Street	Subbasin 8				X
NBC_SUB8_PIPE_02	North Elm Street	Subbasin 8				X
NBC_SUB8_PIPE_03	West Fisher Avenue	Subbasin 8				X
NBC_SUB8_PIPE_04	Church Street	Subbasin 8				X
NBC_SUB9_CULV_01	Baseball Field	Subbasin 9	X	X		X
NBC_SUB9_PIPE_01	Salem and Stewart	Subbasin 9				X

Project ID	Project	Tributary	FEMA No-Rise or CLOMR/ LOMR	404/401 NWP	404/401 IP	Land Disturbance
NBC_SUB9_PIPE_02	North Morrow	Subbasin 9				X
NBC_SUB9_PIPE_03	Bellemeade Street	Subbasin 9				X
NBC_SUB9_PIPE_04	East Washington Street	Subbasin 9				X
Stream Bank Stabilization Projects						
NBC_JB-UT1_BEHI_01	Voss Avenue Streambank Stabilization	Unnamed Tributary 1	X	X		X
NBC_LH-UT6_BEHI_01	Kenbridge Court Streambank Stabilization	Unnamed Tributary 6	X	X		X
NBC_MC_BEHI_01	Autumn Drive Streambank Stabilization	Muddy Creek	X	X		X
NBC_MC-UT2_BEHI_01	Jolson Street Streambank Stabilization	Unnamed Tributary 2	X	X		X
NBC_NBC2_BEHI_01	Roseland Street Streambank Stabilization	NBC2	X	X	X	X
NBC_NBC2_BEHI_02	Fairview Street Streambank Stabilization	NBC2	X	X		X
NBC_NBC3_BEHI_01	Hill Street Streambank Stabilization	NBC3	X	X	X	X
NBC_NBC3_BEHI_02	Benjamin Parkway Streambank Stabilization	NBC3	X	X		X
NBC_NBC3_BEHI_03	Campus Drive Streambank Stabilization	NBC3	X	X		X
NBC_NBC3_BEHI_04	West Wendover Avenue Streambank Stabilization	NBC3	X	X		X

Project ID	Project	Tributary	FEMA No-Rise or CLOMR/ LOMR	404/401 NWP	404/401 IP	Land Disturbance
NBC_NBC3_BEHI_05	Green Valley Road Streambank Stabilization	NBC3	X	X		X
NBC_NBC-UT_BEHI_01	Eugene Court Streambank Stabilization	Unnamed Tributary	X	X		X
NBC_NBC-UT4_BEHI_01	Mimosa Drive Streambank Stabilization	Unnamed Tributary 4	X	X		X
NBC_NBC-UT4_BEHI_02	Mayflower Drive Streambank Stabilization	Unnamed Tributary 4	X	X		X
NBC_NBC-UT5_BEHI_01	Cascade Drive Streambank Stabilization	Unnamed Tributary 5	X	X	X	X
NBC_PL_BEHI_01	East Cone Boulevard Streambank Stabilization	Philadelphia Lake	X	X	X	X
NBC_NBC-TA_BEHI_01	Gracewood Drive Streambank Stabilization	Tributary A	X	X		X
Culvert Condition Assessment Projects						
NBC_PL_CULV_CON_01	Elkhart Drive and Dellwood Drive	Philadelphia Lake		X		X
SCM Projects						
NBC_LH_SCM_01	Starmount Drive Constructed Stormwater Wetlands	Lake Hamilton	X	X		X
NBC_LH_SCM_02	Henderson Road Wet Pond	Lake Hamilton		X		X
NBC_NBC2_SCM_01	Latham Road Constructed Stormwater Wetland	NBC2	X	X		X

Project ID	Project	Tributary	FEMA No-Rise or CLOMR/ LOMR	404/401 NWP	404/401 IP	Land Disturbance
NBC_NBC3_SCM_01	East Lake Drive Constructed Stormwater Wetland	NBC3	X	X		X
NBC_NBC3_SCM_02	East Lake Drive Level Spreader - Vegetated Filter Strip	NBC3	X	X		X
NBC_NBC3_SCM_03	West Radiance Drive Level Spreader - Vegetated Filter Strip	NBC3		X		X
NBC_NBC3_SCM_04	Mimosa Drive Level Spreader - Vegetated Filter Strip	NBC3	X	X		X
NBC_NBC3_SCM_05	West Wendover Avenue Constructed Stormwater Wetlands	NBC3	X	X		X
NBC_NBC3_SCM_06	Ashland Drive Constructed Stormwater Wetlands	NBC3	X	X		X
NBC_NBC-TA_SCM_01	Benjamin Parkway Wet Pond	Tributary A		X		X

9 Preliminary Opinions of Probable Construction Cost

Planning level opinions of probable construction cost were created for each project in the watershed. These planning-level costs for improvements include storm drainage improvements, channel stabilization materials, grading, necessary street improvements/replacements, floodplain benching, water and sewer utility relocations, erosion and sediment control measures, traffic control measures, miscellaneous items (e.g. fencing, walls, etc.), environmental mitigation costs, easement acquisition estimates, and SCMs as appropriate.

Standard contingencies applied to the projects include:

- Construction contingency: 30%
- Real Estate Acquisition (if applicable): 10%
- Geotechnical Investigation: 2%
- Materials Testing: 2%
- Bonding: 1.5%
- Design and Permitting: 20%

Table 9-1 through Table 9-5 below show the costs for each type of project (primary, secondary, stream, and SCMs). Appendix F includes the itemized opinions of probable construction cost.

Table 9-1 Primary System Preliminary OPCC

Project ID	Tributary	Project	OPCC
NBC_JB_CULV_01	Jordan Branch	Martin Avenue	$2,497,000
NBC_JB_CULV_02	Jordan Branch	Murchie and Sharon	$5,746,000
NBC_JB_FB_01	Jordan Branch	Jordan Branch Floodplain Benching	$10,948,000
NBC_JB-UT1_CULV_01	Unnamed Tributary 1	Martin Avenue	$2,414,000
NBC_JB-UT1_CULV_02	Unnamed Tributary 1	Cody Avenue	$2,051,000
NBC_LH_CULV_01	Lake Hamilton	North Holden Road	$3,873,000
NBC_LH_FB_01	Lake Hamilton	Lake Hamilton Floodplain Benching	$7,675,000
NBC_MC_BRG_01	Muddy Creek	Phillips Avenue	$5,832,000
NBC_MC_CULV_01	Muddy Creek	White Street	$3,130,000
NBC_MC_CULV_02	Muddy Creek	East Bessemer	$5,097,000
NBC_MC_FB_01	Muddy Creek	Muddy Creek Floodplain Benching	$6,326,000
NBC_MC-UT2_CULV_01	Unnamed Tributary 2	Phillips Avenue	$3,124,000
NBC_MC-UT2_CULV_02	Unnamed Tributary 2	Textile Drive	$1,999,000
NBC_MC-UT2_FB_01	Unnamed Tributary 2	Unnamed Tributary 2 Floodplain Benching	$657,000
NBC_NBC2_BRG_01	NBC2	Yanceyville Street	$13,064,000
NBC_NBC2_BRG_02	NBC2	North Elm Street	$9,704,000
NBC_NBC2_BRG_03	NBC2	Cridland Road	$4,797,000
NBC_NBC2_FB_01	NBC2	Latham Park Floodplain Benching	$13,505,000
NBC_NBC3_BRG_01	NBC3	Battleground Avenue	$6,472,000
NBC_NBC3_BRG_02	NBC3	West Smith Street	$4,762,000
NBC_NBC-UT_CULV_01	Unnamed Tributary	Hill Street	$3,568,000
NBC_NBC-UT_CULV_02	Unnamed Tributary	West Smith Street	$3,637,000
NBC_NBC-UT_CULV_03	Unnamed Tributary	Guilford Avenue	$13,832,000
NBC_NBC-UT3_CULV_01	Unnamed Tributary 3	Latham Road	$2,845,000
NBC_NBC-UT3_CULV_02	Unnamed Tributary 3	Briarcliff Road	$2,451,000

Project ID	Tributary	Project	OPCC
NBC_NBC-UT3_CULV_03	Unnamed Tributary 3	Cleburne Street	$4,000,000
NBC_NBC-UT4_CULV_01	Unnamed Tributary 4	West Friendly Avenue	$3,765,000
NBC_NBC-UT4_CULV_02	Unnamed Tributary 4	South Josephine Boyd Street	$6,179,000
NBC_PL_CULV_01	Philadelphia Lake	East Cone Boulevard	$6,464,000
NBC_PL_FB_01	Philadelphia Lake	Philadelphia Lake Floodplain Benching	$2,638,000
		Total:	**$163,052,000**

Table 9-2 Secondary System Preliminary OPCC

Project ID	Tributary	Project	OPCC
NBC_SUB3_PIPE_01	Subbasin 3	Benjamin Parkway	$831,000
NBC_SUB6_CULV_01	Subbasin 6	Mayflower Drive	$1,658,000
NBC_SUB6_CULV_02	Subbasin 6	Warren Street/Wright Avenue	$1,971,000
NBC_SUB6_PIPE_01	Subbasin 6	Storm Sewer Area 1	$514,000
NBC_SUB8_CULV_01	Subbasin 8	Parkway Street	$9,902,000
NBC_SUB8_PIPE_01	Subbasin 8	Florence Street	$626,000
NBC_SUB8_PIPE_02	Subbasin 8	North Elm Street	$314,000
NBC_SUB8_PIPE_03	Subbasin 8	West Fisher Avenue	$336,000
NBC_SUB8_PIPE_04	Subbasin 8	Church Street	$717,000
NBC_SUB9_CULV_01	Subbasin 9	Baseball Field	$2,840,000
NBC_SUB9_PIPE_01	Subbasin 9	Salem and Stewart	$1,458,000
NBC_SUB9_PIPE_02	Subbasin 9	North Morrow	$211,000
NBC_SUB9_PIPE_03	Subbasin 9	Bellemeade Street	$69,000
NBC_SUB9_PIPE_04	Subbasin 9	East Washington Street	$484,000
		Total:	**$21,931,000**

Table 9-3 Stream Bank Stabilization (at BEHI Locations) Preliminary OPCC

Project ID	Tributary	Project	OPCC
NBC_JB-UT1_BEHI_01	Unnamed Tributary 1	Voss Avenue Streambank Stabilization	$205,000
NBC_LH-UT6_BEHI_01	Unnamed Tributary 6	Kenbridge Court Streambank Stabilization	$610,000
NBC_MC_BEHI_01	Muddy Creek	Autumn Drive Streambank Stabilization	$503,000
NBC_MC-UT2_BEHI_01	Unnamed Tributary 2	Jolson Street Streambank Stabilization	$144,000
NBC_NBC2_BEHI_01	NBC2	Roseland Street Streambank Stabilization	$2,216,000
NBC_NBC2_BEHI_02	NBC2	Fairview Street Streambank Stabilization	$410,000
NBC_NBC3_BEHI_01	NBC3	Hill Street Streambank Stabilization	$492,000

Project ID	Tributary	Project	OPCC
NBC_NBC3_BEHI_02	NBC3	Benjamin Parkway Streambank Stabilization	$480,000
NBC_NBC3_BEHI_03	NBC3	Campus Drive Streambank Stabilization	$457,000
NBC_NBC3_BEHI_04	NBC3	West Wendover Avenue Streambank Stabilization	$277,000
NBC_NBC3_BEHI_05	NBC3	Green Valley Road Streambank Stabilization	$371,000
NBC_NBC-TA_BEHI_01	Tributary A	Gracewood Drive Streambank Stabilization	$147,000
NBC_NBC-UT_BEHI_01	Unnamed Tributary	Eugene Court Streambank Stabilization	$319,000
NBC_NBC-UT4_BEHI_01	Unnamed Tributary 4	Mimosa Drive Streambank Stabilization	$535,000
NBC_NBC-UT4_BEHI_02	Unnamed Tributary 4	Mayflower Drive Streambank Stabilization	$224,000
NBC_PL_BEHI_01	Philadelphia Lake	East Cone Boulevard Streambank Stabilization	$680,000
NBC_NBC-TA-UT5_BEHI_01	Unnamed Tributary 5	Cascade Drive Streambank Stabilization	$908,000
		Total:	**$8,978,000**

Table 9-4 Culvert Condition Assessments Preliminary OPCC

Project ID	Tributary	Project	OPCC
NBC_PL_CULV_CON_01	Philadelphia Lake	Elkhart Drive & Dellwood Drive	$731,000
		Total:	**$731,000**

Table 9-5 Green Stormwater Infrastructure Preliminary OPCC

Project ID	Tributary	Project	OPCC
NBC_LH_SCM_01	Lake Hamilton	Starmount Drive Constructed Stormwater Wetlands	$3,102,954
NBC_LH_SCM_02	Lake Hamilton	Henderson Road Wet Pond	$3,499,823
NBC_NBC2_SCM_01	NBC2	Latham Road Constructed Stormwater Wetland	$1,182,526
NBC_NBC3_SCM_01	NBC3	East Lake Drive Constructed Stormwater Wetland	$956,316
NBC_NBC3_SCM_02	NBC3	East Lake Drive Level Spreader - Vegetated Filter Strip	$321,249
NBC_NBC3_SCM_03	NBC3	West Radiance Drive Level Spreader - Vegetated Filter Strip	$190,185
NBC_NBC3_SCM_04	NBC3	Mimosa Drive Level Spreader - Vegetated Filter Strip	$138,234
NBC_NBC3_SCM_05	NBC3	West Wendover Avenue Constructed Stormwater Wetlands	$1,276,616
NBC_NBC3_SCM_06	NBC3	Ashland Drive Constructed Stormwater Wetlands	$1,463,928

Project ID	Tributary	Project	OPCC
NBC_NBC-TA_SCM_01	Tributary A	Benjamin Parkway Wet Pond	$1,270,153
		Total:	**$13,401,985**

10 Prioritization Results

The following tables are organized by project category and contain the scores and subsequent rankings of each project. Phased projects share the same prioritization score since they are dependent on each other. The shared score is the highest of the phased projects. Refer to Appendix G for the full scoring matrices for all projects.

Table 10-1 Primary System Project Prioritization Scores and Ranks

Project ID	Project	Prioritization Score	Project Rank for NBC Watershed
NBC_JB_CULV_01	Martin Avenue	351.8	3
NBC_JB_CULV_02	Murchie and Sharon	273.2	22
NBC_JB_FB_01	Jordan Branch Floodplain Benching	--	N/A
NBC_JB-UT1_CULV_01	Martin Avenue	359.6	2
NBC_JB-UT1_CULV_02	Cody Avenue	230.2	30
NBC_LH_CULV_01	North Holden Road	223.7	33
NBC_LH_FB_01	Lake Hamilton Floodplain Benching	--	N/A
NBC_MC_BRG_01	Phillips Avenue	281.6	20
NBC_MC_CULV_01	White Street	109.3	64
NBC_MC_CULV_02	East Bessemer	345.4	5
NBC_MC_FB_01	Muddy Creek Floodplain Benching	--	N/A
NBC_MC-UT2_CULV_01	Phillips Avenue	325.4	14
NBC_MC-UT2_CULV_02	Textile Drive	318.8	15
NBC_MC-UT2_FB_01	Unnamed Tributary 2 Floodplain Benching	--	N/A
NBC_NBC2_BRG_01	Yanceyville Street	330.5	12
NBC_NBC2_BRG_02	North Elm Street	339.3	9
NBC_NBC2_BRG_03	Cridland Road	330.8	11
NBC_NBC2_FB_01	Latham Park Floodplain Benching	314.0	16
NBC_NBC3_BRG_01	Battleground Avenue	313.4	17
NBC_NBC3_BRG_02	West Smith Street	348.6	4
NBC_NBC-UT_CULV_01	Hill Street	248.0	26
NBC_NBC-UT_CULV_02	West Smith Street	344.0	7
NBC_NBC-UT_CULV_03	Guilford Avenue	230.6	29
NBC_NBC-UT3_CULV_01	Latham Road	294.0	19
NBC_NBC-UT3_CULV_02	Briarcliff Road	164.5	39
NBC_NBC-UT3_CULV_03	Cleburne Street	236.0	28

Project ID	Project	Prioritization Score	Project Rank for NBC Watershed
NBC_NBC-UT4_CULV_01	West Friendly Avenue	338.0	10
NBC_NBC-UT4_CULV_02	South Josephine Boyd Street	345.2	6
NBC_PL_CULV_01	East Cone Boulevard	219.4	35
NBC_PL_FB_01	Philadelphia Lake Floodplain Benching	--	N/A

Table 10-2 Secondary System Project Prioritization Scores and Ranks

Project ID	Project	Prioritization Score	Project Rank for NBC Watershed
NBC_SUB3_PIPE_01	Benjamin Parkway	167.5	38
NBC_SUB6_CULV_01	Mayflower Drive	330.1	13
NBC_SUB6_CULV_02	Warren Street/Wright Avenue	302.1	18
NBC_SUB6_PIPE_01	Storm Sewer Area 1	223.0	34
NBC_SUB8_CULV_01	Parkway Street	275.2	21
NBC_SUB8_PIPE_01	Florence Street	259.4	25
NBC_SUB8_PIPE_02	North Elm Street	228.2	31
NBC_SUB8_PIPE_03	West Fisher Avenue	216.2	36
NBC_SUB8_PIPE_04	Church Street	268.8	24
NBC_SUB9_CULV_01	Baseball Field	371.8	1
NBC_SUB9_PIPE_01	Salem and Stewart	245.0	27
NBC_SUB9_PIPE_02	North Morrow	227.1	32
NBC_SUB9_PIPE_03	Bellemeade Street	214.8	37
NBC_SUB9_PIPE_04	East Washington Street	341.7	8

Table 10-3 Stream Bank Stabilization Project Prioritization Scores and Ranks

Project ID	Project	Prioritization Score	Project Rank for NBC Watershed
NBC_JB-UT1_BEHI_01	Voss Avenue Streambank Stabilization	150.2	42
NBC_LH-UT6_BEHI_01	Kenbridge Court Streambank Stabilization	130.8	55
NBC_MC_BEHI_01	Autumn Drive Streambank Stabilization	133.2	54
NBC_MC-UT2_BEHI_01	Jolson Street Streambank Stabilization	142.0	45
NBC_NBC2_BEHI_01	Roseland Street Streambank Stabilization	117.6	56
NBC_NBC2_BEHI_02	Fairview Street Streambank Stabilization	137.8	49
NBC_NBC3_BEHI_01	Hill Street Streambank Stabilization	137.4	51
NBC_NBC3_BEHI_02	Benjamin Parkway Streambank Stabilization	139.2	47
NBC_NBC3_BEHI_03	Campus Drive Streambank Stabilization	139.6	46
NBC_NBC3_BEHI_04	West Wendover Avenue Streambank Stabilization	117.6	57
NBC_NBC3_BEHI_05	Green Valley Road Streambank Stabilization	155.8	40
NBC_NBC-TA_BEHI_01	Gracewood Drive Streambank Stabilization	144.8	44

Project ID	Project	Prioritization Score	Project Rank for NBC Watershed
NBC_NBC-UT_BEHI_01	Eugene Court Streambank Stabilization	138.0	48
NBC_NBC-UT4_BEHI_01	Mimosa Drive Streambank Stabilization	136.0	52
NBC_NBC-UT4_BEHI_02	Mayflower Drive Streambank Stabilization	134.8	53
NBC_PL_BEHI_01	East Cone Boulevard Streambank Stabilization	155.4	41
NBC_TA-UT5_BEHI_01	Cascade Drive Streambank Stabilization	146.8	43
NBC_JB-UT1_BEHI_01	Voss Avenue Streambank Stabilization	150.2	42

Table 10-4 Culvert Condition Assessment Prioritization Scores and Ranks

Project ID	Project	Prioritization Score	Project Rank for NBC Watershed
NBC_PL_CULV_CON_01	Elkhart Drive and Dellwood Drive	271.3	23

Table 10-5 Green Stormwater Infrastructure Prioritization Scores and Ranks

Project ID	Project	Prioritization Score	Project Rank for NBC Watershed
NBC_LH_SCM_01	Starmount Drive Constructed Stormwater Wetlands	136.6	55
NBC_LH_SCM_02	Henderson Road Wet Pond	151.0	44
NBC_NBC2_SCM_01	Latham Road Constructed Stormwater Wetland	131.6	59
NBC_NBC3_SCM_01	East Lake Drive Constructed Stormwater Wetland	149.0	45
NBC_NBC3_SCM_02	East Lake Drive Level Spreader - Vegetated Filter Strip	93.6	67
NBC_NBC3_SCM_03	West Radiance Drive Level Spreader - Vegetated Filter Strip	103.2	66
NBC_NBC3_SCM_04	Mimosa Drive Level Spreader - Vegetated Filter Strip	103.2	65
NBC_NBC3_SCM_05	West Wendover Avenue Constructed Stormwater Wetlands	152.8	43
NBC_NBC3_SCM_06	Ashland Drive Constructed Stormwater Wetlands	156.0	40
NBC_NBC-TA_SCM_01	Benjamin Parkway Wet Pond	139.2	51

Stantec

Stantec is a global leader in sustainable architecture, engineering, and environmental consulting. The diverse perspectives of our partners and interested parties drive us to think beyond what's previously been done on critical issues like climate change, digital transformation, and future-proofing our cities and infrastructure. We innovate at the intersection of community, creativity, and client relationships to advance communities everywhere, so that together we can redefine what's possible.

APPENDIX C

City of Greensboro NPDES Permit Program Water Quality Assessment and Monitoring Plan

Permit Number NCS000248

July 2024

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List of Tables:

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Section 1: Purpose

The purpose of the Water Quality Assessment and Monitoring Program is to monitor and assess the quality of streams within the City of Greensboro. Information gained from this program may be used to help identify and eliminate sources of pollution and illicit discharges, track short-term and long-term trends, and, where possible, gauge the effectiveness of stormwater management efforts and programs conducted by the City.

Section 2: General Water Quality Monitoring Program

2.1 Monitoring Methods

Monitoring methods utilized in this plan will consist of directly accessing the stream to conduct specified monitoring within the stream channel at a point representative of the overall stream flow at the time of monitoring. In most cases, this will be center channel of the stream. When possible, staff will enter the stream and directly fill sample bottles from the stream flow.

2.2 Sample Types and Frequency

Samples collected under this plan will be fixed interval grab samples taken at each site on a monthly basis. A specific day of each month (the third Wednesday of the first month) will be assigned for monitoring to allow for sampling over a range of flows at each monitoring location.

2.3 Monitoring Parameters

Table 2-1 provides a list of the water quality parameters sampled at the monitoring sites.

Table 2-1: Water Quality Monitoring Parameters

Parameters	
Alkalinity	Total Suspended Solids
BOD	Turbidity
COD	Copper
Hardness	Zinc
Fecal Coliform	Cadmium
Total Phosphorus	Lead
Nitrite Nitrogen	Dissolved Oxygen
Total Kjeldahl Nitrogen	Temperature
Nitrate Nitrogen	Conductivity
Total Dissolved Solids	pH

Section 3: Monitoring Sites

3.1 Basis for Locating Monitoring Sites

The goal of the WQ monitoring program plan will be to locate monitoring sites within each major watershed in the City to characterize water quality conditions within the watershed. Twenty monitoring sites will be utilized under this plan to monitor and assess water quality conditions in the City: seven in North Buffalo Creek, five in South Buffalo Creek, and eight in Greensboro's water supply watersheds. For North and South Buffalo Creek Watersheds, one site is located at an upstream point within the watershed and one is located at a downstream point within the watershed. The two water supply watershed sites are located at sites upstream of the city's drinking water reservoirs.

3.2 Site Locations/Description

Table 3-1 contains the description and location of the twenty monitoring sites within the monitoring plan.

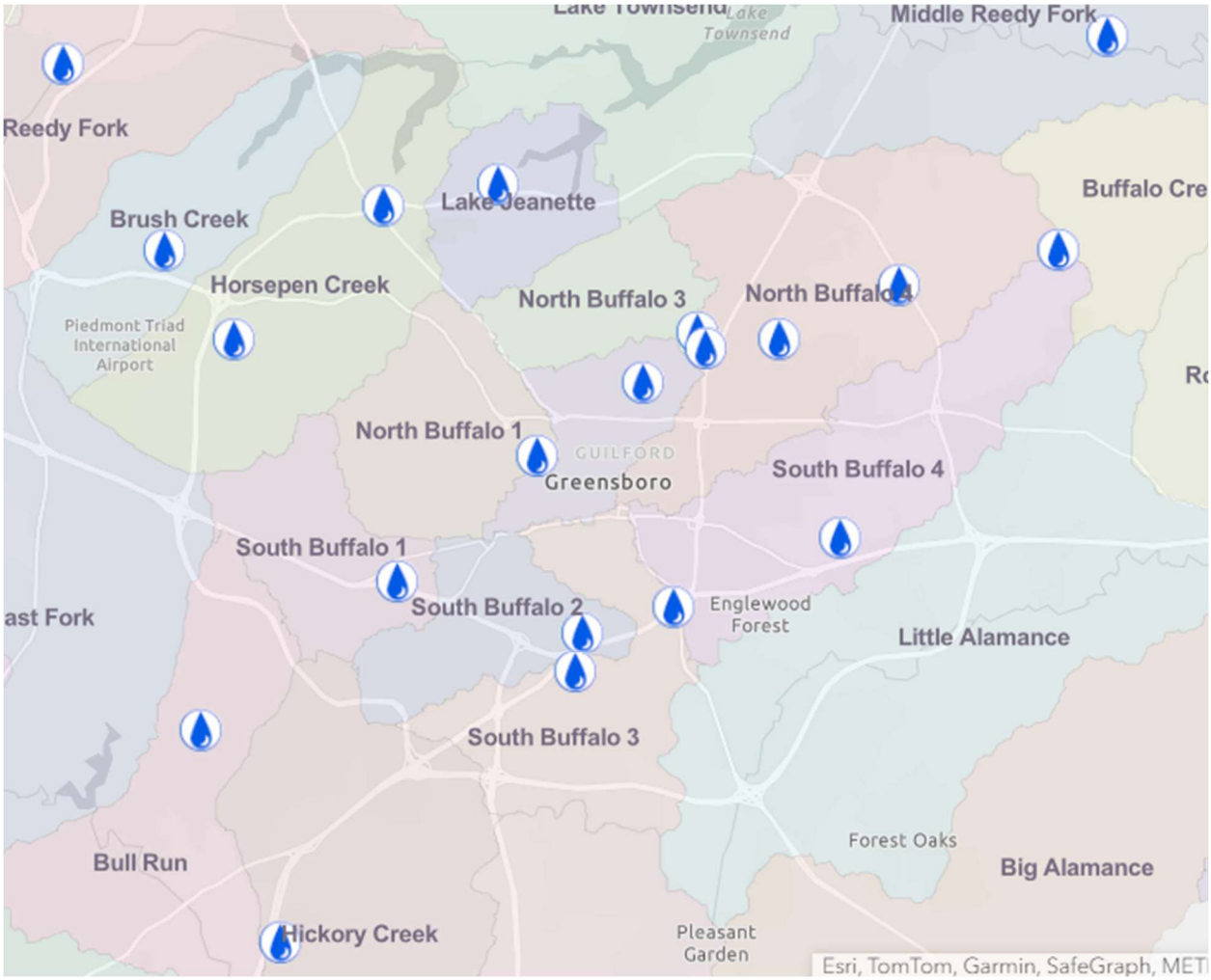
Table 3-1: Description of City of Greensboro Water Quality Monitoring Sites

Site Name	Stream	Location
Randleman	South Buffalo Creek	2410 Randleman Rd.
W JJ	South Buffalo Creek	2610 Randleman Rd.
Fieldcrest	South Buffalo Creek	2213 Martin Luther King Jr. Dr.
McConnell	South Buffalo Creek	3409-R1 McConnell Rd.
Rankin Mill	North Buffalo Creek	1433 Rankin Mill Rd.
White	North Buffalo Creek	2199 White Street
Summit	North Buffalo Creek	2300 Summit Ave
16th	North Buffalo Creek	1500 17th Street
Church	North Buffalo Creek	1909 Golden Gate Dr.
Aycock	North Buffalo Creek	419 Westover Terrace
Merritt	South Buffalo Creek,	1509 Merritt Dr.
McLeansville	Buffalo	6105 McLeansville Rd.
Friendship Church	Reedy Fork	7107 Friendship Church Rd.
Bluff Run	Lake Jeanette	5004 Bluff Run Dr.
Battleground	Horsepen Creek	3924 Battleground Ave.
Bunch	Reedy Fork Creek	5455 Bunch Road
Fleming/Muirfield	Brush	3700 O'Briant Place
Old Oak Ridge	Horsepen Creek	5846 Old Oak Ridge Rd.
Mackay	Bull Run	21 Gatehouse Lane
Kivett	Reddick's Creek	2837 Kivett Dr.

3.3 Site Map

Figure 3-1 shows the location of the twenty monitoring sites within the monitoring plan.

Figure 3-1: Greensboro Water Quality Monitoring Sites



Section 4: Sample and Data Analysis

4.1 Sample Analytical Methods

Table 4-1 shows the monitoring parameters, reporting limits, and analytical methods used to analyze samples collected under the plan.

Table 4-1: Laboratory Analytical Methods and Quantitation Limits

Parameter	Quantitation Limit	Units	Method
Alkalinity, Total	1.0	mg/L	SM2320 B-2011
NO-3-N (Nitrate Nitrogen)	0.050	mg/L	SM4500NO_3 E-2011
BOD-5	2.0	mg/L	SM5210 B-2011
Cadmium, Total	0.0002	mg/l	EPA 200.8
COD	5.0	mg/L	EPA 410.4
Copper, Total	0.002	mg/L	EPA 200.8
Dissolved Solids	25.0	mg/L	SM2540 C-2011
Fecal Coliform	1.0	ecfu/100 mL	SM9222 D-2006
Hardness, Total	1.0	mg/L	SM2340 C-2011
Lead, Total	0.003	mg/L	EPA 200.8
NO-2-N (Nitrite Nitrogen)	0.010	mg/L	SM4500NO_3 E-2011
Total Phosphorus	0.010	mg/L	SM4500 PE-2011
Total Suspended Solids	5.0	mg/L	SM2540 D-2011
Zinc, Total	0.005	mg/L	EPA 200.8

4.2 Quality Assurance

The City contracts with a state certified laboratory to analyze water samples; physical parameters are obtained by City Stormwater staff. The City follows the North Carolina Department of Environmental Quality (NCDEQ) approved procedures, addressing sample handling, preservation, transportation, equipment calibration and maintenance, laboratory protocols, and QA/QC methods.

4.3 Record Keeping

All records and data generated under the monitoring program will be maintained for a minimum period of five years. Field and laboratory data are stored in electronic formats on the WQI Database. Digital copy log books and calibration records are also maintained.

Section 5: Data Evaluation and Assessment

5.1 Methods for Evaluating and Assessing Data

As data is assimilated, the City will analyze the various pollutant parameters in the program and conduct statistical analysis on the data to determine trends, where possible. At a minimum, data will be graphically represented to visualize trends.

5.2 Reporting

Data results will be managed and stored in a similar manner as other water quality data collected by the city's Stormwater Management Division and will adhere to procedures outlined in the divisions Quality Assurance Project Plan (QAPP). Annual summary reports will include the number of samples collected, number and types of parameters analyzed, and data analysis activities to determine trends. Data generated from the Water Quality Assessment and Monitoring Plan will be available upon request. (See NPDES Water Quality Monitoring Plan>Annual Summary Data on Y Drive)

5.3 Monitoring Plan Revisions

The City will review the monitoring plan annually as part of the data analysis and annual report process to determine if any revisions to the plan are necessary based on the past year's assessment and monitoring activities. If revisions are necessary, the City will revise the plan and submit the revisions to NCDEQ for review and approval.

APPENDIX D

CITY OF GREENSBORO
NPDES MS4 STORMWATER DISCHARGE PERMIT

Permit # *NCS000248*

STORMWATER MANAGEMENT PLAN

2024/2025 Annual Report

Prepared for:

North Carolina Department of Environmental Quality
Division of Energy, Mineral & Land Resources
Stormwater Permitting Unit
1617 Mail Service Center
Raleigh, North Carolina 27699-1617

Prepared by:

City of Greensboro
Water Resources Department - Stormwater Management Division
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Greensboro, NC 27402-3136

GREENSBORO

September 26, 2025

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Stormwater Management Plan (SWMP)
FY 2024-2025 Annual Report for
City of Greensboro's NPDES MS4 Discharge Permit

EXECUTIVE SUMMARY

The City of Greensboro's initial National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Discharge Permit (Permit Number NCS000248) became effective on December 30, 1994. The North Carolina Department of Environmental Quality (NCDEQ) issued the City of Greensboro's current permit on June 1, 2024, for a period of five years with an effective expiration date of May 31, 2029. This document includes a summary of NPDES stormwater quality management programs and activities implemented, scheduled to be implemented, or completed during the June 1, 2024 - June 30, 2025 permit term.

The City's NPDES stormwater permit, and associated Stormwater Quality Management Program Plan (Stormwater Plan), is designed to control the discharge of pollutants from the MS4 to the Maximum Extent Practicable (MEP).

Significant Receiving Waters and Watersheds

Greensboro is located near the headwaters of the Cape Fear River Basin in the Piedmont physiographic region of North Carolina, with a majority of the City's jurisdictional watersheds draining eastward towards the Haw River, while a smaller portion of the City area drains south towards the Deep River. The North and South Buffalo Creek Watersheds drain the majority of the City's central urbanized area eastward towards Buffalo Creek. Beyond the eastern City limits, Buffalo Creek drains generally northeastward into the Reedy Fork Creek and the Haw River, a tributary of the Jordan Lake watershed. The City of Greensboro, with a total area of about 131.94 square miles, represents just over 1% of the 9,322 square mile Cape Fear Basin. Existing land uses within Greensboro are broadly classified in Table 1.

Table 1. Land Uses in the City of Greensboro

Land Use Classification	Approximate % within Corporate Limits
Residential	39%
Commercial	13%
Industrial	7%
Open Space/Wooded/Undeveloped	41%
Total (land use does not include public streets and water bodies)	100%

Table 2 shows a listing of the primary streams located within the City of Greensboro MS4 service area. Water quality classifications of receiving streams are provided, along with their use support ratings and key water quality challenges.

Table 2. Primary Receiving Streams within Greensboro Service Area (Upper Cape Fear River Basin)

Receiving Stream Name	Stream Segment	Water Quality Classification*	Use Support Rating	Water Quality Issues	303(d) List
Reedy Fork Creek	Within corporate limits	WS-III;NSW, WS-III;NSW CA	Impaired	Impaired biological integrity, Chlorophyll a, Turbidity	yes
Brush Creek	Within corporate limits	WS-III;NSW	Impaired	Impaired biological integrity, Chlorophyll a	Yes
Horsepen Creek	Within corporate limits	WS-III;NSW, WS-III;NSW CA	Impaired	Impaired biological integrity	Yes
North Buffalo Creek	Within corporate limits	WS-V;NSW	Impaired	Fecal coliform, Impaired biological integrity, Zinc, Cooper, NO2+NO3-N	Yes
South Buffalo Creek	Within corporate limits	WS-V;NSW	Impaired	Turbidity, Impaired biological integrity, Zinc	Yes
East Fork Deep River	Within corporate limits	WS-IV, WS-IV;CA	Impaired	Impaired biological integrity, Turbidity, Fecal coliform	Yes

** Water Quality Classifications:*

NSW = Nutrient Sensitive Waters
WS = Water Supply classification (degree of protective measures).
C = Class C waters – general use category (maintain aquatic life and biological integrity, wildlife, secondary recreation, etc.)
CA = Critical Area

*** Use Support Rating (the degree to which the water body supports its designated uses):*

FS = Fully Supporting
PS = Partially Supporting
NS = Not Supporting
NR = Not Rated

Organizational Structure

The Stormwater Management Utility is one of seven divisions of the City's Water Resources Department (also including water supply, water reclamation, customer service, business, engineering, and operations and maintenance). This organizational arrangement facilitates protecting and improving surface water quality while best managing local water resources.

The following bullet points briefly document the overall organizational structure and functional responsibilities of the City's Stormwater Plan. Although the Stormwater Management Division resides within the Water Resources Department, the program itself is much broader and encompasses and/or extends well beyond the boundaries of the Water Resources Department. Several other departments in the City of Greensboro, as well as those in Guilford County, contribute to stormwater quality management and NPDES-related programs in substantive ways.

- **City Stormwater Management Division**: NPDES MS4 Discharge Permit administration for Greensboro; stormwater utility administration; surface water quality monitoring and operations management; computerized infrastructure management systems; stormwater and surface water quality related complaint response; stormwater conveyance system inventory and detailed MS4 outfall mapping; public education and awareness; stormwater and watershed master planning; site development plan reviews for stormwater management; general stormwater-related technical support and mapping; local Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP) floodplain administration; local water supply watershed protection program administration; stormwater control measures (SCM) evaluations and SCM crediting; SCM inspections and monitoring; field screening and follow-up monitoring activities; industrial monitoring and related activities; industrial inspections and educational efforts; system inspection; special stormwater inspection and enforcement programs; water quality inspections and monitoring programs; overall authority (as delegated from City Manager's Office) over the municipal stormwater quality management programs.

- **City Engineering and Inspections Department**: Project design, construction contract bidding, construction contract administration, and inspections of new development and redevelopment; stormwater capital improvement projects and property acquisition; local construction erosion and sedimentation control program administration.

- **City Parks and Recreation Department**: City of Greensboro parks, greenway and utility easement maintenance coordination and programs; partner in volunteer programs such as Adopt-a-Park.

- **City Planning Department**: Overall City planning including management of plan review process; comprehensive planning; management of City's Technical Review Committee (TRC) for design engineers and developers; zoning management and ordinance development and revisions.

- **City Water Resources Department (beyond Stormwater Division)**: Enhancements to the municipal stormwater system and receiving waters by controlling sanitary sewer overflows (SSOs) and industrial spills; pretreatment programs for major industry; water supply and wastewater treatment programs, including planning and management; water distribution system and sanitary sewer system maintenance programs.
- **City Fire Department**: Spill response program - HAZMAT (HAZardous MATerials) Team, containment of spills; industrial site inspections.

- **City Management Information Systems Department**: Data management including city Geographic Information Systems (GIS) and city database administration; city computer systems management; aerial photography and related city mapping programs.

- **City Legal Department**: Permit-related legal, enforcement and ordinance assistance; other legal services including contract and agreement reviews.

- **(Guilford County) Emergency Management / Health Department**: County emergency management programs, chemical control; county spill response, coordinate cleanup & reporting.

Legal Authority

The required legal authorities for Greensboro's NPDES municipal stormwater program were developed and adopted during the first permit period in a new ordinance to the Greensboro Land Development Ordinance: *Chapter 30 – City of Greensboro Stormwater Management Ordinance* (http://online.encodeplus.com/regs/greensboro-nc/doc-viewer.aspx#secid-144). The stormwater management ordinance became effective on July 1, 1994.

The Chapter 30 ordinance includes the following objectives:

- To provide for the establishment and enforcement of the City's Stormwater Management Program;
- To reduce the discharge of pollutants to the storm sewer system to the maximum extent practicable by requiring, where appropriate, the use of best management practices, structural and/or nonstructural stormwater quantity and quality control measures and other provisions;
- To provide for the inspection and proper maintenance of structural and nonstructural stormwater controls and the municipal separate storm sewer;
- To prohibit non-storm water discharges to the City storm sewer and require the removal of illicit connections to the City storm sewer;
- To prevent improper disposal of materials that degrade water quality;
- To permit sampling and monitoring for pollutants such as those associated with illicit discharges, improper disposal, industrial and construction activities, and the application of pesticides, herbicides, and fertilizers; and,
- To reduce erosion associated with stormwater runoff;
- To provide legal definitions for user fee rate calculations.

To date, no significant changes have been required or considered for the City's legal authority *related to NPDES stormwater program implementation*. Stormwater Management, working with City Management, Council, and Stakeholders has incorporated runoff quantity control and citywide stream buffer requirements into the Code of Ordinance in recent years, but these have not been specific NPDES MS4 discharge permit requirements. Many of these additional requirements along with historic stormwater related regulations are located throughout the Code of Ordinance with a large portion appearing in Chapter 30 which serves as the City's Unified Development Ordinance. Additional ordinance language specific to the Phase II rules, specifically with regard to post-construction runoff, was adopted by City Council on April 7, 2009, and became effective June 1, 2009.

Funding

The City established a stormwater utility funding mechanism partially in response to the initial and ongoing requirements of the NPDES municipal stormwater permit, but also to help ensure a dedicated funding source for stormwater-related programs and activities, along with the desire to manage municipal stormwater issues in a more proactive and comprehensive manner. As impervious area is generally in direct correlation with the volume and quality of surface stormwater runoff, establishing the stormwater billing system based on total impervious area is equitable to all of the City's utility customers. As of July 1, 2024, single-family residences are charged one of three tiers with an average rate of $3.24 per month. Non-single-family properties are billed based upon the number of equivalent residential units (ERUs), which is computed by dividing the total impervious area by the size of the ERU (2,543 square feet), on the given property.

Additionally, as a financial incentive for non-structural and structural best management practice implementation at non-single-family residential sites throughout the City, Greensboro provides a fee crediting mechanism within the stormwater utility. The City also provides technical support and educational assistance for innovative stormwater practices.

The Stormwater Utility is a dedicated balanced enterprise fund with budgeted revenues and expenditures of over *16 million dollars*. This budget represents a slightly higher than normal budget due to an extra investment in capital projects this fiscal year. The chart illustrates the allocation of Stormwater Utility funds by operational category.

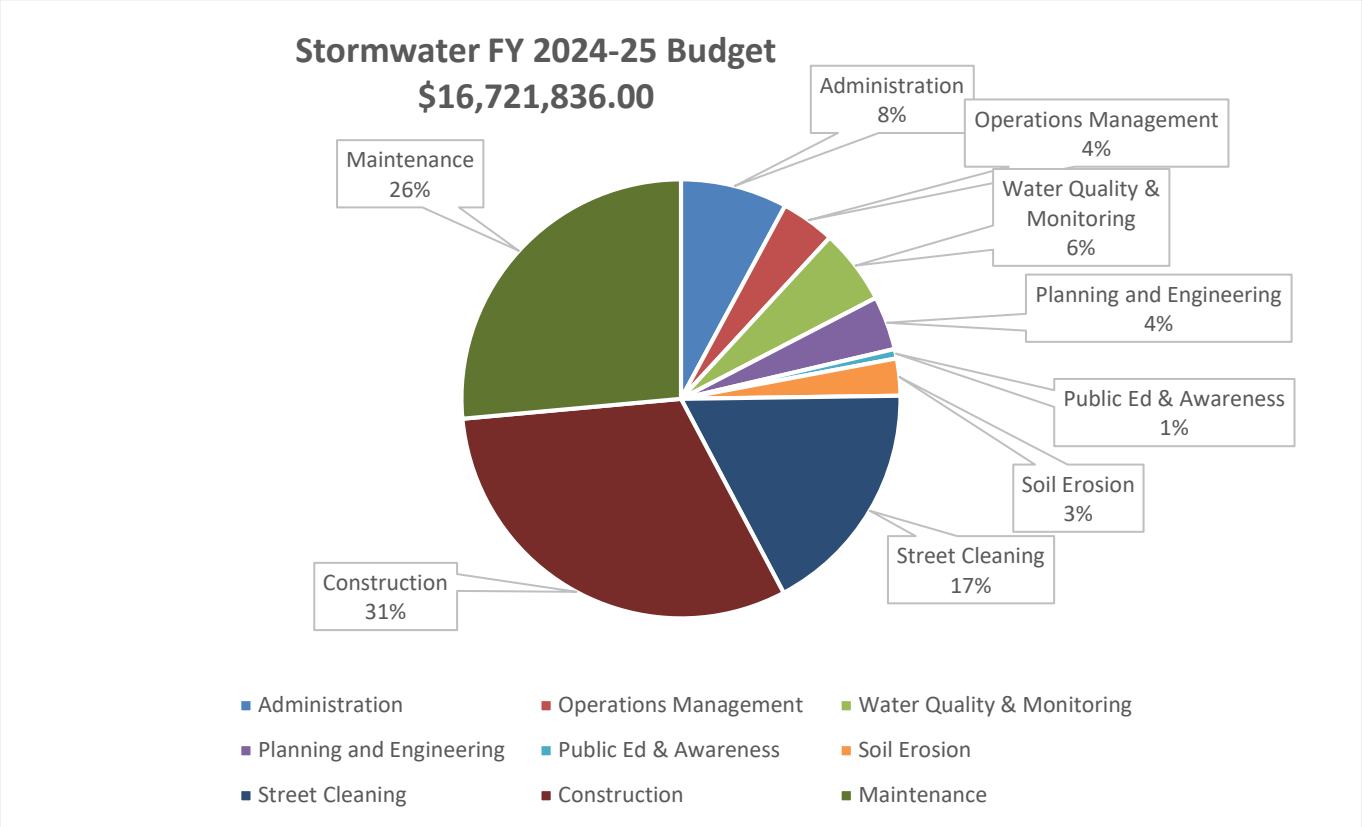

Figure 1. Stormwater budget for FY 2024-2025.

STORMWATER MANAGEMENT PLAN

The following information is the City's stormwater management plan (SWMP) identifying programmatic measures to comply with the City's NPDES permit to the maximum extent practicable. BMP summary tables for each of the regulatory areas are provided, along with narrative for key programs and updates or accomplishments completed during the last permit year (June 1, 2024 - June 30, 2025).

Public Education and Outreach

BMP Summary Table

BMPs for Public Education and Outreach Program		
BMP	**Measurable Goals**	**Comments**
Pollution Prevention Brochures	Distribute brochures through event displays, volunteer participants, informational displays, and field representatives. Various issues addressed include proper disposal of oil and other toxic materials, sediment and erosion control issues, proper application and handling of fertilizers and pesticides, litter prevention, pollution reporting and awareness, etc., for different age groups.	Water Resources attended and/or hosted 49 events during the 2025 fiscal year where Stormwater SMART target pollution brochures were made available. SMART brochures (includes the topics: Litter and Trash, Pet Waste, Yard Waste, Pesticides, Household Chemicals, Vehicle Maintenance) and City's Adopt-a-Stream/Drain Marker handouts were made available to over 4,684 individuals at organized events attended by the City. Brochures and handouts were also made available in the Water Resources customer service area and replenished as needed throughout the year.
Website	Maintain the Stormwater Management Website. Contains information about pollution prevention, stormwater technology, and practices. Provides contacts and forms for pollution reporting and information requests.	Throughout the year, updates were made as needed. http://www.greensboro-nc.gov/stormwater
Stormwater Videos	Stormwater SMART and GTN created several videos to educate residents and students about various pollution prevention measures and volunteer opportunities. SMART shared videos throughout the year on media platforms. Stormwater videos air periodically on Greensboro Television Network (GTN) that appears on the local cable affiliate and are located on the City's YouTube.	SMART - 1,479,554 media messages and educational videos played on a variety of digital devices throughout Greensboro and Guilford County Unincorporated (Meta/Nextdoor). **SMART Greensboro Specific Analytics:** YouTube Impressions (155,508) Spectrum TV Impressions (34,610) Premion TV Impressions (43,643) Google Display Impressions (475,572)

	SMART's videos are aired at Greensboro Grasshopper home games and on My48 as part of the Greensboro SWARM's broadcasting assets and on the videoboard during home games.	**SMART Greensboro/Guilford County Unincorporated Analytics:** Meta/Instagram Impressions (598,774) Nextdoor Impressions (171,447) 29,710 Link Clicks 235,102 Videos played to 100% 12 (SMART's and GTN's) PSAs each run approximately 1-3 times a day on GTN for a total of 12-36 total PSA Shown per day. GTN currently airs on Spectrum, AT&T Uverse and Lumos, as well as the Cablecast App, which can be found on any streaming platform (Roku, Apple TV, Amazon Fire, or Smart TVs/Devices) plus GTN's weblink. Greensboro Grasshoppers played 72 home games. Patron attendance throughout the season: • July 2024 - 53,128 • August 2024 - 38,251 • September 2024 - 22,799 • April 2025 - 45,829 • May 2025 - 59,836 • June 2025 - 43,889 Greensboro SWARM played 24 home games. • The 30-second PSA's were displayed on the videoboard reaching ~36,967 patrons during the season. PSA's were displayed on My 48 4-5 times per broadcast during 4 SWARM games reaching ~1,194 households per game.

BMP Summary Table – *Continued*

Media Campaigns	Advertise with Greensboro SWARM. Promote stormwater-related topics and programs on GSOGoesGreen and Stormwater SMART's social media pages (Facebook, Instagram, X, Nextdoor) as well as on SMART's website. Advertise pollution issues and stormwater related news and programs in the local Hispanic newspaper, La Noticia, and in The Gist and the GSOGoesGreen Volunteer Newsletter.	Greensboro SWARM Basketball Ads - A water quality message was displayed through the following avenues: courtside rotational signs 2 minutes per home game reaching ~36,967 patrons this season through 24 home games, 700 magnet schedules were printed and distributed in the Triad, and over 2,500 game day programs with an advertisement were given out over the season. **SMART's social media campaign included:** Posts/Re-Posts on Facebook (204) Instagram reach (91,214) Facebook reach (424,409) SMART's website saw 41,142 visitors seeking information about pollution prevention at www.stormwatersmart.org, with 1,017 of those visits including their new regional event calendar, www.friendsofcreekweek.org, to which they posted 235 events. Static images and GIFs were shared on Nextdoor and Google Display Network. **GSOGoesGreen social media campaign included:** stormwater topics and related programs shared throughout the year. Topics included: Waste Reduction, Litter Prevention, Rain Barrels (DIY workshops and City-hosted Rain Barrel and Compost Sale), Volunteer Programs (Drain Marker, Lake Cleanups, Wetland Cleanups, and Stream Cleanups), Plastic Free July, Guilford Creek Week, the new GSO WaterWise portal (contains tips on outdoor irrigation and stormwater pollution prevention), and How to Report Stormwater Pollution. The GSOGoesGreen Facebook page had 86 Stormwater-related posts with a

		reach of 37,674 users with 585 reactions (average reaction rate: 1.55%) with 474 video views. The GSOGoesGreen Instagram page had 85 Stormwater-related posts with a reach of 10,114 users with 402 engaged users (average engagement rate: 4.7%) and 6,561 reels plays. On the GSOGoesGreen X page, 79 posts contained Stormwater information. These posts gained 13 likes and 8 retweets. On the City's Nextdoor, site 10 posts contained Stormwater information. Topics included Guilford Creek Week, GSO WaterWise, the City's Yard Waste Policy Reminders, Drain Marker Pop-ups, Flooding, and the City's Rain Barrel and Compost sale with 11,807 impressions. La Noticia distributed 9,000 newspapers and had 100,000 visitors to LaNoticia.com and the Greensboro E-Edition. There were 43 stormwater education information included. Topics included: FOG (6), Motor Oil (5), litter prevention/Adopt-a-Stream (12), Pet Waste (7), Fertilizer (5), and Flooding (6). These ads are also available online. The Gist Newsletter emailed monthly issues throughout the year with stormwater education information included. The Gist has grown from 11,536 subscribers in July 2024 to approximately 15,690 subscribers as of June 30, 2025. Topics included flooding information, how to report Stormwater pollution in Greensboro, and Guilford Creek Week. These newsletters are also available online. The GSOGoesGreen Volunteer Newsletter is sent quarterly and highlights volunteer opportunities—

		including year-round programs like Adopt-a-Stream, Clean-a-Creek and Drain Marker, as well as pop-up events such as Wetland and Lake Cleanups. Information on stormwater-related campaigns within the City are also shared. Three emails were sent to an average of 328 subscribers, with an average open rate of 61.4% and a click rate of 13.1%. This reflects growth from the previous year, when three emails reached approximately 260 subscribers, with an open rate of 60% and a click rate of 10.46%. These newsletters are available to view online here.

BMP Summary Table – *Continued*

Helpline	Established a helpline (336-373-2489) for citizens to report pollution, address water quality and drainage concerns, as well as promote volunteer opportunities.	14 Water Pollution events reported via online form 193 visits to the Report Water Pollution webpage 43 Drainage Concerns reported via online form 231 visits to the Report Drainage Concerns webpage
School and Civic Group Presentations	Develop and present educational talks and activities for schools and civic groups, including our Enviroscape Model, stormwater drain model, and other educational tools.	Approximately 4,684 individuals were reached by the City's Stormwater program at 49 events.
Targeted Commercial Education Initiative	Develop flyer /brochures to inform businesses that have a potential of illicit discharges or improper disposals to the stormwater conveyance system.	Ongoing effort by the Stormwater Program; program initiated in Mid-2003. See page 13 for details.
Watershed Signs	Road signs have been installed at stream crossings identifying the watershed and stream name.	Ongoing effort by the Stormwater Program.
Cooperative Efforts	The City of Greensboro seeks reasonable opportunities to collaborate with neighboring communities for joint educational programs. The City is a member of Stormwater SMART and receives direct education and mass media services through the partnership. The North Carolina Cooperative Extension Services Master Gardeners and Guilford County Soil and Water Conservation District are also partners in Stormwater education. The City collaborates with the City of High Point, Guilford County, the Town of Kernersville, local businesses, and non-profits during Guilford Creek Week and throughout the year. Each year, we strive to provide fun and educational opportunities throughout Guilford County to help raise awareness about the health of our watersheds.	SMART provided 42.5 hours of Stormwater education programming to 889 residents in Greensboro and the surrounding Guilford Area (Gibsonville, Greensboro, Jamestown, Oak Ridge, and Summerfield) and distributed 1,750 stormwater activity booklets to libraries, recreation centers, and other community partners. During Guilford Creek Week, over 28 community programs occurred June 21 – 28, 2025. Alongside community partners, the City hosted 12 events, with over 219 participants, collected over 132 pounds of trash near local waterways, and placed over 7 drain markers. During Pollinators Day at NC Cooperative Extension in Guilford County over 100 people were reached and educated on environmental sustainability on June, 12, 2025.

Target Audience

Current and future target audiences for stormwater education include:

1. General Public, especially homeowners – applies lawn care products, uses chemicals for home and auto maintenance, makes decisions about drainage issues on their properties and participates in volunteer opportunities. Through the City's Education and Outreach programs, and Guilford Creek Week, over 4,903 individuals were reached through school programming, summer camps, library programs, and other community events.
2. Structural SCM Owners – maintenance issues and education about proper SCM maintenance and responsibilities.
3. Industries – potential of water quality impacts due to improper material handling, improper housekeeping practices and illicit discharges.
4. Commercial landscapers, restaurants, mobile washers, concrete companies, painters, drywall installers, masons, automotive repair facilities and kennels – potential water quality impacts due to illegal dumping of wastewater into storm drains and improper chemical handling and application.
5. Through our partnership with Stormwater SMART, approximately 2,639 individuals were reached in the Guilford Area through school programming, educational notebooks, seed packets, library programs, and more. A robust media campaign landed 1,479,554 impressions for educational videos played on a variety of digital devices throughout Greensboro and Guilford County Unincorporated (Meta/Nextdoor). SMART's website had 41,142 visitors.

Identifying Target Pollutants and Sources

Target pollution sources for stormwater education include:

1. Illicit Connections – The discharge of non-stormwater into the stormwater conveyance system can result in biological mortality in receiving streams due to discharges.
2. Improper Disposal – The discharge of used motor oil, oil & grease, organic materials (grass and leaves), and various other pollutants into storm drains can be a problem on construction sites, commercial and residential areas, etc.
3. Water Quality Monitoring – Routine water quality monitoring data will be evaluated to identify target pollutants which impact water quality.
4. Pet Waste – Greensboro has developed a TMDL for fecal coliform for the portion of North Buffalo Creek located within the jurisdictional limits. As a management measure, the City generates educational literature targeting pet owners on the need to pick up after their pet in order to protect water quality. Additionally, staff has observed that a number of public parks and homeowner's associations have installed pet waste bag dispensers and or signage to encourage proper disposal of pet waste. Water Resources gave out approximately 412 dog waste bags with a proper disposal message and a link to our Stormwater webpage throughout the year at various events. The City maintains 24 pet waste stations throughout regional parks and approximately 180,000 bags were provided to the community at neighborhood pet waste stations.
5. Lawns and Gardens – Lawn care chemicals may enter storm drains due to improper application. Yard waste may also be improperly placed into storm drains. These can create blockages in the stormwater conveyance system and cause decreased dissolved oxygen in streams. The Clean Streams Program educates commercial landscape professionals on the proper application of fertilizer and pesticides, as well as aquatic pesticides. Commercial landscape professionals have an opportunity to receive pesticide credit for successful completion.

6. Auto Repair Shops – Many auto repair shops have interior drains that have the potential to be illicit connections (such as older buildings or sites that were previously a different business type). As these locations are identified and dye-testing is conducted, owners and staff are made aware of proper house-keeping practices, including awareness of interior drains and their resulting destinations (i.e., either storm or sanitary sewers).
7. Mobile Auto Washers – car washing activities can generate potentially harmful wash water. An educational and inspection program targeting mobile auto washers on containment, collection, and disposal of wash water has been developed.
8. Restaurants – Many restaurants have Good Housekeeping issues related to disposal of cooking oil, process wastewater generated by cleaning activities, and outdoor storage areas such as trash dumpsters and grease containers that can adversely impact water quality. An educational and inspection program targeting restaurants has been developed and implemented during this reporting period.

Public Outreach Program Narrative

Outreach mechanisms are outlined in the BMP summary table above. During the permit period, Greensboro aims to reach most of the approximately 307,381 individuals in its MS4 service area, as well as those in surrounding areas. The City hosts and attends numerous events throughout the year to present stormwater messaging to the public. Stormwater-related programs and information are also included periodically in The Gist newsletter and the GSOGoesGreen Volunteer Newsletter. Additionally, individuals are regularly exposed to various stormwater-related messages broadcast on our local governmental station. The City also implements several media campaigns through television, newspapers, and social media platforms, including Nextdoor, Facebook, Instagram, and X. Together, these media outlets are designed to effectively reach the residents of Greensboro. To engage Spanish-speaking residents, the City prints some materials in both English and Spanish and shares educational messages through a local Spanish-language newspaper.

Public Involvement and Participation

BMP Summary Table

BMPs for Public Involvement and Participation Program		
BMP	**Measurable Goals**	**Comments**
Adopt-a-Stream	Develop an Adopt-a-Stream Program. Volunteers must pick up trash from their adopted segment of stream twice per year for two years. Added the Clean-a-Creek (one-time cleanup) program for volunteers who are not ready to commit to adopting a stream but still want to contribute.	45 cleanups 419 volunteers 263 bags of trash Approximately 4,910 lbs of trash
Drain Marker Program	Developed a Drain Marker Program. Volunteers attach signs to storm drains. The signs remind residents and visitors to not dump down the drain	12 events 85 volunteers 446 drain markers installed
Adopt-a-Park	Promote and support the Parks and Recreation Department Adopt-a-Park Program. Volunteers are asked to perform four cleanup events per year for their adopted park.	96 Cleanups 721 Volunteers 1,339 Volunteer Hours 358 Bags of Debris Collected
Adopt-a-Street	Promote and support the Parks and Recreation Department Adopt-a-Street Program. Volunteers	294 Cleanups 2,205 Volunteers

	are asked to perform four cleanup events per year for their adopted street segment.	4,513 Volunteer Hours 2,012 Bags of Debris Collected
Stormwater Advisory Board	Board established to help guide Stormwater program on important community issues.	Stormwater Advisory Board reconvenes as needed to address community issues.
Annual Clean-up Events	Promote and support Greensboro Beautiful (GBI) and Guilford Creek Week Cleanups.	**Cleanups:** Big Sweep (9/13/24 – 10/13/24) Winter Wipe Out (2/1/25 – 2/28/25) Great American Cleanup (3/21/25 - 4/30/25) Guilford Creek Week (6/21/25 - 6/28/25)
City Lake Cleanups	Develop monthly lake cleanups (weather permitting) during the Spring and Summer months at the City's lakes in partnership with the Parks and Recreation Department. Volunteers are asked to gather trash from hard-to-reach areas via kayaks within the lakes.	**Lake Brandt** 9/24/24 – 11 volunteers and 34 lbs. of trash 7/23/24 – Canceled due to thunderstorms. 5/27/25 – Canceled due to heavy rain. **Lake Townsend** 8/7/24 – Canceled due to Hurricane Debby flood warnings. 10/16/24 – 16 volunteers and 72 lbs. of trash. 6/25/25 – Canceled due to severe thunderstorm warnings.
Trash Traps	Promote and support Haw River Assembly's (HRA) trash traps at Barber Park (South Buffalo Creek) and the Gillespie Golf Course (Mile Run Creek). Volunteers are asked to gather trash from the trash traps for research.	**South Buffalo Creek Trash Trap** 5 cleanouts Removed 1,385 items from inside the trap: Plastic Film (95), Hard Plastics (475), Styrofoam (722), Metal (45), Glass (20), and Other (28). Outside of the trap, approximately 283 lbs. of trash was collected. **Mile Run Creek Trash Trap** 3 cleanouts Removed 1,281 items from inside the trap: Plastic Film (34), Hard Plastic (584), Styrofoam (1,147), Metal (40), Glass (10), and Other (70).

Poster Contest	A Water Conservation Poster Contest "Make Waves by Saving Water" was held by the City for elementary and middle school students in Guilford County. Winning posters in each division were selected to represent Greensboro in a statewide contest sponsored by NC One Water.	The theme of Greensboro's 2025 Water Conservation Poster Contest was "Make Wakes by Saving Water." There were 25 entries from grades K – 8. There were 1st, 2nd, and 3rd place winners from three grade divisions, K-2, 3-5, and 6-8.
Water Festival	The City hosts an annual Water Festival, offering approximately 250-500 Guilford County fifth-grade students (public, private, and home school associations) the chance to engage in fun, hands-on water activities aligned with Guilford County Schools' fifth-grade curriculum.	A total of 268 Guilford County students attended on April 8, 2025, participating in approximately 9 activities per school group. 18 different divisions and organizations presented, including Stormwater SMART, the City of Greensboro Stormwater Monitoring, and local groups focused on water quality.
Neighbor Woods Program	The Neighbor Woods Program, a partnership between Greensboro Beautiful, the City of Greensboro, NC Cooperative Extension, property owners, and neighborhoods, provides residents with native trees to plant in eligible spaces to restore or expand canopy cover, with community commitment to planting, care, and maintenance, supported by donations and volunteer teams.	300 participants 295 trees planted
Educational Workshops	Sustainable Series DIY Rain Barrel w/Drip Irrigation Workshop, Green Reads Book Club (water themed month), Don't Waste It (DWI), and NC CATCH workshops were offered as a resource for community members and educators.	8/17/2024 – Sustainable Series DIY Rain Barrel w/Drip Irrigation Workshop (21 participants) 8/23/2024 – Green Reads Book Club (20 participants) 10/4/2024 – Don't Waste It Workshop (8 participants) 4/4/2025 – NC CATCH (19 participants)
Household Hazardous Waste Collection	Promote proper disposal of harmful chemicals through the Household Hazardous Waste Collection Center.	1,867,051 lbs. of chemicals were collected from 24,048 drop-offs in Guilford County. Approximately 75% is from City residents.
Fats, Oils, and Grease Inspection Program	Program designed to prevent the excessive introduction of oil, grease, and fats into the sanitary sewer system and the wastewater collection system, which helps prevent sanitary sewer over flows.	Over 6,047 door hangers were distributed and several messages were posted to NextDoor, and other social media sites. 1.32 million gallons of FOG removed from

		grease traps connected to the city of Greensboro wastewater collection system. 457 inspections of FSEs.

Target Audience

Target audiences for the public involvement program include representative age, ethnic, and economic groups in Greensboro, from individuals to businesses. For local citizens who speak Spanish, some materials to promote volunteer programs are printed in both English and Spanish. A local Spanish newspaper will also be used for advertising on select campaigns.

Participation Program Narrative

The public is involved in the City's Stormwater Management Program. The following are ongoing programs that are available in the community.

- **Public Hearings**

  Public hearings are held to address key programs, such as, stream corridor concerns in the community including restoration projects. Additionally, City Council meetings serve as public hearing opportunities.

- **Working with Citizen Volunteers Willing to Educate Others About the Program**

  As part of the drain marker program, for example, volunteers hang an information piece on the mailboxes of neighborhood residents where drain markers are installed.

- **Volunteer Monitoring or Stream Clean-up Activities**

  As part of our Adopt-a-Stream Program, volunteers are asked to note stream conditions on their reporting form. The volunteers are required to clean the stream twice per year. If volunteers are not ready to adopt a stream, they may complete a one-time cleanup (Clean-a-Creek). The City also hosts community pop-up cleanups at streams throughout the year and the Water Resources department partners with the Parks and Recreation department on kayaking lake cleanups that are open to the public. Many volunteers also participate in the Greensboro Beautiful' s annual cleanups (NC Big Sweep, Great American Cleanup, and Winter Wipe Out) and Parks and Recreations Adopt-a-Programs (Park and Street). The City also promotes and supports the trash trap cleanouts held at Barber Park and at the Gillespie Golf Course.

Illicit Discharge Detection and Elimination

The City of Greensboro maintains a program to identify and eliminate illicit discharges and improper disposals from its MS4 service area.

BMP Summary Table

BMPs for Illicit Discharge Detection and Elimination (IDDE) Program		
BMP	**Measurable Goals**	**Comments**
Implementation and enforcement of *Stormwater Management Ordinance*	Enforce current *Stormwater Management Ordinance* (Chapter 30 of the Greensboro Land Development Ordinance) requirements pertaining to the illicit discharge and improper disposal of pollutants and waste.	Ongoing program (Water Quality Section)
Stream water quality monitoring	Conduct routine chemical and physical water quality sampling of major streams. Analyze data, detect potential illicit discharges, and prioritize locations for follow-up investigation.	Ongoing program (Water Quality Section)
Response and investigation of citizens' concerns	Maintain dedicated helpline and field calls related to pollution concerns and environmental questions from citizens. Provide staff response to pollution concerns.	Ongoing program (Water Quality Section, Public Education and Awareness Section, City Contact Center)
Develop and maintain storm sewer system inventory base map of major outfalls	Create map and inventory procedures for the collection of major outfalls that discharge to waters of the State.	Ongoing program (Operations Management Section)
Maintain an inventory of major outfalls that discharges to waters of the State	Maintain an inventory of major outfalls that discharges to waters of the State.	Inventory complete; ongoing collection for annexations and new developments (Operations Management Section)
Establish procedures to identify and eliminate failed septic systems and sanitary sewer overflows.	Establish and maintain procedures to identify and report failed septic systems or sanitary sewer overflows to the appropriate agency (County health department or local utility department).	Ongoing program (Water Quality Section)
Maintain Inspection/detection program to detect dry weather flows at MS4 outfalls	Maintain procedures for detecting and tracing the sources of illicit discharges to the MS4 and for removing the sources.	Ongoing program (Water Quality & Operations Management Sections)

BMP Summary Table – *Continued*

Inter-departmental spill response team	Maintain cooperative agreement and improve relationship with spill response team partners. City Fire and Police are primary responders, while Stormwater is a secondary responder to assist in tracking spills and assessing environmental damage as a result of environmental emergencies.	Ongoing program (City Fire & Police--primary responders; Stormwater Management Division secondary responders)
Commercial/Business education and inspection program	Develop and implement education and inspection program to inform local businesses of stormwater regulations, hazards of unlawful discharges, and penalties for violations.	Ongoing program (Water Quality Section)
Education and outreach programs	Continue ongoing programs and develop new programs to inform municipal employees, local businesses, and the general public of the hazards associated with illicit discharges and improper disposal of pollutants and waste.	Ongoing program (Water Quality Section, Public Education and Awareness Section)

Detection and Elimination

Greensboro continues to implement a comprehensive program of stormwater ordinance enforcement, water quality monitoring, education and outreach, spill and citizen complaint response, and formal inspections in order to prevent, detect, address, and eliminate illicit discharges and improper disposals to the storm sewer system and receiving waters. The ongoing detection and elimination program currently includes the following specific tasks:

1. Conducting stream water quality monitoring activity and conducting immediate follow up when the data suggests a water quality issue.
2. Maintaining venues for public reporting, including helpline via the Contact Center, website reporting forms, app reporting form, etc.
3. Providing professional staff response to citizen reports and complaints.
4. Participating in cooperative spill response team with inter-governmental partners.
5. Implementing a formal commercial and business education and inspection program.
6. Conducting stormwater investigations at NPDES permitted industrial facilities.
7. Conducting field screening of NPDES MS4 outfalls to detect dry weather flows.
8. Educating and training municipal employees and public.

Locating Priority Areas

To locate priority areas for illicit discharge investigations, Greensboro will continue to rely on a combination of water quality monitoring, inspections, complaints or notifications from citizens and city staff, and historical knowledge to locate and verify priority areas. Permanent sampling stations will continue to be located within Greensboro's major watershed sub-basins, and field and laboratory water quality parameters will be analyzed to detect potential illicit discharges and prioritize locations for follow-up investigation.

Removing Sources of Illicit Discharges

Greensboro's Land Development Ordinance (Chapter 30) specifically prohibits the illicit discharge or improper disposal of pollutants and waste to Greensboro's stormwater conveyance system and subsequent receiving surface waters. This ordinance authorizes City staff to utilize enforcement action, when

necessary, to stop an illicit discharge, remove the source, and require cleanup of the impacted area.

According to Stormwater's *Administrative Procedures for Completing an Enforcement Action*, the source of an illicit discharge may be removed through a series of educational efforts, written Notices of Violations (NOV), or progressing to civil penalty, if necessary. Once the source and responsible party of an illicit discharge or improper disposal is identified, an appropriate educational letter or NOV is mailed. Discontinuation of the discharge is required by the NOV, and the responsible party is required to reply in writing to Stormwater staff detailing efforts taken to discontinue the unlawful activity and prevent the activity from occurring in the future. Staff then conducts a follow-up investigation to ensure compliance.

During the July 1, 2023, to June 30, 2024, reporting period, approximately 144 illicit discharges, improper disposals, spills, or other pollution concerns were reported and investigated and resolved, 11 of which resulted in an issuance of a Notice of Violation (enforcement action).

In addition to the standard citizen reporting procedure such as the City Call Center, City Stormwater program has an inspection and education program that proactively addresses small commercial businesses that are identified as having the potential to impact water quality. During the July 1, 2023, to June 30, 2024, reporting period, educational material for horizontal directional drillers was finalized, and more than 25 drillers have received this information. Staff is working with other divisions in Water Resources to identify businesses contracted for this type of work in order to educate the companies on best management practices.

Outfall Screening

The City of Greensboro has identified and mapped 2098 NPDES outfalls. During this reporting period, 364 of these outfalls were inspected and assessed.

Construction Site Stormwater Runoff Control

The City of Greensboro has a locally delegated Erosion and Sediment Control (E&SC) Program implemented by the Erosion and Sediment Control Section of the Engineering and Inspections Department. The E&SC Section is responsible for erosion control plan review, grading permits, erosion control inspections, enforcement, and review of permanent stabilization of commercial development. A Chief E&SC Inspector, an Engineering Specialist, and three E&SC Inspector(s) comprise the section.

BMP Summary Table

BMPs for Construction Site Stormwater Runoff Control		
BMP	**Measurable Goals**	**Comments**
Plan Review, Enforce current E&SC ordinances.	Ongoing program implementation and enforcement. The locally delegated program is regulated by the NCDEQ, Division of Energy, Mineral and Land Resources	Water Resources Dept, Stormwater Management Division, E&SC Section.

E&SC Plan Review

In the City of Greensboro, any proposed land disturbance of one or more acre, including common plans of development that add up to a total of one or more acre, requires a grading permit prior to any land disturbance. For sites requiring a grading permit, a plan submittal consisting of a grading permit application, financial responsibility ownership forms, erosion and sediment control plans, and calculations are required. Plan approval is also required either through the City's Technical Review Committee, or through a grading only process that consists of limited reviewers from the Technical Review Committee prior to grading permit issuance. Once plans are reviewed and approved, a pre-construction meeting is scheduled and a letter of approval is provided to the financially responsible party. As of April 1, 2019, information is provided to the permittee on the requirement to obtain a NC DEQ issued certificate of coverage for the NPDES NCG01 permit.

During the onsite pre-construction meeting, the representative from the erosion and sediment control section reviews local, state and federal requirements with the permittee prior to issuing the grading permit. The City then requires and verifies that the certificate of coverage for the NPDES NCG01 permit is attached to the grading permit located in the permit box. The City also ensures that temporary erosion and sediment control measures are installed, inspected, and accepted prior to mass grading of the site. The City of Greensboro also stipulates that any development resulting in less than one acre of land disturbance indicate proper erosion and sediment control measures on the site plan. These plans are reviewed and approved by the erosion and sediment control section during the technical review process. Therefore, all sites developed that go through the City's Technical Review Committee are reviewed for compliance with erosion and sediment control regulations.

E&SC Program Implementation and Enforcement

The City of Greensboro employs a variety of mechanisms to ensure compliance with the provisions of the Soil Erosion and Sedimentation Control ordinance. First, no site will be issued a grading permit until the plan reviewer is certain that necessary sediment and erosion control measures are adequately detailed on the construction documents. Prior to issuing a grading permit for any site disturbing one acre or more, the City Code requires that the owner/contractor post a bond. Prior to issuing a grading permit for any site disturbing one acre or more, City Code requires that the owner/contractor post a bond. If a contractor begins land disturbance without the required permits, appropriate City staff will issue a stop work order.

Should the field inspector identify deviations from the approved plan during construction, the inspector may provide an inspection report to the owner and contractor indicating required measures and allowable timeframe to bring the site into compliance. If the required items are not addressed within the appropriate time, the inspector may issue a notice of violation (NOV) to the owner. A monetary fine may accompany the NOV. If the required measures are still not addressed as indicated in the NOV, the inspector may issue a stop work order. Additionally, the City of Greensboro reserves the right to deny the issuance of a certificate of occupancy for sites that continue to remain in nonconformance with the erosion and sediment control regulations.

Construction Site Inspections

Site inspections to ensure that proper erosion control measures are provided on construction sites are conducted by qualified field inspectors. Each inspector represents a specific area of the City and inspects sites within this area. Sites may be inspected more often depending on specific site conditions, the progress of construction, citizen complaints and/or previously identified problems.

As site inspections may occur more frequently based on several factors, these same factors apply to the prioritization of site inspections. Specific site conditions, contractor experience, citizen complaints, previous inspections and the progress of construction all impact which site is given priority for inspection on a more frequent basis. During the site inspection, the field inspector ensures that erosion and sediment control measures are implemented according to the approved plan and that no significant offsite sedimentation is occurring. If the inspector recognizes a problem in the field, the inspector may require that additional erosion control measures be installed and maintained in accordance with established enforcement procedures.

Table 3. Data on the number of inspections and enforcement actions carried out by the E&SC Section during the period of June 1, 2024 to June 30, 2025.

INSPECTIONS			
Reporting Period: June 1, 2024 to June 30, 2025			
Universe of active construction sites	205	**Number of active construction sites inspected**	205
Number of construction sites found to be non-compliant after the initial inspection	76	**Number of follow-up inspections**	2072
ENFORCEMENT			
Reporting Period: June 1, 2024 to June 30, 2025			
Number of informal enforcement actions noncompliance			40
Number of formal enforcement actions without penalty			0
Number of formal enforcement actions with penalty			7
Number of stop work orders issued			7

Post-Construction Stormwater Management for New Development and Redevelopment

The City of Greensboro enforces local stormwater management and riparian buffer regulations in addition to State approved water-supply watershed protection regulations. Throughout the NPDES permit compliance period, the City of Greensboro will review existing ordinances and, if necessary, develop and implement revised ordinances in order to *implement the post-construction stormwater management program* with the goal of further minimizing impacts to surface water quality. Ordinance language specific to the Phase II rules, specifically with regard to post-construction runoff, was adopted by City council on April 7, 2009, and became effective June 1, 2009.

BMP Summary Table

BMPs for Post-Construction Site Stormwater Runoff Controls		
BMP	**Measurable Goals**	**Comments**
Post-Construction Stormwater Management Program	Develop and adopt by ordinance a program to address stormwater runoff from new development and redevelopment within 24 months of the permit issue date.	The ordinance was adopted by City Council on April 7, 2009 and became effective June 1, 2009.
Strategies which include BMPs appropriate for the MS4	Develop strategies that include a combination of structural and/or non-structural SCMs implemented in concurrence with (a) above. Provide a mechanism to require long-term operation and maintenance of structural SCMs. Require annual inspection reports of permitted structural SCMs performed by a qualified professional.	City of Greensboro Stormwater Management Manual requires any proposed structural SCM be accompanied by an operation and maintenance plan and agreement concurrent to development plan approval. The city has an extensive inspection program to ensure SCM's are maintained to protect water quality.
Establish nutrient sensitive waters (NSW) protection measures (for programs with development or redevelopment draining to NSW waters)	Develop, adopt, and implement an ordinance to ensure that the best management practices reduce nutrient loading to the maximum extent practicable. In areas where the Environmental Management Commission has approved a Nutrient Sensitive Water Urban Stormwater Management Program, the provisions of that program fulfill the nutrient loading reduction requirement.	The Greensboro Land Development Ordinance was reviewed and modified to ensure structural and non-structural SCMs reduce nutrient loading to the maximum extent practicable.
Deed Restrictions and Protective Covenants	Impose or require recorded deed restrictions, plats, and/or protective covenants that ensure development activities will maintain the project consistent with approved plans.	Current City of Greensboro Land Development Ordinance requires a maintenance note and recorded maintenance agreement to be placed on final plats stating the maintenance responsibilities, consistent with approved plans, for the project SCM.

Establish a program under the Post-Construction minimum measure to control the sources of fecal coliform to the maximum extent practicable.	Coordinate with County health department to control the known sources of fecal coliform from septic systems to the maximum extent practicable.	Stormwater Division coordinates with Guilford County Health Department to control the known sources of fecal coliform from septic systems within the City's jurisdictional limits to the maximum extent practicable. Additionally, the City's Water Resources Department funds and performs an ongoing sewer rehabilitation program to minimize and eliminate cross connections between the storm and sanitary sewer systems.
Operation and Maintenance Plan	Require an operation and maintenance plan that ensures the adequate long-term operation of the structural SCMs required by the program. The operation and maintenance plan may require the owner of each structural SCM to submit a maintenance inspection report on each structural SCM annually to the local program, or the maintenance inspections may be conducted annually by the Permittee.	City of Greensboro Stormwater Division's development plan review process requires a stormwater management plan and separate SCM operation and maintenance plan (consistent with the provisions outlined in the State stormwater design manual) be submitted prior to receiving development plan approval. Currently, the City of Greensboro Stormwater Division conducts maintenance inspections on SCMs within the City's jurisdiction.
Educational materials and training for developers	Provide educational materials and training for developers. New materials may be developed by the permittee, or the permittee may use materials adopted from other programs and adapted to the permittees new development and redevelopment program.	Water Resources Stormwater and Engineering Divisions notify developers and engineers of ordinance changes via direct phone and e-mail, face-to-face meetings upon request regarding proposed site projects, Triad Real Estate and Building Industry Coalition, televised City Council meetings, providing opportunity for public comment, as well as posting the changes on the City website.

BMP Summary Table – *Continued*

Setbacks for Built-upon Areas	Require built-upon areas to be located at least 50 feet landward of all perennial and intermittent surface waters except as provided for in the Permittees Post-Construction Stormwater Ordinance. For purposes of this section, a surface water shall be present if the feature is shown on either the most recent printed version of the soil survey map prepared by the Natural Resources Conservation Service of the United States Department of Agriculture or the most recent version of the 1:24,000 scale (7.5 minute) quadrangle topographic maps prepared by the United States Geologic Survey (USGS). Relief from this requirement may be allowed when surface waters are not present in accordance with the provisions of 15A NCAC 02B .0233(3) (a).	The Greensboro Land Development Ordinance was reviewed and modified to require a 50 foot stream buffer in accordance with NPDES phase II requirements. In addition, the City of Greensboro has updated the riparian buffer requirements according to the Jordan and Randleman Lake Rules. The "Table of Activities and Structures in Stream Buffers (Zone 1 & Zone 2)" located in Chapter 30 of the Greensboro Land Development Ordinance determines the allowable uses within the 50' riparian buffer.

Local Permit Issuance

Currently, Group, Site and Subdivision plans within Greensboro's jurisdiction are reviewed by the City's Technical Review Committee (TRC) for compliance with applicable development regulations. TRC is an interdepartmental team charged with enforcing development standards as they relate to Watershed Protection, Stormwater Management, Water-Supply, Water Reclamation, Zoning, Transportation, Parks and Recreation, Tree Preservation, etc. Approval by members of TRC is a prerequisite to the issuance of a grading permit or building permit. The City has reviewed and modified the Greensboro Land Development Ordinance in order to ensure that plans meet *post-construction stormwater management* requirements as defined by 15A NCAC 2H.0126 (10). The final 15A NCAC 2H.0126 (10)(h) rules define low and high density development thresholds and as such these thresholds and any associated permanent structural control and riparian buffer requirements will be applied to applicable new development or re-development within the City's jurisdictional area. These requirements have now been incorporated in the Greensboro Land Development Ordinance to allow for enforcement by City staff prior to issuance of the applicable construction permit. The post-construction stormwater requirements were adopted by City Council on April 7, 2009 and became effective June 1, 2009. Additionally, the City amended the Land Development Ordinance and adopted Jordan Lake Riparian Buffer requirements on November 9, 2010. These rules became effective on December 1, 2010.

Structural SCM Operation and Maintenance

Greensboro mandates that all required structural stormwater control measures (SCMs) be placed in a drainage maintenance and utility easement (DMUE) connected to the public right-of-way by a 20 foot wide

access easement. The DMUE and access easement for each SCM must be platted before any certificate of occupancy is issued for the site. TRC-approved development plans for structural SCMs include an operation and maintenance plan (consistent with the provisions outlined in the State minimum design criteria) be submitted prior to receiving development plan approval. Furthermore, notes are recorded on the plat indicating that the City has the right to access the site for SCM inspections and that the owner will maintain the SCM per the approved maintenance plan or as directed by the City.

During the reporting period (June 1, 2024 to June 30, 2025), 757 privately owned SCMs were initially inspected by City staff for performance and maintenance compliance. In total, the Water Quality section conducted 576 site visits and/or re-inspections. During this time frame, 66 owners were issued a Notice of Violation (NOV) for failing to complete the required maintenance items. Of the 66 sites with NOVs, 28 have finished and 38 are in the process of completing the required SCM maintenance.

Pollution Prevention/Good Housekeeping for Municipal Operations

Pollution Prevention and Good Housekeeping Programs are an important factor in the improvement of stormwater runoff quality. Municipal departments that utilize various facilities currently implement good housekeeping and pollution prevention programs. Additionally, the City Water Resources Department works to ensure that pollution prevention and good housekeeping measures are being implemented at other municipal facilities to the maximum extent practicable with the intent of improving stormwater runoff quality discharged into receiving streams by those municipal facilities and their operations.

BMP Summary Table

BMPs for Pollution Prevention/Good Housekeeping Program		
BMP	**Measurable Goals**	**Comments**
Street Sweeping	Continue ongoing program with periodic review.	Ongoing program: Stormwater Management and Street Sweeping Divisions.
Erosion and Sedimentation Control	City owned or otherwise public construction sites are regulated by NCDEQ, Division of Energy, Mineral and Land Resources for proper erosion and sediment control.	Ongoing program: City owned and other publicly funded projects obtain appropriate state permits.
Staff Training/Site Operator Education	The Stormwater Management Division of Water Resources distributes education material for training employees on various municipal operations.	Ongoing cooperative effort by the City's departments.
Site Planning/Pollution Prevention Plan for Municipal Facilities	Develop and implement pollution prevention plans that have been determined to have the potential to impact Water Quality.	Ongoing effort by the City of Greensboro.

Site inspection and evaluation of facilities, operations including the MS4 system and associated structural SCMs.	The City maintains mapping programs that consist of all municipal facilities, as well as any related structural SCMs. City Stormwater Management maintains an ongoing inspection program to monitor, document and enforce stormwater discharges to the MS4 system.	The City's Stormwater Management Division has identified a list of specific city facilities and ranked each of them according to their potential to pollute. Inspections of the high and medium ranking facilities have been conducted, including documenting areas where improvements can be made to reduce the potential of generating polluted runoff.

Affected Operations

The facilities listed in the following table are municipal operations that have been issued NPDES Stormwater Discharge permits. These facilities have developed Municipal Pollution Prevention/Good Housekeeping techniques in addition with the education and training material sent out.

Table 4. Municipal Operations that have been issued NPDES Stormwater Discharge Permits.

Municipal Operation	Permit Number
City of Greensboro White St. Landfill	NCG120013
TZ Osborne WWTP	NCG110005
Patton Avenue Service Center	NCG080799
Greensboro Transit Authority (Bus Garage)	NCG080893

Training

The City's Stormwater Management Division of Water Resources provides educational and technical assistance for City facilities pertaining to pollution prevention plans and/or BMPs for the improvement of overall environmental quality. In addition, the Stormwater Management Division also provides assistance for City facilities pertaining to structural and non-structural stormwater BMPs for the improvement of stormwater quality and/or quantity and BMP design and implementation.

The City has identified eight Departments that have a greater potential to contribute pollution to stormwater runoff. The Departments involved in this program are as follows:

1. Coliseum
2. Engineering and Inspections
3. Finance (Equipment Services)
4. Fire
5. Parks and Recreation
6. Police
7. Transportation
8. Water Resources

Approximately 1,315 City of Greensboro employees received training on municipal pollution prevention. This training includes our Learning Management System (LMS) Good Housekeeping Training, which includes portions of Excals Rain Check video and pre and post assessments on pollution prevention; and the Fire Department's annual training of personnel on spill response and pollution prevention.

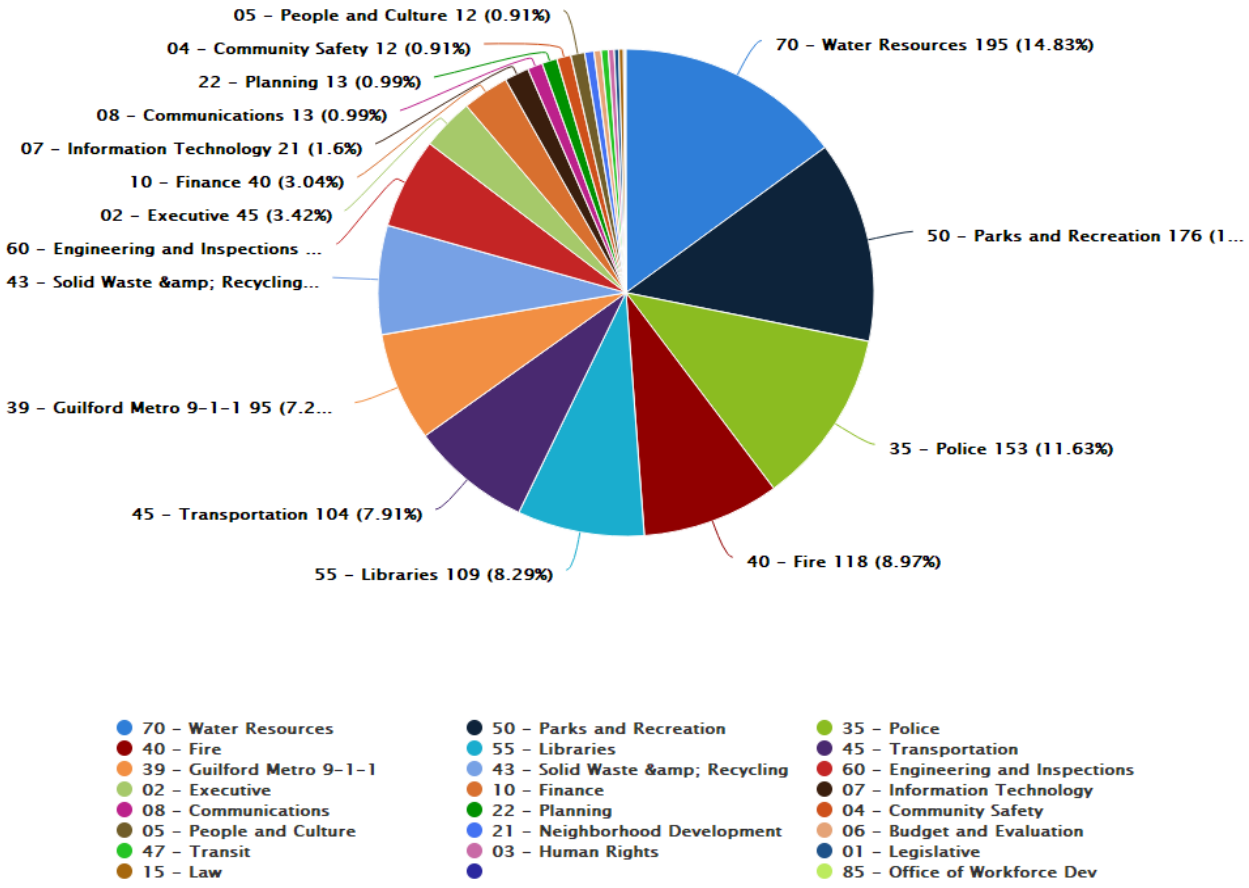

Figure 2. Number of City of Greensboro employees who have received training on municipal pollution prevention.

Collectively, it is the responsibility of the entire City of Greensboro to maintain the NPDES citywide permit and enforce programs collaboratively. The objective is for all municipal departments that engage in various operations to implement good housekeeping and pollution prevention methods in everyday activities and to set a good example for the community to follow.

Site Inspection and Evaluation of Facilities

Stormwater personnel focused on site inspection and evaluation of city owned and operated facilities. A complete list of all City owned and operated facilities was obtained from a GIS layer file. To prioritize each facility, the history of spills/concerns, the proximity to a stream or stormwater conveyance system, and the activities at a particular location were considered when ranking each facility as High, Medium or Low. This ranking is further defined below:

High: Facilities in this category would have a large amount of outdoor processing activities, close proximity to a stream and/or material storage on-site or obvious poor housekeeping issues. Examples of these facilities would be golf courses, satellite fueling stations, facilities that store salt for deicing roadways or the Coliseum that has many vendors using this property at all times.

Medium: This category includes facilities that have some outdoor storage or processing, that may not be in close proximity to a stream. Examples of these type facilities would be larger parks, the science center, water treatment plants and the fire training center.

Low: A facility in low level ranking would have limited or no outdoor processing areas. Examples of these facilities would be libraries, parking decks, rec centers and fire stations.

During the June 1, 2024 to June 30, 2025, reporting period, the stormwater division inspected 23 city-owned facilities.

Table 5. Municipal Operations by Rank.

Municipal Operation	Rank
City of Greensboro White St. Landfill	H
Patton Avenue Service Center	H
Transfer Station	M
Fire Station #1	M
Greensboro Curb Farmers Market	M
Lake Townsend Water Treatment Plant	M

Maintenance and Inspections

The City of Greensboro Stormwater Maintenance Section maintains open and closed stormwater infrastructure and drainage conveyance systems that carry public runoff within the MS4 service area. This section also performs stream maintenance activities and preventative maintenance on most public stormwater infrastructure.

The City's Stormwater Management Division identifies and inspects industrial and related facilities that may discharge stormwater into either the MS4 or receiving streams in Greensboro, and assists the local industrial community in the development and implementation of appropriate stormwater runoff controls. In addition, the City has an ongoing litter pick-up program to clear trash and other floatables from roadways, which helps keep them out of the storm drainage system and surface waters.

Vehicular Operations

The City of Greensboro's vehicular operation centers utilize the City's hazardous waste program to recycle or dispose used oil, antifreeze, batteries, and spare parts and used chemicals. A new salt storage barn was constructed in fall 2002 as a BMP to prevent salt stormwater runoff from entering receiving streams.

Waste Disposal

Waste materials generated from the City's day-to-day activities are managed according to local and state regulations and vendors utilized by Greensboro are audited to ensure environmental compliance. With the ongoing public education and awareness programs, the City will continue to facilitate staff meetings to inform staff of all new and related regulations/programs corresponding with the Municipal Pollution Prevention and Good Housekeeping Program.

Examples of Waste Disposal Programs include**:**

- Hazardous Waste Program
- Solid Waste Recycling
- Lead Disposal Program
- Oil Disposal Program
- Water Treatment Chemicals Disposal Program

Program to Monitor and Evaluate Storm Water Discharges to the Municipal System

The City of Greensboro has developed and implemented an industrial facilities inspection program during the first two permit terms. During the current permit term, the inspection program will be reviewed and revised to reflect current permit conditions. Industrial facilities subject to Section 313 of Title III of the Superfund Amendments and Reauthorization Act of 1985 (SARA), and industrial facilities that the City determines to be contributing or have the potential to contribute a substantial pollutant loading to the municipal separate storm sewer system will be inventoried and evaluated.

BMP Summary Table

BMPs for Monitoring and Evaluating Storm Water Discharges to the MS4		
BMP	**Measurable Goals**	**Comments**
Maintain Inventory of Industrial Sites	The City maintains an inventory of all NPDES permitted industrial facilities. The City will add additional facilities to list that meet the SARA Title III (Section 313) criteria or that contribute substantial pollutant loading to the MS4 system.	The City will update and revise list annually.
Inspection Program	The City has developed a formal inspection program for evaluating industrial facilities. This inspection program will be expanded to include any facility on the above stated list.	The City has an ongoing industrial inspection program with a goal of visiting all listed industrial facilities once per permit cycle. Annual training is conducted for City staff on specific inspection procedures and staff coordinates with NCDEQ on a regular basis to be trained

		on any issues or permit updates.
Establish and Implement Measures to Evaluate Commercial and Industrial Facilities discharging stormwater to the City's MS4	The City has developed the industrial facilities inspection program to evaluate those facilities on the above list and ensure all permit conditions are being met and discharges to the MS4 are not considered substantive.	The City has a strong working relationship with the NCDEQ regional office and county officials. The City's enforcement procedures are utilized when water quality violations are encountered and follow up actions are deemed necessary. NPDES permit deficiencies are addressed in written notification and are also forwarded to NCDEQ (agency with permitting authority).

During the reporting period (June 1, 2024 to June 30, 2025), a total of 38 NPDES permitted facilities were inspected by City staff. Of these 38 inspections, none were listed in the Toxic Release Inventory. The number of facility inspections varies from year to year, with some years having more inspections than others. This variation in facility inspections is due to a previous scheduling agreement between the City of Greensboro and NCDEQ to avoid overlapping inspections of NPDES permitted facilities.

Water Quality Assessment and Monitoring

The City of Greensboro has developed and implemented a comprehensive water quality monitoring and assessment program to evaluate the impacts on water quality. Data collected through monthly fixed-interval sampling is analyzed to identify improvements and/or degradation in water quality over time. Data is evaluated and compared with locally derived watch and action limits. Data is available upon request.

BMP Summary Table

BMPs for Water Quality Assessment and Monitoring		
BMP	**Measurable Goals**	**Comments**
Water Quality Assessment and Monitoring Plan	A DRAFT City of Greensboro Water Quality Assessment and Monitoring Plan was submitted within 12 months of permit issuance as required by the NPDES permit.	Draft document was submitted to NCDEQ for comment and approval within 12 months of permit issuance as required.
Water Quality Monitoring	The City will implement the water quality assessment and monitoring plan in accordance with NCDEQ and the permit schedule.	The City implemented the submitted water quality monitoring plan January 1, 2009.
Revisions to the Water Quality Assessment and Monitoring Plan	The City will conduct an annual review, revise as appropriate, and submit any revisions to NCDEQ for approval.	The City will review and revise annually and coordinate with NCDEQ any proposed changes. The most recent revision occurred in the 2019-20 reporting cycle. This revised plan was submitted with the 2019-2020 annual report.

Total Maximum Daily Load (TMDL)

The City of Greensboro has an EPA and NCDEQ approved TMDL for Fecal Coliform bacteria for North Buffalo Creek. The permittee will utilize BMPs within the six minimum measures to address the permittee's assigned NPDES regulated stormwater waste load allocation (WLA) identified in the approved TMDL to the maximum extent practicable and to the extent authorized by law. Resolute efforts are being made to determine the most efficient best management practices that address the MS4 NPDES regulated Waste Load Allocation identified in the TMDL. Current efforts are continually re-evaluated and adapted as needed. More importantly, new ideas are continuously shared and assessed, with the ultimate goal of improving and protecting water quality.

An assessment of available data, BMP strategies, and TMDL Watershed Plan effectiveness will be conducted and utilized to define the appropriate progress and schedule of the watershed plan within the context of the Maximum Extent Practical (MEP) standard. Activities conducted throughout the program implementation schedule to address the MS4 NPDES regulated waste load allocation (WLA) identified in the TMDL will be evaluated and defined as to the collective contribution to the watershed plan. The results of the analysis will be utilized to prioritize local funding aimed at elimination of the most significant portion of the MS4 waste load allocation for the least resources.

BMP Summary Table

BMPs for Total Maximum Daily Load		
BMP	**Measurable Goals**	**Comments**
(A) Identify, describe and map watershed, outfalls, and streams	Within 12 months the permittee shall prepare a plan that: • Identifies the watershed(s) subject to an approved TMDL with an approved Waste Load Allocation (WLAs) assigned to the permittee; and • Includes a description of the watershed(s); and • Includes a map of the watershed(s) showing streams & outfalls; and • Identifies the locations of currently known major outfalls within its corporate limits with the potential of contributing to the cause(s) of the impairment to the impaired segments, to their tributaries, and to segments and tributaries within the watershed contributing to the impaired segments; and • Includes a schedule (not to exceed 6 months) to discover and locate other unknown major outfalls within its corporate limits that may be contributing to the cause of the impairment to the impaired stream segments, to their tributaries within the watershed contributing to the impaired segments	Description, maps, and outfall information is noted in BMP Narratives following this table.
(B) Evaluate existing measures	Within 12 months the Permittee's plan: • Shall describe existing measures being implemented by the Permittee designed to achieve the MS4's NPDES WLA and to reduce the TMDL pollutant of concern to the MEP within the watershed to which the TMDL applies; and • Provide an explanation as to how those measures are designed to reduce the TMDL pollutant of concern. The Permittee shall continue to implement the existing measures until notified by NCDEQ.	Measures include education, sampling, investigating pollution concerns, industrial inspections, etc. See information in BMP Narratives following this table for a more complete list and descriptions.

BMP Summary Table – *Continued*

(C) Assessment of available monitoring data	Within 24 months the permittee's plan shall include an assessment of available monitoring data. Where long-term data is available, this assessment should include an analysis of the data to show trends.	An assessment of the programmatic management measures, existing TMDL data, relevant watershed data, monitoring data, etc., is performed periodically. An assessment of activities conducted under the TMDL plan will be performed to evaluate the overall effectiveness of the watershed plan and make any adjustments deemed necessary. The assessment will be used, where possible, to evaluate the performance of existing BMPs and identify additional BMP strategies as necessary.
(D) Monitoring Plan	Within 24 months the permittee shall develop a Monitoring Plan for the permittee's assigned NPDES regulated WLA as specified in the TMDL. The permittee shall maintain and implement the Monitoring Plan as additional outfalls are identified and as accumulating data may suggest. Following any review and comment by the Division the permittee shall incorporate any necessary changes to monitoring plan and initiate the plan within 6 months. Modifications to the monitoring plan shall be approved by the Division. Upon request, the requirement to develop a Monitoring Plan may be waived by the Division if the existing and proposed measures are determined to be adequate to achieve the MS4's NPDES WLA to MEP within the watershed to which the TMDL applies.	The monitoring plan for the TMDL Watershed Plan includes current monitoring programs and procedures that will be updated as necessary to achieve the City's waste load allocation (WLA) and reduce the pollutant of concern (POC) to the maximum extent possible.

BMP Summary Table – *Continued*

(E) Additional Measures	Within 24 months the permittee's plan shall: • Describe additional measures to be implemented by the permittee designed to achieve the permittee's MS4's NPDES WLA and to reduce the TMDL pollutant of concern to the MEP within the watershed to which the TMDL applies; and Provide an explanation as to how those measures are designed to achieve the permittee's MS4's NPDES regulated WLA to the MEP within the watershed to which the TMDL applies.	Measures include the FOG Program, sanitary sewer rehabilitation, pet waste stations, and the use of new technology, and the SSO Reduction Committee. See information in BMP Narratives following this table.
(F) Implementation Plan	Within 48 months the permittee's plan shall: • Describe the measures to be implemented within the remainder of the permit term designed to achieve the MS4's NPDES WLA and to reduce the TMDL pollutant of concern to the MEP; and • Identify a schedule, subject to Division approval, for completing the activities. • Implement the permittee's TMDL plan	Current BMPs will continue to be implemented to achieve the Waste Load Allocation to reduce the pollutant of concern to the MEP. This includes existing BMPs and the exploration of additional opportunities.
(G) Incremental Success	The permittee's plan must outline ways to track progress and report successes designed to achieve the MS4's NPDES regulated WLA and to reduce the TMDL pollutant of concern to MEP within the watershed to which the TMDL applies.	The TMDL plan describes ways to track and report successes based on the TMDL BMPs and goals designed to achieve the Waste Load Allocation to reduce the pollutant of concern to the MEP.
(H) Reporting	The permittee shall conduct and submit to the Division an annual assessment of the program designed to achieve the MS4's NPDES WLA and to reduce the TMDL pollutant of concern to the MEP within the watershed to which the TMDL applies. Any monitoring data and information generated from the previous year are to be submitted with each annual report.	Following the schedule per the permit, the TMDL watershed plan addresses and reports on the TMDL program.

BMP Narratives

1) Identify, Describe and Map Watershed, Outfalls, and Streams (A)

Watershed Description

The North Buffalo Creek watershed is located in Greensboro, North Carolina (Guilford County), and is in the headwaters of the Cape Fear River Basin. The eastern flowing stream eventually feeds into the Haw River. The watershed is represented by small floodplain streams that have some bedrock outcroppings and are surrounded by gently sloping uplands. North Buffalo Creek's headwaters lie entirely within urbanized areas (commercial, industrial, and residential with high impervious area) in the city of Greensboro (population ~301,115).

As outlined in the City's TMDL Watershed Plan, the compliance point for Upper North Buffalo Creek TMDL is located where Summit Avenue crosses over North Buffalo Creek. The drainage area from the headwaters to this compliance point is 21.8 mi² and incorporates 8.7 miles of stream. The area is generally deemed as built out, in that no major future land use changes are predicted. The area is 38% residential, 15% right-of-ways, and 20% forest. Impervious surface constitutes >26% of the watershed. In January of 2009, the City started collecting water quality samples at the compliance point on a monthly basis. Samples are analyzed for both physical and analytical parameters.

Drainage Area: Headwaters to TMDL Compliance Point

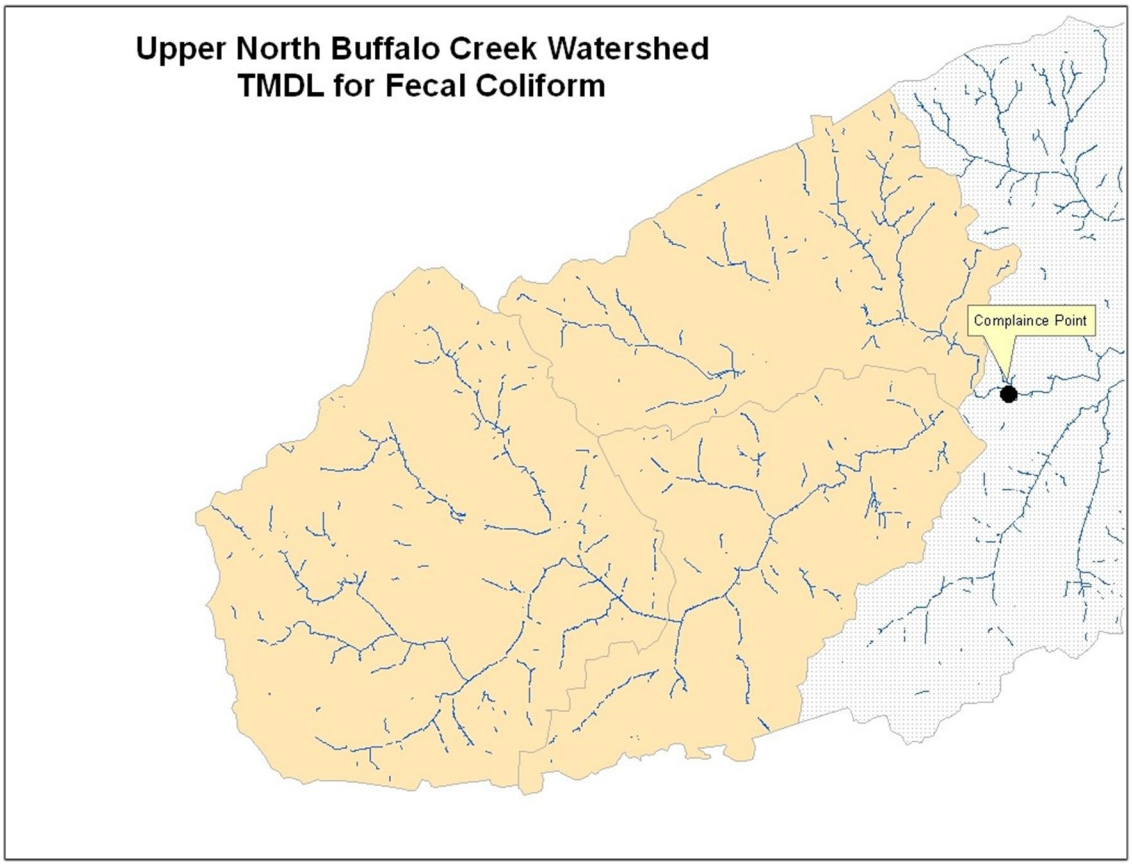

Figure 3. Upper North Buffalo Creek Watershed TMDL for Fecal Coliform.

Outfall Locations
MS4 outfalls have been determined through GIS and the City's ongoing stormwater inventory process. See map below for outfall locations within the TMDL watershed.

Schedule for Locating New Outfalls
Unknown major NPDES outfalls will be identified utilizing the ongoing stormwater inventory procedures through subsequent QAQC checks of various sub basins, ongoing collection efforts involved with new development, and updates due to drainage system repairs and maintenance. Any new outfalls and/or newly identified outfalls will be recorded and mapped on a routine basis.

NPDES Outfalls in TMDL Drainage Area

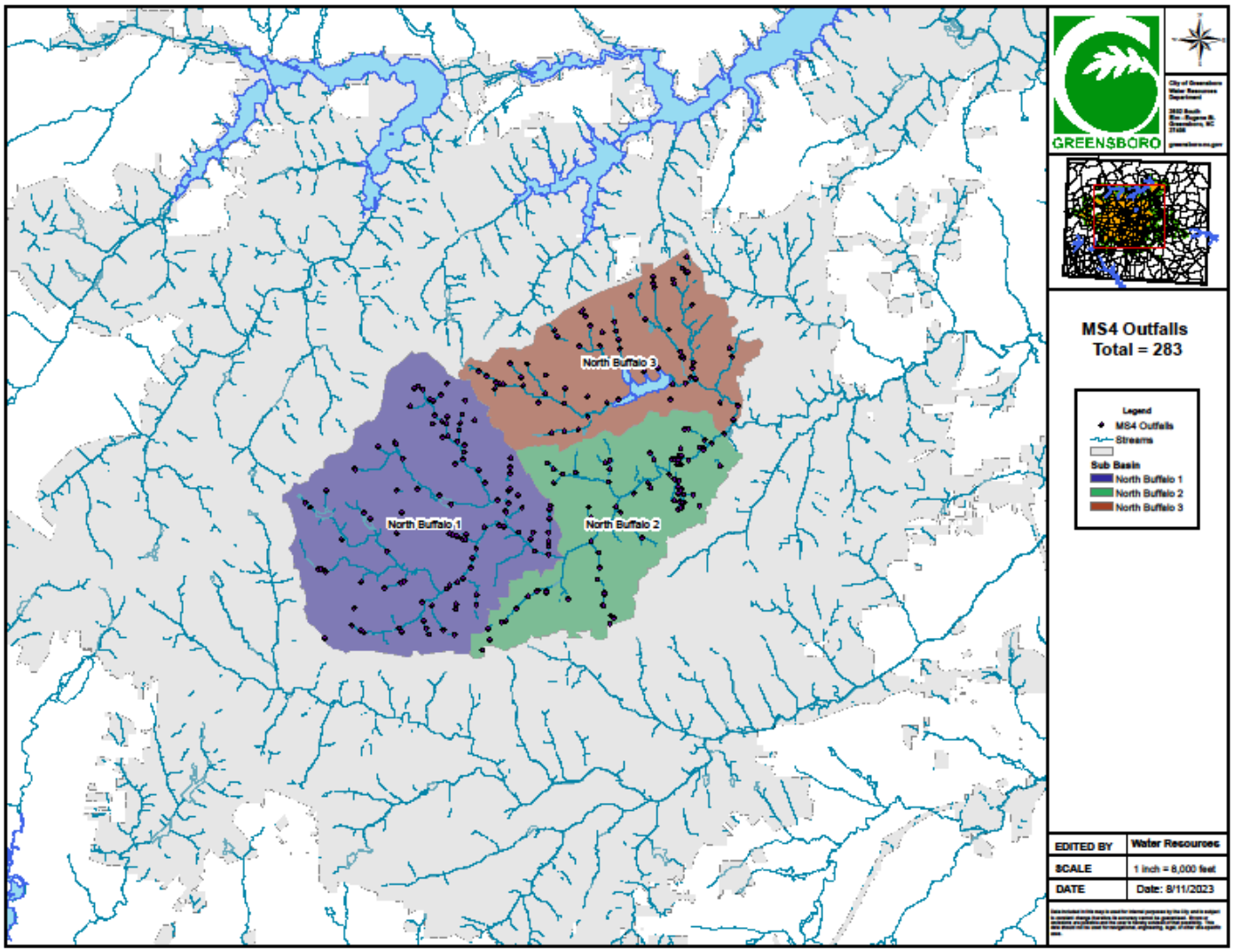

Figure 4. NPDES Outfalls in TMDL Drainage Area.

2) Existing Measures (B)

Outfall Screening
NPDES outfalls are investigated/screened on a routine basis to determine illicit discharges or improper disposals. Locations are determined based on random selection and areas that have not been done before. Any noted concerns are investigated further, which may include tracking, obtaining readings for physical parameters, and/or taking samples to be analyzed in the field or by the contracted lab.

Education
The following are examples of TMDL/pollution education and outreach:

- Engaging citizens with the Drain Marker and Adopt-a-Stream programs, pet waste stations, etc., to encourage personal involvement
- Assisting local universities with stream clean-up events
- Partnering with communities and organizations to use media for a broad-scale approach to pollution education and prevention
- Educating citizens about TMDLs via the City's website (social media, city newsletter, tabling events, etc.)
- Creating and updating education/outreach materials, such as new drain markers reminding dog owners to "scoop the poop."

Small-Quantity Polluters Program
As well as general education, specific business types in the community are identified and educated regarding housekeeping practices and proper waste disposal. This Pollution Prevention Program entails water quality staff to educate businesses that are common polluters, such as painters, landscapers, ready-mix concrete companies, auto repair shops, mobile washers, restaurants, directional drillers, etc. This ongoing prevention program is highly regarded and has been determined to be a worthwhile endeavor in keeping pollution from streams and other water sources.

Fixed Interval Sampling
Monthly sampling and assessments are performed, including the analysis of results and the need for outfall follow-ups; this includes a sampling site at the compliance point in additional to three other monitoring sites in the TMDL watershed. When data suggests an elevated level of fecal coliform, increased follow-up sampling and investigations take place to determine the potential source.

Sanitary Sewer Overflow (SSO) Prevention
Ongoing evaluation of citywide SSOs is being used to direct resources for maintenance and rehabilitation of sanitary sewer lines in the TMDL watershed in an effort to prevent overflows and exfiltration.

Field Observations
Issues discovered by staff through inventory collections, outfall screenings, etc., and water quality staff address potential issues.

Public Concerns/Reports
Reports are followed up by investigating, tracking, resolving, and enforcing violations when applicable. Over the past reporting year, 103 calls were investigated throughout the city. Of those calls, 22 (21.4 %) were in the TMDL watershed and 18 (17.5 %) were in the TMDL watershed upstream of the compliance point.

Industrial Inspection Program
NPDES permitted facilities and TRI facilities are inspected, focusing on a review of the Stormwater Prevention Pollution Plan, spill prevention and response procedures, employee training, housekeeping practices, and outfall monitoring.

3) Additional Measures (E)

Current and Upcoming City Projects
Various projects are taking place throughout the TMDL watershed in an effort to address water quantity and water quality issues. These include stream restoration along the tributary that runs next to the Downtown Greenway, and the Fairview Street Dam Rehabilitation project. Additionally, ongoing stream maintenance continues in Latham Park.

Fats, Oils, and Grease (FOG) Program
This ongoing program seeks to reduce the number of SSOs due to issues caused by fats, oil and grease. New approaches and technology, such as SwiftComply software, are continuously evaluated and implemented where applicable. In addition, two full-time staff positions have been added to support this program, increasing staff in this section from one to three.

North Buffalo Master Watershed Planning
The City of Greensboro hired a consultant to conduct watershed master planning efforts for the North Buffalo Creek watershed. The main goal of this effort is to identify areas across the watershed that are prone to flooding, either due to stormwater infrastructure constraints or increased development upstream. As flooding can result in sanitary sewer issues, investigating drainage solutions can have a direct effect on reducing fecal coliform entering surface waters. In addition, stream walks have been increased in this area to discover water quality issues that need to be addressed. The North Buffalo Creek Master Plan is still being developed.

Sanitary Sewer Rehabilitation
During the reporting year, nearly 500 linear feet of sewer underwent rehabilitation in the North Buffalo watershed up to the compliance point.

Pet Waste Stations
Pet waste stations in the TMDL watershed have been mapped, including both private stations and those maintained by the City of Greensboro. Within this watershed, there are approximately 113 documented pet waste stations (84 private, 29 city maintained). +

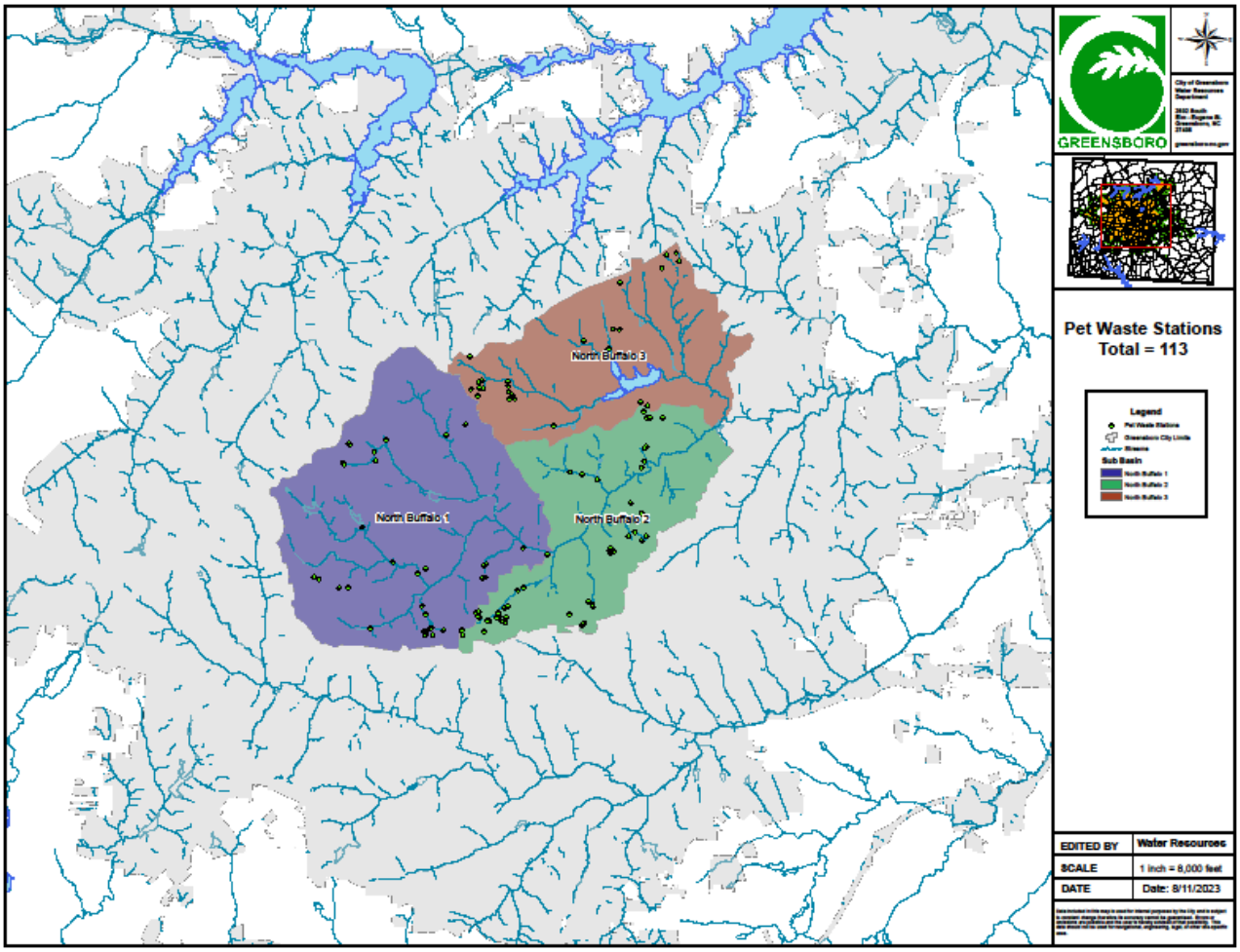

Figure 5. Pet Waste Stations in TMDL Watershed.

New Technology

New technology is always being assessed in an effort to be proactive regarding the City's wastewater collection system. Acoustical testing and assessment tools (such as SL-RAT—Sewer Line Rapid Assessment Tool), could help reduce the number of SSOs, therefore reducing the WLA for the POC. The Operations Division continually explores new and updated equipment to prevent SSOs and to investigate or repair sewer lines. In addition, inflatable plugs are being used when applicable, helping prevent overflows from entering surface waters.

Threatened or Endangered Species Protection Program

The City of Greensboro currently does not have any federally listed aquatic animal species that are listed as threatened or endangered by the U.S. Fish and Wildlife Service or the National Marine Fisheries Service under the provisions of the Endangered Species Act.

For more information on the City of Greensboro's NPDES MS4 Discharge Permit and associated Stormwater Quality Management Program Plan, please visit the Stormwater website at:
www.greensboro-nc.gov/stormwater

APPENDIX E

Nutrient Management Strategy Watershed - Nutrient Offset Credit Reporting Form

SNAP v4.2.0

Please complete and submit the following information to the local government permitting your development project to characterize it and assess the need to purchase nutrient offset credits. Contact and rule implementation information can be found online at:

http://deq.nc.gov/about/divisions/water-resources/planning/nonpoint-source-management/nutrient-offset-information

PROJECT INFORMATION

Applicant Name:			
Project Name:	College Branch RSC		
Project Address:			
Date: *(mm/dd/yyyy)*		**Development Land Use Type:**	Institutional
County:		**Project Activity Type:**	Grant Application
Project Area (sqft):	125,066	**Project Latitude:**	0.000000
Post-Project Built-Upon Area %:	61.49%	**Project Longitude:**	0.000000

WATERSHED INFORMATION

Nutrient Management Watershed:	Jordan_Lake	**N Target Export Rate (lb/ac/yr):**	0.00
Subwatershed:	Haw_River	**P Target Export Rate (lb/ac/yr):**	0.00
Nitrogen Delivery Zone:	Jordan - 020040	**Nitrogen Delivery Factor:**	32%
Phosphorus Delivery Zone:	Jordan - 020040	**Phosphorus Delivery Factor:**	33%

PERMANENT NUTRIENT OFFSET REQUEST

Post-Project Nitrogen Calculations - Projects with No Offsite or Built-Upon Area

(A)	(B)	(C)	(D)		(F)	(G)	*(Where Applicable)*	
TN Untreated Load (lb/yr)	TN Export Target Load (lb/yr)	TN Treated Load (lb/yr)	TN Remaining Reduction Need (lb/yr)		TN Delivery Factor (%)	TN Permanent Offsets Required (lb/yr)	Additional Local Gov't Offsets (lb/yr)	**Total TN Permanent Offsets to Buy (lb/yr)**
20.3	0.0	16.7	0.0		32.0%	0.0		**0.0**

Post-Project Phosphorus Calculations - Projects with No Offsite or Built-Upon Area

(A)	(B)	(C)	(D)		(F)	(G)	*(Where Applicable)*	
TP Untreated Load (lb/yr)	TP Export Target Load (lb/yr)	TP Treated Load (lb/yr)	TP Remaining Reduction Need (lb/yr)		TP Delivery Factor (%)	TP Permanent Offsets Required (lb/yr)	Additional Local Gov't Offsets (lb/yr)	**Total TP Permanent Offsets to Buy (lb/yr)**
2.8	0.0	2.1	0.0		33.0%	0.0		**0.0**

LOCAL GOVERNMENT AUTHORIZATION

Local Government Name:			
Staff Name:		**Phone:**	
Staff Email:		**Date:**	
Local Government Authorizing Signature:			