Wake-Johnston Collaborative Local Watershed Plan

Phase I: Preliminary Findings and Recommendations

Neuse River Basin

Wake & Johnston Counties, North Carolina

August 2013

PREFACE

The Wake-Johnston Collaborative Local Watershed Plan (LWP) was initiated as a collaborative effort between the Counties of Wake and Johnston and the NC Ecosystem Enhancement Program (EEP). Staff and stakeholders from each interest represented on the General Advisory Committee have participated by actively contributing to project tasks and/or providing input on critical preliminary priorities developed during this first planning phase.

In August 2011, the NC Department of Transportation agreed to sponsor a new planning effort, the Neuse 01 Regional Watershed Plan (RWP). This large planning area (580 square miles) encompasses the entire Wake-Johnston Collaborative LWP area, the Upper Swift Creek LWP area, as well as 370 square miles of watershed area not included in a previously studied LWP area. This plan represents the first regional scale plan to be undertaken by EEP and will identify traditional and non-traditional restoration projects to help provide mitigation opportunities generated by the I-540 highway construction within the planning area. Because most elements of the RWP mirror those of the LWP, Phase II and III tasks of the Wake-Johnston Collaborative LWP will be completed as subtasks of the RWP. In Section 6 of this report, the General Advisory Committee proposes recommendations on how best to integrate this local plan into the greater Neuse 01 Regional Watershed Plan.

ACRONYMS

Below is a list of acronyms used in this document with their corresponding full names. For more complete definitions and explanations of these and other terms, refer to the glossary in Appendix C.

AOP	Aquatic Organism Passage
ATU	Aquatic Toxicity Unit
ASL	Above Sea Level
BAU	Biological Assessment Unit
BEHI	Bank Erosion Hazard Index
BMP	Best Management Practice
CU	Catalog Unit
CWMTF	Clean Water Management Trust Fund
DBB	Design-Bid-Build
DEM	Digital Elevation Model
DENR	Department of Environment and Natural Resources
DMF	Division of Marine Fisheries
DSW	Division of Soil and Water
DWQ	Division of Water Quality
EEP	Ecosystem Enhancement Program
EPT	Ephemeroptera Plecoptera Trichoptera
GAC	General Advisory Committee
GIS	Geographic Information System
HU	Hydrologic Unit
LUP	Land Use Plan
LIDAR	Light Detection and Ranging
LWP	Local Watershed Plan
NCDOT	North Carolina Department of Transportation
NCFS	North Carolina Forest Service
NCSU	North Carolina State University
NHEO	Natural Heritage Element Occurrence
NHP	Natural Heritage Program
NLCD	National Land Cover Database
NPS	Non-point Source
NRCS	Natural Resources Conservation Service
NSW	Nutrient Sensitive Waters
NWI	National Wetlands Inventory
PFR	Preliminary Findings Report
PA	Project Atlas
RBRP	River Basin Restoration Priorities
ROW	Right-of-Way
RTE	Rare, Threatened, or Endangered
RWP	Regional Watershed Plan

S&EC	Sediment and Erosion Control
SNHA	Significant Natural Heritage Area
SWCD	Soil and Water Conservation District
TAC	Technical Advisory Committee
TIP	Transportation Improvement Program
TLC	Triangle Land Conservancy
UDO	Unified Development Ordinance
USFWS	United States Fish and Wildlife Service
USGS	United States Geological Survey
UT	Unnamed Tributary
WAR	Watershed Assessment Report
WAT	Watershed Assessment Team
WMP	Watershed Management Plan
WRC	Wildlife Resources Commission
WSW	Water Supply Watershed
WWTP	Waste Water Treatment Plant

Table of Contents

List of Figures

List of Tables

This page is intentionally blank.

This page is intentionally blank.

1 INTRODUCTION

1.1 Purpose of Assessment

The North Carolina Ecosystem Enhancement Program (EEP) is collaborating with Wake and Johnston Counties to develop a Local Watershed Plan (LWP) for portions of the Upper Neuse River Basin (USGS 8-digit Catalog Unit 03020201, USGS, 2012). In 2008, discussions between resource professionals from Wake County government and the Ecosystem Enhancement Program revealed common watershed planning goals that included the need to restore impaired waters and protect threatened habitat. In early 2009, planners identified watersheds in eastern Wake County and western Johnston County that met these common criteria, while also contributing to independent organizational objectives.

The primary goal of the planning initiative is to develop a comprehensive watershed management and restoration strategy for the LWP area. This document represents the results of the first of three component phases of the plan. During this phase, plan participants worked cooperatively to compile and synthesize existing data, to identify priority areas for additional study in the next phase, and to make preliminary project recommendations. In the next phase, plan partners will conduct water quality, biological, habitat, hydrologic, and geomorphological studies to assess current watershed conditions. The objective of this data collection is to help estimate *ecosystem functions*, that is, how well the system is able to maintain good water quality, hydrology, and provide diverse instream and riparian habitat for the fauna and flora of the planning area. Because the watershed is home to a significant number of rare aquatic species, an emphasis on their protection and habitat restoration will be placed on projects selected for the project atlas developed in the latter two components as part of the Neuse 01 Regional Watershed Plan (RWP). Additionally, partners will model ecosystem stressors to help identify where restoration will do the most good. Data analyses and modeling output will also inform development of management and implementation strategies for the RWP.

Two advisory committees, the Technical Advisory Committee (TAC) and the General Advisory Committee (GAC), were assembled to oversee the LWP development. The first phase or component of the plan was based on EEP's LWP methodology (see *EEP LWP Process*). Four major products are anticipated, the first of which is this report, a standalone document that is a compilation of existing data and a general analysis of the watershed. The three remaining products will be developed as chapters of the RWP and include a technical assessment of water quality, habitat, and hydrologic conditions; a final watershed management strategy; and an atlas of restoration and preservation projects.

Through this LWP, collaborators intend to examine sources of pollution and habitat degradation in the subject watersheds. As a part of the RWP, the final watershed management strategy will incorporate the comprehensive interests of both stakeholders and project partners. Also part of the RWP, the Project Atlas (PA) will present stream and wetland restoration, enhancement, and preservation projects, as well as stormwater and agricultural best management practices (BMPs) to be implemented by EEP, local governments, and other organizations. Policy-driven management strategies to be implemented by local governments may be the focus of some plan recommendations as well.

1.2 Description of Local Watershed Planning Area

The LWP study area consists of portions of five watersheds including Beddingfield Creek and adjacent portions of the Neuse River, Poplar Creek, upper Marks Creek, upper Buffalo Creek, and a portion of the Little River (Figure 1). Within these watersheds lie portions of several municipalities including Clayton, Knightdale, Wendell (entirely within), and Zebulon. Residential and commercial development continues to expand from these centers. A segment of Buffalo Creek, a segment of the Little River, and much of the Neuse within the LWP area are designated as impaired waters by the NC Division of Water Quality (DWQ) due to biological and chemical stressors (DWQ, 2010).

The plan watersheds were selected through a combined process of GIS analysis and stakeholder input. The initial screening of the upper Neuse basin (USGS Catalog Unit 03020201) was based on EEP's targeted local watershed (TLW) selection process. Through this process, 14-digit watersheds are scored based on a combination of data representing baseline characteristics such as *total stream miles*, problems such as *303(d)-listed stream miles*, and assets such as existing *Significant Natural Heritage Area (SNHA) acreage*. Based upon data analysis and stakeholder input, priority 14-digit hydrologic units are selected as TLWs and serve as focus areas for watershed improvement efforts. From these TLWs, additional input from local stakeholders in Wake and Johnston counties was incorporated by consensus during facilitated meetings to establish the final LWP area. A summary of data and sources used to select the watersheds for the Wake-Johnston Collaborative LWP is included in Table 1.

Table 1. Watershed Statistics.

Watershed Name	HU Area[1] (mi)	Stream Length[2] (mi)	Ag Area[3] (%)	Forest Area[4] (%)	Imperv Area[5] (%)	WSW Length[6] (%)	SNHA Area[7] (sq mi)	NHEO[8] (#)	303(d) Length[9] (mi)	Animal Ops[10] (#)	Un-buffered Stream[11] (%)
Poplar Creek 03020201100010	9	26	35	47	2.0	0.0	0.0	0	0.0	3	27
Marks Creek 03020201100020	29	69	31	61	1.1	0.0	1.1	3	0	2	17
Beddingfield Ck & Neuse River 03020201100030	41	104	33	55	1.3	25	1.7	2	10.9	13	21
Little River 03020201180020	51	126	38	51	1.9	34	0.5	26	2.9	10	24
Buffalo Creek 03020201180050	58	130	44	47	1.2	0.0	1.6	5	5.8	19	30

1 Hydrologic Unit (HU) Area estimate based on USGS 14-digit HU boundaries (USDA NRCS 1998).
2 Stream Length estimate derived from blue line streams on USGS 1:24,000 scale maps (NC CGIA 2008).
3 Agricultural Area estimate based on 2001 National Land Cover Database (NLCD) (Homer et al., 2004).
4 Forest Area estimate based on 2001 NLCD (Homer et al., 2004).
5 Impervious Area Estimates based on 2001 NLCD (Homer et al., 2004).
6 Water Supply Watershed (WSW) length (NC GIA 2008).
7 Significant Natural Heritage Areas (SNHA) estimates (NC NHP 20071).
8 Natural Heritage Element Occurrences (NHEO) (NC NHP 20072).
9 303(d) List of impaired waters (NC DWQ 2010).
10 Animal Operations estimates based on NC estimates for pork, poultry, and bovine operations in 2007 (NCDA, 2007).
11 Unbuffered Streams estimate based on 2001 NLCD and a 100 foot buffer distance from USGS blue line streams

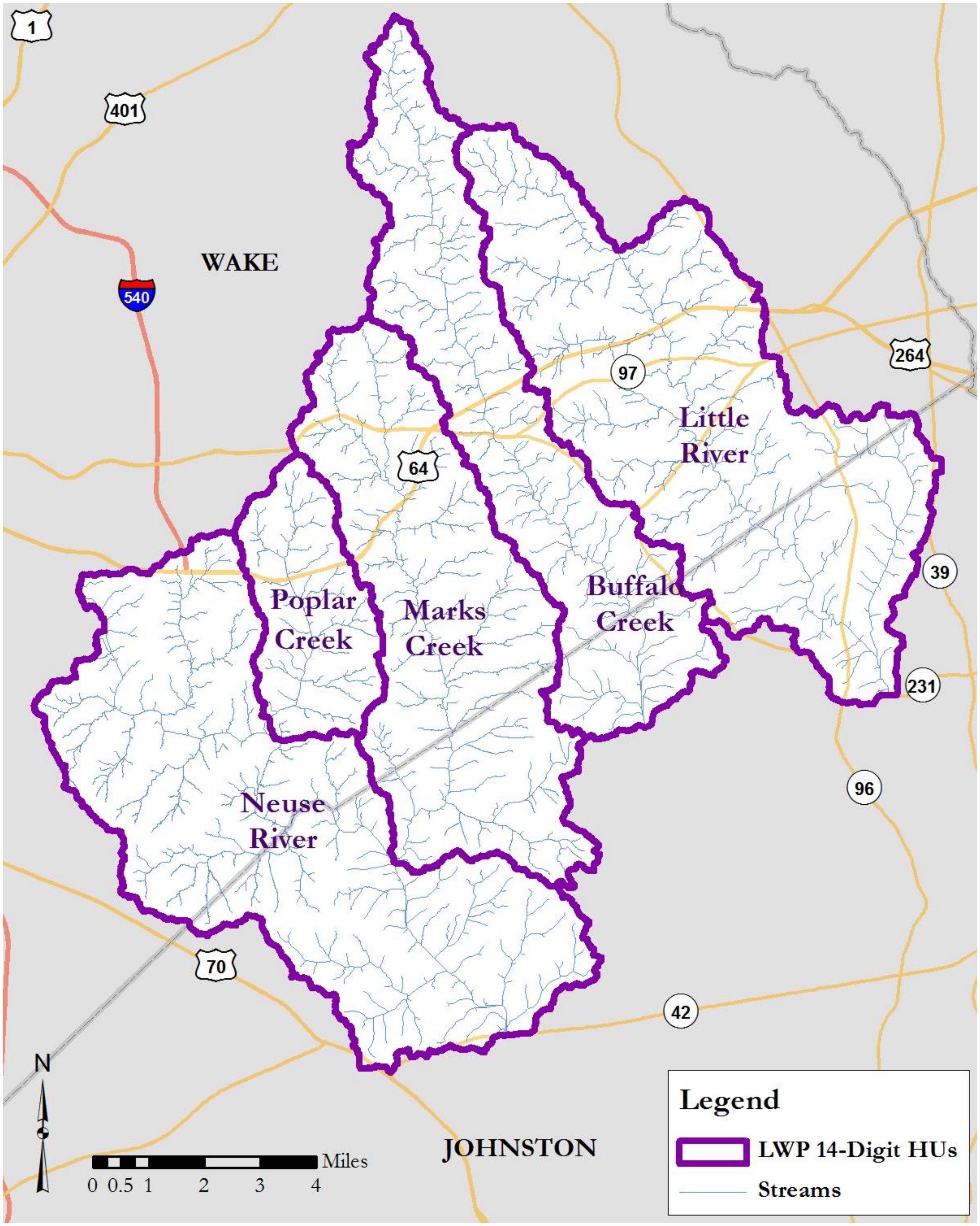

Figure 1. Local Watershed Planning Area.

Poplar Creek ***(HU #03020201100010)***—The Poplar Creek watershed is the first of five HUs included in the LWP area. It is a small watershed covering only nine square miles with about 26 miles of stream. A quarter of streams lack substantial riparian buffer. The Town of Knightdale accounts for most of the developed area, primarily low-density residential land in the north. Agriculture makes up over a third of land use with forest and wetlands accounting for nearly half. DOT has planned two miles of Transportation Improvement Program (TIP) projects within the Poplar Creek watershed. There are multiple NPDES discharges in the watershed and a substantial water quality monitoring data set is maintained by DWQ.

Marks Creek ***(HU #03020201100020)***—The Marks Creek watershed covers 29 square miles and includes 69 miles of stream, 17% of which are unbuffered. Very little of the watershed is developed with less than one percent impervious surface total. Sixty-one percent of the watershed is forested, including a small amount of wetlands. About a third of the land area is used for agriculture. The Clean Water Management Trust Fund (CWMTF) has sponsored six watershed improvement projects in this HU. Water quality data for Marks Creek is sparse although a recent study was completed for Lake Myra that attempted to account for sedimentation patterns in the lake. A NCDOT-sponsored dam removal project was undertaken on a tributary in the headwaters. There are three miles of planned TIP projects within this watershed as well.

Beddingfield Creek & Neuse River ***(HU #03020201100030)***—The Beddingfield Creek watershed encompasses a large segment of the Neuse River downstream of the City of Raleigh. The watershed spans approximately 41 square miles, and includes 104 miles of streams with approximately 21% unbuffered. Almost one-quarter of the area is designated Water Supply Watershed (WSW) by DWQ. One-third of this watershed is agricultural and it contains 13 permitted animal operations. Over half of the area is forest or forested wetland, including a small portion (1.7 square miles) that is designated Significant Natural Heritage Area (SNHA) by the NC Natural Heritage Program (NHP). About 10% of soils are hydric. Eleven percent of the watershed is developed with an average of 1.3% imperviousness concentrated primarily around the Town of Clayton. DOT has programmed four miles of TIP projects for development in the near future. One CWMTF project has been completed in the watershed and the Triangle Land Conservancy (TLC) is actively pursuing additional acquisition in Beddingfield Creek to augment existing conservation areas.

Little River ***(partial HU #03020201180020)***—Over three-quarters of the 51 square mile Little River HU is included in the study area. There are 126 miles of streams here, with nearly one-quarter unbuffered. There are 34 miles of WSW waters and a single water intake in the river. Half of the watershed is either forest or wetlands, with approximately 11% hydric soils. There are 26 documented Natural Heritage Element Occurrences (NHEOs) in the watershed. Thirty-eight percent of the HU is in agricultural land use. There are 10 permitted animal operations, most of them cattle farms. Ten percent of the watershed is developed with a low average imperviousness of about 2%. Although not entirely within the LWP area, this watershed drains into the Atkinson Millpond. The Atkinson Mill Dam was identified as a priority removal or modification project by the interagency NC Dam Removal Task Force (NCDOT, 2002). Two land trust projects, four agricultural BMPs, and one Wildlife Resources Commission (WRC) project have been implemented within this watershed.

Buffalo Creek ***(partial HU #03020201180050)***—Buffalo Creek is located centrally in the LWP watershed. It contains 131 miles of streams, 6.4% of which are on the 303(d) list. Thirty percent of all streams are unbuffered. The watershed covers 58 square miles of the Northern Outer Piedmont. Nearly half of the HU is forested or forested wetlands and over 30% of soils are hydric. The forested area includes six square miles of unfragmented, interior forest. There are 1.6 square miles of designated SNHA. Forty-four percent of land is in agriculture including 19 permitted animal operations—14 cattle, three poultry, and two hog farms. Most of the agriculture is focused in the headwater region. Eight percent of the watershed is developed with relatively low impervious surface (1.2%). There are 13 agricultural BMPs constructed here, as well as one local land trust project and one WRC watershed improvement project.

1.3 Approach

The Wake-Johnston Collaborative was initiated as a joint effort by several cooperating agencies and local governments. EEP and Wake County each have shared and will continue to share responsibility for elements of the assessment and coordination. This preliminary assessment was compiled and developed primarily by EEP under the guidance of the multiagency General Advisory Committee (GAC) and Technical Advisory Committee (TAC). The plan development to this point has followed LWP guidelines (EEP, 2005; EEP, 2012). In Phase I, partners compiled readily available information to characterize watershed conditions. DWQ collected water quality data and provided preliminary interpretation. A team from EEP and Wake County analyzed GIS data and produced mapping products. Wake County and EEP also contracted with DWQ and NCSU biologists to collect benthic macroinvertebrate data and provide analysis.

This planning initiative represents a new LWP paradigm for the Ecosystem Enhancement Program, Wake County, and other partners. The planning effort initially evolved out of discussions between EEP and Wake County regarding potential collaborative mitigation projects sponsored by EEP on public lands managed by the county. Partners have expanded the objectives of the plan to be as comprehensive as possible, including the development of a project atlas that identifies a broad spectrum of watershed improvement projects that meet the needs of municipal interests, mitigation programs, and the general public. The EEP Phase I process (EEP, 2012) is outlined in Figure 2 and has served as a guide for this preliminary work.

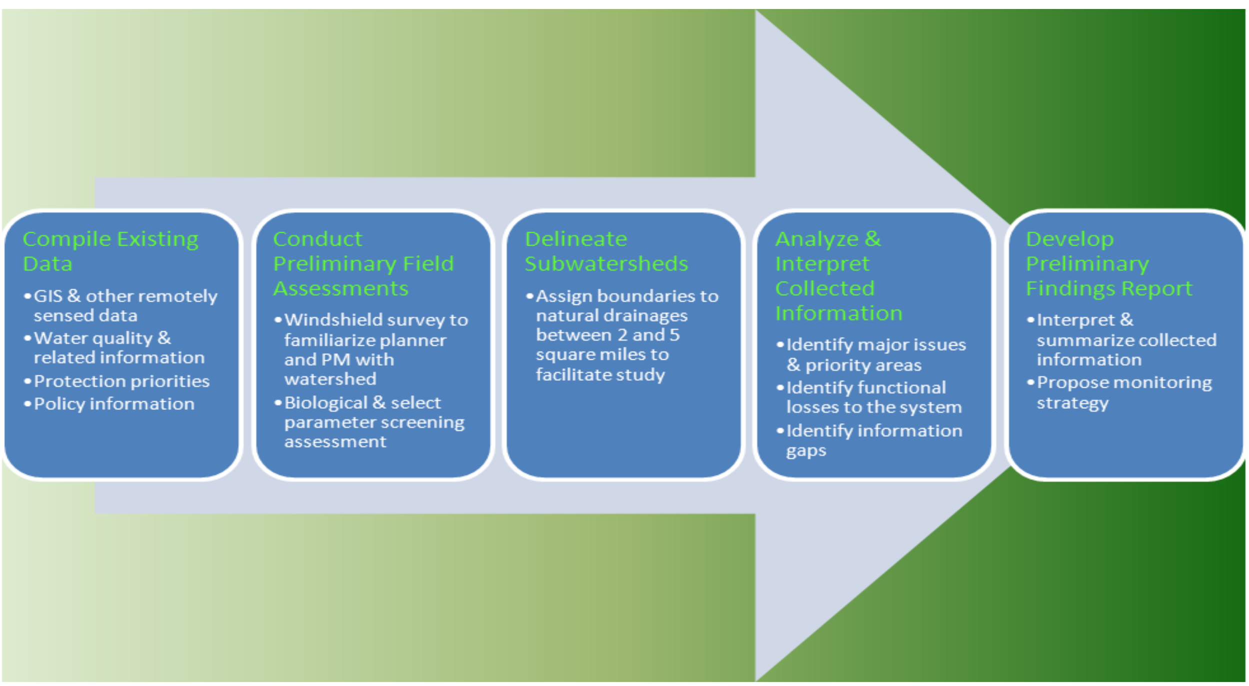

Figure 2. EEP Phase I Local Watershed Planning Process.

Advisory Committees

Two committees were formed to serve as decision-making bodies to guide the plan's development. The General Advisory Committee (GAC) was created in the summer of 2009 and consists of resource agency, nonprofit, academic, and government representatives as well as independent landowners who have provided and will continue to provide input and review of planning products and recommendations. Subsequent results such as discussion of local issues and final consensus-based recommendations for the watershed will be continued and incorporated as part of the Neuse 01 RWP.

The Technical Advisory Committee (TAC) was formed in the same period and consists of specialists who have expertise in relevant fields related to the technical assessment data compiled and collected as a part of this initiative. Members have and will continue to provide guidance and review of interpretive report elements for existing data and new assessment data collected during the Neuse 01 RWP development.

Members of these committees and their affiliations are listed in Table 2.

Table 2. List of Phase I Advisory Committee Members.

NAME	AFFILIATION
Anjie Ackerman	NC Ecosystem Enhancement Program
Rob Breeding	NC Ecosystem Enhancement Program
Kevin Brice	Triangle Land Conservancy
Talmage Brown	Wake County Landowner
Ed Buchan	City of Raleigh Water Public Services
Melinda Clark	Wake County Stormwater Programs
Nora Deamer	NC Division of Water Quality
Barbara Doll	NC State University Sea Grant
Mart Yeager	Wake County (Lake Myra) Landowner
Steve Finn	Wake County Planning
Berry Gray	Johnston County Planning
Debbie Greene	Wake County Sediment & Erosion Control
Leigh Ann Hammerbacher	Triangle Land Conservancy
Brent Henry	Wake County Extension
Mark Hetrick	Town of Zebulon Planning
Tom Hill	NC Division of Soil and Water
Sig Hutchinson	Wake Open Space & Parks Advisory Committee
Glenn Johnson	Wake County Sediment & Erosion Control
Stratford Kay	NC Division of Water Quality
Jessica Kemp	NC Ecosystem Enhancement Program
Dan Line	NC State University
Keith Lankford	Wake County Planning
Tim Lisk	Wake County Open Space Planning
Wright Lowery	Wake County Geographic Information Systems
James Massey	Johnston County Soil & Water Conservation
Sarah McRae	US Fish & Wildlife Service
Rob Nichols	NC Wildlife Resources Commission
Anne Payne	Wake County Community Services
Sharon Peterson	Wake County Long Range Planning
Teresa Piner	Town of Wendell Planning
Calvin Pippin	Wake County Planning Board (Zebulon)
Judy Ratcliffe	NC Natural Heritage Program
Jeff Schaffer	NC Ecosystem Enhancement Program
Kurt Smith	Wake County Watershed Management
Loftee Smith	Wake County Planning Board
Britt Stoddard	Wake County Environmental Services
Will Summer	Clean Water Management Trust Fund
Jeff Triezenberg	Town of Knightdale Planning
Julie Wilkins	Town of Zebulon Planning

2 LWP STUDY AREA FEATURES

2.1 *Geographic Location and Description*

The Wake-Johnston Collaborative LWP study area covers 144 square miles of central North Carolina in the upper Neuse River Basin. The watershed is bracketed by the Neuse River drainage in the west and one of its major tributaries the Little River in the east. Poplar, Marks, and Buffalo creeks each flow southward, lying between the Neuse and Little River drainages. The City of Raleigh is situated just upstream of the watershed, while the towns of Knightdale, Wendell, Zebulon, Clayton, and Willow Springs lie partially or wholly within the watershed. Highway US-64 bisects the northern portion of the watershed, connecting Zebulon and Clayton. Clemmons State Forest is situated adjacent to the Neuse River in the west. Other conservation lands include the Marks Creek Corridor protected under permanent conservation easement by the Triangle Land Conservancy and the upper Little River designated as an important Water Supply Watershed by DWQ and a Significant Natural Heritage Area by the Natural Heritage Program to protect the diversity of freshwater mussels resident in the streams.

2.2 *Topography, Ecoregions, and Related Features*

The entire watershed lies in the Northern Outer Piedmont ecoregion and has a character similar to that of adjacent sections of the Tar and Cape Fear River basins. The watershed is relatively flat to gently rolling, with some important examples of geologic features such as granitic flatrocks and outcroppings. The elevation of the watershed in the north is approximately 450 feet above sea level (ASL) in the Buffalo Creek headwaters and falls to its lowest elevation of about 75 feet ASL at the downstream end of the Neuse River in the south. An elevation map is provided in Section 4 (Figure 3).

2.3 *Previous Studies*

Wake County Watershed Assessment – Biological, Habitat, and Geomorphic Evaluations (CH2M Hill, 2002)

This assessment report includes streams in the LWP Study Area within Wake County. It was intended to support county planning decisions and open space acquisition. Despite the age of the data, biological community and geomorphology data in the report provide a good baseline for comparison with current conditions.

Lake Myra Sediment Study

Wake County and the Biological and Agricultural Engineering Department of NCSU conducted an assessment of sediment accumulation in the upstream portions of Lake Myra. The baseline dataset provides a comparison to subsequent accumulations as the surrounding watershed continues to develop. Information contained in the study may assist recommendations in the RWP. See http://www.bae.ncsu.edu/programs/extension/wqg/srp/lake_myra.html for more information.

Marks Creek Dam Removal

In 2003, NCDOT completed a mitigation project in the headwaters of Marks Creek. The project removed a small but significant dam and restored both stream and wetlands in the footprint of the impoundment. Subsequent monitoring has indicated an array of challenges to the project's success, including erosion of stream banks in the upstream tributaries and a mineral oil contamination spill (NCDOT, 2007b). Additional review of monitoring data from NCDOT should be considered during the RWP assessment work and in the development of recommendations for the headwaters of Marks Creek.

Johnston County Natural Resources Initiative

The Johnston County Natural Resource Initiative (JCNRI) published a Green Infrastructure Report (NC Forest Service, 2012) that resulted from a collaborative effort among county and municipal governments, natural resource professionals, and non-profit organizations. Their charge was to develop and promote strategies in the county for the conservation of natural resources through a network of farms, forests, and open space. Participants included Johnston County Soil and Water, Johnston County Cooperative Extension, Johnston County Planning Department, North Carolina Natural Heritage Program, North Carolina Forest Service, North Carolina Wildlife Resources Commission, North Carolina State University, Triangle Land Conservancy, Triangle J Council of Governments, and staff from the towns of Benson, Clayton, Selma, Smithfield, and Wilson's Mills. The project was sponsored by the U.S. Department of Agriculture Forest Service, Southern Region. The report details stakeholder input from a series of three workshops held to introduce citizens to the initiative and to solicit feedback regarding public values for natural resources in the county.

2.4 Watershed History

Prior to European settlement, the Occaneechee and Sissipahaw tribes, part of the Tuscarora Native American Nation, were the first known inhabitants of the watersheds in the LWP study area. These Native Americans maintained a relatively low impact presence, subsisting primarily by hunting, fishing, trapping, farming, and trading to some degree. The tribes were defeated in the Tuscarora War of 1711 and most surviving members migrated to New York, joining the Iroquois Nation (Powell, 2006).

The first European settlers of the watershed were primarily of English, Scottish, and Irish descent, emigrating primarily from states farther north. The settlers in both the Wake and Johnston portions of the watershed were farmers, primarily growing tobacco and cotton (Powell, 2006). Johnston County was formed in 1746 and Wake County was formed in 1771. After the Revolutionary War, state leaders debated on a capital for North Carolina for many years, ultimately settling on Raleigh in 1792. Due to its proximity to the state capital, several significant trade routes were established through the study area. Tobacco and cotton continued to be major agricultural crops grown, and on the Johnston County side of the watershed, turpentine and lumber became major products by 1900. Swine and cattle also became increasingly important after the Civil War and into the early 20th century. Cattle and swine farmers joined livestock drives to Virginia, where markets remained good until the 1920's (Lassiter, 2004).

During the Great Depression, development around urban centers began to expand and pressures on agriculture necessitated diversification. Farmers began to add sweet potatoes, corn, and soybeans to their fields. Tobacco continued to be a major crop and Johnston County to this day is the largest producer of flue-cured tobacco in North Carolina (Powell, 2006).

By the middle of the 20th century, mechanization of farming began to change the face of agriculture in the watershed. As the average size of farms increased, the actual number declined. Due to their proximity to Raleigh, the municipal centers in the Wake County part of the watershed expanded, reducing the amount of land in agriculture, a trend that continues today (Powell, 2006). On the Johnston County side of the watershed, agriculture still predominates and it contains more farms than any other county in the state (Lassiter, 2004).

3 LOCAL REGULATIONS AND PLANNING

3.1 Wake County

Wake County maintains authority over development activities within the county boundaries that take place outside of municipalities and their extra-territorial jurisdictions. It was deemed to be "fully compliant with state water supply watershed protection program requirements" by the North Carolina Division of Water Quality's October 2009 program compliance audit. The Department of Community Services (Planning) and the Department of Environmental Services have the primary responsibilities for ensuring compliance with any and all water supply watershed protection standards. The primary document related to water supply watershed protection is the county's Unified Development Ordinance (UDO). Among others, it contains provisions describing required actions to manage stormwater (Article 9), to control erosion and sediment (Article 10), to maintain environmental standards (Article 11), and to manage water and wastewater systems (Article 12). The Wake County UDO provides detailed policies for implementing the county's Land Use Plan.

To help achieve the objectives in the Wake County Open Space Plan, considerable effort has been focused on preserving land in the Marks Creek watershed in partnership with the Triangle Land Conservancy. Wake County also manages the stormwater ordinances for Rolesville, Wendell, and Zebulon, via interlocal agreements with each. The county's participation in this Local Watershed Plan is expected to help foster support for both the Stormwater Management Program and the Wake County Comprehensive Watershed Management Plan (2003).

Wake County Land Use Plan's Water Supply Watershed Protection Policies

Non-residential development within mixed use activity centers. Water supply watershed activity centers outside of urban areas are designed to help protect water quality by limiting non-residential land uses to those with characteristics less likely to adversely affect water quality. Emphasis is placed on concentrating more intense non-residential development at intersections of major thoroughfares to ensure that the quality of public drinking water is protected.

The location of non-urban activity centers have been designated on the County's Land Use Classifications Map for the Little River Watershed (partially within the LWP area) as prescribed in the Northeast Area Plan. This plan was sanctioned by the Wake County Board of Commissioners.

Non-residential land use limits. Most of the land within water supply watersheds in the County's jurisdiction is currently zoned Residential-80 Watershed (critical areas) or Residential-40 Watershed (balance of watershed). This zoning generally limits non-residential uses to low-impact types and intensities not likely to impact water quality adversely. It also treats them as special uses requiring additional scrutiny of potential water quality impacts, especially in the critical areas of water supply watersheds.

All land classified as Non-Urban Area/Water Supply Watershed on the General Classifications Map and zoned as Residential-80 is intended to remain subject to the same zoning that strictly limits the types and intensity of non-residential development to those posing little threat to water quality and subjects development to special scrutiny. Land classified as Non-Urban Area/Water Supply Watershed that is currently zoned Residential-40 is subject to supplemental impervious surface coverage limits, buffer requirements, and hazardous material controls necessary to meet the state minimum watershed protection requirements for low-density residential areas.

Within those parts of water supply watersheds classified as Urban Services Area/Water Supply Watershed, non-residential uses may be developed, provided they are consistent with the Land Use Classifications Map. They may be developed either under current residential zoning (as special uses) or under non-residential zoning subject to the supplemental impervious surface coverage limits, buffer requirements, and hazardous material controls necessary to meet the state minimum watershed protection requirements for the low density option.

Areas of Concern:

The Wendell Falls development continues to be of high concern with Wake County. With the economic downturn, the development was placed on indefinite hiatus, leaving several thousand housing lots on Lake Myra cleared of vegetation. With the property's change of ownership, the county continues to be concerned about stabilization of existing land disturbance and the minimization of sedimentation, especially until development and active maintenance resumes.

Potential Water Quality Projects/Needs:

Considering the significant levels of impervious surface associated with streams in this part of the county, many appear to be maintaining acceptable water quality based on Wake County data. The county's primary goal is to maintain the quality of these waters by promoting implementation of BMPs such as rainwater harvesting systems and bio-retention areas. The county is also supportive of improving stormwater ordinances based on solid scientific information. As outlined in the Land Use Plan, the county will promote projects that buffer streams and preserve as much open space as possible in the Marks Creek watershed.

Other Comments:

During the initial discussions leading to the development of this Local Watershed Plan, Wake County and EEP recognized the value of this initiative, hoping to learn from each other and to develop important, mutually beneficial restoration projects. In addition, the partnership will continue to work to secure project funding from outside resources, as well as expand baseline knowledge of watershed function in the area. The LWP has also given Wake County the opportunity to cross train with DENR on a number of watershed management initiatives and to identify watershed projects on existing county property that will provide valuable functional improvements if implemented.

3.2 Johnston County

Similar to Wake County, Johnston County maintains authority over development activities within the county boundaries that take place outside of municipalities and their extra-territorial jurisdictions. The Planning Department is responsible for zoning and administration of development activities. In March 2009, the Board of Commissioners adopted the 2030 Comprehensive Plan. The plan looks forward to achieving development goals while "managing growth, expanding economic opportunities, preserving farmland and the rural character of the county, protecting the environment and cultural elements, and coordinating communication with local governments."

Johnston County's Land Use Plan recognizes the area has a diverse mix of land usage with primary growth along the Wake County line. Secondary growth and rural-conservation areas occur farther southeast (see Land Use Map). There is an Environmentally Sensitive District (ESD) located along the Little River which limits development in the floodplain in general and limits development of impervious surfaces.

Areas of Concern:

Flowers Plantation is a 3,000 acre historically significant area that includes significant residential development. The development predates current stormwater policies and is therefore exempt from the County's stormwater management regulations.

Potential Water Quality Projects/Needs:

Stream channel maintenance, obstruction removal, and stream bank stabilization have been identified by stakeholders as concerns for the Johnston County portion of the LWP area.

3.3 Town of Knightdale

The Town of Knightdale's original Comprehensive Plan was developed in 1993 with the idea that the plan should be updated every five years. Nearing the end of the first cycle of the plan, the Town undertook a major revision with the intent of incorporating the broadest stakeholder input possible. This "citizen-driven process" ultimately resulted in a plan titled the 2027 Comprehensive Plan that was adopted by the Knightdale Town Council in July 2003. This plan in turn was revised during 2009 and 2010 with adoption by the Town Council on January 19, 2011.

The Comprehensive Plan is intended in part to facilitate compatible land uses and to help guide community development within the Town's 25 square mile jurisdictional limits (including extraterritorial jurisdiction). Actions emphasized in the Plan that are complementary to those in this report include preserving natural streams, conserving mature trees and forest patches, promoting stormwater management to ameliorate flooding and improve water quality, managing erosion, and encouraging riparian buffer preservation and enhancement.

To further the implementation of objectives described in the Comprehensive Plan, the Town completed a new and detailed Unified Development Ordinance in November 2005. This new Ordinance was then amended, clarified and revised during 2011 and 2012 in response to the 2009-2010 revisions to the Comprehensive Plan. This document describes explicitly how citizens are to achieve the standards and intentions of the Plan while undertaking their work and daily lives within the Town limits. For development occurring after March 2010, the Ordinance advances the strength of the Neuse River Basin Buffer Rules (DWQ, 2000) by requiring subject riparian buffer land to be "platted as separate lots" to be held in permanent conservation easements by a homeowners association, the Town, the County, or by a non-profit land conservation agency. Stormwater BMPs are also prescribed for an array of development and post-development conditions.

3.4 Town of Wendell

In 2007, the Board of Commissioners for the Town of Wendell adopted its Comprehensive Plan titled "The Town Plan of Wendell—Building a Town for the Next Century." Citizen input was the major driving force for developing the plan's guiding principles.

This stratified conservation plan prescribes land use categories, two of which are the S-1 and S-2 categories, *preserved* open space and *reserved* open space, respectively. The S-1 open space lands consist of natural and rural non-developable lands already under protection, especially those adjacent to streams and water bodies. Included in the plan are protected agricultural lands, forests, wetlands, riparian buffers, land that protects water quality and attenuates flooding, and land that provides recreational opportunities. Wake County school property and designated county open space lands falling within the Town jurisdiction are also included. Intended land usage is for conservation areas, parks, greenways, forestry, and education.

The S-2 open space lands consist of natural and rural areas that are targeted for designation as non-developable. This includes unprotected agricultural land, floodplains, steep slopes, and land adjacent to S-1 designated lands. S-2 lands are typically appropriate for protection designation via conservation easements or open space acquisition, resulting in their reclassification as S-1 lands. Similar to S-1 lands, intended land usage includes conservation areas, parks, greenways, forests, and education. In some cases, low-density residential use may be appropriate.

Other protection measures of note in the Plan include (1) a recommendation to improve water quality by maintaining (or restoring) 100-foot riparian buffers for all streams in the jurisdiction, and (2) an acknowledgement of the need to protect two Federally and state endangered mussel species, the dwarf wedgemussel (*Alasmidonta heterodon*) and the Tar spinymussel (*Elliptio steinstansana*), both documented to occur within the Town's jurisdiction.

The Town also developed and adopted a Unified Development Ordinance in 2010 to help citizens and businesses institute the vision outlined in the Comprehensive Plan. Sections 6 through 8 provide guidelines for protecting the environment, open space, and landscapes within the Town's 35 square mile jurisdiction.

3.5 Town of Zebulon

The Town of Zebulon developed and adopted a Comprehensive Plan in 2008. At the outset of the Plan development process, the Zebulon Planning Department established two general guidelines: (1) to engage a broad array of stakeholders and incorporate their input into Plan recommendations, and (2) to maintain the unique Town atmosphere of Zebulon, as distinguished from suburban Raleigh. The Plan explicitly outlines goals for economic development, environmental resources, transportation, housing, community amenities, utilities, and land use.

Within the Plan is a chapter titled Land Use and Overview (Chapter 9) which effectively serves as the Town's land use plan. Amongst the land use categories is the "Open Space" designation. Included in the open space category are public and private parks, recreational areas, preserved natural areas, natural stream corridors, trails, greenways, protected view sheds, and environmental preservation areas. The category also includes "Developed Open Space" meaning recreation-oriented buildings and outdoor facilities for individual or team activities. The land use goals encourage the incorporation of low impact development in future development projects and the reduction of impervious surfaces in existing developments where stormwater runoff has been identified as a problem.

In September 2011, the Zebulon Planning Department initiated the process to develop a Unified Development Ordinance that will facilitate realizing the objectives laid out in the Comprehensive Plan. The effort is ongoing at the time of this writing.

3.6 City of Raleigh

The City of Raleigh originally adopted a Comprehensive Plan in 1989. This plan was replaced by the current Comprehensive Plan in 2009 when the City Council formally adopted it after a two-year public stakeholder process. "The Plan establishes a vision for the City, provides policy guidance for growth and development," and provides an action strategy for implementing the vision.

There are several relevant management operations and ongoing studies within the LWP area:

1. The Neuse River WWTP on Battlebridge Road manages a bio-solids application project on Wrenn Road.
2. Related to the proposed Little River Reservoir, an instream flow study was begun in 2010 (see Little River Study) with a study committee active as recent as April 2013 (see Little River Water Supply Fact Sheet).

3. Water quality and stream morphology monitoring was specified in the Biological Opinion associated with the operation of the Dempsey Benton WTP (see Technical Paper). Monitoring is ongoing, and results to date are available from the City.
4. Water quality sampling on the Neuse River has been conducted by the Lower Neuse Basin Association since 2006 (see LNRBA Monitoring Information). Recent data not available on the website can be acquired from Wake County Environmental Services.

Potential Water Quality Projects/Needs:

Despite the LWP area being entirely downstream of Falls Lake, more water quality monitoring and subsequent installation of stormwater BMPs could conceivably occur as a result of the Falls Lake Nutrient Management Strategy. In this case, the City of Raleigh would apply similar restrictions throughout its service area as is expected from upstream communities in the Falls Lake watershed.

3.7 State of North Carolina

There are multiple water quality management plans that are broad in scope but have important implications to this local watershed initiative. Three statewide plans are described here for their primary relevance but this selection is not intended to be comprehensive. The Neuse River Nutrient Sensitive Waters Management Strategy (DWQ, 1998) was produced by the NC Division of Water Quality and describes the expansive nonpoint source issues for the basin. It offers a general nutrient reduction strategy and overall reduction goals for waters reaching the estuary. The Neuse River Basinwide Water Quality Plan (DWQ, 2009b) was produced by the NC Division of Water Quality and is updated on a five-year cycle. It provides use support ratings for waters throughout the entire basin and an analysis of water quality information by which impaired waters are identified for North Carolina. The Neuse River Basin Restoration Priorities (EEP, 2010) was produced by EEP and is also updated on a five-year cycle. It provides results of an analysis of assets and problems within 8-digit catalog units. The results are a series of descriptions of priority 14-digit Targeted Local Watersheds (TLWs) in the Neuse Basin that outline specific watershed improvement goals for each. These TLWs are watersheds in which the state focuses its stream, wetland, buffer, and nutrient offset restoration, enhancement, and preservation projects to be constructed for mitigation and other watershed functional improvement in general.

4 Subwatershed Delineation

Delineation of the study watershed was based on a number of needs, the most important of which was to help standardize the size of study units for practical purposes. By keeping the size of subwatersheds relatively small, the GIS team was able to improve confidence that information (e.g., water quality data) collected at one or two points was reasonably representative of conditions in the subwatershed. Each subwatershed has a pourpoint, the most downstream point of flow that was chosen to correspond with a logical accessible break to the extent possible. This was intended to facilitate field sampling and other data collection. Land use within each subwatershed was intended to be as homogeneous as possible. These quality control measures will help to promote an effective monitoring strategy.

Subwatershed Delineation Methodology. Due to the large LWP size (~144 mi^2), subwatersheds were delineated to characterize conditions and better understand the factors influencing different portions of the study area. This characterization is intended to help show where resources should be focused in the field to identify restoration or preservation opportunities. Finally, the subwatershed scale is the level at which success of implementation efforts may best be measured (Center for Watershed Protection, 2000).

The first step in delineating subwatersheds was obtaining the Digital Elevation Models (DEMs) for the LWP area (Figure 3). NC Department of Transportation (DOT) published DEMs for North Carolina based on data collected using Light Detection and Ranging (LIDAR) technology in 2007 (NCDOT, 2007a). The DEM cell size is 20 feet, with a vertical accuracy of 0.2 feet.

The elevation data was processed to develop small watersheds, or catchments, using ESRI's ArcHydro™ extension (ESRI, 2013). Catchment delineation began with DEM reconditioning, a process that corrects any relational errors that may occur between the DEM and the stream network. The "Agree" methodology (Maidment, 2002) ensured that the stream data correctly corresponded with the DEM topography and checked for any errors, such as sinks (i.e., depressions) that may impede the virtual stream flow analysis. Once reconditioned, the direction of flow across the DEM was determined using the "Flow Direction" tool. The flow direction was also used to derive the number of DEM cells (i.e. drainage area) draining through the virtual stream network to create the flow accumulation GIS dataset.

Catchments were then identified for all stream reaches in the study area. Catchment size (i.e., 50 acres or 0.08 square miles) is smaller than the target size for subwatersheds (i.e., typically 1,300–3,000 acres or 2-5 square miles). Catchments, therefore, were combined into larger units (i.e., subwatersheds) by visually inspecting them against the stream network, contours, and aerials. To the degree possible, subwatershed boundaries were made at logical breakpoints based on land use change, large water bodies, and separating mainstem creeks and rivers from headwater areas. In some cases, heads-up digitizing (tracing outlines from a raster images, on-screen) was used to adjust the final watershed boundaries to account for things like road crossings, swamps, or lakes, features that can improperly influence the shape of the virtual flow network.

Figure 4 is a map of the subwatershed delineation. In total, 31 subwatersheds were delineated, ranging from 1.9 to 7.8 square miles in area. The average subwatershed size was 4.6 square miles.

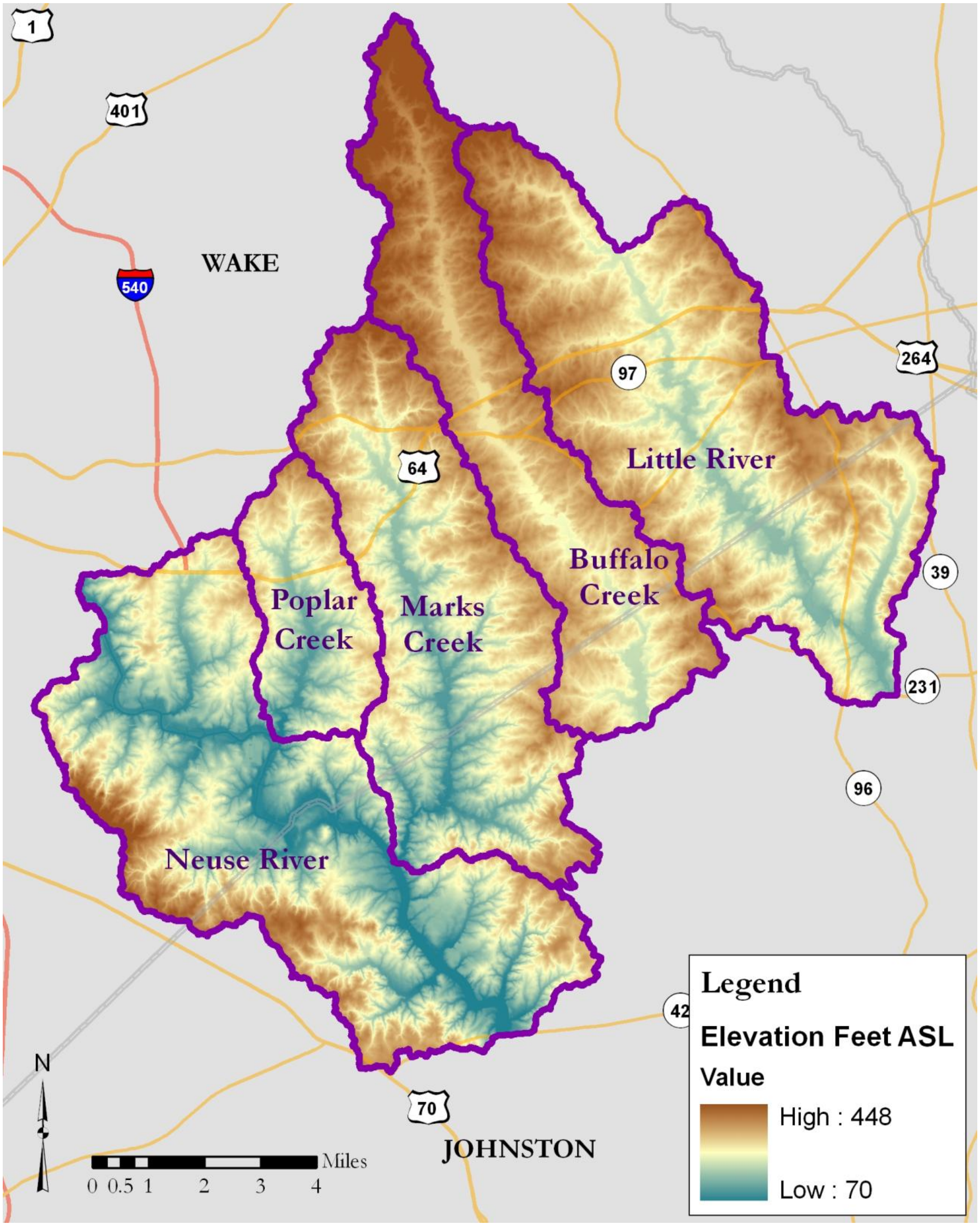

Figure 3. Digital Elevation Model of the LWP Study Area.

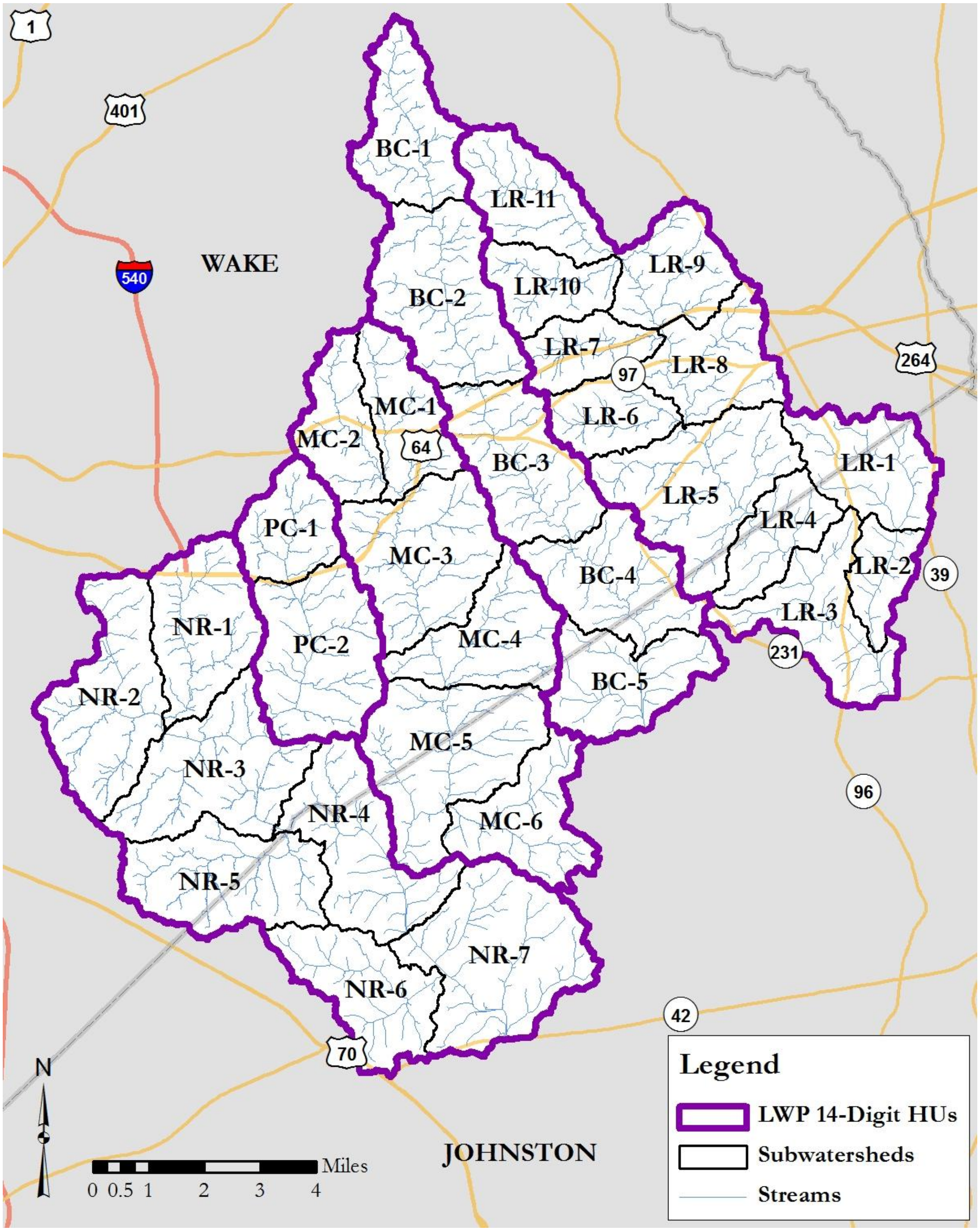

Figure 4. Subwatershed Delineations.

5 PRELIMINARY WATERSHED CHARACTERIZATION AND FUNCTIONAL ASSESSMENT

5.1 Watershed Characterization

Spatial data representing land use, imperviousness, important species and habitats, riparian habitat conditions, and water quality were compiled along with other forms of descriptive data including biological community data and point sources of pollution. Additional interpretation of existing water quality data by the DWQ Watershed Assessment Team (WAT) can be located in Appendix A. Field reconnaissance was also performed by Technical Advisory Committee (TAC) members to document channel conditions and to verify land use information collected from aerial imagery. These data were used to provide the following watershed characterization and were further analyzed to develop the preliminary functional assessment in the next section. To help prioritize recommendations for assessment to be conducted during the RWP, subwatersheds were assigned to different levels of function in seven categories—hydrology, water quality, stormwater, soil erodibility, agricultural impacts, rare species habitats, and preservation potential. High priority subwatersheds in problem categories were assigned based on severity of the issue and in asset categories according to the relative abundance of the resource.

5.1.1 Land Use and Cover

The land cover data used for this analysis (see Figure 5) is the National Land Cover Data (NLCD) from 2006 (Fry et al., 2011). Development has been extensive in some localities in the watershed since 2006, suggesting that more current data might be informative. To help account for recent watershed development, an assessment of historic land use trends will be conducted as part of the RWP.

The LWP study area has diverse land usage ranging from moderately high-density residential (in municipal centers) to low-density, rural, agricultural areas. Over a third of the study area is agricultural with the most extensive amount in the Buffalo Creek portion of the watershed. Urban land cover is localized in the planning area, with the most dense centers occurring in Buffalo Creek (subwatershed BC-3), Little River (LR-7 and LR-8), and along the Neuse River (NR-2 and NR-6). Some open water cover occurs in relatively low amounts throughout the area, the largest impoundments occurring in Buffalo Creek (BC-2 and BC-5) and Little River (LR-5). The densest amount of streams occurs in the Little River (LR-7) with 3.3 miles of streams per square mile and the Neuse (NR-1) and Buffalo Creek (BC-2), each with 3.2 miles of stream per square mile. The most extensive amounts of unfragmented (interior) forest occur in Marks Creek (MC-5 and MC-6) and along the Neuse River (NR-2, NR-4, NR-5, and NR-7). Buffalo Creek and the lower Little River have high road densities and associated high impervious surface cover. Similarly, Poplar Creek has high road densities but the imperviousness is still relatively low, suggesting that development is still ongoing or that the spatial data is outdated and doesn't capture current conditions accurately.

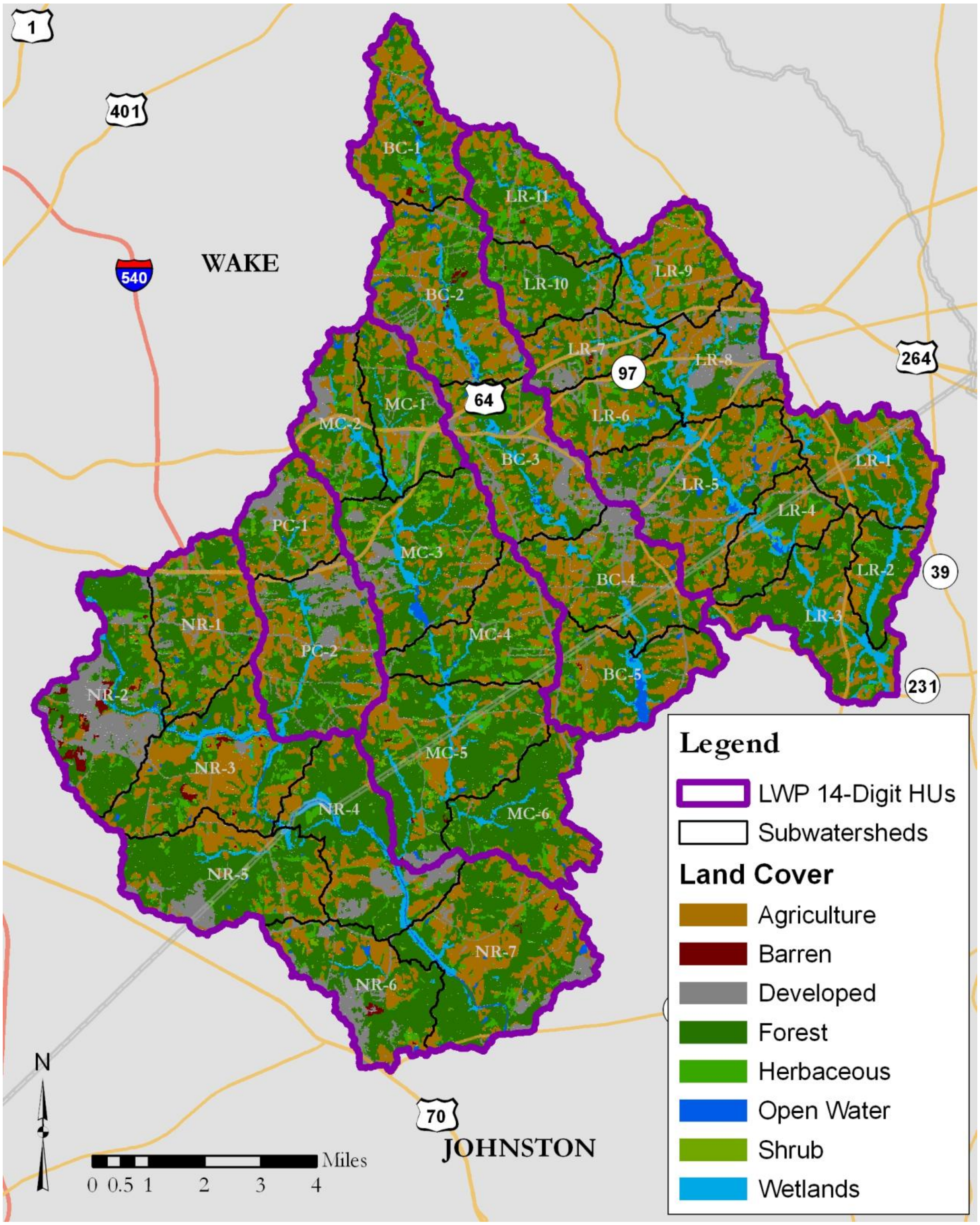

Figure 5. Land Cover in the Wake-Johnston Collaborative LWP Area.

5.1.2 Watershed Impervious Surface Area

Impervious cover is especially important for urban and suburban parts of the watershed. Imperviousness for the watershed was developed using impervious cover data from the National Land Cover Dataset (Fry et al., 2011) and was re-categorized by percentage ranges. Figure 6 illustrates how impervious surfaces are concentrated primarily around municipalities.

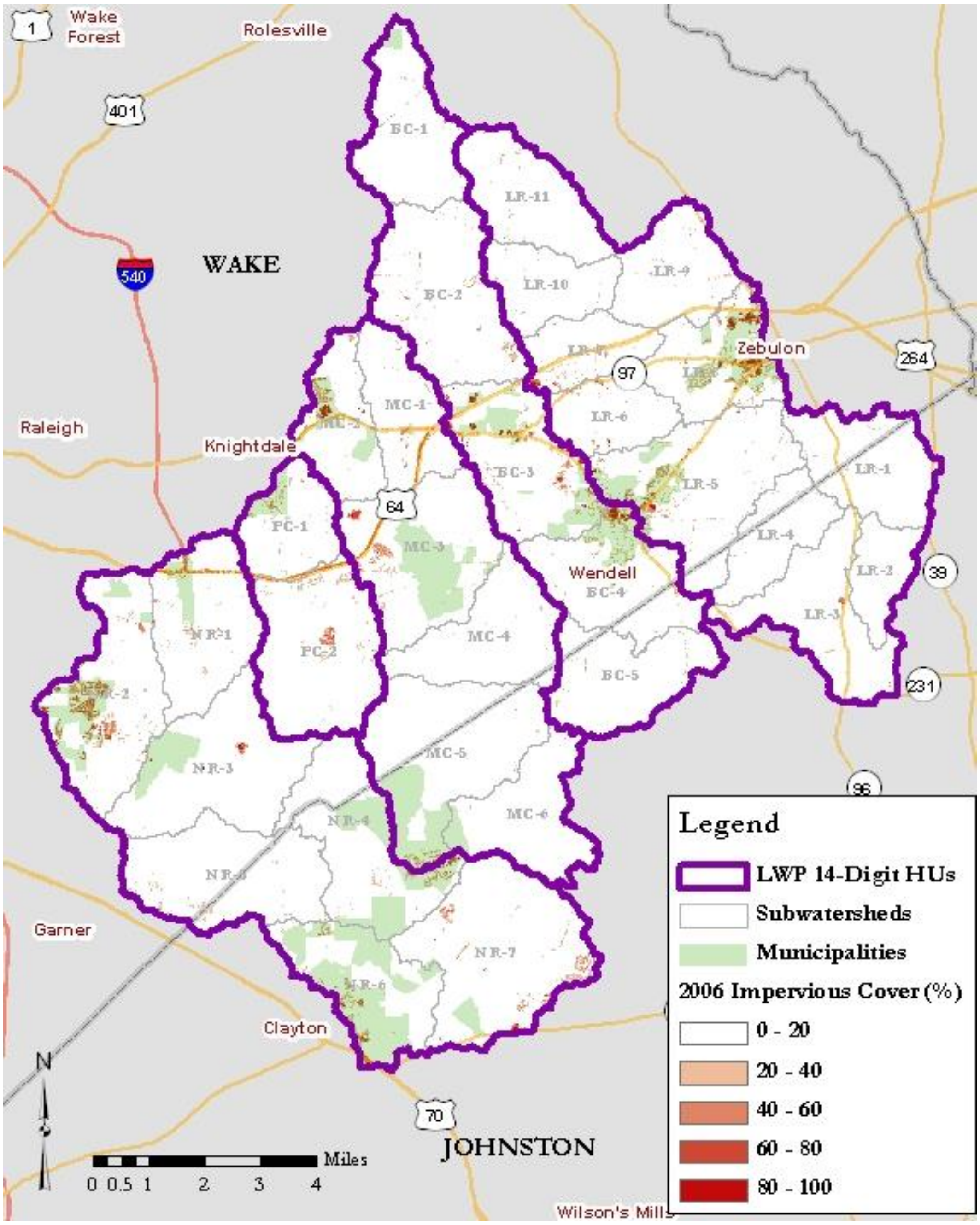

Figure 6. Impervious Surface.

5.1.3 Hydric Soils, Hydrology, and Wetlands

Hydric Soils

Hydric soils in the watershed are significantly associated with riparian zones and wide floodplains. Larger wetlands occur in conjunction with impounded reaches of the watershed on hydric soils. Isolated wetlands not associated with stream flow are found in smaller patches throughout the LWP area as shown in Figure 7. Significant patches of hydric soils that do not indicate extant wetlands suggest a conversion of land usage such as agriculture or development. Hydric soils that are consistently saturated are categorized as "A" series and as "B" series when they are more likely to suffer from periods of drought, providing a less reliable habitat for obligate wetland plants.

Hydrology and Wetlands

Dominated by high order stream and river systems with small to intermediate tributary drainages, the LWP study area drains into the upper Neuse River near the Fall Line. Wetlands are most often riparian and are closely associated with floodplains (see Figure 8), the most extensive of which are created by beaver impoundments. Isolated nonriparian wetlands that exist in the watershed are relatively scarce, and are not well-documented by the National Wetlands Inventory data (US Fish and Wildlife Service, 2006). Extensive farm pond development has occurred in headwaters of creeks, and wetlands tend to be prevalent in those areas. Remnants of pocosins are situated in a few localities in headwaters near interstream divides, especially in the southern part of the LWP study area (NC Forest Service, 2012). Floodplains tend to be wide along the main stem of rivers and in multi-thread channel headwaters. Multiple lakes are maintained in the watershed and a few naturally-occurring semipermanent impoundments are documented in the watershed (NC Natural Heritage Program, 2013). Other features more commonly found in the coastal plain occur as far inland as Buffalo Creek, including an important example of brownwater small stream swamp (NC Natural Heritage Program, 2013). In general, headwater systems in the LWP study area tend to exhibit swamp-like characteristics.

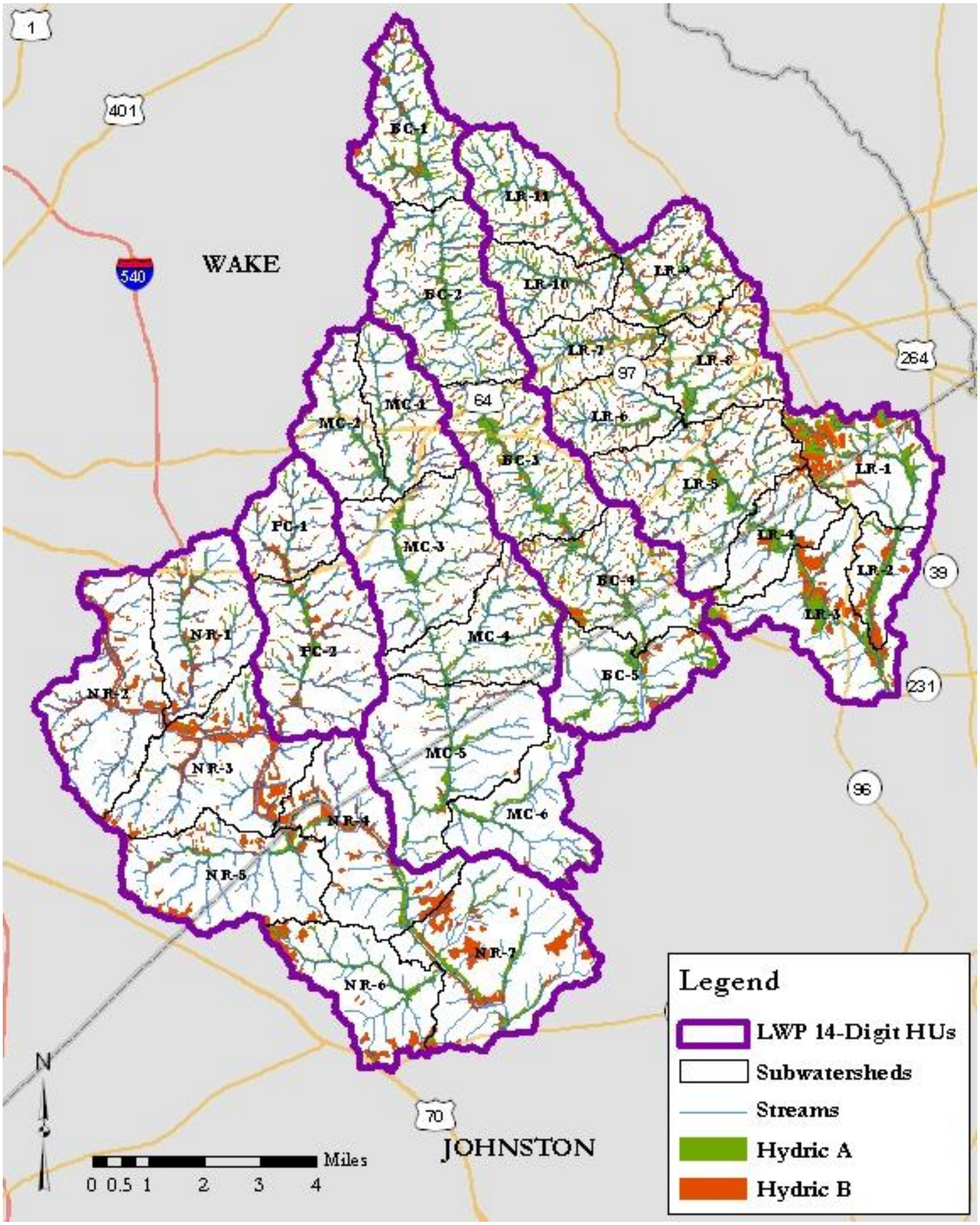

Figure 7. Hydric Soils.

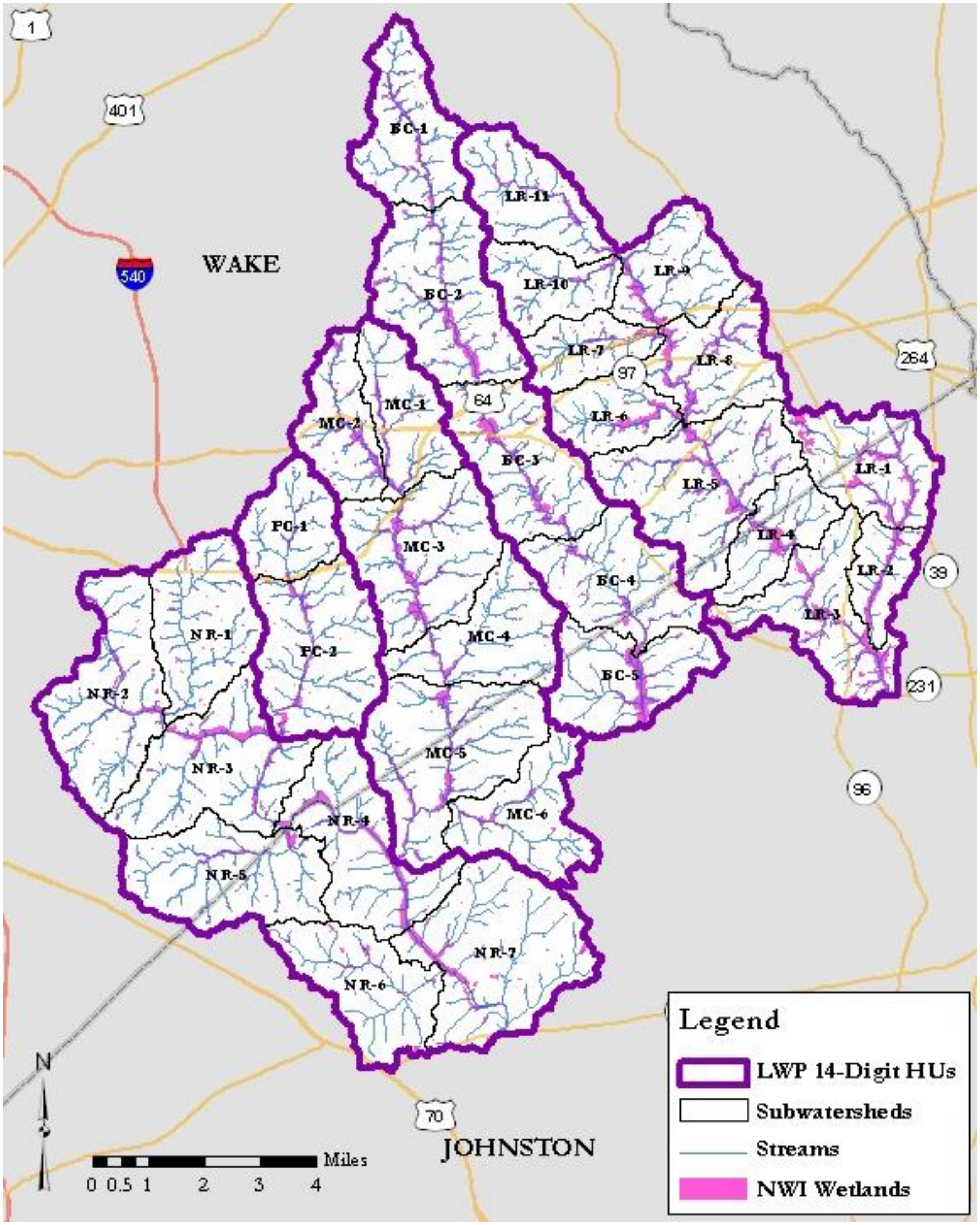

Figure 8. Streams and Wetlands.

5.1.4 Riparian Buffers, Riparian Zone Condition, and Floodplain Disturbance

Riparian areas in the less developed and more agricultural portions of the watershed tend to have better buffer condition, with varying degrees of buffer degradation in areas of denser population and development. Significantly wide floodplains along the Neuse River portion of the watershed have the greatest expanses of intact forested wetlands and riparian buffers. Extensive wetlands and beaver impoundments along the Neuse as well as in most of the Little River subwatersheds have helped to maintain wooded riparian buffers suitable for preservation in those areas.

Riparian Zone Condition

Metrics calculated to represent riparian zone condition included "Denuded Length" of riparian buffer by subwatershed and "Opportunities" for buffer enhancement and restoration. Subwatershed comparisons illustrating the extent of denuded buffers of each width category are depicted in Figures 9a through 9d. Buffer restoration opportunities are presented in Section 7.

Denuded Length. Starting with the 2006 National Land Cover Database (NLCD) coverage in polygon format, each land cover type was classified as either forest or denuded, with open water being included with forested so as not to overestimate the amount of denuded acreage. This coverage was then clipped using the different buffer widths (60, 100, 200, and 300 feet) for the streams in the LWP area. The amount of total denuded acreage could then be computed for each respective buffer width. This total denuded area was divided by the buffer width used to clip it, resulting in a linear footage of denuded area for the LWP. This was further subdivided into the various subwatersheds, for each of which a total linear footage of denuded area was reported and mapped.

Floodplain Disturbance

Another comparison is illustrated in Figure 10 whereby the percentage of total floodplain disturbance for each subwatershed is categorized by extent. These values were calculated from NLCD data (Fry et al., 2011) by identifying the total acreage of denuded land area within the delineated 100-year floodplain (NC Flood Risk Information System, 2011). In many cases the findings from the denuded buffer is corroborated, but the percentage of floodplain disturbance comparison offers a different view, especially in subwatersheds where floodplains are significantly wider than the buffer zone categories (e.g., the Neuse Rivers subwatersheds). In subwatersheds where the disturbance is high, additional field reconnaissance or aerial imagery analysis may be indicated for the RWP assessment.

Figures 9a – 9d. Comparison of Subwatersheds based on Extent of Denuded Buffers.

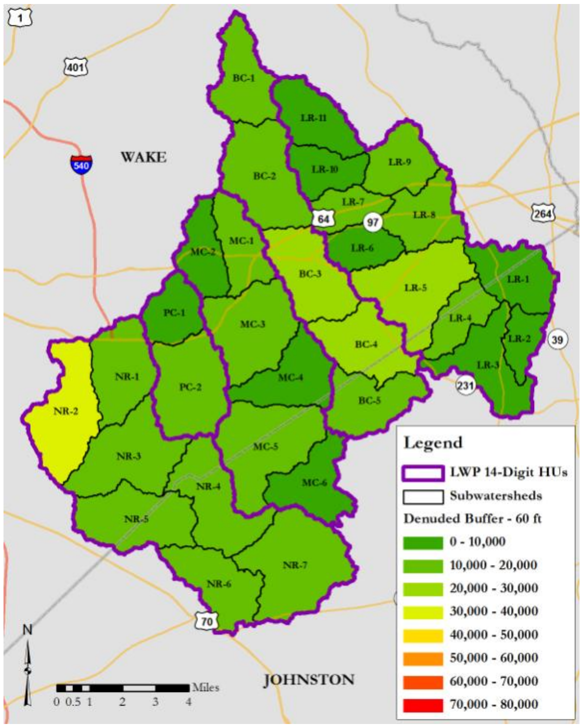

Figure 9a. 60-foot Wide Denuded Buffers

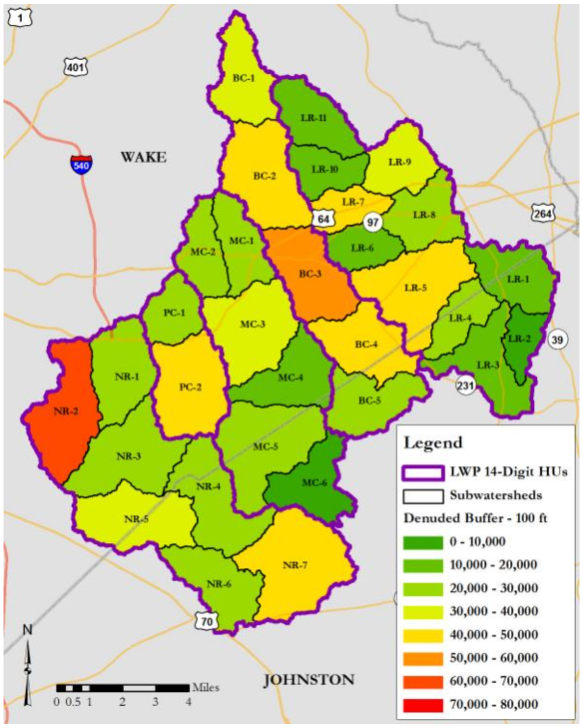

Figure 9b. 100-foot Wide Denuded Buffers

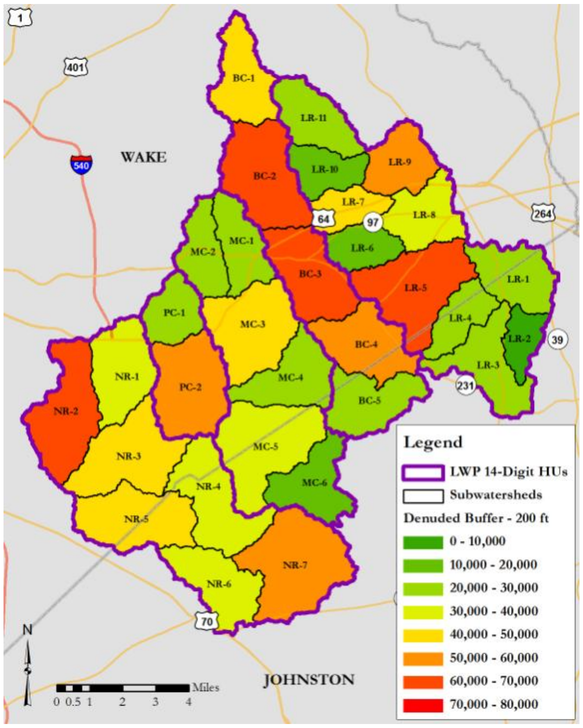

Figure 9c. 200-foot Wide Denuded Buffers

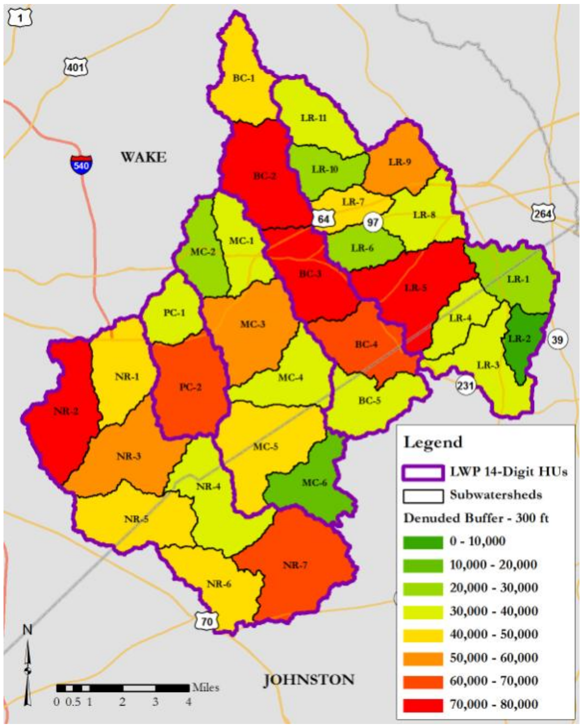

Figure 9d. 300-foot Wide Denuded Buffers

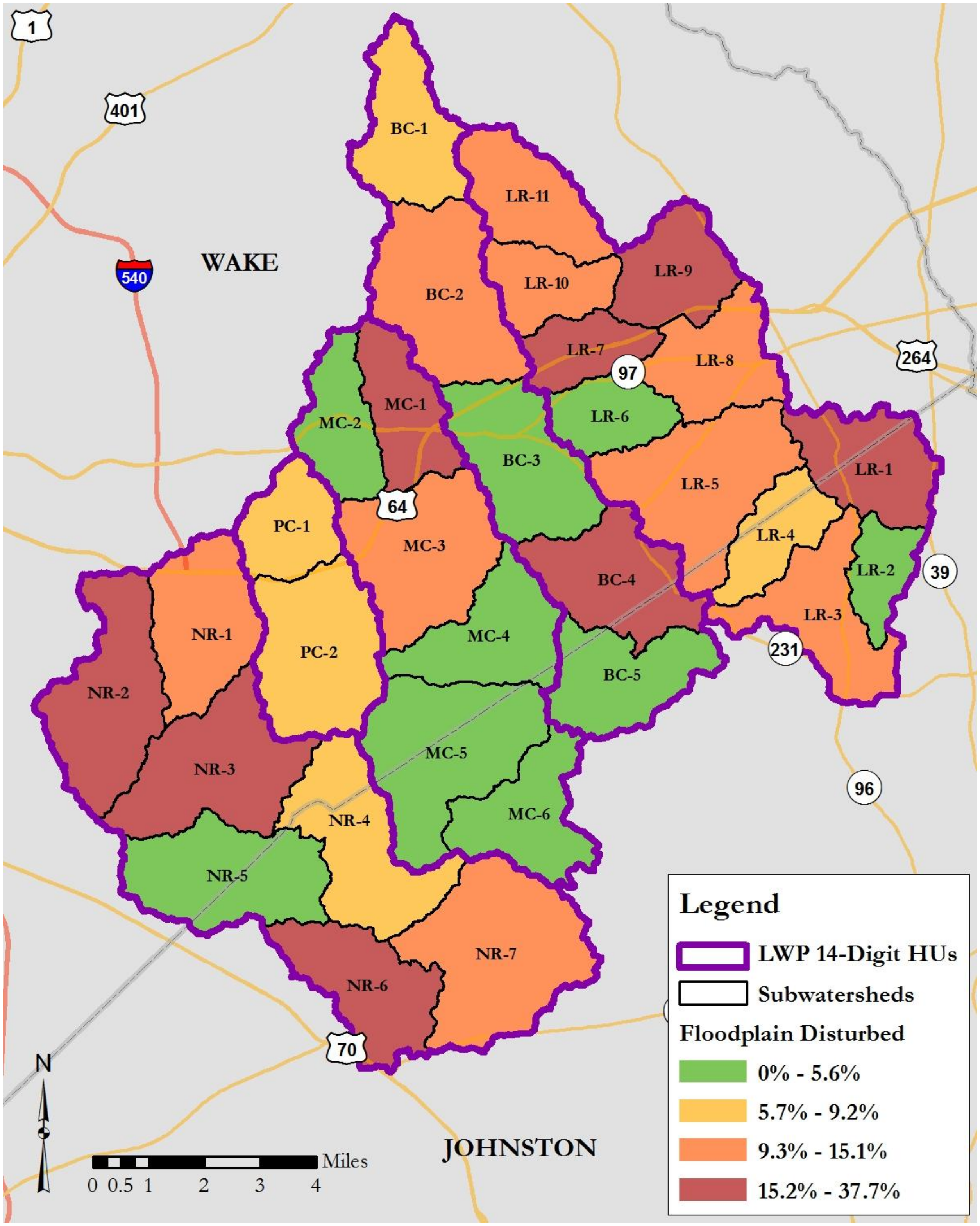

Figure 10. Comparison of Percentage of Floodplain Disturbance.

5.1.5 Channel Condition

General conditions of channels were systematically evaluated during the windshield survey reconnaissance. The field team documented general observations about instream and riparian habitats, and adjacent land use. Habitat conditions were also recorded by the benthic macroinvertebrate sampling team. Streams throughout the watershed tended to show evidence of varying levels of embeddedness. Particularly related to low flow conditions, streams typically exhibit low energy and aren't readily capable of moving substantial sediment loads downstream, especially in parts of the watershed that are heavily impounded. In reaches downstream of urbanized areas during storm flows, it appears that sediment is being moved due to higher flow energy generated by impervious surface runoff. In these reaches, there is evidence of bank erosion and scour. Images in the Windshield Survey Summary below illustrate ongoing sedimentation issues.

5.1.6 Preliminary Field Assessment

Members of the Technical Advisory Committee (TAC) performed reconnaissance of the watershed in the form of a windshield survey. A windshield survey is a cursory field exercise, typically performed by the planner and project manager during early planning phases, intended to provide a general impression of watershed conditions and to help corroborate land usage as it appears on aerial imagery. Observations at each site were documented in a worksheet for future reference (Figure 11). This exercise allowed the TAC members to become familiar with the general attributes of subwatersheds within the planning area and to make a general assessment regarding the suitability of each site for subsequent cross-sectional monitoring. The monitoring of channel morphology at cross sections may be incorporated into assessment work for the RWP.

During the field visits, the team identified and verified dominant land use and cover upstream and downstream of each of the selected road crossings. The team estimated the extent of buffer on both banks and approximated the intensity of land management practices. The relative level of land disturbance was documented as well as the general stream condition. Team members noted other substantial concerns or problems at each stop on the survey as well as positive features such as significant mature forest tracts that may not have been evident on aerial imagery.

SITE ID NUMBER:
SITE INFORMATION:

Latitude: ____________________ Longitude: ____________________
Watershed: ____________________ Stream Name: ____________________
Date: ____________________ Investigator: ____________________

Site Description (eg--"stream name" at "road name", etc.): ____________________

UPSTREAM	DOWNSTREAM
Dominant Land Uses:	
☐ Forest ☐ Pasture ☐ Row Crops ☐ Low Density Residential ☐ High Density Residential ☐ Commercial/Industrial ☐ Other:__________	☐ Forest ☐ Pasture ☐ Row Crops ☐ Low Density Residential ☐ High Density Residential ☐ Commercial/Industrial ☐ Other:__________
Buffer Condition:	
☐ Good ☐ both sides ☐ Fair ☐ one side only ☐ Poor ☐ Absent	☐ Good ☐ both sides ☐ Fair ☐ one side only ☐ Poor ☐ Absent
Bank Condition:	
☐ Good ☐ both sides ☐ Fair ☐ one side only ☐ Poor	☐ Good ☐ both sides ☐ Fair ☐ one side only ☐ Poor
Stream Condition:	
☐ Good ☐ Fair ☐ Poor	☐ Good ☐ Fair ☐ Poor
Potentially Detrimental Features:	
☐ Clearcutting ☐ Construction ☐ Livestock in Stream ☐ Straightened/Altered Channel ☐ Invasive/Exotic Species: ☐ Other:	☐ Clearcutting ☐ Construction ☐ Livestock in Stream ☐ Straightened/Altered Channel ☐ Invasive/Exotic Species: ☐ Other:
Positive Features:	
☐ Large Tracts of Mature Forest ☐ Conservation Tillage ☐ Stormwater BMPs ☐ Other BMPs: ☐ Important Species Identified: ☐ Other:	☐ Large Tracts of Mature Forest ☐ Conservation Tillage ☐ Stormwater BMPs ☐ Other BMPs: ☐ Important Species Identified: ☐ Other:

Figure 11. Example of Field Reconnaissance Form used for Windshield Surveys.

Windshield Survey Summary

A field team of Technical Advisory Committee members documented conditions throughout the watershed at selected road crossings. Photographs of streams and riparian zones were taken to document current watershed conditions. These particular crossings were being investigated for future usage as semipermanent cross section sampling sites to help assess long-term changes in stream morphology and instream habitat. Additional information was collected to verify accuracy of land cover spatial data using windshield survey forms (Figure 11).

Site 1 (Beddingfield Creek at Shotwell Road, Subwatershed NR-5) – Figure 12.

This site appears aggraded with large sand bars along banks. The stream maintains a sand bed with some minor gravel. It contains stumps or timbers instream upstream of the bridge. Discharge is estimated to be three to four cubic feet per second (CFS). *Team members believe this is likely a good cross sectional survey site.*

Site 2 (Marks Creek, lower site near Knightdale Road, Subwatershed MC-5) – Not pictured.

This section of Marks Creek has a large channel on a broad bend with mostly pools. Bedrock occurs adjacent to the bridge. *This is probably not a good survey site.*

Figure 12. Beddingfield Creek at Shotwell Road.

Site 3 (Poplar Creek, lower, near Poole Road, Subwatershed PC-2) – Not pictured.

This section of Poplar Creek has a sand bed with legacy toppled trees along its banks. There are ponds and wetlands along the right bank floodplain. It appears to be straightened because the right bank shows a levee in places. Discharge is estimated at about five CFS. *The team believes this is a good cross sectional survey site.*

Site 4 (Poplar Creek, upper, near Smithfield Road, Subwatershed PC-1) – Not pictured.

Headwater channel morphology has low banks and adjacent wet areas. *The team considers this a good cross sectional survey site.*

Site 5 (Marks Creek, upper, near 64 bypass, Subwatershed MC-1) – Figure 13.

This part of Marks Creek has a sand bed with some beaver dams that do not reach the top of bank. This reach consists mostly of pools. *This is probably not a good survey site.*

Figure 13. Marks Creek.

Site 6 (Buffalo Creek, lower, at Poole Road, Subwatershed BC-4) – Figures 14a and 14b.

The stream has a sand bed and tannin-stained water. Bedrock appears to be controlling the grade and the floodplain is relatively low upstream of the bridge. There is a marked contrast downstream with rip-rap and poor riparian vegetation. *This is probably not a good survey site.*

Figure 14. Lower Buffalo Creek, (a) Upstream (above) and (b) Downstream (below).

Site 7 (Little River at SR-231, Subwatershed LR-3) – Figure 15.

The river at this site is large and slow-moving, possibly impounded. The drainage area is approximately 50 square miles. *The team agreed that this is probably not a good geomorphic survey site.*

Figure 15. Little River.

Site 8 (Snipe Creek at Earpsboro Road, Subwatershed LR-1) – Figures 16a and 16b.

This is a smaller, steeper, gravel-bed channel with a significant amount of sand. The low banks and recent clear-cut adjacent to left bank leaves the floodplain vulnerable. *This is probably a good survey site.* See photos.

Figure 16. Snipe Creek, (a) Downstream (above) and (b) Riparian Zone showing clear-cutting (above right).

Site 9 (Rocky Branch at Riley Hill Rd, "The Rocks" Preserve, Subwatershed LR-10) – Figure 17.

The stream is narrow at the road with a bedrock slide downstream. Morphology appears to be characteristic of Fall Line stream reaches. *This is probably not a good survey site.*

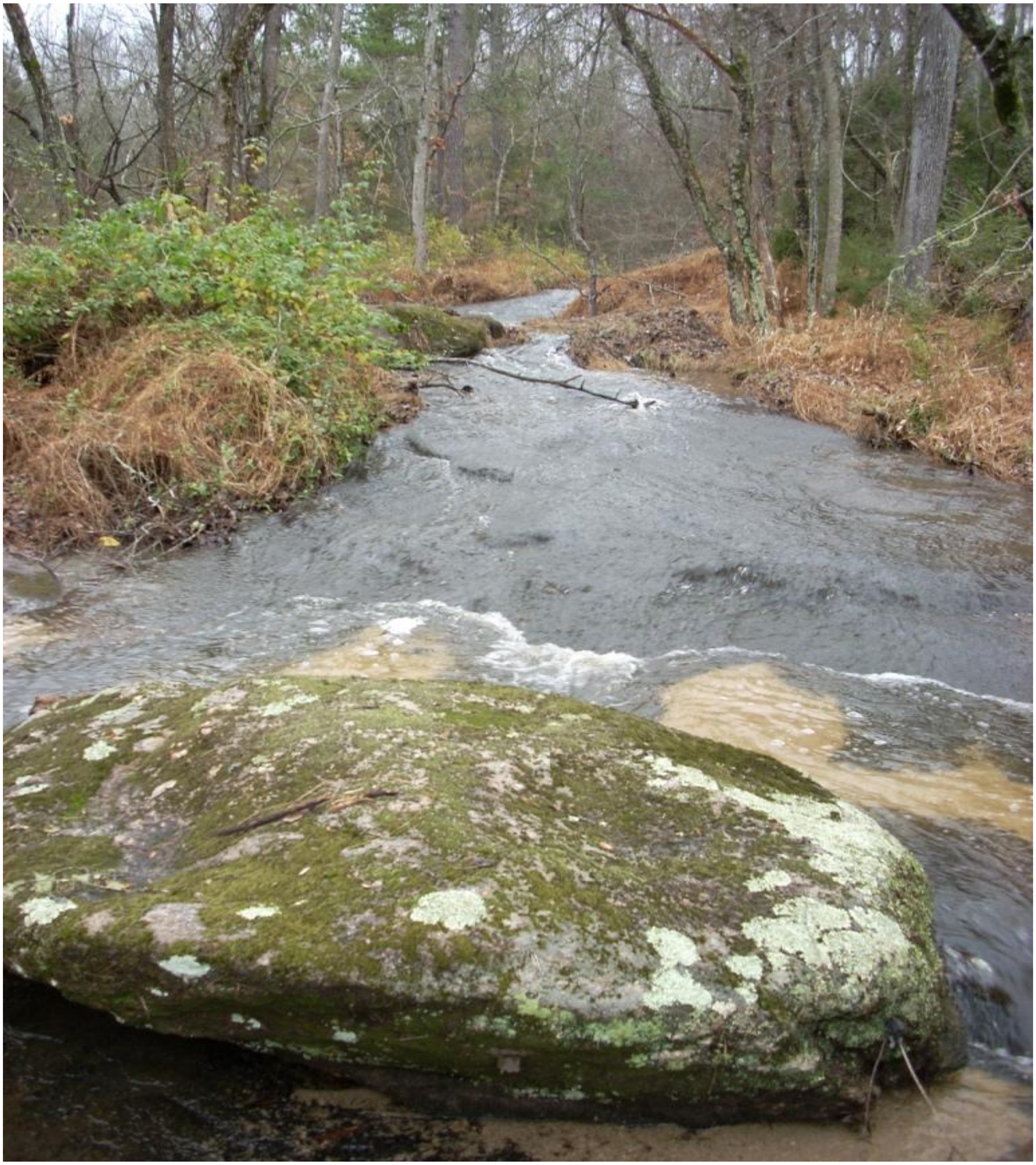

Figure 17. Rocky Branch.

Site 10 (Hominy Creek at Buck Road, Subwatershed LR-11) – Figure 18.

This site has a multi-threaded channel with adjacent wetlands. *The team determined that this is not a good cross sectional survey site.*

Figure 18. Hominy Creek.

Site 11 (Buffalo Creek, upper, near Riley Hill School Road, Subwatershed BC-2) – Figure 19.

Buffalo Creek has a sand bed at this site. *Team members believe this may be a suitable site for long-term survey.*

Figure 19. Upper Buffalo Creek.

5.1.7 Water Quality and Biological Data

There are three major goals for compiling water quality data during Phase I: (1) to identify gaps in information that may be filled during subsequent phases of the planning process, (2) to assist in the preliminary identification of major watershed stressors, and (3) to establish a basis for making decisions guiding the next steps of the LWP process.

Data that exists and is readily available to characterize the LWP study area is summarized in Table 3 below. The Division of Water Quality Watershed Assessment Team (WAT) assembled a detailed summary that can be found in *Appendix A*. From the summary report, a list of information gaps were identified that should be addressed to make the stressor identification and decision-making process more successful. In general, water quality data generated by sample collections is sparse throughout the watershed, but synoptic benthic macroinvertebrate sampling does provide a clearer understanding of impairment issues in major streams and rivers.

Stream Impairment

Portions of Buffalo Creek and the Little River, as well as major sections of the Neuse River within the LWP study area, are included on the 2010 303(d) list of impaired waters for the state (DWQ, 2010). These stream segments are listed due to poor water quality and habitat conditions for aquatic life. More detailed examination of the causes of these impairment ratings should be undertaken in the RWP assessment.

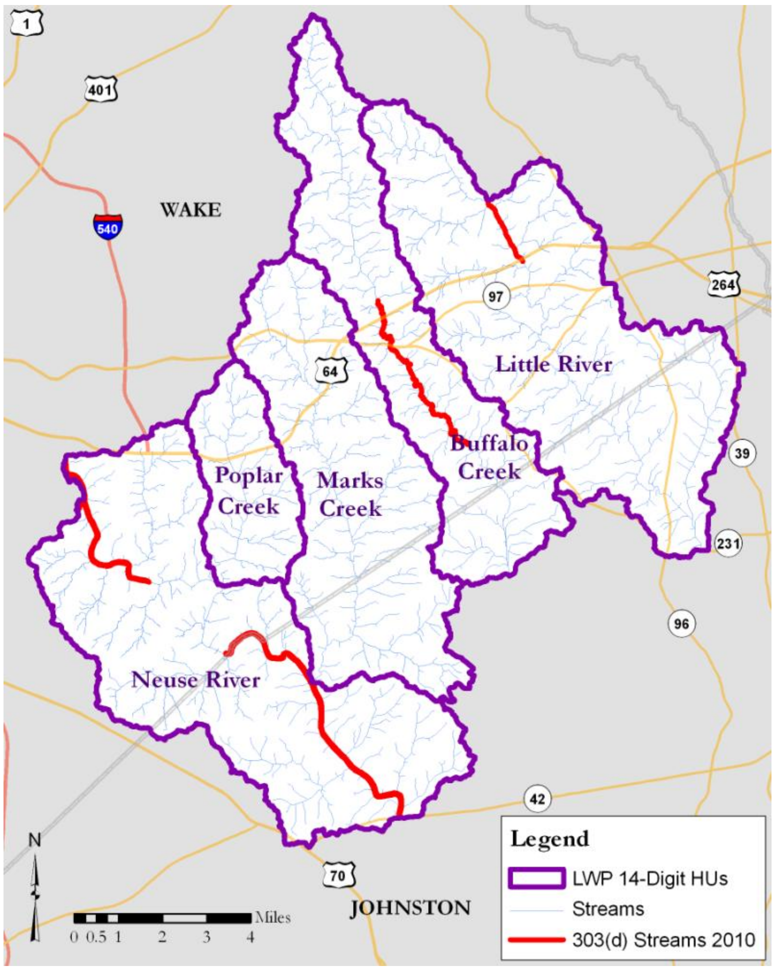

Figure 20. Impaired Streams from the 2010 303(d) List.

Table 3. Locations, Descriptions, and Types of Water Quality Data in the LWP Area 2000-2009.

Stream Location and County	Class	Use Support Rating	Benthos	Fish	Habitat	Physical / Chemical WQ	*In situ* Field Readings	Geomorph	Flow
Beddingfield Creek SR 1553	C	ND	LWP		LWP	LWP	LWP		
Poplar Creek SR 2233	C	S	LWP		LWP	LWP	LWP		
Poplar Creek SR 2049	C	S	LWP		LWP	LWP, LNRBA	LWP, LNRBA		
Marks Creek SR2501	C	S	LWP, WC		LWP, WC	LWP	LWP	WC	
Marks Creek SR 1714	C	S	LWP, DWQ, WC	DWQ	LWP, DWQ, WC	LWP	LWP	WC	USGS
Buffalo Creek SR 2224	C	ND	LWP		LWP	LWP	LWP		
Buffalo Creek SR1007	B	I	LWP, DWQ	DWQ	LWP, DWQ, WC	LWP	LWP	WC	
Hominy Creek SR 2329	WS-II HQW	ND	LWP		LWP	LWP	LWP		
Rocky Branch SR 2320	WS-II HQW	ND	LWP		LWP	LWP	LWP		
Snipes Creek SR 1723	C	ND	LWP		LWP	LWP	LWP		
Little River NC 231	WS-IV	S	LWP		LWP	LWP	LWP		
Poplar Creek SR2511	C	S	WC		WC			WC	
Buffalo Creek SR 2320	C	S	WC		WC			WC	
Neuse River US 64	C	S	DWQ		DWQ				
Neuse River NC 42	WS-IV	I	DWQ		DWQ	LNRBA			USGS
Neuse River Milburnie Dam US	C	S				LNRBA			
Neuse River Milburnie Dam DS	C	S				LNRBA			
Neuse River SR 2555	C	S				LNRBA			
Neuse River SR 1700	WS-V	I				LNRBA			
Little River NC 97	WS-II HQW	S							USGS
Little River SR 2333	WS-II HQW	I				LNRBA	LNRBA		
Little Creek NC 97	C	S				LNRBA	LNRBA		
Little Creek NC 39	C	S				LNRBA	LNRBA		

USGS United States Geological Survey Gage
LWP Wake-Johnston Local Watershed Plan
LNRBA Lower Neuse River Basin Association
DWQ NC Division of Water Quality Biological Assessment
WC Wake County Comprehensive Watershed Management Plan (2003)

Class (NC DWQ): B - , C - , HQW – High Quality Waters, WS-II-V = Water Supply Watershed II-V
Use Support Ratings (NC DWQ): S – Supporting; ND – No Data; I -- Impaired
SR = State Route

Stream Chemistry and Pollution Sources

The DWQ Watershed Assessment Team compiled water quality data from multiple sources (Appendix A). DWQ ambient data as well as other sources were analyzed for potential contributions to stream water quality degradation. The most significant stressors evident in the data summary include low dissolved oxygen and nutrient inputs. The widespread DO problems are to some degree due to the slow flow attributable to natural swamp or impounded conditions.

As with most Piedmont watersheds in North Carolina, the LWP study area has an abundance of nonpoint source pollution issues, plus an array of point sources like wastewater treatment plants and similar facilities. This Neuse River portion of the watershed is influenced by upstream inputs and potential releases from the impoundment above the Milburnie Dam. The Little River subwatersheds lie just downstream of the Towns of Rolesville and Wake Forest that are home to several small package plants. Table 4 below summarizes the National Pollution Discharge Elimination System permitted facilities in the LWP watershed.

Table 4. NPDES Permitted Facilities with the Wake-Johnston LWP Area.

Permit Number	Facility Name	Major/Minor	Receiving Stream	Latitude	Longitude
NC0038938	Corinth-Holder Elementary & Middle School	100% Domestic < 1 MGD	Little River	35.7344	-78.2830
NC0051322	Ashley Hills WWTP	100% Domestic < 1 MGD	Poplar Creek	35.7563	-78.4686
NC0062219	Kings Grant Subdivision WWTP	100% Domestic < 1 MGD	Poplar Creek	35.7302	-78.4605
NC0064378	Willowbrook WWTP	100% Domestic < 1 MGD	Beddingfield Creek	35.6811	-78.5000
NC0065706	Cottonwood/Baywood	100% Domestic < 1 MGD	Poplar Creek	35.7625	-78.4727
NC0081540	Square D Company	Groundwater Remediation	Marks Creek (Lake Myra)	35.8277	-78.4588
NC0086266	Woodtrace WTP	Water Treatment Plant	Rocky Branch	35.8430	-78.4005

Biological Communities and Aquatic Habitat

During Phase I, partners from NCSU and DWQ performed full-scale benthic macroinvertebrate sampling at 11 stations throughout the watershed. In conjunction with these samples, teams collected habitat data according to state standard operating procedures (DWQ, 2006b). Results are summarized in Table 5. The only site to rate as "good" was in the Neuse subwatershed at Beddingfield Creek. This site is the focus of NC Forest Service conservation efforts and includes some of the most intact riparian and instream habitat identified during reconnaissance. Three other sites qualified for a "good/fair" bioclassification rating. Five sites rated "fair", indicating that causes of impairment should be investigated in subsequent assessment work of the RWP. The two remaining sites were rated "indeterminate" due to swamp like conditions.

Table 5. Benthic Macroinvertebrate Community Statistics.

Station Location	Beddingfield Creek	Poplar Creek, Smithfield Rd	Poplar Creek, Bethlehem Rd	Marks Creek, Eagle Rock Rd	Marks Creek, Prichard Rd.	Buffalo Creek, Mitchell Mill R	Buffalo Creek, Poole Rd.	Hominy Creek, Buck Rd.	Rocky Creek, Riley Hill Rd	Snipe Creek, Taylors Mill Rd	Little River, above NC 231
Taxa/Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Ephemeroptera	6	2	4	3	6	1	4	2	6	4	7
Plecoptera	2	1	1	-	1	-	-	-	-	-	-
Trichoptera	10	6	6	4	8	2	5	2	3	1	7
Diptera: misc.	3	4	4	2	2	3	1	4	5	5	2
Diptera: Chironomidae	10	9	13	8	7	8	8	6	8	6	8
Coleoptera	6	7	4	7	9	3	7	5	5	3	3
Odonata	7	7	7	6	6	5	7	4	6	5	5
Oligochaeta	3	1	1	1	3	1	3	1	1	1	1
Megaloptera	1	2	1	2	3	-	1	1	1	1	-
Crustacea	3	3	1	4	2	3	5	4	4	2	3
Mollusca	1	3	3	6	4	2	8	2	-	2	2
Other Misc Taxa	-	2	-	5	3	-	2	4	-	-	2
Total Taxa Richness	52	47	45	48	54	28	51	35	39	30	40
Total Abundance	217	187	177	144	248	113	172	88	131	72	170
EPT Taxa Richness	18	9	11	7	15	3	9	4	9	5	14
EPT Abundance	93	37	48	20	95	21	45	15	46	34	65
Biotic Index Value	5.2	6.2	5.8	6.9	5.5	7.1	6.7	7.1	6.5	6.6	6.0
Bioclassification	Good	Fair	G/F	Fair	G/F	NA	Fair	NA	Fair	Fair	G/F

Rare, Threatened, and Endangered Species

Rare species have been documented in localized regions of the watershed. Surveys by the Natural Heritage Program, the NC Wildlife Resources Commission, and the US Fish and Wildlife Service identified species of special concern, threatened, or endangered status in significant portions of the Little River and Neuse subwatersheds within the planning area. These include four rare plant species, eight rare mussel species, one fish, two amphibians, one bird species and one significant occurrence of a colonial nesting bird colony. In addition to these occurrences, four unique examples of high-quality habitats exist within the watershed boundaries. Global and state status rankings shown in Table 7 below are assigned by the NC Natural Heritage Program (NHP, 2011).

Table 6. Rare Species and Habitats.

COMMON NAME	SCIENTIFIC NAME	GLOBAL RANK	STATE RANK
Mussels			
Atlantic Pigtoe	*Fusconaia masoni*	G2	S1
Creeper	*Strophitus undulatus*	G5	S2
Dwarf Wedgemussel	*Alasmidonta heterodon*	G1G2	S1
Eastern Lampmussel	*Lampsilis radiata*	G5	S1S2
Green Floater	*Lasmigona subviridis*	G3	S1
Notched Rainbow	*Villosa constricta*	G3	S3
Roanoke Slabshell	*Elliptio roanokensis*	G3	S1
Triangle Floater	*Alasmidonta undulata*	G4	S2
Amphibians			
Four-toed Salamander	*Hemidactylium scutatum*	G5	S3
Least Brook Lamprey	*Lampetra aepyptera*	G5	S2
Neuse River Waterdog	*Necturus lewisi*	G3	S3
Plants			
Buffalo Clover	*Trifolium reflexum*	G3G4	S1S2
Granite Flatsedge	*Cyperus granitophilus*	G3G4	S2
Michaux's Sumac	*Rhus michauxii*	G2G3	S2
Small's Portulaca	*Portulaca smallii*	G3	S2
Birds			
Red-cockaded Woodpecker	*Picoides borealis*	G3	S2
Habitats			
Coastal plain semipermanent impoundment		G5	S4
Coastal plain small stream swamp (brownwater subtype)		G5	S2S3
Colonial Wading Bird Colony		NR	S3
Granitic flatrock		G3	S2
Piedmont/mountain semipermanent impoundment		G5	S4

G1 = rarest globally G5 = most common S1 = rarest in state S5 = most common NR = not rated

5.2 PRELIMINARY IDENTIFICATION OF PROBLEMS AND ASSETS

5.2.1 Stressors

According to the state's impaired waters list, the biological community and ambient data indicate multiple stressors in the watershed, including sediment, nutrients, low dissolved oxygen, zinc, and copper. Preliminary reconnaissance and *in situ* water quality assessment confirm variable levels of sedimentation and flow-related dissolved oxygen issues throughout the LWP watershed. These and other identified stressors (Table 6.) should be studied further in later phases of the plan to help identify causes and sources.

Table 7. Watershed Stressors and Potential Solutions.

Stressors and Issues	Potential Study	Potential Management Strategy
Impoundments	Undertake detailed flow study	Collaborate with American Rivers and NCDOT to investigate dam removals and aquatic connectivity
Stream bank erosion	Verify remotely-sensed erosion data in the field	Promote stream restoration, riparian buffer, & livestock exclusion projects
Livestock access to streams	Assess extent of this problem, especially in the southern half of the watershed	Promote livestock exclusion projects
Upland erosion	Use recent aerial imagery to assess extent	Promote agriculture & forestry BMPs, support erosion & sedimentation control ordinances, subdivision ordinance modifications, steep slope ordinance, public education
Sedimentation	Assess instream sedimentation in wadeable streams	Encourage and undertake wider buffer projects and agricultural BMPs
Nutrients	Assess nutrient levels in impaired reaches	Promote agricultural BMPs, riparian buffers, watershed education programs, and installation of stormwater BMPs
Lack of adequate forested buffer	Field verify identified buffer projects	Undertake stream restoration and riparian buffers, promote wider buffer projects
Stream channelization	Field check areas that appear ditched on remotely sensed data	Undertake stream restoration projects
Impervious cover	Verify estimated data in the field	Promote stormwater BMPs, stormwater ordinances, & low impact development
Urban toxicants	Toxicity screening throughout the watershed	Promote watershed education programs and stormwater BMPs

Preliminary Functional Assessment of Hydrologic Issues

Compiled data from existing sources and from watershed reconnaissance reveals problematic hydrologic conditions in localized areas of the watershed, including low dissolved oxygen due in part to low flow. Also there are extensive flow obstructions and potential aquatic organism barriers. Reconnaissance for benthic study and for stream geomorphological assessment revealed flow issues concentrated in Hominy Creek, Buffalo Creek, Little River, and the Neuse River. Beaver impoundments were common in the Little River subwatersheds. The subwatersheds identified in Figure 21 below should serve as the primary focus areas for additional hydrologic assessment in the RWP.

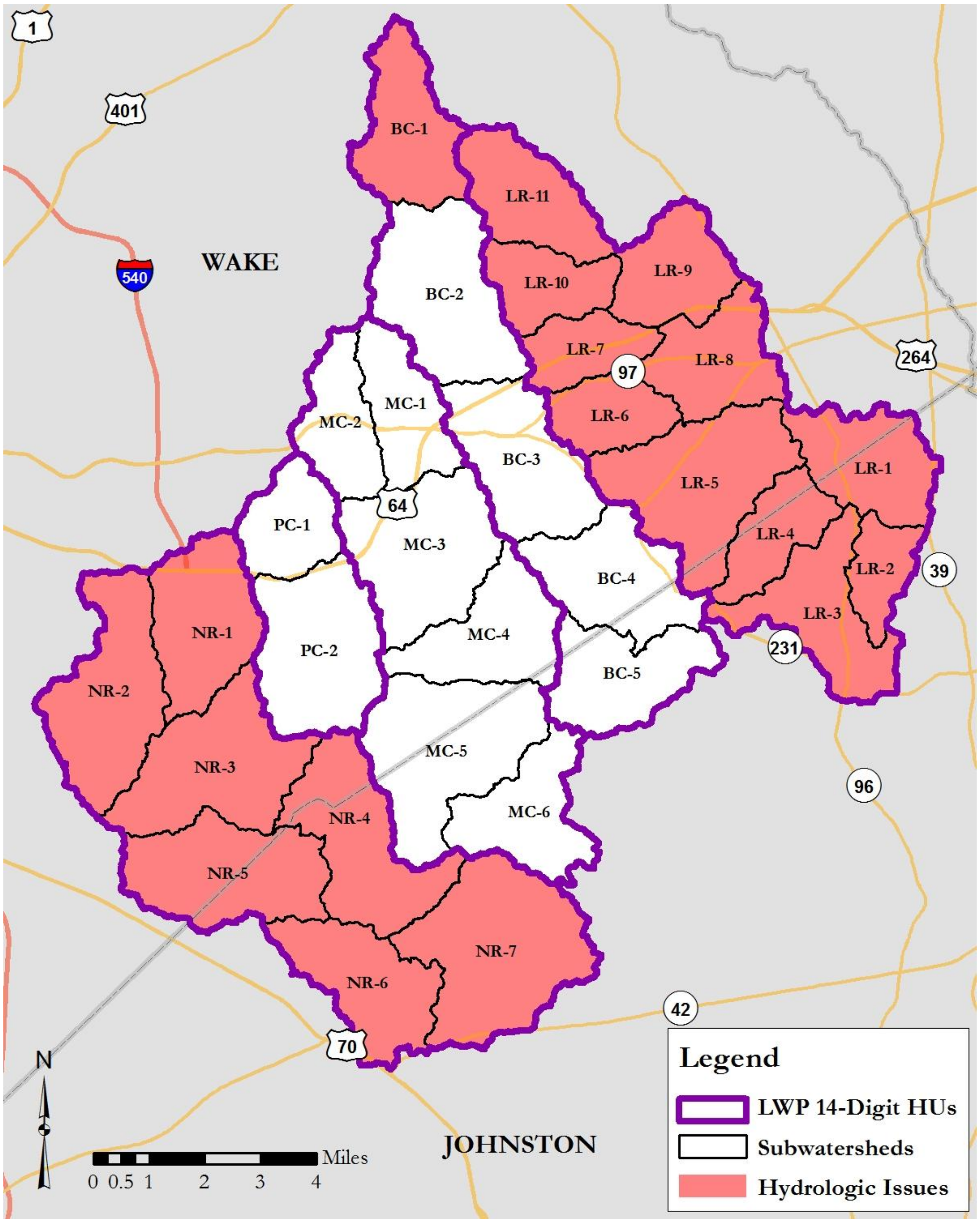

Figure 21. High Priority Subwatersheds for Hydrologic Issues (mostly excessive impoundment).

Preliminary Functional Assessment of Erosion and Sedimentation Issues

Soil types that are easily worn away by rainstorms are considered highly erodible. Sandy loam soils (Creedmoor, Granville, and Mayodan series) are common in the watershed and those on significant slopes (typically greater than 6%) are more prone to erosion. Priority subwatersheds identified in Figure 22 below have high amounts of erodible soils as well as instream sedimentation issues identified during the windshield reconnaissance.

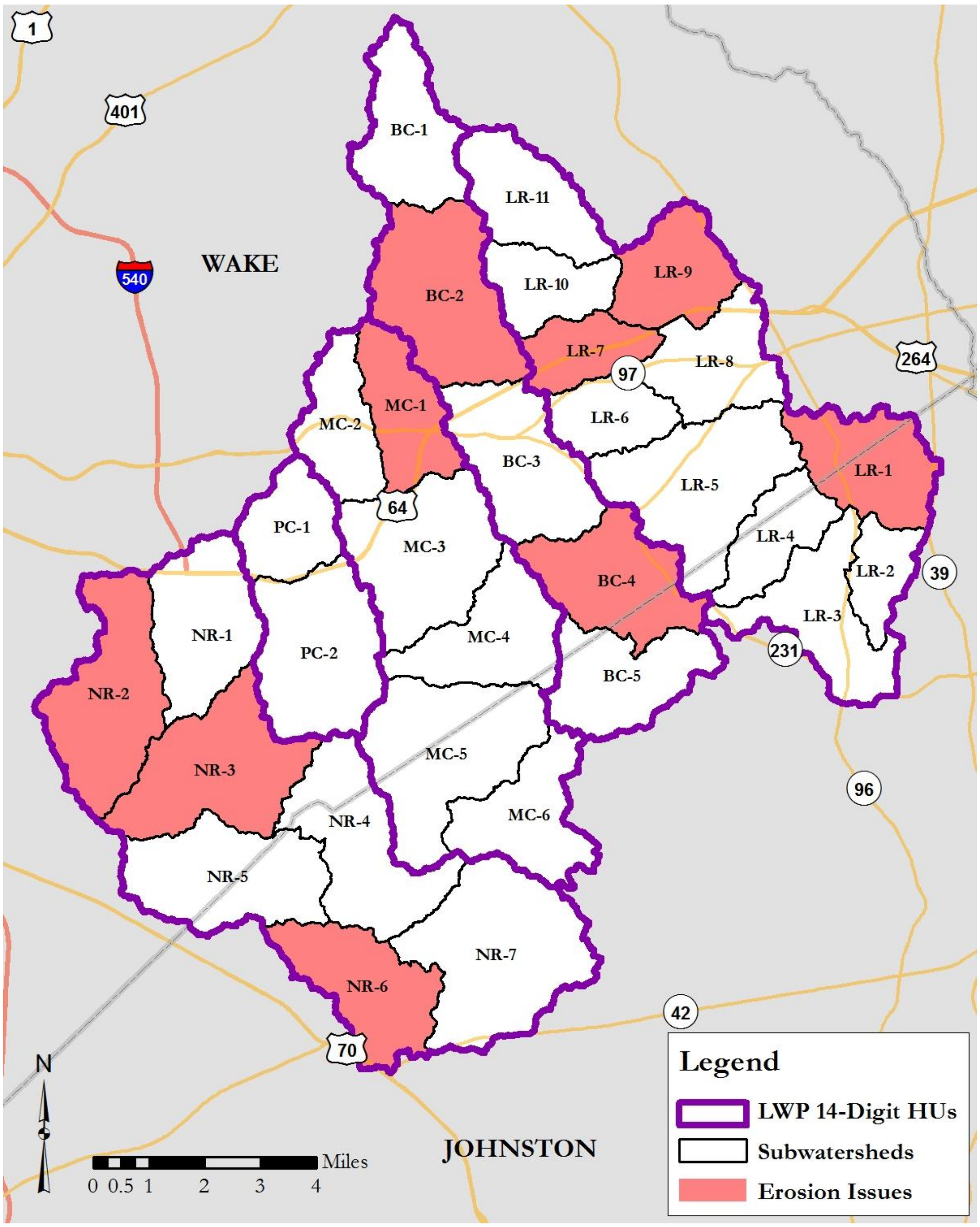

Figure 22. High Priority Subwatersheds for Erosion and Sedimentation Issues.

Preliminary Functional Assessment of Stormwater Issues

Figure 23 identifies subwatersheds where development has occurred or is actively occurring. Concentrations of impervious surface typically are found around municipalities in the watershed and compound impacts of stormwater runoff.

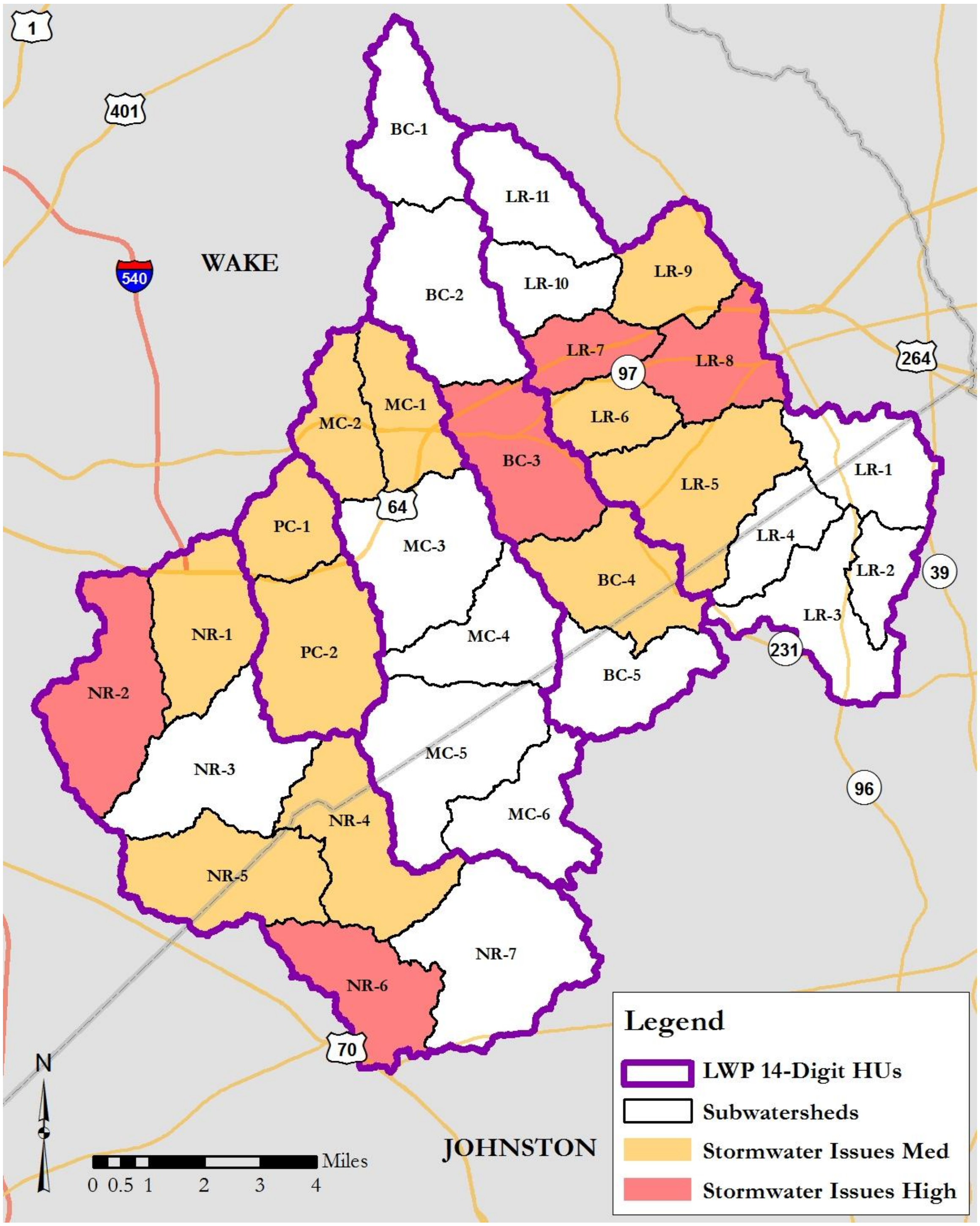

Figure 23. High Priority Subwatersheds for Stormwater Issues.

Preliminary Functional Assessment of Agricultural Impacts

Figure 24 identifies subwatersheds where high proportions of land are used for row crops and pasture. Active agriculture was verified during field reconnaissance.

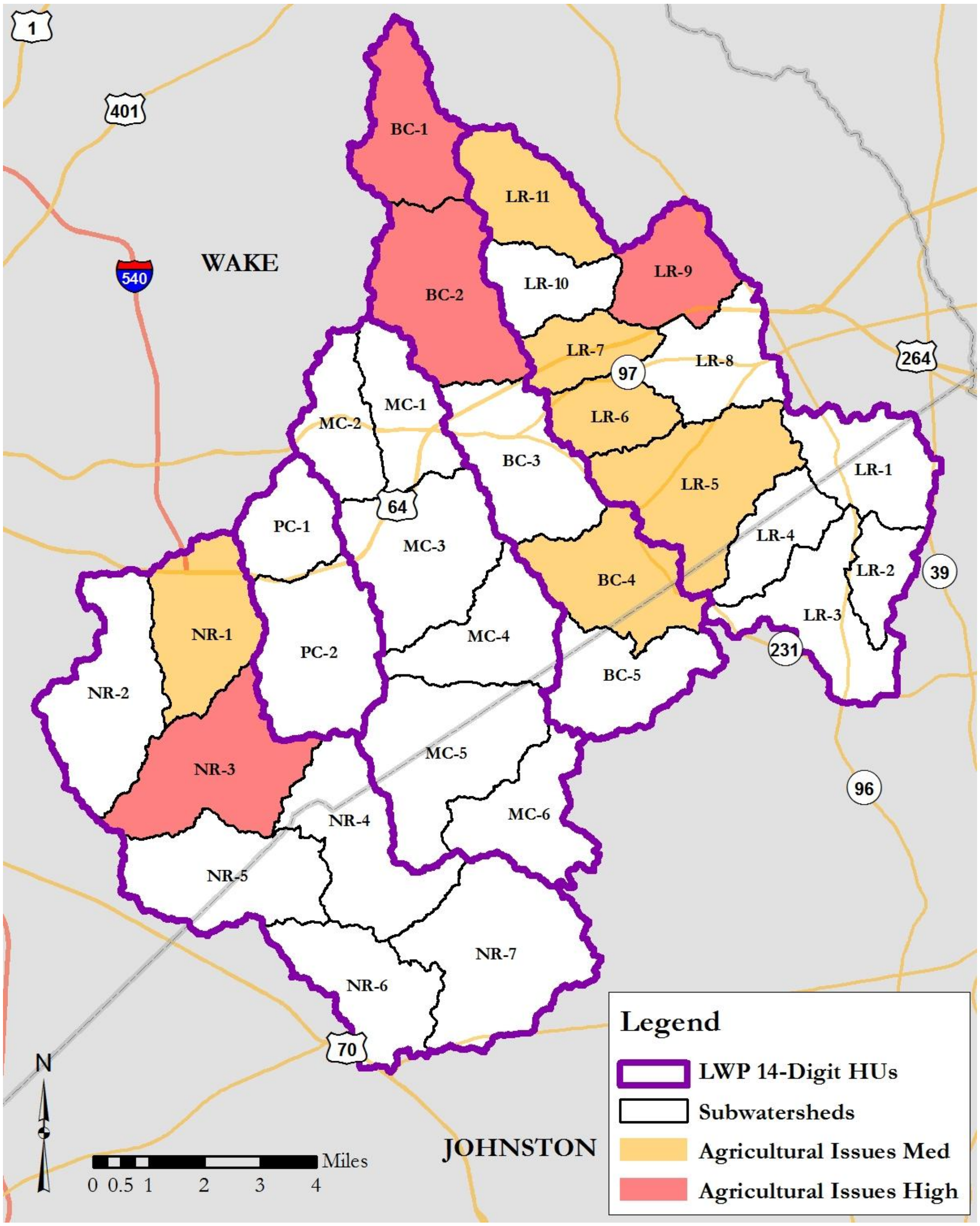

Figure 24. High Priority Subwatersheds for Agricultural Issues.

Preliminary Functional Assessment of Water Quality Issues

Figure 25 identifies subwatersheds prioritized for water quality issues because of their 303(d)-listing status and due to their low-rated benthic communities identified by sampling conducted by NCSU and DWQ as a part of this plan. This includes all of the Buffalo Creek subwatersheds, several Neuse subwatersheds, and the upper Little River.

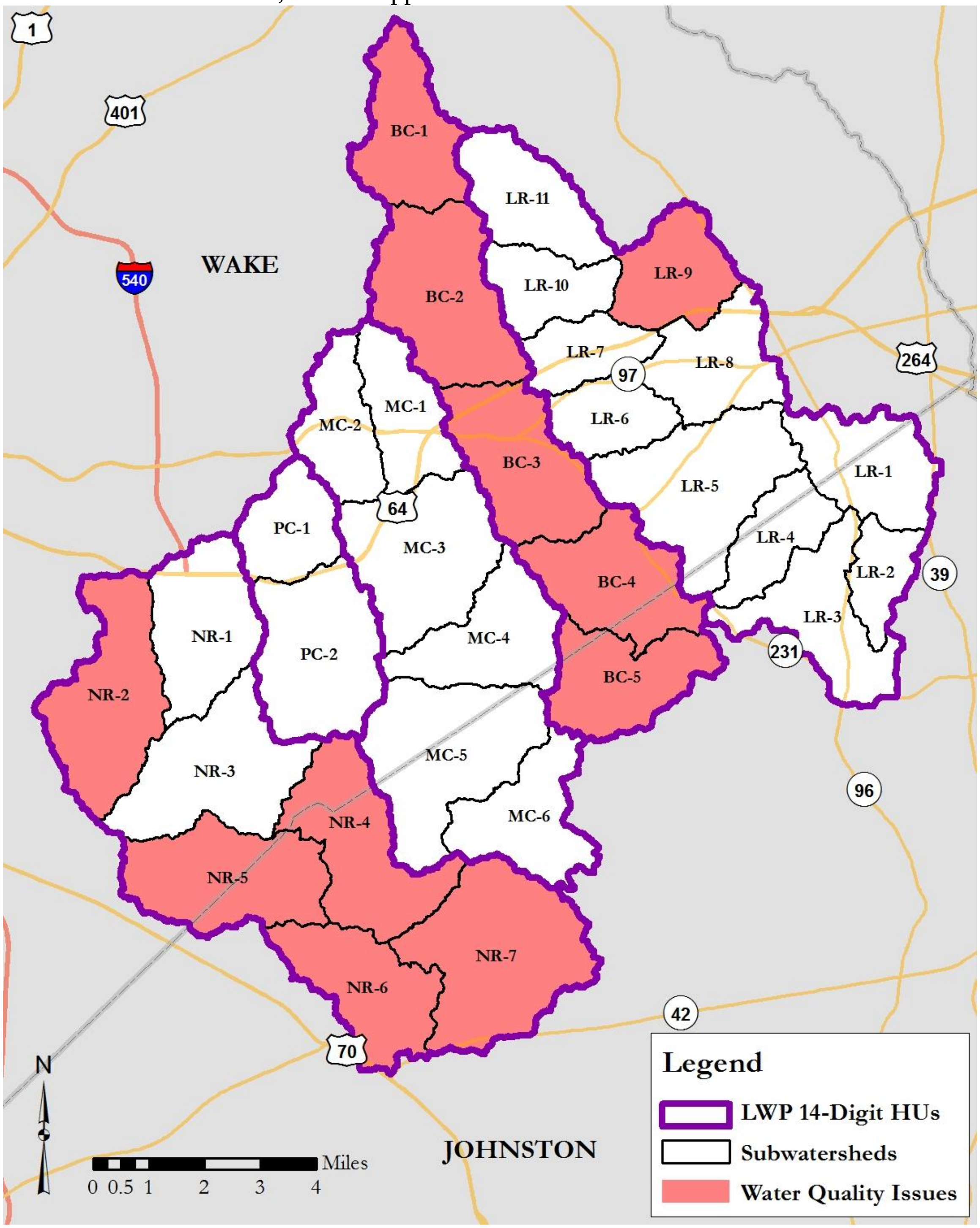

Figure 25. High Priority Subwatersheds for Water Quality Issues.

5.2.2 Assets

Preliminary Functional Assessment of Rare Species Habitats

One important reason for developing this Local Watershed Plan is to expand the capability to develop successful restoration projects in watersheds that benefit rare species. Reaches of the Neuse and Little River that pass through the LWP study area are home to several rare mussel species. Additional rare species include several amphibians and plants, as well as rare community types. Compatibility of conserving these populations and communities with restoration and preservation projects in priority subwatersheds (Figure 26) should be further investigated in later plan phases.

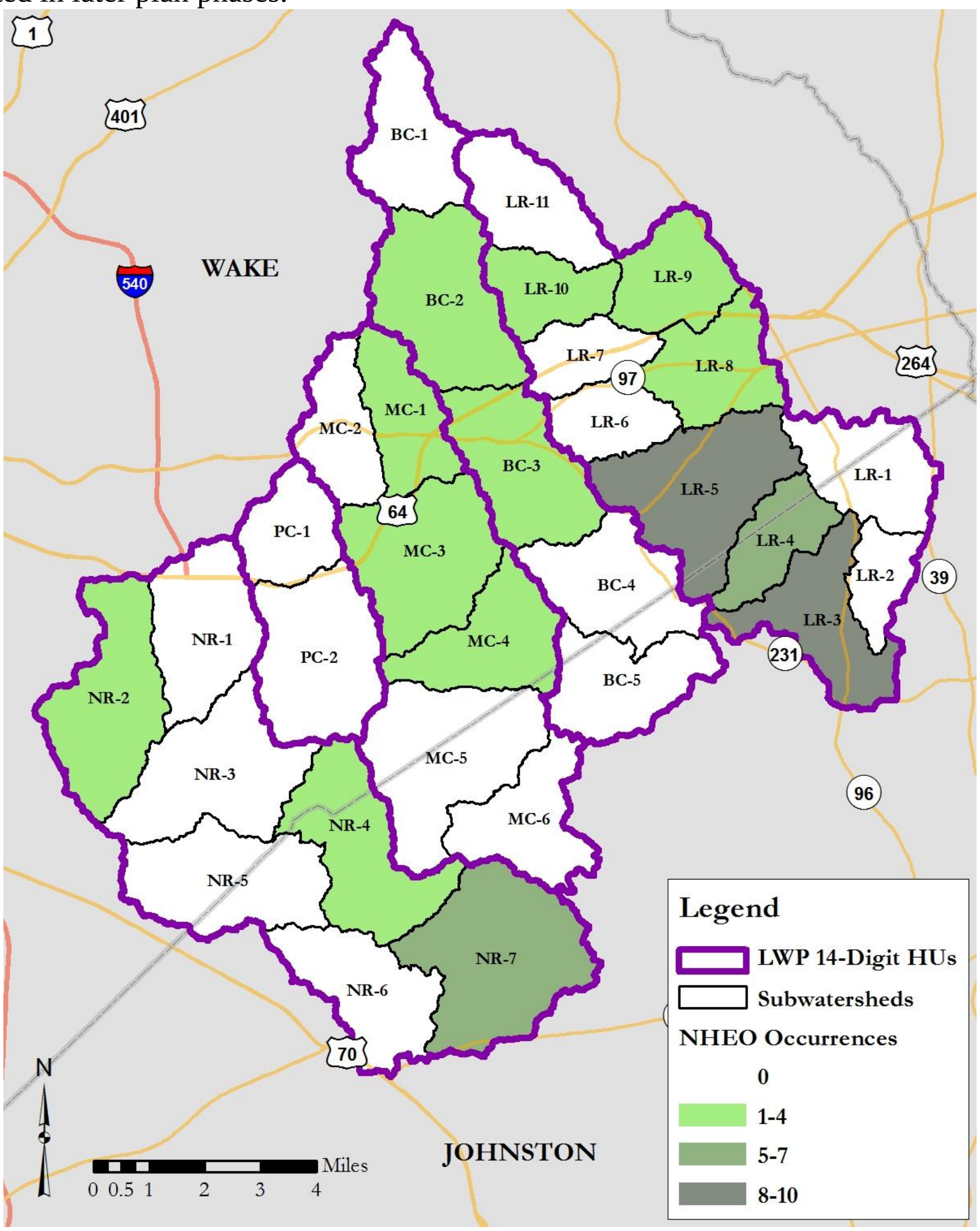

Figure 26. High Priority Subwatersheds for Rare Species.

Preliminary Assessment of Preservation Priorities

Figure 27 identifies subwatersheds for preservation priorities based on their extensive forested, wetland, and conservation lands. Because many of the subwatersheds contained similar amounts of preservation assets, a more detailed analysis as part of the RWP might improve differentiation that would promote a more focused preservation prioritization. Additional work may include assessing riparian corridors (including buffers) that contribute to the connectivity of significant habitat areas, and an assessment of how significantly large patches of high quality habitats might augment existing conservation lands or stand alone as reference quality project sites.

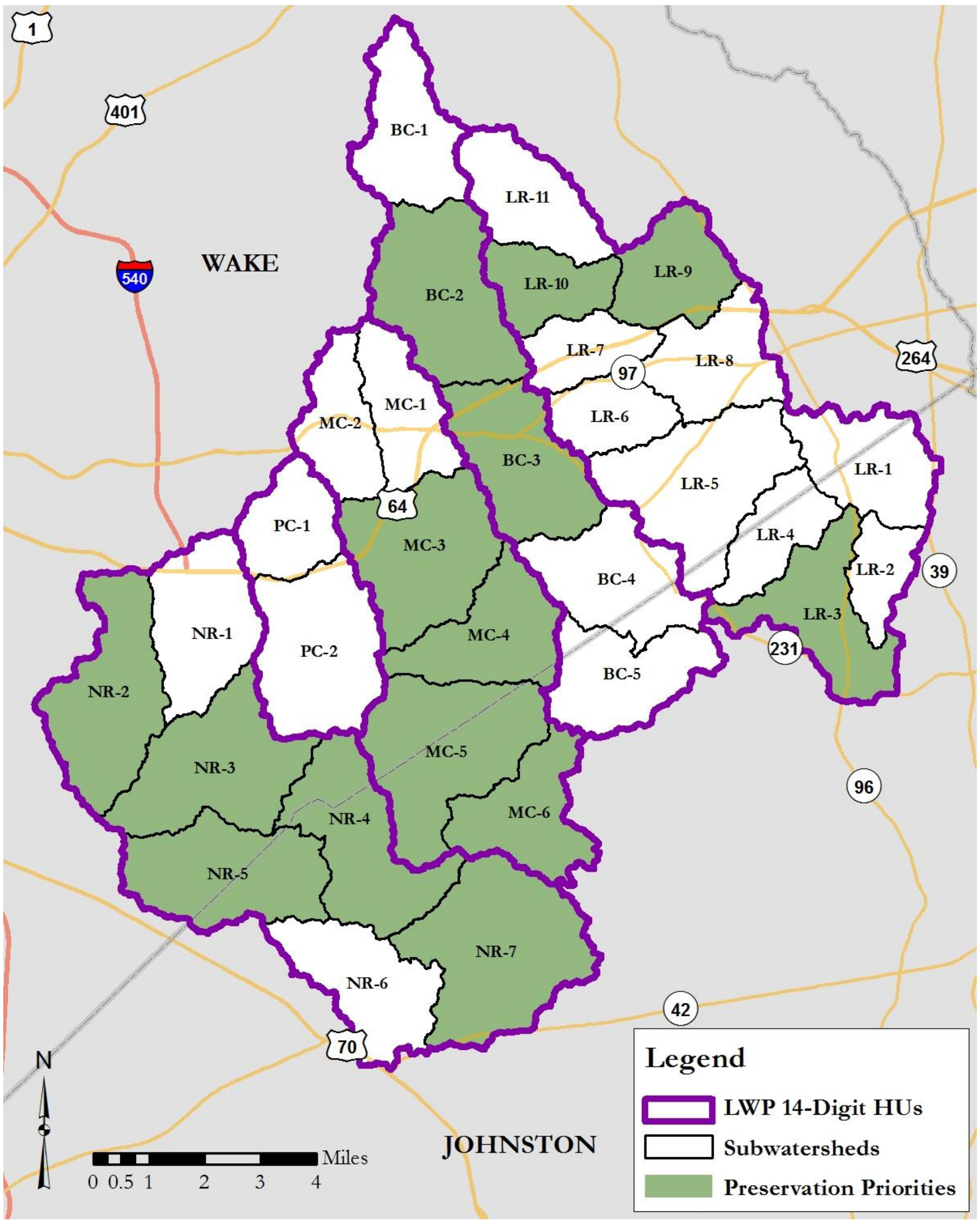

Figure 27. High Priority Subwatersheds for Preservation Opportunities.

6 RECOMMENDATIONS FOR FUTURE ASSESSMENT

Watershed analysis in the RWP sections of this planning initiative will require additional focused assessment in an array of categories. Additional data should be assembled or developed to characterize the watershed more completely to improve the quality of recommendations generated by the stakeholder GAC during the RWP. The following subsections represent datasets and approaches identified during Phase I as critical for a clear understanding of functional stressors in the LWP study area. The final subsection outlines general recommendations for completion of the plan, including a strategy to incorporate plan elements into the Neuse 01 RWP that encompasses all of the WJC LWP area and an additional 430+ square miles of watershed area. Incorporating the LWP will provide a joint mechanism for completing additional critical assessments in the watershed that might otherwise not be possible, and will generate equivalent plan elements that help meet EEP and EPA planning standards.

6.1 Data Gaps

The following section presents data (D) and assessments (A) identified during Phase I as important for further development during the RWP. These elements are absent or underrepresented in the above preliminary assessment, and are critical for a robust watershed assessment and analysis that will inform the management recommendations to be completed in the RWP.

Spatial data

- Current and historic land cover layers (D)
- Livestock access to streams (A)
- Rectify stream mapping differences (D & A)

Water quality

- Screening for the wide array of chemical and sediment inputs usually associated with urbanizing/urbanized areas (D & A)
- Benthic community assessment (A)
- Fish community assessment (A)
- DO, pH or specific conductance (A)
- Other suspected chemical parameters (A)

Hydrology

A general screening of hydrologic conditions for the LWP study watershed indicates some subwatersheds have significant flow issues, resulting in a poor understanding of water quality and habitat impacts. Additional assessment should be focused in subwatersheds NS-1 through NS-7, BC-1, and LR-1 through LR-11, to help clarify the degree of flow impacts.

- Flow obstructions & aquatic organism barriers (A)
- Effects of dams in and outside the LWP area believed to have significant hydrologic influence on the planning area (A)

Channel and bank condition

- Instream habitat embeddedness (A)
- Bank Erosion Hazard Index (A)
- Baseline stream cross-section parameters & regional curve development (A)
- Scour related to impervious surface (A)
- Identify and characterize reference quality streams for detailed comparison (D & A)

Riparian zone condition

- Pasture used for livestock (A)
- Row crops (A)
- Riparian corridors contribution to the connectivity of significant habitat areas and other high quality habitat patches (A)
- Identify and characterize reference quality riparian corridors for detailed comparison (D & A)

RTE Species

- Natural Heritage or similar surveys (A)
- Special studies including habitat assessment and documentation of host fish species (D &A)
- Aquatic organism passage and aquatic habitat connectivity (D & A)

Modeling

Models are included here in order that required data for model calibration can be collected along with other assessment data whenever possible.

- BMP modeling (D & A)
- Modeling of aquatic organism barriers (D & A)
- General modeling of project configurations and efficiency (D & A)

6.2 Objectives and Focus Areas for Future Study

Based on the data compiled and analyzed for the preliminary assessment priorities presented in Section 5, particular subwatersheds should be targeted for additional focused study. Table 8 summarizes these recommended focus areas for priority assessment in the RWP.

Table 6. Focus Subwatersheds for Additional Study.

Subwatershed	Hydrologic	Erosion/ Sediment	Stormwater	Agriculture	Water Quality	Rare Species	Preservation
NR-1	H		s	s			
NR-2	H	H	H		H	s	H
NR-3	H	H		H			H
NR-4	H		s		H	s	H
NR-5	H		s		H		H
NR-6		H	H		H		
NR-7					H	H	H
PC-1			s				
PC-2			s				
MC-1		H	s			s	
MC-2			s				
MC-3						s	H
MC-4						s	H
MC-5							H
MC-6							H
BC-1	H			H	H		
BC-2		H		H	H	s	H
BC-3			H		H	s	H
BC-4		H	s	s	H		
BC-5					H		
LR-1	H						
LR-2	H						
LR-3	H			s		H	H
LR-4	H	H				H	
LR-5	H		s	s		H	
LR-6	H		s	s			
LR-7	H	H	H	s			
LR-8	H		H			s	
LR-9	H	H	s	H	H	s	H
LR-10	H					s	H
LR-11	H			s			

H = highest priority s = secondary priority

6.3 Recommended Assessment Approach

Localized Stream Impacts

Within the focus subwatersheds identified above, future work should concentrate additional detailed watershed assessment that fills data gaps and provides analyses needed to inform project-scale decisions on priorities. To the extent possible, water quality and biological sampling should be used to identify sources of stressor impacts by using a sampling design that brackets suspect reaches or potential sources. Recommendations for the watershed plan should reflect the scale at which watershed parameters are assessed with care taken not to overreach a reasonable interpretation of the data.

Flow and Stormwater Input Mechanisms

Because much of the LWP watershed is affected by sluggish flow and impoundments, a detailed understanding of how these features impact water quality and habitat conditions is in order. Questions that should be addressed by additional sampling and modeling include:

- What is the prevalence and pattern of distribution of impoundments?
- What are the functions of each impoundment? Does it reduce suspended sediment and nutrient inputs to the stream? Does it increase water temperature and exacerbate temperature fluctuation?
- Do impoundments trap coarse sediments?
- Does flow or impoundment provide or limit habitat for species of concern?
- Do impoundments impede movement of aquatic species or effectively fragment aquatic habitat?
- What is the prevalence and pattern of distribution of significant impervious surfaces relative to the stream network?
- Are there apparent areas where the impacts of runoff are particularly pronounced?
- What is the relative impact of each "patch of impervious surface" on receiving streams?

Some existing plans (e.g., NCFS, 2012) provide additional information regarding flow and related issues. These plans should be screened for relevant recommendations for additional assessment and monitoring.

Field Verification

For GIS and remotely sensed projects that are identified in this document, a stratified approach to verifying the highest priority projects should be followed. First, identify a subset of projects that meet current mitigation projections and needs of the partner stakeholders. Then a technical team can systematically visit each of the priority sites. The team should assess the technical viability of the project, followed by landowner contact to determine the overall viability of each priority project.

6.4 Modeling

Build Out

Historical land use trends should be analyzed as part of the RWP assessment, especially as they may identify prior converted wetland areas that may be identified for restoration projects. A more sophisticated analysis than the one presented above will yield more comprehensive results and provide a better starting point for field investigations.

Due to the number of incorporated jurisdictions, the Wake-Johnston planning area should include a model that predicts the impacts of future development as well. The EEP LWP Project Team should work with the Regional Watershed Planning consultant to insure that a comprehensive build out assessment is conducted for inclusion in the Wake-Johnston Collaborative.

Stream Geomorphology and Hydrologic Modeling

The Technical Advisory Committee recommends developing a localized regional curve to inform management recommendations in the RWP process and to improve project design capacity in the study watersheds when restoration projects are implemented.

Some portions of the watershed are heavily impounded, in great part by beaver dams. The impacts of these prevalent impoundments are poorly understood at this point. A sound understanding of how nutrient, chemical, and sediment inputs are moving through the system, as well as resulting oxygen and temperature conditions, is critical for making sound recommendations in the watershed management plan. The project team should develop a comprehensive flow model calibrated with base flow and storm flow data to understand how impoundments are affecting stressor inputs and habitat conditions for aquatic life.

Dam Removal Impacts

During this Phase I process, members of the General Advisory Committee joined with StanTec, an environmental consulting firm, to apply for Section 319 funds to examine the impacts and benefits of removing the major dams within or adjacent to the planning area. Unfortunately the proposal was not funded. The value of understanding how these removals or modifications might benefit the watershed is important to making well-founded recommendations in the Watershed Management Plan.

In addition to analyzing major dam impacts, smaller natural and man-made structures that impede aquatic organism passage or fragment aquatic habitat should be documented and modeled. This will provide the basis for sound recommendations for dam and aquatic organism obstruction removals that are prioritized based on realistic opportunities (including both non-mitigation and mitigation projects). The project team should work with the NC Aquatic Connectivity Team coordinated by American Rivers to solicit advice and develop joint priorities.

6.5 General Recommendations

The Wake-Johnston Collaborative Local Watershed Plan (LWP) was initiated as a collaborative effort between the Counties of Wake and Johnston and the Ecosystem Enhancement Program, with the intention of staff from each performing the majority of the work with a minimal dedicated budget aside from commitment of staff time. Stakeholders from each agency or interest represented on the General Advisory Committee (see Table 2) have participated by actively contributing to project tasks and/or providing input on critical preliminary priorities developed during this first planning phase.

In August 2011, the NC Department of Transportation agreed to sponsor a new planning effort, the Neuse 01 Regional Watershed Plan (RWP). This large planning area (580 square miles) encompasses the entire Wake-Johnston Collaborative LWP area, the Upper Swift Creek LWP area, as well as 365 square miles of watersheds not included in any LWP area. By combining effort and resources of the Wake-Johnston LWP with those of the Neuse 01 RWP, the Collaborative will be better able to complete the remaining watershed planning tasks and begin the important work of implementing the watershed improvement priorities.

With that in mind, the General Advisory Committee proposes the following recommendations:

1. Establish the General Advisory Committee as Neuse 01 Subgroup. Because the LWP study area comprises about one-quarter of the RWP study area and because an informed, active stakeholder group exists, the General Advisory Committee (GAC) should represent and act as the primary advisory group for this portion of the RWP area.

2. Combine monitoring and assessment elements. To make efficient use of limited resources and to help improve the coverage of necessary assessment data, much of the watershed assessment data collection should be concentrated in the Wake-Johnston Collaborative LWP watershed. The recommended monitoring and assessment identified in Section 5 should be carried out to the extent possible in the LWP area and extrapolated to similar subwatersheds in the remainder of the Neuse 01 Regional Watershed Planning area.

3. Expand emphasis on rare species and habitats. Work with NC Natural Heritage Program, NC Wildlife Resources Commission, and US Fish and Wildlife Service to incorporate rare, threatened, and endangered (RTE) species and habitat data into analyses and prioritizations to emphasize their protection and rehabilitation in restoration projects, without compromising the protection of these species and habitats as they currently exist. The GAC recognizes the sensitivity of information related to rare species and wants to ensure the analyses in this Local Watershed Plan and the adjunct Neuse 01 Regional Watershed Plan do not compromise the fitness of these resources in any way. Instead, the LWP is intended to improve the circumstances for these species and habitats by recommending projects that not only meet the basic goals of watershed plans (improving water quality, hydrology, and habitat), but also incorporate elements that rehabilitate degraded habitats that specifically benefit the rare species. The added value of improving watershed conditions for rare species is a logical choice when focusing scarce mitigation project dollars in targeted watersheds.

4. Enhance land protection and forestry-related goals. Work with the NC Forest Service and Triangle Land Conservancy to incorporate compatible priorities such as those in the Johnston County Natural Resources Initiative Green Infrastructure Assessment Report (NCFS, 2012). Similar assessments for the Wake County portions of the watershed should be considered.

5. Emphasize stormwater BMPs. Focus stormwater BMP project recommendations within the jurisdictions of municipalities and develop a stratified prioritization per municipality, especially because most projects will be pursued via grants from non-mitigation sources. In the event that a municipality or county can provide easements, and BMP options are approved to generate mitigation credit, EEP may pursue projects there.

6. Incorporate LWP Atlas into the EEP Online Mapping Tool (under development). The GAC recommends completing the LWP Atlas as an element of the online mapping tool. The tool should include traditional elements for restoration, enhancement and preservation (as recommended in previous section) as well as non-traditional mitigation (NTM) projects. These NTM projects should include aquatic obstruction removal, rare species habitat enhancement and restoration, wildlife corridors and habitat patch reconnection, and biofiltration headwater wetlands.

7. Incorporate LWP Watershed Assessment Report and Watershed Management Plan into the RWP. In the assessment and recommendations sections of the RWP, the Wake-Johnston Collaborative LWP documents should be included as separate sections or chapters as appropriate. To help ensure the LWP meets watershed management plan criteria (see EPA, 2008), the watershed assessment report and the final management plan chapters of the RWP should contain required elements equivalent to a stand-alone watershed management plan. For mitigation projects, EEP gives highest priority to restoration and preservation projects located in LWP areas. For non-mitigation projects to qualify for many Federal and state programs (e.g., Section 319 funding), they typically must be within a watershed planning area that meets EPA watershed plan criteria.

8. Collaborate with NCDOT. In subsequent phases of the plan, stakeholders should work with DOT representatives to better understand the sources of impacts to the surrounding watershed, particularly the impacts related to the construction of I-540. By consulting more closely with DOT, the GAC can better understand the nature of those impacts and can make better recommendations for offsetting them. Because some projects in the LWP Atlas may generate mitigation credit for impacts from the construction of I-540, DOT should have an active role in identifying those projects.

9. Expand Public Outreach. During the development of Phase I, landowner representatives on the advisory committees have indicated they believe there is little public recognition of the plan and its goals. The General Advisory Committee assembled a subcommittee to work on outreach issues. The GAC recommends expanding the role of the subcommittee to include general outreach to the public at large and focused collaboration with individual and groups of landowners who have an interest in project development.

10. Investigate Partnership Projects. One of the original concepts for this LWP included an emphasis on mitigation projects to be constructed on public lands owned by the counties or municipalities. EEP and Wake County jointly examined eight potential project sites in the field to assess their feasibility. Although none of these projects have been jointly developed to date, the GAC recommends continuing and expanding efforts to develop these and similar collaborative projects. As discussions advance, a logical approach would be to re-engage Wake County Open Space staff as well as initiating discussions with appropriate Johnston County staff and municipal representatives to determine the current viability of partnership projects.

7 RESTORATION AND PROTECTION OPPORTUNITIES

In this section, general restoration objectives for each of the 14-digit watersheds are presented before specific project opportunities. To the extent practicable, projects that help meet these watershed-specific objectives should be high priority projects when the opportunity to implement them arises.

Poplar Creek. Preservation of intact riparian corridors and the restoration of streams and buffers should be examined as preliminary priorities for this watershed.

Marks Creek. Priority projects for this watershed should focus on stabilizing streambank erosion and restoring absent or inadequate wooded buffers in the riparian zone. There are nearly 4,000 acres of unfragmented forest in Marks Creek suggesting good opportunities for preservation and habitat reconnection via corridor restoration.

Beddingfield Creek & Neuse River. Priorities for this watershed include expansion and reconnection of conservation areas with intact habitat and buffer restoration along eroding stream banks. Stormwater projects should be sought in developed areas. Stream restoration projects are also a priority in localized areas of degradation.

Little River. Buffer and stream restoration projects are most important for this part of the Little River. Projects that improve the natural flow of streams should also be considered high priority. These are intended to address the needs of the rich assemblage of rare aquatic species.

Buffalo Creek. Projects that address flow restoration and reduction of impoundments are high priorities for this watershed. Buffer projects are also very important in this watershed.

7.1 Degraded Buffer Opportunities

Using the 2006 NLCD coverage in polygon format, each land cover type was classified as either “denuded” or “not denuded”; open water was included with “not denuded” so as not to overestimate the amount of denuded acreage. The denuded buffer layer was then clipped using the different buffer widths (60, 100, 200, and 300 feet) for the streams in the LWP area. For each buffer width, a corresponding area for a minimum project length of 4000 feet was computed by multiplying the respective buffer width by 4000 feet. For 60 foot buffers, this corresponds to 5.5 acres. For 100 foot buffer, the area is 9.0 acres, for 200 foot buffer the area is 18.0 acres, and for 300 foot buffers the area is 27.5 acres. These were set as the minimum allowed area. For each buffer width, only those polygons meeting or exceeding the corresponding minimum area were included in the buffer restoration opportunities maps below (Figures 28 to 31). Of particular note, the 60 foot analysis yielded the least acreage (and presumably, fewer potential projects) due to the fact that more trees grow along the undevelopable land adjacent to streams. No attempt was made to account for small “not denuded” breaks that divided otherwise contiguous polygons designated as “denuded”. A more detailed analysis will likely indicate additional potential buffer projects, but the current analysis offers an abundant number of opportunities to investigate in the field during the interim between now and the completion of the final Project Atlas.

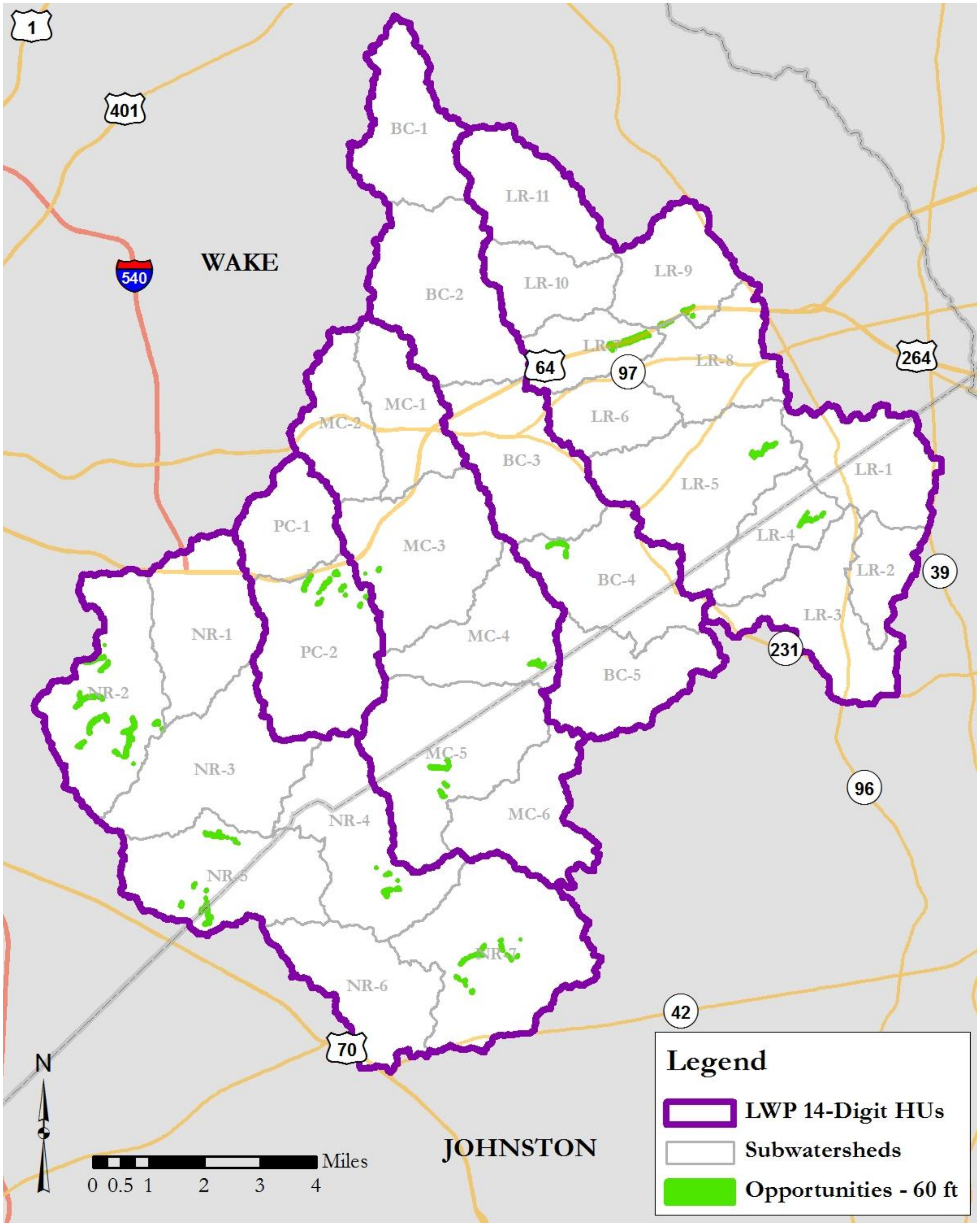

Figure 28. Potential 60'-wide Buffer Restoration Opportunities.

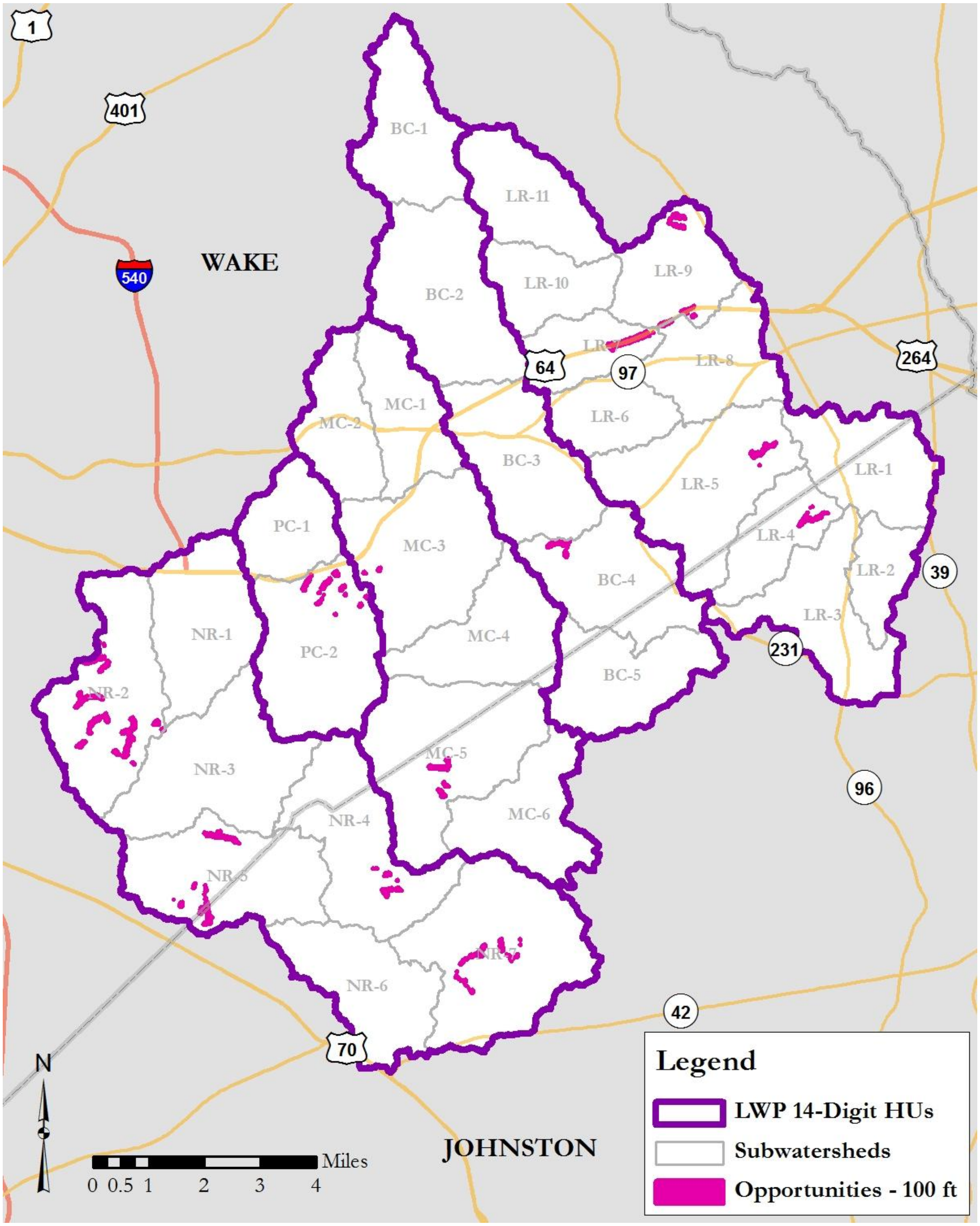

Figure 29. Potential 100'-wide Buffer Restoration Opportunities.

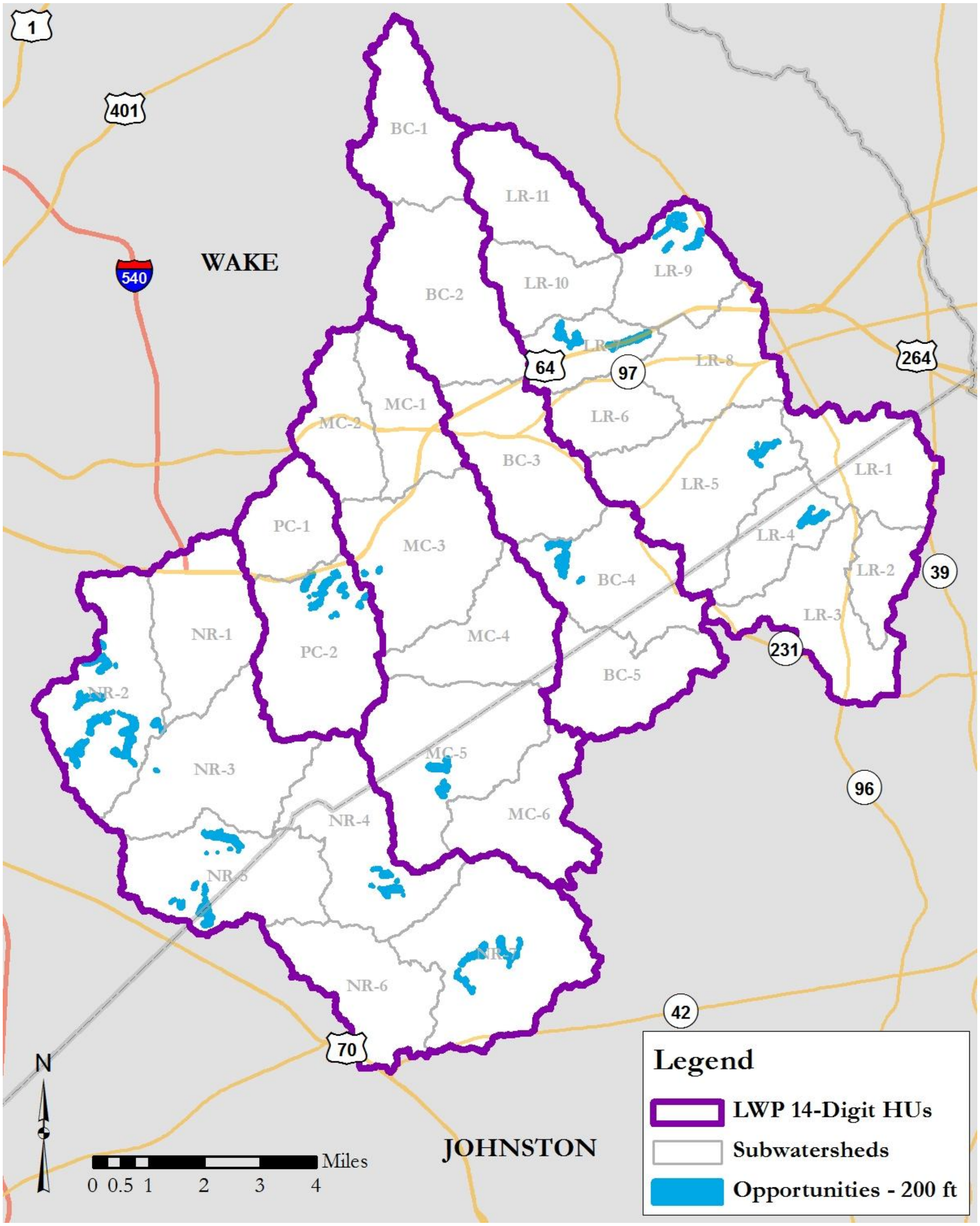

Figure 30. Potential 200'-wide Buffer Restoration Opportunities.

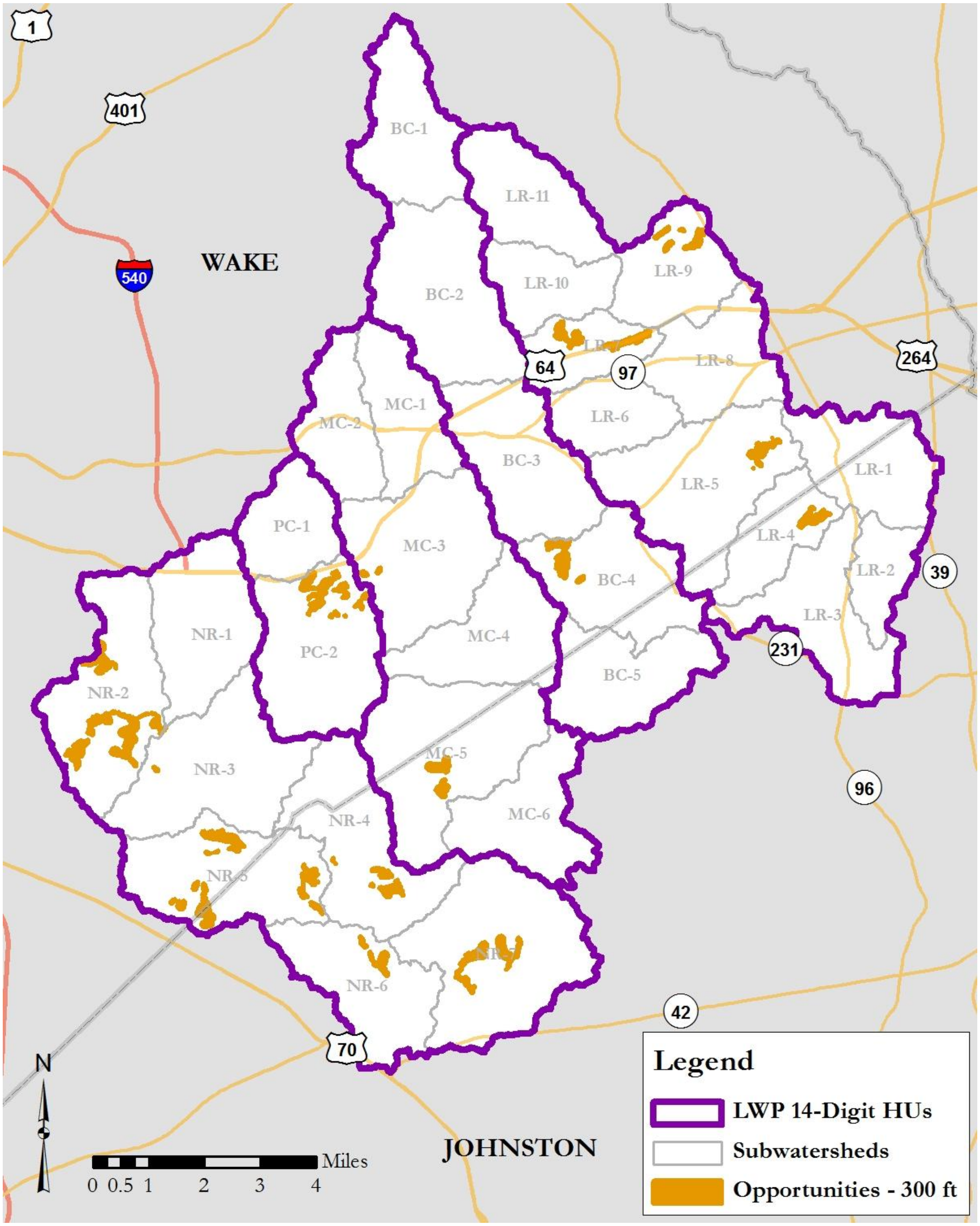

Figure 31. Potential 300'-wide Buffer Restoration Opportunities.

7.2 Stream Opportunities

To identify a preliminary set of potential stream and wetland project sites, an aerial review of the watersheds was performed. High resolution imagery was used to identify and evaluate potential sites that should be further assessed in the field in the event that mitigation or other projects should be needed before the completion of the Project Atlas in the RWP. Preliminary site evaluation criteria are described below, followed by maps of priority sites that warrant field assessment to evaluate project viability.

Stream Restoration and Enhancement Evaluation

Stream restoration and enhancement projects identified in the remote sensing assessment included reaches that measured approximately between 1,000 and 2,500 linear feet. Greater length was preferable but no contiguous sites of greater length were identifiable on the aerial imagery. Fifty foot riparian buffers on both sides were assessed based on condition of forest cover. Poor buffers were determined to have little or no forest cover while fair buffers were determined to have sparse to intermediate forest cover. Channelization was identified as straightened streams. Livestock access to streams and banks was determined. A stream restoration/enhancement rating was assigned based on an aggregated score of each of these characteristics, and the projects were rated as high, medium, or low priority. High ranking projects are generally described as those that are typically 2,000 linear feet or longer, having riparian buffer typically less than 20 feet on the majority of the reach, with livestock accessing the stream, including visible signs of erosion, and consisting of two or fewer parcels. Table 9 describes and Figure 32 illustrates the highest ranking projects.

Table 7. Top Four Potential Stream Restoration and Enhancement Projects.

Project	Estimated Length	Buffer Condition	Channel Condition	Site Description
1	737	Fair	Poor	Adjacent to a dirt road. Good potential restoration.
1	1,009	Poor	Poor	Mostly a one-sided buffer. Utility ROW is parallel.
2	743	Poor	Fair	Owned by the City of Raleigh.
3	1,769	Poor	Fair	Single owner opportunity.
3	387	Poor	Poor	Tributary of downstream project opportunity.
4	614	Poor	Fair	Cattle Farm and pasture near US-264.
4	226	Poor	Poor	Tributary to larger site. Drains from US-264.
4	274	Fair	Fair	Tributary to a larger project. Thin buffer.

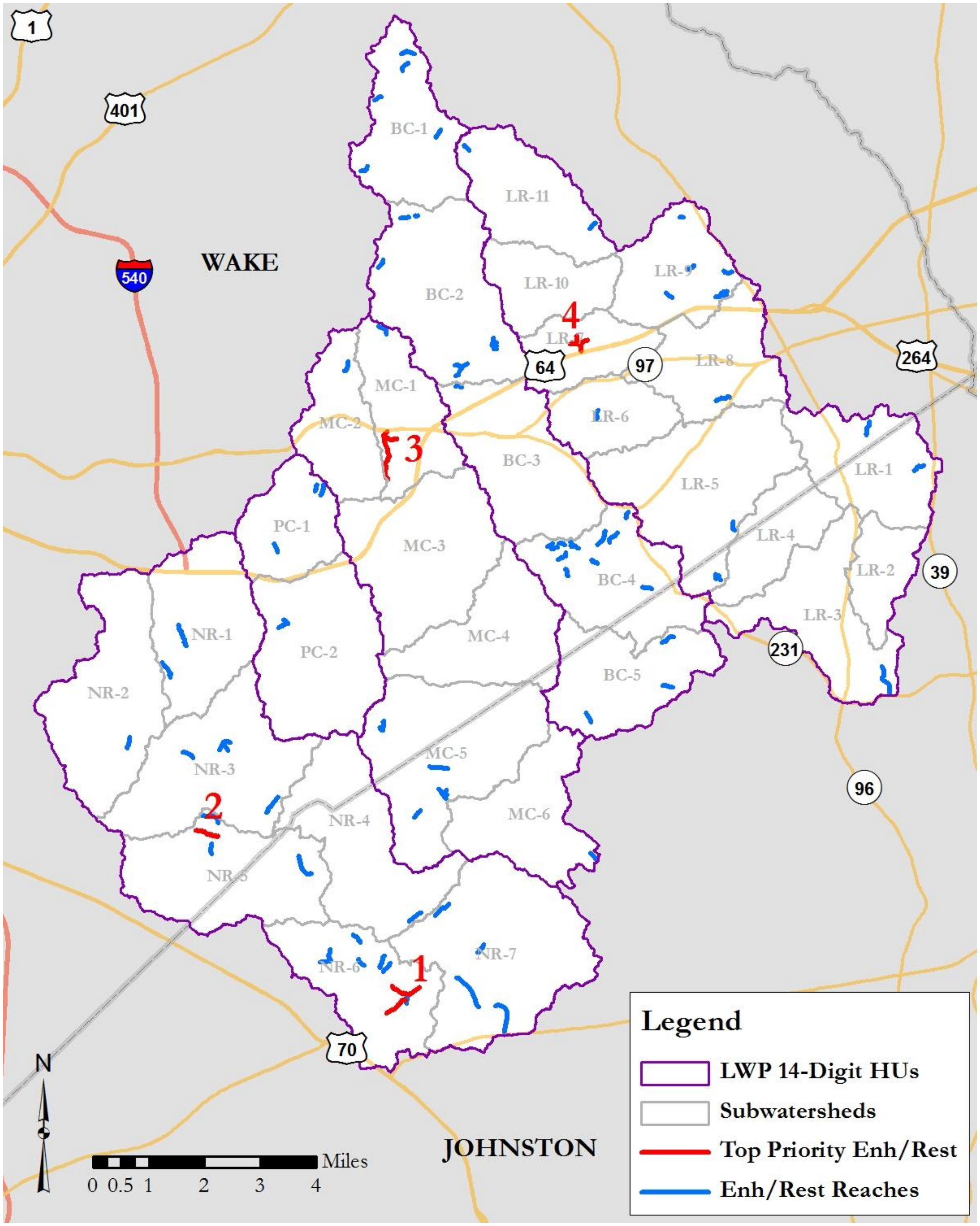

Figure 32. Stream Restoration and Enhancement Opportunities.

Stream Preservation Evaluation

Stream preservation projects were identified using remotely sensed data (Table 10, Figure 34). Sites identified were approximately between 1,000 and 3,000 linear feet with limited impacts to the stream or riparian buffer. Contiguous tributaries with good or excellent buffer and channel condition were included also if they were approximately 1,000 feet or longer. Disturbances of 100 feet or more constituted a break and the buffers on either side of the break were then considered separately. Forested buffer 100 feet or wider was determined to be in fair condition when the forest was immature or slightly fragmented; it was considered in good condition when the forest appeared mature and contiguous. Tributaries were assessed for disturbance as well; those with little buffer were considered a break because they essentially transported untreated runoff into the main stream. Channel condition was determined to the extent possible from the imagery. A stream preservation rating was determined by combining criteria scores. A hypothetical high priority stream preservation project would be 3,000 feet or longer and have riparian buffer widths averaging 200 feet, with little channelization or evident bank impacts. Medium priority sites would be typically between 1,000 and 3,000 feet with buffers averaging 150 feet, with mostly mature forest, but with multiple parcels. Low priority sites were less than 1,000 feet, had narrow buffers, and/or many parcels. Note that none of the potential projects met the "high priority" criterion for stream length.

Table 8. Top Four Potential Stream Preservation Projects.

Project	Estimated Length	Buffer Condition	Channel Condition	Site Description
1	997	Good	Excellent	Headwater. Mature evergreen forest. Possible beaver impoundments.
2	1,181	Good	Good	Part of a large area of well-forested streams and tributaries.
2	1,320	Good	Good	Part of a large forest complex that includes the Marks Creek Floodplain SNHA.
3	1,543	Good	Good	Headwater. Single owner. Mostly forested.
4	1,320	Fair	Good	Good site in developing area.

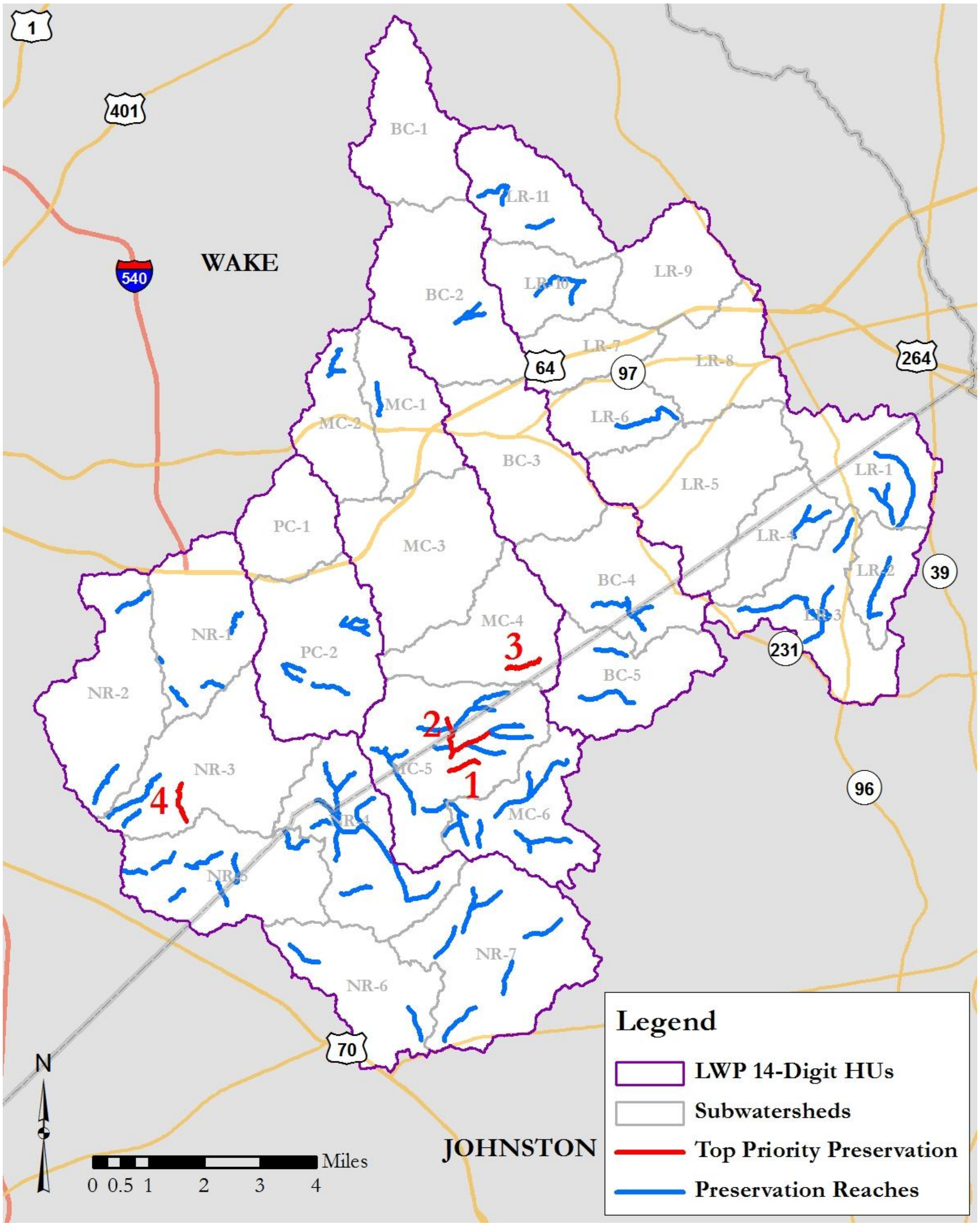

Figure 33. Stream Preservation Opportunities.

7.3 Wetland Opportunities

Similar to the stream assessment, wetland opportunities were identified using high resolution aerial imagery and customized criteria for identifying and ranking potential projects.

Wetland Restoration and Enhancement Evaluation

Wetland and enhancement sites were identified by searching for contiguous patches two or more acres on hydric soils maps (NC Department of Agriculture, 2007), on wetlands maps based on National Wetlands Inventory data (US Fish and Wildlife Service, 2006), and visibly wet areas on high resolution aerial images (see Table 11 and Figure 34, below). These patches were characterized as hydrologically altered based on visible ditching, as having poor (little or no forest cover) or fair (sparse to intermediate forest cover) vegetation, and as at-risk for development when adjacent encroachment appeared to be a threat. A wetland restoration and enhancement rating was assigned to each identified potential project. Hypothetical high priority projects were typically larger than six acres with little vegetation. Ditching was present and the project existed on two or fewer parcels. Medium priority sites were those of about three to five acres with some evident impact to vegetation and hydrologic alteration. Low priority identified sites were typically between one and three acres with limited evidence of ditching or poor vegetation. These sites typically occurred on five or more parcels. None of the top six priority wetland restoration projects were larger than five acres, but qualified as "top priority" based on their other criteria scores.

Table 9. Top Six Potential Wetland Enhancement and Restoration Projects.

Project	Estimated Acres	Ditching	Vegetation	Site Description
1	1.4	Moderate	Poor	Nonriparian wetland on ridge.
2	1.1	Moderate	Poor	Nonriparian wetland enhancement opportunity.
3	3.3	High	Poor	May have some stream opportunity as well.
4	1.4	Moderate	Poor	Nonriparian wetland. May be an old farm pond.
5	4.9	Moderate	Poor	Potential wetland restoration opportunity.
6	1.4	High	Poor	Edge of a farm field.

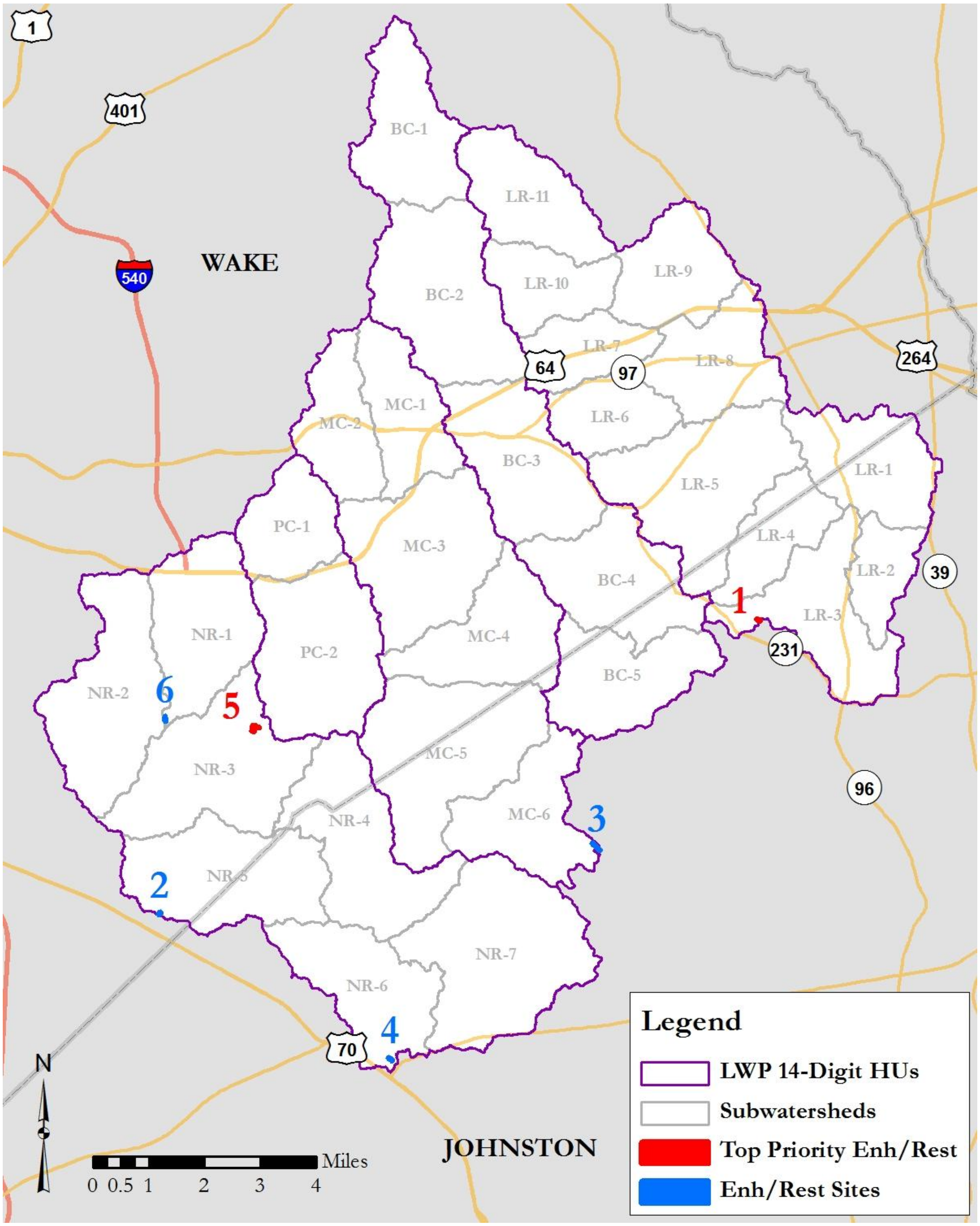

Figure 34. Wetland Enhancement and Restoration Opportunities.

Wetland Preservation Evaluation

Potential wetland preservation projects were identified using the same data as for the restoration and enhancement projects (see Table 12, Figure 35). Sites identified were greater than five acres. They were assessed according to the condition of their vegetation. It was considered good when no significant impacts were noticeable and the vegetation appeared to be mature. Fair vegetation was determined when partial impacts were noticeable on the imagery and it appeared to be early successional. Hypothetical projects with high ratings would typically be larger than 10 acres, with good mature vegetation and little evidence of ditching. These sites occurred on two or fewer parcels. Medium priority sites were typically between seven and 10 acres and had mostly intact vegetation. Low priority identified sites were typically between five and seven acres with mostly intact vegetation but existed on five or more parcels.

Table 10. Top 13 Potential Wetland Preservation Projects.

Project	Estimated Acres	Vegetation	Site Description
1	12.7	Excellent	Nonriparian wetland on ridgeline. Possibly enhancement.
2	12.7	Excellent	Nonriparian wetland enhancement on ridgeline. Good vegetation.
3	5.4	Excellent	Nonriparian wetland enhancement near ridgeline.
4	2.0	Excellent	Nonriparian wetland enhancement.
5	14.0	Good	Large area owned in part by NCDOT.
6	18.2	Good	Riparian wetland preservation, large, few landowners.
7	4.2	Good	Riparian wetland preservation, possibly part of an old farm pond.
8	27.8	Good	Riparian wetland preservation, possible beaver impoundments.
9	7.6	Good	Riparian wetland preservation, possible beaver impoundments.
10	6.9	Excellent	Riparian wetland preservation, braided system with beaver impoundments.
11	13.2	Good	Riparian wetland preservation.
12	14.3	Good	Riparian wetland preservation, possibly braided system with beaver impoundments.
13	9.6	Good	Riparian wetland preservation, may be partially cleared.

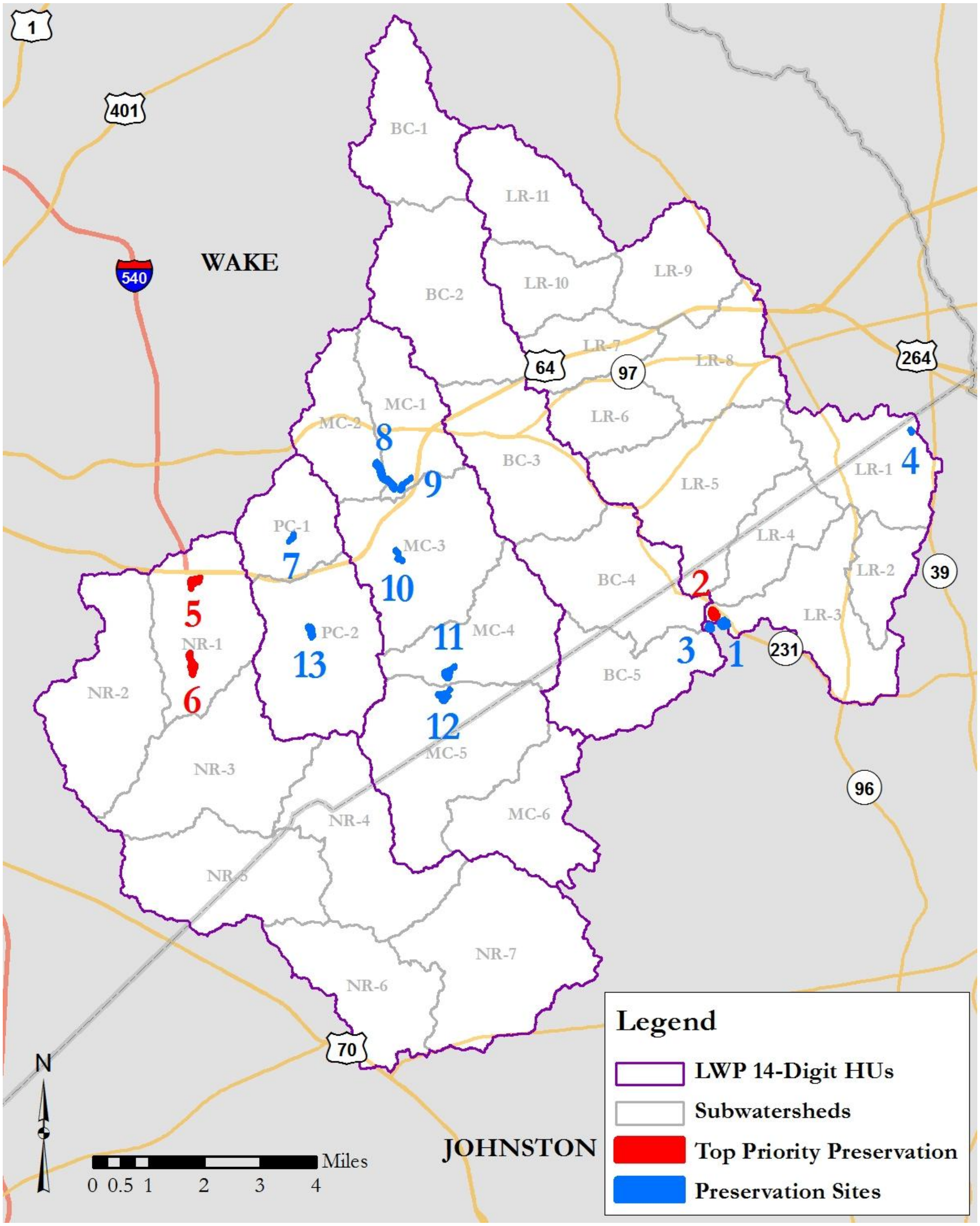

Figure 35. Wetland Preservation Opportunities.

7.4 BMP Opportunities

Best Management Practices Criteria

BMP projects were subjectively identified by consultation with local stakeholders throughout the watershed (see Table 13, Figure 36). These priorities were suggested by municipal representatives, landowners, and individual citizens and no attempt to be comprehensive has been made to this point. Additional input regarding priority BMP project potential in subsequent planning phases is in order.

Table 11. Potential Best Management Practices Projects.

Project	Estimated Acres	Site Description
1	2.5	School parking lot and ball field drainage with existing BMP.
2	10	Drainage from car dealership. Existing pond with some function.
3	5	Drainage off factory building and parking lot. No visible BMP.
4	8	Industrial Plant (Glaxo).
5	7.5	Riprapped ditch leading to stormwater pond.
6	4.5	Junk cars in field. Debris clean-up and BMP potential.
7	1	Ridge top junk pile.
8	6	Recent aerials showed turbid looking pond.
9	3.5	Drains small commercial building and parking lot.
10	2	Drains a church parking lot.
11	0	Bare earth in the floodplain. Appears to be fill or excavation spoil piles.
12	3	Open space adjacent to school parking lot.
13	4	Drains a commercial industrial facility.
14	4	Adjacent to school parking lot. Close to the Neuse River.
15	0	Poorly maintained erosion and sediment control on new development.

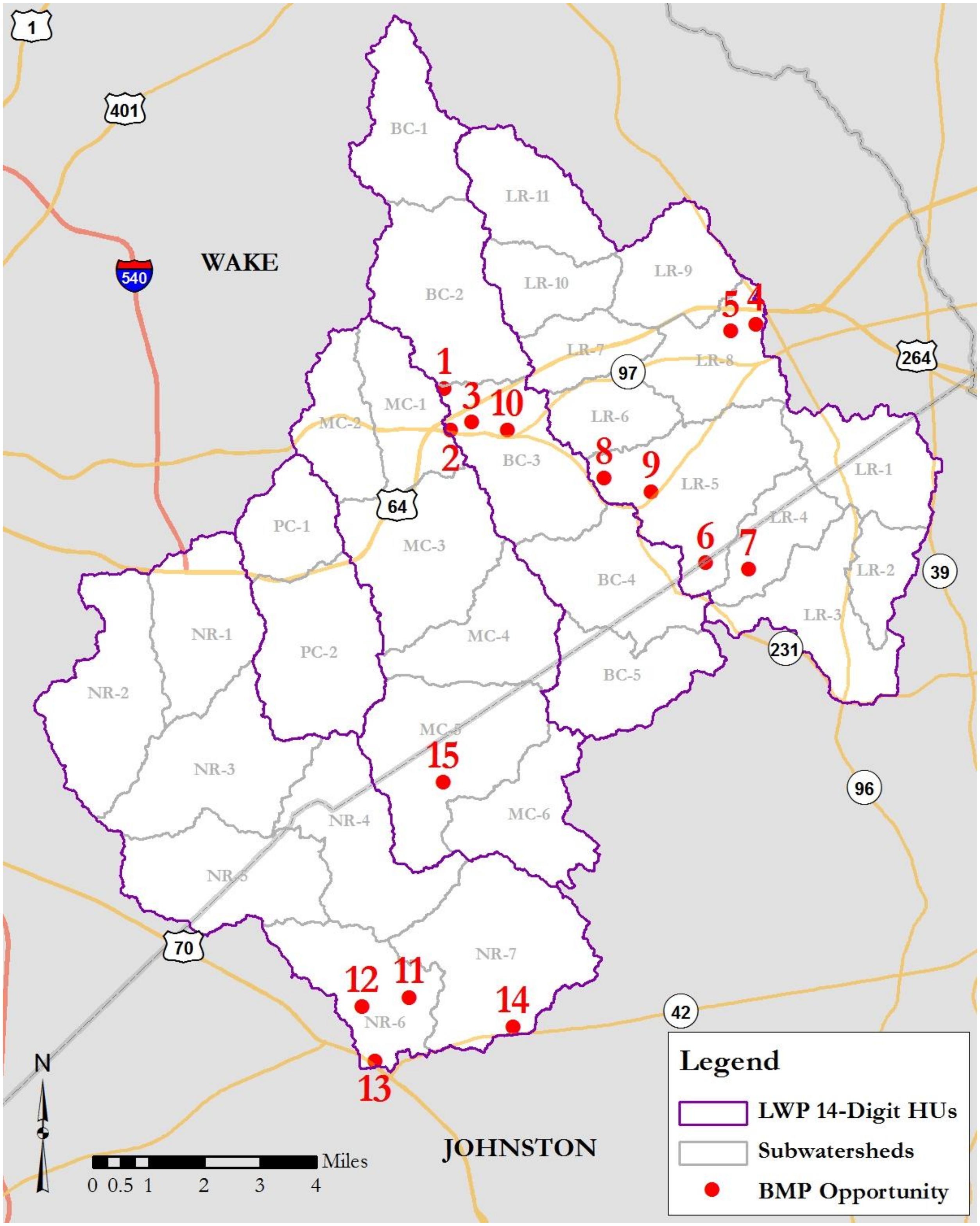

Figure 36. Best Management Practices (BMP) Project Opportunities.

References

Brown, A.V. and P.P. Brussock. Comparisons of benthic invertebrates between riffles and pools, 1990. Hydrobiologia 220: 99 – 108.

Center for Watershed Protection. 2000. Article 28: Basic Concepts in Watershed Planning: The Practice of Watershed Protection. T. Schueler and H. Holland, eds. Ellicott City, MD.

CH2M Hill, 2002. Wake County Watershed Assessment – Biological, Habitat, and Geomorphic Evaluations. Technical Memorandum No. 6. (Prepared for Wake County Watershed Management Plan Task Force). Raleigh, NC.

CH2M Hill, 2003. Comprehensive Watershed Management Plan for Wake County, NC.

Doll, B.A., G.L. Grabow, K.R. Hall, J. Halley, W.A. Harman, G.D. Jennings and D.E. Wise, 2003. Stream Restoration: A Natural Channel Design Handbook. NC Stream Restoration Institute, NC State University. 128 pp.

ESRI, 2013. Arc Hydro: GIS for Water Resources. (online at: http://www.esri.com/library/fliers/pdfs/archydro.pdf).

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, *PE&RS*, Vol. 77(9):858-864.

Griffith, G.E., Omernik, J.M., Comstock, J.A., Schafale, M.P., McNab, W.H., Lenat, D.R., MacPherson, T.F., Glover, J.B., and Shelburne, M.B., 2002. *Ecoregions of North Carolina and South Carolina*, (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, US Geological Survey (map scale 1:1,500,000).

Homer, C. C. Huang, L. Yang, B. Wylie and M. Coan. 2004. Development of a 2001 National Land Cover Database for the United States. Photogrammetric Engineering and Remote Sensing, Vol. 70, No. 7, July 2004, pp. 829-840. Online at http://www.mrlc.gov/mrlc2k_nlcd.asp

Lassiter, Thomas J. 2004. Johnston County: Its History Since 1746. Hometown Heritage Publishers.

Maidment, D. R., ed., 2002. *Arc Hydro: GIS for Water Resources*, ESRI Press, Redlands, Ca.

Mayer, P.M., S.K. Reynolds, and T.J. Canfield, 2005. Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations. EPA/600/R-05/118.

N.C. Center for Geographic Information and Analysis (2008). Unpublished data delivered to NC EEP documenting GIS analytical steps used to estimate watershed-based metrics.

NC Department of Agriculture. 2007. Unpublished data provided to NC EEP in October 2007.

N.C. Department of Transportation. 2002. Minutes of the NC Dam Removal Task Force Meeting, February 21, 2002.

N.C. Department of Transportation, 2007a. Data published based on the Flood Mapping LIDAR data. GIS web site: http://www.ncdot.org/it/gis/. Accessed July 2009.

N.C. Department of Transportation, 2007b. Annual Report: Marks Creek Mitigation Site, Wake County, TIP No. R-2547 WM.

N.C. Division of Water Quality. 1998. Neuse River Nutrient Strategy. (online at: http://portal.ncdenr.org/web/wq/ps/nps/neuse.)

N.C. Division of Water Quality. 2000. Neuse River Basin: Protection and Maintenance of Existing Riparian Buffers. (online at: Neuse River Buffer Rules)

N.C. Division of Water Quality, 2006a. Basinwide Assessment Report - Neuse River Basin. Environmental Sciences Section. http://portal.ncdenr.org/c/document_library/get_file?p_l_id=1169848&folderId=722215&name=DLFE-41615.pdf

N.C. Division of Water Quality, 2006b. Standard Operating Procedures for Benthic Macroinvertebrates. Environmental Sciences Section, Biological Assessment Unit.

N.C. Division of Water Quality, 2006c. Standard Operating Procedures for Stream Fish Community Assessment Program. Environmental Sciences Section, Biological Assessment Unit. http://portal.ncdenr.org/c/document_library/get_file?uuid=36784c06-f53d-430e-90f9-2f643c9b645b&groupId=38364.

N.C. Division of Water Quality, 2007. "Redbook", Surface Waters and Wetlands Standards. NC Administrative Code 15A NCAC 02B.0100, .0200 and .0300.

N.C. Division of Water Quality, 2008. NC 303(d) List of Impaired Waters. Classification and Standards Section. http://portal.ncdenr.org/web/wq/ps/mtu/assessment

N.C. Division of Water Quality, 2009a. Scope of Work for Wake-Johnston Collaborative Local Watershed Plan, Water Quality Monitoring. Prepared by DWQ Watershed Assessment Team (WAT).

N.C. Division of Water Quality, 2009b. Final Neuse River Basinwide Water Quality Plan. Planning Section. http://portal.ncdenr.org/web/wq/ps/bpu/basin/neuse/2009.

N.C. Division of Water Quality, 2009c. Small Streams Biocriteria Development. Environmental Sciences Section.

N.C. Division of Water Quality, 2010. NC 303(d) List of Impaired Waters. Classification and Standards Section. http://portal.ncdenr.org/web/wq/ps/mtu/assessment

N.C. Division of Water Quality, 2012. NC 303(d) List of Impaired Waters. Classification and Standards Section. http://portal.ncdenr.org/web/wq/ps/mtu/assessment

N.C. Ecosystem Enhancement Program, 2005. NC Ecosystem Enhancement Program Local Watershed Planning Manual. Unpublished internal guidance.

N.C. Ecosystem Enhancement Program, 2010. Neuse River Basin Restoration Priorities. (online at http://portal.ncdenr.org/c/document_library/get_file?uuid=665be84c-cf93-477b-918c-1993778ef11f&groupId=60329).

N.C. Ecosystem Enhancement Program, 2012. NC Ecosystem Enhancement Program Local Watershed Planning Manual. (online at: http://portal.ncdenr.org/c/document_library/get_file?uuid=07477766-468b-44f0-a379-e0274c75f4bb&groupId=60329).

N.C. Flood Risk Information System, 2011. North Carolina Flood Zone. (online at: http://data.nconemap.com/geoportal/catalog/search/resource/details.page?uuid=%7B0E8F1900-B26A-41C4-9E6E-ACD5BBF9E82E%7D.

N.C. Forest Service, 2012. Johnston County Natural Resources Initiative Green Infrastructure Assessment Report.

N.C. Natural Heritage Program[1]. 2007. Natural Heritage Element Occurrences. Data received by EEP on October 2007.

N.C. Natural Heritage Program[2]. 2007. Significant Natural Heritage Areas. Data received by EEP on October 2007.

N.C. Natural Heritage Program, 2013. 2013 Biennial Protection Plan – List of Significant Natural Heritage Areas. (online at: http://portal.ncdenr.org/c/document_library/get_file?uuid=8cbf71a7-35c6-4836-b8de-6920759def5d&groupId=61587.

N.C. State University, 2009. Wake-Johnston County Water Quality Investigation.

Powell, William S. 2006. Encyclopedia of North Carolina. University of North Carolina Press, Chapel Hill, NC.

US Department of Agriculture Natural Resource Conservation Service. 1998. Hydrologic Units - North Carolina Subbasins: Natural Resources Conservation Service, Raleigh, NC.

U.S. Environmental Protection Agency. 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers. EPA 841-B-99-002.

U.S. Environmental Protection Agency. 2001. Protocol for Developing Pathogen TMDLs. EPA 841-R-00-002.

U.S. Environmental Protection Agency. 2008. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. EPA 841-B-08-002.

U.S. Fish and Wildlife Service. 2006. National Wetlands Inventory. Data downloaded October 2007. (online at: http://www.fws.gov/wetlands/Data/Data-Download.html).

U.S. Geological Survey, 2006. National Land Cover Dataset. (online at: http://www.mrlc.gov/nlcd2006.php).

U.S. Geological Survey, 2012. Federal Standards and Procedures for the National Watershed Boundary Dataset (WBD).

Appendix A. Existing Water Quality Data Summary

Wake-Johnston Collaborative Local Watershed Plan

Review of Existing Water Quality Data

Prepared by the North Carolina Division of Water Quality
Watershed Assessment Team
January 10, 2010

Table of Contents

Introduction

The North Carolina Ecosystem Enhancement Program (EEP), in collaboration with Wake County Environmental Services and Johnston County, is developing a local watershed plan (LWP) for portions of five United States Geologic Survey (USGS) 14-digit hydrologic units (HUs) including 03020201100/010, 020, 030 and 03020201180/050 and 020 within two NC Division of Water Quality (DWQ) designated Neuse River sub-basins (03-04-02 and 03-04-06) located along the county line between Wake and Johnston counties near the Towns of Knightdale, Wendell and Zebulon (Figure 1). The area lies close to the dividing line that separates the Northern Outer Piedmont Level IV Ecoregion from the Rolling Coastal Plain Level IV Ecoregion (Griffith, et al., 2002).

A noteworthy phenomenon in this area is low flow and swamp-like conditions in some stream segments. These conditions were observed by several field personnel over the past roughly nine years and reported in various assessments summarized in this report. Low flow conditions are caused by several factors related to geology, upstream impoundments (both beaver and human) and recent drought conditions. If streams are not flowing, low biological scores may result that are more indicative of low flow and low dissolved oxygen rather than degraded water quality due to pollution or deficient habitats.

DWQ's Watershed Assessment Team (WAT) is assisting in the development of the LWP by providing a review of existing reports and water quality data, assisting with water quality monitoring, providing water quality data (lab analyses conducted by DWQ's Laboratory Section) and drafting interpretive reports. These tasks were previously described in a Scope of Work drafted by WAT in October (DWQ, 2009a).

The goal of this report is to review recent existing water quality data from the selected local watershed planning (LWP) area in order to (1) help identify where problems/stressors may exist, (2) identify where additional assessments may need to be conducted (due to data gaps), and (3) to help stakeholders develop an overall watershed plan that meets mitigation needs and incorporates management recommendations alleviate current and future stressors that may negatively impact water quality and other watershed functions.

Overview of Sources of Existing Water Quality Data

Five primary sources of information and data are summarized in this report.

1. Portions of DWQ's Neuse River Basinwide Assessment Report (DWQ, 2006a) that include sub-basins 03-04-02 and 06 were reviewed. Water quality data summarized from these sub-basins include two locations for benthic macroinvertebrate and fish community assessments and aquatic habitat mostly dating back to 2005. Figure 1 and Table 1 provide a map and listing of existing biological monitoring locations conducted by various groups.

2. DWQ's Basin Information Management System (BIMS) database which contains information on dischargers permitted under the National Pollution Discharge Elimination System (NPDES) programs and other state programs was queried to

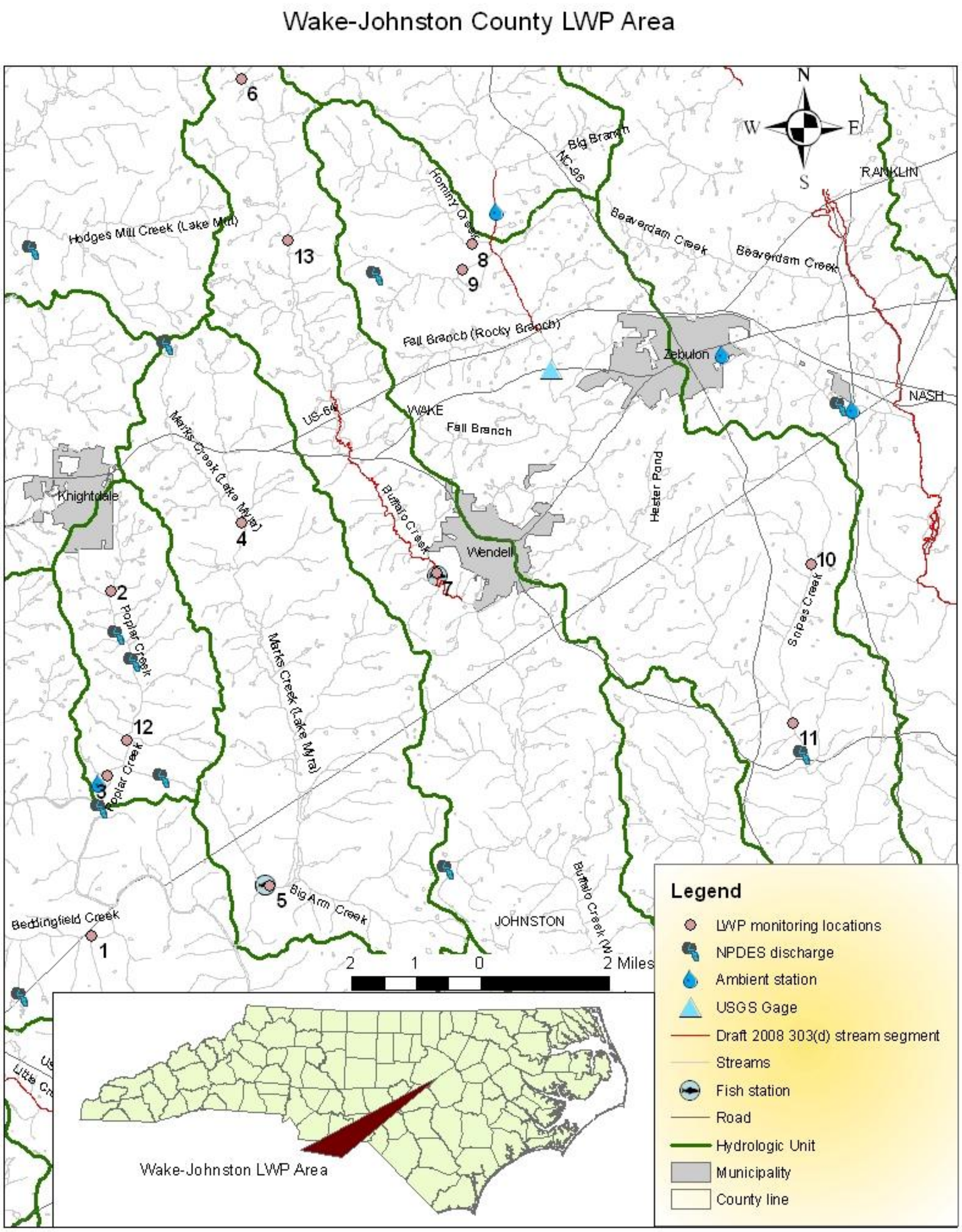

Figure 1. Wake-Johnston County Local Watershed Planning (LWP) Area. Numbers adjacent to LWP monitoring locations correspond to map codes in Table 1.

Table 1. Locations, descriptions and types of water quality monitoring within Wake-Johnston LWP area 2000 – 2009.

Map Code	Stream Location and County	Class	Use Support Rating	Latitude	Longitude	Benthos	Fish	Habitat	Phys/Chem	*In situ* Field Readings	Geomorph.	Flow
1	Beddingfield Creek at Shotwell Rd., SR 1553, Johnston	C, NSW	ND	35.6948	-78.4799	x		x	x	x		
2	Poplar Creek at Smithfield Rd., SR 2233, Wake	C, NSW	S	35.7724	-78.4742	x		x	x	x		
3	Poplar Creek at Bethlehem Rd., SR 2049, Wake	C, NSW	S	35.7307	-78.4754	x		x	x,y	x,y		
4	Marks Creek at Eagle Rock Rd., SR 2501, Wake	C, NSW	S	35.7876	-78.4377	x,z		x,z	x	x	z	
5	Marks Creek at Prichard Rd., SR 1714 Johnston	C, NSW	S	35.7058	-78.4305	x,yy,z	yy	x,yy,z	x	x,	z	
6	Buffalo Creek at Mitchell Mill Rd., SR 2224 Wake	C, NSW	ND	35.8878	-78.4373	x		x	x	x		
7	Buffalo Creek at Poole Rd., SR 1007, Wake	B, NSW	I	35.7760	-78.3837	x,yy	yy	x,yy,z	x	x	z	
8	Hominy Creek at Buck Rd., SR 2329, Wake	WS-II, HWQ, NSW	ND	35.8502	-78.3733	x		x	x	x		
9	Rocky Branch (Big Canal) at Riley Hill Rd. SR 2320, Wake	WS-II, HQW, NSW	ND	35.8445	-78.3763	x		x	x	x		
10	Snipes Creek at Taylors Mill Rd., SR 1723, Johnston	C, NSW	ND	35.7775	-78.2801	x		x	x	x		
11	Little River above NC 231, Johnston	WS-IV, NSW	S	35.7417	-78.2855	x		x	x	x		
12	Poplar Creek at Grasshopper Rd.,	C, NSW	S	35.7387	-78.4699	z		z			z	

Table 1. Locations, descriptions and types of water quality monitoring within Wake-Johnston LWP area 2000 – 2009.

Map Code	Stream Location and County	Class	Use Support Rating	Latitude	Longitude	Benthos	Fish	Habitat	Phys/Chem	*In situ* Field Readings	Geomorph.	Flow
	SR 2511, Wake											
13	Buffalo Creek at Riley Hill School Rd., SR 2320, Wake	C, NSW	S	35.8512	-78.4245	z		z			z	
-	Little River at NC 97, Wake – USGS Gage	WS-II, HWQ, NSW	S	35.8219	-78.3517							w
-	Little River at Smithfield Rd., SR 2333, Wake - LNRBA	WS-II, HWQ, NSW	I	35.8577	-78.3665				y	y		
-	Little Creek at NC 97, Wake - LNRBA	C NSW	S	35.8277	-78.3017				y	y		
-	Little Creek at NC 39, Wake - LNRBA	C NSW	S	35.8127	-78.2683				y	y		

Notes: w – United States Geological Survey (USGS) Gage No. 02088383
x - Wake-Johnston Local Watershed Plan (LWP).
y - Lower Neuse River Basin Association (LNRBA) location.
yy - North Carolina Division of Water Quality's Biological Assessment Unit (BAU).
z - Wake County Comprehensive Watershed Management Plan conducted by CH2M Hill (2003).

Map codes 1 – 11 correspond to benthic assessment (NCSU, 2009) and water quality monitoring locations (DWQ, 2009a) for current LWP.
Poplar Creek at Bethlehem Rd (Map code 3) is also a LNRBA monitoring station - J4080000.
Little River at Smithfield Rd. (Map code 12) is LNRBA monitoring station J5620000.
Little Creek at NC 97 and Little Creek at NC 39 are LNRBA monitoring stations J6410000 and J6450000 respectively, are nearby the LWP area and were summarized for comparison purposes.
Geomorph is the abbreviation for Geomorphologic Assessment. In this case, a Rosgen Level 1 stream type classification based on Rosgen concepts as outlined in by Doll et al., (2003).

Use Support Ratings (DWQ, 2009b): S – Supporting; ND – No Data; I – Impaired.

identify NPDES facilities in the LWP area, and further identify those that had water quality permit violations during the period 2005 through 2009.

3. The EPA Storage and Retrieval (STORET) database was used to download physical and chemical monitoring results from the DWQ's Ambient Monitoring System (AMS) including data from the NPDES Coalition program. The Lower Neuse River Basin Association (LNRBA) collected water quality data at four locations in and nearby the LWP area in cooperation with DWQ as part of a memorandum of agreement (MOA) between the two entities. The LNRBA is voluntary and is composed of several NPDES permittees within the Neuse river basin. The LNRBA program collects physical and chemical data that compliments the DWQ AMS program. More information can be reviewed at the following website[1] http://h2o.enr.state.nc.us/esb/coalitions.html

4. Wake County's Comprehensive Watershed Management Plan prepared by CH2M Hill (2003) was reviewed to cull pertinent data applicable to streams within the LWP area. (Table 1 and Figure 1)[2].

5. The recent benthic macroinvertebrate assessment (NCSU, 2009) conducted in August, 2009 at 11 locations within the LWP area as shown in Figure 1 and described in Table 1 was also reviewed. The team consisted of staff from WAT and the North Carolina State University Biological and Agricultural Engineering Extension Program (NCSU-BAE).

Secondary sources of information included the DWQ's 2009 Basinwide Water Quality Plan, the revised draft 2008 303(d) list of impaired waterbodies, the United States Geological Survey (USGS) Real-Time Stream Flow Data website and various geographic information system (GIS) geospatial data layers downloaded from the NC Onemap website http://www.nconemap.com and other sources.

DWQ Stream Classifications, Water Quality Standards and Action Levels

Surface Water Classifications and Supplemental Classifications are designations applied to surface water bodies, such as streams, rivers and lakes, which define the best uses to be protected within these waters (for example swimming, fishing, drinking water supply, aquatic life propagation) and carry with them an associated set of water quality standards to protect those uses. Each classification has associated standards that are used to determine if the designated uses are being protected. The DWQ Classification and Standards Unit's home page (http://h2o.enr.state.nc.us/csu/) provides details on stream classifications, water quality

[1] As of January 20, 2010, (the date of this report) the NCDWQ is phasing in a new web site. Therefore the reader may be redirected to a new URL other than the one provided in this report.

[2] The CH2M Hill report provided little water quality data. The benthic bioclassification ratings are discussed below. The biologists used NCDWQ protocols so their data were comparable. Habitat data were collected using the Mecklenburg Habitat Assessment Protocol (MHAP) and therefore were not comparable to BAU's method. CH2M Hill reviewed existing ambient water quality data but additional data were not collected. Essentially, biological, chemical and other data and watershed characteristics were integrated to classify and prioritize sub-watersheds for the entire County. For example, each sub-watershed was classified as healthy, impacted or degraded and then prioritized for management. Geomorphologic data and Rosgen stream type are provided in the Appendix for applicable sites listed in Table 1.

standards, action levels and hyperlinks to a database that will identify the surface water quality classifications for streams with the LWP area.

An Action Level represents a concentration of a contaminant in water that if reached or exceeded, certain actions may be warranted. Action Levels are applied to substances that generally are not bioaccumulative and have variable toxicity to aquatic life because of chemical form, solubility, stream characteristics (e.g. hardness and/or pH).

Our review of existing data for this LWP discovered that toxicity (parameters with action levels assigned) was not assessed in the waters of this LWP.

Water quality standards (http://www.epa.gov/waterscience/standards/about/) are the foundation of the water quality-based control program mandated by the Clean Water Act. Water quality standards define the goals for a waterbody by designating its uses, setting criteria to protect those uses, and establishing provisions to protect water quality from pollutants. A water quality standard consists of four basic elements:

1. Designated uses of the water body (e.g., recreation, water supply, aquatic life, agriculture);

2. Water quality criteria to protect designated uses (numeric pollutant concentrations and narrative requirements);

3. An antidegradation policy to maintain and protect existing uses and high quality waters; and,

4. General policies addressing implementation issues (e.g., low flows, variances, mixing zones).

All waters of the Neuse River Basin have a supplemental Nutrient Sensitive Waters (NSW) classification. See NCDENR Division of Water Quality "Redbook" – Surface Waters and Wetlands Standards (2007) 15A NCAC 02B .0232 p. 54 at the following link that provides http://h2o.enr.state.nc.us/admin/rules/documents/redbook_1may07_full_with_cover.pdf details relative to the Neuse River Basin nutrient sensitive waters management strategy. The Environmental Management Commission established a goal to reduce the average annual load of nitrogen delivered the Neuse River Estuary and to meet that goal promulgated several rules applicable to all waters in the Basin. For example one management strategy involves maintaining and protecting existing riparian buffers to maintain their nutrient removal functions.

Streams within the LWP area where water quality monitoring is currently underway are classified as Class C and NSW. Hominy Creek, Rock Branch and the Little River at Smithfiled Road carry both a Water Supply (WS-) classification and a High Quality Waters (HQW) designation. Buffalo Creek at Poole Road is classified as Class B – freshwater protected for primary recreation which includes swimming.

Impaired Waters List

Section 303(d) of the Clean Water Act (CWA) requires states to develop a list of waters not meeting DWQ water quality standards or which have impaired uses. Listed waters must be prioritized, and a management strategy must subsequently be developed for all listed waters. The following link provides more information http://h2o.enr.state.nc.us/tmdl/General_303d.htm about the impaired streams list. Two streams are listed as impaired on DWQ's revised draft 2008 303(d) list of impaired waterbodies. Comments may be submitted electronically by 11:59 PM on January 25, 2010 to jennifer.everett@ncdenr.gov. The list may be modified based on the comments received. The final list and responses to comments will be available on the website above after EPA approval.

1. Little River (Moores Pond, Mitchell Mill Pond) from Big Branch downstream to SR 2368 (2.9 miles). Low dissolved oxygen standard violation.

2. Buffalo Creek from dam at Robertson Pond to a point 200 feet upstream from West Haywood Street near Wendell (5.8 miles). Biological integrity.

Summary of Existing Water Quality Assessments

Chemical and Physical Monitoring

The NPDES Discharge Monitoring Coalition Program was developed by DWQ to create an effective water quality program to assess where human activities and natural forces may be contributing to water pollution. A general understanding of the potential impacts that pollutants can have on water quality can be obtained through routine (monthly) sampling of physical and chemical parameters from fixed water quality monitoring stations within a watershed context. In order to better utilize the resources spent by NPDES permittees, the monitoring locations are coordinated with the State's existing ambient and biological monitoring networks. This integrated management of monitoring resources reduces duplication and provides a more complete picture of watershed conditions and helps with use support assessments and other DWQ programs (e.g., 303(d) reporting and development of NPDES permit limits).

Staff from DWQ's Ecosystems Unit review and summarize these data in five-year cycles by comparing parameter concentrations to an Evaluation Level (EL) which may be a water quality standard, an action level, an ecological threshold, or simply an arbitrary threshold that facilitates a rapid data review. The most recent summary of these data was conducted in the 2006 Neuse River Basinwide Assessment Report (DWQ, 2006a). Parameters included field readings (dissolved oxygen (DO), pH, temperature and specific conductance), nutrients (ammonia nitrogen, nitrite-nitrate nitrogen, total Kjeldhal nitrogen and total phosphorus), total suspended residue, turbidity and fecal coliform.

Our review of AMS data included all chemical and physical data (same parameters as above) collected by the LNRBA during January, 2000 through July, 2009. (Data collection for the two Little Creek locations began in May 2000.) They collected samples from four stations in and nearby the LWP. Two nearby stations are located in Little Creek, one upstream and one downstream of the former Zebulon wastewater treatment plant (WWTP). Zebulon merged water and sewer operations in 2006 with the City of Raleigh Public Utilities Department (CORPUD).[3]

[3] CORPUD is currently permitted to discharge 2.2 million gallons per day (MGD) and is considering expansion to 6.0 MGD with discharges to both Little Creek and nearby in the Little River.

Selected data were compared with two other LNRBA stations in Figures 2 through 4; one in Poplar Creek and the other in the Little River, both of which lie within the LWP area. The Poplar Creek station is also where benthics were surveyed in August, 2009. There are no DWQ ambient monitoring stations nearby the LWP.

Field data collected for the recent benthic survey in August, 2009 are also briefly discussed below. These data are located in the Appendix.

Field Data

Field data represent measurements for dissolved oxygen (DO), specific conductance, pH and water temperature collected and recorded during stream visits. Specific conductance and DO data collected by LNRBA during the roughly nine-year period beginning in January, 2000 through July, 2009 are portrayed graphically in Figures 2 through 4 and are discussed below. The grand mean in the figures below is the mean of all observations for all four stations. The Appendix presents all LNRBA data.

Dissolved Oxygen

With respect to field parameters, DO is one of the most important of all the chemical measurements. DO provides valuable information about the ability of the water to support aquatic life and the capacity of water to assimilate point and nonpoint discharges. Water quality standards for DO vary depending on the classification of the body of water but generally consistent instantaneous values less than 4.0 mg/L can be problematic and may violate water quality standards. Patterns of low DO can occur naturally in and near swamp waters and during drought conditions in the Piedmont and in areas of Slate Belt geology.

In the Poplar Creek location at SR 2049, DO observations were always above 4.0 mg/L during the period of record (Figure 2 below). At both Little Creek locations, low DO levels were observed occasionally but were not consistent enough to cause concern. However, in the Little River at SR 2333, levels below 4.0 mg/L were observed 42% of the time which is the stated reason for placing it on the 2008 revised draft 303(d) impaired waterbodies list. The cause for low DO may be related to low flow rather than pollutants with high biochemical oxygen demand (BOD) although assessment work has not been conducted to confirm this. Low flows may also result in a loss of or access to certain habitats by aquatic organisms. Impoundments result in swamp-like conditions.

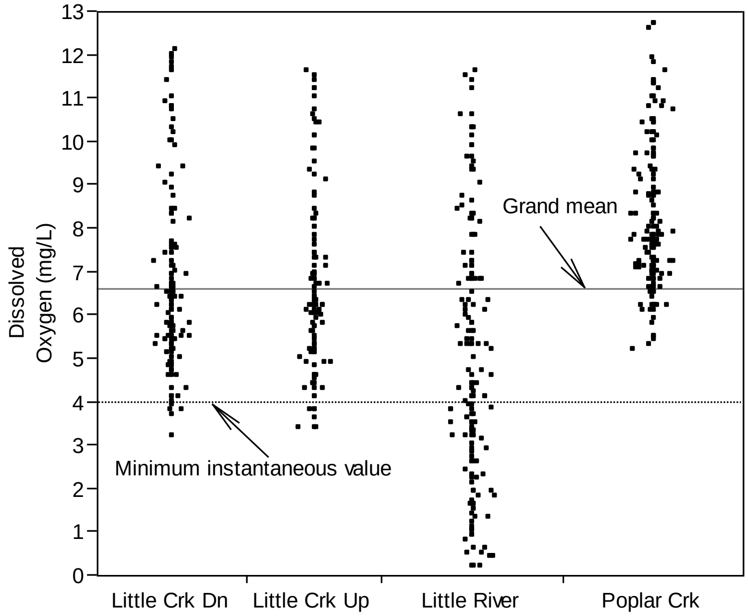

Figure 2. Dissolved oxygen in LNRBA stations January, 2000 through July, 2009. See Table A1 in the Appendix for summary statistics. Minimum instantaneous value is the value below which may violate water quality standards.

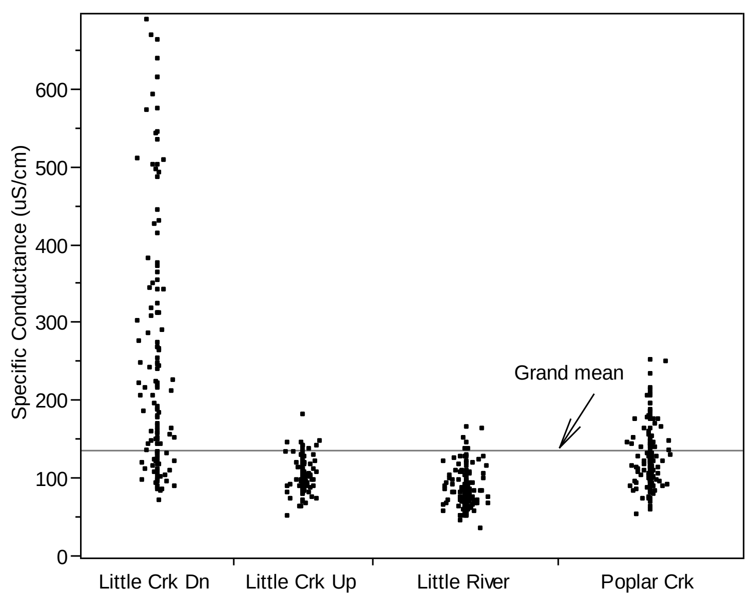

Figure 3. Specific conductance in LNRBA stations January, 2000 through July, 2009. See Table A1 in Appendix for summary statistics. Little Crk Dn is downstream of WWTP discharge.

For the benthic survey conducted in August, 2009, field biologists recorded DO levels below 4.0 mg/L in four locations (see Appendix) including the upstream location in Marks Creek at Eagle Rock Road, both Buffalo Creek locations and in Hominy Creek at Buck Road.

Specific Conductance
Specific conductance is a measure of how well water can conduct an electrical current. Conductivity increases with increasing amount and mobility of ions. These ions, which come from the breakdown of compounds, conduct electricity because they are negatively or positively charged when dissolved in water.

Therefore, conductivity is an indirect measure of the presence of dissolved solids such as chloride, nitrate, sulfate, phosphate, sodium, magnesium, calcium, and iron, and can be used as an indicator of water pollution. There is no evaluation level for this parameter; however, background concentration for a particular LWP area is important to know because each watershed is unique and varies by geology and soil type. Background levels are easily obtained by taking measurements at several locations and streams within a watershed. For example, the benthic survey conducted in August, 2009 within the LWP recorded specific conductance levels ranging from 178 uS/cm to 55 uS/cm (See Appendix, Table A3). Frequent monitoring in these locations over time will help to determine whether the range of levels is due to natural variability or the result of upstream point or non-point source pollution.

Elevated conductance above background levels may be related to non-point pollution associated with land use (mining, urbanization, agriculture, road salts, land clearing, etc.) or point sources (e.g., upstream sewer line leaks, straight pipes). This is evident by comparing data from the four coalition sites (Figure 3 above). For example, the range of specific conductance levels downstream of the Little Creek WWTP discharge was between 71 uS/cm to 688 uS/cm. Whereas, in the other three locations, the range was more narrow; the maximum level reaching 250 uS/cm in Poplar Creek at Bethlehem Road.

This location in Poplar Creek also had the highest level (178 uS/cm) during the benthic survey conducted in August, 2009. The Snipe Creek location had the lowest level (55 uS/cm). See Table A3 in the Appendix.

Temperature
Water temperature exceeded the standard of 32° C only twice and therefore is of little concern (See Appendix). Both occurrences were in the Little River at SR 2333. The range of temperatures for each location was within expected values. Higher values may be related to dysfunctional riparian zones (i.e. the lack of shading) as opposed to a heated discharge.

Temperature measurements in the benthic locations in August, 2009 were within expected values.

pH
The pH of natural waters can vary throughout the state. Low values (< 7.0 s.u.) can be found in waters rich in dissolved organic matter, such as swamp lands, whereas high values (> 7.0 s.u.) may be found during algal blooms. Point source dischargers can also influence the pH of a stream. The water quality standards for pH in freshwaters consider values < 6.0 s.u. or > 9.0 s.u. to warrant attention.

pH readings below 6.0 s.u. were occasionally observed upstream of the Little Creek WWTP and in the Little River at SR 2333. The low pH observations may be related to either a high concentration of dissolved organic matter or somewhat acidic groundwater discharges or measurement error.

pH readings in the benthic locations in August, 2009 were within the water quality standard.

Laboratory Results

Turbidity

Turbidity is a measure of the cloudiness of water- the cloudier the water, the greater the turbidity. Turbidity in water is caused by suspended matter such as clay, silt, and organic matter and by plankton and other microscopic organisms that interfere with the passage of light through the water. Turbidity is closely related to total suspended solids (TSS), but also includes plankton and other organisms. Increased turbidity can often be the result of intense or sustained rainfall events. The DWQ water quality standard (and EL) is 50 NTU.

High values of turbidity may indicate a stressor to benthic macroinvertebrates, fish and aquatic life. Higher turbidity increases water temperatures because suspended particles absorb more heat. Suspended materials can clog fish gills, reducing resistance to disease in fish, lowering growth rates, and affecting egg and larval development. As the particles settle, they can blanket the stream bottom filling aquatic habitat (especially in slow moving, lower gradient streams), smother fish eggs and benthic macroinvertebrates (USEPA, http://www.epa.gov/owow/monitoring/volunteer/stream/vms55.html). Sources of turbidity in the LWP area and its tributaries may include: upland soil erosion; urban runoff; eroding stream banks; bedload; and, excessive algal growth.

Turbidity levels detected rarely exceeded 50 NTUs and only in the Poplar Creek location. See Figure A8 in the Appendix.

Fecal coliform bacteria

Fecal coliform bacteria indicate the presence of pathogenic organisms (viruses, protozoans, bacteria). Sources include soil erosion, animal waste (wildlife, pets, livestock), leaking sewer lines, straight pipes and maltreated effluents. Once in-stream, many factors affect pathogen survival including exposure to sunlight, predation, nutrient levels, toxic substances and resuspension of sediment (USEPA, 2001). Unfortunately, stream conditions favorable for aquatic insects and fish (lower solar radiation, cooler temperatures, low turbidity) are also favorable for pathogen survival so it is important to manage sources if possible.

Results for fecal coliform data are provided in the Appendix in Table A1 and Figure A6. To determine whether fecal coliform bacteria are exceeding water quality standards, five samples must be collected within a 30-day period. This requires a special sampling effort not obtained through the routine monthly sampling conducted as part of the LNRBA and DWQ ambient water quality monitoring programs. The 400 cols/100 mL EL value represents the concentration which if exceeded in more than 20% of the samples collected within a 30-day period could represent a standard violation. For our purposes, it provides a value for which to compare results among monitoring locations.

Fecal coliform indicator data from the four coalition locations were below 400 cols/100 mL most of the time during the period of record. The Poplar Creek location appeared to exceed the EL more times than both Little Creek locations (26 monitoring events vs 13 monitoring events) while the Little River exceeded the EL on only five occasions. More investigation may be warranted in the Poplar Creek sub-watershed. The exceedences may be related to the two WWTPs upstream that discharge to Poplar Creek (Ashley Hills and Kings Grant Subdivision discussed below).

Nutrients

Nutrients are chemical elements and compounds found in the environment that plants and animals need to grow and survive. For water-quality investigations the various forms of nitrogen and phosphorus are the nutrients of interest. The forms include nitrate, nitrite, ammonia, organic nitrogen (in the form of plant material or other organic compounds), and phosphates (orthophosphate and others). Nitrate is the most common form of nitrogen and phosphates are the most common forms of phosphorus found in natural waters. Elevated concentrations of nutrients in water bodies can potentially cause eutrophication (excessive growth and decomposition of microscopic and macroscopic vegetation) and hypoxia (low dissolved oxygen) depending on other conditions (e.g. a lack of riparian vegetation and shading).

DWQ has not established water quality standards for nutrients but has developed a plan to manage excess nutrients including the requirements covered under the supplemental NSW classification assigned to the Neuse River Basin. See the following website for details on the plan http://h2o.enr.state.nc.us/csu/swstdsfaq.html#NC_Nutrient_Plan.

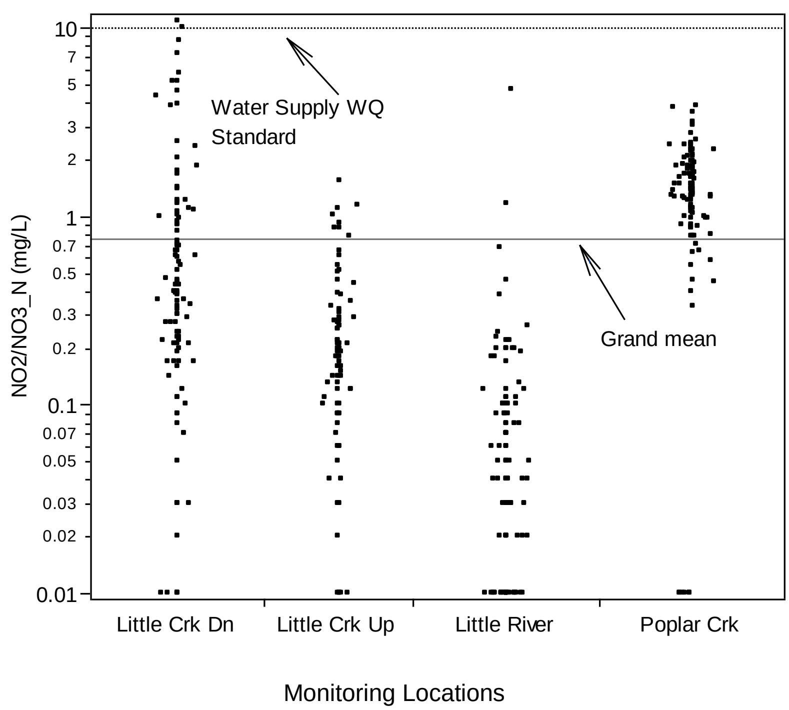

Figure 4. Nitrate-nitrite nitrogen levels for LNRBA stations January, 2000 through July, 2009. See Table A1 in Appendix for summary statistics. Little Crk Dn is downstream of WWTP discharge. Y axis is log scale.

Waters with a Water Supply (WS) designation are assigned a **nitrate-nitrite nitrogen** standard of 10 mg/L which can be used as a benchmark for comparison purposes (Figure 4 above). Data from monitoring locations downstream of WWTP discharges are also useful to review and compare to provide a point of reference. For example at the LNRBA station in Little Creek downstream of the WWTP, nitrate-nitrite values range from laboratory detection limits (0.01 mg/L) to a maximum of 10.8 mg/L, while upstream of the WWTP in Little Creek, levels reached a maximum of only 1.5 mg/L. The upstream maximum value is likely the value that should be considered closer to representative of the maximum "background" level (or within the range) for this stream and others in the LWP area.

More investigation may be warranted in the Poplar Creek sub-watershed to determine sources of somewhat elevated nitrate-nitrite nitrogen. For example, in Poplar Creek, most of the measurements were greater than the grand mean (Figure 4 above). And, one out of ten (10%) of the observations were 2.4 mg/L or above (See Table A1 in the Appendix). Two minor WWTPs (< 1.0 MGD) discharge to Poplar Creek which may explain the somewhat elevated values but more investigation would be needed for more certainty (see Summary of NPDES Facilities below). The occasional higher values are not major concerns but there may be a source(s) (leaking septic systems, sewer lines or livestock operations) in the sub-watershed that occasionally discharges excess nutrients which in turn contribute to the nitrogen load downstream in the basin.

There was not a major difference in total Kjeldhal nitrogen (TKN), a measure or both ammonia nitrogen and organic nitrogen, between locations. The same pattern emerges from review of the total phosphorus (TP) data (see Figure A12 in the Appendix). However, there was one elevated TP value (3.0 mg/L) on May 23, 2008 for the Poplar Creek location (see Table A1 in the Appendix). This may be an aberration since both turbidity and total suspend residue values were not elevated and stream flows in the area on that day were roughly average for the month. Nitrate-nitrite nitrogen on that day was somewhat elevated as well (2.2 mg/L). Again, some additional investigations may be needed in Poplar Creek to determine if sources (e.g., livestock operations or stockpiled fertilizer) of these and other potential pollutants are present in the sub-watershed.

Biological Assessments

The DWQ Biological Assessment Unit (BAU) evaluates water quality of streams and rivers using biological communities (benthic macroinvertebrates and fish) and aquatic habitat. There are several reasons for using biological surveys in monitoring water quality. Conventional water quality surveys do not integrate fluctuations in water quality between sampling periods; short-term critical events may often be missed. The biota reflect both long and short term conditions, since many species in these communities have life cycles of a year or more. Fish and benthic macroinvertebrate communities consist of pollution tolerant and intolerant species. More diversity and numbers of intolerant species generally indicate better water quality.

Metrics derived from biological samples include the number of taxa, the number of EPT taxa (i.e. taxa representing mayflies, stoneflies and caddisflies), and a biotic index. North Carolina's biotic index (NCBI) is based on tolerance values (i.e. tolerance to pollution) of individual taxa on a scale of 0 – 10 with higher numbers reflecting more tolerant taxa and polluted conditions. From these metrics one of five Bioclassifications can be assigned. These are: Poor, Fair, Good-Fair, Good and Excellent.

Until recently, benthos samples from watersheds less that 3 mi^2 were not bioclassified but received a Not Impaired or Not Rated designation based on EPT richness criteria for EPT samples (using Qual 4 methods) on larger streams. Sites that would rate "Good-Fair" or better are considered "Not Impaired". However, staffs with BAU have recently developed biocriteria for small streams (DWQ, 2009c) of which was used by NCSU in their recent benthos survey (summarized below) for this LWP. More details of the BAU protocol for fish and benthic macroinvertebrates (including small stream biocriteria) are provided at the following website http://h2o.enr.state.nc.us/esb/BAU.html.

Tables 2 and 3 provide benthic macroinvertebrate and fish data extracted from the 2006 Neuse basinwide assessment report http://h2o.enr.state.nc.us/esb/bar.html, the CH2M Hill Wake County Comprehensive Watershed Management Plan (2003) and the recent NCSU benthos report for this LWP conducted in August, 2009.

Benthic macroinvertebrate assessments

In general, benthic communities throughout the LWP were likely stressed due to water quality conditions impacted by low flow/dissolved oxygen problems related to drought, instream impoundments, beaver ponds and limited benthic access to aquatic habitats. As noted in the NCSU report (2009), the assessment team had difficulties finding appropriate monitoring locations due to zero or low flow conditions. Two locations (Buffalo Creek at Mitchell Mill Road and Hominy Creek at Buck Road) were not rated due to swamp-like conditions with dissolved oxygen below 2.0 mg/L. Many substantial segments of the Little River were described as longitudinal wetlands. A similar problem (locating sites with adequate flow conditions) was encountered by the CH2M Hill team in 2001.

Table 2. Summary of benthic macroinvertebrate and total habitat data for Wake-Johnston LWP area.

Map Code	Location	Date	Program	EPT Taxa Richness	NCBI	Bioclassification	Unique Taxa
1	Beddingfield Creek at Shotwell Rd., SR 1553, Johnston	August, 2009	LWP	18	5.2	Good	yes+
2	Poplar Creek at Smithfield Rd., SR 2233, Wake	August, 2009	LWP	9	6.2	Fair	yes+
3	Poplar Creek at Bethlehem Rd., SR 2049, Wake	August, 2009	LWP	11	5.8	Good-Fair	yes+
4	Marks Creek at Eagle Rock Rd., SR 2501, Wake	August, 2009	LWP	7	6.9	Fair	no
4	Marks Creek at Eagle Rock Rd., SR 2501, Wake	August, 2001	CH2M Hill	5	7.39	Fair	-
5	Marks Creek at Prichard Rd., SR 1714 Johnston	August, 2009	LWP	15	5.5	Good-Fair	yes
5	Marks Creek at Prichard Rd., SR 1714 Johnston	August, 2005	BAU	16	4.84	Good-Fair	-
5	Marks Creek at Prichard Rd., SR 1714 Johnston	August, 2001	CH2M Hill	13	5.60	Good-Fair	-
5	Marks Creek at Prichard Rd., SR 1714 Johnston	Sept., 2000	BAU	19	5.12	Good-Fair	-
6	Buffalo Creek at Mitchell Mill Rd., SR 2224 Wake	August, 2009	LWP	3	7.1	N/A	no
7	Buffalo Creek at Poole Rd., SR 1007, Wake	August, 2009	LWP	9	6.7	Fair	no
7	Buffalo Creek at Poole Rd., SR 1007, Wake	July, 2005	BAU	15	6.91	Fair	-
8	Hominy Creek at Buck Rd., SR 2329, Wake	August, 2009	LWP	4	7.1	N/A	yes
9	Rocky (Fall) Branch at Riley Hill Rd. SR 2320, Wake	August, 2009	LWP	9	6.5	Fair	yes
10	Snipes Creek at Taylors Mill Rd., SR 1723, Johnston	August, 2009	LWP	5	6.6	Fair	yes
11	Little River above NC 231, Johnston	August, 2009	LWP	14	6.0	Good-Fair	no
12	Poplar Creek at Grasshopper Rd., SR 2511, Wake	August, 2001	CH2M Hill	8	5.71	Good-Fair	-
13	Buffalo Creek at Riley Hill School Rd., SR 2320, Wake	August, 2001	CH2M Hill	1	8.21	Poor	-

Notes: Bioclassifications for the current LWP were calculated using BAU criteria for small piedmont streams (DWQ, 2009c). Most of the unique taxa were collected at locations noted as yes+. Unique taxa were not noted in other assessments (i.e, BAU and CH2M Hill).
N/A – Locations that were considered more swamp like with little flow, therefore piedmont criteria may not apply.
LWP – Refers to the Wake-Johnston County Local Watershed Plan currently in development.
CH2M Hill – The consultant which prepared the Comprehensive Watershed Management Plan for Wake County (CH2M Hill, 2003).
BAU – The Biological Assessment Unit (BAU) of the North Carolina Division of Water Quality (DWQ).
EPT – Ephemeroptera, Plecoptera and Trichoptera are three taxonomic Orders of pollution sensitive aquatic insects.
NCBI – North Carolina Biotic Index for all species collected (DWQ, 2006b).

For the reasons described above, the extent to which point and non-point source pollutants stress the benthic community within the LWP area is unclear; however, some evidence is provided by a predominance of pollution tolerant taxa as reflected by a higher NCBI for locations where low flow may not be a major factor. For example, NCBI scores in Table 2 above for both upstream locations in Marks and Poplar Creeks (NCBI = 6.9 and 6.2 respectively), Buffalo Creek at Poole Road (NCBI = 6.7) and Snipes Creek (NCBI = 6.6) suggested that pollutant stressors may be playing a role in addition to other stress factors.

Bioclassifications did not change between years at locations where assessments occurred in different years conducted by two or more different groups. For example in Table 2 above, the upstream location in Marks Creek at Eagle Rock Road was rated Fair in 2001 and 2009, as was Buffalo Creek at Poole Road in 2005 and 2009. As noted by the NCSU assessment team in 2009, low flow/velocity leading to macrophytic growth and low dissolved oxygen may be some of the stress factors in the Marks Creek segment (nutrient data were not available for this location). There were no unique taxa collected from either location.

The downstream location in Marks Creek at Prichard Road was rated Good-Fair in all four assessments between 2000 and 2009 (Table 2) indicating stable water quality conditions. In was interesting that habitat conditions in this location degraded substantially between 2005 and 2009 (see habitat section below) from a total score of 74 to 52.

Other findings from the NCSU (2009) benthos report include the following.

- Beddingfield Creek at Shotwell Road (partially within the Clemmons State Forest) was the only location rated Good. Many of the unique taxa were identified in this location.
- The benthic community in the downstream location in Poplar Creek at Bethlehem Road had some intolerant taxa in common with the Beddingfield Creek location. Unique taxa were identified in both locations.
- Downstream reaches of both Poplar and Marks Creek were less degraded than the upstream reaches suggesting that stressors were affecting the benthic community in upstream segments of these streams.
- Dominant taxa in the downstream location in Buffalo Creek at Poole Road were mostly pollution tolerant taxa which suggested upstream pollution sources. No uncommon or unique taxa were identified.
- Habitat conditions in the form of numerous midstream sediment bars in Snipe Creek may be partially responsible for the degraded benthic community surveyed in this location. Unique taxa were identified in this location.
- The benthic community in Rocky Branch was degraded (Fair) but consisted of unique and uncommon taxa not found in other LWP locations. Habitat conditions were scored as one of the highest (80).

Fish community assessments

BAU conducted fish assessments in the downstream location in Marks Creek at Pritchard Road and in Buffalo Creek at Poole Road (Table 3 below). The Marks Creek location is part of DWQ’s ambient monitoring program where assessments recur in five-year increments. The Buffalo Creek location was monitored in 2005 by request of the DWQ’s Raleigh Regional Office which needed baseline data for a special study. The Wake County assessment conducted by CH2M Hill reviewed existing fish assessments conducted by BAU and did not conduct fish assessments themselves. BAU Fish ratings in Marks Creek indicated that water quality and habitats supported fish communities. The assessment in Buffalo Creek also indicated supportive water quality and habitat conditions. The benthic community, on the other hand, was less tolerant of conditions in Buffalo Creek (Table 2).

Table 3. Summary of existing BAU fish data for Wake-Johnston LWP area.

Map Code	Location	Date	NCIBI Score	NCIBI Rating
5	Marks Creek at Prichard Rd., SR 1714 Johnston	August, 2005	52	Good
5	Marks Creek at Prichard Rd., SR 1714 Johnston	April, 2000	54	Excellent
5	Marks Creek at Prichard Rd., SR 1714 Johnston	May, 1995	50	Good
7	Buffalo Creek at Poole Rd., SR 1007, Wake	April, 2005	48	Good

Notes: NCBI – North Carolina Index of Biotic Integrity (BAU, 2006). BAU - the Biological Assessment Unit (BAU) of the North Carolina Division of Water Quality (DWQ).

Habitat Assessments

The primary purpose of aquatic habitat assessments is to evaluate the quality of stream and riparian characters that influence communities of benthic macroinvertebrates or fish. This information is always collected when biological assessments are made, and is sometimes collected as part of other investigations. Habitat assessments determine, among many things, if a variety of substrate types are present, the condition of stream banks and quality of riffles and pools. The homogenization of habitat structure by human intervention is considered one of the major stressors of aquatic systems (USEPA, 1999).

Aquatic habitat assessments, in addition to other assessment methods such as chemical and physical monitoring, can help ascertain reasons for the condition of fish and aquatic insect communities (USEPA, 1999). For example, if habitat conditions are capable of supporting and maintaining a diversity of aquatic life, and the diversity of aquatic communities is depressed compared with reference conditions, then other water quality stressors may be responsible for the lack of diversity. Habitat conditions also provide evidence of altered flow regimes or hydrology due to increases in impervious surfaces in a watershed, deforestation or other perturbations such as hurricanes.

BAU developed a method to assess habitat during the mid-1990s. Metrics used by BAU to assess habitat quality for fish and benthic macroinvertebrates are based on key physical characteristics of the stream channel and surrounding riparian area along the stream. The assessment qualitatively evaluates reach scale (100 - 200 meters) conditions of existing habitat structure (riffles, pools, leaf packs, root mats, sticks and logs, bottom substrate) along with those that have the potential to degrade habitat and water quality such as the condition of riparian vegetation and stream bank stability (i.e. increased sedimentation).

Eight different sub-habitat attributes in piedmont and mountain streams are assessed qualitatively and individual metric scores are summed to provide a maximum habitat score of 100. Habitat ratings (good, fair, poor for example) have not been developed for habitat scores; although in general, habitat scores below 65 for mountain/piedmont streams are considered low to poor quality, while score 65 or higher are considered moderate to high quality. Individual, sub-habitat components (metrics) used to assess habitat are listed in Table 4. Coastal plain metric scores where applicable are in parentheses.

Table 4. Metrics used to assess habitat in piedmont, mountain streams (and coastal plain).

Metric Number	**Max Score**	**Metric Name**	**Description**
I	5 (15)	Channel modification	Assesses the evidence of dredging and/or channel alterations.
II	20	Instream habitat	Considers the percentage of a stream reach that is favorable for benthos colonization or fish cover. Type of cover assessed are rocks, macrophytes, sticks and leaf packs, snags and logs, and undercut banks or root mats.
III	15	Bottom substrate	Represents an assessment of the entire reach for the sizes of particles (gravel, cobble, etc.) composing the stream bottom. Embeddedness is only assessed at riffles.
IV	10	Pool variety	Assesses the presence/absence and frequency and sizes of pools.
V	16 (N/A)	Riffle habitats	Assesses length and width of riffles.
VI	14 (20)	Stream bank stability and vegetation	Assesses bank stability and types of riparian vegetation (e.g. wooded, mixed, grasses, etc.).
VII	10	Light penetration	Assesses whether the riparian vegetation (canopy) can block sunlight on the stream when the sun is directly above the stream.
VIII	10	Riparian vegetation zone width	Assesses width of riparian vegetation and whether there are breaks in the vegetation.

Notes: Metric scores for coastal plain streams, where different from mountain/piedmont, are in parentheses. Riffles habitats are not assessed (N/A) for coastal plain streams.

Table 5. Aquatic habitat data (Mountain/Piedmont protocol) collected during benthic macroinvertebrate assessments, 2000 - 2009.

Map Code	Location	Date	Program	Channel (5)	Instream Habitat (20)	Substrate (15)	Pools (10)	Riffles (16)	Bank Stability (14)	Shade (10)	Riparian Width (10)	Total Score (100)
1	Beddingfield Creek at Shotwell Rd., SR 1553, Johnston	August, 2009	LWP	4	12	6	4	7	9	10	6	58
2	Poplar Creek at Smithfield Rd., SR 2233, Wake	August, 2009	LWP	4	11	3	0	0	10	10	10	48
3	Poplar Creek at Bethlehem Rd., SR 2049, Wake	August, 2009	LWP	4	9	3	4	6	12	10	10	58
4	Marks Creek at Eagle Rock Rd., SR 2501, Wake	August, 2009	LWP	2	8	8	8	7	10	10	10	63
5	Marks Creek at Prichard Rd., SR 1714 Johnston	August, 2009	LWP	4	8	3	4	3	11	7	9	52
5	Marks Creek at Prichard Rd., SR 1714 Johnston	August, 2005	BAU	5	16	4	10	10	12	7	10	74
5	Marks Creek at Prichard Rd., SR 1714 Johnston	Sept., 2000	BAU	5	12	4	10	7	10	7	10	65
6	Buffalo Creek at Mitchell Mill Rd., SR 2224 Wake	August, 2009	LWP	5	16	3	10	7	14	10	10	75
7	Buffalo Creek at Poole Rd., SR 1007, Wake	August, 2009	LWP	4	16	3	6	7	8	10	8	62
7	Buffalo Creek at Poole Rd., SR 1007, Wake	July, 2005	BAU	5	7	3	0	0	4	5	9	43
8	Hominy Creek at Buck Rd., SR 2329, Wake	August, 2009	LWP	4	15	1	6	3	14	8	8	59
9	Rocky (Fall) Branch at Riley Hill Rd. SR 2320, Wake	August, 2009	LWP	5	16	3	6	16	14	10	10	80
10	Snipes Creek at Taylors Mill Rd., SR 1723, Johnston	August, 2009	LWP	4	16	8	8	12	8	10	10	76
11	Little River above NC 231, Johnston	August, 2009	LWP	5	16	8	10	7	14	10	10	80

Table 6. Existing aquatic habitat data collected by BAU during fish assessments, 2000 – 2005.

Map Code	Location	Date	Protocol	Channel (5, 15)	Instream Habitat (20)	Substrate (15)	Pools (10)	Riffles (16)	Bank Stability (14, 20)	Shade (10)	Riparian Width (10)	Total Score (100)
5	Marks Creek at Prichard Rd., SR 1714 Johnston	April, 2005	MP	5	14	3	10	5	12	3	10	62
5	Marks Creek at Prichard Rd., SR 1714 Johnston	April, 2005	CP	15	15	7	10	n/a	18	3	10	78
5	Marks Creek at Prichard Rd., SR 1714 Johnston	April, 2000	MP	5	14	7	7	3	10	2	8	56
7	Buffalo Creek at Poole Rd., SR 1007, Wake	April, 2005	CP	15	16	13	10	n/a	14	5	9	82
7	Buffalo Creek at Poole Rd., SR 1007, Wake	April, 2005	MP	5	16	3	10	3	10	5	9	61

MP is Mountain/Piedmont protocol and CP is the Coastal Plain protocol. These streams exhibited characteristics of both the Northern Outer Piedmont and the Rolling Coastal Plain Ecoregions.

General observations relative to habitat attributes associated with benthic surveys (Table 5) include the following. Sub-habitats that were mostly on the high side for most locations included channel modification, instream habitat, bank stability, shade and riparian width. In terms of water quality, the above metrics (except for instream habitat) are important for the maintenance of water quality functions. Stable banks keep sediment in place; shade maintains cooler water temperatures during summer months and protects aquatic organisms from ultraviolet radiation. Vegetated riparian zones help to stabilize stream banks and remove pollutants. Many studies have shown that vegetated riparian zones are effective at removing nitrogen (Mayer, et al., 2005).

Attributes that were generally on the low side included riffles and substrates. Pool scores were mixed - some high and some low. Riffles (frequency and condition) are important habitats that help to maintain and support an abundant and diverse aquatic community (Brown and Brussock, 1990; DWQ, 2006b; USEPA, 1999) providing food and refugia. They also play a role in water quality functions serving as a re-aeration point. Low substrate scores indicate either riffle embeddedness or homogeneous substrates.

Two locations were assessed in previous years. Of note was the difference of certain metrics between 2005 and 2009 at the downstream location in Marks Creek at Prichard Road and at Buffalo Creek at Poole Road. Instream habitat, pools and riffles degraded substantially between years in Marks Creek, while instream habitat and riffles in Buffalo Creek improved over the same period (Table 5). Bioclassifications however did not change between periods. It is not unusual for habitat conditions to change over time as they are subjected to occasional high velocity flow regimes. In fluvial geomorphologic terms, the stream and its channel are in dynamic equilibrium (Doll, et al., 2003). However, upstream development and other watershed disturbances can disrupt the dynamic equilibrium resulting in degraded habitats as was observed in Snipes Creek described below.

It was noted in the NCSU benthic report that Snipes Creek was likely an incised system at that numerous midstream sand bars were observed. It was also noted that habitat conditions may be partially responsible for the degraded benthic community surveyed in this location.

Notable habitat attributes associated with fish surveys (Table 6) include the following. Shade scores were lower than expected given that the fish sites were also benthic sites both of which were assessed by BAU. It is likely the differences are the result of variability (i.e., error) associated with qualitative assessments. Other metrics however were judged similarly and given comparable scores. As mentioned above, water quality and habitats supported fish communities.

USGS Stream Flow Data

USGS monitors stage and discharge in the Little River at NC 97 (55 square mile drainage) in cooperation with the City of Raleigh, providing real time data along with daily, monthly and annual statistics (Figure 1). Data are available from October 2, 2008 to the present. The following link will take you to the website USGS gage number 02088383 where data and graphs can be viewed.

Lake Myra Sediment Study

Wake County is cooperation with NCSU-BAE conducted a bathymetric survey of the upstream bottom portions of Lake Myra on DATE to determine the extent of sediment accumulation. The following website provides a few pictures of the survey. The objective of the study was to compare current existing sediment levels with those in the future as the upstream watershed begins to develop. http://www.bae.ncsu.edu/programs/extension/wqg/srp/lake_myra.html

Summary of NPDES Facilities

The DWQ BIMS database was queried to identify active water quality permits during 2005 through 2009, and to summarize compliance, violations and penalty amounts. Sites identified are depicted in Figure 5 and summarized in Table 7. Violation type and penalties paid are summarized in Table 8.

Table 7. NPDES permitted facilities within the Wake-Johnston LWP area.

Map Code	Permit Number	Facility Name	Major/Minor	Receiving Stream	Latitude	Longitude
A	NC0038938	Corinth-Holder Elementary & Middle School	100% Domestic < 1 MGD	Little River	35.7344	-78.2830
B	NC0051322	Ashley Hills WWTP	100% Domestic < 1 MGD	Poplar Creek	35.7563	-78.4686
C	NC0062219	Kings Grant Subdivision WWTP	100% Domestic < 1 MGD	Poplar Creek	35.7302	-78.4605
D	NC0064378	Willowbrook WWTP	100% Domestic < 1 MGD	Beddingfield Creek	35.6811	-78.5000
E	NC0065706	Cottonwood/Baywood	100% Domestic < 1 MGD	Poplar Creek	35.7625	-78.4727
F	NC0081540	Square D Company	Groundwater Remediation	Marks Creek (Lake Myra)	35.8277	-78.4588
G	NC0086266	Woodtrace WTP	Water Treatment Plant	Rocky Branch	35.8430	-78.4005

Notes: WWTP – Wastewater Treatment Plant; WTP – Water Treatment Plant; MGD – Million gallons per day. Square D Company completed remediation as of January, 2008.

Three minor wastewater treatment plants (WWTP) discharge domestic wastewater to Poplar Creek. The Little River and Beddingfield Creek receive treated wastewater from minor WWTPs including Corinth-Holder Elementary and Middle School and Willowbrook WWTP respectively. Rocky Branch receives wastewater from the Woodtrace water treatment plant (WTP). Until recently, a groundwater remediation facility discharged to Marks Creek but remediation was complete as of January, 2008. A summary of the violations is provided below.

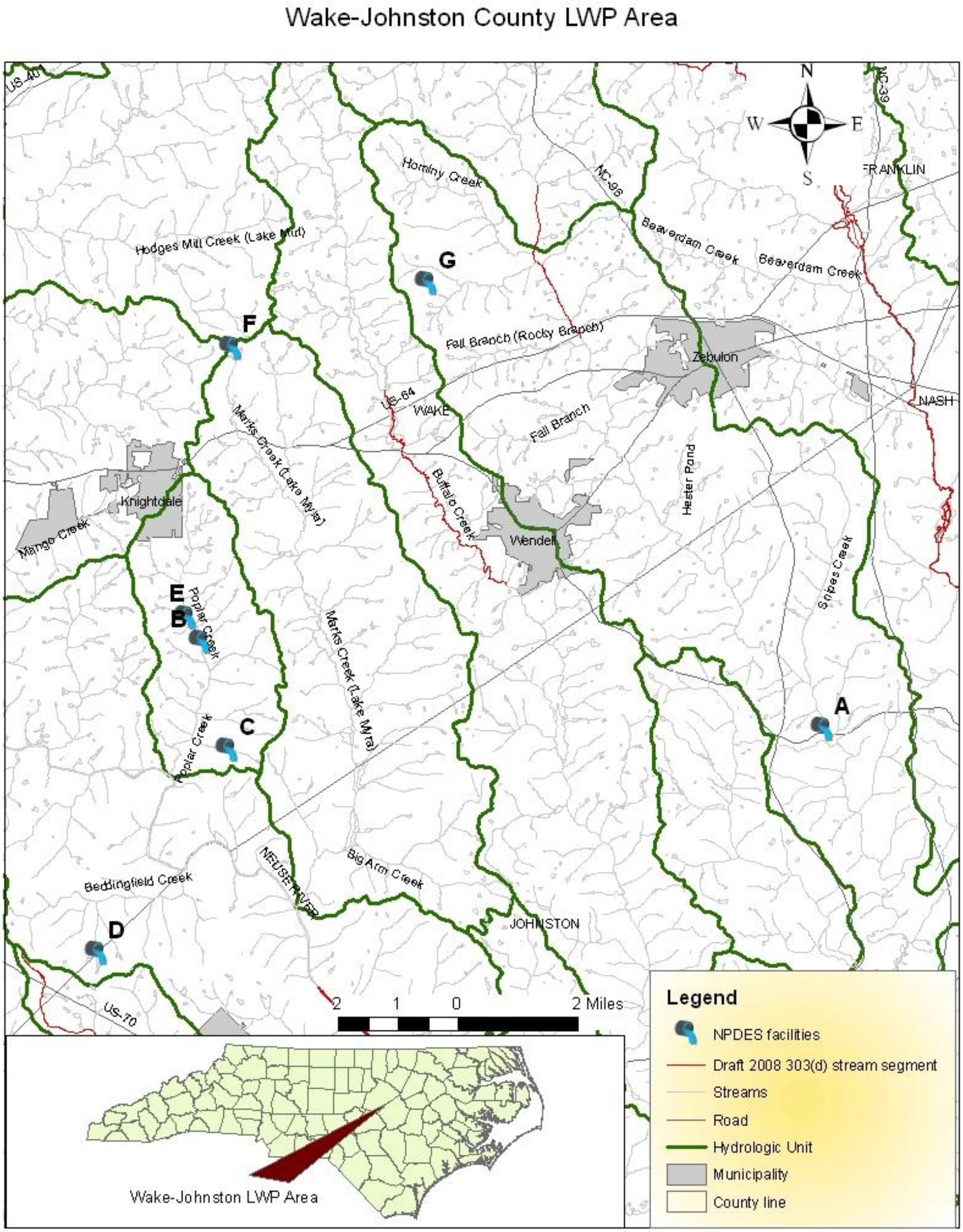

Figure 5. NPDES facilities located in the LWP area. Letter codes for each facility are explained in Tables 7 and 8.

Table 8. NPDES facilities with reported violations including penalties paid (January, 2005 – September, 2009).

Map Code	Permit No.	Facility Name	Parameter	Penalties Paid ($)
A	NC0038938	Corinth-Holder Elementary & Middle School	Administrative errors	1,500
B	NC0051322	Ashley Hills WWTP	BOD, Fecal coliform, Ammonia-N, administrative errors	9,000
C	NC0062219	Kings Grant Subdivision WWTP	Administrative Errors	0
D	NC0064378	Willowbrook WWTP	BOD, Fecal coliform, Ammonia-N, administrative errors	300
E	NC0065706	Cottonwood/Baywood	BOD, Fecal coliform, Ammonia-N, administrative errors	9,000
F	NC0081540	Square D Company	Administrative errors	0
G	NC0086266	Woodtrace WTP	Manganese, TSS, administrative errors	11,500

Notes: BOD is biochemical oxygen demand. TSS is total suspended solids. Square D Company was only facility required to conduct whole effluent toxicity testing – all tests passed.

Both Square D and Kings Grant Subdivision were cited for administrative errors (frequency of reporting, incorrect units of measure) but did not receive a financial penalty. The Woodtrace WTP paid the highest penalty over the period ($11,500) for parameter limit violations. Ashley Hills and Cottonwood/Baywood WWTPs both of which discharge to Poplar Creek paid $9,000 for parameter limit violations and administrative errors each and Willowbrook and Corinth-Hodler Elementary and Middle School paid the least in penalties for administrative and parameter limit violations.

Occasional compliance problems note above are not likely to have major effects to water quality of the receiving streams. However, since there are three discharges in the Poplar Creek sub-watershed and water quality concerns in the headwater areas were identified, it would be a good idea conduct additional investigations and monitoring in this sub-watershed to identify other potential stressors to water quality.

Summary and Conclusions

Water quality data from several sources were reviewed for streams within the Wake-Johnston County LWP area. The review was conducted to help identify water quality problems, guide further monitoring and assist with developing a watershed plan that meets EEP mitigation needs and protects and improves water quality and other watershed functions.

The chemical, physical and biological data reviewed were from DWQ's ambient monitoring program and the 2006 Neuse River Basinwide Assessment Report, the STORET database for streams monitored by the LNRBA, Wake County's Comprehensive Watershed Management Plan completed in 2003 and the recent benthic assessment report conducted by NCSU in August, 2009. DWQ's BIMS database was also mined to review and summarize monitoring and compliance data for several NPDES facilities.

Overall water quality trends across the LWP area.

Existing ambient chemical and physical data were scant. There were only two LNRBA ambient locations with data to evaluate. These monthly data were compared with data from two other LNRBA locations nearby the LWP for the period of January, 2000 through July, 2009. Based on ambient data alone, the Poplar Creek sub-watershed emerged with the most water quality concerns. Other locations of concern are noted below.

- Field readings were as expected with noted exceptions in the Little River where DO levels were below water quality standards and somewhat elevated specific conductance levels in Poplar Creek at Bethlehem Road. In Poplar Creek, the elevated specific conductance observations suggest upstream pollution inputs but more investigation needs to be conducted to rule this out.

- Ambient chemical and physical data collected by the LNRBA indicated somewhat elevated nitrite-nitrate nitrogen levels in Poplar Creek compared to other locations. This may be due to upstream NPDES discharges but more investigation is warranted to determine if other sources may be contributing to the nutrient load.

- Fecal coliform bacteria data in Poplar Creek suggest that there may be a source of contamination in the sub-watershed upstream of the monitoring locations. Levels above 400 cols/100 mL were exceeded on more occasions than in the other locations. Sources need to be investigated further.

- Portions of the Little River and Buffalo Creek are listed as impaired on the revised 2008 draft 303(d) impaired waterbodies list for low dissolved oxygen and biological integrity respectively. The cause for low DO may be related to low flow rather than pollutants with high biochemical oxygen demand (BOD) although assessment work has not been conducted to confirm this. It was noted that portions of steams within the LWP experience periods of low flow due to climatic conditions, impoundments and beaver.

Existing biological communities (benthic and fish) indicated a range of water quality and habitat conditions suggesting opportunities for improvement. Of the nine benthic locations that were rated in the 2009 survey, four supported aquatic communities and five did not. However, there was evidence of good water quality in many locations as indicated by the collection of uniquel taxa. Fish communities in the two locations monitored in 2005 and prior, were supported by water quality and habitat conditions.

- The best water quality conditions were found in Beddingfield Creek which received a Good rating. A large portion of the drainage area is within Clemmons State Forest.

- No change in water quality conditions were detected between assessment periods for each of three benthic locations that had benthic surveys in previous years including the Marks Creek downstream location at Prichard Road (Good-Fair in 2000, '01, '05 and

'09), the Marks Creek upstream location at Eagle Rock Road (Fair in 2001 and '09) and Buffalo Creek at Poole Road (Fair in 2005 and '09).

- Upstream reaches of both Poplar and Marks Creek were more degraded than downstream suggesting that more investigations are needed to identify potential stressors in headwater areas.

- Unstable habitats in Snipes Creek may be partially responsible for the degraded benthic community in this sub-watershed. More investigation may be needed to determine cause of habitat degradation.

- Buffalo Creek at Poole Road may need further investigation to determine if low dissolved oxygen levels are caused by low flow problems and if other pollutant stressors are contributing to the degraded benthic community.

References

Allan, J. D., 2004. Landscapes and Riverscapes: The Influence of Land Use on Stream Ecosystems. Annual Review of Ecology, Evolution, & Systematics . 35:257-84.

Brown, A.V. and P.P. Brussock. Comparisons of benthic invertebrates between riffles and pools, 1990. Hydrobiologia 220: 99 – 108. December.

CH2M Hill, 2003. Comprehensive Watershed Management Plan for Wake County, NC. January.

Doll, B.A., G.L. Grabow, K.R. Hall, J. Halley, W.A. Harman, G.D. Jennings and D.E. Wise, 2003. Stream Restoration: A Natural Channel Design Handbook. NC Stream Restoration Institute, NC State University. 128 pp.

Griffith, G.E., Omernik, J.M., Comstock, J.A., Schafale, M.P., McNab, W.H., Lenat, D.R., MacPherson, T.F., Glover, J.B., and Shelburne, M.B., 2002. *Ecoregions of North Carolina and South Carolina,* (color poster with map, descriptive text, summary tables, and photographs): Reston, Virginia, US Geological Survey (map scale 1:1,500,000).

Mayer, P.M., S.K. Reynolds, and T.J. Canfield, 2005. Riparian Buffer Width, Vegetative Cover, and Nitrogen Removal Effectiveness: A Review of Current Science and Regulations. EPA/600/R-05/118. October.

NCDENR, 2007. Division of Water Quality "Redbook", Surface Waters and Wetlands Standards. NC Administrative Code 15A NCAC 02B.0100, .0200 and .0300. May.

DWQ, 2006a. Basinwide Assessment Report - Neuse River Basin. Environmental Sciences Section. April. http://h2o.enr.state.nc.us/esb/Basinwide/Neuse06BasinReportFinal.pdf

DWQ, 2006b. Standard Operating Procedures for Benthic Macroinvertebrates. Environmental Sciences Section, Biological Assessment Unit. July. http://h2o.enr.state.nc.us/esb/BAUwww/benthossop.pdf

DWQ, 2006c. Standard Operating Procedures for Stream Fish Community Assessment Program. Environmental Sciences Section, Biological Assessment Unit. August. http://h2o.enr.state.nc.us/esb/BAUwww/IBI%20Methods.2006.Final.pdf

DWQ, 2009a. Scope of Work for Wake-Johnston Collaborative Local Watershed Plan, Water Quality Monitoring. Prepared by DWQ Watershed Assessment Team (WAT). October.

DWQ, 2009b. Final Neuse River Basinwide Water Quality Plan. July. Planning Section. http://h2o.enr.state.nc.us/basinwide/index.htm.

DWQ, 2009c. Small Streams Biocriteria Development. Environmental Sciences Section. May.
NCSU, 2009. Wake-Johnston County Water Quality Investigation. August.

Sedell, J. R., G. H. Reeves, F. R. Hauer, J A. Stanford and C. P. Hawkins, 1990. Role of Refugia in Recovery from Disturbances: Modern Fragmented and Disconnected River Systems. Environmental Management. Vol. 14, No 5, pp. 711-724.

USEPA. 1999. Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers. EPA 841-B-99-002.

USEPA. 2001. Protocol for Developing Pathogen TMDLs. EPA 841-R-00-002. January.

Appendix A Summary statistics (Little Creek, Little River, Poplar Creek).

This section of the Appendix presents tabular summary statistics for chemical and physical data collected by LNRBA nearby and within the LWP area.

Table A1. LNRBA ambient monitoring data – January, 2000 through July, 2009.

Parameter	Stats.	Little Creek Dn J6450000	Little Creek Up J6410000	Little River J5620000	Poplar Creek J4080000
NO2/NO3_N (mg/L)	N	106	91	114	113
	Min	0.01	0.01	0.01	0.01
	10%	0.03	0.02	0.01	0.56
	Median	0.40	0.19	0.04	1.40
	90%	3.90	0.60	0.21	2.38
	Max	10.80	1.54	4.74	3.86
	Std Dev	2.0	0.3	0.5	0.8
TKN_N (mg/L)	N	106	90	113	111
	Min	0.20	0.20	0.10	0.10
	10%	0.40	0.38	0.25	0.22
	Median	0.67	0.60	0.50	0.44
	90%	1.23	0.87	0.92	0.79
	Max	2.10	3.70	2.25	1.79
	Std Dev	0.3	0.4	0.3	0.3
NH3_ N (mg/L)	N	106	91	113	112
	Min	0.01	0.01	0.01	0.01
	10%	0.01	0.01	0.01	0.01
	Median	0.06	0.07	0.05	0.06
	90%	0.19	0.16	0.12	0.18
	Max	3.60	0.53	0.42	0.53
	Std Dev	0.4	0.1	0.1	0.1
TP (mg/L)	N	106	91	113	113
	Min	0.02	0.01	0.01	0.01
	10%	0.06	0.06	0.03	0.07
	Median	0.14	0.11	0.08	0.14
	90%	0.34	0.19	0.15	0.28
	Max	0.73	0.82	0.78	3.03
	Std Dev	0.1	0.1	0.1	0.3
Suspended Residue (mg/L)	N	86	77	114	113
	Min	1.0	3.0	1.0	1.0
	10%	2.9	3.5	1.0	2.8
	Median	5.6	5.3	3.7	6.5
	90%	11.3	15.6	9.7	32.6
	Max	75	99	60	191
	Std Dev	8.4	13.8	6.5	31.3
Turbidity (NTU)	N	86	77	114	113
	Min	4	1	0.4	2
	10%	5	7	3	4
	Median	9	10	6	10
	90%	14	17	16	26
	Max	40	36	38	130
	Std Dev	5.0	6.0	6.6	17.0

Table A1. LNRBA ambient monitoring data – January, 2000 through July, 2009.

Parameter	Stats.	Little Creek Dn J6450000	Little Creek Up J6410000	Little River J5620000	Poplar Creek J4080000
Fecal Coliform (cols/100 mL)	N	106	91	114	113
	Min	8	7	3	20
	10%	23.7	26	14.5	55.4
	Median	67	86	51.5	132
	90%	600	538	220	636
	Max	9200	11400	1100	6800
	Std Dev	1246	1429	165	755

Notes: Period of record for both Little Creek locations began in May, 2000. Up and Down (Dn) are upstream and downstream of WWTP treated effluent discharge.

Table A2. LNRBA ambient field monitoring data – January, 2000 through July, 2009.

Parameter	Stats.	Little Creek Dn J6450000	Little Creek Up J6410000	Little River J5620000	Poplar Creek J4080000
Dissolved Oxygen (mg/L)	N	135	122	163	162
	Min	3.2	3.4	0.2	5.2
	10%	4.6	4.33	1.24	6.2
	Median	6.3	6.2	4.4	7.7
	90%	10.4	10.1	9.4	10.9
	Max	12.1	11.6	11.6	12.7
	Std Dev	2.1	2.0	2.9	1.7
Temp (°C)	N	135	122	163	162
	Min	3.0	2.8	2.9	2.0
	10%	8.2	8.0	6.8	7.0
	Median	21.5	20.6	20.4	19.8
	90%	25.2	23.4	26.8	24.3
	Max	28.5	27.4	32.5	27.4
	Std Dev	6.4	5.9	7.5	6.5
pH (su)	N	135	121	163	161
	Min	5.7	5.4	5.3	6.1
	10%	6.6	6.1	6.1	6.5
	Median	6.8	6.6	6.5	7.0
	90%	7.2	6.8	6.9	7.4
	Max	7.5	7.5	8.0	7.8
	Std Dev	0.3	0.3	0.4	0.3
Specific Conduct. (uS/cm)	N	135	122	163	162
	Min	71	50	34	52
	10%	99	80	58	86
	Median	188	101	78	117
	90%	509	132	118	178
	Max	688	180	164	250
	Std Dev	156.9	20.7	23.4	37.3

Notes: Period of record for both Little Creek locations began in May, 2000. Up and Down (Dn) are upstream and downstream of WWTP treated effluent discharge.

Appendix A continued. This section of the Appendix presents the same data as above but in graphs as

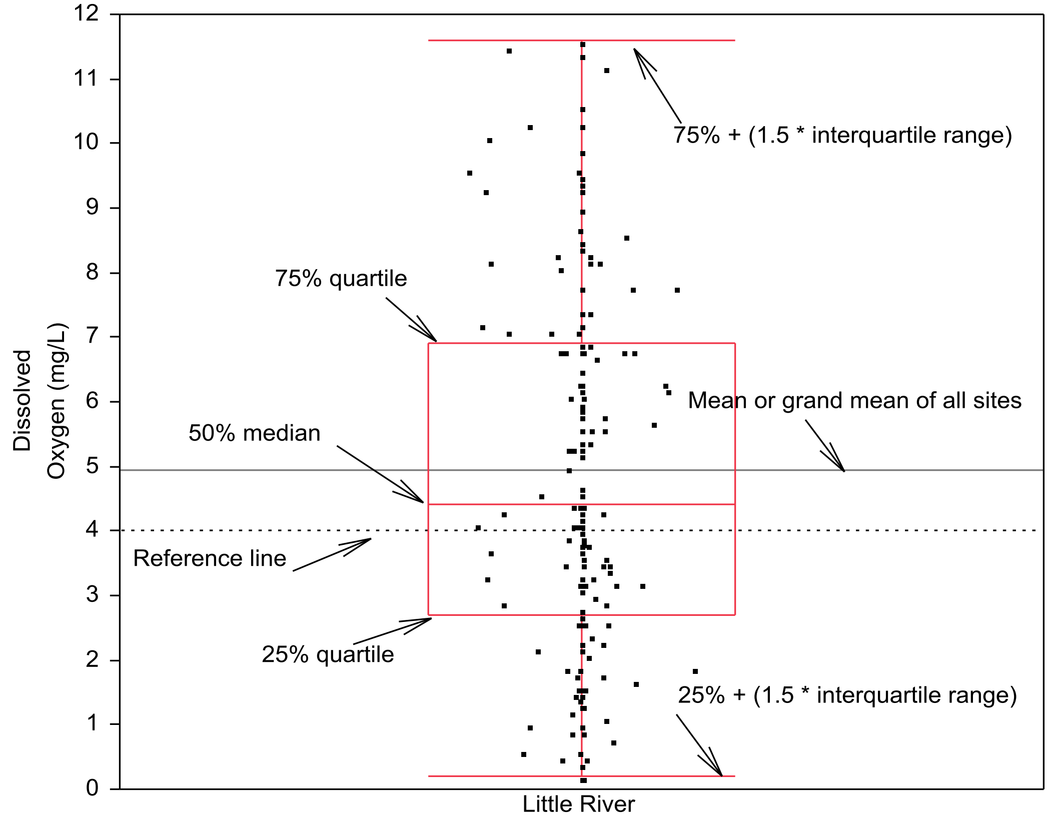

Figure A1. An example box plot with explanations of summary statistics. The interquartile range is the difference between quartiles or percentiles. Points above or below the end of upper and lower whisker are outliers.

explained in Figure A1 below.

Figures A2 through A12. below portray ambient data collected by LNRBA during the roughly nine-year period beginning in January, 2000 through July, 2009 (data collection for the two Little Creek locations began in May 2000).

- Little Creek Down at NC 39 is station No. J6450000 downstream of Zebulon WWTP.
- Little Creek Up at NC 97 is station No. J6410000 upstream of Zebulon WWTP.
- Little River at DR 2333 is station No. J5620000.
- Poplar Creek at SR 2049 is station No. J4080000.

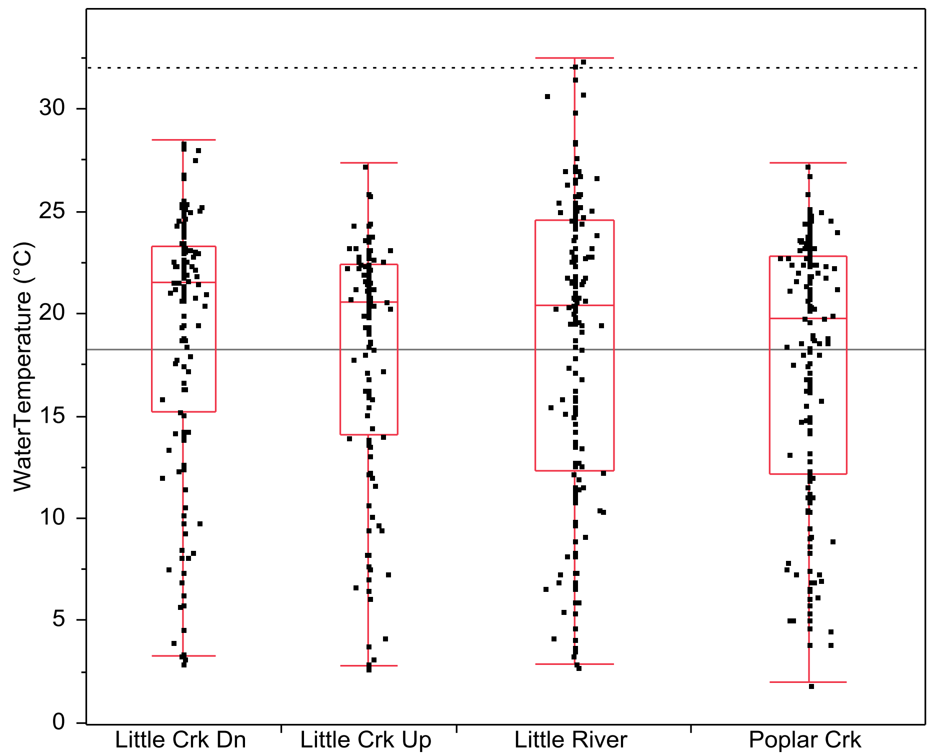

Figure A2. Water temperature (°C).

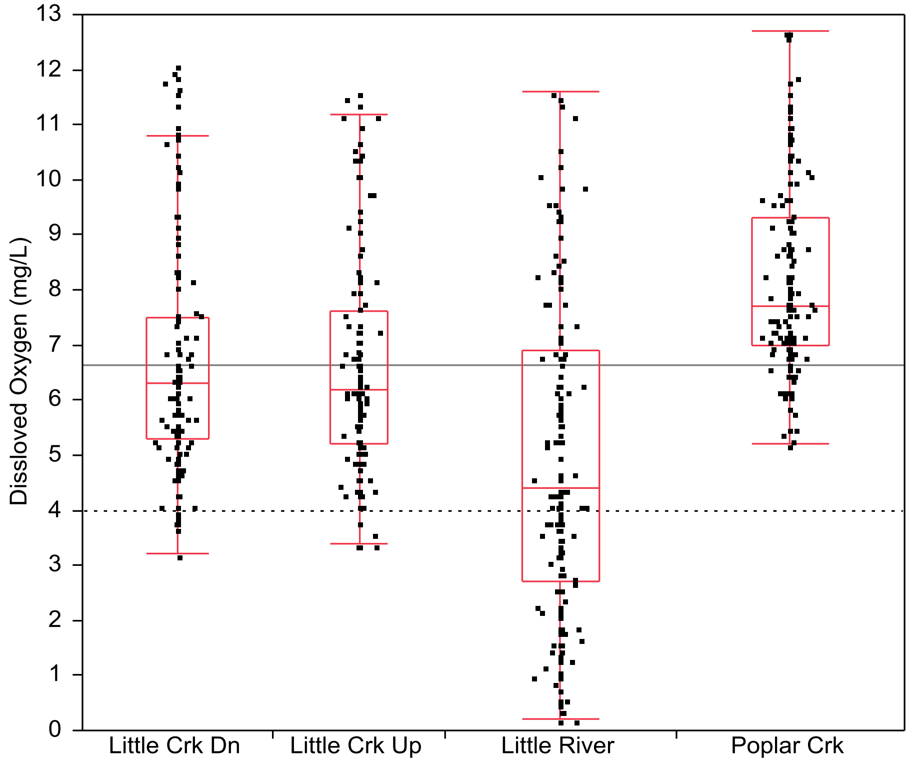

Figure A3. Dissolved Oxygen (mg/L).

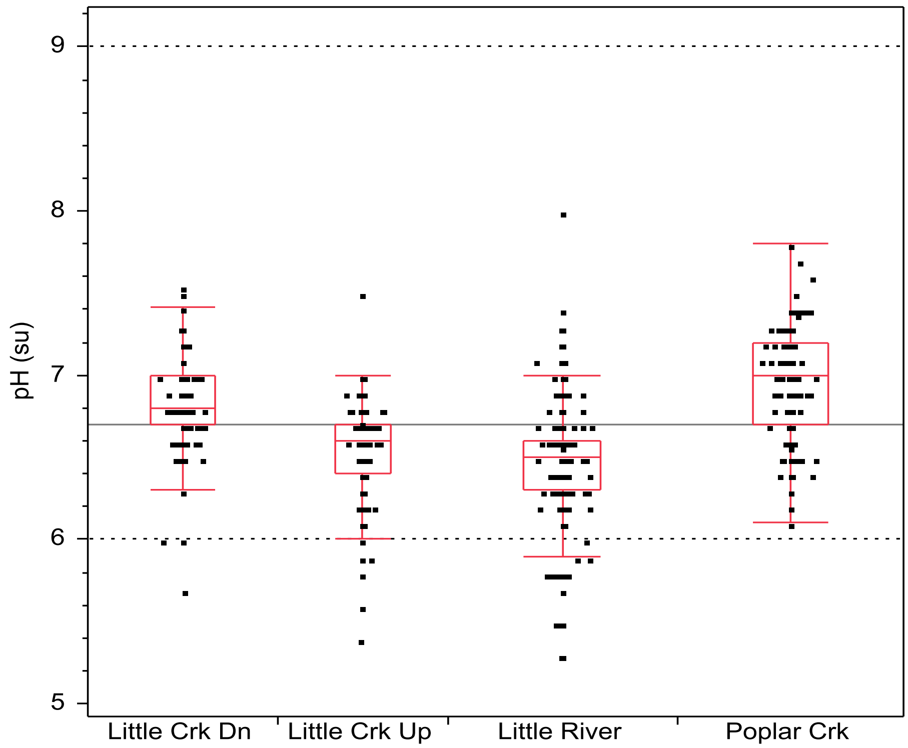

Figure A4. pH (s.u.).

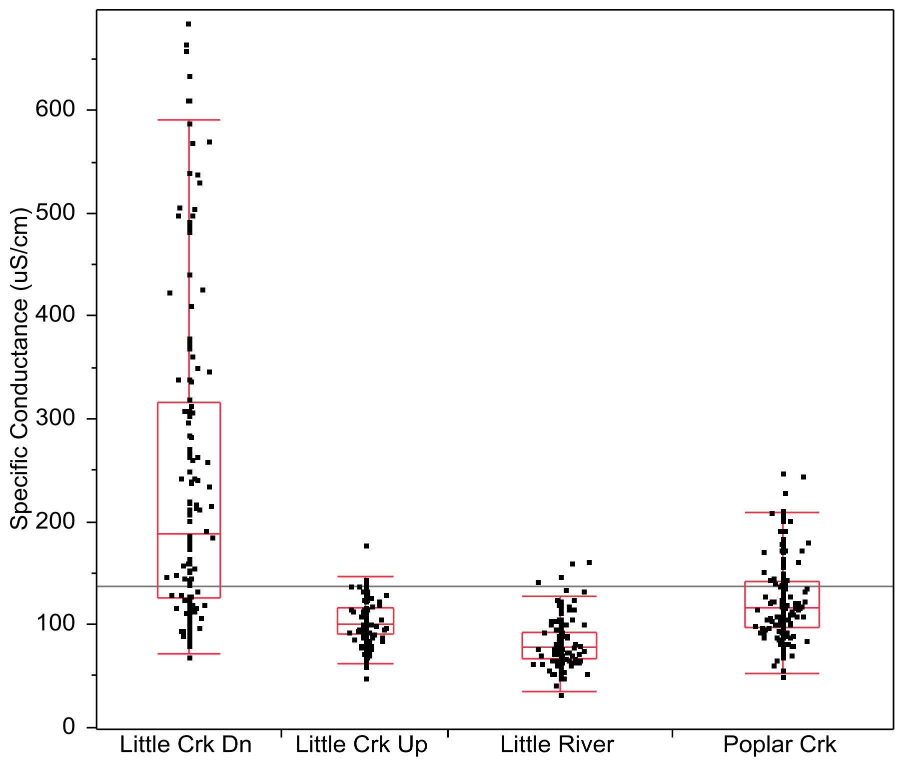

Figure A5. Specific Conductance (uS/cm).

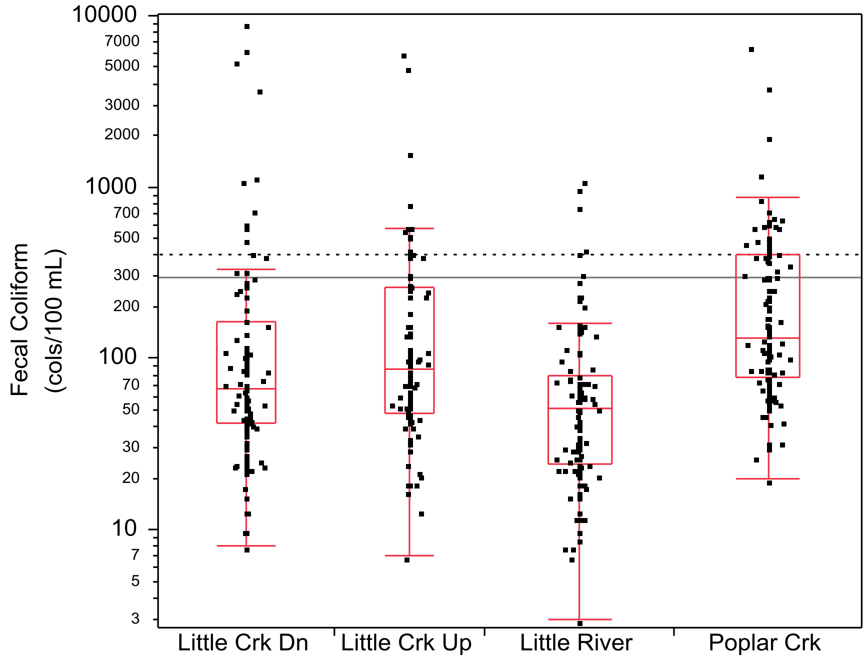

Figure A6. Fecal Coliform bacteria (cols/100 mL).

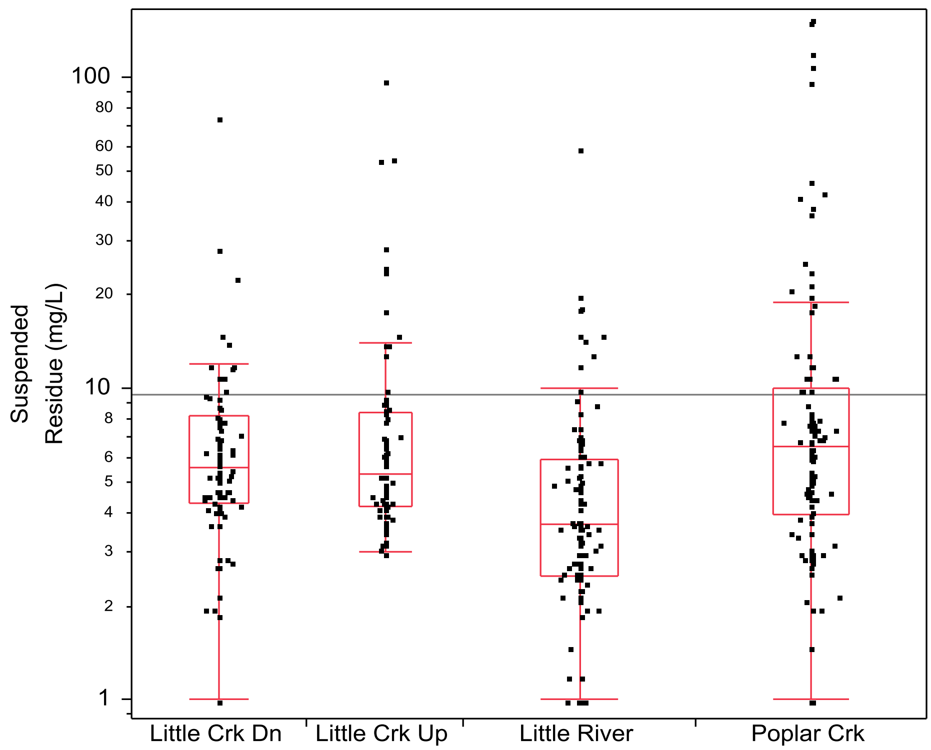

Figure A7. Suspended Residue (mg/L).

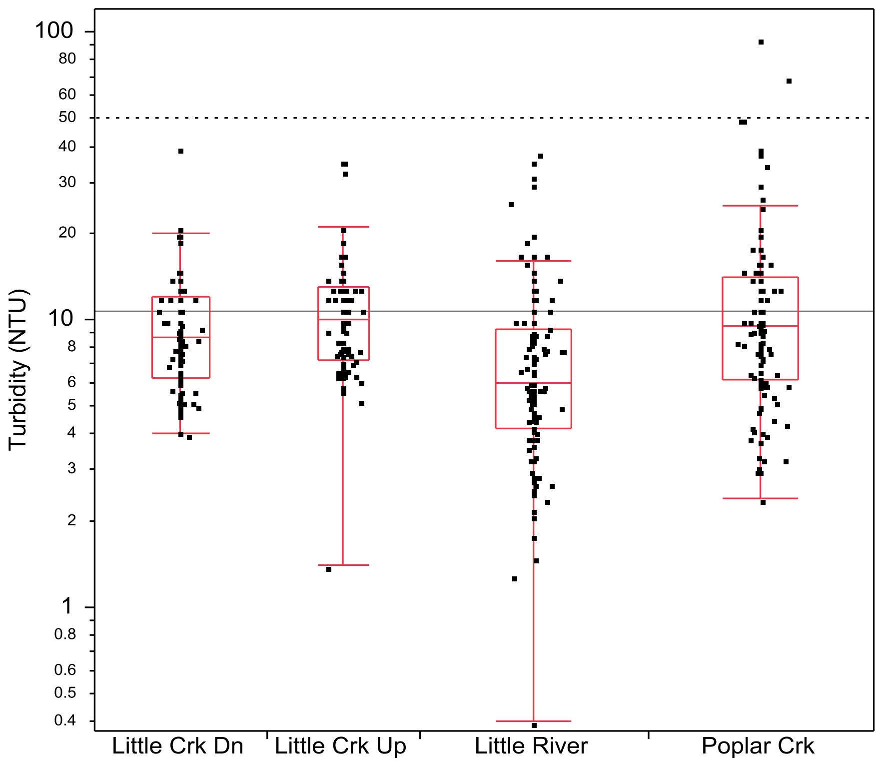

Figure A8. Turbidity (NTU).

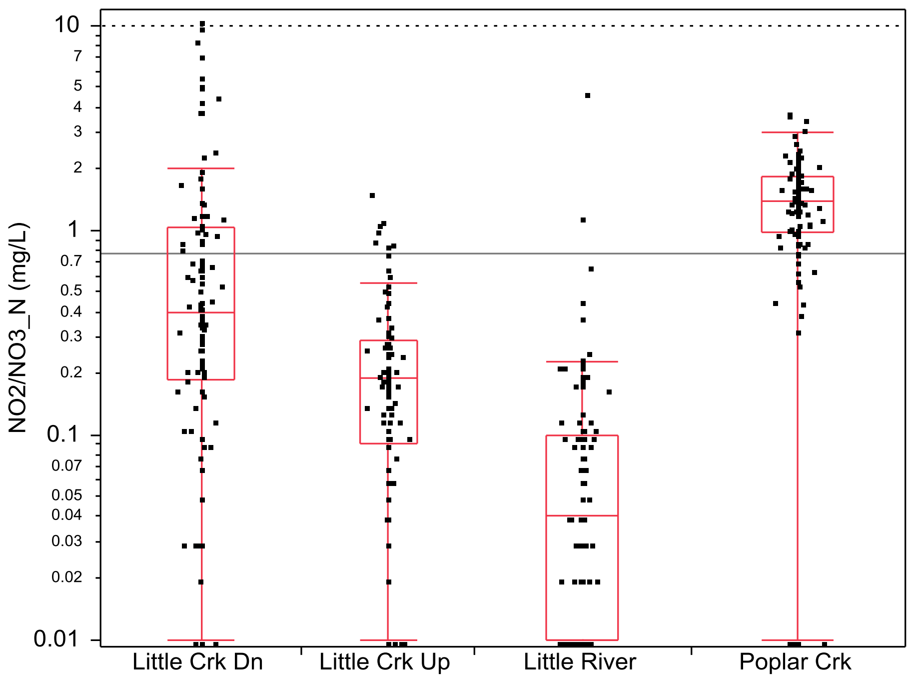

Figure A9. Nitrite-nitrate nitrogen (mg/L).

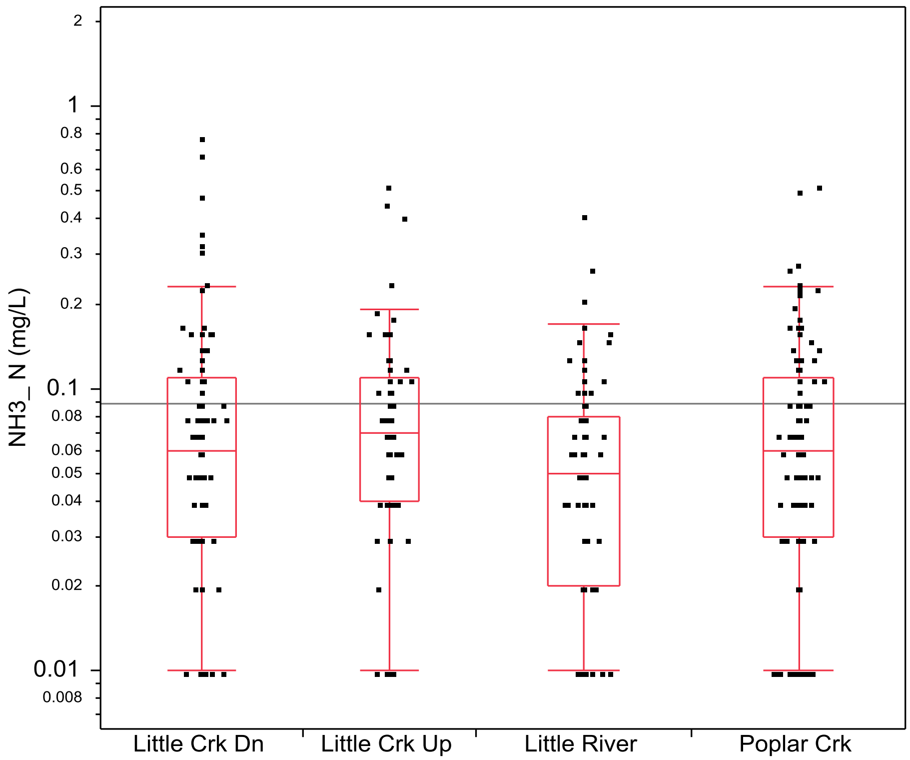

Figure A10. Ammonia nitrogen (mg/L).

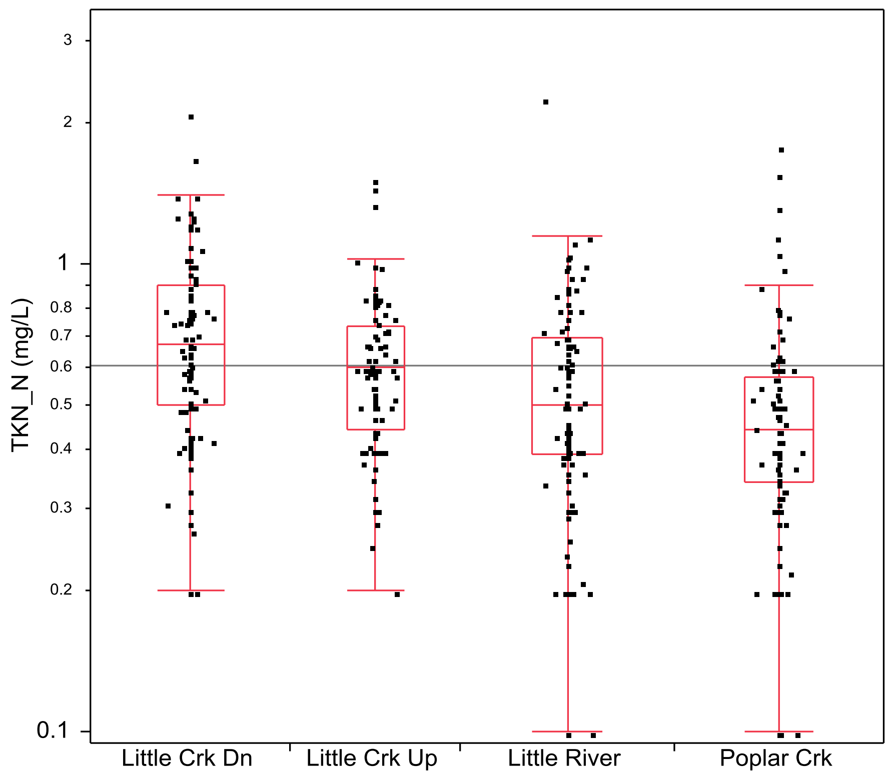

Figure A11. Total Kjeldahl nitrogen (mg/L).

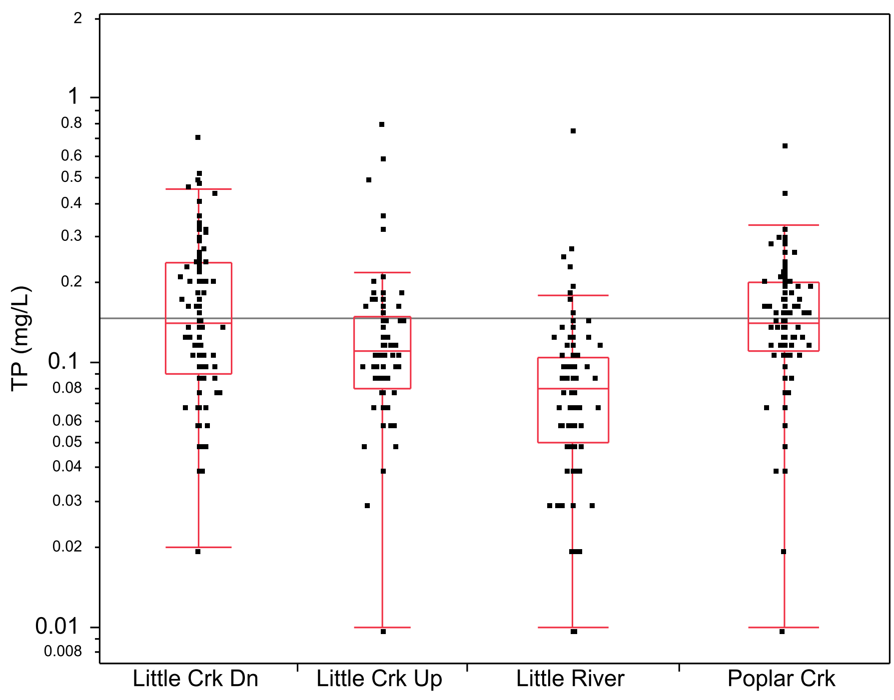

Figure A12. Total Phosphorus (mg/L).

Appendix B Summary statistics for Neuse River water quality data

The data in this section are from the LNRBA's ambient monitoring stations along an approximately 18 mile segment of the Neuse River beginning at the Milburnie Dam downstream to NC 42 near Clayton. They are ordered within each figure by the most upstream location (J2360000) on the left to the most downstream location (J4130000) on the right. Raleigh's Neuse River WWTP (NC00229033) discharges between stations J4230000 and J4170000 as indicated in the Figure B1. Table B1 describes each station and the monitoring period of record portrayed in Figures B2 – B22 and Table B2 below.

Table B1. LNRBA's ambient monitoring stations in the Neuse River within the LWP area.

Station	Location	Monitoring Period	Latitude	Longitude
J2360000	Neuse River above Milburnie Dam	Jan 2000 – Dec 2009	35.8022	-78.5386
J2363000	Neuse River below Milburnie Dam	Oct 2004 – Jan 2007	35.8002	-78.5400
J4050000	Neuse River at SR 2555	Jan 2000 – Dec 2009	35.7266	-78.5139
J4130000	Neuse River at SR 1700	Jan 2000 – Dec 2009	35.6749	-78.4364
J4170000	Neuse River at NC 42	May 2000 – Dec 2009	35.6473	-78.4056

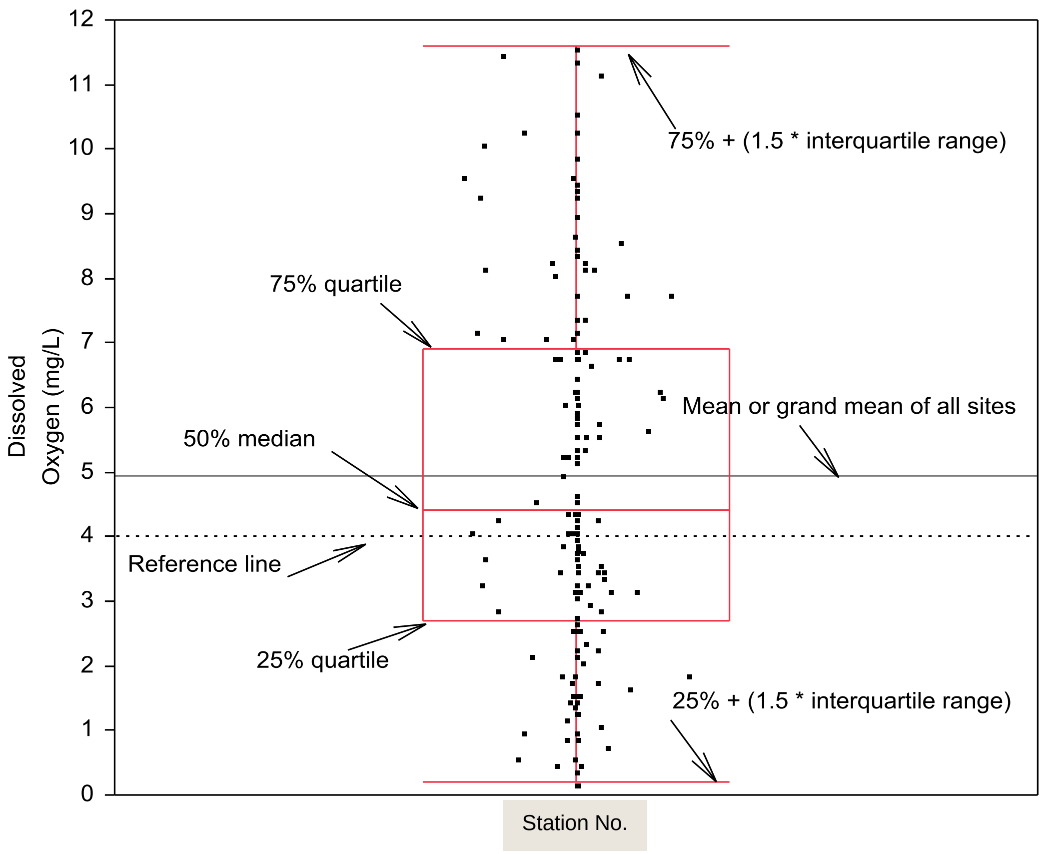

Figure B1. An example box plot with explanations of summary statistics. The interquartile range is the difference between quartiles or percentiles. Points above or below the end of upper and lower whisker are outliers.

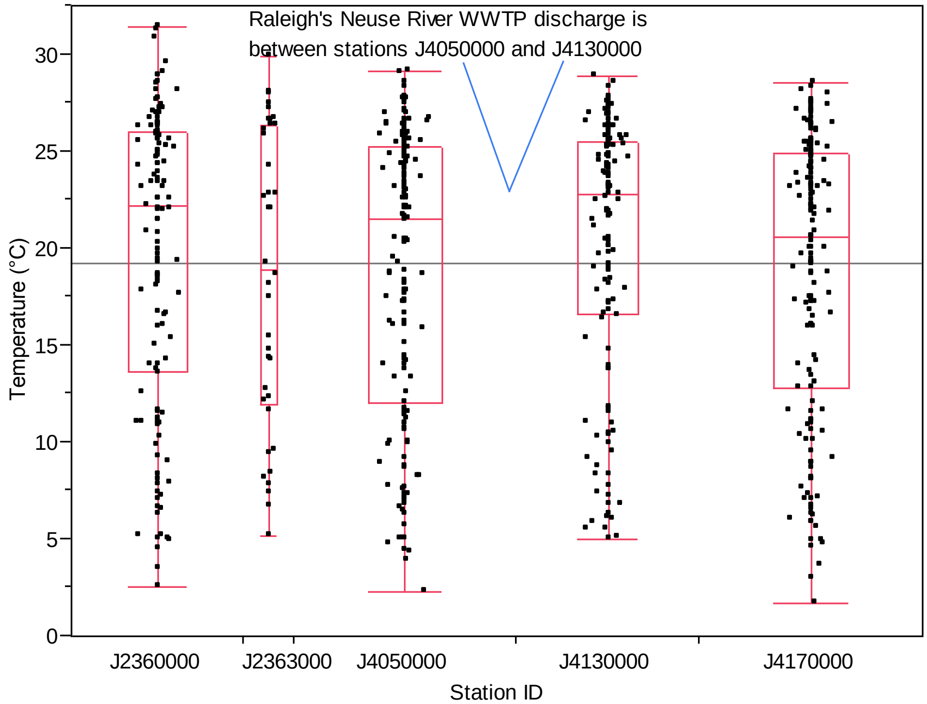

Figure B2. Temperature (°C).

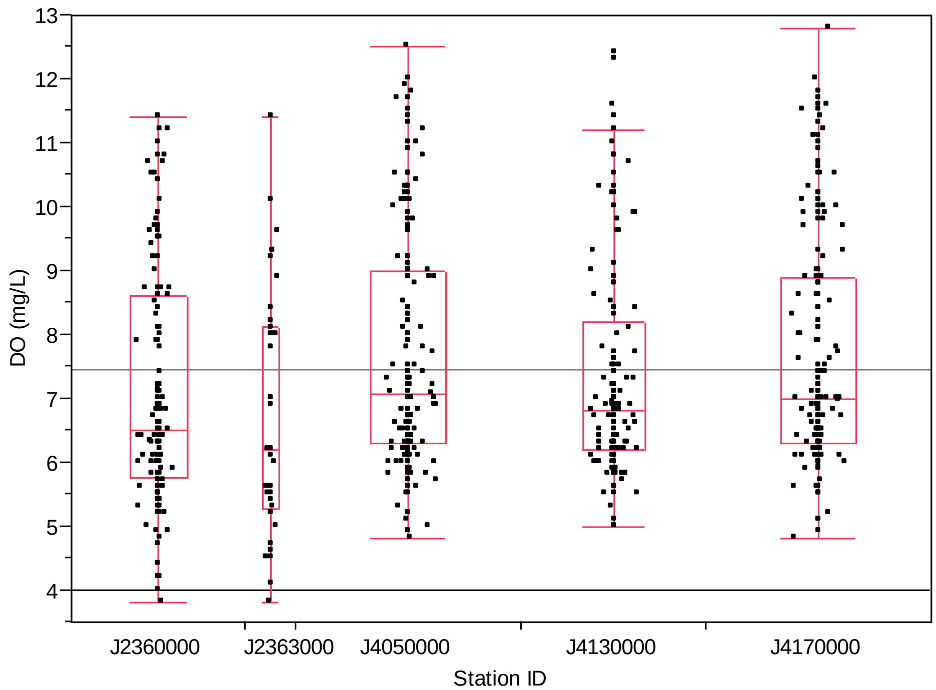

Figure B3. Dissolved Oxygen (mg/L).

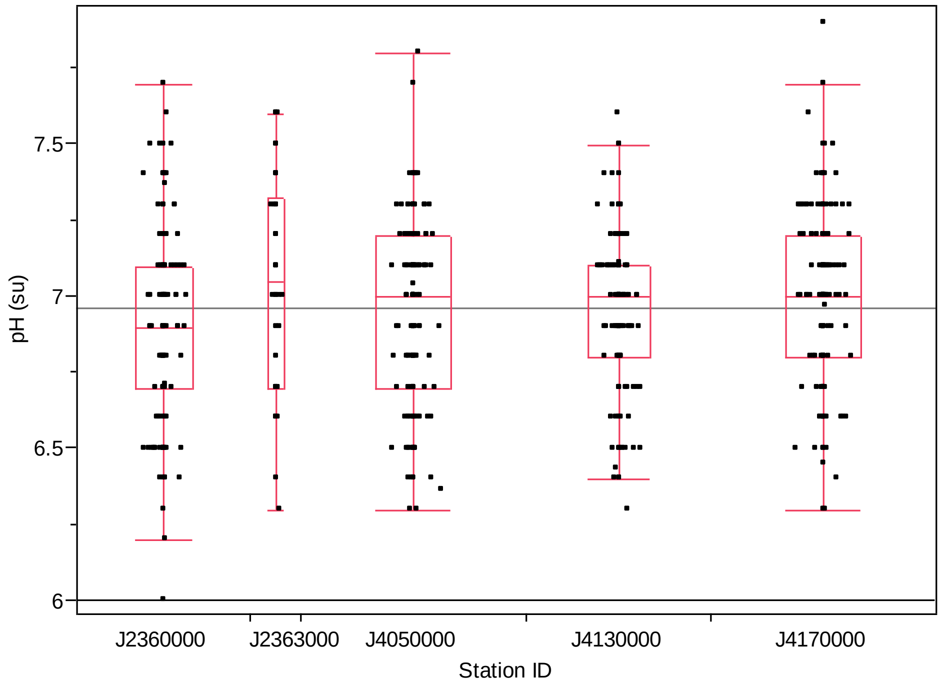

Figure B4. pH (su).

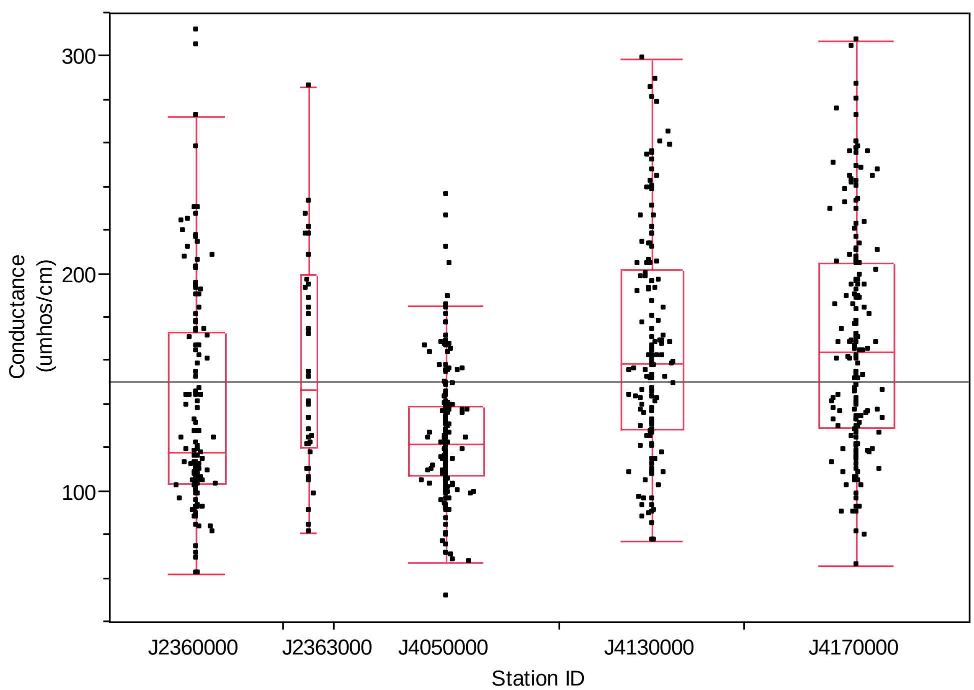

Figure B5. Specific conductance (umhos/cm).

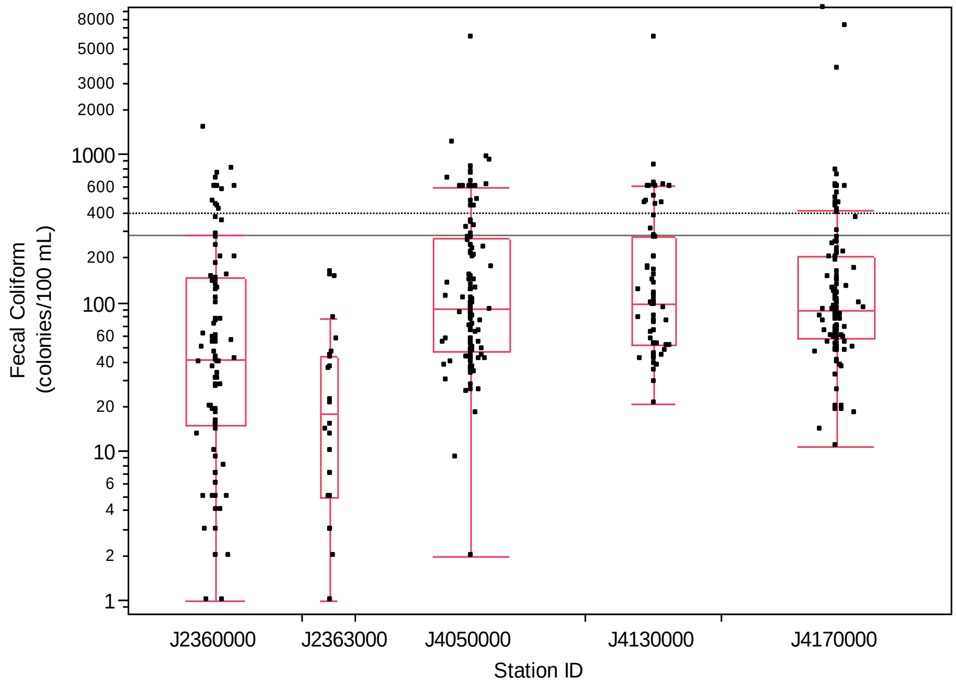

Figure B6. Fecal Coliform (cols/100 mL).

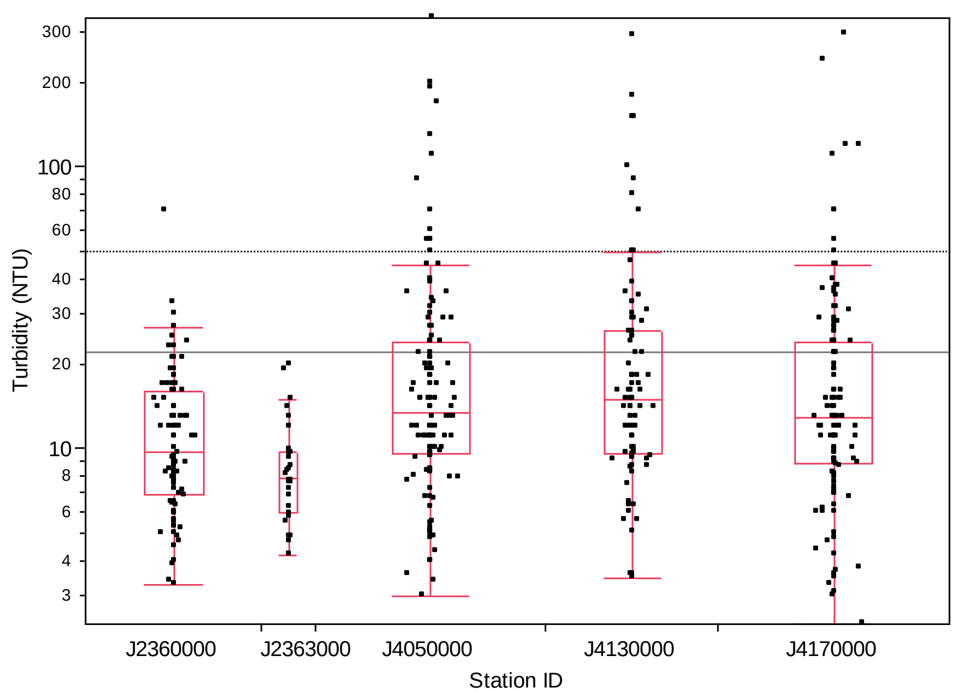

Figure B7. Turbidity (NTUs).

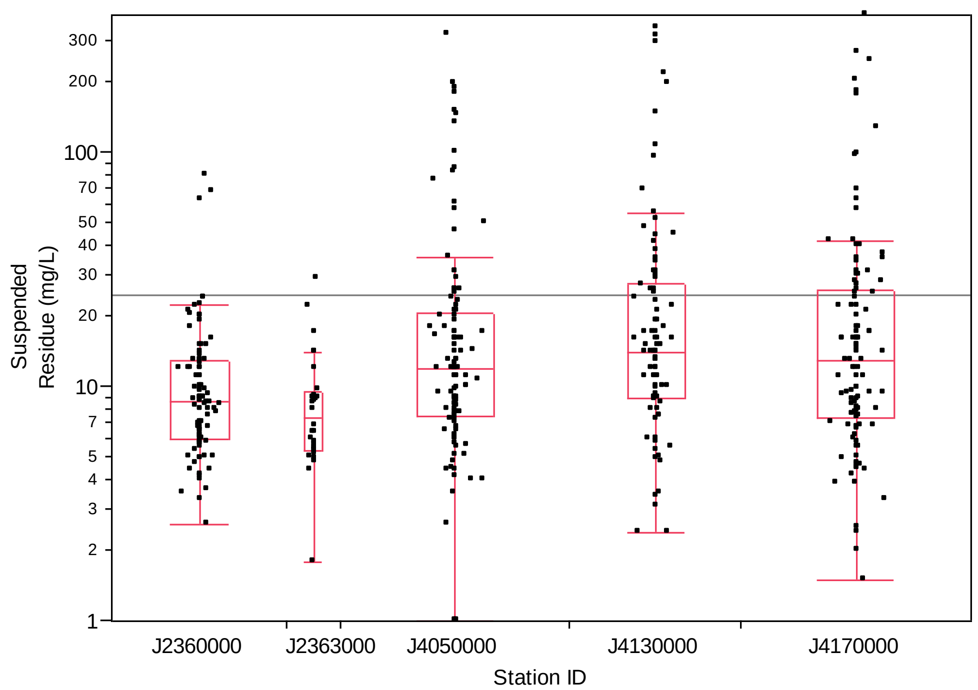

Figure B8. Suspended Residue (mg/L).

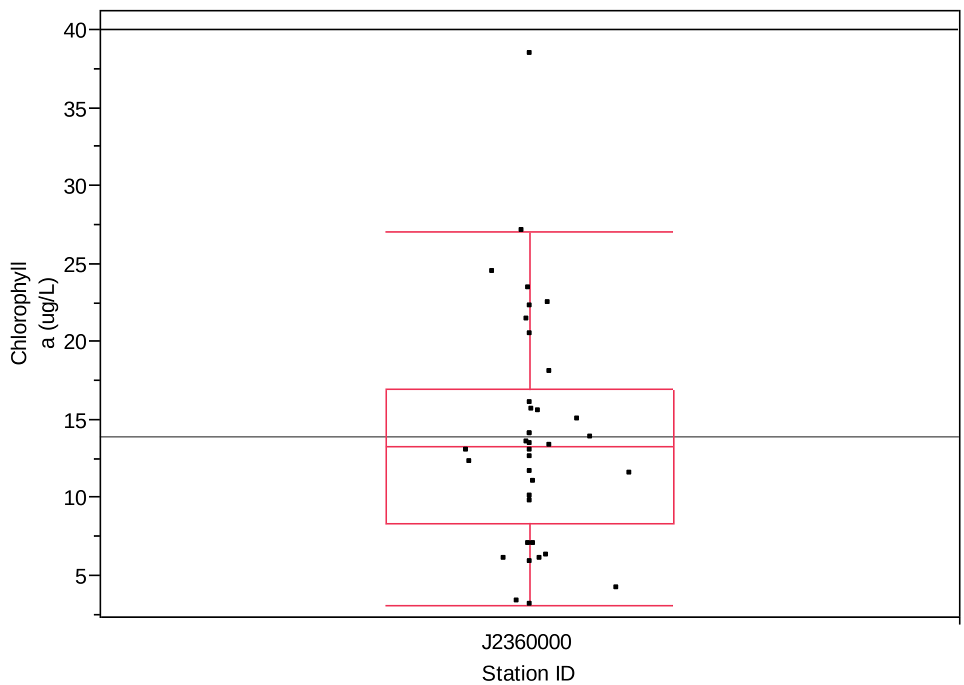

Figure B9. Chorophyll a (ug/L). Chlorophyll a data collected from 01/01/2003 to 07/31/2007 was removed from the database because of questions concerning the reliability of the analysis.

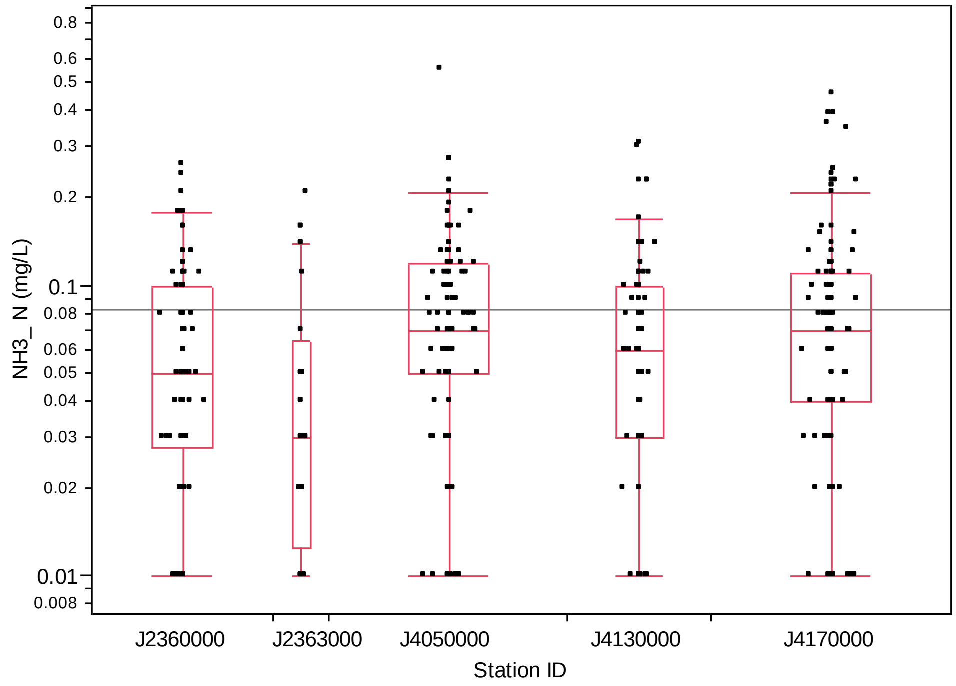

Figure B10. Ammonia nitrogen (mg/L).

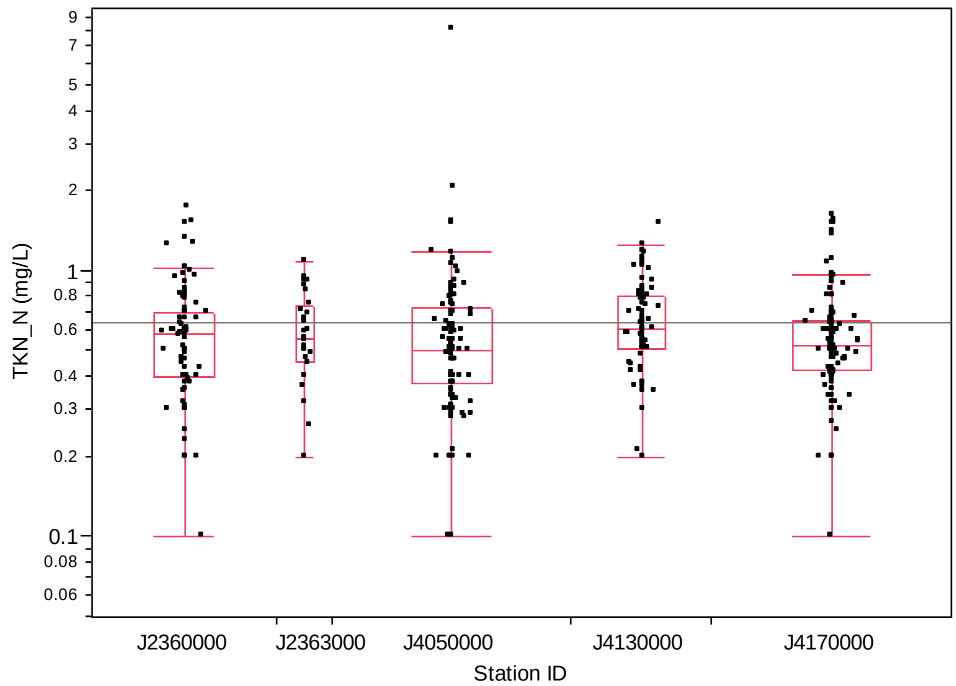

Figure B11. Total Kjeldahl nitrogen (mg/L).

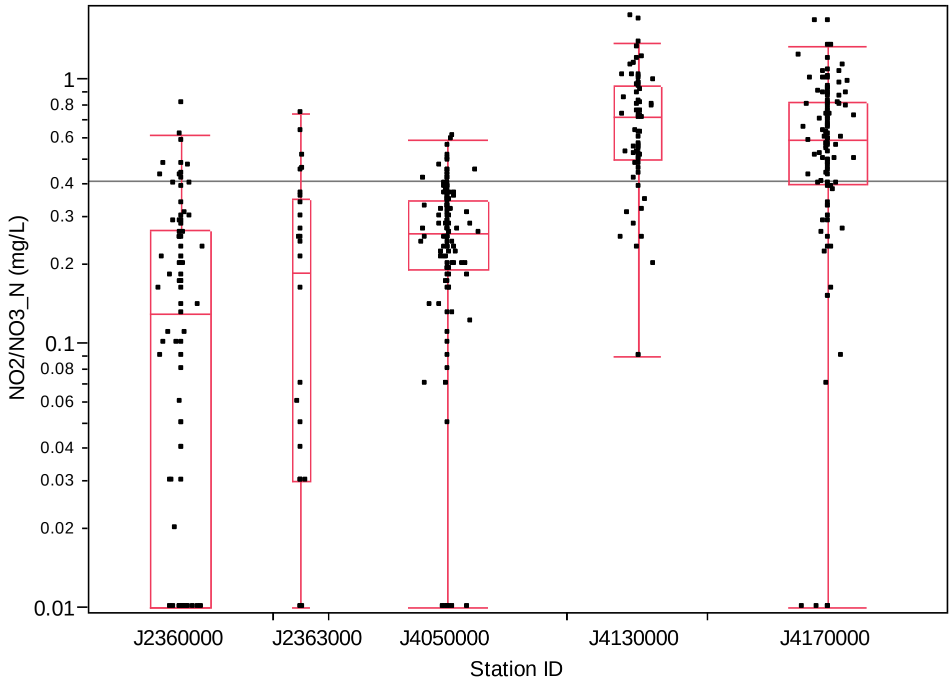

Figure B12. Nitrite-Nitrate nitrogen (mg/L). Note a shift upwards in the median value downstream of the Neuse WWTP.

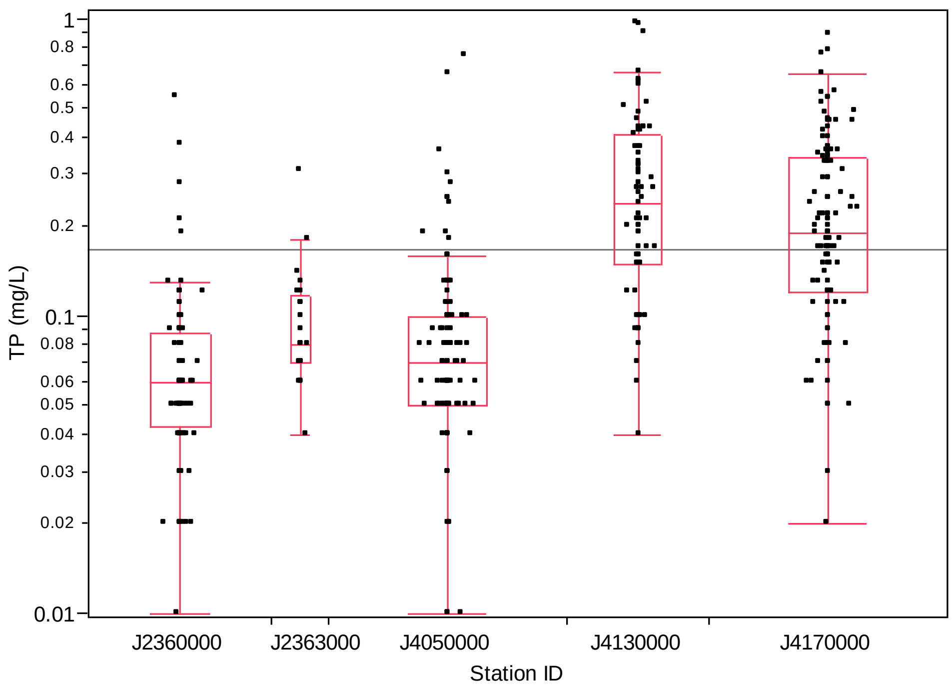

Figure B12. Total Phosphorus (mg/L). Again note an upward shift in median value.

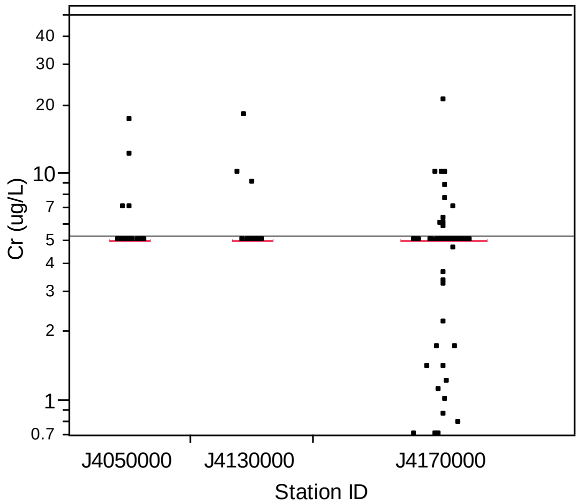

Figure B13. Chromium (ug/L).

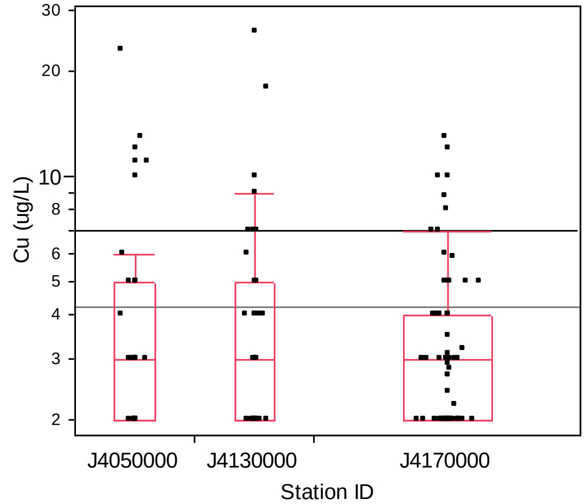

Figure B14. Copper (ug/L).

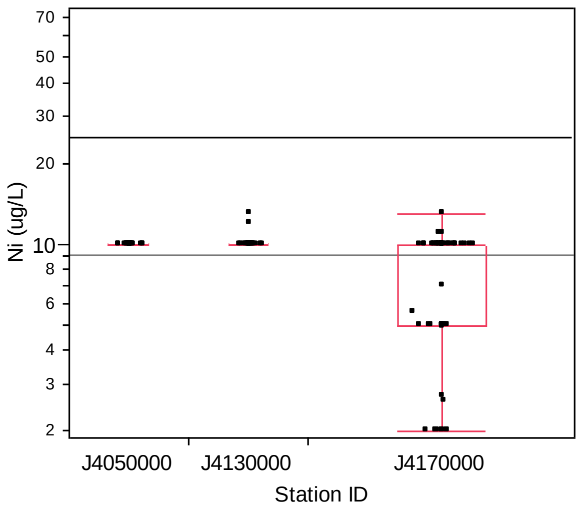

Figure B15. Nickel (ug/L).

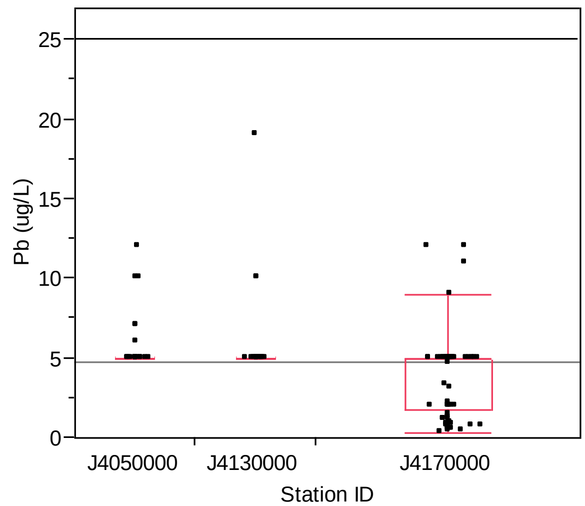

Figure B16. Lead (ug/L).

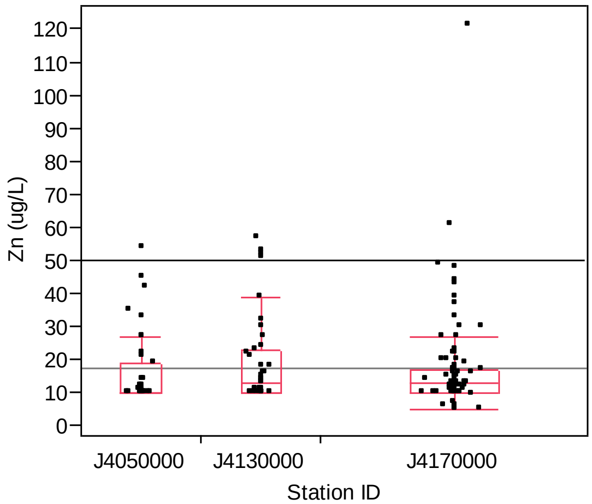

Figure B17. Zinc (mg/L).

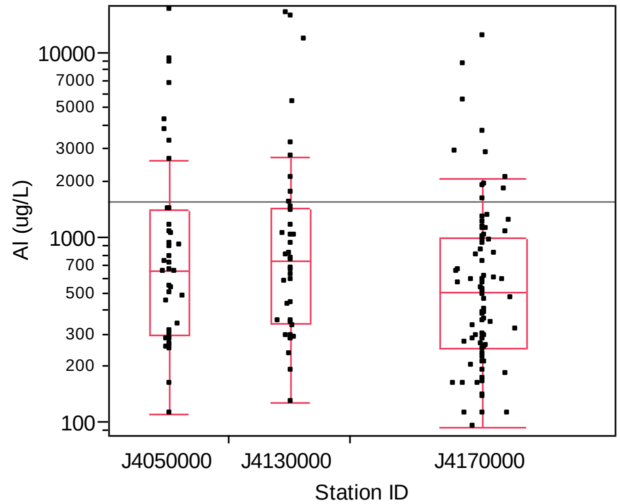

Figure B18. Aluminum (ug/L).

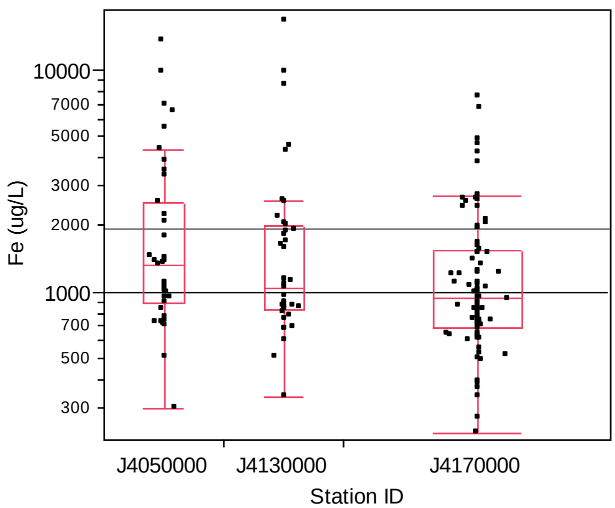

Figure B19. Iron (mg/L).

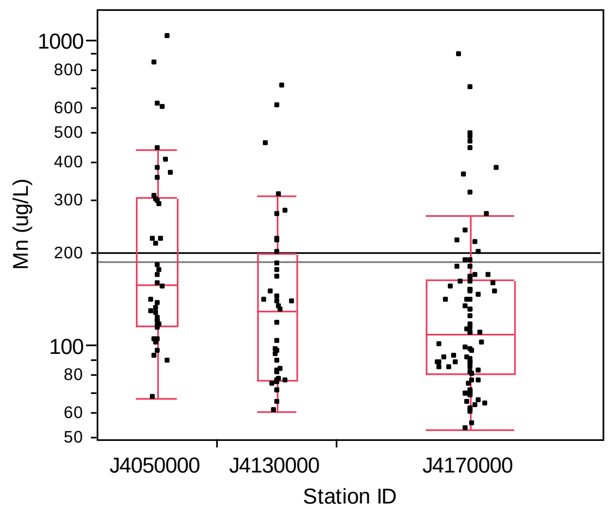

Figure B20. Manganese (ug/L).

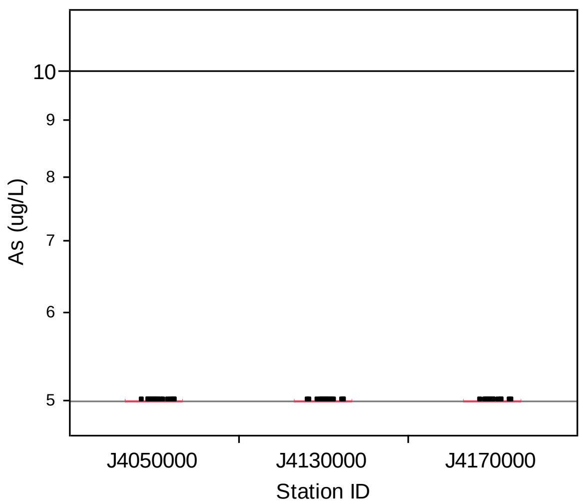

Figure B21. Arsenic (ug/L).

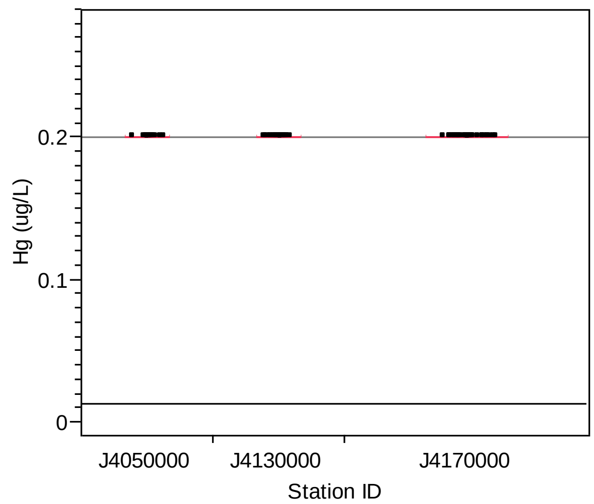

Figure B22. Mercury (ug/L).

This section of Appendix B presents tabular summary statistics for chemical and physical data collected by LNRBA from stations along the Neuse River during the period including January 2000 through December 2009 as described in Table B1 above.

Table B2. LNRBA ambient monitoring data along the Neuse River

Parameter	Stats	Site				
		J2360000	J2363000	J4050000	J4130000	J4170000
pH (su)	N	133	38	171	141	171
	Mean	6.9	7.0	7.0	7.0	7.0
	Min	6.0	6.3	6.3	6.3	6.3
	10%	6.5	6.6	6.5	6.6	6.6
	Median	6.9	7.1	7.0	7.0	7.0
	90%	7.3	7.5	7.3	7.3	7.3
	Max	7.7	7.6	7.8	7.6	7.9
	Std Dev	0.3	0.4	0.3	0.3	0.3
DO (mg/L)	N	133	38	171	141	171
	Mean	7.1	6.7	7.7	7.4	7.7
	Min	3.8	3.8	4.8	5	4.8
	10%	5.2	4.5	5.8	5.8	6.0
	Median	6.5	6.2	7.1	6.8	7.0
	90%	10.0	9.3	10.5	10.2	10.6
	Max	11.4	11.4	12.5	12.4	12.8
	Std Dev	1.9	1.9	1.8	1.7	1.8
Conductance (umhos/cm)	N	133	38	171	141	171
	Mean	139	158	126	167	169
	Min	62	81	51	77	66
	10%	91	97	93	102	108
	Median	118	147	122	159	164
	90%	214	222	167	244	248
	Max	312	286	236	299	307
	Std Dev	51	50	30	51	52
Temperature (°C)	N	133	38	171	141	171
	Mean	19.7	18.5	18.9	20.2	18.6
	Min	2.5	5.2	2.3	5.0	1.7
	10%	7.3	7.8	7.2	8.3	7.0
	Median	22.2	18.9	21.5	22.8	20.6
	90%	27.7	27.5	26.7	26.9	26.5
	Max	31.4	29.9	29.1	28.9	28.5
	Std Dev	7.7	7.6	7.4	6.8	7.2
Fecal Coliform (colonies/100 mL)	N	92	28	121	71	121
	Mean	147	37	423	281	329
	Min	1	1	2	21	11
	10%	4	2	36	42	40
	Median	42	18	92	98	90
	90%	543	150	608	600	588
	Max	1500	160	12000	6000	9600
	Std Dev	242	46	1488	719	1129
Suspended Residue (mg/L)	N	92	28	120	90	120
	Mean	12	9	26	35	29

Parameter	Stats	Site				
		J2360000	J2363000	J4050000	J4130000	J4170000
	Min	3	2	1	2	2
	10%	4	5	5	5	5
	Median	9	7	12	14	13
	90%	20	18	61	68	56
	Max	80	29	321	340	388
	Std Dev	12	6	46	64	55
Turbidity (NTU)	N	92	28	120	90	120
	Mean	12	9	27	28	24
	Min	3	4	3	4	2
	10%	5	5	5	6	5
	Median	10	8	14	15	13
	90%	21	15	55	50	40
	Max	70	20	340	294	298
	Std Dev	9	4	44	42	38
Chlorophyll a (ug/L)	N	37	0	0	0	0
	Mean	14	.	.	.	.
	Min	3	.	.	.	.
	10%	5	.	.	.	.
	Median	13	.	.	.	.
	90%	24	.	.	.	.
	Max	38	.	.	.	.
	Std Dev	7	.	.	.	.
NH3_ N (mg/L)	N	90	28	118	71	119
	Mean	0.08	0.06	0.09	0.08	0.09
	Min	0.01	0.01	0.01	0.01	0.01
	10%	0.01	0.01	0.02	0.01	0.01
	Median	0.05	0.03	0.07	0.06	0.07
	90%	0.16	0.16	0.16	0.14	0.22
	Max	1.25	0.21	0.56	0.31	0.46
	Std Dev	0.14	0.06	0.07	0.06	0.08
TKN_N (mg/L)	N	93	28	120	71	120
	Mean	0.60	0.60	0.73	0.67	0.59
	Min	0.10	0.20	0.10	0.20	0.10
	10%	0.30	0.31	0.29	0.37	0.32
	Median	0.58	0.56	0.50	0.61	0.53
	90%	0.99	0.92	0.91	1.06	0.94
	Max	1.73	1.09	12.68	1.51	1.61
	Std Dev	0.30	0.22	1.33	0.26	0.28
NO2/NO3_N (mg/L)	N	93	28	120	71	120
	Mean	0.17	0.21	0.27	0.72	0.62
	Min	0.01	0.01	0.01	0.09	0.01
	10%	0.01	0.01	0.09	0.29	0.17
	Median	0.13	0.19	0.26	0.72	0.60
	90%	0.43	0.52	0.43	1.14	1.01
	Max	0.81	0.74	0.61	1.74	1.66
	Std Dev	0.17	0.21	0.13	0.34	0.33
TP (mg/L)	N	92	28	119	71	119
	Mean	0.08	0.13	0.10	0.29	0.24

Parameter	Stats	Site				
		J2360000	J2363000	J4050000	J4130000	J4170000
	Min	0.01	0.04	0.01	0.04	0.02
	10%	0.03	0.06	0.04	0.09	0.08
	Median	0.06	0.08	0.07	0.24	0.19
	90%	0.12	0.19	0.16	0.58	0.46
	Max	0.55	1.10	0.75	0.97	0.89
	Std Dev	0.07	0.20	0.10	0.20	0.17
Cd (ug/L)	N	0	0	39	39	86
	Mean	.	.	1	1	1
	Min	.	.	1	1	0
	10%	.	.	1	1	0
	Median	.	.	1	1	1
	90%	.	.	1	1	1
	Max	.	.	1	1	1
	Std Dev	.	.	0	0	0
Cr (ug/L)	N	0	0	39	39	83
	Mean	.	.	6	6	5
	Min	.	.	5	5	1
	10%	.	.	5	5	1
	Median	.	.	5	5	5
	90%	.	.	7	5	10
	Max	.	.	17	18	21
	Std Dev	.	.	2	2	3
Cu (ug/L)	N	0	0	39	39	86
	Mean	.	.	5	5	4
	Min	.	.	2	2	2
	10%	.	.	2	2	2
	Median	.	.	3	3	3
	90%	.	.	11	9	7
	Max	.	.	23	26	34
	Std Dev	.	.	4	5	4
Ni (ug/L)	N	0	0	39	39	86
	Mean	.	.	10	10	8
	Min	.	.	10	10	2
	10%	.	.	10	10	2
	Median	.	.	10	10	10
	90%	.	.	10	10	10
	Max	.	.	10	13	80
	Std Dev	.	.	0	1	8
Pb (ug/L)	N	0	0	39	39	85
	Mean	.	.	6	6	4
	Min	.	.	5	5	0
	10%	.	.	5	5	1
	Median	.	.	5	5	5
	90%	.	.	7	5	5
	Max	.	.	12	19	12
	Std Dev	.	.	2	2	2
Zn (ug/L)	N	0	0	39	39	86
	Mean	.	.	16	19	17

Parameter	Stats	Site				
		J2360000	J2363000	J4050000	J4130000	J4170000
	Min	.	.	10	10	5
	10%	.	.	10	10	6
	Median	.	.	10	13	13
	90%	.	.	35	51	34
	Max	.	.	54	57	121
	Std Dev	.	.	11	14	16
Al (ug/L)	N	0	0	39	39	85
	Mean	.	.	1899	2011	1196
	Min	.	.	111	128	94
	10%	.	.	254	280	160
	Median	.	.	661	754	503
	90%	.	.	6685	5409	1984
	Max	.	.	16909	16095	19902
	Std Dev	.	.	3311	3802	2677
Fe (ug/L)	N	0	0	39	39	86
	Mean	.	.	2359	2169	1601
	Min	.	.	300	337	230
	10%	.	.	714	677	514
	Median	.	.	1331	1050	941
	90%	.	.	6522	4546	2653
	Max	.	.	13605	16590	19960
	Std Dev	.	.	2770	3082	2378
Mn (ug/L)	N	0	0	39	39	86
	Mean	.	.	250	197	156
	Min	.	.	67	61	53
	10%	.	.	95	71	66
	Median	.	.	158	131	110
	90%	.	.	599	455	329
	Max	.	.	1024	1358	899
	Std Dev	.	.	211	238	139
As (ug/L)	N	0	0	39	39	39
	Mean	.	.	5	5	5
	Min	.	.	5	5	5
	10%	.	.	5	5	5
	Median	.	.	5	5	5
	90%	.	.	5	5	5
	Max	.	.	5	5	5
	Std Dev	.	.	0	0	0
Hg (ug/L)	N	0	0	39	39	72
	Mean	.	.	0.2	0.2	0.2
	Min	.	.	0.2	0.2	0.2
	10%	.	.	0.2	0.2	0.2
	Median	.	.	0.2	0.2	0.2
	90%	.	.	0.2	0.2	0.2
	Max	.	.	0.2	0.2	0.2
	Std Dev	.	.	0	0	0

Appendix C Geomorphologic Data CH2M Hill (2003).

This section of the Appendix and Table C4 below present the geomorphology assessment data and Rosgen stream type mined from the CH2M Hill report for the locations that are within the Wake-Johnston County LWP area. As stated in the CH2M Hill report, stream type classifications were used to make a preliminary determination about restoration activities most likely to succeed in a given stream reach. For example, as was explained, a "G" type stream reacts poorly to log sills, boulder clusters and deflectors because this stream type is still incising and widening. On the other hand, root wads and boulder toe protection would promote stability in G type streams.

Table C1. Results of Geomorphologic Assessments conducted by CH2M Hill (2003).

Code	Location	Bankfull Width (ft)	Bankfull Depth (ft)	Floodprone Width (ft)	W/D	Entrenchment	Dominant Bed Material	Stream Type	Bioclassification
4	Marks Creek at Eagle Rock Rd., SR 2501, Wake	22	2	100	11.00	Slight	Sand	E5	Fair
5	Marks Creek at Prichard Rd., SR 1714 Johnston	30	2	100	15.00	Slight	Sand	C5	Good- Fair
7	Buffalo Creek at Poole Rd., SR 1007, Wake	25.4	1.4	100	18.14	Slight	Sand	C5	Fair
12	Poplar Creek at Grasshopper Rd., SR 2511, Wake	20	2	30	10.00	Moderate	Sand	B5	Good-Fair
13	Buffalo Creek at Riley Hill School Rd., SR 2320, Wake	25	4.2	100	5.95	Slight	Silt	E6	Poor

Notes: The number 5 or 6 under stream type is the nomenclature used by Rosgen to identify channel material. The benthic bioclassification is the rating given by CH2M Hill biologists for the location in 2001.

They went on to explain that streams with "F" and "G" channels typically do not support the habitat and biological diversity of the more stable "E" and "B" channels and provided an example that supported this statement. However, as Table C1 shows, this was not always the case. Water quality conditions (likely low DO) in both Marks Creek at Eagle Rock Road and Buffalo Creek at Riley Hill School Road (both E types) during that timeframe may have masked the expression of typical benthic diversity that one might expect under normal climatic conditions. As mentioned in the Biological Assessment section of this report however (Table 2), Marks Creek at Eagle Rock Road continues to be non-supportive of the benthic community (rated Fair in 2009).

Appendix D Field readings from benthic survey (NCSU, 2009)

Table D1. Field readings collected in benthic macroinvertebrate survey locations within the LWP area in August, 2009.

Site Code	Stream Location and County	Water Temperature (°C)	Dissolved Oxygen (mg/L)	Specific Conductance (uS/cm)	pH (s.u.)
1	Beddingfield Creek at Shotwell Rd., SR 1553, Johnston	24.1	9.0	141	6.5
2	Poplar Creek at Smithfield Rd., SR 2233, Wake	23.1	6.6	100	6.0
3	Poplar Creek at Bethlehem Rd., SR 2049, Wake	24.1	8.5	178	6.5
4	Marks Creek at Eagle Rock Rd., SR 2501, Wake	26.4	3.7	120	6.1
5	Marks Creek at Prichard Rd., SR 1714 Johnston	24.9	7.4	95	6.4
6	Buffalo Creek at Mitchell Mill Rd., SR 2224 Wake	26.1	1.4f	81	6.4
7	Buffalo Creek at Poole Rd., SR 1007, Wake	26.8	3.5	95	6.5
8	Hominy Creek at Buck Rd., SR 2329, Wake	23.4	1.6f	73	6.4
9	Rocky Branch (Big Canal) at Riley Hill Rd. SR 2320, Wake	24.5	4.7	62	6.9
10	Snipes Creek at Taylors Mill Rd., SR 1723, Johnston	24.6	5.4	55	6.8
11	Little River above NC 231, Johnston	27.0	4.8	85	7.0

f – Low stream flow was evident in these locations. Site codes correspond to those in Figure 1 of main document.

Appendix E Dam and other data

The information that follows was obtained from various sources. These data were not summarized in depth but links to the reports etc., are provided for the reader to examine to determine the usefulness and feasibility of further summarization and assessment. As other data and sources become available they will be examined and incorporated as needed.

- A detailed explanation and report related to a spill (in April 2006) of approximately 16,000 gallons of transformer oil from a Progress Energy Substation in a UT to Marks Creek near a NCDOT mitigation project can be found at the link that follows. http://www.ncdot.org/doh/preconstruct/pe/neu/Monitoring/2007Monitoring/R-2547WM_Marks_Creek_Stream.html.

- A follow-up report in 2008 by NCDOT (see link that follows) stated that the Mark Creek site continues to recover with much of the affected vegetation returning. http://www.ncdot.org/doh/preconstruct/pe/neu/Monitoring/2008Monitoring/R-2547WMMarksCreekStreamReport2008.pdf

Other North Carolina BAU Fish data.

- DWQ collected fish from two locations on the Little River near Mitchell Mill Pond (outside of the LWP area) in 1995, 2000 and 2004 (Table E1 below). A list by scientific name and number of of species can be reviewed at the following link http://portal.ncdenr.org/web/wq/ess/bau/ncibi-data

Table E1. North Carolina Biological Assessment Unit fish monitoring locations.

Stream	Location	County	Lat	Long	Date
Little R	NC 96	Wake	35.9180	-78.3894	07/19/95
Little R	NC 96	Wake	35.9180	-78.3894	04/04/00
Little R	SR 2224	Wake	35.9136	-78.3872	06/11/04

Dam Removal Task Force Meeting in February 2002

Minutes of the Task Force meeting in February 2002 were summarized by Dave Schiller of NCDOT. Members included folks from the NC Divisions of Water Quality, Coastal Management, Marine Fisheries and Department Transportation along with folks from US Army Corps of Engineers and Fish and Wildlife Service. Dave explained the procedure they used to prioritize dam removal and the benefits of removing various dams. The essentially used a combination of best professional judgment and group consensus based on a mean value index system, on a scale that ranged from 0 to 4 using three categories: Threatened and Endangered Species, Water Quality and Anadromous Fish. Table E2 below (extracted from the minutes) summaries the scores from the meeting. Larry Eaton is currently the DWQ representative.

Table E2. Preliminary Rankings of Environmental Advantages of Dam Removal Based on "Means of Means".*

	Threatened & Endangered Species Value				Water Quality Value				Anadromous Fish Value					
Dam	NCWRC	NHP	USFWS	Mean	DWQ-Pen	DWQ-D	EPA	Mean	NCMFS	NCWRC	NMFS	USFWS	Mean	Mean of Means
Lowell	4.0	4.0	4.0	4.0	4.0		3.5	3.8	3.0	5.0	3.0	3.0	3.5	3.75
Lock & Dam #2	3.0	3.0	4.0	3.3	1.0		4.0	2.5	4.0	4.0	5.0	5.0	4.5	3.44
Lock & Dam #3	3.0	3.0	3.0	3.0	1.0		4.0	2.5	4.0	3.0	5.0	5.0	4.3	3.25
Carbonton Dam	5.0	5.0	5.0	5.0	4.0		4.0	4.0	0.0	0.0	1.0	1.0	0.5	3.17
Atkinson's Millpond	4.0	4.0	4.0	4.0	3.0		4.0	3.5	2.0	4.0	1.0	1.0	2.0	3.17
Fishing Creek Millpond	4.0	4.0	5.0	4.3	3.0		3.5	3.3	3.0	0.0	2.0	2.0	1.8	3.11
Buckhorn	3.0	3.0	4.0	3.3	2.0		3.5	2.8	2.0	2.0	4.0	4.0	3.0	3.03
Rocky Mount Millpond	3.0	3.0	1.0	2.3	4.0		4.5	4.3	2.0	1.0	2.0	2.0	1.8	2.78
Milburnie	1.0	1.0	2.0	1.3	0.0		4.6	2.3	2.0	5.0	5.0	5.0	4.3	2.63
Wiggins Millpond	1.0	1.0	1.0	1.0	3.0		4.5	3.8	2.0	3.0	2.0	2.0	2.3	2.33
Hoggards Mill	0.0	0.0	0.0	0.0	3.0		3.5	3.3	4.0	5.0	2.0	2.0	3.3	2.17

DRTF February,
25, 2002

*This Table was prepared by Dave Schiller with the NCDOT, as part of the minutes of the Task Force meeting held on February 21, 2002.

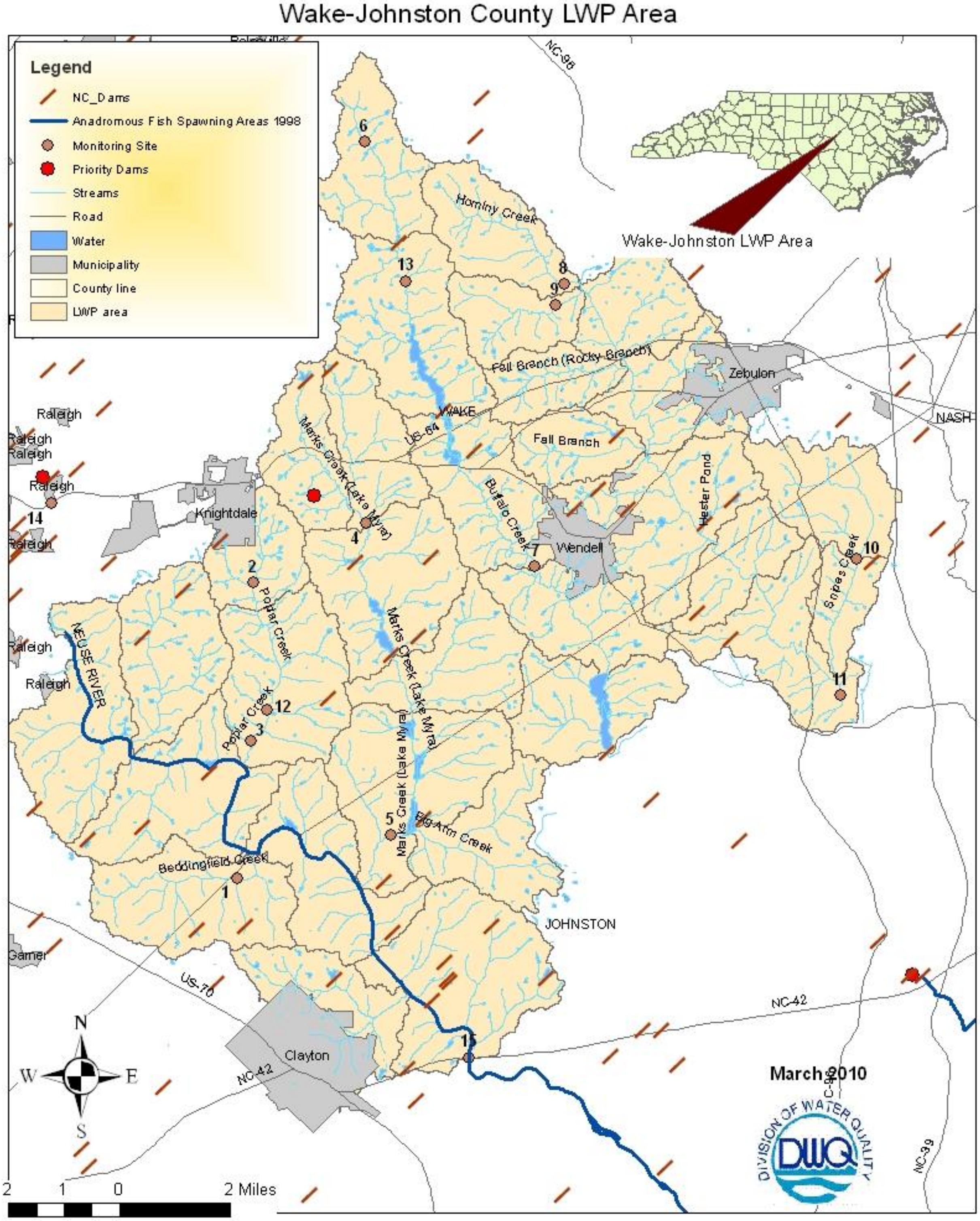

Figure E1. Dams, prioritized dams and anadromous fish spawning areas within LWP area.

Dam Information

Figure E1 above portrays dam data from the NC Dam Safety Program and the Aquatic Obstruction Inventory headed up by the US Army Corps of Engineers (USACE), US Fish and Wildlife Service (USFWS) and NC Division of Land Resources. Also portrayed are Anadromous Fish Spawning Areas. These data were prepared by the NC Division of Marine Fisheries to enhance planning, siting, and impact analysis in areas directly affecting the fish-spawning in areas for fish that swim upstream to spawn.

Marks Creek Mitigation Site (TIP No. R-2547 WM)

- The following was extracted from the NCDOT monitoring report for 2008 for the above project (link below). This was the final assessment and NCDOT proposed to close out the site. *The stream mitigation project involved the restoration of an unnamed tributary to Marks Creek (the Main Tributary to Marks Creek) and four of its tributaries (the North, West, Southwest, and South Tributaries). As part of the project, NCDOT drained an approximately 10-acre pond and removed the dam in its entirety. In addition, new channels were constructed as near as practicable to their former locations before initial dam construction was implemented. The reconnection of the Main Tributary to Marks Creek and its tributaries to their original floodplain resulted in Priority I restoration of approximately 3,200 linear feet. Design and construction was implemented during 2002 by NCDOT. Stream restoration involved the construction of new channels and the installation of rootwads, rock vanes, rock cross vanes, log vanes to control grade and stabilize the channel. It also included the installation of native vegetation.*
http://www.ncdot.org/doh/preconstruct/pe/neu/Monitoring/2008Monitoring/R-2547WMMarksCreekStreamReport2008.pdf

Priority Dams (Milburnie Dam Information)

- The link that follows is a Final Prospectus prepared by Restoration Systems LLC., posted on the Wilmington District USACE's website describing the establishment of a stream and wetland compensatory mitigation bank, known as Milburnie Dam Stream Restoration Bank for Federal and State permits. It provides a summary and description of a proposal to restore approximately 29,000 linear feet reach of the Neuse River by removing the Milburnie Dam. Prior to any dam demolition activities, they intend to undertake a wide range of pre-project investigations to collect baseline data related to sediment, habitat, water quality, benthic macroinvertebrates, fish, mussels, snails and amphibians. http://www.saw.usace.army.mil/wetlands/Notices/current_notices.html

- Additional data may be available from Restoration Systems LLC., but as of this writing they have not been contacted.

Priority Dams (Atkinson Mill Dam)

- Lynnette Batt, who works for American Rivers conservation organization, provided some information on the Atkinson Mill Dam including several data sets used in this document. Her group is working towards removal of the dam and plans to talk with the owner in a few weeks. She reported that the owner has been contacted several times by various groups but it not interested in its removal. It was built around 1757 and has hydro power and milling capabilities. The owner allows public access for fishing and recreation.

Priority Dams (Marks Creek-See Figure E1 above)

- No data were available. It is not listed on the NC Dam Safety Inventory. http://www.dlr.enr.state.nc.us/pages/damsafetyprogram.html

Documented Fish spp. Occurrences

- These data are being researched by the NC Wildlife Resources Commission (Shannon Deaton). Scott Chappell with the NC Division of Marine Fisheries suggested they be contacted to research inland freshwater anadromous species occurrences. They will try to get the data to me by March 30.

Appendix B. Benthic Macroinvertebrate Water Quality Investigation

Wake/Johnson County Water Quality Investigation August, 2009

Background: The Ecosystem Enhancement Program along with Wake and Johnson County Planning Units have begun a local watershed assessment process in partnership with DWQ, Triangle land Conservancy, Clean Water Trust Fund, NC Division of Fish and Wildlife, North Carolina State University's Cooperative Extension and a number of other partners in an effort to improve the quality of Wake and Johnston Counties waters. Degraded water quality and habitat conditions have been frequently recorded at many Wake County locations. For example in a 2001 investigation of Wake County streams CHM2Hill documented Fair or Good/Fair bioclassifications at 92% of the sites surveyed (CHM2Hill 2002). Urbanization and extensive agricultural practices were listed as potential sources of perturbation. In Wake County alone, 303d listed streams have risen in the last two years from 88 miles to 188 miles.

The planning process is designed to better understand and characterize the watersheds through existing data and new data gathered through and directed by the local watershed planning process. Original benthic, chemical and physical monitoring data is being collected to assist the effort and add to already available data. Stressors will be identified and strategies aimed at remediation will be identified. The strategies will be captured in a detailed watershed plan and a catalogue of projects.

The catalogue developed will provide an excellent inventory of science based projects aimed at improving water quality in support of a number of programs aimed at preservation, restoration, and enhancement of water resources. In addition to being useful to multiple interests, it should provide an excellent basis for grant writing and project selection for up to ten years.

Current monitoring information is a critical step in the planning process. Biological data were collected from eleven locations in two Neuse River sub-basins (03-04-02 and 0304-06) in Wake and Johnson Counties as part of this project. These data will denote current water quality conditions and, where appropriate, comparisons to previous information may help determine trends in water quality conditions.

Station Selection: Table 1 lists the eleven monitoring locations selected for this review. Two sites were sampled from locations in the Poplar, Marks and Buffalo Creek catchments. In addition a site was also surveyed in Beddingfield Creek and from four locations (three tributaries) in the Little River basin. An attempt was made to select locations that would coincide with other monitoring programs; i.e. Wake County monitoring programs or the CM2MHill investigation in 2001. During the field evaluations members of the Watershed Assessment Team (WAT) and NCSU/Wake County were given specific locations to evaluate and conduct investigations. In addition to benthic insects, water quality field indicators and site coordinates were also collected at each location.

Table 1. Benthic Macroinvertebrate Monitoring Locations. Wake/Johnson Counties, August 2009

Site #	Stream Name	Location/Co	Coordinates	DWQ Hab Score	Visible LU/LC	Water Quality			
						Temp	DO	Cond	pH
#1	Beddingfield Cr	Shotwell Rd., Johnson Co	N 35 41.690 W 78 28.793	58	Residential	24.1	9.0	141	6.5
#2	Poplar Creek	Smithfield Rd., Wake Co	N 35 46.19 W 78 28.42	48	Residential	23.1	6.6	100	6.0
#3	Poplar Creek	Bethlehem Rd., Wake Co	N 35 43.79 W 78 28.65	58	Residential	24.1	8.5	178	6.5
#4	Marks Creek	Eagle Rock Rd., Wake Co	N 35 47.52 W 78 26.44	63	Residential	26.4	3.7	120	6.1
#5	Marks Creek	Prichard Rd., Johnson Co	N 35 42.14 W 78 25.87	52	Forest/Pasture	24.9	7.4	95	6.4
#6	Buffalo Creek	Mitchell Mill Rd., Wake Co	N 35 53.270 W 78 26.239	75	Forest	26.1	1.4f	81	6.4
#7	Buffalo Creek	Pool Rd., Wake Co	N 35 46.535 W 78 23.073	62	Forest/Fallow	26.8	3.5	95	6.5
#8	Hominy Creek	Buck Rd., Wake Co	N 35 47.701 W 78 32.085	59	Forest	23.4	1.6f	73	6.4
#9	Rocky Branch	Riley Hill Rd., Wake Co	N 35 50.669 W 78 22.578	80	Forest	24.5	4.7	62	6.9
#10	Snipe Creek	Taylors Mill Rd., Johnson Co	N 35 46.652 W 78 16.804	76	Forest	24.6	5.4	55	6.8
#11	Little River	Above NC 231, Johnson Co	N 35 44.504 W 78 17.127	90	Forest	27.0	4.8	85	7.0

f-flow related values

Both field teams had difficulties finding appropriate monitoring locations in these catchments. Many of the proposed monitoring locations initially selected from maps were lentic, no or low flow conditions due to impoundments and/or due to recent climatic conditions. Lentic systems can be depauperate of benthic insects and data collected from these systems may be misinterpreted and should not be compared to lotic or flowing systems. For example the middle reach of Marks Creek at Turnipseed Road, the lower reach of Buffalo Creek at Stotts Mill Road in Johnson County and numerous locations in the Upper Little River catchment had no discernable flow and were not sampled. The photographs below were from potential Little River locations at Glory and Morphus Bridge Roads in Wake County.

Methods: The collection method was selected to mimic those used by the NC Division of Water Quality (DWQ 2006). These methods include collection of a kick net sample from the riffle habitat, a sweep net sample from a productive bank area, a leaf pack and conducting visual inspection of all habitat types for rare or cryptic organisms. All taxa (rather than just EPT taxa) are "picked" in the field and preserved for identification. This method is termed the Qual 4 collection method in the DWQ protocol document. This protocol rather than the "Full Scale" protocol was used at all tributary locations; it was felt that catchment size was less than or near three square miles at these locations. A full scale protocol was employed at the only large river location: Little River near NC 231. This method is much more intensive and uses epifaunal collections in addition to Qual 4 methods (DWQ 2006). Organisms are then categorized as Abundant (10 or more specimens), Common (3 to 9 specimens) and Rare (less than 3 specimens). In addition to benthic collections, NC DWQ habitat evaluations were also conducted at each of these locations and the results summarized on Table 1.

In addition to taxa richness of the insect fauna at these locations, a biotic index is also calculated for each location. Numeric values of 0 to 10 have been assigned to each benthic insect commonly collected in North Carolina (DWQ 2006). These values are based on the organisms relative tolerance to stress; 0 represents intolerant conditions and 10 represents very tolerant taxa. Recently the NC Division of Water Quality has developed bioclassifications for small mountain and piedmont stream systems based on the biotic index values of the insect fauna (DWQ 2008).

Results and Discussion: Table 2 summarizes the results of the benthic invertebrate collections and Appendix 1 lists all of the taxa collected at each location.

- <u>#1 – Beddingfield Creek at Shotwell Rd (Johnson County)</u>. EPT taxa richness (18) and biotic index (5.2) values resulted in a Good bioclassification at this location. In addition a dissolved oxygen value of 9.0 ppm was also the highest recorded during this investigation. These data are despite the residential landuse at the collection location and a 400 acre development in the headwaters of this feature. Much of the catchment drains the Clemmons State Forest and some of the land in the drainage area appears to be owned by the City of Raleigh and may be part of their wastewater application area. Many rare taxa were collected only at this location including the mayflies *Serratella deficiens* and *Baetis flavistriga*, stoneflies *Eccoptura xanthenses* and *Leuctra*, caddisflies *Diplectrona modesta* and *Neophylax oligus* and the beetle *Ancytarsus bicolor*. This site represents the best water quality conditions noted during this investigation and should receive watershed protection.

Table 2. Benthic Macroinvertebrate Summary. Wake/Johnson Water Quality Investigation, August 2009.

Station Location	Beddingfield Creek	Poplar Creek,Smithfield Rd	Poplar Creek,Bethlehem Rd	Marks Creek,Eagle Rock Rd	Marks Creek,Prichard Rd	Buffalo Creek,Mitchell Mill R	Buffalo Creek,Pool Rd	Hominy Creek,Buck Rd.	Rocky Creek,Riley Hill Rd	Snipe Creek,Taylors Mill Rd	Little River,above NC 231
Taxa/Station	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**10**	**11**
Ephemeroptera	6	2	4	3	6	1	4	2	6	4	7
Plecoptera	2	1	1	-	1	-	-	-	-	-	-
Trichoptera	10	6	6	4	8	2	5	2	3	1	7
Misc Diptera	3	4	4	2	2	3	1	4	5	5	2
Diptera: Chironomidae	10	9	13	8	7	8	8	6	8	6	8
Coleoptera	6	7	4	7	9	3	7	5	5	3	3
Odonata	7	7	7	6	6	5	7	4	6	5	5
Oligochaeta	3	1	1	1	3	1	3	1	1	1	1
Megaloptera	1	2	1	2	3	-	1	1	1	1	-
Crustacea	3	3	1	4	2	3	5	4	4	2	3
Mollusca	1	3	3	6	4	2	8	2	-	2	2
Other Misc Taxa	-	2	-	5	3	-	2	4	-	-	2
Total Taxa Richness	52	47	45	48	54	28	51	35	39	30	40
Total Abundance	217	187	177	144	248	113	172	88	131	72	170
EPT Taxa Richness	18	9	11	7	15	3	9	4	9	5	14
EPT Abundance	93	37	48	20	95	21	45	15	46	34	65
Biotic Index Value	5.2	6.2	5.8	6.9	5.5	7.1	6.7	7.1	6.5	6.6	6.0
Bioclassification*	Good	Fair	G/F	Fair	G/F	NA	Fair	NA	Fair	Fair	G/F

*Bioclassifications were calculated using new DWQ criteria for small piedmont streams (DWQ June, 2008), except the data from the site #11 (Little River). NA – these locations had very little flow, more typical of swamp streams. Piedmont biocriteria may not apply to these stream types.

- <u>#2 – Poplar Creek at Smithfield Road (Wake County)</u>. Poplar Creek at this location is a very small stream (1 meter wide) and has a bottom substrate dominated by shifting sand. Much of the catchment drains sections of Knightdale which may be partially responsible for this habitat degradation and a slightly depressed pH value (6.0). This site received the lowest DWQ habitat score (48) for all locations surveyed during this investigation. EPT taxa richness (9) and biotic index (6.2) values from this location resulted in a Fair bioclassification. Despite low scores several intolerant taxa were collected from this location; most notably *Diplectrona modesta*, *Leuctra* and *Parametriocnemus lundbecki.*

- <u>#3 – Poplar Creek at Bethlehem Road (Wake County)</u>. This is the downstream location in this catchment and is near the confluence with the Neuse River. EPT taxa richness (11) and biotic index (5.8) were slightly improved from the upstream location and resulted in a Good/Fair bioclassification. Higher dissolved oxygen and pH values were also noted at this site compared to the upstream location. The biological data compare favorably to the information collected by CM2Hill during their 2001 investigation (EPT=8, BI=5.71, Bioclass=Good/Fair) at their Grasshopper Road location on Poplar Creek. These data suggest that there has been no discernable change in the water quality conditions in this catchment between surveys. This site also had some intolerant taxa in common with the site at Beddingfield Creek (*Serratella deficens*, *Eccoptura xanthenses* and *Lype diversa*) and was the only location at which an intolerant caddisfly was collected (*Lepidostoma*). The Asiatic Clam (*Corbicula fluminea*) was found at this site and not at the upstream location, perhaps due to its proximity to the Neuse River.

- #4 – Marks Creek at Eagle Rock Road (Wake County). This upstream location on Marks Creek is in a rapidly developing area due to construction of the outer beltline. The water velocity at this location was reduced which may have allow for the growth of macrophytes and aufwuchs material in the stream, which in turn may have been partially responsible for the very low dissolved oxygen (3.7 ppm) and slightly depressed pH values (6.1) recorded during the investigation. EPT taxa richness (7) and biotic index(6.9) values from this site resulted in a Fair bioclassification. These data also compared well to the information collected by CM2Hill during their 2001 investigation (EPT=5, BI=7.39, Bioclass=Fair), again suggesting that there's been little change in the biointegrity of this feature between investigations. It is interesting to note that the Asiatic Clam (*Corbicula fluminea*) was found at this site. Apparently Lake Myra didn't prevent upstream migration of this exotic species.

- #5 – Marks Creek at Pritchard Road (Johnson County). Water quality conditions improved significantly at this location compared to the upstream site at Eagle Rock Road in Wake County. Lower water temperature, conductivity and higher dissolved oxygen and pH were recorded here. The benthic fauna improved as well. Much higher taxa richness and abundance values were found at this location and many intolerant taxa or taxa found only at tributary locations were collected at this location (*Baetis intercalaris, Isonychia spp, Tricorythodes spp Polycentropus spp, Hydropsyche venularis, Oecetis persimilis,* and *Macromia spp*). The stonefly *Eccoptura xanthenes* was also collected at this location. The benthic data resulted in a Good/Fair bioclassification and compares well to the 2001 CM2Hill information (this study; EPT=15, BI=5.5: 2001; EPT=13, BI=5.6). A Good/Fair bioclassification was also recorded at this location by DWQ as part of their basinwide survey in 2000. Insect abundance was much greater at this location than all sites sampled during this investigation.

- #6 – Buffalo Creek at Mitchell Mill Road (Wake). This collection location was moved from the proposed site at Riley Hill School Road (CM2Hill location) due to lack of discernible flow. It appeared that much of the headwater sections of this feature have become inundated with beaver populations. The primary land use in the catchment is agriculture and fallow fields, and much of the riparian zones next to streams are wooded. The site at Mitchell Mill Road had discernible flow only in very short reaches and appeared more swamp-like than stream-like and for this reason was not give a bioclassification. The dissolved oxygen value at collection was only 1.4ppm at this location. EPT taxa richness (3) and biotic index (7.1) values would have resulted in an inappropriate poor bioclassification. The fauna was overwhelmingly dominated by filter-feeders (i.e. *Cheumatopsyche* spp., *Rheotanytarsus* spp., and *Sphaerium* spp) and tolerant chironomidae (esp *Chirnomus* spp., and *Glyptotendipes* spp.). The Poor bioclassification given to this stream at Riley Hill School Road in 2001 may also be an artifact of low flow conditions in the catchment and should not be used as an indication of water quality.

- #7 – Buffalo Creek at Pool Road (Wake County). The integrity of the benthic fauna improves substantially at this location compared to the upstream site at Mitchell Mill Road. Despite much more development and agricultural activities near the stream at this location, flow has increased. However EPT taxa richness (9) and biotic index (6.7) values resulted in a Fair bioclassification. A dissolved oxygen value of only 3.5ppm was recorded during collection. The fauna at this site is dominated by tolerant taxa including mayflies *Caenis* spp (biotic index=7.4) and *Stenacron interpunctatum* (BI=6.9), caddisflies *Cheumatopsyche* spp (BI=6.2) and chironomidae *Ablabesmyia parajanta/janta* (BI=7.4) and *Conchapelopia* group (BI=8.4).

- #8 – Hominy Creek at Buck Road (Wake County). Station selection was an issue in this catchment as well due to the lack of discernable flow. Apparently beaver populations have also inundated this catchment as well. Much of the catchment appears to be forested with some small agricultural activities. An indication of very low flow conditions, more swamp-like than stream-like, was a dissolve oxygen value of only 1.6ppm during collection. EPT taxa richness was low (4) and biotic index value very high (7.1). These values would have resulted in a poor bioclassification, but is more likely due to the lack of flow than water quality perturbations. The EPT abundance of only 15 was the lowest value recorded during this investigation. Interestingly however a single specimen of *Brachycentrus spinae*, a very intolerant caddisfly, was also collected from this location.

- #9 – Rocky Creek at Riley Hill Road (Wake County). This site is located at the Rocks Preserve and has a very unusual bedrock outcrop within in the stream feature. The catchment appeared to be primarily forested with small agricultural activities. The DWQ habitat assessment at this particular location was very high (80 points). However the benthic fauna was limited; EPT taxa richness was low (9) and the biotic index value relatively high (6.5) resulting in a Fair bioclassification. Despite relatively low taxa richness this location did have some unusual specimens. For example it's the only tributary site that had populations of the mayflies *Paraleptophlebia* spp and *Acerpenna pygmaea*. In addition a very unusual caddisfly was also only collected at this location. *Phylocentropus* spp are capable of diverting stream flow through a buried tube system and remove suspended food particles in a filter very unlike other filter-feeding organisms.

- #10 – Snipe Creek at Taylors Mill Road (Johnson County). Snipe Creek is a small tributary of the Little River in Johnson County, the landuse in the catchment appears to be mostly forest with agricultural activities. The stream is deeply incised with a substrate dominated by sand. Depositional bars are common in the reach sampled as part of this investigation. Riffle habitats were limited to short/narrow sections between very long reaches of no flow. The total abundance value of insects (72) was extremely low at this location perhaps reflecting the effects of sediment deposition and historical land use characteristics. Only tolerant EPT taxa were abundant (i.e. Caenis spp., Stenonema modestum and Cheumatopsyche spp.). EPT taxa richness (5) and biotic index value (6.6) resulted in a Fair bioclassification.

- #11 – Little River above NC 231 (Johnson County). Extensive reaches of the Little River catchment have no discernable flow and extremely low dissolved oxygen values (DOs of 1ppm were common at sites the field teams visited). An investigation conducted by Ecoscience Inc. noted very little change in elevation along a significant reach of the Little River (personal communication, Matt Cusack with Ecoscience). The existence of numerous beaver populations in tributaries of the Little River and the location of numerous run-of-the-river dams in Wake County have created essentially a longitudinal wetland for significant reaches of the Little River (see photographs in station selection section of this report). Benthic invertebrates were collected from a location slightly above NC 231 near the lower end of the study area. A full scale collection protocol was employed at this location. These data resulted in a Good/Fair bioclassification; EPT taxa richness was 14 and the biotic index was 6.0. DWQ classification criteria for large rivers were used at this location. The benthic fauna was dominated largely by tolerant taxa (*Baetis propinquus, Stenonema modestum, Caenis* spp., *Cheumatopsyche* spp., *Cricotopus bicinctus*: C/O sp1, and *Progomphus obscurus*). The Leptocerid caddisfly *Oecetis perisimillis* was also abundant at this location.

Summary and Significant Findings: Benthic macroinvertebrate samples were collected from eleven locations in Wake/Johnson Counties to support the local watershed assessment planning process. The planning process is designed to better understand and characterize the watersheds through existing data and any new data gathered through and directed by the local watershed planning process. Eventually a catalogue will be developed to provide an inventory of science based projects aimed at improving water quality in support of a number of programs aimed at preservation, restoration, and enhancement of water resources.

Only one location was given a Good bioclassification based on criteria developed by the NC Division of Water Quality. Beddingfield Creek at Shotwell Road in Johnson County had 18 EPT taxa and was given a 5.2 biotic index; it also had the highest recorded dissolved oxygen of all sites surveyed. All other monitoring locations were given either Good/Fair or Fair bioclassifications and it was felt that bioclassification criteria were inappropriate at two locations due swamp-like conditions within the catchments. Interestingly headwater reaches of both Poplar and Marks Creeks had lower EPT taxa richness and abundance values (plus higher biotic index values) than downstream reaches within these catchments, suggesting that upstream perturbations were problematic. In addition both upstream locations also had slightly lower pH values than downstream reaches. Marks Creek at the Prichard Road location had the highest EPT taxa richness and abundance values, second only to the Beddingfield Creek location, and overall had the greatest number of benthic insects. It is possible that Lake Myra is acting as a filter for upstream pollutants and improving the water quality downstream.

Extremely low EPT taxa richness (3 and 4, respectively), EPT abundance (21 and 15, respectively) and dissolve oxygen values (1.4ppm and 1.6ppm, respectively) at Buffalo Creek at Mitchell Mill Road and Hominy Creek at Buck Road were recorded. These values suggest that low flow conditions are common in the headwater reaches of both Buffalo Creek and the Little River and those benthic insect populations are responding to these conditions. These two locations were not given bioclassifications due to low flow. Flow conditions improve significantly at the downstream location on Buffalo Creek at Pool Road and insect abundance and diversity increases. However, unlike the downstream site at Marks Creek at Shotwell Road, bioclassification was give only a Fair rating due to the very high biotic index value (6.7). The dominant taxa at this location are tolerant.

Fair bioclassifications were also assigned to the monitoring locations at Rocky Creek at Riley Hill Road and Snipe Creek at Taylors Mill Roads. The benthic fauna at these two locations were also dominated by tolerant taxa resulting in elevated biotic index values; 6.5 and 6.6 respectively. The channel at the Snipe Creek location was deeply incised with numerous midstream sediment bars. These unstable habitat conditions are likely responsible for the very low taxa richness and abundance values at this location.

Appropriate collecting conditions in the Little River were difficult to find due to the lack of discernable flow at bridge crossings in Wake County. Flow appeared to be restricted due to run-of-the-river impoundments at many of the bridge crossings and/or a plethora of beaver dams. Dissolved oxygen values recorded at these location were extremely low (1ppm at many locations), well below the state water quality standards. The Division of Water Quality has collected benthos samples only at Highway 96 Bridge in Wake County and at SR 1722 in Johnson County. A benthic sample was collected near NC 231 in Johnson County as part of this investigation. A Good/Fair rating was given to this location based on EPT taxa richness (14) and biotic index (6.0) values. These data compare favorable to DWQ data collected from SR 1722 in 07/91 which also resulted in a Good/Fair bioclassification. Additional investigations documenting water quality conditions and trends will be conducted.

Despite Good/Fair or Fair water quality conditions at most monitoring locations (Good at Beddingfield Creek), rare or unusual benthic insect taxa were collected. Table 3 lists these taxa and their collection locations. The Beddingfield and Poplar Creek locations had most of these taxa, although significantly rare taxa were also collected from Rocky Creek, Snipe Creek, Marks Creek at Prichard Road, and Hominy Creek.

Table 3. Significantly Rare Taxa. Wake/Johnson Water Quality Investigation, August 2009.

Taxa (Biotic Index Value)	Taxonomic Group	Collection Location (s)
Serratella deficiens (2.8)	Mayfly	Beddingfield Cr. and Poplar Cr. at Bethlehem Rd
Paraleptophlebia spp (0.9)	Mayfly	Rocky Creek at Riley Hill Rd
Leuctra spp (2.5)	Stonefly	Beddingfield Cr. and Poplar Cr. at Smithfield Rd
Eccoptura xanthenes (3.7)	Stonefly	Beddingfield Cr., Poplar Cr. at Bethlehem Rd. and Marks Cr. at Prichard Rd.
Brachycentrus spinae (0.0)	Caddisfly	Hominy Creek at Buck Rd.
Phylocentropus spp (6.2)	Caddisfly	Rocky Creek at Riley Hill Rd
Diplectrona modesta (2.2)	Caddisfly	Beddingfield Cr. and Poplar Cr. at Smithfield Rd
Lepidostoma spp (0.9)	Caddisfly	Poplar Cr at Bethlehem Rd.
Lype diversa (4.1)	Caddisfly	Beddingfield Cr. and Poplar Cr. at Bethlehem Rd
Neophylax oligius (2.2)	Caddisfly	Beddingfield Creek
Dixa spp (2.6)	Diptera	Beddingfield Creek, Snipe Creek at Taylors Mill Rd.
Parametriocnemus lundbecki (3.7)	Chironomidae	Beddingfield Creek
Anchytarsus bicolor (3.6)	Beetle	Beddingfield Creek
Hagenius brevistylus (4.0)	Dragonfly	Beddingfield Cr. and Poplar Cr. at Bethlehem Rd
Ophiogomphus spp (5.5)	Dragonfly	Beddingfield Cr., Poplar Cr at Smithfield Rd and Poplar Cr. at Bethlehem Rd

References:

CH2MHill, 2002. Technical Memorandum No. 6. Wake County Watershed Assessment – Biological, Habitat, and Geomorphologic Evaluations.

North Carolina Division of Water Quality. 2008. Technical Memorandum, June 22, 2008 from Eric Fleek to Jimmie Overton. Biocriteria for the small streams of the North Carolina Mountains and Piedmont.

North Carolina Division of Water Quality (DWQ). 2006. Standard Operating Procedures for Benthic Macroinvertebrates. NC Department of Environment and Natural Resources. Environmental Sciences Section, Biological Assessment Unit. Raleigh, NC.

Appendix 1. Benthic macroinvertebrates – Wake/Johnson County Water Quality Investigation. August, 2009.

Station Location	Beddingfield Creek	Poplar Creek,Smithfield Rd.	Poplar Creek,Bethlehem Rd	Marks Creek,Eagle Rock Rd	Marks Creek,Prichard Rd.	Buffalo Creek,Mitchell Mill R	Buffalo Creek,Pool Rd.	Hominy Creek,Buck Rd.	Rocky Creek,Riley Hill Rd	Snipe Creek, Taylors Mill Rd	Little River,above NC 231
Taxa name (BI)/Site #	1	2	3	4	5	6	7	8	9	10	11
Ephemeroptera											
Family Baetidae											
Acerpenna pygmaea (3.9)									A		R
Baetis propinquus (5.8)	C	A	C		A					R	A
Baetis flavistriga (7.0)	C										
Baetis intercalaris (7.0)					A						C
Centroptilum spp (6.6)	R				R						R
Family Caenidae											
Caenis spp (7.4)				R		A	A	R	A	A	A
Family Ephemerellidae											
Serratella deficiens (2.8)	A		R								
Family Heptageniidae											
Stenacron interpunctatum (6.9)							A		C	C	
Stenonema modestum (5.5)	A	C	A	C	A		A	C	C	A	A
Family Leptophlebiidae											
Paraleptophlebia spp (0.9)									R		
Family Oligoneuriidae											
Isonychia spp (3.5)	R		C	C	A		R		C		C
Family Tricorythidae											
Tricorythodes spp (5.1)					A						
Plecoptera											
Family Leuctridae											
Leuctra spp (2.5)	R	C									
Family Perlidae											
Eccoptura xanthenes (3.7)	A		C		R						
Trichoptera											
Family Brachycentridae											
Brachycentrus spinae (0.0)								R			
Family Dipseudopsidae											
Phylocentropus spp (6.2)									C		
Family Hydropsychidae											
Cheumatopsyche spp (6.2)	A	A	A	A	A	A	A	A	A	A	A
Diplectrona modesta (2.2)	R	R									
Hydropsyche betteni (7.8)	A	C	C		C				C		R
Hydropsyche venularis (5.0)	R				C						R

Family Hydroptilidae											
Hydroptila spp (6.2)											C
Family Lepidostomatidae											
Lepidostoma spp (0.9)			R								
Family Leptoceridae											
Nectopsyche exquisite (4.1)					R						R
Oecetis perisimillis (4.7)			C	R	A		R				A
Oecetis spp (4.7)							R				
Triaenodes injusta (2.5)	A	C	A	R	A		R				
Triaenodes abus (?)							R				
Family Limnephilidae											
Pycnopsyche guttifer (2.6)	R										
Family Philopotamidae											
Chimarra spp (2.8)	A	C			C	R					R
Family Phryganeidae											
Ptilostomis spp (6.4)	R	R		R							
Family Polycentropodidae											
Polycentropus spp (3.5)					C						
Family Psychomyiidae											
Lype diversa (4.1)	R		R								
Family Uenoidae											
Neophylax oligius (2.2)	A										
Diptera: Misc families											
Family Ceratopogonidae											
Palpomyia (complex) (6.9)		R		R		C		R	R		
Family Culicidae											
Anopheles spp (8.6)									R	C	
Culex spp (10.0)										R	
Family Dixidae											
Dixa spp (2.6)	R									R	
Family Empididae (7.6)		C									
Family Ptychoteridae											
Bittacomorpha spp (?)		R						R			
Family Simuliidae											
Simulium spp (6.0)	A	R	C	R	C	R	R		R	C	C
Family Tabanidae											
Tabanus spp (9.2)			R			R			R	R	
Family Tanyderidae											
Protoplasa fitchii (4.3)			R								
Family Tipulidae											
Pseudolimnophila spp (7.2)	R							R			
Tipula spp (7.3)			C		C			R	C		C
Diptera: Chironomidae											
Ablabesmyia mallochi (7.2)											R

Ablabesmyia parajanta/janta (7.4)	R						A		R		
Clinotanypus pinguis (8.7)				R					C		
Chironomus spp (9.6)						A					
Conchapelopia Group (8.4)	C	A	A	A	R	C	A	A	R	R	R
Corynoneura spp (6.0)			R								R
Cryptochironomus fulvus (6.4)	R					R				R	
Cricotopus bicinctus: C/O sp1 (8.5)											A
Dicrotendipes neomodestus (8.1)							C				
Glyptotendipes spp (9.5)						C					
Microtendipes spp (5.5)									A	R	
Natarsia spp (10.0)	R	R	C	C	R	C	C	R		R	C
Othocladius (Euorthcladius): C/O sp 3 (9.1)		R									
Parametriocnemus lundbecki (3.7)	R	A									
Paratendipes spp (5.1)	R										
Phaenopsectra spp (6.5)	A	R	R	C			C	R	A	R	R
Phaenopsectra flavipes (7.9)			R								
Polypedilum convictum (4.9)	A		A	C	A	C	R	R		C	A
Polypedilum illinoense (9.0)		C	R						R		
Polypedilum halterale (7.3)						C					
Polypedilum scalaenum (8.4)		C					R				
Procladius spp (9.1)								R	R		
Rheocritcotopus spp (7.3)				R							
Rheotanytarsus spp (5.9)	R	R	R	R	C	A		R	R		
Robackia demeijerei (3.7)			R								
Stenochironomus spp (6.5)		C	C		R						
Tanytarsus spp (6.8)			R	R	C		C				A
Thienemaniella spp (5.9)	R		R								
Tvetenia bavarica gp. (E sp. 1) (3.7)			R		R						
Coleoptera											
Family Dryopidae											
Helichus spp (4.6)	A	A	A	R	A			R	C		
Family Dytiscidae											
Copelatus spp (10.0)				R							
Hydaticus bimarginatus (9.1)					R						
Hydroporus spp (8.6)	C			R	R	R	C	R		R	
Family Elmidae											
Ancyronyx variegates (6.5)			A	A	R		C		C		
Dubiraphia spp (5.9)					R		R			R	
Macronychus glabratus (4.6)	A	A	A	C	A		R				C
Promoresia spp (2.4)	C	C	C		A		C			C	A
Stenelmis spp (5.1)	C						R		C		
Family Gyrinidae											
Dineutus spp (6.2)		C		R	A	C	C	R			C
Family Haliplidae											
Peltodytes spp (8.7)		C			R			C			

Family Helodidae											
Scirtes spp (?)						R		R	R		
Family Hydrophilidae											
Berosus spp (8.4)				R							
Enochrus spp (8.8)		R									
Tropisternus spp (9.7)									R		
Family Ptilodactylidae											
Anchytarsus bicolor (3.6)	C	R									
Odonata											
Family Aeshnidae											
Basiaeschna janta (7.4)				C			C		R	R	C
Boyeria vinosa (5.9)	A	A	A		C		R		C		
Family Calopterygidae											
Calopteryx spp (7.8)	A	A	A	A		C			R	C	
Family Coenagrionidae											
Argia spp (8.2)		R	R	C	R						
Enallagma spp (8.9)			R	C	A	C	C	C	C	C	R
Family Cordulegasteridae											
Cordulegaster spp (5.7)	R	A									
Family Corduliidae											
Neurocordulia spp (5.0)				C		A	C	C		C	
Family Gomphidae											
Gomphus spp (5.8)	C	A	C	C	C	R	C	R	C	R	R
Hagenius brevistylus (4.0)	R		R								
Ophiogomphus spp (5.5)	C	C	C								
Progomphus obscurus (8.2)	R	A	R		R		R				A
Family Libellulidae											
Erythemis simplicicollis (9.7)						R			R		
Pachydiplax longipennis (9.9)							C	R			
Family Macromiidae											
Macromia spp (6.2)					C						R
Oligochaeta											
Family Lumbriculidae (7.0)	R	R	C	C	C	R	R	C	R	R	R
Family Nadidae											
Pristina spp (9.6)					R		C				
Family Cambarinicolidae (6.0)	C				A						
Family Tubificidae (immature) (7.1)							C				
Megaloptera											
Family Corydalidae											
Corydalus cornnutus (5.2)					C						
Nigronia serricornis (5.0)	C	A	C	C	C				R		
Family Sialidae											
Sialis spp (7.2)		R		C	A		R	A	A	R	
Crustacea											

Family Asellidae											
Lirceus spp (7.9)	R	R		R			C	C	R	R	A
Family Cambaridae (7.5)	A	C	C		C	A	C	C	R		
Cambarus spp (7.6)		R		R						R	R
Procambarus spp (7.0)	R					R					
Family Gammaridae											
Crangonyx spp (7.9)				C		C	C	C	A		
Family Palaemonidae											
Palaemonetes spp (7.1)				R			A				C
Family Talitridae											
Hyallela azteca (7.8)					R		A	C	C		
Mollusca											
Family Ancylidae											
Ferrissia spp (6.6)			R		R						R
Family Hydrobiidae											
Amnicola spp (5.2)							R				
Family Lymnaeidae											
Pseudosuccinea columella (7.7)		C					R				
Family Physidae											
Physella spp (8.8)	R	R		C	R		R				
Family Planorbidae											
Helisoma anceps (6.2)				C			R				
Menetus dilatatus (8.2)							C			R	
Family Viviparidae											
Campeloma decisum (6.5)		A	C	C		C	R	C			
Corbiculidae											
Corbicula fluminea (6.1)			A	A	A						A
Family Sphaeriidae											
Sphaerium spp (7.6)				C	C	A	A	C			
Pisidium spp (6.5)				R			R			R	
Other Taxa											
Family Glossiphoniidae											
Batracobdella phalera (7.6)				R							
Helobdella stagnalis (8.6)								C			
Placobdella papillifera (9.0)		C		C				R			R
Hydracarinia (5.5)				A	R		R	R			C
Nematomorpha											
Gordius spp (?)		R									
Planariidae											
Dugesia tigrina (7.2)				R	A		C	C			
Polyclad											
Prostoma graecens (6.1)					R						
Family Sisyridae											
Climacia spp (8.4)				C							

Total Taxa Richness	52	47	45	48	54	28	51	35	39	30	40
Total Abundance	217	187	177	144	248	113	172	88	131	72	170
EPT Taxa Richness	18	9	11	7	15	3	9	4	9	5	14
EPT Abundance	93	37	48	20	95	21	45	15	46	34	65
Biotic Index Value	5.2	6.2	5.8	6.9	5.5	7.1	6.7	7.1	6.5	6.6	6.0
Bioclassification*	Good	Fair	G/F	Fair	G/F	NA	Fair	NA	Fair	Fair	G/F

*Bioclassifications were calculated using new DWQ criteria for small piedmont streams (DWQ June, 2008), except the data from the site #11 (Little River). NA – these locations had very little flow, more typical of swamp streams. Piedmont biocriteria may not apply to these stream types.

Glossary of Terms

The following list of terms and definitions is intended to assist readers who are unfamiliar with some aspects of watershed assessment and planning. The Glossary attempts to explain terms less often used in common language and is not comprehensive.

303(d) List – North Carolina's official record of impaired water bodies across the state. The development and biannual update of this list is a requirement of the US Environmental Protection Agency in its role of enforcing the Clean Water Act.

8-Digit Hydrologic Unit (8-digit HU) – The fourth order delineation of rivers into subbasins, formerly reported as catalog units by the US Geological Survey. There are 54 entire or partial 8-digit HUs in North Carolina, each averaging approximately 700 square miles (approximately two counties) in size.

12-Digit Hydrologic Unit (12-digit HU) – The recent sixth order delineation of subwatersheds ranging between 16 and 60 square miles, according to the Federal Standards and Procedures for the National Watershed Boundary Dataset, Third Edition (2012). These will be the Local Watershed Planning scale EEP uses from 2013 onward.

14-Digit Hydrologic Unit (14-digit HU) – The historic sixth order delineation of subwatersheds ranging approximately from five to 90 square miles in area. These have been the scale of Local Watershed Planning until 2013 and are referred to as HUs in EEP watershed plans.

Above Sea Level (ASL) – Unit of altitude measurement typically measured in feet or meters.

Aggradation – The deposition of sediment by a river or stream.

Ambient Data – Water quality data collected via grab sampling by the Division of Water Quality at set stations across the state. Many sites have an extensive sampling history dating back many years and serve as high quality references for comparison to current water quality assessments.

Aquatic Organism Passage (AOP) – Term used to indicate the opportunity for fish or other fauna to move upstream or downstream of a potential obstacle, such as a manmade dam, a beaver dam, or a road culvert. The ecological importance of an obstruction can be great, especially when migratory species (e.g., American Shad) require upstream access to nursery or spawning habitat.

Aquatic Toxicity Unit (ATU) – ATU is a specialized section of DWQ that assesses the safety of discharge waters that are reintroduced to streams and rivers after treatment. ATU also performs testing of ambient waters using bioassays (e.g., *Ceriodaphnia*/ water flea and fathead minnow survival testing) to assist with special studies and toxicity screening of planning watersheds.

Bank Erosion Hazard Index (BEHI) – A composite measurement representing the degree of streambank instability at a particular site.

Bankfull – The measurement representing the geomorphologic channel-forming flow for a stream or river. Geomorphologic features such as scour lines, tops of bars, and rack lines are indicators that help identify the stage representing bankfull for a stream.

Benthic Macroinvertebrate – One of many taxa of aquatic insects that live on or in stream substrates. The community of benthic macroinvertebrates indicates the long term water and habitat quality at a sampling site. The particular species present or absent may indicate which water quality and habitat stressors are dominant.

Best Management Practice (BMP) – Term used to describe a constructed project or a procedure that efficiently and effectively maintains or improves the quality and flows of water and habitats over a period of time.

Bioclassification – A specific water quality rating attributed to a segment of stream or other water body, developed using benthic macroinvertebrate community data. Typically, streams rated Excellent, Good, or Good/Fair are considered to be "supporting their uses" while streams rated Fair or Poor are considered to be "not supporting their uses" and are nominated for inclusion on the state's 303(d) List of Impaired Waters. Small streams and swamp streams have special adjustments and calculations used to indicate their ratings.

Biological Assessment Unit (BAU) – This specialized section within DWQ performs *in situ* sampling of aquatic bug and fish communities to determine the level of watershed function at a particular site. BAU provides data support and analysis for EEP watershed planning as well as DWQ basinwide planning. These data are used to assign bioclassifications and levels of impairment to NC streams and water bodies.

Biotic Index – The summary measure of tolerance values of benthic macroinvertebrates relative to their abundance in a sample. This measure is developed by BAU, a section of DWR (formerly DWQ), to assign a water quality rating to a stream reach.

Buffer – An area adjacent to a stream, wetland, or shoreline where development activities (e.g., buildings, logging) are typically restricted or prohibited; may be managed as streamside (riparian) zones where undisturbed vegetation and soils act as filters of pollutants in stormwater runoff; buffer zone widths vary depending on state and local rules, but are typically a minimum of 25 to 50 feet on each side of perennial streams; in N.C., buffer rules have been established for all (or portions) of the upper Cape Fear, lower Catawba, Neuse and Tar-Pamlico river basins

Carolina Bay – A shallow oval freshwater depression typically found in the coastal plain. These features may have extensive emergent wetlands or they may be forested.

Catalog Unit (CU) – Typically this refers to USGS 8-digit catalog units, the watershed boundaries within which EEP must deliver mitigation projects for impacts therein. The requirement for mitigation within an impacted CU is policy-driven and is intended to keep restoration projects close to their impacts.

Catchment – A term defined in the Federal Standards and Procedures for the National Watershed Boundary Dataset, Third Edition (2012) as a watershed ranging in size between five and 16 square miles, resulting from a seventh order delineation and represented by a 14-digit HU code (not to be confused with the former sixth order delineation that is now represented by a 12-digit HU code).

Channel – Term that refers to the natural trough formed by erosive movement of waters running downslope in low lying areas through time. "Channel" also refers to excavated ditches or canals used for transporting water.

Clean Water Management Trust Fund (CWMTF) – A state agency in North Carolina that assesses and disperses funding for water quality improvement projects, including acquisitions for preservation, municipal infrastructure upgrades, best management practices implementation, and stream/wetland restoration.

Compensatory Mitigation – Any mitigation action taken to compensate for stream and/or wetland impacts associated with a 401/404-permitted project; includes Restoration, Enhancement, Creation and Preservation, with varying degrees of mitigation credit granted by the U.S. Army Corps of Engineers and the DWQ; compensatory mitigation is the basic regulatory tool by which "unavoidable" impacts to streams, riparian buffers, and wetlands are intended to be minimized (or compensated for) in order to meet the nationwide goal of "no net loss" of wetlands.

Comprehensive Plan – Document produced by a local government that describes how the municipality plans to manage its economic growth and development for a defined period of time. Typical plans may be developed for a 30-year duration with some provisions for adaptive updating at discreet points in time.

Conservation Easement – A legally-binding condition attached to a parcel or part of a parcel of land, requiring that certain conditions be maintained for a defined period of time. As a condition for release of mitigation credit, EEP restoration, enhancement, and preservation projects must be developed only on properties upon which permanent conservation easements have been made.

Corridor (or Wildlife Corridor) – A narrow area of habitat lying between two or more otherwise disjunct larger habitat patches that allows for the movement of wildlife. Riparian buffers along streams and rivers can serve as effective wildlife corridors.

Denuded Buffer – Refers to a buffer that has had most or all of its woody vegetation removed.

Department of Environment and Natural Resources – The agency responsible for regulating and managing the water and land resources of North Carolina.

Department of Transportation (DOT) – See North Carolina Department of Transportation.

Design-Bid-Build (DBB) – Term used in mitigation context that refers to the mechanism by which a restoration project is contracted and developed. The steps involved in developing an EEP DBB project include project site acquisition, design by a qualified consulting firm (via contract), construction by a private contractor (via bidding process), and monitoring to meet success criteria by a qualified monitoring firm (via contract).

Digital Elevation Model (DEM) – Term used in Geographic Information Systems that refers to a 3-dimensional representation of land surfaces in a watershed.

Division of Marine Fisheries (DMF) – The state agency responsible for managing the fisheries resources of the state, including migratory species that utilize inland rivers. This agency also administers the recreational and commercial permitting system related to managing North Carolina's fisheries.

Division of Soil and Water Conservation (DSWC) – The section within the North Carolina Department of Agriculture and Consumer Services responsible for protecting and improving soil and water resources throughout the state.

Division of Water Quality (DWQ) – A former division of the North Carolina Department of Natural Resources, DWQ is now (as of 2013) a section within the Division of Water Resources. Historically, DWQ has been the agency responsible for regulating water quality related activities and permitting the usage of wetlands in the state.

Division of Water Resources (DWR) – The division of the North Carolina Department of Natural Resources responsible for protecting the state's water resources for drinking and other uses. In 2013, the Division of Water Quality was merged into DWR.

Drainage (also Drainage Area) – This refers to the area from the highest points to the place where all water flow exits a watershed.

Ecoregion – Refers to a defined geographic region that is categorized according to its soil characteristics, climate, and landforms (among other features). For planning purposes, EEP utilizes the four different levels of ecoregions developed by the USGS and EPA.

Ecosystem Enhancement Program (EEP) – The state agency responsible for restoring and protecting North Carolina's wetlands and waterways for future generations while offsetting unavoidable environmental impacts due to development and road construction. EEP is responsible for producing viable mitigation projects for the NC Department of Transportation and the state's in-lieu fee programs.

Ecosystem Function – For EEP, this refers to the primary services provided by natural systems related to their degree of diversion from a natural or pristine state. This function is divided into three categories: (1) water quality, the state of purity of water that promotes survival of aquatic organisms and provides safe water for drinking, (2) hydrology, the ability of a watershed to regulate appropriate water flows in streams and wetlands and to provide adequate levels of flood water attenuation, and (3) habitat, the water column, soils, riparian areas, and plant communities that support the abundance of organisms dependent on them for survival and persistence.

Embeddedness – In the context of stream geomorphology, embeddedness is the degree to which coarser substrates like rocks and pebbles are surrounded by finer sediments like sand and silt in a stream bed. The more embedded a stream is, the fewer spaces between substrates are available for organisms like benthic macroinvertebrates to live in, and the poorer the habitat quality.

Enhancement – Actions taken to increase wetland, stream, or riparian buffer functions through the manipulation of either vegetation or hydrology. Stream or wetland enhancement is a category of mitigation, but is credited at a lower rate than full-scale restoration.

Ephemeroptera-Plecoptera-Trichoptera (EPT) – These are three genera of benthic macroinvertebrates that collectively comprise the most environmentally sensitive group of aquatic bugs. The community of these three taxa collected at a site in a watershed is often used as a measure of water quality or watershed health.

Erodible Soils (also Highly Erodible Soils) – A category of soils that are prone to weathering due to their texture, composition, landscape position, and topography.

Erosion and Sediment Control (ESC) – See “Sediment and Erosion Control.”

Fall Line – The narrow zone marking the geological boundary between the piedmont and coastal plain where the parallel rivers exhibit an abundance of significant waterfalls to drops in elevation. This line approximately follows the path of Interstate 95 in North Carolina.

Floodplain – Area of land on each side of a stream channel that is inundated periodically by flood waters; important zone for dissipating the energy of peak storm flow discharges and for storing waters that otherwise might damage in-stream habitat and/or cause downstream flood damage; typically includes high-quality riparian habitat (if undisturbed); waters flowing in incised (down-cut) streams may not be able to access the adjacent floodplain area to dissipate the volume and energy of higher storm flow events.

Floodplain Access – The ability of a stream or river to overflow its banks during storm events. This capacity allows for deposition of sediments over a broad area and dissipates water energy that might otherwise lead to increased bank instability.

Floodplain Disturbance – Refers to a state of activities in the areas immediately adjacent to streams and rivers. Movement of earth, access by livestock, and clearcutting are types of disturbance that can lead to instability of banks and soils in general, and may result in detrimental sedimentation in a stream bed.

Full-Delivery Project – A full-delivery project is a mitigation project developed, designed, constructed, and monitored for a required period so that mitigation credits generated are the complete responsibility of the provider. EEP solicits full-delivery projects via a Request-for-Proposals process per North Carolina policies.

Full-Delivery Provider – A consulting and/or construction firm that produces full-delivery projects for mitigation credit.

Functional Assessment – An integrated analysis of water quality, hydrologic, and habitat data that represents the level of integrity of the natural system in a watershed. For EEP watershed plans, functional assessment is most often performed at the subwatershed scale (1-5 square mile delineated areas) to identify which subwatersheds will benefit the most from particular types of restoration projects.

General Advisory Committee (GAC) – The group of stakeholders serving as the primary decision-making body for the Wake-Johnston Collaborative Local Watershed Plan.

Geographic Information System (GIS) – Term that refers to computer software and databases used to develop maps and analyze spatial data. ESRI ArcGIS is the software platform EEP utilizes for geographic analysis.

Grade – Refers to the use of heavy machinery to move soil such that different slope and aspect is constructed for landscape, project site, or stream bed.

Habitat – The physical space, substrate, and biological components (e.g., plants) that make up the elements required for an organism to survive, feed, grow, and reproduce.

Heads-up Digitizing – Refers to GIS process whereby outlines from a raster images are traced on-screen to draw boundaries.

Hydric Soils – Soils that are subject to flooding or ponding, forming their characteristic state under saturated, anaerobic conditions.

Hydrologic Unit (HU) – Typically refers to USGS 14-digit hydrologic units for EEP plans initiated prior to 2013. For plans initiated in 2013 or later, HU refers to USGS 12-digit hydrologic units.

Hydrology – Refers to the status and distribution of water in a wetland or stream, or in the upper surface of the earth.

Impaired Waters – In North Carolina, streams, rivers, and other water bodies determined to have quality conditions that are below standards for their normal usage, including biological communities, recreation, drinking water supply, and food provision.

Imperviousness (or Impervious Surface) – Refers to the condition of the earth's surface and the degree to which water (e.g., rainfall) can penetrate and settle into the water table. Watersheds with high imperviousness are typically heavily developed with lots of paved roads, leading to excessive surface water runoff with high energy that destabilizes surface soil and stream banks.

Impoundment – A body of water created by the damming or blocking of a significant volume of downstream flow.

Index of Biotic Integrity (IBI) – A rating scale that indicates the level of watershed function, based on metrics developed by sampling biological communities. In North Carolina, the IBI is based on the condition of fish communities sampled by Biological Assessment Unit in the Division of Water Resources (formerly in DWQ).

In-Lieu Fee – A payment made by a 401/404permittee to EEP in lieu of having to site and construct compensatory mitigation project(s) to offset permitted impacts; in such cases, EEP becomes the party responsible for instituting the required amount and type of compensatory mitigation (e.g., so many thousands of restored stream feet, so many acres of restored wetlands). The required fee is based on a statutory schedule of fees, on a per stream foot or per wetlands acre basis.

Instream Habitat – Refers to aquatic habitats including substrates on stream beds, the water column, and the zone immediately below and along the sides of the stream bed.

Interstream Divide – The high ridge of land that separates one watershed from another.

Land Trust – A private, not-for-profit organization that exists to conserve land by developing conservation easements and land purchases to be held in stewardship for a defined period of time (including in perpetuity).

Land Use Plan (LUP) – A document outlining a county or municipal strategy that identifies current land use and predicts future land use patterns within a specific boundary.

Light Detection and Ranging (LIDAR) – Technology for determining the earth's surface topography to a very fine scale using lasers that bounce light off the surface and use the time to retrieval to calculate distance, in a similar manor as radar.

Local Watershed Plan (LWP) – The fine-scale plans EEP develops with stakeholders in a relatively small geographic region, typically consisting of one or a few 14-digit hydrologic units. To date, EEP has developed approximately 40 LWPs across the state.

Microhabitat – Term referring to a particular small-scale habitat condition that differs in some significant way from its surroundings.

Mitigation – See Compensatory Mitigation.

Mitigation Credit – The amount of value assigned to the linear stream footage or the wetland acreage of a restoration, enhancement, or preservation project.

Multi-thread Channel – Refers to the condition of a stream where more than one channel transports the flow downstream in the same section of a watershed. This condition most often exists in headwaters of watersheds.

National Land Cover Database (NLCD) – The database of spatial geographic information developed by the Multi-Resolution Land Characteristics Consortium (MRLC) that provides a 16-class land cover classification scheme based on Landsat satellite data (2001 and 2006, with an accuracy assessment performed in 2011). These data were used in the development of land cover information in the Wake-Johnston Collaborative LWP.

National Wetlands Inventory (NWI) – The database of all documented wetlands in the US, based on a methodology developed by the US Fish and Wildlife Service. The program maintains and distributes wetlands spatial data to public users as well as identifying and projecting trends in wetland distribution and condition across the country.

Natural Heritage Element Occurrence (NHEO) – A spatial data designation by the North Carolina Natural Heritage Program that indicates the approximate geographic location of an identified individual, population, or unique ecological community.

Natural Heritage Program (NHP) – The state agency responsible for managing North Carolina's rare species. Its mission is "to provide science and incentives to inform conservation decisions and support conservation of significant natural areas" in the state.

Natural Resources Conservation Service (NRCS) – A Federal agency within the US Department of Agriculture that sponsors state NRCS programs. The NRCS in NC "works with landowners through conservation planning and assistance designed to benefit the soil, water, air, plants, and animals that result in productive lands and healthy ecosystems." (NRCS, 2013. http://www.nrcs.usda.gov/wps/portal/nrcs/main/national/about/)

Non-point Source (NPS) – Term that refers to pollutants that are broadly distributed throughout a watershed that are not attributable to a particular or identifiable causal agent.

North Carolina Department of Transportation (NCDOT) – The state agency responsible for developing and maintaining roads and highways in North Carolina.

North Carolina Forest Service (NCFS) – The agency responsible for management of North Carolina's publicly owned forests. The Forest Service is administered by the NC Department of Agriculture.

North Carolina State University (NCSU) – Part of the system of public universities in North Carolina, this is the primary agricultural research school in the state, housing most of its Agricultural Extension programs.

Nutrient Sensitive Waters (NSW) – Streams, rivers, lakes, and estuaries designated by the NC Division of Water Quality as being prone to degradation due to inputs of nitrogen, phosphorus, and other nutrients from agricultural and other runoff. For the Neuse River, DWQ has developed a nutrient reduction strategy to help improve water quality conditions throughout the basin.

Open Space – Natural land that has not been converted to residential, suburban, or commercial development, including floodplains, farms, wetlands, parks, fields, and forests. Open space programs exist for many counties in North Carolina and typically consist of protected parcels of the land types mentioned above, held in conservation or similar easement.

Order – see Stream Order.

Permitted Impact – Refers to alterations of wetlands, streams, or other waters in the United States subject to protections of the Clean Water Act. To dredge, fill, or ditch any of these waters requires a permit by the appropriate government agency (e.g., US Army Corp of Engineers, NC Division of Water Resources, etc.).

Phase I, II, III, and IV Planning – The tiered structure EEP attributes to its Local Watershed Planning efforts. These levels are summarized below.

- Phase I – Collection and preliminary synthesis of existing information; development of Preliminary Findings Report.
- Phase II – Collection and detailed analysis of new watershed data; development of Watershed Assessment Report.
- Phase III – Development of management recommendations and project atlas; development of Watershed Management Plan.
- Phase IV – Implementation of the LWP through mitigation, outreach, and collaboration.

Preliminary Findings Report (PFR) – The report developed as part of the Phase I Local Watershed Planning process. This report typically contains a description of the LWP watershed, a subwatershed delineation to facilitate subsequent study, a preliminary watershed characterization based on existing data, a preliminary identification of stressors, and a preliminary atlas of potential projects.

Preservation – For EEP, preservation refers to a project whereby a permanent conservation easement is purchased and held for mitigation credit. The preservation to impact mitigation credit ratio is typically 10:1.

Project Atlas (PA) – A Project Atlas is a standalone document or Watershed Management Plan section that identifies a prioritized array of mapped projects that will provide the most functional improvement to a watershed if they're implemented.

Rare, Threatened, or Endangered Species (RTE) – This refers to the subset of species in a watershed that have special status attributed to them by the US Fish and Wildlife Service or the NC Natural Heritage Program.

Re-establishment – Manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a former aquatic resource. "Re-establishment" results in the rebuilding of a former aquatic resource and results in a gain in aquatic resource area and functions.

Regional Curve – This is a term referring to the graphic representation of the relationship between bankfull channel dimensions and drainage area specific to a defined geographic area. See also "bankfull" and "drainage."

Regional Watershed Plan (RWP) – A planning methodology under development by the Ecosystem Enhancement Program (as of 2013) that combines elements of the fine-scale assessment and recommendations of its Local Watershed Plans with the broad-scale recommendations of its River Basin Restoration Priorities Plans. The intention is to develop a hybrid planning method that can accomplish the goals of each.

Rehabilitation – Manipulation of the physical, chemical, or biological characteristics of a site with the goal of returning natural/historic functions to a degraded aquatic resource. "Rehabilitation" results in a gain in aquatic resource functions, but does not result in a gain in aquatic resource area.

Remote Sensing – Term referring to a method for observing and delineating land usage using aerial or satellite imagery.

Restoration – The reestablishment of wetlands or stream hydrology and wetlands vegetation into an area where wetland conditions (or stable stream bank and stream channel conditions) have been lost. Examples include (1) stream restoration using natural channel design methods coupled with re-vegetation of the riparian buffer, (2) riparian wetlands restoration through the plugging of ditches, (3) re-connection of adjacent stream channel to the floodplain, and (4) planting of native species to re-vegetate a riparian area. This type of compensatory mitigation project receives the greatest mitigation credit under the 401/404 regulatory framework.

Riparian Buffer – Relating to the strip of land adjacent to streams and rivers, including stream banks and adjoining floodplain area. These are important streamside zones of natural vegetation that, when disturbed or removed, can have serious negative consequences for water quality in streams and rivers.

Riparian Zone – The area immediately adjacent to streams and rivers, that when naturally vegetated, serves important water quality functions such as filtration and flow energy dissipation.

Riprap – Term referring to large-sized stones placed along waterways, ditches, and bridge crossing used to stabilize edges that might otherwise be prone to erosion.

River Basin Restoration Priorities (RBRP) – The broad-scale plans EEP develops on a five-year basis, used to identify focus areas (14-digit HUs) for restoration projects. These priorities are identified by analyzing the following indicator data:

- Baseline Characteristics – Basic features of an HU such as total area and total stream length.
- Assets – Important features having significant high functional value in a HU such as designated High Quality Waters or Significant Natural Heritage Areas.
- Problems – Features that represent significant stressors in an HU such as impaired streams or permitted livestock operations.
- Opportunities – For EEP, these features include the potential for new projects to augment the functions of existing watershed project such as those water quality improvement projects sponsored by the Clean Water Management Trust Fund or the DWR-administered 319 Program.

Sediment and Erosion Control (S&EC) – Term that refers to protection measures used at a project site after vegetation removal and grading occur to prevent topsoil loss and subsequent stream pollution during rain events. Examples of these measures include installation of sediment traps and fencing, planting of temporary seed mixtures, or temporary bypass channels.

Sedimentation – Process whereby eroded soils are deposited in streams, rivers, or lakes that is accelerated by any activity that disturbs the land surface or removes vegetation (e.g., road construction, agriculture/forestry, urban development). Sediment source areas include upland sites, intermediate slopes, riparian zones, and stream banks and channel scour areas.

Significant Natural Heritage Area (SNHA) – A designation assigned to a terrestrial or aquatic site considered to have special biodiversity significance such as the presence of a rare species or a rare outstanding example of a particular habitat type.

Sinuosity – Refers to the relative curviness of a stream or river.

Slope – The measure of the degree of altitude loss or gain between one point and another on a site in a landscape. For restoration purposes, the slope of a streambed is an important feature in restoration project design.

Snag – Term referring to large woody debris found in streams or rivers upon which other debris accumulates, creating a diverse microhabitat condition.

Soil and Water Conservation District (SWCD) – County-based agency responsible for administering the NC Department of Agriculture programs related to protecting and improving soil and water resources throughout the state.

Source – In the context of pollutants, a source is an identified causal agent of a particular water quality or habitat stressor.

Stem Count (or “stems”) – Refers to the number of individual woody plants that are needed meet defined success criteria for wetland, riparian buffer, stream, or nutrient offset projects. Typically a specific number of stems (measuring 5 inches diameter at breast height) per acre are required as indicated by a quadrat sampling protocol determined before project construction.

Stormwater – Refers to water and runoff generated by rainfall that is responsible for transporting pollutants and organic matter overland and downstream.

Stream Geomorphology – Term referring to the physical conditions of a stream or river, including condition of the bed substrate, the longitudinal pattern, the degree of incision or aggradation, bank integrity, and floodplain connectivity, among others.

Stream Order (also “order”) – Stream order refers to the position of a tributary in a watershed based on the amount of branching that occurs upstream. “High order” streams are those attributed with a high number and refer to larger streams (or rivers) and while “low order” streams have low rank numbers and refer to smaller streams.

Stressor – Refers to a condition or stimulus that causes stress to an organism or system. Stressors can include water quality conditions like low dissolved oxygen that stresses aquatic organisms or sedimentation that degrades benthic macroinvertebrate habitat.

Subwatershed – For EEP, this is a subdivision of a 14-digit HU delineated for additional study in the Local Watershed Planning Process.

Technical Advisory Committee (TAC) – The group of stakeholders and subset of the General Advisory Committee for the Wake-Johnston Collaborative LWP that worked together to review existing data and to propose additional monitoring and assessment strategies.

Tolerance Value – Refers to a metric assigned to a species of benthic macroinvertebrate that indicates how sensitive individuals are to stressors associated with the water column or sediment.

Transportation Improvement Program (TIP) – The program within the NC Department of Transportation responsible for developing a multi-year strategic plan for developing projects that improve and expand the state’s current infrastructure, including projects like bridge improvements, road widening, new road construction, and culvert replacements.

Triangle Land Conservancy (TLC) – A Non-governmental Organization that works to conserve property in the vicinity Raleigh, Durham, and Chapel Hill with the goals of protecting water quality and wildlife habitat, promoting farming and local food resources, and providing natural places where people can experience nature.

Tributary – A stream that flows into a greater stream system; a branch of a stream.

Unified Development Ordinance (UDO) – A legal document produced by a local county or municipal government that describes the specific requirements for subject citizens to develop or modify real property within a particular jurisdiction.

United States Fish and Wildlife Service (USFWS) – This is the Federal agency responsible for managing the nation's rare and endangered species, including aquatic species like certain endangered mussels, amphibians, and plants in the Wake-Johnston Collaborative LWP area.

United States Geological Survey (USGS) – The Federal agency responsible for defining mapping standards and watershed boundary delineation methods. The USGS is the primary source for 8- 12- and 14-digit hydrologic unit boundary information used in EEP planning.

Unnamed Tributary (UT) – Refers to a branch of a stream that doesn't have a known or documented name, usually because it is very small or isolated.

Waste Water Treatment Plant (WWTP) – A facility that receives residential and/or municipal waste water for quality improvement through chemical treatment, biological treatment, and filtration before being released into existing bodies of water.

Water Quality (WQ) – Refers to the condition of surface or subsurface waters with respect to their level of purity, and the specific measure of conditions such as:

- Dissolved Oxygen (DO) – The oxygen contained in the water column required for survival of most aquatic organisms.
- pH – The level of acidity or alkalinity of water, due to the quantity of hydrogen ions it contains.
- Specific Conductance (SC) – A measure of the amount of charged particles dissociated in water, usually assumed as a proxy for the degree of pollution; waters with higher SC often have higher levels of pollutants.
- Nutrients & Fertilizers – Chemical compounds, either naturally occurring or synthetic, that are used to increase the growth and production of plants such as crops. Forms of the elements Nitrogen (N) and Phosphorus (P) are of greatest concern in many basins and priority watershed in North Carolina where specific nutrient reduction strategies have been implemented.
- Pesticides – Organic chemical compounds used to reduce or eliminate detrimental insects and rodents from plant crops.
- Herbicides – Organic chemical compounds used to reduce the presence of weeds in crop fields and lawns.

Watershed – An area of land drained by a river and stream system, separated from similar areas by a higher ridge of land known as an "interstream divide."

Watershed Assessment Report (WAR) – The document produced as the major product for Phase II of an EEP Local Watershed Plan. This document typically includes the description of data collected as a part of the plan and the results of an integrated analysis of newly collected and existing data for the subject watershed. A customized functional assessment analysis is performed for subwatersheds and particular stressors associated with each are identified.

Watershed Assessment Team (WAT) – The specialized group within DWQ that collects water quality data and provides analytical support for EEP watershed planning, special studies, and NCDOT projects. Tasks performed by the WAT team included biological sampling, toxicity testing, and physicochemical water quality monitoring and assessment.

Watershed Management Plan (WMP) – The document produced as the major product for Phase III of an EEP Local Watershed Plan. This document typically includes a description of the watershed, details of the stakeholder process, results of the watershed characterization work, management strategies, an atlas of restoration projects (may be a standalone document), and an implementation strategy.

Water Supply Watershed (WSW) – The designation by DWR in North Carolina for watersheds draining into waters used for drinking water supply. These watersheds have particular protective measures in place to help ensure the waters within are safe for consumption.

Wetlands – These are areas characterized by three key features: hydrophytic (water-adapted) plants, hydric soils, and specific indicators of periodic saturation or inundation by water. In North Carolina, several different types of wetlands are recognized, including tidal marshes, estuarine fringe forests, wet flats, pocosins, freshwater marshes, bottomland hardwood forests, headwater forests, bogs, and seeps. For purposes of mitigation, EEP distinguishes between "riparian" wetlands that receive the majority of their hydrology by overbank flow of streams, and "nonriparian" wetlands that are made wet primarily by precipitation or subsurface lateral flow.

Wildlife Resources Commission (WRC) – The agency in North Carolina whose primary responsibility is to manage the game and nongame wildlife of the state. WRC conserves and sustains these fish and wildlife resources through research, scientific management, wise use, and public input. The Commission is the regulatory agency responsible for the enforcement of N.C. fishing, hunting, trapping and boating laws.

Windshield Survey – A cursory watershed reconnaissance performed to familiarize technical evaluators with conditions within a watershed related to water quality, riparian and wetland habitat condition, and stream geomorphological condition. A windshield survey also functions as a method for verifying land use observations on the ground (as opposed to via remote sensing methods).

Wooded Buffer – Refers to a riparian area that is stabilized primarily through the planting and establishment of woody plant (i.e., not herbaceous). A prescribed number of individuals of tree and shrub species are required for a buffer project to meet success criteria and receive mitigation credit.