Middle Cape Fear Local Watershed Plan

Technical Memorandum 3: Model Calibration Report

North Carolina Department of Environment and Natural Resources
Ecosystem Enhancement Program

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Technical Memorandum 3: Model Calibration Report

Prepared For:

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Table of Contents

1 Introduction 1-1
2 Model Selection and Parameters 2-1
2.1 Methods 2-1
2.2 Model Selection 2-1
2.3 Watershed Delineation 2-1
2.4 Field Data Collection 2-1
2.5 Other Data Sources 2-5
2.5.1 Meteorological Data 2-5
2.5.2 Land Use/Land Cover Data 2-7
2.5.3 Soils 2-7
2.5.4 Harris Lake 2-7
2.5.5 Point Sources 2-7
3 Model Calibration 3-1
4 Results and Discussion 4-1
4.1 Water Yield 4-1
4.2 Sediment Yield 4-4
4.3 Nutrient Loading 4-6
4.4 Summary 4-10
4.5 Future Modeling 4-10
5 References 5-1

List of Figures

Figure 1.1 Vicinity Map
Figure 1.2 Local Watershed Plan Project Flow Chart
Figure 2.1 Data Inputs for the SWAT Model
Figure 2.2 Data Flow in the SWAT Model
Figure 2.3 Field Site Locations
Figure 2.4 Weather Stations
Figure 2.5 Modeled Land Use/Land Cover
Figure 2.6 Modeled Soils
Figure 2.7 Wastewater Discharges
Figure 3.1 Modeled Stream Segments
Figure 3.2 Modeled Catchments
Figure 4.1 Major Drainages for Results Discussion
Figure 4.2 Average Annual Discharges for Study Watersheds
Figure 4.3 Relative Water Yield (%)
Figure 4.4 Average Annual Sediment Concentrations for Study Watersheds
Figure 4.5 Sediment Yield (tons/ha-yr)
Figure 4.6 Average Annual Total Nitrogen Concentrations for Study Watersheds
Figure 4.7 Average Annual Phosphorus Concentrations for Study Watersheds
Figure 4.8 Total Nitrogen Yield (kg N/ha)
Figure 4.9 Total Phosphorus Yield (kg P/ha)

Appendices

Appendix 1 Field Data Model Inputs
Appendix 2 Model Parameters for Harris Lake

1 Introduction

The North Carolina Wetlands Restoration Program (NCWRP) contracted with Buck Engineering in 2002 to perform a technical assessment of three 14-digit hydrologic units (HUs) in the Middle Cape Fear River Basin. This work is being completed as part of the Local Watershed Planning (LWP) initiative, which is currently administered by the North Carolina Ecosystem Enhancement Program (EEP). This Technical Memorandum documents selection and calibration of a watershed model for the LWP effort.

The three HUs are parallel drainages to the Cape Fear River and are located within portions of Chatham, Wake, and Harnett Counties (Figure 1.1). The total land area for the HUs totals approximately 180 square miles. The HUs include parts of the towns of Apex, Holly Springs, and Fuquay-Varina and the portion of Raven Rock State Park north and east of the Cape Fear River. Major streams in the watersheds include: tributaries to Harris Lake (White Oak Creek, Little White Oak Creek, Buckhorn Creek, Utley Creek, and Cary Branch), Parkers Creek, Mill Creek, Avents Creek, Hector Creek, Kenneth Creek, Neills Creek, and Dry Creek.

For the purposes of this study, the three hydrologic units were further divided into subwatersheds based on their drainage system in order to develop more manageable units for analysis and management. Using a geographic information system (GIS), the three watersheds were divided into 19 subwatersheds, ranging in size from 3.6 to 16.5 square miles. Refer to Technical Memorandum 1 for an overview of the project subwatersheds.

The information presented in this document supplements the watershed characterization and field data summary submitted to the EEP in Technical Memorandums 1 and 2 (Figure 1.2). Buck Engineering calibrated an empirical model, the Soil and Water Assessment Tool (SWAT), with existing and project data to assess general land use impacts to water quality and to provide an estimate of baseline watershed conditions. The choice of SWAT considered numeric goals and objectives and will be able to give an indication of progress towards achieving them. The SWAT model incorporates existing geographic, environmental, and management conditions together with land use conditions to estimate sediment and nutrient loadings.

Other modeling tasks described in this report include delineating model catchments based on stream networks and groupings of uniform watershed characteristics, obtaining and processing meteorological data, defining watershed hydrology, calibrating the model, and documenting the results.

Future tasks will involve modeling various land use and management scenarios, including estimates of land development, implementation of best management practices, and adoption of stormwater and buffer regulations.

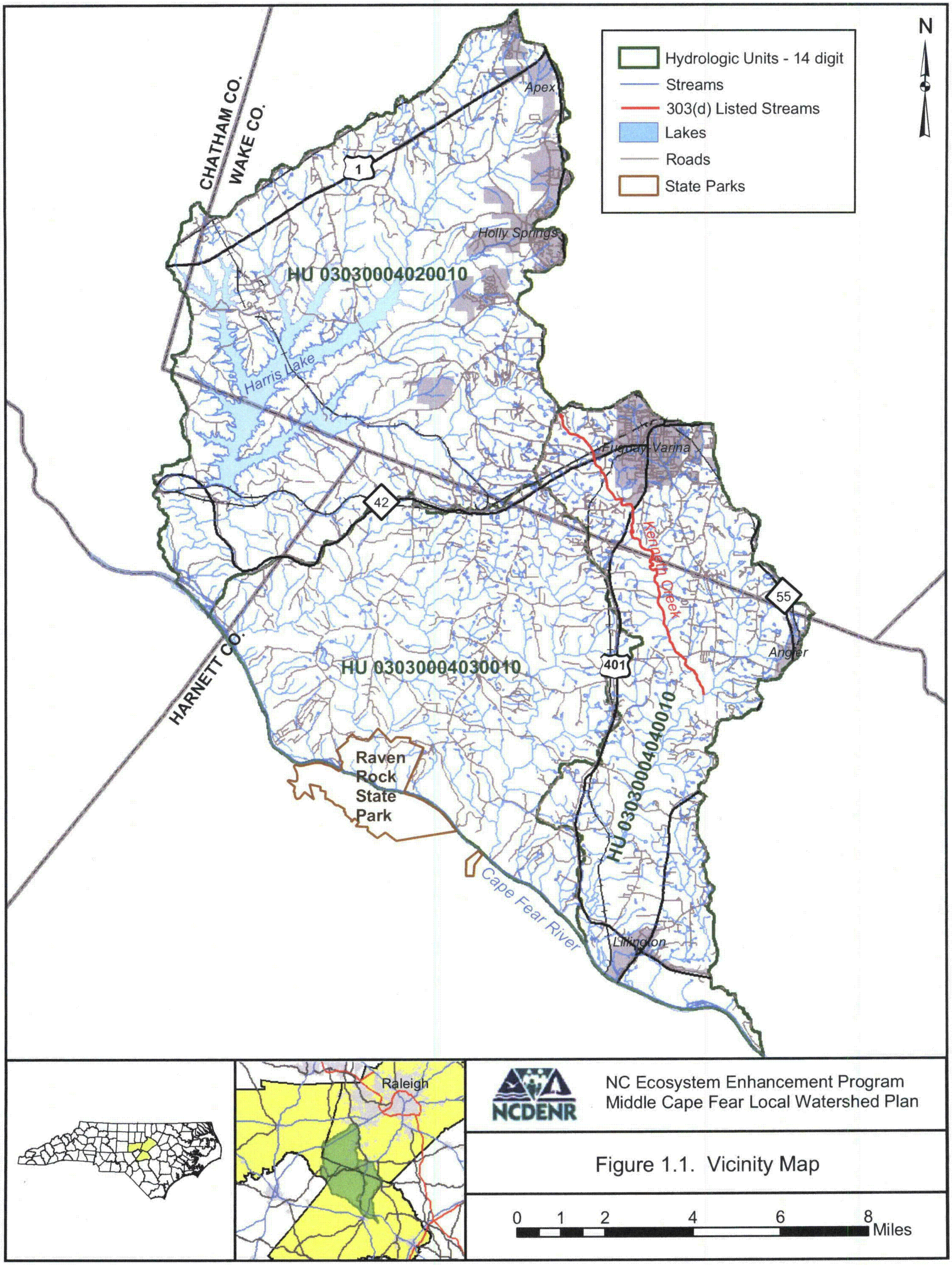


Figure 1.1. Vicinity Map

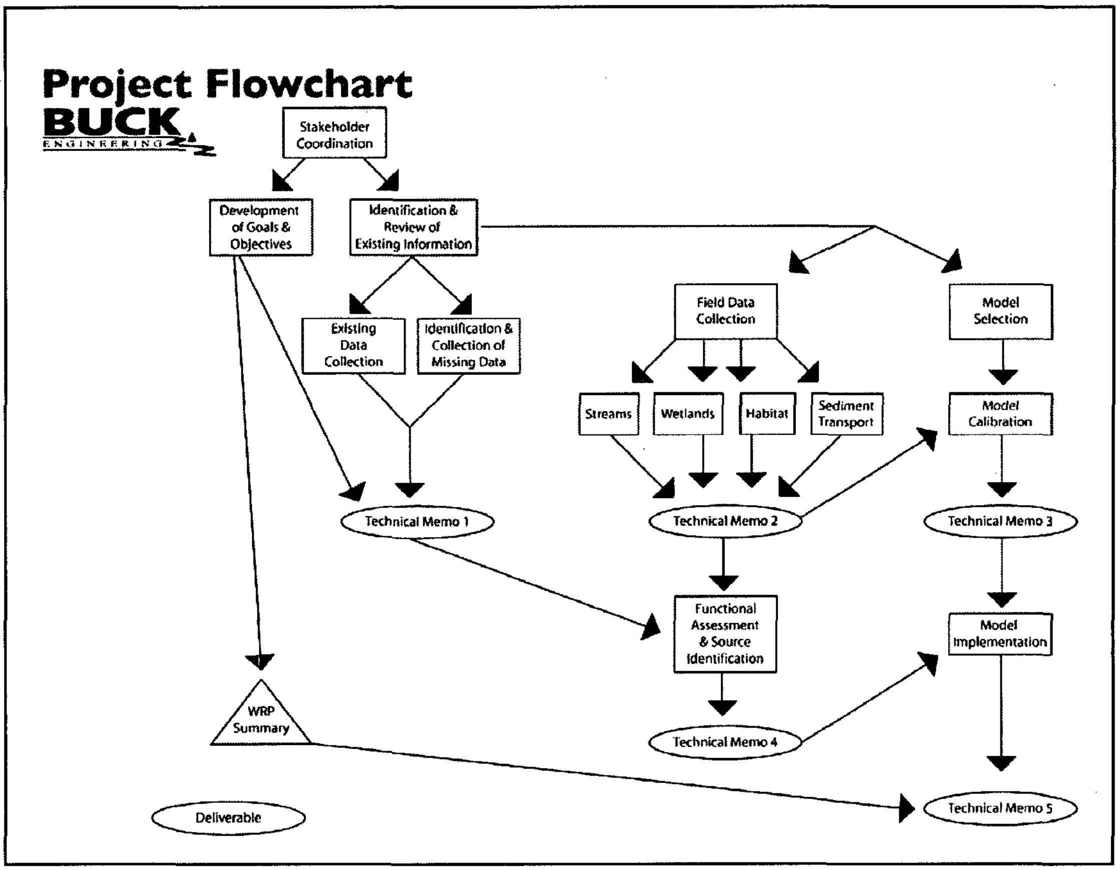


Figure 1.2 Local Watershed Plan Project Flow Chart

2 Model Selection and Parameters

2.1 Methods

Water quality modeling techniques were employed to produce sediment and nutrient loading estimates for the project watershed. The model incorporates existing geographic, environmental, and management conditions together with current land use conditions to estimate sediment and nutrient loadings.

2.2 Model Selection

The Soil and Water Assessment Tool (Neitsch et al., 2002) was selected for the sediment and nutrient analysis. SWAT was developed to quantify the impact of land management practices in large, complex watersheds. It is designed to integrate many land cover, land use, and environmental features of a watershed with land and stream management practices into water quality predictions. SWAT's ability to predict water quality, sediment, and nutrient response to changing land use and management conditions makes it an ideal model to predict conditions in the project area.

The SWAT model requires topographic, hydrographic, land use, soils, and weather data to simulate surface water quality (Figure 2.1). Soil, groundwater, reservoir, and stream processes components are modeled (Figure 2.2).

2.3 Watershed Delineation

A digital elevation model (DEM) for the project area was developed based on 1:24,000 topographic maps. ESRI GIS software Spatial Analyst was use to delineate watershed boundaries. For modeling purposes, the three hydrologic units that make up the project area were delineated and adopted as the model boundaries (Figure 1.1).

2.4 Field Data Collection

The SWAT model requires information about channel dimensions, Manning's n, stream cover, and bank erodibility parameters. Under a previous project task, field data measurements were taken at selected study sites to fulfill this data requirement. Results were extrapolated from site locations to larger representative areas.

Twenty-two stream sites were surveyed within the project area watershed to determine channel dimension, assess stream bank condition, and measure bed materials. Sites were selected to represent a wide range of drainage areas from each portion of the study area. An initial reconnaissance of the area was performed to determine whether the sites were viable. Sites with poor or dangerous access and sites with unusual hydraulics were excluded from the study. Selected sites were deemed to be representative of typical stream conditions in the vicinity. Selected sites are presented in Figure 2.3.

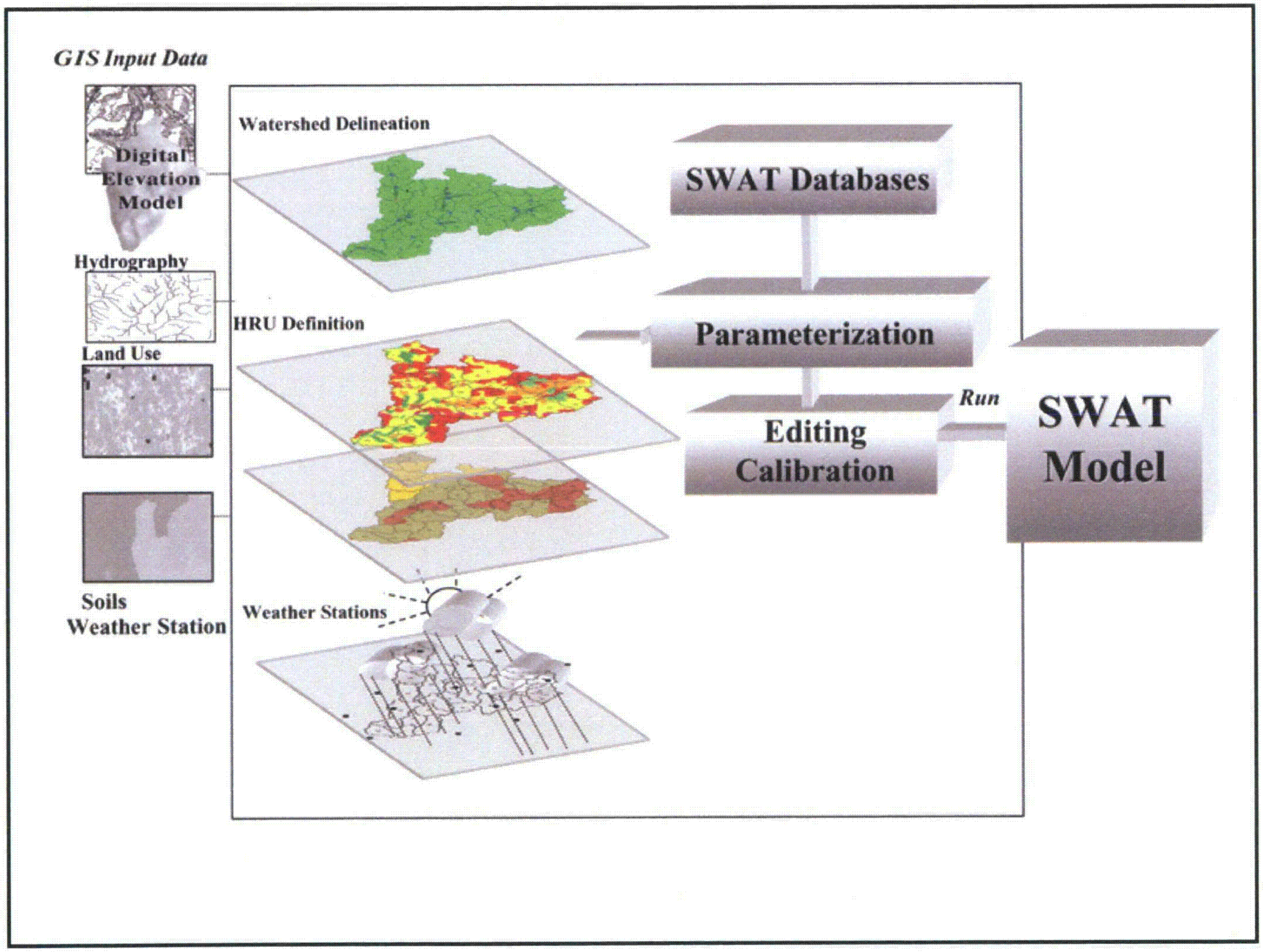


Figure 2.1 Data Inputs for the SWAT Model

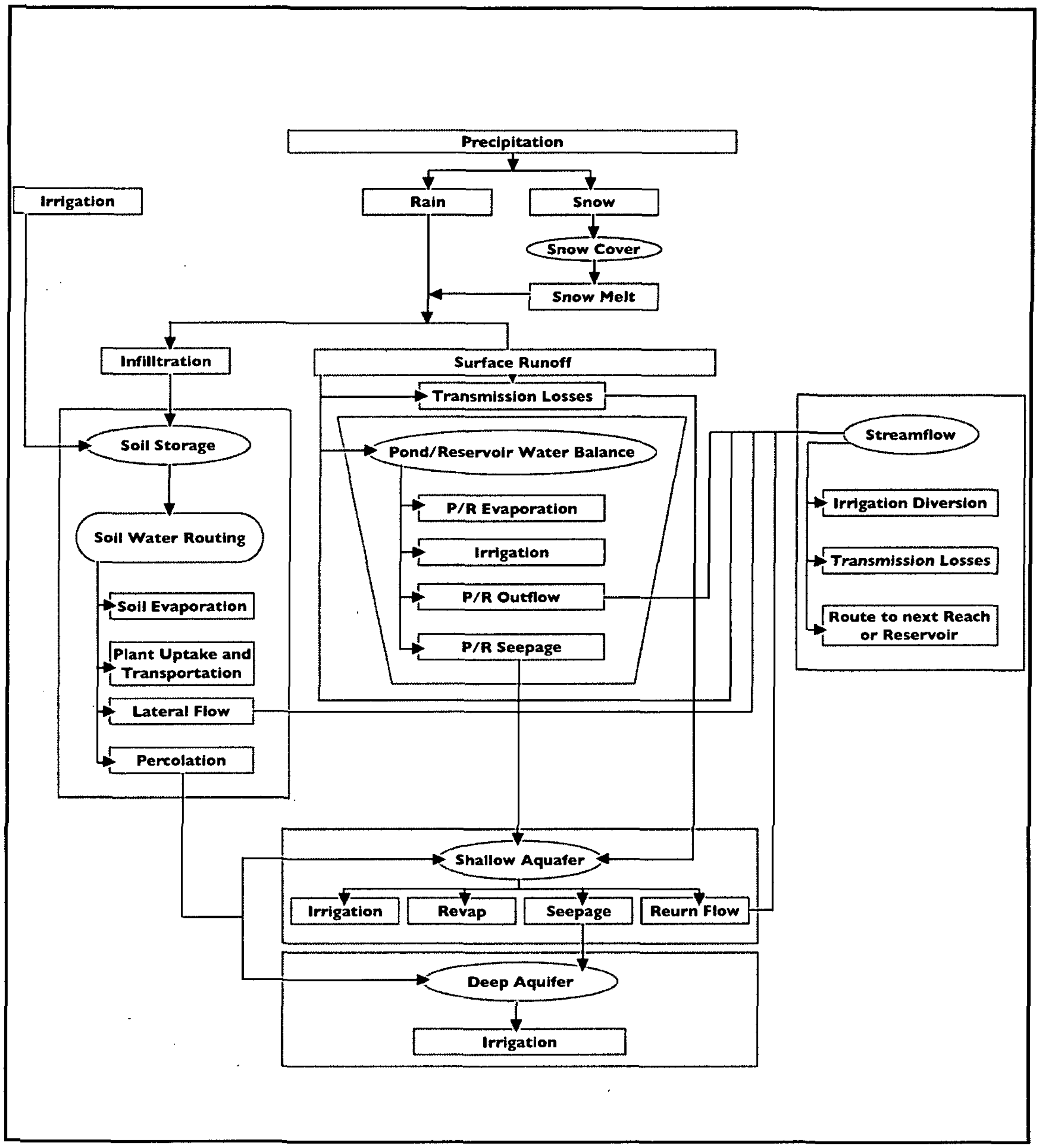
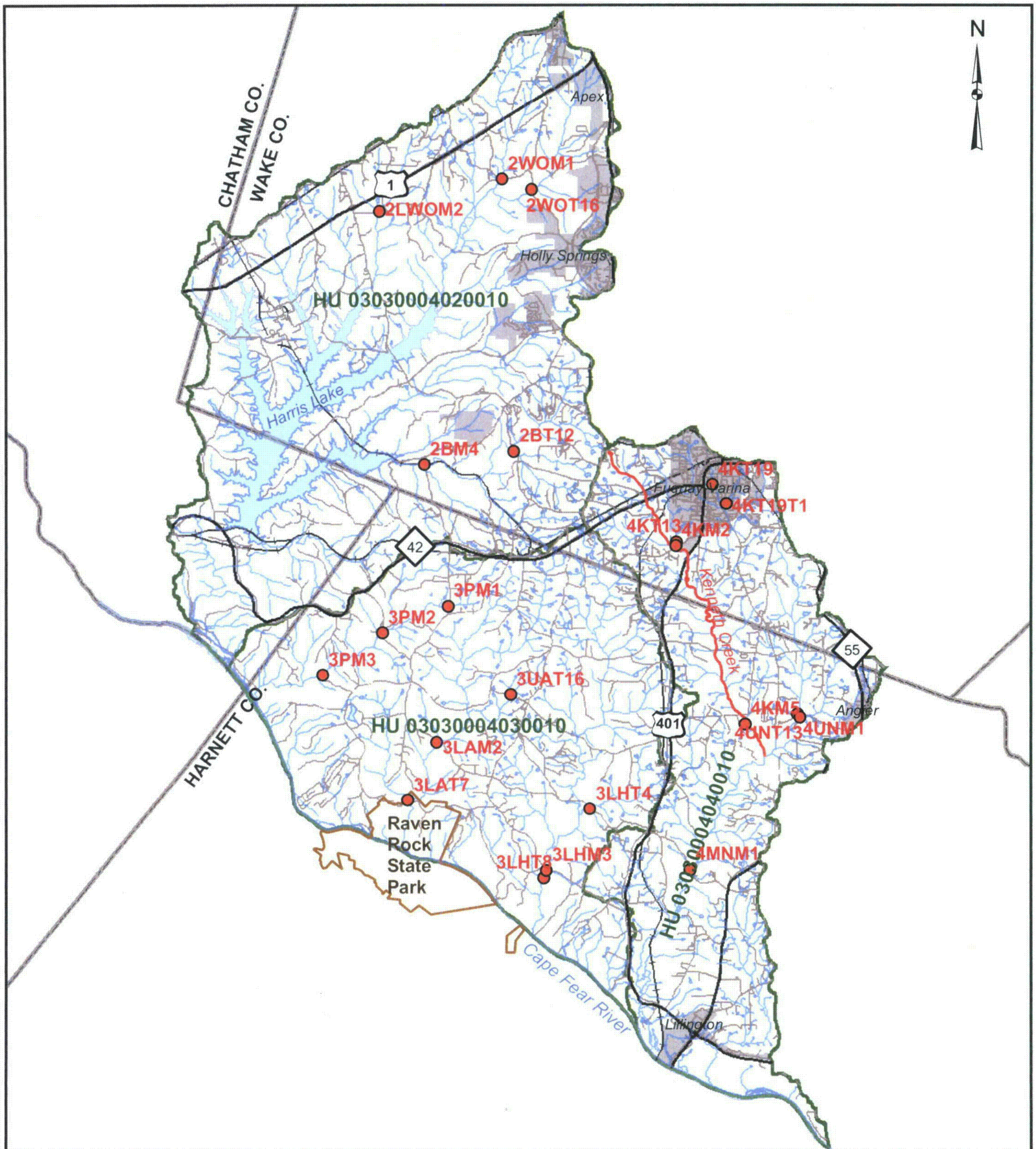


Figure 2.2 Data Flow in the SWAT Model



Study Sites

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Figure 2.3 Field Site Locations

0 1 2 4 6 8 Miles

A riffle cross section (or a cross-over in sand bed streams) was surveyed up or downstream of a road crossing at a location that did not appear to be adversely impacted by the bridge or culvert. Where the channel exhibited pattern, pools were also surveyed at meander bends. Scour pools caused by woody debris or other in-stream blockages were not selected to be surveyed. A total of 34 cross sections were surveyed. Cross-section measurements were taken of the floodplain, top of bank, bankfull, edge of baseflow channel, water surface, and other channel features.

A modified Wolman pebble count analysis was used on course riffles that exhibited cobble and course gravel as the dominant substrate (Bunte and Abt, 2001). In sand/fine gravel bed streams bulk samples were taken of the bed material using standard USGS sampling procedures. Bulk samples were composed of at least 10 composite samples collected in equal increments across the baseflow stream channel. This bulk sample was then dried and sieved to determine the percent composition of individual sized particles.

Bank Erodibility Hazard Index (BEHI) estimates were performed at each site (Rosgen, 2000). The BEHI values were helpful in determining bulk erodibilty for the modeling phase to calibrate erosion volume. The qualitative BEHI scores (e.g., low, medium, high) were used to choose the appropriate modeling parameters based on best professional judgment.

A summary of the data relevant to the SWAT model input for each of the 22 field surveys is listed in Appendix 1. Detailed cross section and sediment data were presented in Technical Memorandum 2 Appendices A and B, respectively. Photos were taken at each cross section looking upstream and downstream and, where an unusual condition existed, photos were taken of each bank. These photos were presented in Technical Memorandum 2 Appendix 3.

2.5 Other Data Sources

Other data required for model calibration and implementation were secured and are described below.

2.5.1 Meteorological Data

Weather station data were obtained from the Clayton, NC National Weather Service station. This weather station is the closest to the Project Area (Figure 2.4), is in the same geophysiographic region, and has a similar altitude. Weather statistics over the past 29 years from this site were used as a source to generate simulated weather for model runs.

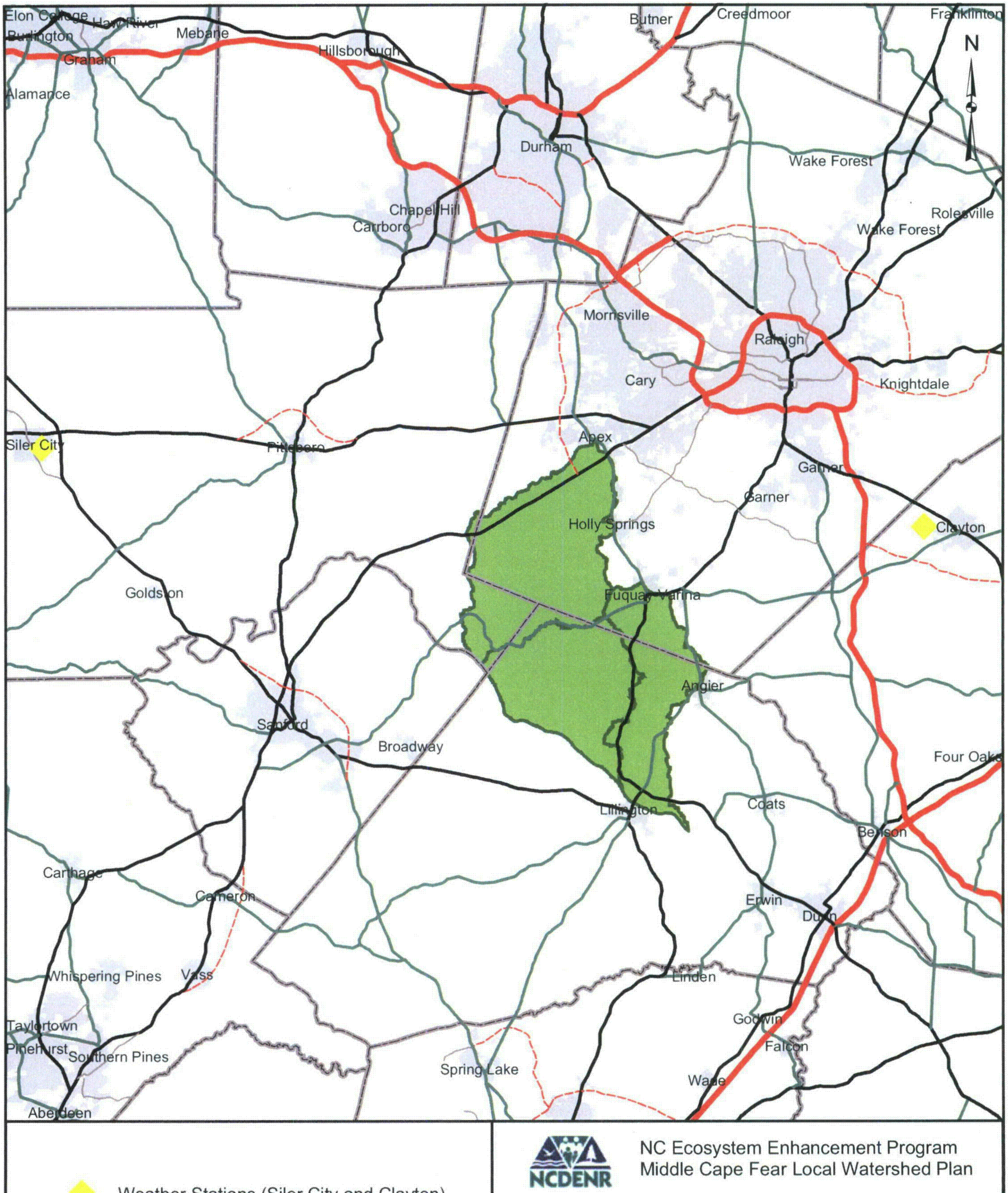

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Figure 2.4 Weather Stations

2.5.2 Land Use/Land Cover Data

Multiple GIS data sources were processed and combined to create a current land use/land cover dataset for use in SWAT: existing land cover (EarthSat, 1996), 2003 aerial imagery (SPOT, 2003), hydrology (NCCGIA, 2000), roads (NCDOT, 1999), and the National Wetlands Inventory (NWI) (USFWS, 1999). The EarthSat land cover dataset was the basis for creation of the updated dataset. Areas where land use in the SPOT imagery differed from the existing land cover data based on visual comparison were digitized as polygon features and incorporated into the new land use/land cover dataset. Similarly, NWI wetlands, hydrology, and roads datasets were also used to update the EarthSat land cover data. Attribute information was added to the new dataset to enable SWAT to interpret the land use/land cover type (Figure 2.5).

2.5.3 Soils

Nineteen distinct soil types are located within the project watershed (Figure 2.6). GIS soils data from the State Soil Geographic (STATSGO) dataset for Chatham County (USDA, 1998a) and the Soil Survey Geographic (SSURGO) datasets for Wake (USDA, 1998b) and Harnett (USDA, 1998c) counties were compiled to create a single dataset for use in SWAT. The more general STATSGO soils data were used in Chatham County because SSURGO soils information is not yet available. Using the STATSGO and SSURGO datasets provided more detailed GIS data than are available in the default SWAT soils data. Attribute information was added to the new soils dataset to enable SWAT to interpret the soil type.

2.5.4 Harris Lake

Harris Lake was modeled as it has the potential to mitigate downstream sediment and nutrient pollution and because water quality in the lake may be impacted by the future development. Model parameters for the reservoir are presented in Appendix 2.

2.5.5 Point Sources

Six discharges of treated waste are permitted under the National Pollutant Discharge Elimination System (NPDES) in the project watershed (Figure 2.7). Three of the permits are for municipal wastewater treatment facilities (Angier, Fuquay-Varina, and Holly Springs). Two additional permits are for small discharges associated with private waste treatment facilities. Progress Energy also has an NPDES permit for its discharge to Harris Lake. None of these discharges are large enough to have significant impact on model results.

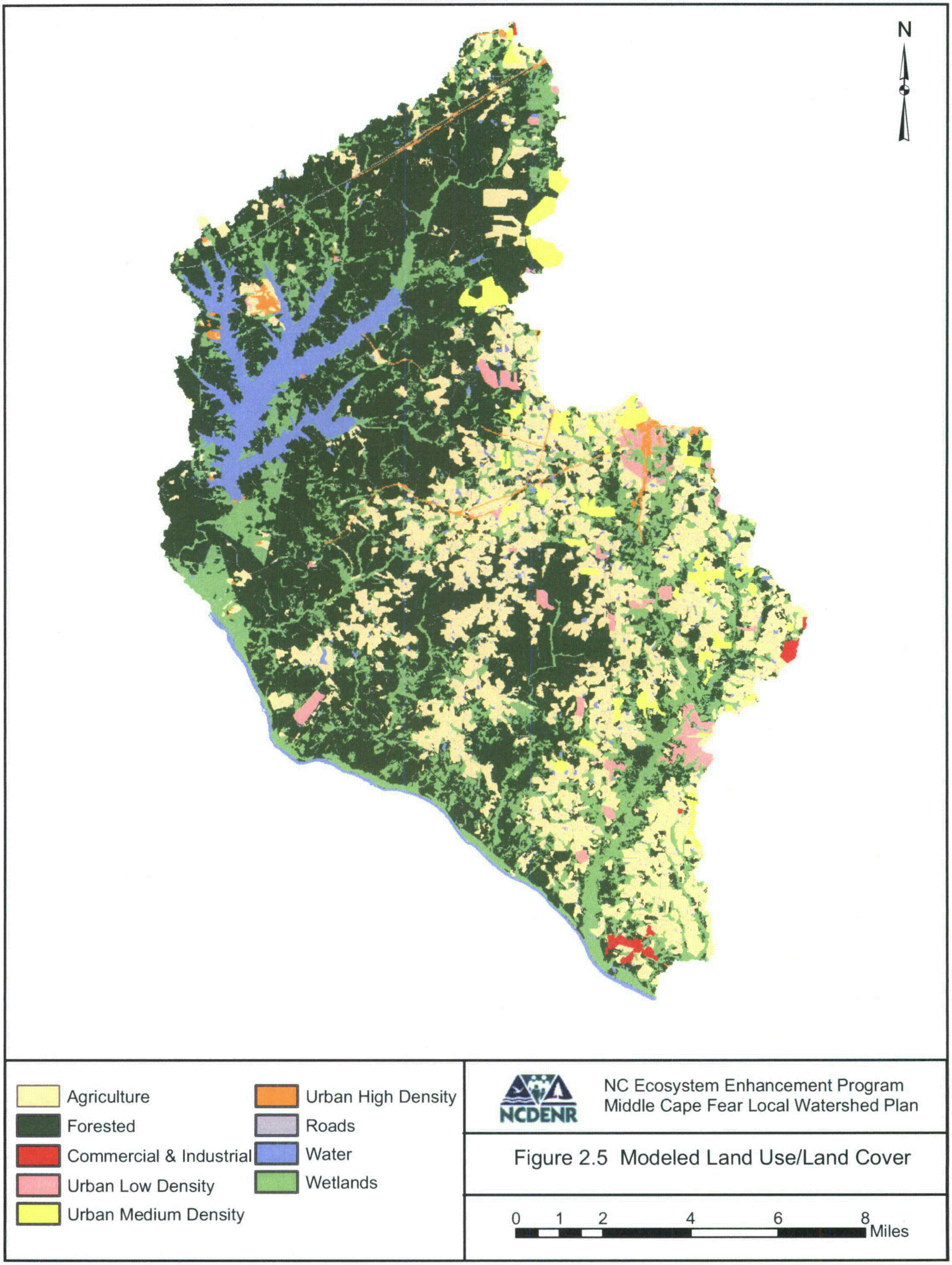

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Figure 2.5 Modeled Land Use/Land Cover

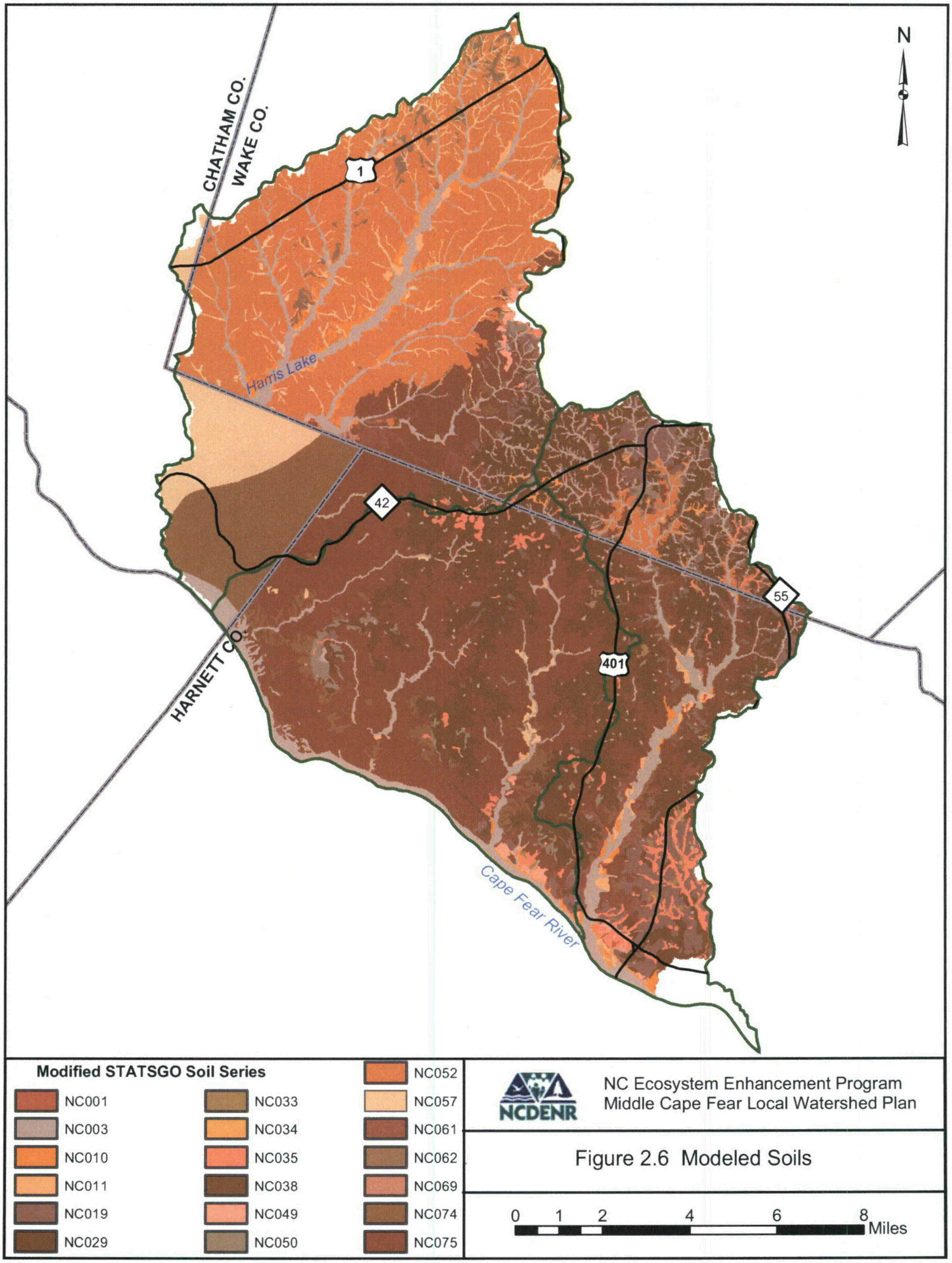
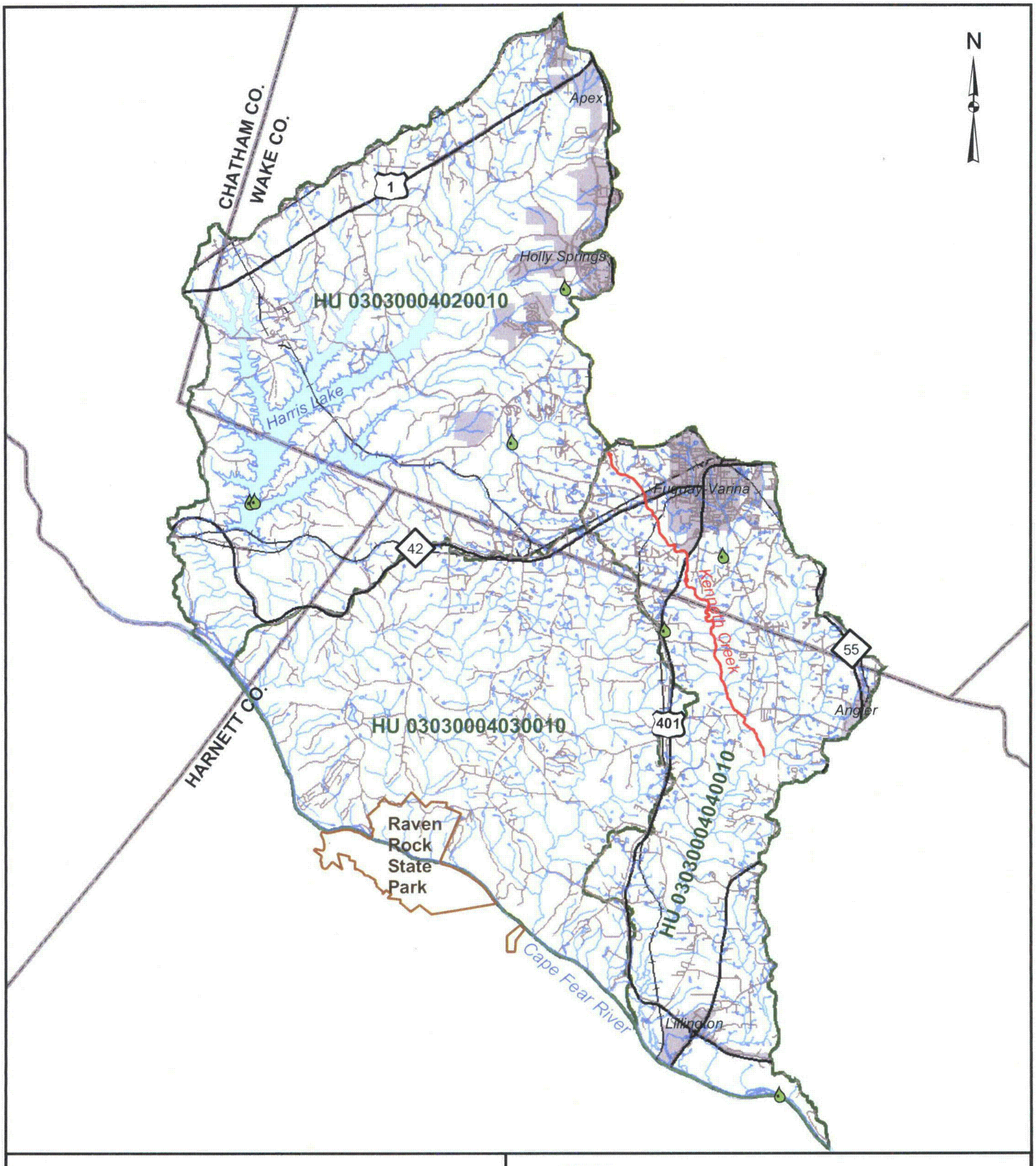


Figure 2.6 Modeled Soils



NPDES - Point Source Discharges

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Figure 2.7 Wastewater Discharges

0 1 2 4 6 8 Miles

3 Model Calibration

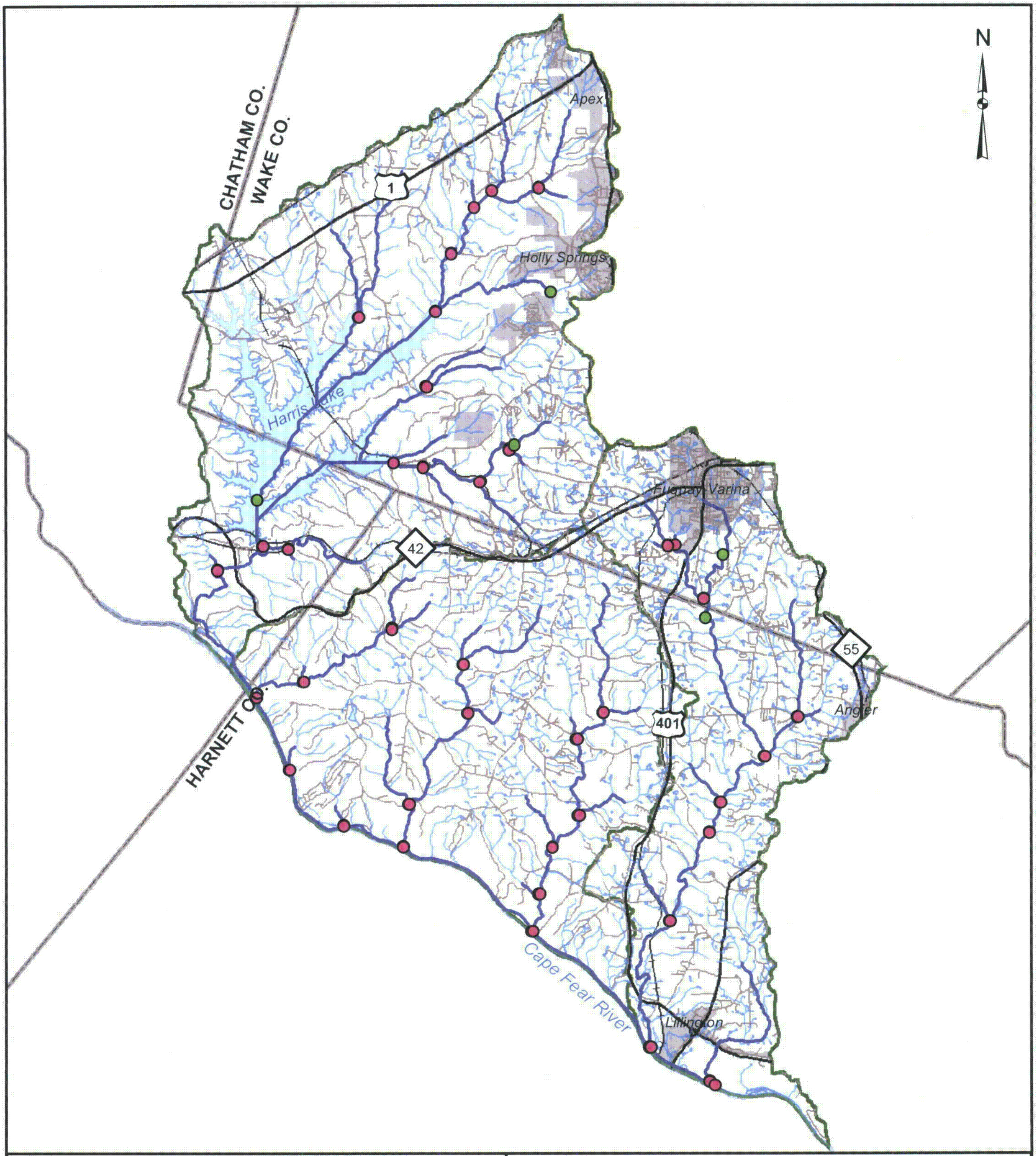
Stream channel segmentation was based upon the DEM and existing stream hydrography. ESRI GIS software Spatial Analyst was use to determine the location of all channels with drainage areas greater than one square mile. Reaches were linked at their confluences with routing nodes (Figure 3.1). A total of 720 stream miles in 160 reaches were modeled within the 180 square mile watershed. The catchments associated with each of these reaches are shown in Figure 3.2.

Current land use and soils data were overlain with the 74 catchment boundaries to create tables of the hydraulic response units (HRUs), unique combination of soil and land use for each catchment. The SWAT model was then parameterized with the spatial data described above.

Channel dimensions, Manning's n, stream cover, and bank erodibility parameters were entered for each stream reach to reflect values observed and recorded in the field. At locations where field measurements were taken at study sites, the data were used directly in the selection of model parameters. In other areas, best professional judgment was used to extrapolate known channel characteristics.

The model was run for a five year period of simulated weather. The initial mean annual runoff value from the model was 1.05 cubic feet per second (cfs) per year. This compared favorably to the USGS estimate for the region of 1.1 cubic feet per second per year (Giese and Mason, 1993). Because hydraulic processes are important to essentially all model components, hydraulic calibration was achieved by minor global adjustment of the runoff curve numbers so that a final modeled mean annual runoff value of 1.1 cubic feet per second per year was achieved. This resulted in an average flow of 198 cfs at the combined outlets of the study area.

As detailed water quality data are not yet available for the study area, calibration of the model was limited to hydrology at this time. However, sediment and nutrient concentrations predicted by the model were in the range of typical piedmont values. Detailed calibration of sediment and nutrients can be completed as field data is supplied.



Modeled Stream Segments

Outlets

Linking stream added Outlet

Manually added Point Source

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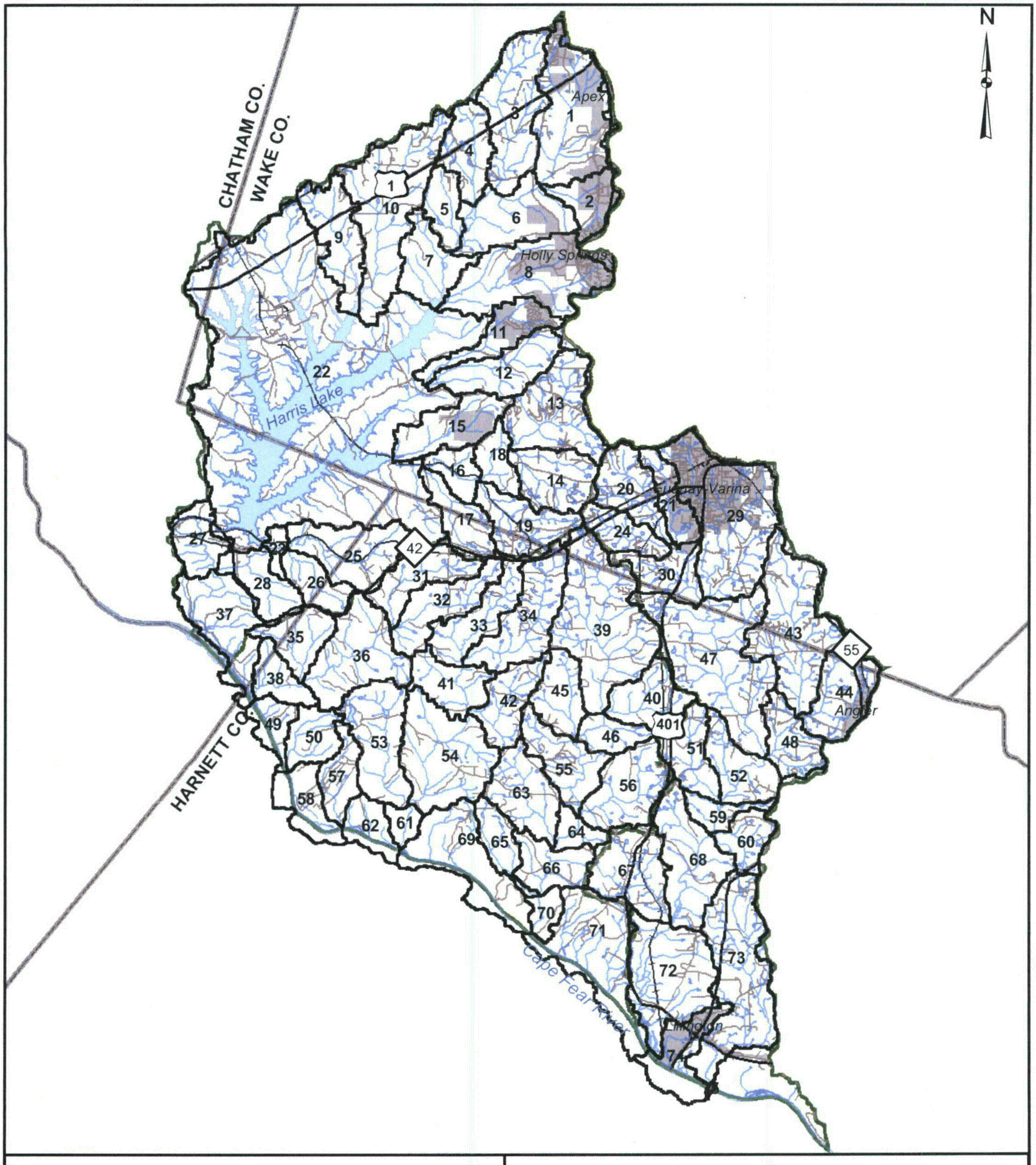
Figure 3.1 Modeled Stream Segments

0 1 2 4 6 8 Miles



Modeled Catchments

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Figure 3.2 Modeled Catchments

0 1 2 4 6 8 Miles

4 Results and Discussion

For ease of discussion, the results presented here are summarized by the major drainages in the study area: Buckhorn Creek (including Harris Lake), Parkers Creek, Avents Creek, Hector Creek, and Neills Creek (including the Kenneth Creek drainage). Figure 4.1 shows the locations of these drainages. The Dry Creek drainage was modeled; however, results are not presented because field data were not available (e.g., channel dimensions) and the calibration of the model was therefore incomplete. In consultation with the EEP, the decision was made to drop Dry Creek from the modeling analysis and spend available resources in other study drainages.

4.1 Water Yield

Water yield was relatively consistent throughout the study area with all watersheds' discharge within a few percent of the study area's mean annual runoff of 1.1 ft/year. As a result, discharges from each of the five major drainages were proportional to their drainage area. The Buckhorn Creek drainage, by far the largest sub-watershed in the project area, produced the greatest discharge and the smallest sub-watershed, Parkers Creek, produced the least water (Figure 4.2).

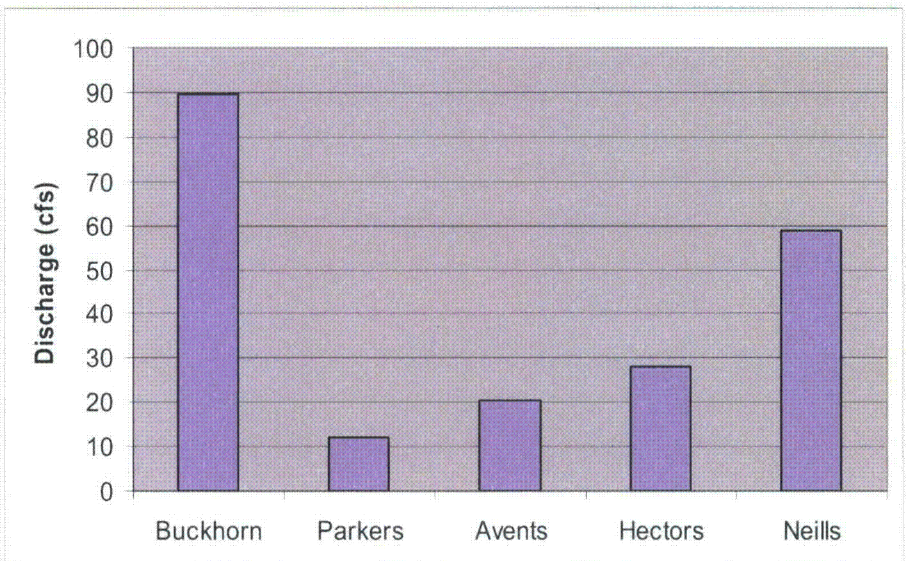


Figure 4.2 Average Annual Discharges for Study Watersheds

The sandy soils in the lower portion of the basin produced the most water while urbanized headwater catchments produced the least (Figure 4.3). Harris Lake also had a small effect on water yield. However, all catchments within the study area produced at least 95% of the maximum modeled water yield meaning that no major net hydrologic impacts were observed within the study area.

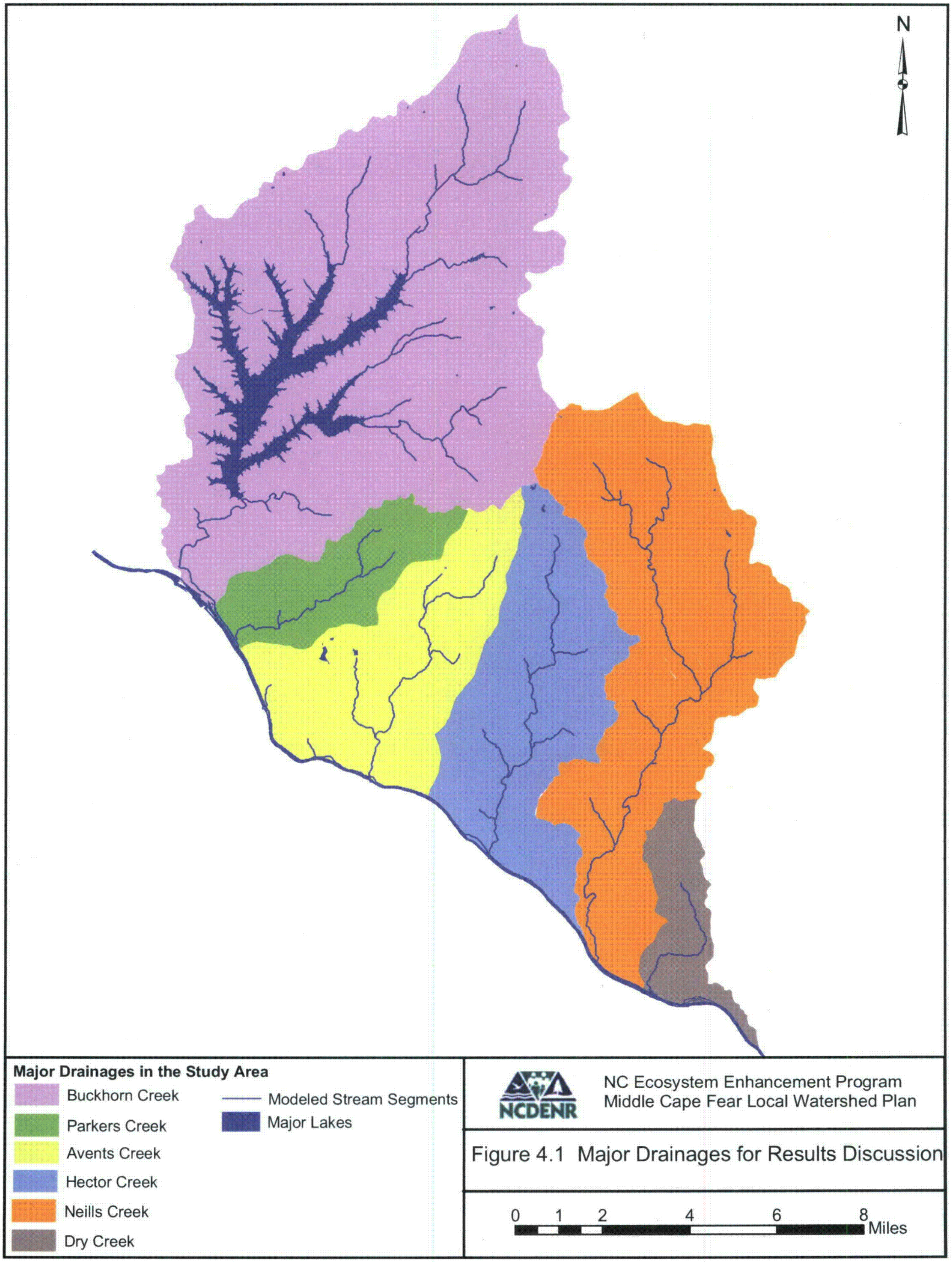
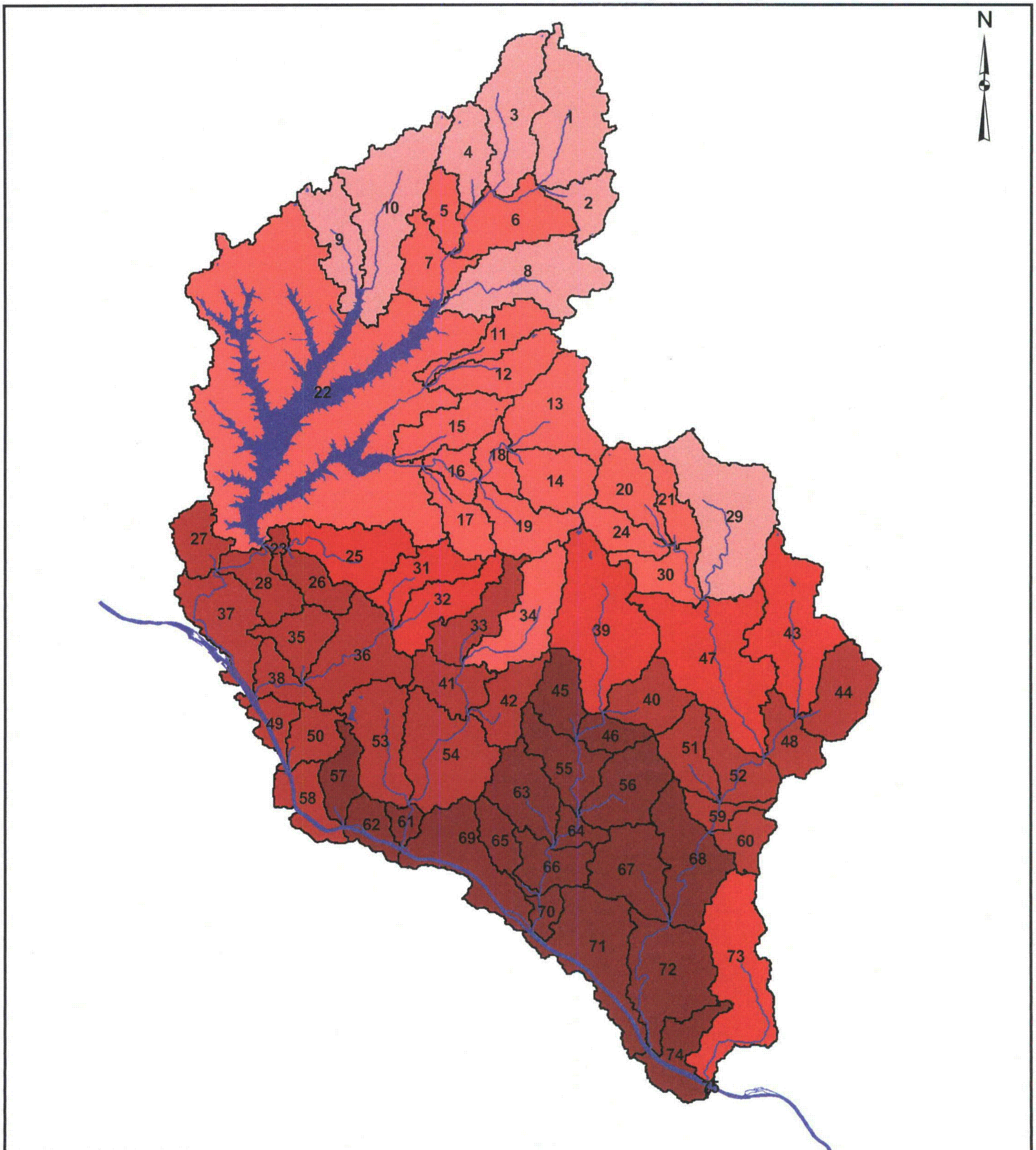


Figure 4.1 Major Drainages for Results Discussion



Relative Water Yield by Catchment (%)

- 0.959 - 0.967
- 0.968 - 0.974
- 0.975 - 0.980
- 0.981 - 0.989
- 0.990 - 1.000

Modeled Stream Segments

Major Lakes

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Figure 4.3 Relative Water Yield (%)

0 1 2 4 6 8 Miles

4.2 Sediment Yield

Sediment yield is highly variable throughout the study area due to both channel conditions and land management. Harris Lake in the Buckhorn Creek watershed is a major sediment sink and sediment concentrations below the lake are dramatically lower than any other watershed in the study area (Figure 4.4). Parkers Creek also is predicted to have a relatively low instream sediment concentration, primarily due to the large percentage of forest cover in the watershed. Avents, Hectors, and Neills Creek sub-watersheds each show relatively high sediment discharge with Neills Creek predicted to have the highest sediment concentration of the study area sub-watersheds.

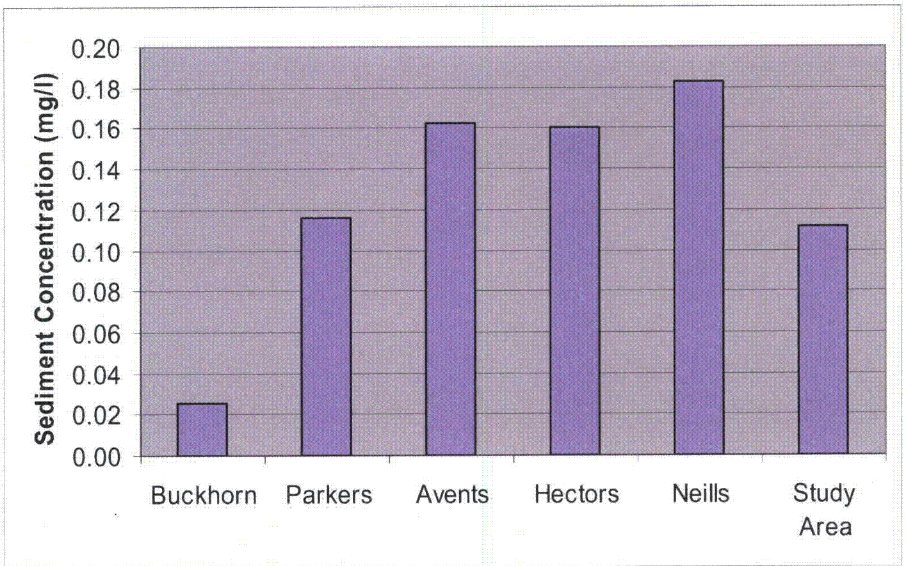

Figure 4.4 Average Annual Sediment Concentrations for Study Watersheds

Sediment yield by catchment is presented in Figure 4.5. Headwater reaches in urbanizing areas had the highest relative sediment yield. Catchments along the Cape Fear River flood plain had very low sediment yield. This is indicative of active floodplains that are capturing sediments before they reach the Cape Fear River.

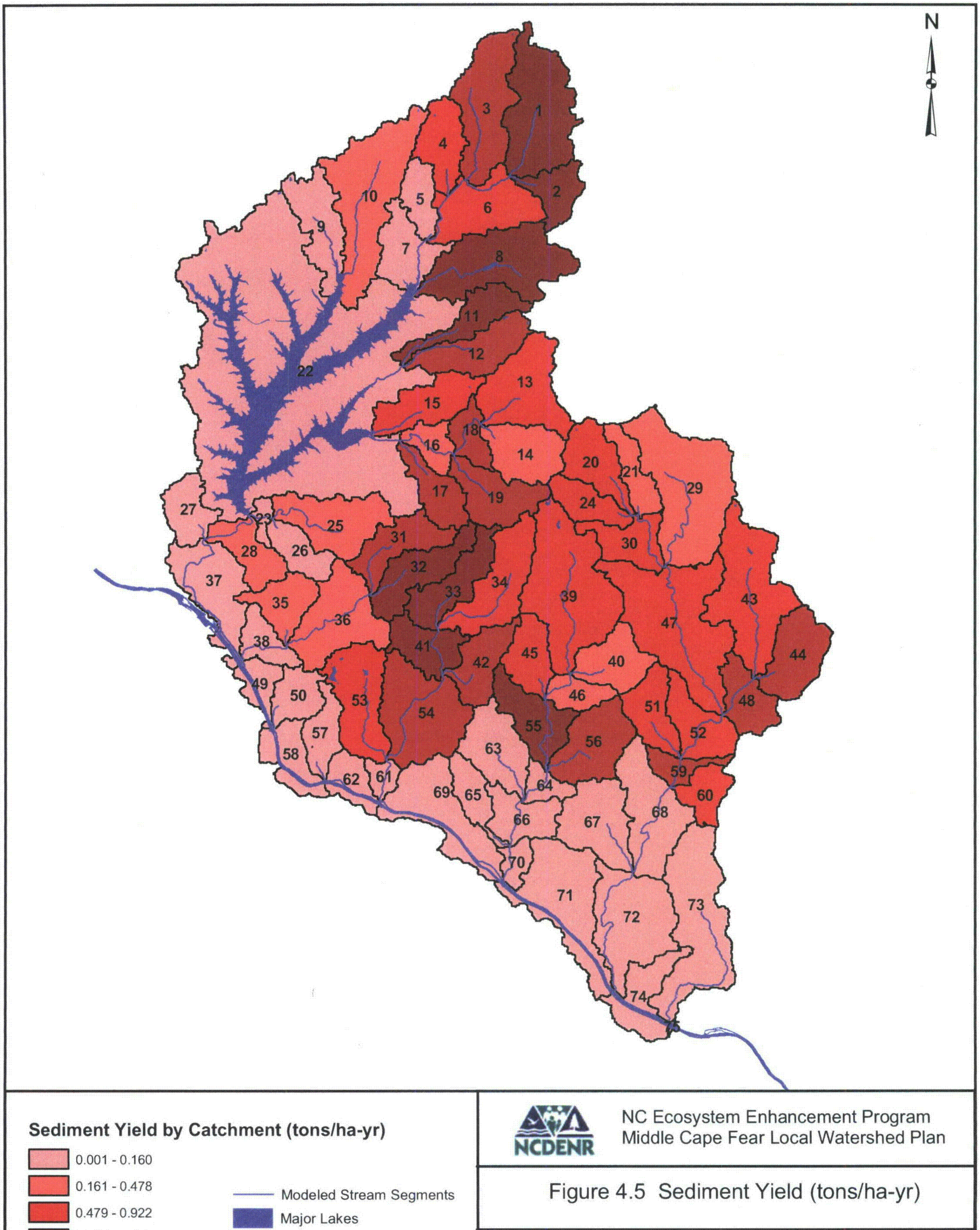

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Figure 4.5 Sediment Yield (tons/ha-yr)

4.3 Nutrient Loading

Nutrient loading is relatively high throughout most of the study area with an average of 1.7 mg/l total nitrogen (TN) and 0.2 mg/l total phosphorus (TP). Parkers and Avents Creeks were predicted to have significantly less nutrient than the other sub-watersheds (Figures 4.6 and 4.7). Buckhorn Creek was predicted to have very low phosphorus concentrations (Figure 4.7) but nitrogen concentrations approximately equal to the study area average. This is due to the fact the Harris Lake, as an effective sediment trap, collected phosphorus bound to sediments but allows the more soluble nitrogen compounds to pass through the lake. Neills Creek demonstrated the highest nutrient concentrations.

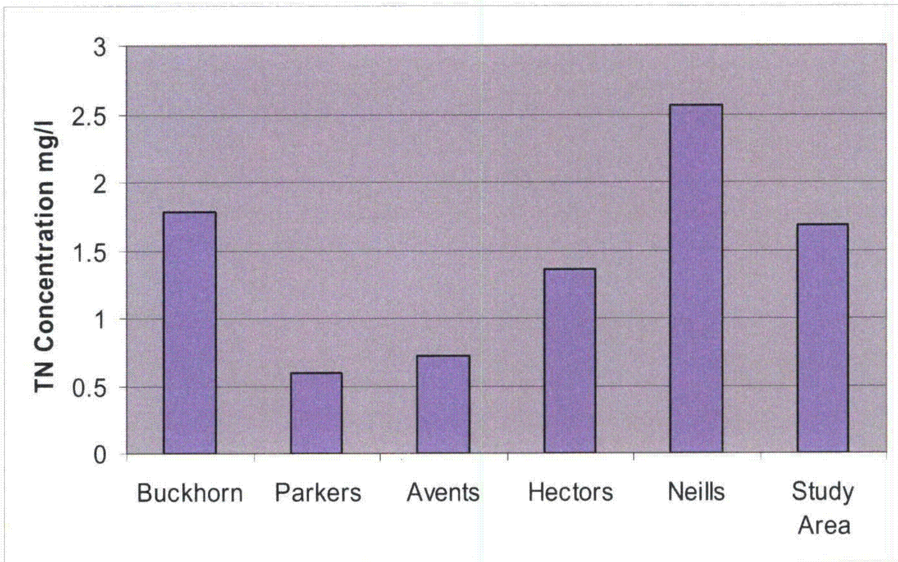

Figure 4.6 Average Annual Total Nitrogen Concentrations for Study Watersheds

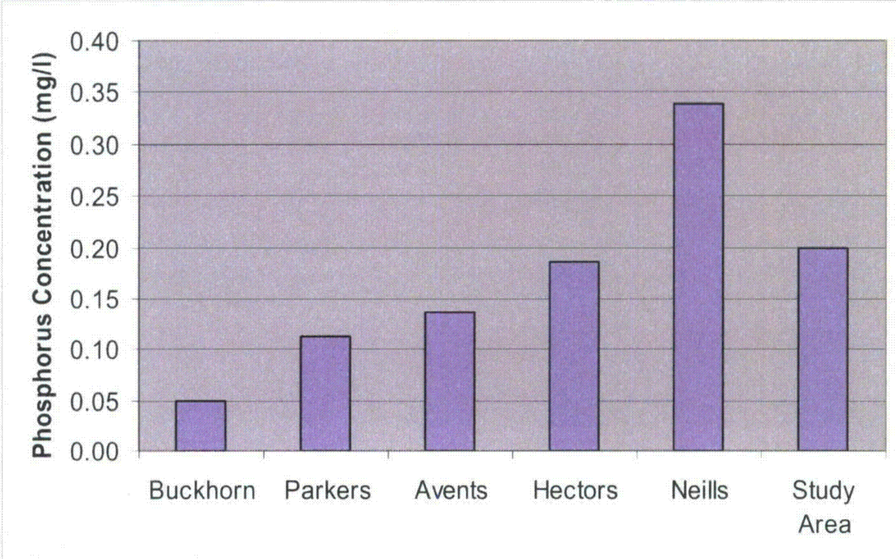

Figure 4.7 Average Annual Phosphorus Concentrations for Study Watersheds

TN yield by catchment is presented in Figure 4.8. Headwater reaches in urbanizing areas had the highest relative nitrogen supply. Agricultural catchments also produced relatively high nitrogen loads, particularly in the Parkers Creek and Avents Creek sub-watersheds. Unlike the pattern observed with sediment, catchments along the Cape Fear River flood plain contributed significantly to the study areas nitrogen supply. This is due, in some part, to the sandy soils that permit dissolved nitrogen to pass quickly into tributaries and streams.

TP yield by catchment is presented in Figure 4.9. Headwater reaches in urbanizing areas had the highest relative phosphorus supply. Catchments along the Cape Fear River flood plain had very low phosphorus supply. This very low TP yield is the result of limited erosion along low slope stream channels and active floodplains that collect phosphorus associated with sediment.

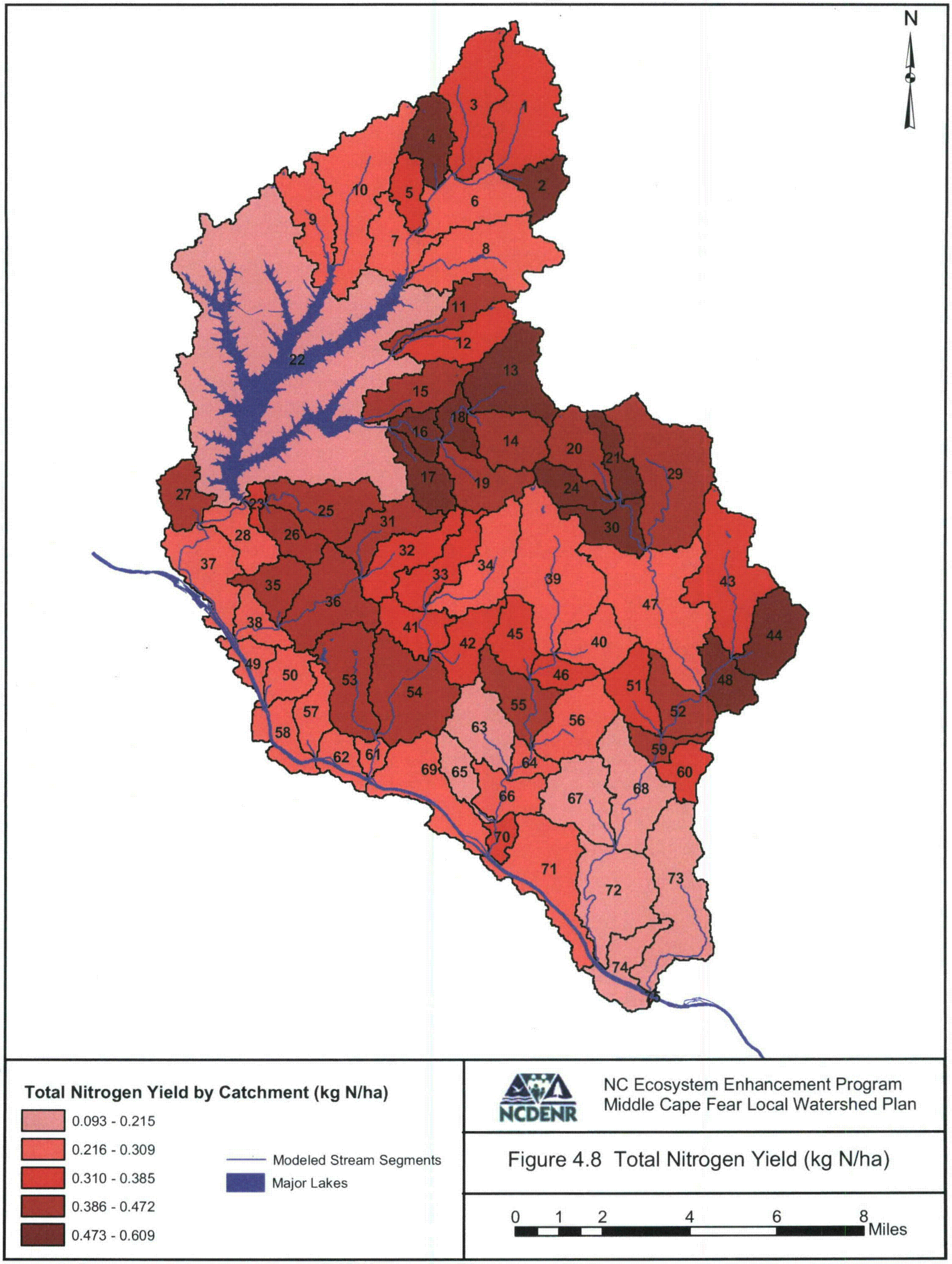

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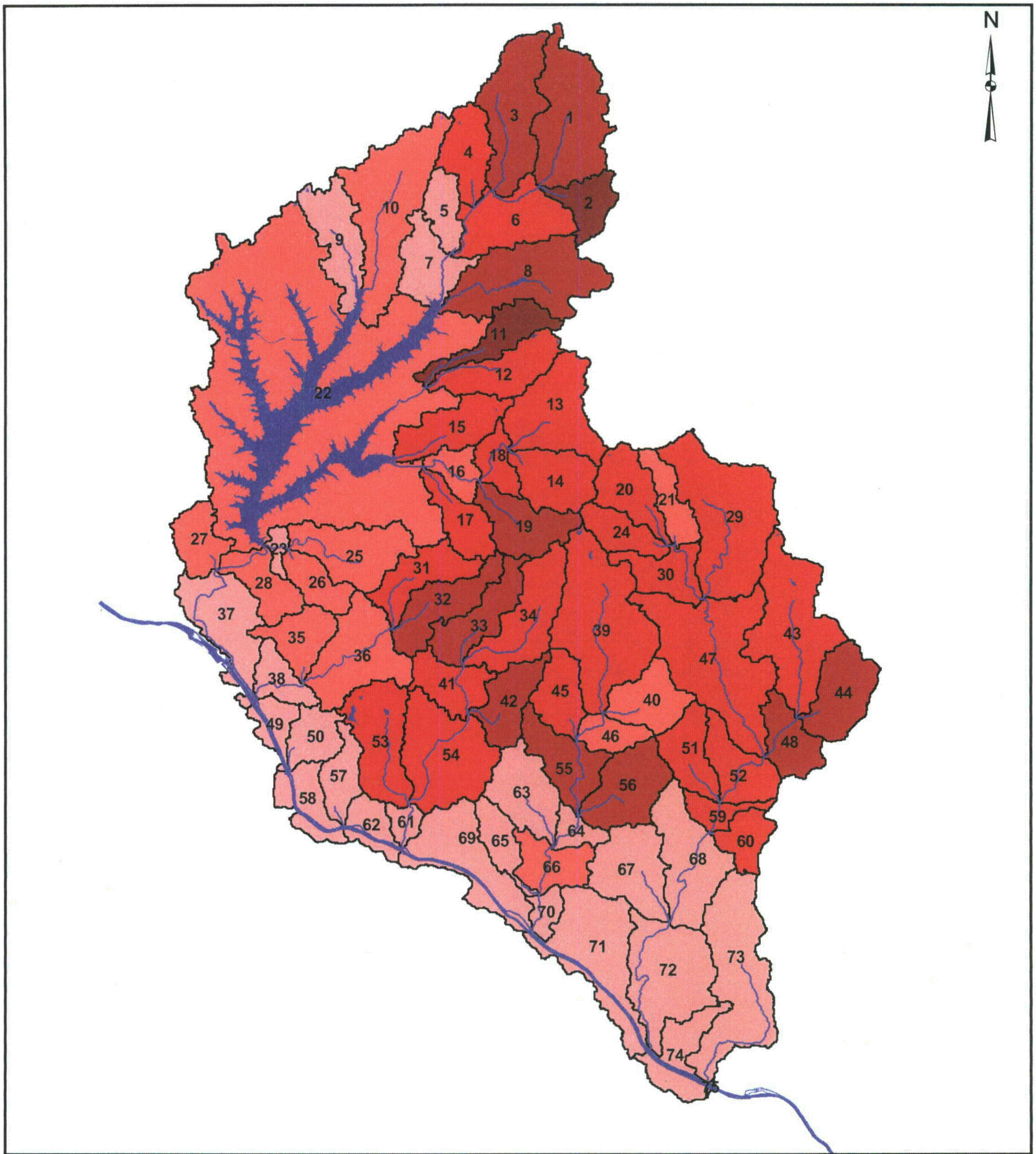
Figure 4.8 Total Nitrogen Yield (kg N/ha)



Total Phosphorus Yield by Catchment (kg P/ha)

- 0.000 - 0.015
- 0.016 - 0.036
- 0.037 - 0.067
- 0.068 - 0.097
- 0.098 - 0.169

Modeled Stream Segments
Major Lakes

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Figure 4.9 Total Phosphorus Yield (kg P/ha)

0 1 2 4 6 8 Miles

4.4 Summary

Nutrient and sediment loadings vary greatly throughout the study area. Harris Lake has a strong water quality effect as it traps significant amount of sediment and phosphorus. Agricultural activities and channel erosion from developed areas result in some catchments with very high sediment and nutrient sources. Transport and storage of sediments as they move through the steeper headwater creeks and onto the Cape Fear floodplain play an important role in pollutant delivery. The location of resources is crucial in determining the importance of upstream pollutant sources.

4.5 Future Modeling

This model has provided an estimate of baseline conditions for discharge, sediment, and common nutrients based on existing land use and management. The calibrated model presented in this report will be used to test various future land use conditions. Examples of model scenarios include potential causes of water quality degradation, including wetland and forest cover loss to other land uses, future transportation impacts, and other land cover alterations. In addition, various methods to reduce the impacts of future land use scenarios (e.g., stormwater management, preservation and restoration opportunities, and conservation development options) will be modeled.

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Table of Contents

1 Introduction 1-1
1.1 Background 1-1
1.2 Watershed Functions 1-4
1.3 Data Collection 1-6
1.4 Determination of Functionality 1-6
2 Habitat Function Assessment 2-1
2.1 Habitat Fragmentation 2-1
2.2 Selected Field Assessment of Habitat 2-3
2.3 Presence of Invasive Species 2-6
2.4 NCDWQ Benthic Surveys 2-7
2.5 Substrate 2-12
2.6 Overall Habitat Function Assessment 2-13
3 Hydrologic Function Assessment 3-1
3.1 Headwater/Riparian Assessments 3-1
3.2 Bank Height Ratios 3-3
3.3 Percent Impervious Land Cover 3-5
3.4 Infrastructure 3-8
3.5 Overall Hydrological Function Assessment 3-9
4 Water Quality Function Assessment 4-1
4.1 Bank Erosion Hazard Index (BEHI) 4-1
4.2 Modeling Results 4-3
4.3 NCDWQ Benthic Community Results 4-5
4.4 Headwater/Riparian Assessments 4-8
4.5 Overall Water Quality Function Assessment 4-11
5 Projected Impacts to Watershed Functions 5-1
5.1 Projected Land Use Changes 5-1
5.2 Projected Impacts by FAU 5-3
6 Summary and Conclusions 6-1
6.1 Summary 6-1
6.2 Conclusions 6-1
6.3 General Management Recommendations Based on Functional Assessment .. 6-3
7 References 7-1

List of Figures

Figure 1.1	Vicinity Map
Figure 1.2	Functional Assessment Units
Figure 1.3	Metrics Used to Determine Watershed Functions
Figure 2.1	Habitat Classifications & Index Ranks
Figure 2.2	Overall Habitat Function by FAU
Figure 3.1	Percent Impervious by FAU
Figure 3.2	Overall Hydrologic Function by FAU
Figure 4.1	Overall Water Quality Function by FAU
Figure 5.1	Projected "Build Out" Land Use

List of Tables

Table 2.1	Land Use Habitat Classifications
Table 2.2	Habitat Fragmentation Results
Table 2.3	Overall Habitat Function by FAU
Table 3.1	Fraction Total Impervious by Land Use
Table 3.2	Percent Impervious Results
Table 3.3	Overall Hydrologic Function by FAU
Table 4.1	Overall Water Quality Function by FAU
Table 5.1	Predicted Agricultural and Forested Land Use Conversions
Table 5.2	Estimated Direct Impacts from Future NCDOT Projects

1 Introduction

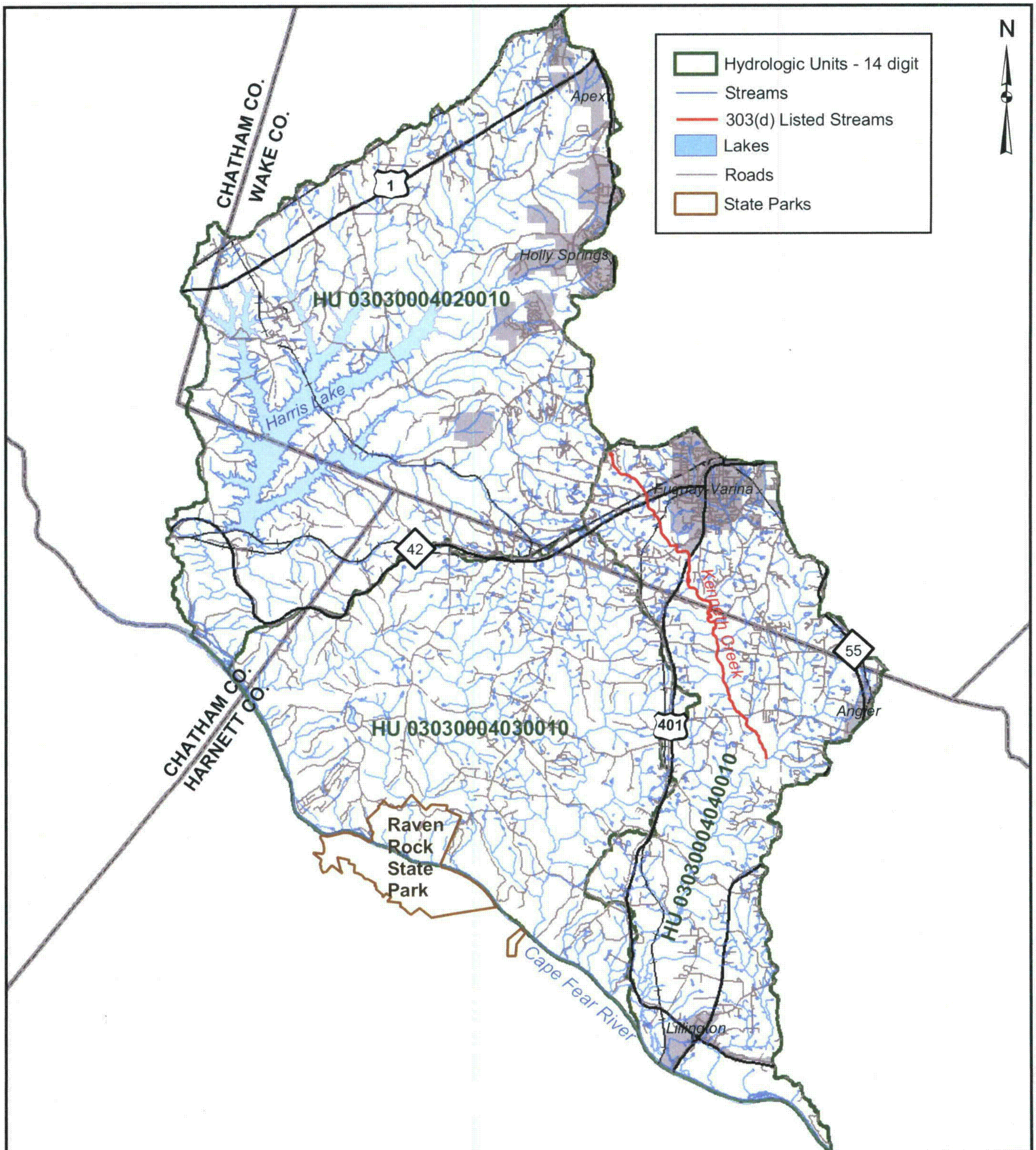
1.1 Background

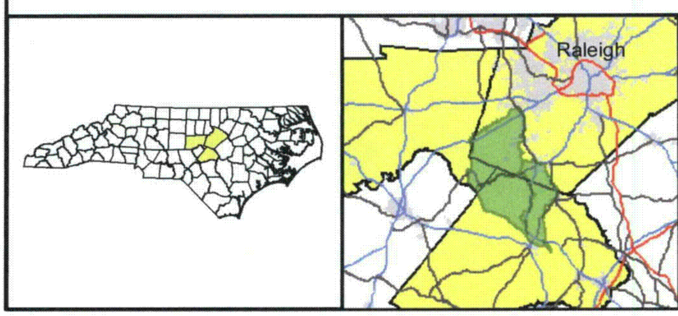
The North Carolina Wetlands Restoration Program (NCWRP) contracted with Buck Engineering in 2002 to perform a technical assessment of three 14-digit hydrologic units (HUs) in the Middle Cape Fear River Basin. This work is being completed as part of the Local Watershed Planning (LWP) initiative that is currently administered by the North Carolina Ecosystem Enhancement Program (EEP). This Technical Memorandum presents a functional status overview of the three HUs in terms of water quality, hydrology, and habitat. It also suggests potential sources of observed degradation. The information described here will assist in identification and prioritization of watershed management strategies to address functional deficits.

The three HUs are parallel drainages to the Cape Fear River and are located within portions of Chatham, Wake, and Harnett Counties (Figure 1.1). The total land area for the HUs is approximately 180 square miles. The watersheds include parts of the towns of Apex, Holly Springs, and Fuquay-Varina and the portion of Raven Rock State Park north and east of the Cape Fear River. Major streams in the HUs include: tributaries to Harris Lake (White Oak Creek, Little White Oak Creek, Buckhorn Creek, Utley Creek, and Cary Branch), Parkers Creek, Mill Creek, Avents Creek, Hector Creek, Kenneth Creek, Neills Creek, and Dry Creek.

For the purposes of this report, the three HUs were further divided into 12 functional assessment units (FAUs) with generally similar land use, landform, and riparian condition (Figure 1.2). The Parkers, Avents, and Hector Creek sub-watersheds represent the largest FAUs. Initially, it was thought that it would be necessary to split the upper and lower portions of these sub-watersheds into unique FAUs. However, land use in these sub-watersheds is homogeneous and stream types are consistent in both the headwaters and downstream sections.

The Harris Lake and Dry Creek sub-watersheds, as well as small drainages which flow directly into the Cape Fear River, were excluded from the functional assessment process. Although nutrient management is a key concern for the management of Harris Lake, Buck Engineering determined it to be outside the relevant scope of issues important to the rest of the study area. Also, any sediment impacts within the drainage to the lake are contained within the lake. The Dry Creek sub-watershed and the small drainages directly to the Cape Fear River have no monitoring data available, which impedes model calibration. Due to the small size of their land areas compared to the other drainages, these areas also have a limited impact on the water quality of Cape Fear River. Therefore, it was determined that it would be more cost-effective to apply project resources to the other parts of the study area.





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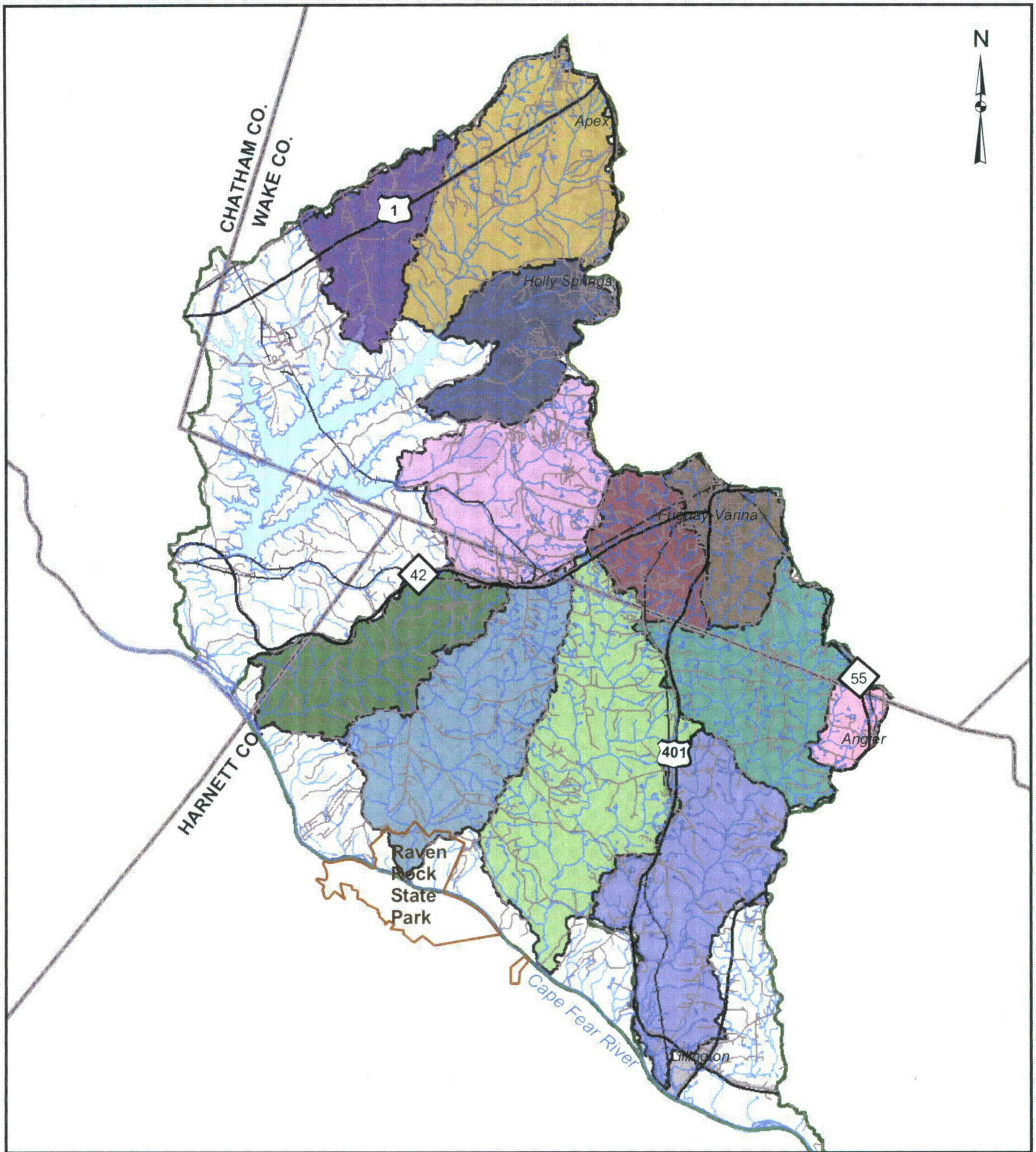
Middle Cape Fear Local Watershed Plan

Figure 1.1. Vicinity Map



Buckhorn Creek	Hector Creek
Utley Crk/Cary Br/Norris Br	Upper Neills Creek - Urban
White Oak Creek	Kenneth Crk/Upper Neills Crk - Rural
Little White Oak Creek	Middle/Lower Neills Creek
Parkers Creek	Kenneth Creek - Suburban
Avents Creek	Kenneth Creek - Urban

NC Ecosystem Enhancement Program
Middle Cape Fear Local Watershed Plan

Figure 1.2 Functional Assessment Units

0 1 2 4 6 8 Miles

1.2 Watershed Functions

The EEP works to replace functional watershed losses through stream, buffer, and wetland improvement and protection projects. In this section, the discussion focuses on the three principal watershed functions: habitat, hydrology, and water quality. This is most easily accomplished by describing what constitutes properly functioning systems. These systems function in a "natural" manner. Impacted systems do not provide the high level of function associated with natural systems. However, as this functional assessment demonstrates, completely undeveloped catchments are not a requirement for achieving a functional system. Certainly, less developed catchments have a better chance of proper functioning. Land use management also plays a role in watershed functions.

1.2.1 Habitat Function

Habitat may be divided into aquatic and terrestrial components. Due to the regulatory emphasis placed on aquatic resources, there is typically more focus on assessing aquatic habitat. It is also the case that aquatic habitat covers a more finite, and hence easier to investigate, area. Additionally, instream habitat reflects a response to watershed activities, so it tends to represent more than just aquatic habitat. Nevertheless, a comprehensive watershed assessment requires a determination of what represents functioning habitat for both categories.

Functioning aquatic habitat provides a setting in which aquatic communities, such as fish and benthic invertebrates, can be both diverse and balanced. Such communities meet the designated use of biological integrity, as determined by established metrics such as the North Carolina Biotic Index (NCDWQ, 2001), which measures pollution tolerance of organisms relative to their abundance. Good habitat in the study area has abundant and diverse microhabitat (sticks, leaf packs, logs, vegetated mats, and root masses), limited embeddedness (covering of channel by fine sediment), stable streambanks, and a variety of bottom substrate (sand, gravel, cobbles and boulders). Poor water quality due to toxicants might cause a degraded invertebrate community despite functioning habitat. A benthic macroinvertebrate survey allows for the distinction between degradation due to habitat and degradation due to water quality.

For terrestrial habitat, a functioning system allows wildlife to move about more easily to find necessary resources (food, shelter, and community) and does not endanger or threaten native species. Properly functioning systems in the study area have minimally fragmented forest land cover that promotes wildlife travel and provides resources. Another term that expresses this is connectedness, or the degree to which good habitat connects with other good habitat. Threatened and endangered species may be impacted by an abundance of invasive species and/or widespread development. Small-scale, niche ecosystems are not the focus of terrestrial habitat function in this project; rather, the focus is broader and looks at wildlife as a whole, not individual species that might inhabit a niche environment.

1.2.2 Hydrologic Function

Functioning streams effectively transport water and sediment. Good hydrologic function is most apparent in the stream channel, but extends to the riparian and upland areas, as well. A functioning stream channel has low bank height ratios (vertical stability), reasonably stable streambanks (lateral stability), higher base flows, and lower peak flows. Riparian zones in catchments that display good hydrologic function promote groundwater recharge and store stormwater discharge and deposited sediment. Upland areas have higher amounts of pervious cover that encourages infiltration, as opposed to rapid runoff to stormwater conveyance systems. Infiltration provides surface water storage and slowly delivers water to the stream channel network slowly, if at all (due to uptake by vegetation, loss to deep groundwater, and soil field capacity).

1.2.3 Water Quality Function

Good water quality function is exemplified by lower pollutant levels that do not prevent attainment of designated uses, such as biological integrity, recreation, or water supply. Practices that lead to good water quality are also considered part of a functioning system. For example, functioning riparian areas filter overland flow and are not circumvented by stormwater conveyance systems. Instream pollutant levels are a key indicator of water quality function; however, these quantities may be highly dynamic and difficult to characterize without extensive monitoring data over a full range of stream flows. Alternatives include benthic invertebrate or other biological monitoring that provide long term indicators of water quality. Sediment bioassays and chemistry also provide longer term evidence of water quality, as many toxic pollutants adhere to fine-grained, organic-rich sediment.

Available data may be compared with state or local water quality standards to assess the frequency of exceedances, and with reference streams (which have minimal impacts) for a comparison on the higher quality end of the spectrum. A functioning stream has a very low frequency of exceedances of water quality standards and pollutant levels in the range of those of reference streams. Water column bioassays, where test organisms are exposed to water samples, are another measure of water quality function. However, toxic episodes may be very infrequent and difficult to capture, though present nonetheless. Evidence of toxicity that degrades an aquatic community is clear evidence of impaired water quality function.

Benthic invertebrate surveys are considered to be suitable for assessing water quality function. These surveys use metrics that assess pollution tolerance and diversity of communities. The metrics are scored to arrive at a bioclassification. The temptation is to equate bioclassification with water quality function, but care must be taken because habitat is also a factor. Careful interpretation of the invertebrate survey results typically provides an indication of what roles habitat and water quality played in determining a given bioclassification.

1.3 Data Collection

The majority of data for this analysis was collected earlier in the development of the local watershed plan. Water quality data, land use plans, natural resource information, transportation improvements, and other GIS information were collected during the first phase of the project and were presented in Technical Memorandum 1. Field assessments at selected study sites for a variety of geomorphologic and habitat indicators were performed and presented in Technical Memorandum 2. For this analysis, headwater sites at selected locations throughout the FAUs were visited in order to supplement existing information, as needed. Floodplain vegetation, topography, and management were observed at these sites.

1.4 Determination of Functionality

To complete a functional assessment of habitat, hydrology, and water quality in the project area, Buck Engineering employed a "strength of evidence" approach (USEPA, 1998; USEPA, 2000). This approach uses the logical evaluation of various types (lines) of evidence to assess the strengths and weaknesses of that evidence in order to determine which of the options being assessed has the highest degree of support.

For each of the three watershed functions in each FAU, Buck Engineering applied ratings of *Functioning, Functioning at Risk,* or *Not Functioning*. These ratings are based on four (hydrology and water quality) or five (habitat) distinct metrics using a 'strength of evidence' approach. Each metric received a rating of *Functioning, Functioning at Risk,* or *Not Functioning* and these were considered in the determination of the overall rating. The metrics, and data on which they are based, are considered "lines of evidence."

Buck Engineering considered all lines of evidence developed during the course of the study using a process that incorporated existing scientific knowledge and best professional judgment in order to consider the strengths and limitations of each source of information. Lines of evidence (metrics) considered for the habitat function include land use, field assessment using the Mecklenburg Habitat Assessment Protocol (CH2M Hill, 2001), invasive species abundance, habitat assessment as part of benthic surveys, and substrate analysis. For hydrologic function, headwater assessments, bank height ratios, percent impervious cover, and levels of existing or planned infrastructure were examined. Last, the lines of evidence for assessing water quality function were Bank Erosion Hazard Index (Rosgen, 2001), watershed modeling results, benthic monitoring data, and riparian area assessments. See Figure 1.3 for a flow diagram that outlines the metrics that determined each function.

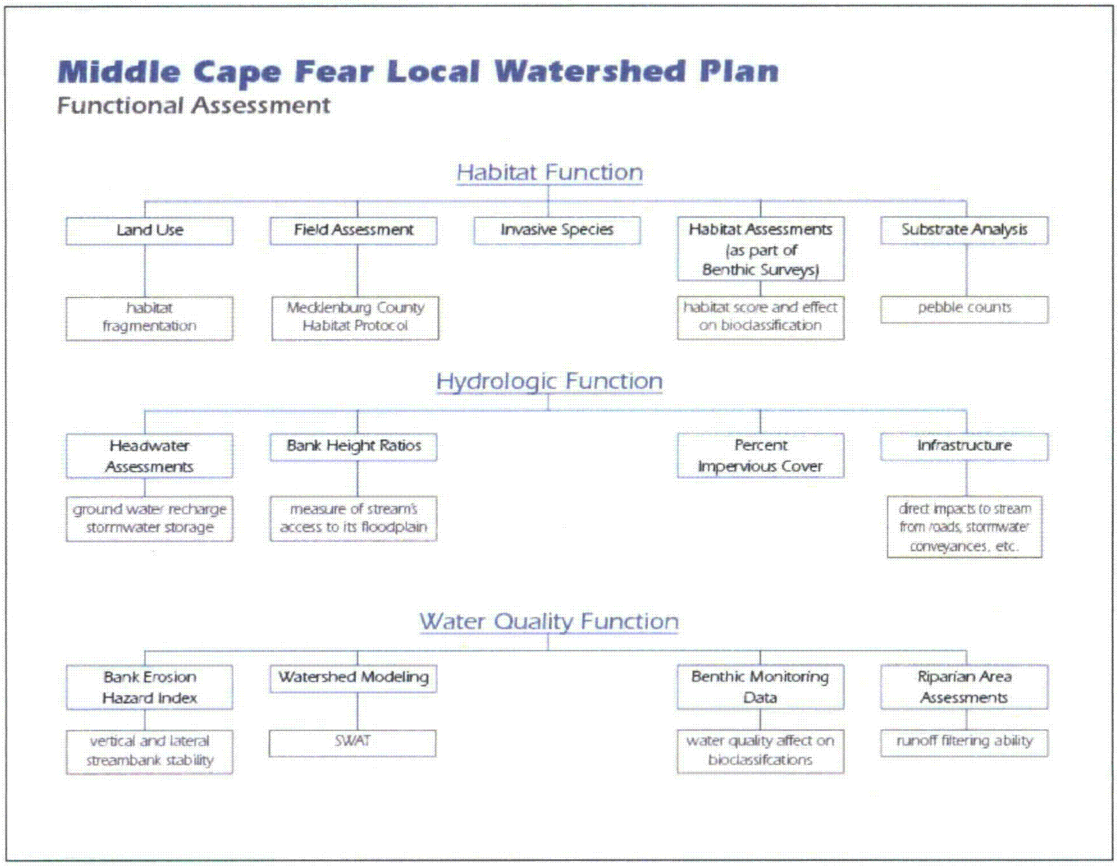


Figure 1.3 Metrics Used to Determine Watershed Functions

The endpoint of this process is a decision regarding the most probable level of function for each metric, and collectively, for each FAU. Levels of function are described as follows:

- **Functioning** - existing conditions indicated that function was achieved without immediate risk of alteration. If several sites within an assessment unit were assessed, an attempt was made to broadly characterize function by collectively considering all sites. Minor degradation at a particular site was overlooked if evidence suggested that impacts did not extend beyond its local area.
- **Functioning at Risk** - observed conditions indicated that function was minimally achieved, though immediate risk of alteration exists. Evidence of risk was considered in several forms. It may have been a local impact that extended slightly to other areas of an assessment unit, or a more widespread problem that did not hinder function significantly. Also, a function may have been rated 'at risk' if land use or channel conditions in an assessment had recently and dramatically changed, but the impacts were not yet observed. An attempt was made to avoid speculation of risk if development or other alterations were planned beyond the near future.

- **Not Functioning** - existing conditions indicate that function is not being achieved. Noteworthy functional failure at any site(s) that impacted other parts of the assessment unit or that indicated designated use degradation earned this rating.

2 Habitat Function Assessment

Buck Engineering assessed habitat function in each of the 12 FAUs using five metrics: habitat fragmentation, field assessment using the Mecklenburg Habitat Assessment Protocol, presence of invasive species, benthic surveys by the NC Division of Water Quality (NCDWQ), and substrate analysis (pebble counts).

The following sections present background and summary results for each metric. The introduction to each metric describes how it was used to assess habitat function. At the conclusion of this chapter, an overall habitat function rating for each FAU is provided. Potential sources of observed degradation are also cited.

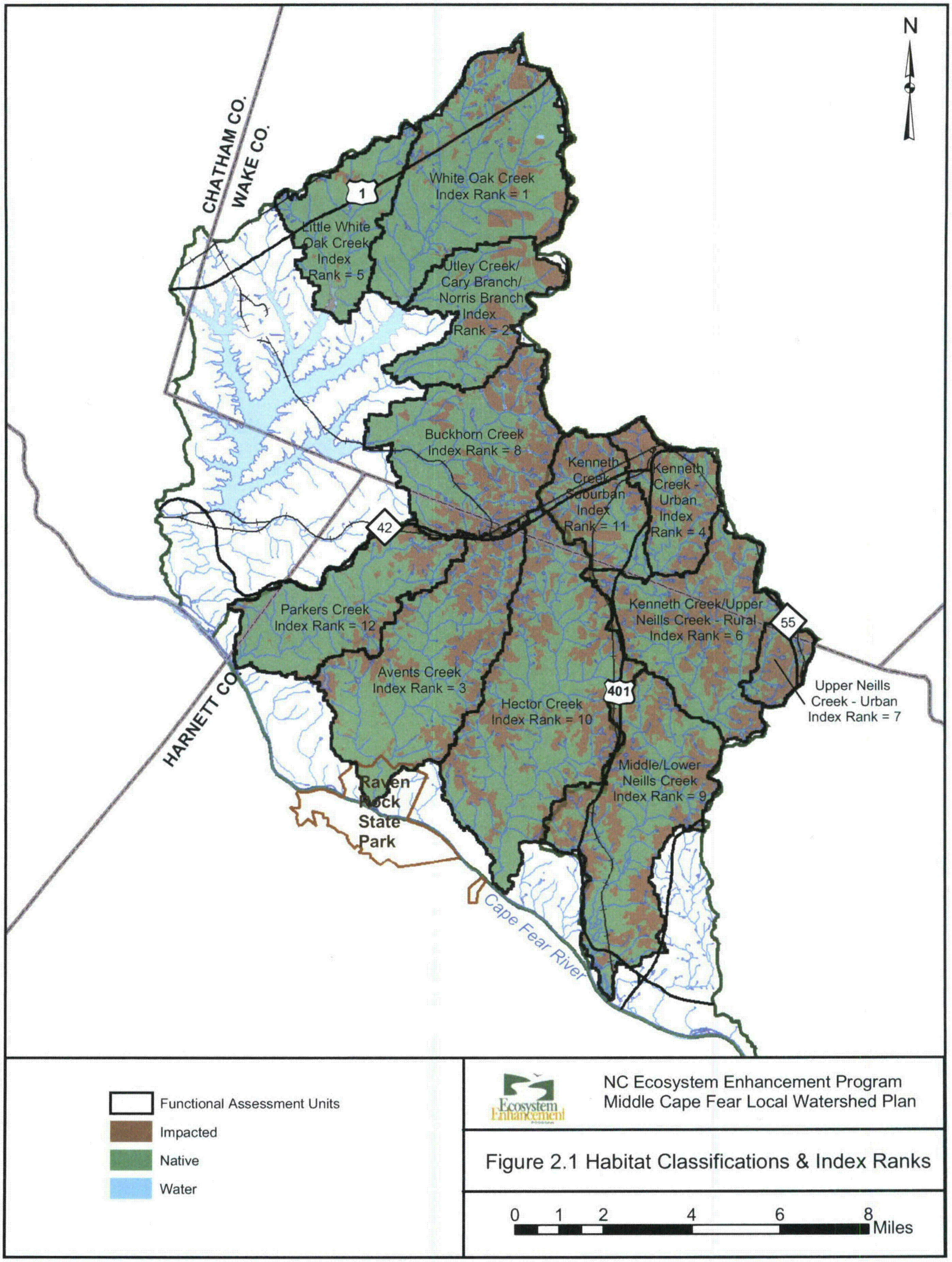
2.1 Habitat Fragmentation

Habitat fragmentation is a metric of terrestrial habitat function. More fragmented habitats are considered less functional. Low habitat fragmentation indicates good connectivity, which allows wildlife to more easily find food, shelter, and other members of their community.

Land use data in GIS format, previously acquired for the project and used as an input for watershed modeling, were analyzed to determine habitat fragmentation. The land uses were grouped into three classes - Impacted, Native, or Water (Table 2.1). The study-wide land use polygons were then clipped to each FAU using ArcView® GIS. The resultant data for each FAU included a text descriptor of the habitat class and the area of each polygon (Figure 2.1).

Table 2.1. Land Use Habitat Classifications

Land Use Type	Habitat Class
Agricultural	Impacted
Forested	Native
High Density Residential	Impacted
Low Density Residential	Impacted
Medium Density Residential	Impacted
Pasture, Rangeland	Impacted
Transportation	Impacted
Urban, Commercial	Impacted
Urban, Industrial	Impacted
Water	Water
Wetlands	Native



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Middle Cape Fear Local Watershed Plan

Figure 2.1 Habitat Classifications & Index Ranks

Buck Engineering analyzed the data using Patch Analyst 3.1. This software is an extension to ArcView GIS that facilitates the spatial analysis of landscape patches and modeling of attributes associated with patches (Rempel, 2004). Patch Analyst was used to calculate an area estimate and mean patch size estimate for the three habitat classes. Further analysis of the results was focused on the "Native" habitat class. For each FAU, the percent of native area present and rank of mean patch size were weighted equally and combined to create a "Habitat Index." Next, "Habitat Index" for the 12 FAUs was ranked. The function ratings assigned were:

- Functioning (F) – rank <5
- Functioning at Risk (FR) – rank ≥ 5 and rank < 9
- Not Functioning (NF) – rank ≥ 9

Results of this analysis are presented in Table 2.2 and Figure 2.1.

Table 2.2. Habitat Fragmentation Results

Functional Assessment Unit	Habitat Index Rank	Function Rating
Buckhorn Creek	8	FR
Utley Creek/Cary Branch/Norris Branch	2	F
White Oak Creek	1	F
Little White Oak Creek	5	FR
Parkers Creek	12	NF
Avents Creek	3	F
Hector Creek	10	NF
Upper Neills Creek - Urban	7	FR
Kenneth Creek/Upper Neills Creek -Rural	6	FR
Middle/Lower Neills Creek	9	NF
Kenneth Creek - Suburban	11	NF
Kenneth Creek - Urban	4	F

2.2 Selected Field Assessment of Habitat

In a previous phase of the LWP project, Buck Engineering assessed habitat at selected study sites (refer to Technical Memorandum 2). Each study reach channel was evaluated for stream and terrestrial habitat features and habitat quality based upon the modified Mecklenburg County Habitat Assessment Protocol (MCHAP) (CH2M Hill, 2001). Terrestrial habitat surrounding an addition 11 headwater sites upstream of study reaches were also evaluated with the modified Mecklenburg Habitat Assessment Protocol.

Quantitative habitat scores were developed for each reach. Starting from the downstream end of each study reach, channel habitat was evaluated for instream cover, benthic substrate, riffle embeddedness, pool substrate, channel alteration, sediment deposition, riffle and pool frequency, channel flow, and bank stability. These data were used to determine a qualitative habitat score for each reach. Scores are on a scale of 1 to 200. These scores are qualitative measures of stream habitat as the protocol does not have specific rankings or classifications associated with the quantitative measures. However, these relative scores provide a basis to compare habitat quality at different sites within the watershed and are a baseline number to which future habitat conditions may be compared. Determinations for the functional value of habitat in each FAU are described below.

2.2.1 Buckhorn Creek FAU

Productive habitats expected for the stream types in this unit made up 50-70% of stream length at monitoring sites. Fine sediment and silt surrounded and filled 25-50% of the living spaces around and in the substrate. Additionally, 20-50% of the bottom was affected by deposition with slight deposition in pools. The FAU had moderate MCHAP scores ranging from 134 to 147. However, due to the consistent presence of fine materials in the stream channel and moderately stable banks, this FAU was determined to be *Functioning at Risk*.

2.2.2 Utley Creek/Cary Branch/Norris Branch FAU

A full MCHAP scoring was not conducted in this watershed. However, partial assessment at four sites indicated limited riparian buffer and unstable bank sections in both the Cary Branch and Norris Branch catchments. Therefore, the field habitat assessment rating for this FAU was assumed to be *Functioning at Risk*.

2.2.3 White Oak Creek FAU

Productive habitat(s) expected for the stream types in this unit made up 50-70% of the studied reaches. However, overall MCHAP scores were relatively low (115-131) due to the multiple observations of riffles embedded with sediment and silt. Therefore, the field habitat assessment rating for this FAU was determined to be *Functioning at Risk*.

2.2.4 Little White Oak Creek FAU

Ninety percent of the study reaches in this unit were embedded by sediment and silt. Therefore, the field habitat assessment rating for this FAU was determined to be *Not Functioning*.

2.2.5 Parkers Creek FAU

Productive aquatic habitat made up of a mixture of cobble and course gravel made up 70% of the studies reaches. Only 20% of the studied length was imbedded by small sediments of less than 2mm. Therefore, the field habitat assessment rating for this FAU was determined to be *Functioning*.

2.2.6 Avents Creek FAU

MCHAP scores as high as 183 and productive aquatic habitat in 70% of the study reaches clearly identified this unit as containing high quality habitat. Therefore, the field habitat assessment rating for this FAU was determined to be *Functioning*.

2.2.7 Hector Creek FAU

MCHAP scores as high as 161 and productive aquatic habitat in 60% of the study reaches suggested that this unit contains high quality habitat. This conclusion is supported by generally high quality riparian habitat in the watershed. Therefore, the field habitat assessment rating for this FAU was determined to be *Functioning*.

2.2.8 Upper Neills Creek – Urban FAU

Productive habitats comprised less than 50% of the studies reaches. However, there was little to no embeddedness due to by fine silt. Limited areas were affected by sand and silt accumulation. Therefore, the field habitat assessment rating for this FAU was determined to be *Functioning at Risk*.

2.2.9 Kenneth Creek/Upper Neills Creek - Rural FAU

Moderate MCHAP scores resulted from productive habitats at 70% of the studied reaches. However, silt surrounded and filled 40% of the living spaces around and in between the gravel. Therefore, the field habitat assessment rating for this FAU was determined to be *Functioning at Risk*.

2.2.10 Middle/Lower Neills Creek FAU

High MCHAP scores (183-187) and productive habitats were found in this unit. Therefore, the field habitat assessment rating for this FAU was determined to be *Functioning*.

2.2.11 Kenneth Creek - Suburban FAU

Productive habitats made up 70% of the studied reaches. However, 20-30% of the streambanks had bank erosional areas. Therefore, the field habitat assessment rating for this FAU was determined to be *Functioning at Risk*.

2.2.12 Kenneth Creek - Urban FAU

Very low MCHAP scores (as low as 52) clearly identified poor habitat. Therefore, the field habitat assessment rating for this FAU was determined to be *Not Functioning*.

2.3 Presence of Invasive Species

Invasive species such as privet and multiflora rose are an indicator of poor habitat quality. These species may out-compete native species, alter species composition, decrease rare species, or degrade the overall functioning of an ecosystem. The transformation of healthy riparian zones into communities dominated by invasive species may also affect animals that rely on the native species for food or habitat.

Through the field assessment process described in Technical Memorandum 2 and other visits within the study area, Buck Engineering was able to evaluate the presence of invasive species at multiple locations. Data collected within each FAU were evaluated to determine an overall functional rating for the presence of invasive species.

2.3.1 Buckhorn Creek FAU

Invasive species presence at three headwater sites visited during the field assessment was low. Therefore, the invasive species rating for this FAU was determined to be *Functioning.*

2.3.2 Utley Creek/Cary Branch/Norris Branch FAU

Invasive species presence in one area of the FAU was low in the headwaters, while it was medium/high downstream. In another area, invasive species presence was medium in the headwaters and high downstream. Therefore, the invasive species rating for this FAU was determined to be *Functioning at Risk.*

2.3.3 White Oak Creek FAU

Invasive species presence at all but one site visited was low. At one headwater area, invasive species presence was rated medium due to observations of honeysuckle. Therefore, the invasive species rating for this FAU was determined to be *Functioning.*

2.3.4 Little White Oak Creek FAU

Invasive species presence at both a headwaters and mainstem site was low. Therefore, the invasive species rating for this FAU was determined to be *Functioning.*

2.3.5 Parkers Creek FAU

Invasive species presence at both a headwaters and mainstem site was medium. Therefore, the invasive species rating for this FAU was determined to be *Functioning at Risk*.

2.3.6 Avents Creek FAU

Invasive species presence at a headwaters site was low and no other notations regarding invasive species were made at other study sites. Therefore, the invasive species rating for this FAU was determined to be *Functioning.*

2.3.7 Hector Creek FAU

Invasive species presence at a headwaters site was medium. Therefore, the invasive species rating for this FAU was determined to be *Functioning at Risk.*

2.3.8 Upper Neills Creek – Urban FAU

Invasive species presence at visited sites was high. Therefore, the invasive species rating for this FAU was determined to be *Not Functioning.*

2.3.9 Kenneth Creek/Upper Neills Creek - Rural FAU

Invasive species presence at visited sites was high. Therefore, the invasive species rating for this FAU was determined to be *Not Functioning.*

2.3.10 Middle/Lower Neills Creek

Invasive species presence at visited sites was high. Therefore, the invasive species rating for this FAU was determined to be *Not Functioning.*

2.3.11 Kenneth Creek - Suburban FAU

Invasive species presence at a headwaters site was medium/high and one study site within the FAU was recommended for exotic species removal. Therefore, the invasive species rating for this FAU was determined to be *Not Functioning.*

2.3.12 Kenneth Creek - Urban FAU

Invasive species presence at the headwaters of one site was medium/high. Two other sites were recommended for exotic species removal. Therefore, the invasive species rating for this FAU was determined to be *Not Functioning.*

2.4 NCDWQ Benthic Surveys

NCDWQ benthic surveys provide a metric of aquatic habitat function (NCDWQ, 2001). Functioning aquatic habitat offers a setting in which aquatic communities, such as fish and benthic invertebrates, can be both diverse and balanced. Such a community meets the designated use of biological integrity. Good habitat has abundant and diverse microhabitat, limited embeddedness, stable streambanks, and a variety of bottom substrate.

During March and April 2003, NCDWQ surveyed the benthic macroinvertebrate communities at 13 locations within 8 of the FAUs in the project area. NCDWQ did not assess streams in the following FAUs: Utley Creek/Cary Branch/Norris Branch, Little White Oak Creek, Upper Neills Creek-Urban, and Kenneth Creek-Urban.

As part of each survey, scientists completed a habitat assessment that yielded a score from 0 to 100. A higher score represents better habitat. The habitat characteristics measured, with the maximum possible scores in parentheses, include:

- Channel modification (5)
- Instream habitat (20)
- Bottom substrate (15)
- Pool variety (10)
- Riffle habitats (16)
- Bank stability and vegetation (14)
- Light penetration (10)
- Riparian zone width (10).

The characteristics and possible scores listed above are for Piedmont region streams. Habitat comparisons in the project area are complicated by the fact that four of the 13 survey sites displayed characteristics more typical of Coastal Plain streams (e.g., few riffles, sandier substrate) than Piedmont streams. For Coastal Plain streams, the following habitat characteristics and possible scores apply:

- Channel modification (15)
- Instream habitat (20)
- Bottom substrate (15)
- Pool variety (10)
- Bank stability and vegetation (20)
- Light penetration (10)
- Riparian zone width (10).

The Coastal Plain ranking increases the importance of channel modification and bank stability, while excluding riffle habitats.

Where benthic survey data were available, each FAU was rated as *Functioning*, *Functioning at Risk*, or *Not Functioning*. To determine this, the habitat scores, as well as NCDWQ's assessment of the influence of habitat on the bioclassification, was considered. The bioclassification is an overall rating of benthic community based on measures of diversity (number of EPT taxa) and pollution tolerance (based on NC Biotic Index). Essentially, the habitat scores were treated at face value (regardless of whether the stream was considered a Piedmont or Coastal Plain stream). However, if NCDWQ stated that the habitat adversely affected the bioclassification, the habitat function rating was reduced. By the same token, if the stream was considered "not impaired" ("Good" bioclassification or better), then the habitat function was at least *Functioning at Risk.*

It should be noted that drought conditions in the study area were extreme and had been prevalent for several years prior to the collection of data by NCDWQ. Though adequate flows were available during the sampling period, the drought may have caused changes in the benthic community that persisted beyond its end. This is particularly an issue in the Triassic Basin ecoregion, where streams normally dry up for parts of the summer. The Triassic Basin streams were more severely impacted by the 2002 drought than other streams in the study area. Subsequently, NCDWQ did not complete bioclassifications for all Triassic Basin streams.

2.4.1 Buckhorn Creek FAU

Although Buckhorn Creek flows into Harris Lake, it does not fall within the Triassic Basin as do some of the other tributaries to the lake. Nevertheless, NCDWQ gave it a low habitat score of 56 due to severe erosion, infrequent riffles, numerous breaks in the riparian zone, and very embedded substrate. Although an impaired benthic community would be expected in such a setting, that was not the case as NCDWQ assigned a "Good" bioclassification. These two results balance one another, so a habitat rating of *Functioning at Risk* was assigned.

2.4.2 White Oak Creek FAU

NCDWQ surveyed Little Branch, a tributary to White Oak Creek. This site is located within the Triassic Basin. The stream's substrate was primarily gravel, with some sand. There were infrequent riffles and severe bank erosion. Apparently NCDWQ could not determine the geographic province in which this stream resides, as they rated its habitat at 79 using the Coastal Plain criteria and 67 using the Piedmont criteria. NCDWQ listed the bioclassification as "Not Rated," due to the effects of the 2002 drought on Triassic Basin streams.

It is difficult to rate White Oak Creek's habitat function given the ambiguity between Coastal Plain and Piedmont settings, and lack of a bioclassification. However, it was determined that, due to severe bank erosion, an appropriate rating would be *Functioning at Risk*.

2.4.3 Parkers Creek FAU

NCDWQ surveyed the benthic communities at two sites in the Parkers Creek FAU, one in the headwaters and one approximately halfway between the headwaters and the Cape Fear River. Because the headwater site had such a small drainage area, NCDWQ could only assign a bioclassification of "Not Impaired." However, the community was clearly diverse and intolerant. It received a high habitat score in light of frequent riffles, rocky substrate, no embeddedness, a good canopy cover and ample instream habitat (e.g., woody material, leaf packs).

The downstream site had a drainage area of 3.8 square miles. Although still small by most measures, it earned a "Good" bioclassification. The site got a fairly low habitat score of 63, with a massive bank failure noted. It should be noted that NCDWQ limited the downstream benthic survey to an EPT sample, as a full sample would have been difficult to collect in turbid conditions produced by an earlier thunderstorm.

Based on this information, it was determined that the Parkers Creek habitat should be rated as *Functioning*. An eye should be kept on sedimentation from the stream channel and development within the watershed in the coming years.

2.4.4 Avents Creek FAU

NCDWQ sampled Avents Creek in a single location toward the stream's mouth. The site is located just within Raven Rock State Park, and the stream is classified as a High Quality Water by NCDWQ. The stream received a habitat score of 88, indicating high quality habitat. Diverse substrate, plentiful instream microhabitat, and frequent riffles were key factors. Coupled with an "Excellent" bioclassification, Avents Creek warrants a habitat rating of *Functioning*.

2.4.5 Hector Creek FAU

NCDWQ conducted three benthic community surveys in the Hector Creek FAU, one on Coopers Branch, and the others on Hector Creek in its headwaters and lower reach.

The Coopers Branch site had a drainage area of 2.1 square miles, and received a "Good" bioclassification. The habitat alternated between riffles with a diversity of instream habitat and substrate size, and pools with notable siltation. Forest composed the bulk of the surrounding land use, with some scattered residential areas included.

The upper Hector Creek site caused confusion over whether it was in the Piedmont or Coastal Plain. Sand dominated the substrate but there were also cobbles, gravel, and woody debris. Cattle access the stream and cause erosion, though the surrounding land use is primarily forest. NCDWQ gave the site a "Good" bioclassification, and noted that habitat insufficiencies kept it from getting a higher score.

NCDWQ's survey of the lower Hector Creek site revealed improved habitat due to higher proportions of boulders and cobbles, less bank erosion, and more frequent riffles. Subsequently, it received a habitat score of 86 and an "Excellent" bioclassification.

In an uncommon scenario, the headwaters of Hector Creek tend to have less functioning habitat compared to the lower reaches of the watershed. Sedimentation is the main threat to the upper watershed and, if it is not addressed, it may lead to habitat degradation in the lower reaches. At present, however, function has only been slightly impaired, and this degradation is limited to an isolated area. We believe that the most appropriate rating to apply to habitat of the Hector Creek FAU is *Functioning*.

2.4.6 Kenneth Creek/Upper Neills Creek – Rural FAU

NCDWQ sampled two sites in this FAU, a lower Kenneth Creek site at Chalybeate Springs Road and a headwaters site along Neills Creek site. The lower Kenneth Creek site was below the Fuquay-Varina wastewater treatment plant (WWTP). This treatment plant has a poor compliance record, including violations of toxic parameters such as mercury and lead. NCDWQ used the Coastal Plain rating for this site and found marginal habitat, with sand dominant and an overall score of 69. They concluded the site earned a "Poor" bioclassification, and emphasized that the primary cause was poor water quality, not habitat insufficiencies.

The upstream Neills Creek site contains the outskirts of Angier within its watershed. Its substrate was equal parts sand, cobble, and gravel. The habitat included frequent riffles, abundant pools and stable streambanks. The surrounding land use included the typical rural suburban blend of forest, low density residential, and pasture. Despite the suitable habitat, the EPT taxa were practically non-existent. NCDWQ gave it a "Not Rated" bioclassification because the stream was less than 2 meters wide, but the survey indicated degradation. It appears that either an extended drought or a toxic event occurred in the stream.

Were it not for poor water quality, the benthic communities might have been rated "Not Impaired." The instream habitat in this FAU is certainly not exemplary, but it is probably sufficient to classify it as *Functioning at Risk*.

2.4.7 Middle/Lower Neills Creek FAU

The downstream Neills Creek site had deeper water, making it difficult for NCDWQ to conduct the sample. Of all the project survey sites, this one most resembles the Coastal Plain description. There were no riffles and the substrate was entirely sand and silts, but there were some large snags. The site earned a 70 habitat score, with low marks for bank stability and vegetation. NCDWQ also noted a sewage smell in the water, though the WWTP was well upstream on Kenneth Creek. Based on EPT taxa collected and the NC Biotic Index, NCDWQ gave the stream a "Fair" (impaired) bioclassification.

The benthic community in the Middle/Lower Neills Creek FAU is impaired; however, it is more likely that water quality degradation has been the cause. Improvements are needed in different areas, depending on the reach. For example, the downstream reach would benefit from more stable streambanks. The habitat is rated *Functioning at Risk*.

2.4.8 Kenneth Creek – Suburban FAU

NCDWQ sampled Kenneth Creek, a tributary to Neills Creek, in two locations. The upstream site was in a suburban residential area on the outskirts of Fuquay-Varina. A greenway provided forest cover on one bank. In this reach, the stream had diverse substrate and was very sinuous. The outside streambanks were subject to severe erosion. Despite a habitat score of 64, the stream received a "Good" bioclassification. It seems that water quality (nutrient enrichment) limited the benthos more than, or as much as, the habitat. Subsequently, we assigned this FAU a rating of *Functioning at Risk*.

2.5 Substrate

Substrate, or stream channel bottom sediment, contributes to habitat function because it is one of the most important components of aquatic community habitat. Benthic invertebrates live in and on stream substrate, and fish use it for protection and spawning beds. Ideally, substrate will have a mix of class sizes that range from fine (silt) to very coarse (cobbles and boulders). This, of course, is dependent on a number of factors, including local geology. Substrate affects the functioning of habitat when an accumulation of finer grained particles (e.g., sands and smaller) covers the channel. A metric known as embeddedness measures this accumulation. Embedded substrate essentially creates unstable habitat for aquatic communities, particularly benthic invertebrates.

To assess the suitability of bed substrate for aquatic habitat, Buck Engineering conducted pebble counts in each FAU. Based on the diversity of class sizes, we assigned substrate ratings of *Functioning, Functioning at Risk, and Not Functioning.*

2.5.1 Buckhorn Creek FAU

Coarse substrate was plentiful in this unit. Therefore, the substrate rating for this FAU was determined to be *Functioning.*

2.5.2 White Oak Creek FAU

Gravel was the dominant substrate for streams in this FAU. As gravels generally provide excellent aquatic habitat the substrate rating for this FAU was determined to be *Functioning.*

2.5.3 Little White Oak Creek FAU

We observed a bimodal distribution with fines dominant. Therefore, the substrate rating for this FAU was determined to be *Not Functioning.*

2.5.4 Parkers Creek FAU

This FAU has sites with gravel dominated substrate with some bedrock present. Therefore, the substrate rating for this FAU was determined to be *Functioning.*

2.5.5 Avents Creek FAU

We observed a tri-modal distribution with fines, gravel and bedrock. Therefore, the substrate rating for this FAU was determined to be *Functioning at Risk.*

2.5.6 Hector Creek FAU

The streams in this unit typically have broad, gravel-centered curves. Therefore, the substrate rating for this FAU was determined to be *Functioning.*

2.5.7 Upper Neills Creek – Urban FAU

A tri-modal distribution of fines, gravel and bedrock form this unit's substrate. An accumulation of fine-grained material, however, makes this FAU *Functioning at Risk*.

2.5.8 Kenneth Creek/Upper Neills Creek – Rural FAU

The monitored sites in this unit had sites with gravel dominated substrate with some bedrock present. Therefore, the substrate rating for this FAU was determined to be *Functioning.*

2.5.9 Middle/Lower Neills Creek FAU

We observed sandy substrate with some gravel in this unit. Therefore, the substrate rating for this FAU was determined to be *Functioning.*

2.5.10 Kenneth Creek – Suburban FAU

The monitored site had some sand on top of gravel. Therefore, the substrate rating for this FAU was determined to be *Functioning at Risk*

2.5.11 Kenneth Creek – Urban FAU

As with the suburban Kenneth Creek unit, this unit had some aggradation, with sand on top of gravel. Therefore, the substrate rating for this FAU was determined to be *Functioning at Risk*

2.6 Overall Habitat Function Assessment

Table 2.3 and Figure 2.2 summarize the function ratings for each metric and provide an overall habitat rating for each assessment unit. Buck Engineering used a "strength of evidence" approach (see Section 1.4) to arrive at the overall ratings. In general, we tended to place more emphasis on benthic data since they are most directly tied to habitat function. Below, we provide a summary statement of how we reached each overall rating, and a brief discussion of the main pollution sources in those FAUs rated *Functioning at Risk* or *Not Functioning*.

Table 2.3. Overall Habitat Function by FAU

Functional Assessment Unit	**Land Use**	**Field Data**	**Invasive Species**	**Benthic Data**	**Substrate**	**Overall**
Buckhorn Creek	FR	FR	F	FR	F	***FR***
Utley Creek/Cary Branch/Norris Branch	F	FR	FR	ND	ND	***FR***
White Oak Creek	F	FR	F	FR	F	***FR***
Little White Oak Creek	F	NF	F	ND	NF	***FR***
Parkers Creek	F	F	FR	F	F	***F***
Avents Creek	FR	F	F	F	FR	***F***
Hector Creek	FR	F	FR	F	F	***F***
Upper Neills Creek - Urban	NF	FR	NF	ND	FR	***NF***
Kenneth Creek/Upper Neills Creek - Rural	NF	FR	NF	FR	F	***FR***
Middle/Lower Neills Creek	FR	F	NF	FR	F	***FR***
Kenneth Creek - Suburban	NF	FR	NF	FR	FR	***FR***
Kenneth Creek - Urban	NF	NF	NF	ND	FR	***NF***

Note: F = Functioning, FR = Functioning at Risk, NF = Not Functioning, ND = no data

2.6.1 Buckhorn Creek FAU

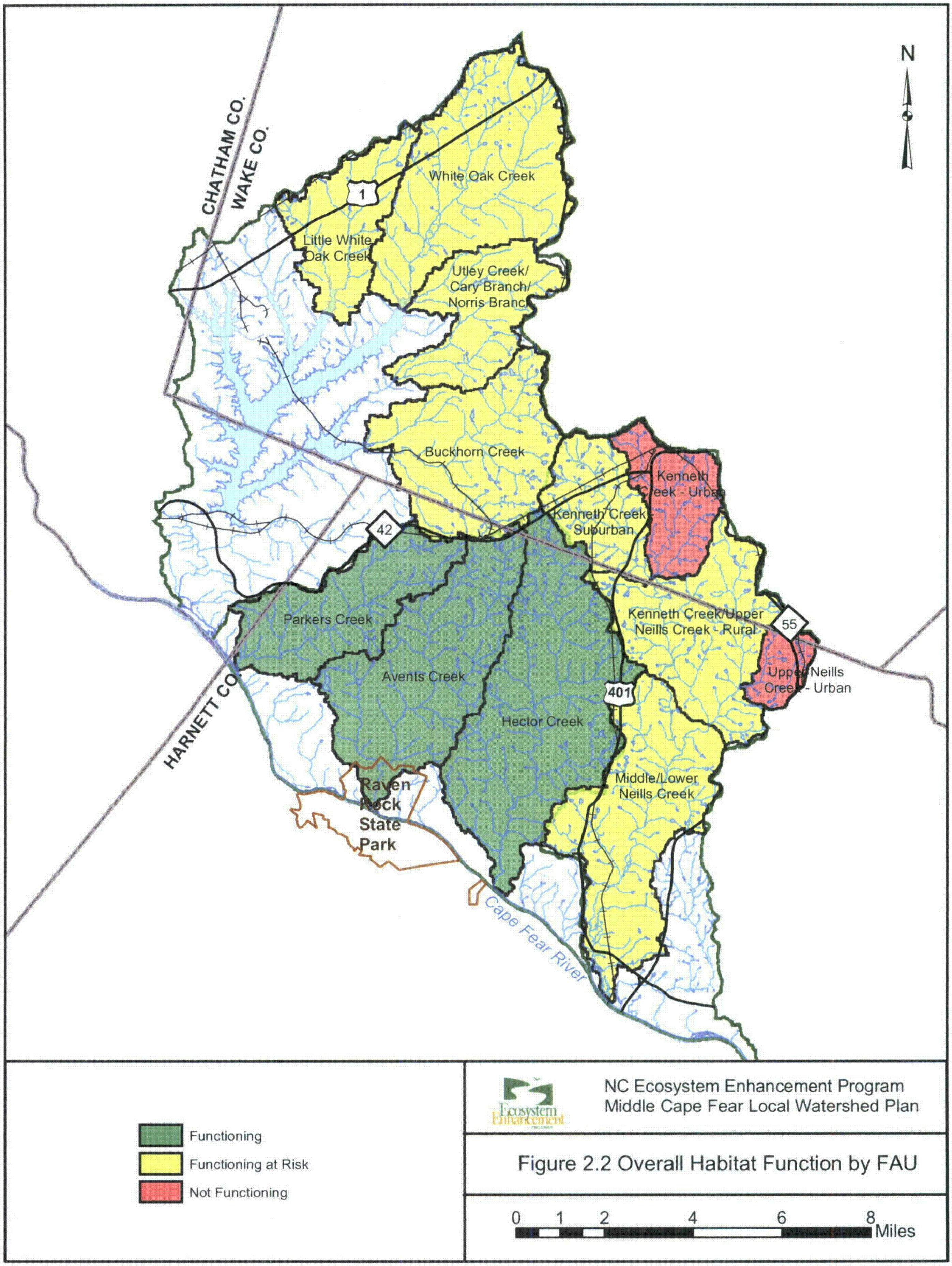
The function ratings for metrics in this FAU were divided between *Functioning at Risk* and *Functioning*, with three out of five of the former. Based on the habitat function rating for the benthic data, this FAU was given a rating of Functioning at Risk.

Source of Degradation - The primary cause of pollution in this FAU is sediment, most of which probably comes from severe, localized streambank erosion. This erosion is likely due to land altering activities such as silviculture or agriculture.

2.6.2 Utley Creek/Cary Branch/Norris Branch FAU

This FAU had one *Functioning* and two *Functioning at Risk* ratings, with no data for two other metrics (benthic data and substrate). Because it had a majority of *Functioning at Risk* ratings and the instream habitat rating represents a response to watershed activities, we selected a rating of *Functioning at Risk*.

Source of Degradation - Habitat function in this FAU is threatened by impacts to riparian buffer and unstable bank sections. The noted response is likely due to the impacts associated with development in the headwaters area.



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Middle Cape Fear Local Watershed Plan

Figure 2.2 Overall Habitat Function by FAU

2.6.3 White Oak Creek FAU

We rated three metrics as *Functioning* and two metric as *Functioning at Risk* in this FAU. Based on the benthic data rating, the determination for this FAU was *Functioning at Risk*.

Source of Degradation - Localized, severe streambank erosion is the primary source of sediment that causes habitat function degradation.

2.6.4 Little White Oak Creek FAU

This FAU had two *Not Functioning* and two *Functioning* ratings for habitat metrics. No data were available for the benthic communities. The terrestrial habitat was good, while the aquatic habitat showed problems. In particular the streams were choked with sediment and showed no bedform diversity. A benthic survey is needed to resolve the ambiguity between functioning and not functioning habitats. We gave this FAU an overall rating of *Functioning at Risk*.

Source of Degradation - The source of the stream sediment appears to be eroding streambanks. After incising over time, streams in this FAU are widening, which is resulting in streambank erosion.

2.6.5 Parkers Creek FAU

This FAU had four *Functioning* metrics and only the invasive species metric was *Functioning at Risk*. Therefore, we assigned a rating of *Functioning*.

2.6.6 Avents Creek FAU

Avents Creek FAU received three *Functioning at Risk* and two *Functioning* metric ratings. The benthic habitat data were excellent, so we decided that other habitat shortcomings did not impact the overall function and gave it a rating of *Functioning*.

2.6.7 Hector Creek FAU

The two terrestrial metrics rated *Functioning at Risk* and the three aquatic metrics rated *Functioning*. Apparently, the land use impacts have not yet extended to the stream channel network. Therefore, this FAU gets an overall rating of *Functioning*.

2.6.8 Upper Neills Creek – Urban FAU

The aquatic habitat of this FAU was minimally functional (*Functioning at Risk*), while the terrestrial habitat was *Not Functioning*. Although benthic survey data were not available, we decided this FAU had some of the worst habitat in the project area and applied an overall rating of *Not Functioning*.

Source of Degradation - Aggradation is primary cause of instream habitat loss. This sediment probably originates from both upland and instream sources. The terrestrial habitat metrics, including poor connectivity and abundant invasive species, degrade habitat function.

2.6.9 Kenneth Creek/Upper Neills Creek - Rural FAU

This is another case of an FAU with *Not Functioning* terrestrial habitat metrics (land use and invasive species) and better aquatic habitat, with two *Functioning at Risk* ratings and one (substrate/pebble count) *Functioning* rating. Taken collectively, impacts are fairly widespread, so the most applicable rating is *Functioning at Risk*.

Source of Degradation - Development, with associated forest fragmentation and invasive species encroachment, harms terrestrial habitat function.

2.6.10 Middle/Lower Neills Creek FAU

In this FAU, only the invasive species metric was *Not Functioning*, while two metrics were *Functioning at Risk* and two others were *Functioning*. Based on the benthic habitat, the overall rating for this FAU is *Functioning at Risk*.

Source of Degradation - The primary source of habitat degradation is eroding streambanks. Additional vegetative cover would be beneficial to reducing high levels of embeddedness.

2.6.11 Kenneth Creek - Suburban FAU

In this FAU, the terrestrial habitat rated *Not Functioning* and the aquatic habitat rated *Functioning at Risk*. We believe the land impacts have not yet affected the stream channels to their full extent. However, it should be noted that rapidly changing land use may cause a downward trend in this FAU and it is at risk of becoming *Not Functioning*. The current rating is *Functioning at Risk*.

Source of Degradation - Again, sediment is the problem in this FAU, and the source is likely streambank erosion.

2.6.12 Kenneth Creek - Urban FAU

This FAU is the least functional of any in the project area. It received three *Not Functioning* ratings and one *Functioning at Risk* rating. NCDWQ did not collect benthic data. Based on overall evidence, we assigned a rating of *Not Functioning*.

Source of Degradation - The problem in this FAU is due to changing land use. Urban impacts fragment upland habitat, and invasive species tend to out compete native ones.

3 Hydrologic Function Assessment

We assessed hydrologic function in each of the 12 functional assessment units using four metrics: headwater/riparian assessments; bank height ratios; percent impervious; and infrastructure. In the following sections, we present background and summary results for each metric. At the conclusion of this chapter, we provide an overall hydrologic function rating for each FAU. Potential sources of observed degradation are also included.

3.1 Headwater/Riparian Assessments

To assess hydrologic function, Buck Engineering conducted riparian surveys, paying close attention to floodplain topography and features that would store surface runoff and recharge ground water. These observations were used to characterize hydrologic function in each FAU. A riparian area that provides hydrologic function promotes runoff storage and recharges groundwater. Based on the riparian assessments, we rated hydrologic function as *Functioning, Functioning at Risk,* or *Not Functioning.*

3.1.1 Buckhorn Creek FAU

We examined the floodplains and riparian areas of one headwater and two mainstem reaches in the Buckhorn Creek functional assessment unit. The mainstem floodplains provided similar hydrologic function, facilitating groundwater recharge and stormwater storage. With plentiful forest cover and bedrock holding its grade (allowing the stream to readily access its floodplain), the headwater reach provided adequate hydrologic function. In sum, Buckhorn Creek has a rating of *Functioning*.

3.1.2 Utley Creek/Cary Branch/Norris Branch FAU

Surveys of one headwater and one mainstem reach for both Cary Branch and Norris Branch provided insight to hydrologic function in this assessment unit. The headwater floodplains were narrow (about 50 feet), but wider than others in the project area. The Norris Branch headwater site exhibited compromised hydrologic function, as fill from home development and sewer lines limited its abilities to recharge groundwater and store stormwater. The other three reaches in this assessment unit provided groundwater recharge and stormwater storage via their floodplains.

Collectively, Cary Branch's hydrologic function is adequate, but further development may extend the impacts seen in upper Norris Branch. Consequently, we believe the best description for this unit is *Functioning at Risk*.

3.1.3 White Oak Creek FAU

We considered six reaches in the White Oak Creek FAU, including three headwater and three mainstem reaches. The headwater floodplains were narrow (20-30 feet), but were not effectively limited by structures such as timber debris, with one exception. An unnamed tributary to Little Branch had flow-disrupting, woody debris in its floodplain.

Groundwater discharge occurred in only this headwater reach. The mainstem reaches had much wider floodplains of at least 200 feet. They had been recently inundated and typically had depressions that could store stormwater and promote groundwater recharge.

Taken as a whole, White Oak Creek's riparian areas are relatively unimpacted and adequately service their hydrologic function. Therefore, the most applicable rating is *Functioning*.

3.1.4 Little White Oak Creek FAU

Buck Engineering surveyed a headwater and a mainstem reach in this assessment unit. The headwater site had a narrow (20 feet) floodplain with active springs and discharges. The mainstem site had a very wide floodplain (more than 300 feet) with minor depressions that provide some stormwater storage capability. Primarily owing to its forest cover, Little White Oak Creek's hydrologic processes are *Functioning*.

3.1.5 Parkers Creek FAU

Surveys of one headwater and one mainstem reach of Parkers Creek provided insight to hydrologic function in this assessment unit. Neither floodplain had drainage features such as ditches; both were able to provide groundwater recharge and stormwater storage. Parkers Creek's floodplains have hydrologic function and are rated *Functioning*.

3.1.6 Avents Creek FAU

Buck Engineering investigated one headwater site in the Avents Creek FAU. This reach had good riparian buffers, no ditches, and functioning groundwater recharge and stormwater storage capacity. The most appropriate rating is *Functioning*.

3.1.7 Hector Creek FAU

Buck Engineering investigated one headwater site in the Hector Creek FAU. Similar to the Avents Creek site, this reach provided groundwater recharge and stormwater storage, and had not been ditched. As such, we rated this unit as *Functioning*.

3.1.8 Upper Neills Creek – Urban FAU

No data were collected in this FAU; however, site visits in the area suggest that riparian areas are *Not Functioning*.

3.1.9 Kenneth Creek/Upper Neills Creek – Rural FAU

Buck Engineering surveyed one headwater reach in this functional assessment unit. The riparian buffers in this area have been severely compromised. They do not appear to store stormwater or recharge groundwater, and have ditches running through them. Clearly, the best description of the floodplain for this unit is *Not Functioning*.

3.1.10 Middle/Lower Neills Creek FAU

Buck Engineering surveyed one headwater reach in this functional assessment unit. Though this site has very suitable riparian buffers, it has been ditched, which prevents the buffers from performing their hydrologic functions. This site may be a good choice for restoration as removing or altering the ditches would allow the existing riparian buffers to slow stormwater delivery and recharge groundwater. Currently, the most appropriate rating for this site is *Not Functioning*.

3.1.11 Kenneth Creek – Suburban FAU

Buck Engineering surveyed one headwater reach in this functional assessment unit. This reach had functioning riparian buffers in terms of storing stormwater and recharging groundwater, but recent development nearby threatens its buffers' integrity. It should be noted that the study site may be a good wetland preservation site. Given the threat caused by development, we characterized the floodplain as *Functioning at Risk*.

3.1.12 Kenneth Creek – Urban FAU

Buck Engineering surveyed one headwater reach in this functional assessment unit. The riparian buffer on the right bank in this urban area was 50 feet wide, and had two canopies and a predominantly hardwood coverage. The left bank, on the other hand, had no buffer whatsoever. Additionally, ditches, bridges and culverts further degraded the buffers' filtering capability. Thus, though this unit's buffers have some redeeming qualities, they do not contribute to higher groundwater levels or to stormwater storage. Consequently, the floodplain was considered *Not Functioning*.

3.2 Bank Height Ratios

To assess whether a stream is incised (i.e., does not have access to its floodplain), Buck Engineering measured bank height ratios in each FAU. A functioning stream will access its floodplain to dissipate the stream's energy at high flows and, as discharge velocity decreases over the floodplain, the stream will deposit sediment. In contrast, an incised stream will access the floodplain less frequently, if at all. Consequently, storm events direct their energy towards further erosion of the channel, and deposit sediment in areas where carrying capacity declines. Thus, based on the degree of incision, we assigned ratings of *Functioning*, *Functioning at Risk,* and *Not Functioning.*

3.2.1 Buckhorn Creek FAU

Despite numerous rock outcroppings, steep valley walls have resulted in many incised streams with high bank height ratios. Restoration in this unit would have relatively high benefit and high risk. Therefore, the FAU rating based on bank height ratios is *Not Functioning.*

3.2.2 Utley Creek/Cary Branch/Norris Branch FAU

The streams in this FAU have a mixed level of access to their floodplains. Poorly managed riparian buffers may encourage erosion. Therefore, the FAU rating based on bank height ratios is *Functioning at Risk.*

3.2.3 White Oak Creek FAU

Buck Engineering observed a mixed level of access to floodplains in this unit, but generally this unit has active floodplains. However, the soils are not ideal to prevent incision. Currently, the FAU rating based on bank height ratios is *Functioning.*

3.2.4 Little White Oak Creek FAU

The streams in this unit typically have inactive floodplains. Existing head-cuts are likely to proceed upstream to affect excellent headwater streams. Therefore, the FAU rating based on bank height ratios is *Not Functioning.*

3.2.5 Parkers Creek FAU

The streams in this unit have a mixed level of access to their floodplains. Many streams are responding to relatively old forestry impacts and are vulnerable to future development. Therefore, the FAU rating based on bank height ratios is *Functioning at Risk.*

3.2.6 Avents Creek FAU

We found active floodplains, but also possible downcutting in some areas due to straightened channels. However, grade control, in the form of bedrock or large boulders, mitigates this threat in many locations. Therefore, the FAU rating based on bank height ratios is *Functioning.*

3.2.7 Hector Creek FAU

The streams in this unit typically have active floodplains with generally good vertical stability. Therefore, the FAU rating based on bank height ratios is *Functioning.*

3.2.8 Upper Neills Creek – Urban FAU

No data were collected in this FAU; however, site visits in the area noted localized channel incision. Therefore, the FAU rating based on bank height ratios is *Functioning at Risk*.

3.2.9 Kenneth Creek/Upper Neills Creek – Rural FAU

These apparently high discharge streams are at risk of losing contact with their floodplains. Therefore, the FAU rating based on bank height ratios is *Functioning at Risk.*

3.2.10 Middle/Lower Neills Creek FAU

We observed swamp and stable floodplain in much of this unit. Aggradation appears to be limited, so public concern about it may be assuaged. Therefore, the FAU rating based on bank height ratios is *Functioning.*

3.2.11 Kenneth Creek – Suburban FAU

These apparently high discharge streams are at risk of losing contact with their floodplains. Therefore, the FAU rating based on bank height ratios is *Functioning at Risk.*

3.2.12 Kenneth Creek – Urban FAU

There are many ditches and gullies in this unit. Therefore, the FAU rating based on bank height ratios is *Not Functioning.*

3.3 Percent Impervious Land Cover

Land use data in GIS format, previously acquired for the project and used as an input for watershed modeling, were analyzed to determine the percent impervious area of each FAU. (Refer to Technical Memorandum 3 for more detailed information on the land use data set.) The study area-wide land use polygons were clipped to each FAU using ArcView GIS. The resultant data for each FAU included a text descriptor of the land use type and the area of each polygon. The area of each polygon was then multiplied by a Fraction Total Impervious (FIMP) factor to calculate the impervious area for that polygon. FIMPs are associated with specific land use types. Table 3.1 shows the FIMP ratios associated with land use types in this study.

Table 3.1. Fraction Total Impervious by Land Use

Land Use Type	% Impervious
Agricultural	0
Forested	0
High Density Residential	60%
Low Density Residential	12%
Medium Density Residential	32%
Pasture, Rangeland	0%
Transportation	98%
Urban, Commercial	75.5%
Urban, Industrial	84%
Water	0%
Wetlands	0%

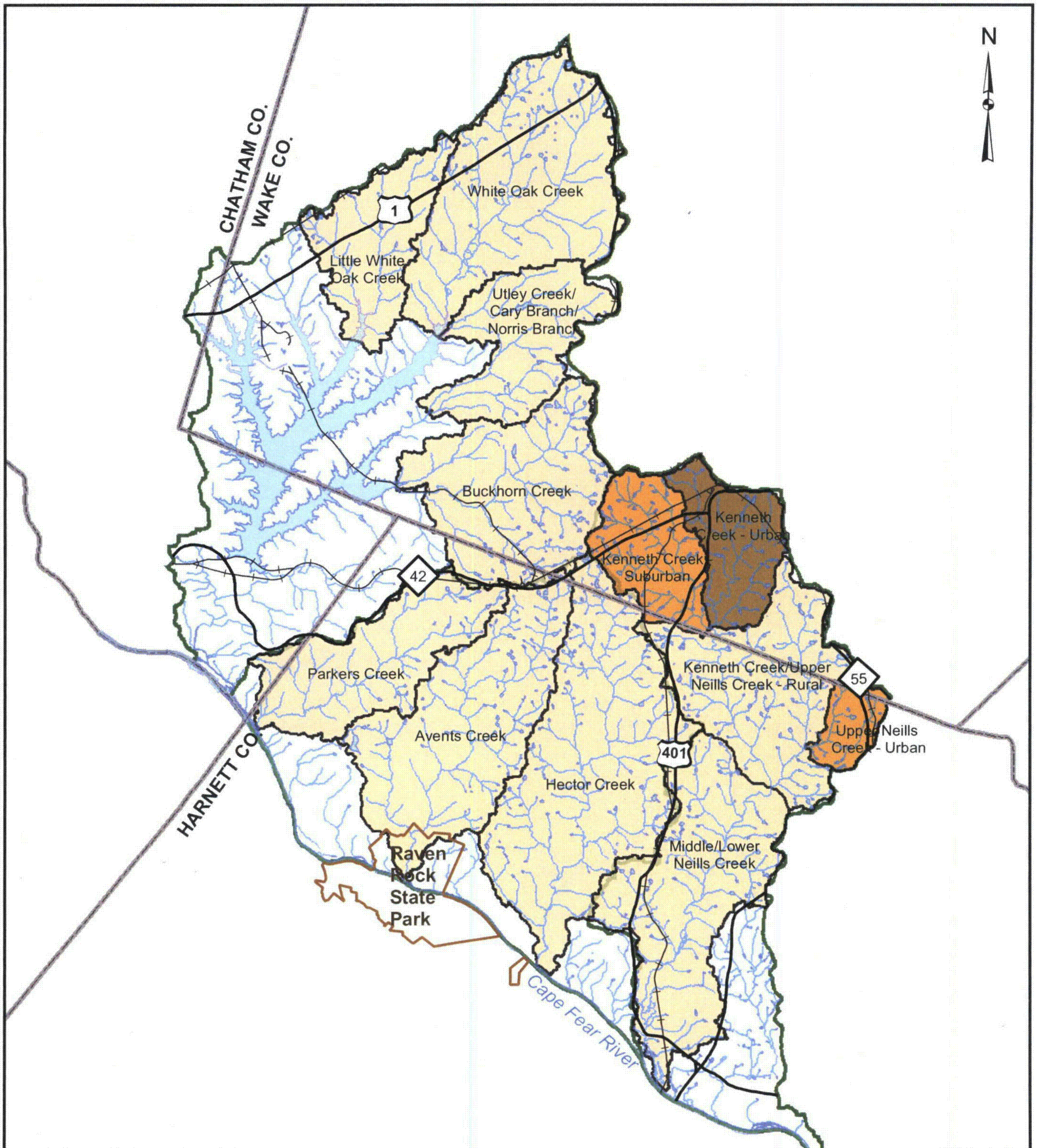
The resulting data were summarized to calculate the total area, impervious area, and percent impervious area for each FAU and are listed in Table 3.2 and shown in Figure 3.1. We then assigned the FAUs ratings for the percent impervious area function using the following thresholds:

- Functioning (F) - < 5% impervious area
- Functioning at Risk (FR) - > 5% and < 10% impervious area
- Not Functioning (NF) - > 10% impervious area

Research shows that stream channels become generally unstable once impervious area in a catchment exceeds 10% (Center for Watershed Protection, 1994; Booth, 1991; Booth and Reinelt, 1993). More impervious area yields increased peak discharge rates that erode stream channels (Center for Watershed Protection, 1994). Impervious area also decreases base flow which is important for aquatic life viability.

Table 3.2. Percent Impervious Results

Functional Assessment Unit	Total Area (ac)	Impervious Area (ac)	% Impervious Area	Function Rating
Buckhorn Creek	7,785	248	3	F
Utley Creek/Cary Branch/Norris Branch	4,831	251	5	FR
White Oak Creek	9,930	368	4	F
Little White Oak Creek	4,378	104	2	F
Parkers Creek	5,871	85	1	F
Avents Creek	9,279	151	2	F
Hector Creek	12,443	263	2	F
Upper Neills Creek – Urban	1,361	120	9	FR
Kenneth Creek/Upper Neills Creek –Rural	7,202	297	4	F
Middle/Lower Neills Creek	9,104	286	3	F
Kenneth Creek – Suburban	3,598	229	6	FR
Kenneth Creek – Urban	3,267	386	12	NF



Percent Impervious

- < 5 %
- >= 5 % and <= 10 %
- > 10 %

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Figure 3.1 Percent Impervious by FAU

0 1 2 4 6 8 Miles

3.4 Infrastructure

Infrastructure such as roads and sewer lines has the ability to alter hydrologic functions within a watershed. These structures can prevent groundwater recharge and stormwater storage. Rapid runoff from roads can also cause localized impacts to streambank stability. The 12 FAUs were assessed to determine hydrologic functionality based on the likely impacts associated with existing infrastructure, as well as any planned and funded improvements.

3.4.1 Buckhorn Creek FAU

There are no planned roads or other infrastructure in this unit. Some roads currently exist between Holly Springs and Apex. Based on the amount of infrastructure, the rating for this FAU is *Functioning.*

3.4.2 Utley Creek/Cary Branch/Norris Branch FAU

New roads are planned in headwaters of this unit and numerous roads exist in the vicinity of Holly Springs. Based on the amount of infrastructure, the rating for this FAU is *Functioning at Risk.*

3.4.3 White Oak Creek FAU

This FAU will likely experience rapid growth in coming years. The Western Wake Freeway and Apex Peakway will be built in its headwaters, and improvements to US 1 are also planned. Based on the amount of infrastructure, the rating for this FAU is *Functioning at Risk.*

3.4.4 Little White Oak Creek FAU

Improvements to US 1 are planned for this watershed and a moderate amount of roads currently exist. Based on the amount of infrastructure, the rating for this FAU is *Functioning at Risk.*

3.4.5 Parkers Creek FAU

This unit has very little existing infrastructure. Therefore, the rating for this FAU is *Functioning.*

3.4.6 Avents Creek FAU

This unit has very little existing infrastructure. Therefore, the rating for this FAU is *Functioning.*

3.4.7 Hector Creek FAU

This unit has very little existing infrastructure. Therefore, the rating for this FAU is *Functioning.*

3.4.8 Upper Neills Creek – Urban FAU

Although no road improvements are planned for this unit, NC 55 currently runs through it as well as other smaller roads. Based on the amount of infrastructure, the rating for this FAU is *Functioning at Risk.*

3.4.9 Kenneth Creek/Upper Neills Creek – Rural FAU

There is a planned Harnett County waste water treatment plant (WWTP) sewer line that will soon be built in the unit and cross Kenneth and Neills Creek numerous times. Based on the amount of infrastructure, the rating for this FAU is *Functioning at Risk.*

3.4.10 Middle/Lower Neills Creek FAU

There is a planned Harnett County waste water treatment plant (WWTP) sewer line that will soon be built in the unit and cross Neills Creek numerous times. Based on the amount of infrastructure, the rating for this FAU is *Functioning at Risk.*

3.4.11 Kenneth Creek – Suburban FAU

This unit has a moderate amount of existing infrastructure in the area around Fuquay-Varina. Therefore, the rating for this FAU is *Functioning at Risk.*

3.4.12 Kenneth Creek – Urban FAU

This unit has planned NCDOT roadway projects and existing urban infrastructure within Fuquay-Varina. Based on the amount of infrastructure, the rating for this FAU is *Not Functioning.*

3.5 Overall Hydrological Function Assessment

Table 3.3 and Figure 3.2 summarize the function ratings for each metric and provide an overall hydrologic function rating for each assessment unit. Buck Engineering used a "strength of evidence" approach (see Section 1.4) to arrive at the overall ratings. Below, we provide a summary statement of how we reached each overall rating, and a brief discussion of the main pollution sources in those FAUs rated *Functioning at Risk* or *Not Functioning*.

Table 3.3 Overall Hydrologic Function by FAU

Functional Assessment Unit	Headwater Assessments	Bank Height Ratio	% Impervious	Infrastructure	Overall
Buckhorn Creek	F	NF	F	F	***FR***
Utley Creek/Cary Branch	FR	FR	FR	FR	***FR***
White Oak Creek	F	F	F	FR	***F***
Little White Oak Creek	F	NF	F	FR	***FR***
Parkers Creek	F	FR	F	F	***F***
Avents Creek	F	F	F	F	***F***
Hector Creek	F	F	F	F	***F***
Upper Neills Creek - Urban	NF	FR	FR	FR	***FR***
Kenneth Creek/Upper Neills Creek – Rural	NF	FR	F	FR	***FR***
Middle/Lower Neills Creek	NF	F	F	FR	***FR***
Kenneth Creek - Suburban	FR	FR	FR	FR	***FR***
Kenneth Creek - Urban	NF	NF	NF	NF	***NF***

Note: F = Functioning, FR = Functioning at Risk, NF = Not Functioning, ND = no data

3.5.1 Buckhorn Creek FAU

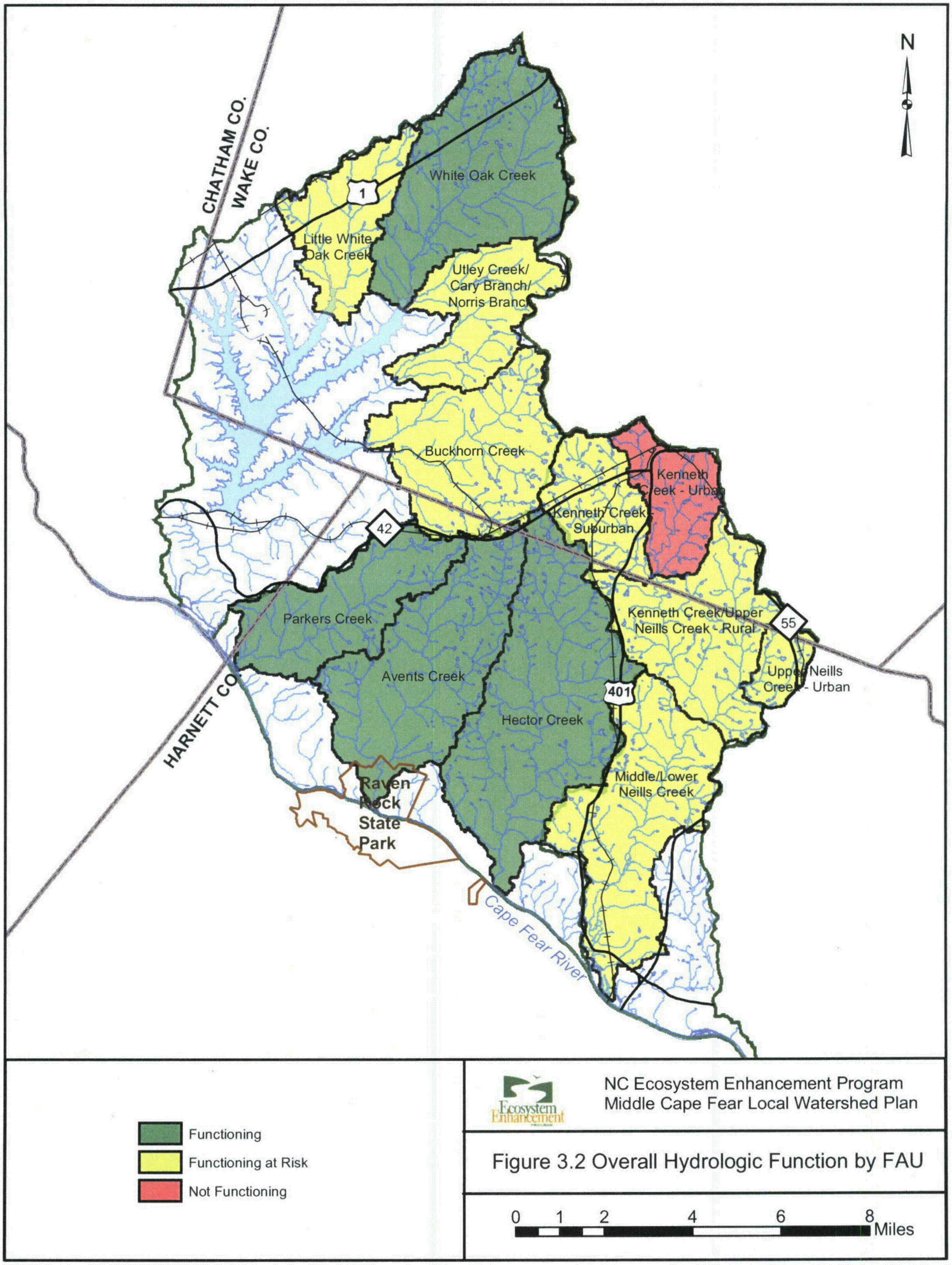
The function ratings for metrics in this FAU were mostly *Functioning*, though bank height ratios were *Not Functioning*, indicating the stream has lost connection with its floodplain. This warrants a rating of *Functioning at Risk*.

Source of Degradation - The primary cause of functional loss in this FAU is channel incision, which is likely a response to geographical limitations (e.g., narrow valleys) and limited channel sinuosity. Also, flashier stream flows brought about by increased development probably contribute to incising stream channels.

3.5.2 Utley Creek/Cary Branch/Norris Branch FAU

This FAU had four *Functioning at Risk* ratings. Given this agreement, we selected *Functioning at Risk* for an overall rating.

Source of Degradation - One mainstem reach had poorly managed riparian buffers that contributed to the potential loss of hydrologic function. Past forestry activities caused the buffer impacts.



NC Ecosystem Enhancement Program
Middle Cape Fear Local Watershed Plan

Figure 3.2 Overall Hydrologic Function by FAU

3.5.3 White Oak Creek FAU

We rated three metrics as *Functioning* and one metric as *Functioning at Risk* in this FAU. Planned infrastructure could put this FAU at risk. Currently, the most appropriate rating is *Functioning*.

3.5.4 Little White Oak Creek FAU

This FAU had mixed ratings for hydrologic function: two *Functioning*, one *Functioning at Risk,* and one *Not Functioning*. The upland land cover promoted good hydrologic function, while the instream observations showed pronounced incision. Infrastructure plans also threaten natural hydrologic patterns. Since restoration may be possible, we chose an overall rating of *Functioning at Risk*.

Source of Degradation - The observed incision is likely more a product of erosive soils than altered watershed hydrology. Low impervious cover amounts support this conclusion.

3.5.5 Parkers Creek FAU

This FAU had three *Functioning* metrics and only the bank height ratio metric *Functioning at Risk*. The overall rating is *Functioning*.

3.5.6 Avents Creek FAU

Avents Creek FAU received four *Functioning* metric ratings. Therefore, we assigned an overall rating of *Functioning*.

3.5.7 Hector Creek FAU

All four metrics rated *Functioning*. Therefore, the most appropriate rating is *Functioning*.

3.5.8 Upper Neills Creek – Urban FAU

The headwater assessment yielded a *Not Functioning* rating, while the other three metrics got a *Functioning at Risk*. Strength of evidence points to an overall assessment of *Functioning at Risk*.

Source of Degradation - Based on field reconnaissance and photographs, the headwater areas are impacted by agriculture and urban development and are in need of restoration.

3.5.9 Kenneth Creek/Upper Neills Creek - Rural FAU

This FAU had mixed ratings for hydrologic function: two *Functioning at Risk*, one *Functioning*, and one *Not Functioning*. Low impervious cover promoted infiltration, while the riparian areas did not provide good hydrologic function. Bank height ratios and infrastructure plans also threaten natural hydrologic behavior. We chose an overall rating of *Functioning at Risk*.

Source of Degradation - The headwater areas do not provide the hydrologic function expected of them. Many headwater streams in this FAU begin in agricultural fields and have little or no riparian buffer. Further, many of these streams are fed by field ditches where no filter strips are present. BMP planning for the FAU should focus on these areas.

3.5.10 Middle/Lower Neills Creek

In this FAU, only the headwater (riparian areas) metric was *Not Functioning*, while two metrics were *Functioning* and one was *Functioning at Risk* (infrastructure). On balance, the most appropriate rating is *Functioning at Risk*.

Source of Degradation - Once again, the headwater areas are in need of restoration efforts to improve their hydrologic function. Plans for a sewer line to cross the area are underway, so BMP implementation should be performed as soon as possible.

3.5.11 Kenneth Creek - Suburban FAU

All four metrics rated *Functioning at Risk* in this FAU. We noted that owing to rapidly changing land use, function is trending downward. The current rating is *Functioning at Risk*.

Source of Degradation - This is a developing area that already shows signs of stress. Low Impact Development (LID) practices would enhance hydrologic function.

3.5.12 Kenneth Creek - Urban FAU

This FAU is the least functional of any in the project area. It received four *Not Functioning* ratings for hydrologic function. Based on the overall evidence, we assigned a rating of *Not Functioning*.

Source of Degradation - This area has traditional urban impacts, such as poor stormwater storage and groundwater recharge, plus channelization. Intense LID efforts are needed to restore this area.

4 Water Quality Function Assessment

We assessed water quality function in each of the 12 functional assessment units using four metrics: Bank Erosion Hazard Index (BEHI), modeling results, NCDWQ benthic monitoring, and headwater/riparian assessments. In the following sections we present background and summary results for each metric. At the conclusion of this chapter, we provide an overall water quality function rating for each FAU.

4.1 Bank Erosion Hazard Index (BEHI)

Lateral streambank stability is an indicator of the sediment supplied to the stream due to bank erosion. The potential lateral erosion accretion was determined in the field by measuring the Bank Erosion Hazard Index (BEHI) (Rosgen, 2001) throughout each study reach (refer to Technical Memorandum 2). For this assessment, BEHI results for individual study sites within each FAU were assessed to determine an overall rating for the unit.

4.1.1 Buckhorn Creek FAU

We investigated two reaches in this unit and observed somewhat divergent conditions. One reach was deeply incised, but exhibited only moderate erosion due to the presence of mature riparian vegetation. A second reach was both vertically and laterally stable due to the presence of bedrock and mature vegetation. Therefore, the BEHI rating for this FAU was determined to be *Functioning.*

4.1.2 Utley Creek/Cary Branch/Norris Branch FAU

Two sites in this unit provided insight to water quality function. The first site had vertical instability and moderate lateral instability, but was well-vegetated. The water appeared "milky" and we noted a beaver dam upstream. The second site had vertical and lateral stability, though a narrow riparian buffer. Therefore, the BEHI rating for this FAU was determined to be *Functioning at Risk.*

4.1.3 White Oak Creek FAU

Buck Engineering studied three sites in this unit, with two sites exhibiting eroding stream banks. This condition threatens habitat as fine materials are introduced and mass wasting limits vegetative cover from growing on the banks. The third site had a straight channel, vertically and laterally stable banks. Therefore, the BEHI rating for this FAU was determined to be *Not Functioning.*

4.1.4 Little White Oak Creek FAU

The surveyed reach in this unit is an unstable stream for more than 1,000 feet in length. The streambanks exhibit significant erosion and the reach would be appropriate for a restoration project. Therefore, the BEHI rating for this FAU was determined to be *Not Functioning*.

4.1.5 Parkers Creek FAU

We investigated three reaches in the Parkers Creek FAU. The first reach was laterally stable, as evidenced by low bank height ratios and BEHI scores. The next reach was moderately stable, although there were a few areas with severe bank erosion. The final reach had good habitat and stable banks, although the bank height ratios were high. Taken in sum, the BEHI rating for this FAU was determined to be *Functioning at Risk*.

4.1.6 Avents Creek FAU

Five reaches in this unit provided insight on water quality function using BEHI. In general, we saw a variety of bank stability. One site had excellent geomorphology, with low bank height ratios, sufficient sinuosity and good riparian vegetation. However, other sites were quite incised, probably as a result of channel damage from historic land use, such as silviculture. Poor buffer conditions with limited mature vegetation have led to heavy erosion and channel widening. However, the poorest of the sites appear to have widened to a point where they are beginning to form a new floodplain at a lower level and so are generally trending towards stability. Based on these assessments, the BEHI rating for this FAU was determined to be *Functioning at Risk*.

4.1.7 Hector Creek FAU

Buck Engineering surveyed six reaches in this unit. We observed a distribution of unstable, moderately stable, and stable streambanks. One site demonstrated obvious lateral instability and three sites had moderately unstable streambanks. Other notable features included cattle with access to the channel (one site) and well-vegetated streambanks (one site). Based on these findings, the BEHI rating for this FAU was determined to be *Functioning at Risk*.

4.1.8 Upper Neills Creek – Urban FAU

Two reaches were investigated to assess channel stability. We found both reaches exhibited lateral instability. Along one of the reaches, unlimited access to the channel by horses hastens streambank erosion. Therefore, the BEHI rating for this FAU was determined to be *Not Functioning*.

4.1.9 Kenneth Creek/Upper Neills Creek – Rural FAU

Two reaches in this FAU demonstrated moderately stable streambanks. One reach had good vegetation with rooting depths below bankfull. The second reach had low bank height ratios and BEHI scores, indicative of a stable channel. Therefore, the BEHI rating for this FAU was determined to be *Functioning*.

4.1.10 Middle/Lower Neills Creek FAU

One reach was studied in this FAU. It was geomorphically stable, as evidenced by low bank height ratios, appropriate sinuosity, and sufficient bedform diversity. The riparian buffer is also forested in a stage of late successional growth with a variety of vegetation. The BEHI rating for this FAU was determined to be *Functioning*.

4.1.11 Kenneth Creek – Suburban FAU

We reviewed two reaches in this FAU. The first reach was functioning but vulnerable to the removal of the riparian vegetation. Kenneth Creek (downstream) had a high BEHI score along the study reach. The reach has a high potential for erosion. The overall BEHI rating for this FAU was determined to be *Functioning at Risk*.

4.1.12 Kenneth Creek – Urban FAU

Three reaches in this unit provided insight to channel stability. All three sites had unstable channels. The first reach had been down-cut to bedrock and was now eroding its banks. The next reach had experienced aggradation, with moderately unstable streambanks. The last site exhibited moderate lateral instability. Therefore, the BEHI rating for this FAU was determined to be *Not Functioning*.

4.2 Modeling Results

Water quality modeling was performed with the Soil and Water Assessment Tool (SWAT) to produce sediment and nutrient loading estimates for the FAUs. The model incorporates existing geographic, environmental, and management conditions together with current land use conditions to estimate sediment and nutrient loadings. Description of model calibration and general results were presented in Technical Memo 3.

We rated each FAU as *Functioning, Functioning at Risk, or Not Functioning* in terms of water quality based on the model results outlined below.

4.2.1 Buckhorn Creek FAU

Harris Lake in the Buckhorn Creek watershed is a major sediment sink and sediment concentrations below the lake are dramatically lower than any other watershed in the study area. However, beyond the effect of the lake, the Buckhorn Creek FAU produced relatively little sediment and phosphorus yields compared to other FAUs. Therefore, the modeling rating for this FAU was determined to be *Functioning.*

4.2.2 Utley Creek/Cary Branch/Norris Branch FAU

As with Buckhorn Creek, this FAU drains to Harris Lake which is a major sediment and nutrient sink in the system. However, this FAU is predicted to provide a moderate sediment load and relatively high phosphorus load to the lake. Therefore, the modeling rating for this FAU was determined to be *Functioning at Risk.*

4.2.3 White Oak Creek FAU

As with all of the FAUs in hydrologic unit 03030004020010, this tributary to Harris Lake is a major sediment and nutrient sink in the system. However, this FAU is predicted to provide a relatively high sediment load and average phosphorus load to the lake. Therefore, the modeling rating for this FAU was determined to be *Functioning at Risk.*

4.2.4 Little White Oak Creek FAU

As with all of the FAUs in hydrologic unit 03030004020010, this FAU drains to Harris Lake which is a major sediment and nutrient sink in the system. However, this FAU is predicted to provide a high sediment load and phosphorus load to the lake. Therefore, the modeling rating for this FAU was determined to be *Not Functioning*.

4.2.5 Parkers Creek FAU

Parkers Creek is predicted to have a relatively low instream sediment concentration, primarily due to the large percentage of forest cover in the watershed. Forest cover also resulted in low predicted nutrient loading from this FAU. Therefore the modeling rating for this FAU was determined to be *Functioning*.

4.2.6 Avents Creek FAU

Like Parkers Creek, Avents Creek was predicted to have significantly less nutrient concentrations than the other sub-watersheds. However, Avents Creek was predicted to have a relatively high sediment yield. Taking these two assessments together the modeling rating for this FAU was determined to be *Functioning at Risk*.

4.2.7 Hector Creek FAU

Hector Creek was predicted to have below average nutrient concentrations for both phosphorus and especially total nitrogen. However, this FAU was predicted to have above average instream sediment concentration. Based on these findings, the modeling rating for this FAU was determined to be *Functioning at Risk*.

4.2.8 Upper Neills Creek – Urban FAU

This FAU was predicted to produce high concentrations of sediment and nutrients. Therefore, the modeling rating for this FAU was determined to be *Not Functioning*.

4.2.9 Kenneth Creek/Upper Neills Creek – Rural FAU

This FAU was predicted to produce high concentrations of sediment and nutrients. Therefore, the modeling rating for this FAU was determined to be *Not Functioning*.

4.2.10 Middle/Lower Neills Creek FAU

Portions of this FAU have catchments that are predicted to be sinks of sediment and nutrients from upland areas. Overall, this FAU is predicted to have relatively low sediment and nutrient yields and so the modeling rating for this FAU was determined to be *Functioning*.

4.2.11 Kenneth Creek – Suburban FAU

This FAU had relatively low nutrient loads due to limited sources. However, significant sediment yield was predicted as the result of some bank instability. The overall modeling rating for this FAU was determined to be *Functioning at Risk*.

4.2.12 Kenneth Creek – Urban FAU

This FAU was predicted to produce high concentrations of sediment and nutrients. Therefore, the modeling rating for this FAU was determined to be *Not Functioning*.

4.3 NCDWQ Benthic Community Results

During March and April 2003, NCDWQ surveyed the benthic macroinvertebrate communities at 12 locations within the project area as described in Section 2.4. These surveys include several measures that provide insight to longer term water quality conditions: 1) the NC Biotic Index (NCBI), which measures pollution tolerance of organisms relative to their abundance; 2) EPT Taxa Richness, which measures diversity of pollution intolerant organisms; 3) bioclassification, an overall rating of "Excellent," "Good," "Good-Fair," "Fair," or "Poor" based on the NCBI and EPT Taxa Richness scores; and 4) NCDWQ notations of certain faunal assemblages that serve as water quality indicators (e.g., organic enrichment/low dissolved oxygen, sedimentation, toxic stress) (NCDWQ, 2001). Functional water quality supports a diverse and balanced benthic invertebrate community, which is reflected in the measures above.

We rated each functional assessment unit (FAU) as *Functioning, Functioning at Risk, or Not Functioning* in terms of water quality based on a review of the four measures listed above for each functional assessment unit. However, we also considered the role that water quality (not habitat) played in each measure's determination.

It should be noted that NCDWQ did not assess the following FAUs: Utley Creek/Cary Branch, Little White Oak Creek, Upper Neills Creek-Urban, and Kenneth Creek-Urban.

4.3.1 Buckhorn Creek FAU

Despite a low habitat score for Buckhorn Creek, NCDWQ assigned a "Good" bioclassification. This indicates that water quality did not stress the benthic community. Also, mussels were only found at this site. Some signs of tolerance were evident; however, abundant periphyton (attached algae) growth and presence of a tolerant, filter-feeding caddisfly suggest a degree of nutrient enrichment. Nevertheless, habitat problems appear to be the issue in this unit, so the applicable rating is *Functioning*.

4.3.2 White Oak Creek FAU

NCDWQ surveyed Little Branch, a tributary to White Oak Creek. This site is located within the Triassic Basin, whose smaller streams typically run dry during the summer. That likely happened in White Oak Creek during the 2002 drought, and may be the cause of low total and EPT taxa richness, and high NCBI scores. Because NCDWQ believed the drought influenced the benthic community, they gave this stream a "Not Rated" bioclassification. In keeping with this perspective, White Oak Creek's water quality function based on NCDWQ benthic survey results was *Not Rated*.

4.3.3 Parkers Creek FAU

NCDWQ surveyed the benthic communities at two sites in the Parkers Creek FAU, one in the headwaters and another downstream. Because the headwater site had such a small drainage area, NCDWQ could only assign a bioclassification of "Not Impaired." However, the community was clearly diverse and quite intolerant of pollution. Even though it received a high habitat score, the water quality at this site was evidently also good.

The downstream site had a drainage area of 3.8 square miles, still small by most measures though large enough to earn a "Good" bioclassification. The site received a fairly low habitat score of 63, with a massive bank failure noted, so the water quality is likely to be adequate, otherwise the bioclassification would have been lower. NCDWQ noted thick algal mats on the rocks and organic enrichment tolerant mayflies, so nutrients may be reaching detrimental levels.

Although nutrient enrichment may impact this area, taken in sum, we believe that Parker Creek's water quality is *Functioning*.

4.3.4 Avents Creek FAU

NCDWQ sampled Avents Creek at a single location toward the stream's mouth. The site is located just within Raven Rock State Park, and the stream is classified as a High Quality Water. NCDWQ noted numerous intolerant taxa and a high degree of diversity, but, even with a high habitat score, it only received a "Good" bioclassification using Piedmont criteria. NCDWQ debated which criteria to apply since the substrate was rocky, and ended up applying Coastal Plain criteria and an 'Excellent' bioclassification.

Although there appear to be problems that were not fully fleshed out in the NCDWQ assessment, Avents Creek warrants a rating of *Functioning*.

4.3.5 Hector Creek FAU

NCDWQ conducted three benthic community surveys in the Hector Creek FAU; one on Coopers Branch and the others on Hector Creek in its headwaters and lower reach.

The Coopers Branch site had a drainage area of 2.1 square miles, and received a "Good" bioclassification. A very low NCBI suggests good water quality, but low EPT taxa richness does not. Water quality problems are also indicated by algal growth on the rocks and the absence of long lived stoneflies.

The upper Hector Creek site received a "Good" bioclassification, with a very pollution intolerant community evidenced by a low NCBI. NCDWQ noted that habitat insufficiencies (rather than water quality ones) likely kept it from getting a higher bioclassification.

NCDWQ's survey of the lower Hector Creek site revealed abundant EPT taxa and a low NCBI, both indicative of good water quality. In fact, NCDWQ noted in their report that both Hector Creek sites indicated high water quality and no decline since the first study in 1988.

Though there is some room for improvement in the Hector Creek functional assessment unit, its water quality is *Functioning*.

4.3.6 Kenneth Creek/Upper Neills Creek – Rural FAU

The lower Kenneth Creek site was below the Fuquay-Varina WWTP. As described previously, this treatment plant has a poor compliance record. NCDWQ used the Coastal Plain rating for this site and found marginal habitat, with sand dominant and an overall score of 69. They concluded the site earned a "Poor" bioclassification, and emphasized that the primary cause was poor water quality, not habitat insufficiencies.

The upstream Neills Creek is located in the outskirts of Angier with surrounding land use that includes the typical rural suburban blend of forest, low density residential, and pasture. Despite suitable habitat, the EPT taxa were practically non-existent. NCDWQ gave the site a "Not Rated" bioclassification because the stream was less than 2 meters wide. However, the survey indicated degradation. It appears that either an extended drought or a toxic event affected biota in the stream.

Were it not for the poor water quality at the lower site, both benthic communities might have rated not impaired. Consequently, the water quality in this FAU receives a rating of *Not Functioning*.

4.3.7 Middle/Lower Neills Creek FAU

The Neills Creek sampling site had deeper water, making it hard for NCDWQ to conduct the sample. They noted a sewage smell in the water, though the WWTP was well upstream on Kenneth Creek. Based on EPT taxa collected and the NC Biotic Index, NCDWQ gave the stream a "Fair" (impaired) bioclassification. The site earned a suitable habitat score, so water quality appears to be impacted. NCDWQ conjectured that either, "prolonged low flow conditions have lengthened the zone of influence of the WWTP discharge upstream on Kenneth Creek, or the suspected toxic impact to the upstream Neills Creek site is also being seen at this site." This site rated "Good-Fair" in 1988, so considerable decline has occurred.

In sum, water quality degradation is the mostly likely cause of the impaired benthic community in Neills Creek. Consequently, we conclude that water quality is *Not Functioning*.

4.3.8 Kenneth Creek – Suburban FAU

NCDWQ sampled Kenneth Creek, a tributary to Neills Creek, in two locations. The upstream site is located in a suburban residential area on the outskirts of Fuquay-Varina. In this reach, the stream had diverse substrate and was very sinuous. The outside streambanks were subject to severe erosion. Despite a habitat score of 64, the stream received a "Good" bioclassification. It appears that water quality (nutrient enrichment) limited the benthos more than, or as much as, the habitat. Consequently, we applied a rating of *Functioning at Risk*.

4.4 Headwater/Riparian Assessments

To assess water quality function, Buck Engineering conducted riparian surveys, paying close attention to the condition of buffers and their ability to filter pollutant loading. These observations were used to characterize water quality function in each assessment unit. Riparian buffers that filter runoff exemplify water quality function. After presenting an overview of the riparian assessments, we rate water quality function as *Functioning, Functioning at Risk,* or *Not Functioning.*

4.4.1 Buckhorn Creek FAU

We examined the floodplains and riparian areas of one headwater and two mainstem reaches in the Buckhorn Creek FAU. All three reaches graded well in terms of riparian filtering function. The two mainstem sites had hardwoods as the dominant cover and buffer widths in excess of 200 feet. In sum, the riparian buffer filtering capability of Buckhorn Creek is *Functioning*.

4.4.2 Utley Creek/Cary Branch/Norris Branch FAU

Surveys of one headwater and one mainstem reach for each of Cary Branch and Norris Branch provided insight to filtering/water quality function in this assessment unit. For the most part, the Cary Branch riparian areas were in excellent shape with two canopies, widths of greater than 200 feet. One mainstem bank, however, had just one pine canopy and evident impacts from forestry. Norris Branch had far less functional riparian areas. Surveys revealed narrower (less than 10 feet to greater than 50 feet) buffers with one canopy. The left bank of the mainstem was exceptional, with a buffer wider than 200 feet. Collectively, Cary Branch's riparian filtering function is adequate, but further development may extend the impacts seen in upper Norris Branch. Consequently, we applied this unit a rating of *Functioning at Risk*.

4.4.3 White Oak Creek FAU

We looked at six reaches in the White Oak Creek functional assessment unit, including three headwater and three mainstem reaches. All of the headwater buffers were at least 100 feet wide with very minimal impacts from forestry. The potential for future impacts is clear, however, as part of one reach (an unnamed tributary to Big Branch) is located within a pine plantation. The surveyed mainstem reaches have minimally functional riparian areas as their width diminishes to 25 feet in many places and forestry encroaches. Some of their filtering capacity has been compromised.

White Oak Creek's headwater riparian areas are relatively unimpacted and adequately serving their filtering function, but the mainstem sites are threatened and are not effectively filtering pollutants. Taken as a whole, the appropriate rating for the White Oak Creek riparian filtering capacity is *Functioning at Risk*.

4.4.4 Little White Oak Creek FAU

Buck Engineering surveyed a headwater and a mainstem reach in this assessment unit. Each bank's riparian zone was wider than 200 feet and had middle-aged hardwood as the dominant cover. Little White Oak Creek's buffers have filtering capabilities that are *Functioning*.

4.4.5 Parkers Creek FAU

Surveys of one headwater and one mainstem reach of Parkers Creek provided insight to hydrologic function in this assessment unit. The riparian buffer along the mainstem was wider than 200 feet, dominated by young pines and limited to a single canopy. The mainstem has a history of forestry and pasture uses. Forestry created lasting impacts, while the possible impacts from grazing are less obvious. The headwater riparian areas also have buffers wider than 200 feet, but they are covered by mixed forest and a two-layer canopy. The headwater buffers were probably once the focus of forestry, but impacts from that activity are no longer evident.

Parkers Creek's riparian buffers now provide full filtration function; however, forestry may put that at risk. Consequently, we assigned a rating of *Functioning at Risk*.

4.4.6 Avents Creek FAU

Buck Engineering investigated one headwater site in the Avents Creek FAU. Both banks had 30-foot buffers with hardwoods as the dominant cover and two canopies. Combined with no visible impacts, these observations indicate that Avents Creek's riparian buffers are *Functioning*.

4.4.7 Hector Creek FAU

Buck Engineering investigated one headwater site in the Hector Creek FAU. Both streambanks had buffers that were 50-feet wide, though a single canopy of pine covered the right bank, and hardwoods with an understory canopy composed the left bank. However, we observed a pine plantation further downstream on the left bank. Therefore, we rated this unit as *Functioning at Risk*.

4.4.8 Kenneth Creek/Upper Neills Creek – Rural FAU

Buck Engineering surveyed one headwater reach in this unit. The riparian buffers in this area have been severely compromised. They range in width from 0 to 15 feet, are composed of grass and shrubs, and, most importantly, have ditches running through them. Clearly, the best description of the buffer filtering capacity of this unit is *Not Functioning*.

4.4.9 Middle/Lower Neills Creek FAU

Buck Engineering investigated one headwater site in the Neills Creek FAU. Both buffers extended more than 150 feet beyond the streambanks, and had a mixed coverage of pine and hardwood and a two layer canopy. Forestry and pasture uses may have impacted the buffer. There are ditches that bypass the buffers' filtering capacity.

Though this site has very suitable riparian buffers, it has been ditched, which prevents the buffers from performing their filtering function. This site may be a good choice for restoration as removing or altering the ditches would allow the existing riparian buffers to filter runoff. However, currently the rating for the FAU is *Not Functioning*.

4.4.10 Kenneth Creek – Suburban FAU

Buck Engineering surveyed one headwater reach in this unit. This reach had functioning riparian buffers with widths in excess of 200 feet and dominant bottomland hardwoods. Buck Engineering's field notes suggest this may be a good wetland preservation site. Recent development nearby and potential upstream forestry threaten the integrity of the system. Given this, we characterized the buffer filtration capacity as *Functioning at Risk*.

4.4.11 <u>Kenneth Creek – Urban FAU</u>

Buck Engineering surveyed one headwater reach in this unit. The riparian buffer on the right bank in this urban area was 50 feet wide, and had two canopies and a predominantly hardwood coverage. The left bank, on the other hand, had no buffer with lawns extended to the streambank. Additionally, ditches, bridges, and culverts further degraded the buffers' filtering capability. Thus, though this unit's buffers have some redeeming qualities, we consider the overall riparian filtering to be *Not Functioning*.

4.5 Overall Water Quality Function Assessment

Table 4.1 and Figure 4.1 summarize the function ratings for each metric and provide an overall water quality function rating for each assessment unit. Buck Engineering used a "strength of evidence" approach (see Section 1.4) to arrive at the overall ratings. As with the habitat function, we weighted benthic data most strongly because it provides a longer term measure and most closely approximates a designated use (biological integrity). Below, we provide a summary statement of how we reached each overall rating, and a brief discussion of the main pollution sources in those FAUs rated *Functioning at Risk* or *Not Functioning.*

Table 4.1 Overall Water Quality Function by FAU

Functional Assessment Unit	BEHI	Modeling	Monitoring	Riparian Area Assessments	Overall
Buckhorn Creek	F	F	F	F	***F***
Utley Creek/Cary Branch/Norris Branch	FR	FR	ND	FR	***FR***
White Oak Creek	NF	FR	ND	FR	***FR***
Little White Oak Creek	NF	NF	ND	F	***NF***
Parkers Creek	FR	F	F	FR	***F***
Avents Creek	FR	FR	F	F	***F***
Hector Creek	FR	FR	F	FR	***FR***
Upper Neills Creek – Urban	NF	NF	ND	ND	***NF***
Kenneth Creek/Upper Neills Creek – Rural	F	NF	NF	NF	***NF***
Middle/Lower Neills Creek	F	F	NF	NF	***NF***
Kenneth Creek – Suburban	FR	FR	FR	FR	***FR***
Kenneth Creek – Urban	NF	NF	ND	NF	***NF***

Note: F = Functioning, FR = Functioning at Risk, NF = Not Functioning, ND = no data

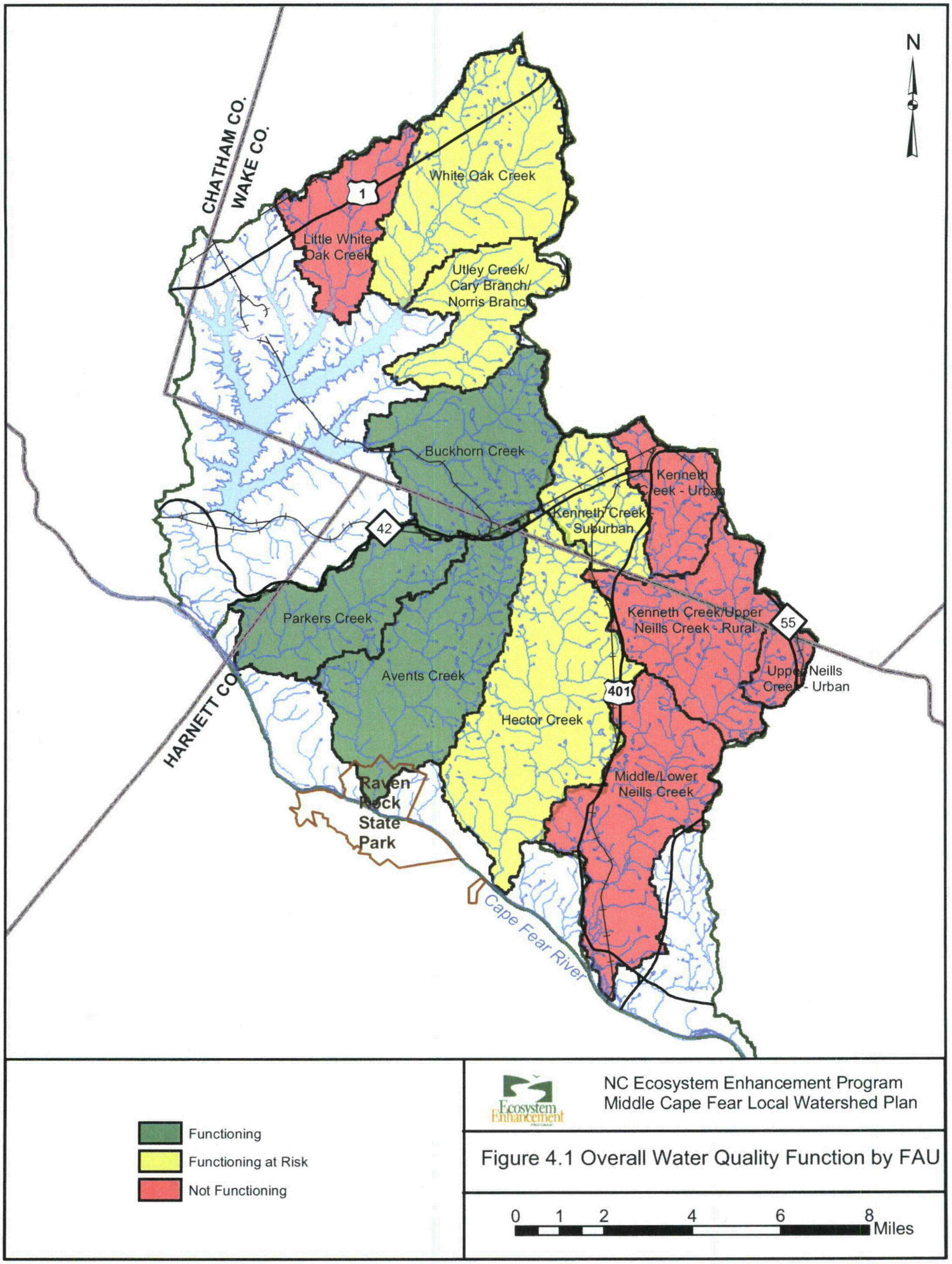


Figure 4.1 Overall Water Quality Function by FAU

4.5.1 Buckhorn Creek FAU

The ratings for all water quality metrics in this FAU were *Functioning*. Clearly, this warrants an overall rating of *Functioning*.

4.5.2 Utley Creek/Cary Branch/Norris Branch FAU

This FAU had three *Functioning at Risk* ratings. NCDWQ did not conduct a benthic survey at this site. Thus we selected an overall rating of *Functioning at Risk*.

Source of Degradation - Limited riparian buffers and concern about stream stability limit confidence in the water quality of this FAU.

4.5.3 White Oak Creek FAU

We rated two metrics as *Functioning at Risk* and one metric (BEHI) as *Not Functioning* in this FAU. NCDWQ conducted a benthic survey at this site, but did not rate the stream due to concerns of drought and the Triassic Basin setting. We chose an overall rating of *Functioning at Risk*.

Source of Degradation - Eroding streambanks and a Triassic Basin setting constrain water quality function in this FAU. Eroding streambanks appeared to be the result of past channelization and impervious surfaces surrounding the US 1 corridor.

4.5.4 Little White Oak Creek FAU

This FAU had one *Functioning* and two *Not Functioning* ratings for water quality. NCDWQ did not conduct a benthic survey at this site. Although this unit is probably not far from demonstrating some degree of function, we chose an overall rating of *Not Functioning*.

Source of Degradation - Sediment is the primary water quality problem in this FAU. It likely emanates from streambank erosion as pronounced incision and erosive soils are common to the FAU.

4.5.5 Parkers Creek FAU

This FAU had two *Functioning* metrics and two *Functioning at Risk* ones. Because of the benthic survey score, the FAU was assigned an overall rating of *Functioning*.

4.5.6 Avents Creek FAU

Avents Creek FAU received two *Functioning* and two *Functioning at Risk* metric ratings. Since the benthic survey indicated good water quality, we assigned an overall rating of *Functioning*.

4.5.7 Hector Creek FAU

Only the benthic monitoring rated water quality as *Functioning*, while the other three metrics rated *Functioning at Risk*. We concluded that enough risk was evident to select an overall rating of *Functioning at Risk*.

Source of Degradation - The tributaries in this unit demonstrate eroding streambanks, in part due to forestry and agricultural practices harming the vegetative cover and riparian buffers.

4.5.8 Upper Neills Creek – Urban FAU

Modeling results and BEHI produced *Not Functioning* ratings, while no data were collected for the other metrics. Strength of evidence points to *Not Functioning* as the overall rating for the FAU.

Source of Degradation - Erosive streambanks and cleared riparian areas are the primary sources of water quality function loss.

4.5.9 Kenneth Creek/Upper Neills Creek - Rural FAU

This FAU had one *Functioning* (BEHI) and three *Not Functioning* metric ratings. The benthic survey suggested a toxic episode and the riparian areas did not provide suitable filtration. We chose an overall rating of *Not Functioning*.

Source of Degradation - Sediment chemistry analyses of semi-volatile organics, pesticides, and metals are recommended to aid determination of the source of toxicity.

4.5.10 Middle/Lower Neills Creek FAU

In this FAU there were two metrics (BEHI and modeling) indicating *Functioning* water quality and two metric that demonstrated water quality was *Not Functioning*. This FAU also suggested a toxic episode had impacted the benthic invertebrate community. The benthic results receive higher weight, so we recommend an overall rating of *Not Functioning*.

Source of Degradation - Sediment chemistry analyses of semi-volatile organics, pesticides, and metals are recommended to aid determination of the source of toxicity.

4.5.11 <u>Kenneth Creek - Suburban FAU</u>

All four metrics rated *Functioning at Risk.* We noted that owing to rapidly changing land use, water quality function in this FAU may begin to decline. The current rating is *<u>Functioning at Risk</u>.*

<u>Source of Degradation</u> - The benthic survey noted eroding outside streambanks and evidence of nutrient enrichment as water quality shortcomings.

4.5.12 <u>Kenneth Creek - Urban FAU</u>

This FAU is the least functional of any in the project area. It received three *Not Functioning* ratings for water quality. NCDWQ did not conduct a benthic survey at this site. Based on overall evidence, we assigned a rating of *<u>Not Functioning</u>*.

<u>Source of Degradation</u> - Urban impacts are pervasive enough to cause a nearly complete lack of water quality function. LID implementation is necessary to restore this area.

5 Projected Impacts to Watershed Functions

In this section, we describe projected impacts to watershed functions resulting from planned infrastructure and/or estimated land use change. This is a task that goes beyond observational science, and should be read with this in mind. Nevertheless, it is well documented that development impacts water quality, and development is certain to continue in the project area.

5.1 Projected Land Use Changes

Open space in the project area is rapidly being converted to residential and commercial uses, particularly in the headwaters. Growth in residential land and conversion of agricultural land has been the most pronounced. In Technical Memorandum 1, analysis of aerial photography taken in 1949 and 2003 showed agricultural land use declining from 32% to 17% and urban land use increasing from 2% to 13% over that period. Between 1990 and 2000, the towns of Fuquay-Varina, Apex and Holly Springs increased in population by 73%, 307% and 912%, respectively.

This growth is likely to continue. Apex's 2010 Land Use Plan shows forested areas in the White Oak Creek subwatershed classified as low density residential. A new sewer line in Harnett County will connect Fuquay-Varina with Lillington and likely spur development along its corridor. This will impact the Kenneth Creek/Upper Neills Creek - Rural and Middle/Lower Neills Creek FAUs.

5.1.1 Projected Land Conversion

We used existing GIS data resources provided by local governments and NCDOT to estimate future "build out" land use conditions in the study area (Figure 5.1). Based on these data, approximately 37% of agricultural and 35% of forested land will be converted to residential and industrial/commercial uses across the project area. These changes are shown by FAU in Table 5.1.

Table 5.1. Predicted Agricultural and Forested Land Use Conversions

Functional Assessment Unit	% Agricultural Converted	% Forested Converted
Buckhorn Creek	1%	3%
Utley Creek/Cary Branch/Norris Branch	68%	74%
White Oak Creek	73%	62%
Little White Oak Creek	32%	17%
Parkers Creek	0%	0%
Avents Creek	0%	0%
Hector Creek	8%	19%
Upper Neills Creek – Urban	52%	55%
Kenneth Creek/Upper Neills Creek –Rural	77%	76%
Middle/Lower Neills Creek	57%	62%
Kenneth Creek – Suburban	67%	57%
Kenneth Creek – Urban	38%	63%

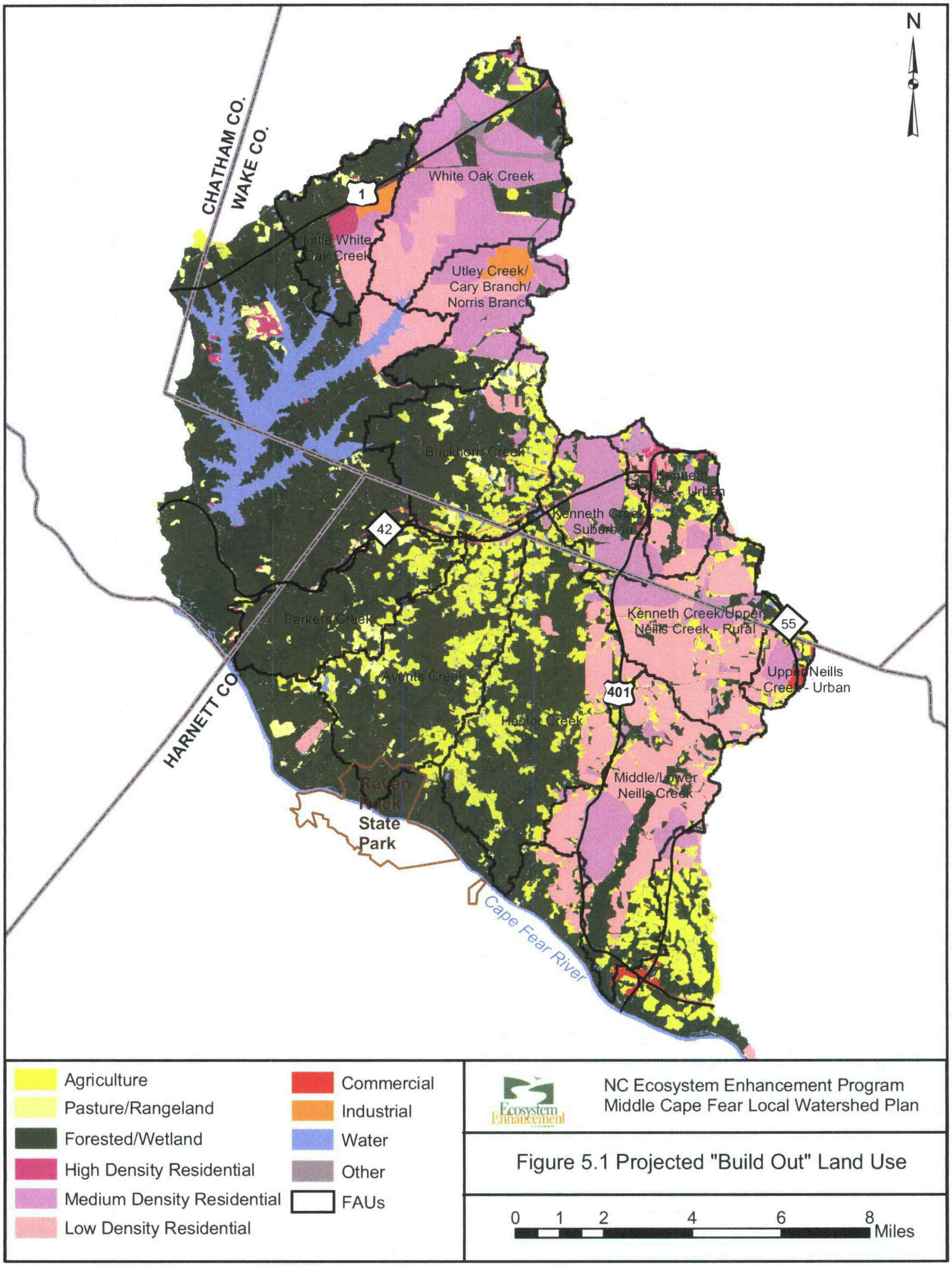


Figure 5.1 Projected "Build Out" Land Use

5.1.2 Current/Future NCDOT Impacts

Using GIS, Buck Engineering estimated impacts to streams, wetlands, and lakes from NCDOT's development of the Apex Peakway and the Holly Springs Outer Loop. We received the Holly Springs Outer Loop from NCDOT as a shapefile that delineated the project boundaries. The Apex Peakway, however, appeared only as a linear feature, so we buffered it by 150 feet on each side to estimate the project boundaries. We then estimated the wetlands, lakes, and streams that would be impacted during road construction to calculate the direct impacts from the road projects. Table 5.2 lists the impacts by project.

Table 5.2. Estimated Direct Impacts from NCDOT Projects.

NCDOT Project	Stream Impacts (feet)	Wetland Impacts (acres)	Lake Impacts (acres)
Apex Peakway	2,603	1.51	1.39
Holly Springs Outer Loop	8,864	9.98	3.29

Note that we have only estimated the direct impacts by the road projects on the water resources. Other impacts, including increased pollutant loading associated with roads (e.g., organics, metals, and nutrients) and hydrologic modification, are likely to occur.

5.2 Projected Impacts by FAU

5.2.1 Buckhorn Creek FAU

No major roads are planned in this unit, though existing development between Holly Springs and Apex may result in further watershed function impacts. Buckhorn Creek is incised and streambank erosion is severe in some locations. The stream channel is fairly embedded with fine sediments, but the benthic community does not yet show degradation. This could change if streambed scour from incision ceases, and widening, as the stream attempts to build a new floodplain, begins. Widening may deliver a proportionately greater volume of sediment to the channel which could impair the benthic invertebrate community. Restoration in this unit has been characterized as having high benefit and high risk due to the generally steep valleys found in this FAU.

5.2.2 Utley Creek/Cary Branch/Norris Branch FAU

New roads planned in the headwaters of this FAU will add to existing roads in Holly Springs. Some of the riparian buffers in this FAU are in poor condition and only a portion of the stream network has access to its floodplain during moderate floods. Without management, further degradation to the riparian buffers and function they provide will likely occur. Additionally, incision will migrate upstream along head cuts until bedrock or some other resistant structure stops their progress.

5.2.3 White Oak Creek FAU

The road plans in the FAU are significant: Western Wake Freeway, US 1 improvements, and Apex Peakway amount to expected rapid growth. Active management will be necessary to prevent significant loss of watershed function. Bank erosion and widespread embeddedness of stream substrate indicate the stream network is attempting to build a new floodplain. This process may be accelerated by impervious cover expansion associated with road enhancements and replaced with continued incision, raising pollution concerns.

5.2.4 Little White Oak Creek FAU

Planned road changes in this FAU are limited to US 1 improvements. Current problems in the watershed are primarily in the stream network with severely eroding streambanks and high degrees of embeddedness. As with White Oak Creek, these are indications that the stream network is attempting widen and to build a new floodplain. This process may be accelerated by impervious cover expansion associated with road enhancements and replaced with continued incision, raising pollution concerns.

5.2.5 Parkers Creek FAU

This FAU has very little existing infrastructure and this is not expected to change significantly in the near future. However, there are indications of nutrient enrichment, vulnerability to incision, and the threat of impacts to the riparian buffers from forestry. Thus, should development increase without infrastructure changes, it will be important to manage sites during and post construction to maintain the watershed's good functions.

5.2.6 Avents Creek FAU

As with Parkers Creek, this FAU has very little existing infrastructure and this is not expected to change significantly. The spatially limited monitoring that is available suggests that this watershed is highly functional. Future efforts should focus on preservation in this area and its watershed functions.

5.2.7 Hector Creek FAU

As with Parkers and Avents Creek, Hector Creek FAU has little existing infrastructure and no planned major roadways. This FAU does have sediment accumulation in the headwater stream channels. The threats are minimal (e.g., small numbers of cattle in the stream), but should be addressed to maintain good watershed functions.

5.2.8 Upper Neills Creek – Urban FAU

This FAU is dissected by the Highway 55 corridor. Development is ongoing and further development will certainly occur in this area. A lack of monitoring data in this FAU limits our ability to project impacts from development. We have observed land disturbing activities that limit upland function. To date these activities have not yet severely impacted the stream network. However, aquatic impacts may soon be expressed, even without increased development. Additional development will hasten functional loss and make recovery more difficult. Consequently, any future development should use LID practices to minimize stress on watershed functions.

5.2.9 Kenneth Creek/Upper Neills Creek - Rural FAU

A waste water treatment plant sewer line is planned to run through this FAU. The sewer line by itself may not cause much impact, although some riparian hydrologic function will be compromised, particularly during construction. The most serious threat to watershed functions from the sewer line placement is the development that is likely to occur along the mainstem corridor. The presence of sewer service eases one important and common constraint to development. The elimination of that constraint, combined with its location within five miles of Fuquay-Varina, a bedroom community of the Research Triangle area, makes increases in residential or other urban land use in this FAU probable.

Like several other FAUs in this study, this Kenneth Creek/Upper Neills Creek – Rural FAU has *Not Functioning* terrestrial habitat, but has aquatic habitat *Functioning at Risk.* Worse yet, it appears that a toxic episode has markedly degraded the benthic invertebrate community. It is possible that the toxicity originated at the Fuquay-Varina WWTP, which will be taken off line when the new sewer line is completed. Given the Fuquay-Varina WWTP's poor compliance record, water quality function will benefit to some extent from the sewer line placement. However, further development will hasten overall watershed function loss and make recovery difficult. Consequently, it is imperative that new development use LID practices to minimize stress on watershed functions.

5.2.10 Middle/Lower Neills Creek FAU

This FAU is in somewhat of the same situation as the Kenneth Creek/Upper Neills Creek - Rural FAU in that its current levels of function are similar (*Functioning at Risk* for habitat and hydrology, and *Not Functioning* for water quality) and the soon to be constructed sewer line placement and toxicity issues apply. The differences between the two FAUs are that the lower FAU is in somewhat better condition with less urban land and less incised stream channels and the lower FAU is slightly further from existing municipalities (Fuquay-Varina and Lillington) making development there somewhat less likely. As a result, immediate and projected stress from development in the lower watershed is less of an issue and threat.

5.2.11 Kenneth Creek - Suburban FAU

No new highway projects are proposed in this FAU, although further development around Fuquay-Varina is likely. Currently, this FAU has *at risk* watershed functions. We observed eroding outside streambanks and evidence of nutrient enrichment (e.g., algal mats). The land use in the FAU has been rapidly changing and this trend may continue for some time. Consequently, this is another watershed that should implement LID practices, or face the consequences of impaired watershed functions and the necessity for costly retrofit BMPs to restore them.

5.2.12 Kenneth Creek - Urban FAU

This unit has planned NCDOT projects and existing urban infrastructure within Fuquay-Varina. Combined with *Not Functioning* ratings for all three broad categories, the prospects for this FAU are not promising. Restoration of watershed function will require costly and challenging to implement retrofit BMPs. Multiple land owners would likely need to be involved in any project of significant size. If Fuquay-Varina decides to undertake retrofit BMP implementation, care should be taken in their design to account for additional development.

6 Summary and Conclusions

6.1 Summary

This Technical Memorandum presented a functional status overview of 12 assessment units in terms of three major functions: habitat, hydrology, and water quality (Table 6.1). We examined a suite of four or five metrics for each major function. Next, we used a "strength of evidence" approach to determine a functional rating for each metric and major function in all the FAUs. This process will enable EEP to focus and prioritize efforts on preservation, restoration, or some combination of those actions. It also provides a sense of how functions are interrelated and of the best approach for achieving restoration.

Table 6.1 Habitat, Hydrology, and Water Quality Function by FAU

Functional Assessment Unit	**Habitat**	**Hydrology**	**Water Quality**
Buckhorn Creek	***FR***	***FR***	***F***
Utley Creek/Cary Branch/Norris Branch	***FR***	***FR***	***FR***
White Oak Creek	***FR***	***F***	***FR***
Little White Oak Creek	***FR***	***FR***	***NF***
Parkers Creek	***F***	***F***	***F***
Avents Creek	***F***	***F***	***F***
Hector Creek	***F***	***F***	***FR***
Upper Neills Creek – Urban	***NF***	***FR***	***NF***
Kenneth Creek/Upper Neills Creek – Rural	***FR***	***FR***	***NF***
Middle/Lower Neills Creek	***FR***	***FR***	***NF***
Kenneth Creek – Suburban	***FR***	***FR***	***FR***
Kenneth Creek – Urban	***NF***	***NF***	***NF***

Note: F = Functioning, FR = Functioning at Risk, NF = Not Functioning

6.2 Conclusions

In this section we provide conclusions based on functional assessment and a preliminary view of our final recommendations. More detail will be provided in the final project report.

6.2.1 Habitat

Streambank erosion is pervasive and probably the single greatest source of habitat function loss because much of the stream channels have become embedded with fine sediment. This is harmful to benthic invertebrates, as they prefer more stable and diverse habitat. Loss of benthic invertebrates in a stream has consequences for fish and other organisms in the food web. Benthic surveys indicate that sedimentation is probably a common cause of function loss.

Given the high amount of aggraded sediment, the pebble count studies proved coarser than expected, probably owing to sandy soils and, in some cases, scour from stream incision. Coarser substrate is generally considered to be more functional.

Terrestrial habitat function varies widely. Some FAUs (Parkers, Avents, Hector, and Little White Oak Creeks) exhibit very good riparian and upland habitat. The same cannot be said for the more urban FAUs (Kenneth and Neills Creeks), as their metrics typically range between *Functioning at Risk* and *Not Functioning*.

6.2.2 Hydrology

Hydrologic function in the watershed tends to be in better condition than either of the other major functions. Once again, the Parkers, Avents, Hector, and Little White Oak Creeks FAUs are the most functional, followed by a number of *Functioning at Risk* streams. Kenneth Creek-Urban is the only *Not Functioning* FAU.

The project area tends to have very low impervious cover as compared to many Piedmont watersheds. Impervious cover has a tremendous impact on hydrologic function. Surprisingly though, bank height ratios are higher than expected and suggest a sizeable amount of incised stream channel. The discrepancy between low impervious cover and incised streams might be explained by the erosive nature of the soil. In addition, previously straightened stream channels with heavily vegetated banks have been able to maintain some degree of lateral stability.

6.2.3 Water Quality

Water quality in the project area is generally good. Most of its problems relate to sediment that likely originates with streambank erosion. Nutrient enrichment is a secondary problem that has probably not caused any biological degradation in the project area.

The apparent and notable water quality failure in the project area is the evidence of toxicity in Kenneth Creek/Upper Neills Creek - Rural FAU and Middle/Lower Neills Creek FAU. The benthic invertebrate communities there have been largely wiped out, and those that persist are pollution tolerant. NCDWQ suspects that a toxic episode created these impaired communities. The source of this toxicity remains a mystery. Stream sediment sampling might link it to metals, organics, or pesticides.

The filtering and sediment accretion functions of riparian buffers have a balanced distribution with equal numbers of *Functioning* and *Not Functioning* FAUs, plus a great number of *Functioning at Risk*. Typically the problems are not related to ditching or clearing for residential development, though those practices exist. More often, loss of function stems from buffers that have been cleared during forestry practices. These now appear as young pines with a single canopy and limited root mass in the stream banks.

6.3 General Management Recommendations Based on Functional Assessment

An important aspect of assessing a watershed's major functions is to provide a sense of where and how to direct resources for restoration and preservation. Of course, resource allocation depends on the decision makers' values and attitudes toward cost, benefit, and risk. However, by understanding where an FAU's functions are falling short, how those affect the broader project area, and what the immediate threats are, decision makers need mainly to only consider cost information to prioritize actions. Specific management recommendations for each FAU will be presented in the final report. General discussion of where types of actions can be recommended area briefly discussed below.

To begin, the existing level of function can guide planning. *Functioning* areas should primarily be targets for preservation. With widespread development, functioning areas are likely to become scarcer, so efforts should be made to protect them. These areas can provide valuable services beyond their boundaries by contributing, for instance, intolerant organisms to colonize polluted areas via downstream drift; higher base flows and lower storm flows; and large areas of terrestrial habitat to which only connecting corridors are needed to protect wildlife.

Preservation, BMPs, and restoration are appropriate for *Functioning at Risk* areas. Further insight comes from examining the sources of risk and function. As an example, a common source of risk in the project area is severely eroding streambanks. The near-term goal would be to prevent sedimentation in the stream channel by deflecting flow with root wads or veins and replanting the bank. The point is that rather quick action must be taken to maintain some level of function. The long-term goal would be to stabilize the channel by undertaking restoration using natural channel design. Stormwater management (to reduce peak flow events) might be another long-term task. For at risk areas, it would also be advisable to preserve sources of function, such as good riparian buffers.

For areas determined to be *Not Functioning*, restoration and BMPs are the main options. If the waterbody is on the state's 303(d) list, then a Total Maximum Daily Load (TMDL) or management strategy is a regulatory requirement. Those are planning documents that describe how much a given pollutant must be reduced and from which sources those reductions should come. Site restoration is currently not required of 303(d) listed waters, with the exception of NPDES permitted sources, including NPDES point source and stormwater sources.

A local government must prioritize where to focus their limited resources for preservation, restoration, and other watershed improvements, and this prioritizing should reflect their values. For instance, would a municipality prefer to address *Functioning at Risk* areas or *Not Functioning* ones? Presumably, it would cost less to restore a

Functioning at Risk area, since it is less removed from being *Functioning.* A local government's answer to this question will vary depending on their values and resources.

Again, specific management recommendations for each FAU will be presented in the final report in a form that will allow land managers and local governments to plan future activities in the light of watershed functions.

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Middle Cape Fear
Local Watershed Plan

Technical Memorandum 5:
Conclusions and Recommendations

Ecosystem Enhancement
PROGRAM

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Ecosystem Enhancement Program

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Middle Cape Fear Local Watershed Plan

Technical Memorandum 5: Conclusions and Recommendations

Prepared For:

NC Department of Environment and Natural Resources, Ecosystem Enhancement Program

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Table of Contents

1 Introduction 1-1

1.1 Background 1-1

2 Management Opportunities 2-1

2.1 Preservation 2-1

2.1.1 Field-Identified Opportunities 2-1

2.1.2 GIS-Identified Preservation Opportunities 2-1

2.2 Stream Restoration 2-5

2.3 Agricultural BMPs 2-6

2.4 Stormwater BMPs 2-7

2.4.1 Retrofit BMPs versus New-Construction BMPs 2-7

2.4.2 Identified Stormwater BMPs 2-8

3 Management Strategy Prioritization 3-1

3.1 Prioritization Matrices 3-1

3.1.1 Preservation 3-1

3.1.2 Stream Restoration 3-1

3.1.3 Agricultural BMPs 3-2

3.1.4 Stormwater BMPs 3-2

3.2 Application of Prioritization Matrices 3-2

3.3 Other Consideration Factors 3-3

3.4 Results 3-4

4 Land Use Controls 4-1

4.1 Land Use Impacts 4-1

4.1.1 Past Land Use Trends 4-1

4.1.2 Anticipated Future Land Use 4-3

4.1.3 Likely Impacts from Anticipated Development 4-5

4.2 Land Use Controls to Minimize Development Impacts 4-7

4.2.1 Low Impact Development 4-7

4.2.2 Stormwater Ordinances 4-9

5 Conclusions and Action Items 5-1

6 References 6-1

List of Figures

Figure 1.1	Vicinity Map
Figure 2.1	Parcels > 200 Acres with High and Medium-High Priority Habitat
Figure 3.1	Opportunity Sites
Figure 4.1	Broad Land Use Types in the Vicinity of the Study Area, 1943 and 2003
Figure 4.2	Major Infrastructure Relevant to Potential Study Area Development
Figure 4.3	Anticipated Land Use in 2020
Figure 4.4	Model Catchments Nested within FAUs
Figure 4.5	Daily Maximum Stream Discharge for the Study Area for Two Five-Year Periods

List of Tables

Table 2.1	GAP Habitat Priorities
Table 2.2	Potential Preservation: Percent High-quality & Med-High Habitat
Table 3.1	Sample Priority Matrix Based on Assessment Rating
Table 3.2	Habitat Priority Matrix Based on Assessment Rating
Table 3.3	Hydrology Priority Matrix Based on Assessment Rating
Table 3.4	Water Quality Priority Matrix Based on Assessment Rating
Table 3.5	Opportunities to Improve/Maintain Watershed Functions
Table 4.1	Census Data for Communities in and Surrounding the Study Area
Table 4.2	Existing and Anticipated Land Use of the Study Area: 2004 and 2020
Table 4.3	Predicted Changes in Pollutant Yields by FAU, 2004-2020
Table 4.4	Predicted Sediment Load Reductions under LID Development Scenarios

Appendices

Appendix 1	Preservation Opportunity Fact Sheets
Appendix 2	Stream Restoration Opportunity Fact Sheets
Appendix 3	Agricultural BMP Opportunity Fact Sheets
Appendix 4	Stormwater BMP Opportunity Fact Sheets

1 Introduction

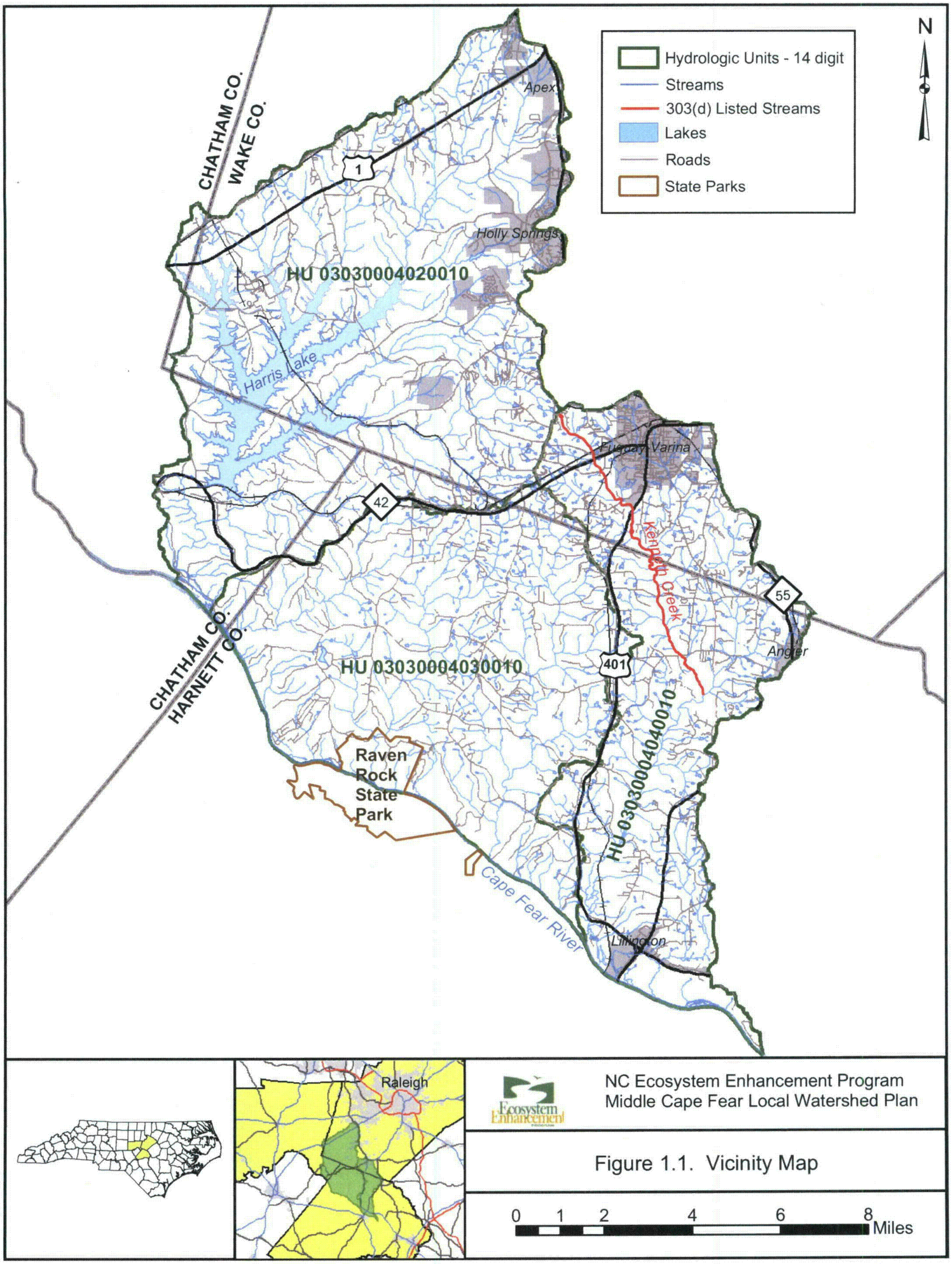
1.1 Background

The North Carolina Wetlands Restoration Program (NCWRP) contracted with Buck Engineering in 2002 to perform a technical assessment of three 14-digit hydrologic units (HUs) in the Middle Cape Fear River Basin. This work is being completed as part of the Local Watershed Planning (LWP) initiative that is currently administered by the North Carolina Ecosystem Enhancement Program (EEP). This Technical Memorandum presents project conclusions and recommendations for management actions based on work completed for the previous four project memos and recent efforts to prioritize management opportunities. The prioritization is based on a number of factors, including the functional assessment (Technical Memorandum 4), feasibility, and expected benefit. The information described in this memo identifies and prioritizes opportunities to address functional deficits.

The three HUs are parallel drainages to the Cape Fear River and are located within portions of Chatham, Wake, and Harnett Counties (Figure 1.1). The total land area for the HUs is approximately 180 square miles. The watersheds include parts of the towns of Apex, Holly Springs, and Fuquay-Varina and the portion of Raven Rock State Park north and east of the Cape Fear River. Major streams in the HUs include: tributaries to Harris Lake (White Oak Creek, Little White Oak Creek, Buckhorn Creek, Utley Creek, and Cary Branch), Parkers Creek, Mill Creek, Avents Creek, Hector Creek, Kenneth Creek, Neills Creek, and Dry Creek.

Based on analyses performed in previous phase of the project, the three HUs were further divided into 12 functional assessment units (FAUs) with generally similar land use, landform, and riparian condition (Figure 1.2). The Parkers, Avents, and Hector Creek sub-watersheds represent the largest FAUs. Initially, it was thought that it would be necessary to split the upper and lower portions of these sub-watersheds into unique FAUs. However, land use in these sub-watersheds is homogeneous and stream types are consistent in both the headwater and downstream sections.

The Harris Lake and Dry Creek sub-watersheds, as well as small drainages flowing directly into the Cape Fear River, were excluded from the functional assessment process. Although nutrient management is a key concern for the management of Harris Lake, it was determined to be outside the relevant scope of issues important to the rest of the study area. Also, any sediment impacts within the drainage to Harris Lake are contained within the waterbody. The Dry Creek sub-watershed and the small drainages directly to the Cape Fear River have no monitoring data available, which impedes model calibration. Due to the small size of their land areas compared to the other drainages, these regions also have a limited impact on the water quality of Cape Fear River. Therefore, it was determined that it would be more cost-effective to apply project resources to the other parts of the study area.



NC Ecosystem Enhancement Program
Middle Cape Fear Local Watershed Plan

Figure 1.1. Vicinity Map

2 Management Opportunities

Five management opportunity categories were assessed for their ability to maintain or improve watershed function:

1) preservation,
2) stream restoration,
3) agricultural BMPs,
4) stormwater BMPs,
5) land use controls.

This section provides descriptions of each of the first four opportunity categories and discusses their potential use in the project area. Land use controls are discussed in Section 4.

2.1 Preservation

Preserving high-quality stream reaches and adjacent forest is an important part of managing aquatic resources. Preservation involves identifying areas that provide good habitat, hydrology, and water quality functions, and protecting those areas to maintain functional benefits. Preservation can be accomplished through conservation easements or property purchase. Preservation can be relatively inexpensive because it avoids design and implementation costs.

2.1.1 Field-Identified Opportunities

Field work performed in earlier phases of the project included visits to numerous stream crossings throughout the project area. Preservation opportunities were noted when field staff encountered examples of healthy stream reaches and forested riparian buffers and catchments. Sites were also sought with relatively few landowners. This minimizes transaction costs and makes it easier to achieve consensus on preservation opportunities.

Five preservation opportunities were identified in the project area. They are described in Appendix 1. All of the sites have intact riparian buffers and good aquatic habitat. They represent unique conditions in the study area.

2.1.2 GIS-Identified Preservation Opportunities

As described in Technical Memorandum 1, the Biological Resources Division of the United States Geological Survey and North Carolina State University are sponsoring a habitat gap analysis in North Carolina (GAP). The purpose of this study is to assess the extent to which native animal and plant species are being protected. Resources used in the development of gap data for North Carolina include state-level land use, national land cover, National Wetland Inventory, National Elevation Data Set, and detailed soils information. Ground-truthing of data was performed.

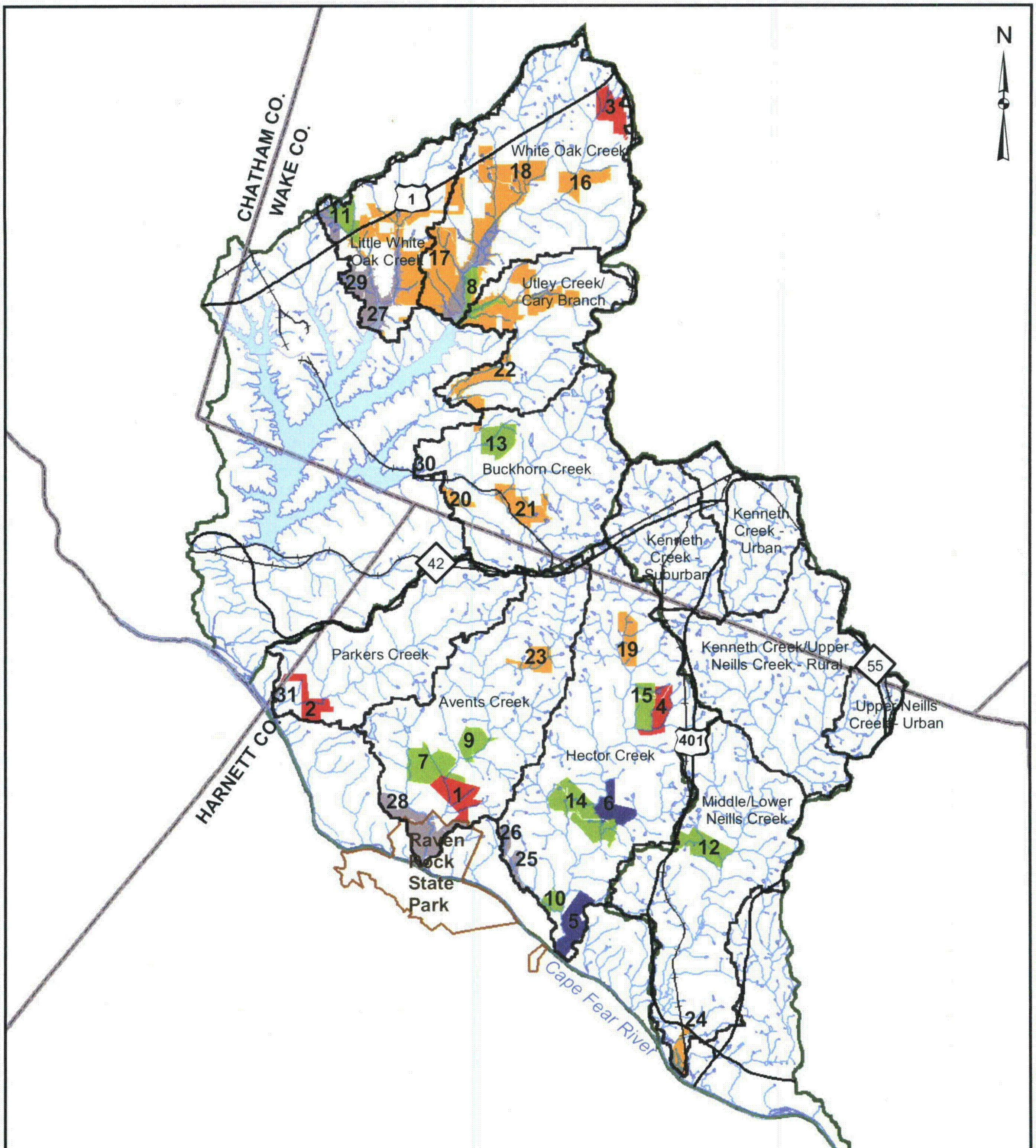
Habitat priorities for this project were determined based on consultation with the NC Wildlife Resources Commission, US Fish and Wildlife Service, NC Natural Heritage Program, and land trusts (Table 2.1). Sites are rated based on habitat quality.

Table 2.1. GAP Habitat Priorities

GAP Habitat Description	Priority Ranking	Explanation of Ranking
Agricultural Fields	Low	Common, impacted habitat
Agricultural Pasture/Hay and Natural Herbaceous	Low	Common, impacted habitat
Barren (bare rock and sand)	Low	Generally impacted habitat
Barren (quarries, strip mines, and gravel pits)	Low	Common, impacted habitat
Coastal Plain Dry to Dry-Mesic Oak Forest	Med-High	Late successional and provide high-quality habitat
Coastal Plain Fresh Water Emergent	Med-High	Water quality benefits, but very common
Coastal Plain Mixed Bottomland	Med-High	Water quality benefits, but very common
Coastal Plain Nonriverine Wet Flat Forests	Med-High	High-quality habitat for wildlife; bottomland systems provide water quality benefits
Coastal Plain Oak Bottomland Forest	High	Late successional and provide high-quality habitat; bottomland systems provide water quality benefits
Coniferous Cultivated Plantation	Low	Common, impacted habitat
Coniferous Regeneration	Low	Common, impacted habitat
Cypress-Gum Floodplain Forest	High	Late successional and provide high-quality habitat; bottomland systems provide water quality benefits
Dry Mesic Oak Pine Forests	Medium	Oak forests are late successional and provide high-quality habitat
Floodplain Wet Shrublands	Med-High	Good water quality benefits, but very common habitat
Mesic Longleaf Pine	High	Unique habitat
Peatland Atlantic White Cedar	High	Extremely unique habitat
Piedmont Deciduous Mesic Forest	Med-High	Good habitat benefits, but very common
Piedmont Dry-Mesic Oak and Hardwood Forests	Med-High	Late successional and provide high-quality habitat
Piedmont Dry-Mesic Pine Forests	Medium	Good wildlife benefits, but very common habitat
Piedmont Emergent Vegetation	Medium	Water quality benefits, but very common habitat
Piedmont Mixed Bottomland Forests	Med-High	Water quality benefits, but very common habitat
Piedmont Mixed Successional Forests	Low	Common, impacted habitat
Piedmont Oak Bottomland and Swamp Forests	High	Late successional and provide high-quality habitat; bottomland systems provide water quality benefits

GAP Habitat Description	Priority Ranking	Explanation of Ranking
Piedmont Submerged Aquatic Vegetation	Medium	Some water quality benefits, but usually backwaters of a lake (e.g., Harris Lake)
Piedmont Xeric Pine Forests	Low	Common, impacted habitat (assume plantation)
Piedmont Xeric Woodlands	Medium	Common, but may be later successional
Pocosin Woodlands and Shrubland	High	High because of uniqueness
Pond Cypress - Gum Swamps, Savannas, and Lakeshores	High	Late successional and provide high-quality habitat; bottomland systems provide water quality benefits
Residential Urban	Low	Common, impacted habitat
Riverbank Shrublands	Med-High	Provide stability for stream systems
Seepage and Streamhead Swamp	High	Can encompass high-quality and rare habitats
Urban High-Intensity Developed and Transportation Corridor	Low	Common, impacted habitat
Urban Low-Density Developed	Low	Common, impacted habitat
Xeric Longleaf Pine	High	Unique habitat
Xeric Pine-Hardwood Woodlands and Forests	Medium	Good habitat benefits, but very common

GAP data were used to locate potential preservation opportunities that were not identified during field surveys. These sites are typically located away from road crossings or in upland areas, and were not observed during field visits. To perform the analysis, the locations of all high and medium-high quality habitat in the study area were combined with parcel data. Parcels with areas less than 200 acres were then removed from the resultant dataset in order to limit the search to larger parcels. In most cases, only a fraction of the acreage of the parcel contained high or medium-high quality habitat. Therefore, the acreage of high and medium-high quality habitat within the parcels was summed and the percent high and medium-high quality habitat determined (Figure 2.1). Potential preservation sites are prioritized based on the percent high and medium-high quality habitat from Table 2.2.



Functional Assessment Units

Percent of Parcel with High/Medium-High Quality Habitat

- < 10%
- 10% - 20%
- 20% - 30%
- 30% - 40%
- > 40%

7 Priority Rank

Ecosystem Enhancement

NC Ecosystem Enhancement Program
Middle Cape Fear Local Watershed Plan

Figure 2.1. Parcels > 200 Acres with High and Medium-High Priority Habitat

0 1 2 4 6 8 Miles

Table 2.2. Potential Preservation: Percent High-Quality & Med-High Habitat

Rank	PIN	% High & Med-High Quality Habitat
1	0623-95-8251.000	60%
2	0614-35-8422.000	47%
3	0741606782	45%
4	0654-24-3186.000	41%
5	0642-21-5585.000	36%
6	0643-64-8175.000	31%
7	0623-68-8650.000	26%
8	0628955306	25%
9	0634-11-8109.000	25%
10	0632-92-5540.000	23%
11	0619788444	23%
12	0652-69-7689.000	23%
13	0637454017	22%
14	0643-32-5147.000	21%
15	0654-04-5846.000	21%
16	0740431039	19%
17	0730408350	18%
18	0730634462	17%
19	0645-82-8633.000	16%
20	0626777815	15%
21	0636862311	15%
22	0638575457	15%
23	0635-90-1255.000	14%
24	0650-56-4463.000	12%
25	0632-56-8360.000	10%
26	0632-48-3572.000	8%
27	0618420089	7%
28	0613-82-9215.000	6%
29	0619147086	5%
30	0627123577	4%
31	0604-86-0726.000	3%

2.2 Stream Restoration

Human activity has significantly altered the natural structure and functions of streams throughout the study area. Agricultural practices over the past decades have resulted in the straightening, dredging, and relocation of streams. Removal of vegetation from stream banks has left stream channels without the protection of densely rooted soil and limited shade for aquatic habitats. Road construction and development have also resulted in stream channelization and buffer disturbance. Further, the majority of study area streams now exhibit flashier hydrology than the streams in their natural condition. Such streams typically experience higher flood flows and experience more severe reductions in flow during droughts than unimpacted streams.

Many of these changes to the watershed and streams have negatively impacted the study area. Unstable stream banks and eroding stream beds have led to excessive sedimentation and the loss of aquatic habitat. Bedform diversity has been reduced in many reaches and water quality has likely been impacted by the loss of riffles (e.g., reduced oxygenation). Also, many streams are now incised and rarely access their floodplains.

Stream restoration attempts to address the loss of stream and floodplain functions by constructing and promoting the maintenance of stable streams. Stable streams are configured so that their width and depth (dimension), slope (profile), and meander pattern through the valley allow the stream to carry its flow and sediment without aggrading or degrading over time. Measurements of stable dimension, pattern, and profile are determined by locating and surveying stable streams that exhibit natural fluvial processes. By restoring stable dimension, pattern, and profile, a stream can be returned to an equilibrium state where balanced erosive and aggrading processes maintain stream form and habitat over time.

Stream restoration does not necessarily return a stream to its pre-disturbance condition; rather, it creates a dimension, pattern, and profile that will be stable and maximize functions given the constraints of existing land use and infrastructure. However, streams are generally restored to a configuration that resembles its natural condition as nearly as possible.

Stream restoration is particularly effective at reducing sediment pollution and subsequent habitat loss. In the North Carolina Piedmont, erosion rates on unprotected and unstable stream channels have ranged as high as 5 to 10 tons per year per linear foot (Jessup, 2004). Erosion at this rate can damage floodplains, property, and structures along the eroding reach and impair aquatic functions for miles downstream (Waters, 1995).

Buck Engineering identified nine significant restoration sites within the project area. They are described in Appendix 2. Each of these sites represents an opportunity to stabilize shifting stream banks, control hundreds of tons of sediment pollution per year, reestablish and enhance acres of riparian habitat and wetlands, and restore natural aquatic habitat. By providing these diverse and enduring environmental benefits, stream restoration projects like the ones suggested can become key elements in efforts to protect streams. A well-planned and constructed stream restoration project can complement other water resource projects and achieve far-ranging improvements in watershed health.

2.3 Agricultural BMPs

In this report, agricultural best management practices (BMPs) refer to measures that address both traditional agriculture (i.e., farming) as well as forestry. These practices are designed to maintain more natural interaction between agricultural operations and water resources. For example, farming BMPs include prevention of soil erosion by use of contour tillage and minimization of nutrient loss through fertilizer application education or filter strips. Forestry BMPs are operational techniques used to protect water quality during timber harvesting, such as riparian management zones, and methods to protect waterways and non-target vegetation from contact with pesticides and fertilizer.

Inadequate agricultural and forestry practices were noted during field visits to the project area. Based on these observations, six BMP opportunities were identified. They are described in Appendix 3. The opportunities address impacts from timber clear cutting, fertilizer application, and livestock access to stream channels. Implementation of these management recommendations will improve watershed functions, particularly habitat and water quality functions. Hydrologic function is typically less impacted by agriculture as this land use still allows water to infiltrate the soil profile.

2.4 Stormwater BMPs

When pervious land cover is replaced with pavement or rooftops, stormwater runoff increases in volume and velocity through the stream network. If left unabated, stormwater runoff can adversely impact aquatic resources by delivering increased contaminant concentrations and by changing the timing, volume, and location of stormwater discharges. Pollutants that have been associated with stormwater runoff include oils, semi-volatile organics, antifreeze, tars, soaps, fertilizers, pesticides, solvents, salts and metals (Bales et al., 1999; Burton and Pitt, 2001; Davis et al., 2001). The hydrologic impacts from unabated stormwater runoff include erosion from downcutting or widening; subsequent impairment of a stream's ability to access its floodplain; and habitat degradation that results when increased peak flows wash away microhabitat (e.g., sticks, leaf packs, and other woody debris).

Stormwater impacts may be minimized with the installation of structural BMPs, including stormwater ponds or wetlands, bioretention areas, sand filters, or grassy swales. Detailed descriptions of each of these practices may be obtained from Hunt and Lucas (2003). Specific BMP selection depends on the size of the catchment area, the percent of impervious cover in the catchment area, and amount of land available for BMP implementation.

It should be noted that many BMPs may need to be implemented to observe measurable improvements in watershed function. When several BMP options are available, implementation should begin in areas with the greatest potential for improved function and additional steps installed to the extent feasible.

2.4.1 Retrofit BMPs versus New-Construction BMPs

Stormwater BMPs may be retrofitted to treat runoff from an already developed site, or they may be incorporated into the designs for new development. BMPs for new development are typically more cost effective and easier to install than retrofit BMPs. However, as a general rule, new development BMPs should only be expected to maintain watershed function when installed in areas previously consisting of pervious land cover.

New development BMPs are especially necessary in areas where rapid and widespread development replaces forested and herbaceous/pasture land; otherwise, significant loss of watershed function should be expected. Two sectors of the project area that are expected to experience such growth in the near future are the White Oak FAU near Apex and the Middle/Lower Neills Creek FAU between Fuquay-Varina and Lillington (see Section 4.1). It is recommended that stormwater ordinances be implemented in advance of this suburban expansion to promote new development BMPs and mitigate possible loss of watershed function.

Retrofit stormwater BMPs, though expensive and challenging to install, can improve watershed function by reducing impacts from currently developed land. Since urban land has been shown to be a major source of pollution and stormwater, it is not surprising that improvements can be made by installing retrofit BMPs. Implementing stormwater BMPs can reduce contamination associated with roads, parking lots, rooftops, lawns, vegetable gardens, industrial areas, and construction sites.

2.4.2 Identified Stormwater BMPs

A feasibility study was conducted to search for suitable retrofit BMP locations. The study results do not include design specifications for the BMPs, nor, in some cases, the type of BMP. The search focused on areas that generated significant stormwater runoff and had sufficient space to treat it within urban areas along NC Highway 55 (Angier, Fuquay-Varina, Holly Springs, and Apex).

Seven retrofit stormwater BMP opportunities were identified. They are described in Appendix 4. Generally, the chosen sites would treat runoff from approximately 1- to 20-acre catchments. They include measures to address runoff from parking lots, industrial areas, and commercial lots. Stormwater wetlands or bioretention areas are probably the most appropriate BMPs for the sites.

3 Management Strategy Prioritization

This section describes the methods used to rank the identified management opportunities, considering watershed needs and expected benefits. Priority matrices (Section 3.1) were used as the primary decision criteria, but high-quality habitat (based on GAP data), modeling results, and feasibility were used to adjust ratings as necessary. This resulted in rankings within each of four management opportunity categories: preservation, stream restoration, agricultural BMPs, and stormwater BMPs.

3.1 Prioritization Matrices

Priority matrices were developed by applying a priority classification (High, Medium, or Low) to combinations of opportunity type and functional status for each of the watershed functions (habitat, hydrology, and water quality). Table 3.1 shows the matrix framework.

Table 3.1 Sample Priority Matrix Based on Assessment Rating.

Opportunity	**Priority Classification**		
	Functioning	**Functioning at Risk**	**Not Functioning**
Preservation			
Stream Restoration			
Stormwater BMPs			
Agricultural BMPs			

During development of the matrices, a high priority was placed on opportunities that would result in the greatest benefit per function level and a low priority on opportunities that would provide minimal benefit. The approach to evaluating each type of opportunity is described below.

3.1.1 Preservation

Preservation is as a practice that maintains the status quo. For this reason, higher priorities were assigned to *Functioning* systems. Since preservation alone will not improve the quality of a less functioning system, lesser priorities were assigned to systems that are *Not Functioning.*

3.1.2 Stream Restoration

Stream restoration can improve all watershed functions, in some circumstances. A *Functioning* system is not likely to require stream restoration, so a low priority was assigned. Stream restoration is most beneficial for a system that is *Functioning at Risk.* In this case, the watershed has probably not reached the level of development (i.e., percentage of impervious cover) that causes highly erosive storm flows, which can reduce the effectiveness of stream restoration measures. Consequently, when it appeared that high impervious cover caused a *Not Functioning* rating, the priority for stream restoration was reduced to medium. In fact, if the watershed is built out (i.e., once impervious cover reaches approximately 30-40%), then a low priority was applied to restoration.

3.1.3 Agricultural BMPs

Unlike stormwater, the threat from agricultural and forestry practices in the study area is diminishing because land use is rarely converted to agriculture or forestry; rather, it is most common for land cover to be converted from forestry or agriculture to developed land. To assign priority classifications, however, it was assumed that agriculture/forestry was a primary cause of habitat degradation. Consequently, the same priority classifications were assigned as for stormwater BMPs.

3.1.4 Stormwater BMPs

Degradation by stormwater increases as impervious cover increases. These impacts are probably the single greatest threat in the project watershed, as urban land use in the area increases. To assign priority classifications, it was assumed that stormwater was a primary cause of habitat degradation. Consequently, high priorities were assigned to *Not Functioning* and *Functioning at Risk* FAUs. To maintain a *Functioning* system, medium priority on stormwater BMPs were assigned.

3.2 Application of Prioritization Matrices

The prioritization matrices are shown in Tables 3.2, 3.3, and 3.4.

Table 3.2 Habitat Priority Matrix Based on Assessment Rating.

Opportunity	Priority Classification		
	Functioning	Functioning at Risk	Not Functioning
Preservation	High	Medium	Low
Stream Restoration	Low	High	Medium
Stormwater BMPs	Medium	High	High
Agricultural BMPs	Medium	High	High

Table 3.3 Hydrology Priority Matrix Based on Assessment Rating.

Opportunity	Priority Classification		
	Functioning	Functioning at Risk	Not Functioning
Preservation	High	Medium-High	Low
Stream Restoration	Low	High	Medium
Stormwater BMPs	Medium	High	High
Agricultural BMPs	Low	Medium	High

Table 3.4 Water Quality Priority Matrix Based on Assessment Rating.

Opportunity	Priority Classification		
	Functioning	Functioning at Risk	Not Functioning
Preservation	High	Medium	Low
Stream Restoration	Low	Medium	Medium
Stormwater BMPs	Medium	High	High
Agricultural BMPs	Medium	High	High

For each opportunity, Buck Engineering assigned functional ratings for the FAU where the opportunity is located. For example, a restoration opportunity is located in the Little White Oak FAU. This assessment unit had *Functioning at Risk* habitat, *Functioning* hydrology, and *Functioning at Risk* water quality functions (see Technical Memorandum 4). Therefore, according to the habitat matrix (Table 3.2), stream restoration in a *Functioning at Risk* FAU yields a priority classification of High. Using the same approach, hydrology and water quality functions result in low and medium priorities, respectively.

The individual opportunities were ranked within each of the four categories: preservation, stream restoration, agricultural BMPs, and stormwater BMPs. The ranking procedure began with comparison of the results from the prioritization matrices. Priority ratings from the three functions (habitat, hydrology, and water quality) were weighted equally. Thus, we compared the average priority rating for each opportunity. This produced a first-cut ranking within the various opportunities. It should be noted that this screening produced many opportunities with similar rankings.

3.3 Other Consideration Factors

When rankings were similar or equal, other factors such as modeling results and presence of high-quality habitat, were examined. Restoration and preservation opportunities that fell within or adjacent to unique and valuable terrestrial habitat as identified by GAP data were assigned more favorable priority rankings. For example, a restoration opportunity in the Parkers Creek FAU was originally designated as the lowest of nine restoration opportunities. However, due to its medium-high quality habitat, this opportunity was promoted over two sites in the Kenneth Creek watershed where no significant terrestrial habitat was present. In this and other cases, Buck Engineering felt that restored riparian habitat would both complement and be supported by nearby high-quality environments and, therefore present a more comprehensive, and potentially more successful, project.

Likewise, modeling results were used to adjust final opportunity priorities and resolve tie scores. In catchments where modeling predicted that land cover conditions were generally sufficient to support good water quality, preservation opportunities were promoted in the rankings. Also, where the model suggested excellent assimilative capacity for instream sediment due to active floodplain processes, the rank of BMP opportunities were reduced. This was, in effect, an acknowledgement of the ability of the stream to accommodate its current sediment load.

Finally, where conditions suggested that opportunity implementation would be problematic or likely face unusual hurdles, opportunity ranks were reduced.

Applying best professional judgment was most necessary for ranking stormwater BMPs, because all opportunities had an average priority rating of High, and none of them were located in an area with high-quality habitat. BMP feasibility and the expected benefit of implementation were used to rank the opportunities.

3.4 Results

Results are provided in the Table 3.5 and shown in Figure 3.1. The final rankings should be interpreted by local governments as a preliminary list of the most feasible and beneficial opportunities. It is important to note, however, that all of the listed opportunities are viable projects.

Large-scale improvements in function should not be expected by implementing a single opportunity in a FAU. More likely, a group of practices will be needed to improve function. With this in mind, local governments or other watershed stakeholders may wish to group practices to improve the chances of restoring function in a tributary or higher order stream. Further clustering of BMPs or practices in other tributaries would improve the chances of restoring function to FAUs.

In addition, it should be noted that the opportunities presented in this report were identified during the field assessment of the study area, which was limited to road crossings. The opportunities presented are not comprehensive. There are likely many other similar opportunities that could be identified if additional resources were devoted to the assessment.

Table 3.5 Opportunities to Improve/Maintain Watershed Functions.

Opportunity ID	FAU Assessment (Habitat/Hydrology/ Water Quality)*	FAU Opportunity Priorities	Initial Priority Ranking	High-quality Habitat (GAP)	Final Priority Ranking	Location
P1	F/F/FR	H/H/M	2	YES (close proximity)	**2**	Coopers Branch trib to Hector Creek
P2	FR/FR/F	M/M-H/M	4 (tie)		**3**	UT to Buckhorn Creek
P3	F/F/F	H/H/H	1	YES (Med-High)	**1**	Mill Creek and Avents Creek
P4	FR/FR/FR	M/M-H/M	4 (tie)		**5**	UT to Kenneth Creek
P5	FR/F/FR	M/H/M	3		**4**	UT to White Oak Creek
B1	FR/F/FR	M/L/H	3	YES (Med-High)	**1**	UT to White Oak Creek
B2	F/F/F	M/L/M	6	YES (close proximity)	**6**	Parkers Creek (close to R4)
B3	FR/FR/NF	H/M/H	1 (tie)	YES (High)	**3**	Kenneth Creek
B4	FR/FR/NF	H/M/H	1 (tie)		**2**	UT to Neills Creek
B5	F/F/FR	M/L/H	4 (tie)	YES (Med-High)	**5**	UT to Hector Creek
B6	F/F/FR	M/L/H	4 (tie)	YES (Med-High)	**4**	Hector Creek
R1	FR/FR/NF	H/H/M	1	YES (Med-High)	**1**	Little White Oak Creek
R2	FR/F/FR	H/L/M	3 (tie)	YES (close proximity)	**3**	Big Branch (White Oak Creek FAU)
R3	FR/F/FR	H/L/M	3 (tie)		**6**	Little Branch (White Oak Creek FAU)
R4	F/F/F	L/L/L	9	YES (Med-High)	**7**	Parkers Creek (close to B2)
R5	NF/NF/NF	M/M/M	3 (tie)		**4**	Kenneth Creek
R6	F/F/FR	L/L/M	8	YES (Med-High)	**5**	Hector Creek
R7	NF/NF/NF	L-M/L-M/M	6 (tie)		**9**	UT to Kenneth Creek
R8	NF/NF/NF	L-M/L-M/M	6 (tie)		**8**	UT to Kenneth Creek
R9	FR/FR/NF	H/H/M	2		**2**	UT to Neills Creek
S1	NF/FR/NF	H/H/H	3		**3**	UT to Neills Creek (Factory site)
S2	NF/FR/NF	H/H/H	5		**5**	UT to Neills Creek (Medical Dr. site)
S3	NF/NF/NF	H/H/H	2		**2**	UT to Kenneth Creek (CVS site)
S4	NF/NF/NF	H/H/H	6		**6**	UT to Kenneth Creek (N Fuquay-Varina)
S5	NF/NF/NF	H/H/H	1		**1**	UT to Kenneth Creek (SW Fuquay-Varina)
S6	NF/NF/NF	H/H/H	4		**4**	UT to Kenneth Creek (NE Fuquay-Varina)

* F = Functioning, FR = Functioning at Risk, NF = Not Functioning

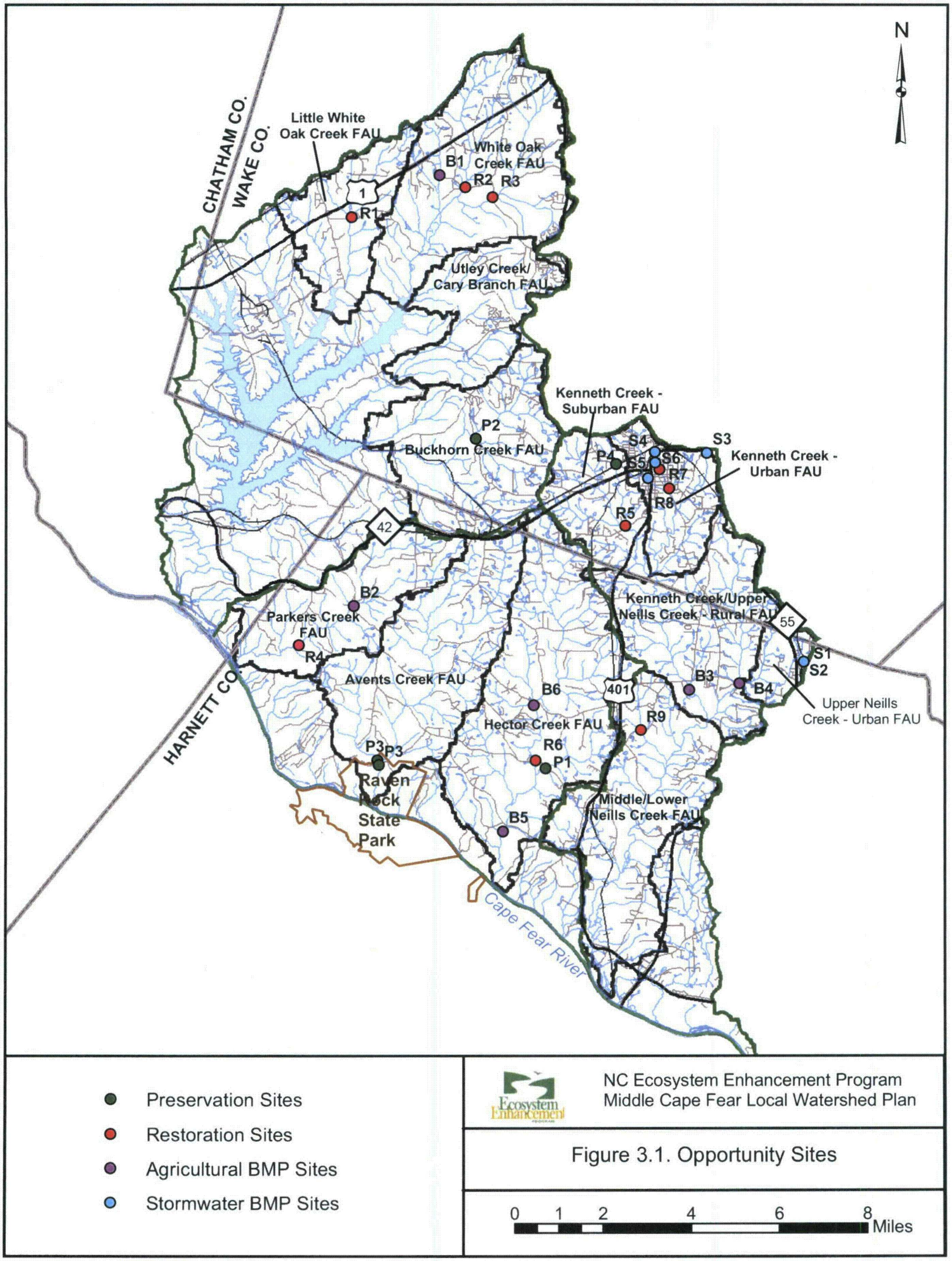


Figure 3.1. Opportunity Sites

4 Land Use Controls

4.1 Land Use Impacts

A survey of local governments and agencies was conducted to determine likely development patterns in the study area over the next ten to fifteen years. Results of this survey were used to produce a map and GIS data layer of possible land use patterns in the year 2020. Due to existing and planned infrastructure, it is anticipated that most new development during this period will be concentrated in portions of the watershed that support or will support major transportation corridors. Several catchments within the study area are predicted to have minor land use changes between now and 2020. The anticipated future land use data layer was used to support SWAT model runs to assess the impact of development over the next ten to fifteen years. The model was then used to determine the mitigative effects of possible moderate and aggressive planning measures to control impact of growth on the functional state of the watershed.

4.1.1 Past Land Use Trends

Long-term land use trend data are not available for the exact catchments that make up the study area. However, data derived from 1949 aerial photography in the general area suggest relatively stable land use over the past fifty years. Agricultural land use has decreased significantly as urban and suburban areas have been established, a trend seen throughout much of North Carolina. However, much of the lost of agricultural land in the watershed during the past fifty years was the result of the construction of Harris Lake (Figure 4.1). Overall, forest cover has remained relatively stable over time.

The recent history of land use patterns in the study area indicates that urban development is rapidly becoming an important feature of the landscape. While no major urban centers are located within the study area, the influence of migration to the Triangle (Raleigh, Durham, and Chapel Hill) area is evidenced in US Census data. Between the 1990 and 2000 Census periods, the three counties comprising the study area experienced a 45% growth in population. During this same period, the three largest municipalities in the study area, while still quite small, experienced population growth approaching, and in one case exceeding, 100% growth (Table 4.1). These growth rates were not due to annexation of existing areas; rather, they were primarily due to new housing (i.e., population density growth closely tracked with population growth).

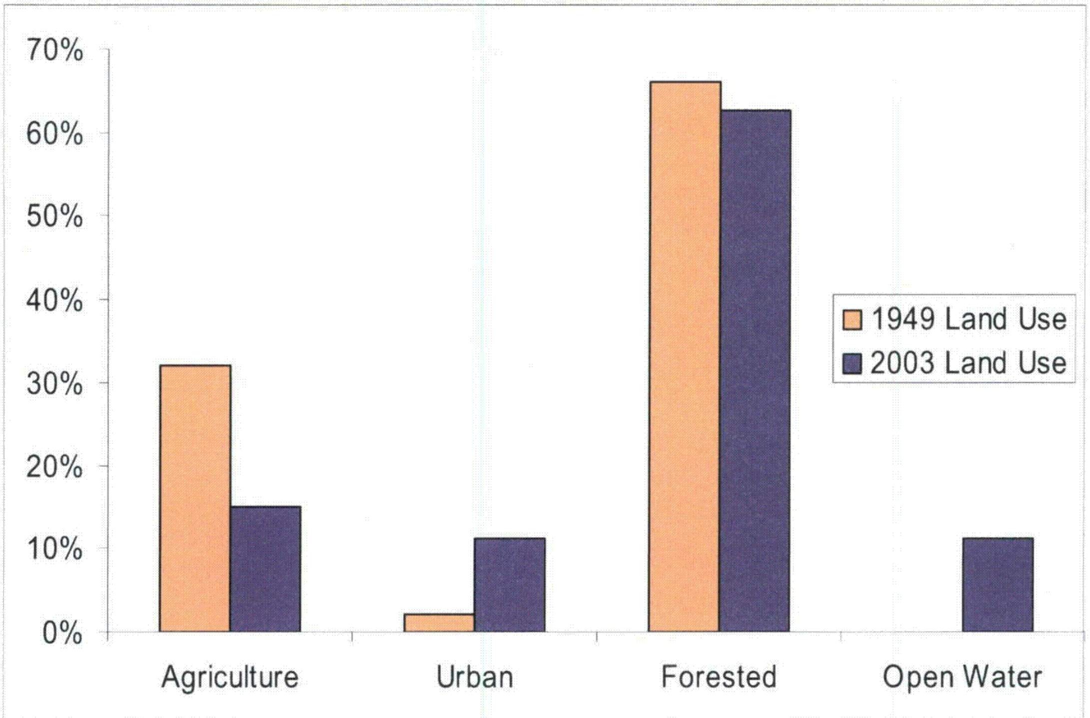


Figure 4.1 Broad Land Use Types in the Vicinity of the Study Area, 1949 and 2003.

Table 4.1. Census Data for Communities in and Surrounding the Study Area.

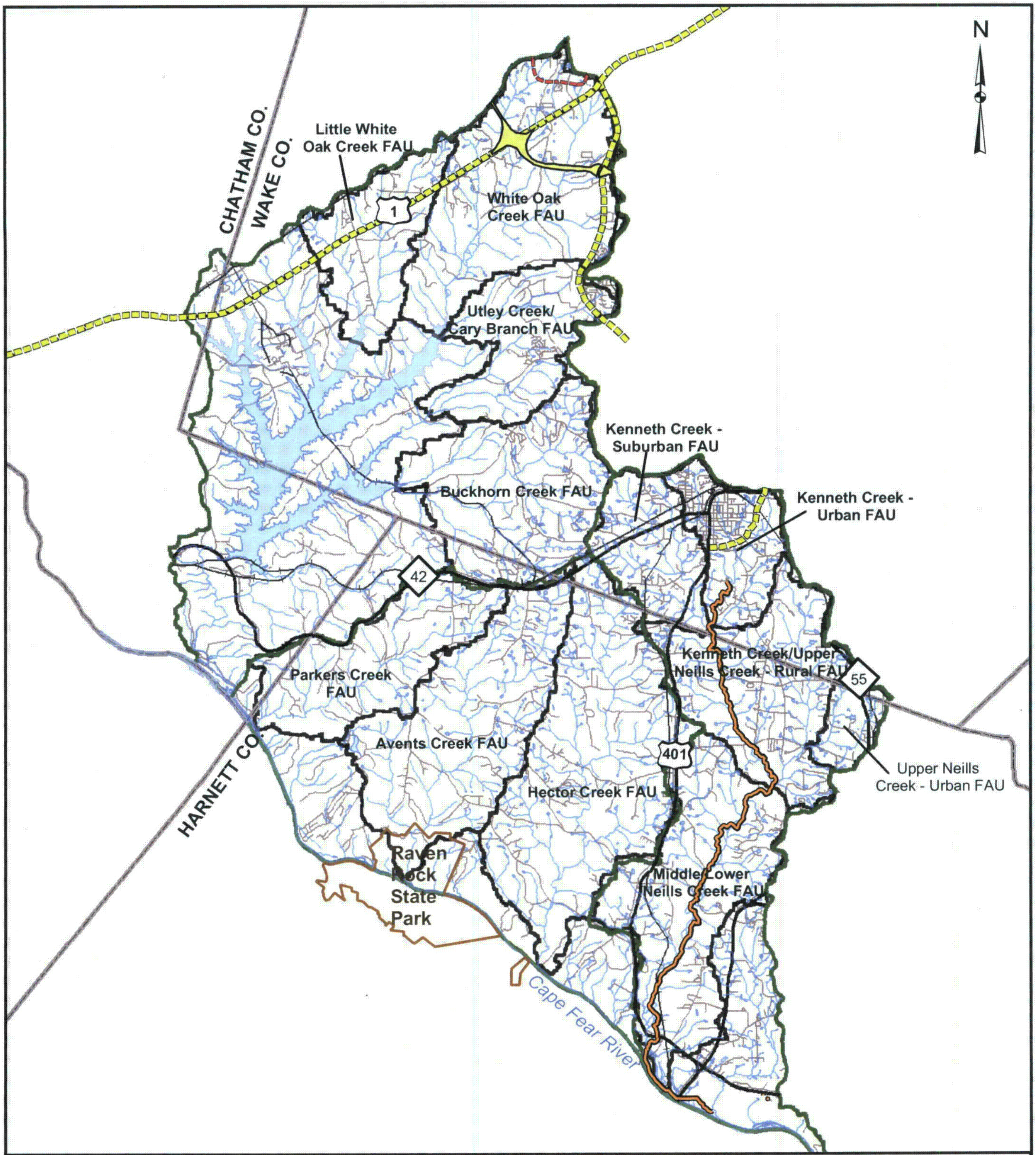
Geographic Area	1990 Population	2000 Population	% Growth	1990 Housing Units	2000 Housing Units	% Growth
Harnett County	67,822	91,025	34%	27,896	38,605	38%
Wake County	423,380	627,846	48%	177,146	258,953	46%
Chatham County	38,759	49,329	27%	16,642	21,358	28%
Town of Apex	4,968	20,212	307%	1,826	3,375	85%
Town of Holly Springs	908	9,192	912%	335	3,642	987%
Town of Fuquay-Varina	4,562	7,898	73%	1,959	3,375	72%

4.1.2 Anticipated Future Land Use

Current land use plans from the towns of Apex, Holly Springs, Fuquay-Varina and Wake and Harnett counties were reviewed to determine likely areas for residential, commercial, and industrial growth. These plans were discussed with representatives of the local governments to further define areas where future urban growth was likely. This land use information was supplemented with plans for roads, sewer lines, and other infrastructure as provided by the NC Department of Transportation and Wake and Harnett County planning offices. Likely spurs to rapid growth are three new or planned major roads (the Apex Peakway, NC 55 bypass of Holly Springs, and the US 401 Fuquay-Varina loop), as well as a major sewer line to the future Harnett County regional wastewater treatment plant (Figure 4.2).

The infrastructure data were used to construct a GIS data layer describing anticipated land use conditions for the year 2020 (Figure 4.3). In general, widespread low and medium density urban development, along with some associated commercial development, is anticipated along the upper reaches of White Oak Creek, Little White Oak Creek, Utley Creek, Kenneth Creek, and Neills Creek. The percentage of various land use types in the study area under present conditions, as well as those anticipated in 2020, are presented in Table 4.2.

Urban development was categorized based on density of impervious surface. High density development, typical of truly urban downtown environments, was defined as areas where impervious surfaces make up more than 50% of total land area and curb densities are greater than 0.05 miles per acre. Medium density development was defined as urban areas with approximately 25% impervious surface and moderate curb density. Low density development was defined as residential areas where impervious surface area is less that 10% of total area and curbs are uncommon.



Harnett Regional WWTP Sewer Line
Western Wake Freeway (proposed)
NCDOT Roadway TIP Projects
Apex Peakway

Ecosystem Enhancement

NC Ecosystem Enhancement Program
Middle Cape Fear Local Watershed Plan

Figure 4.2. Major Infrastructure Relevant to Potential Study Area Development

0 1 2 4 6 8 Miles

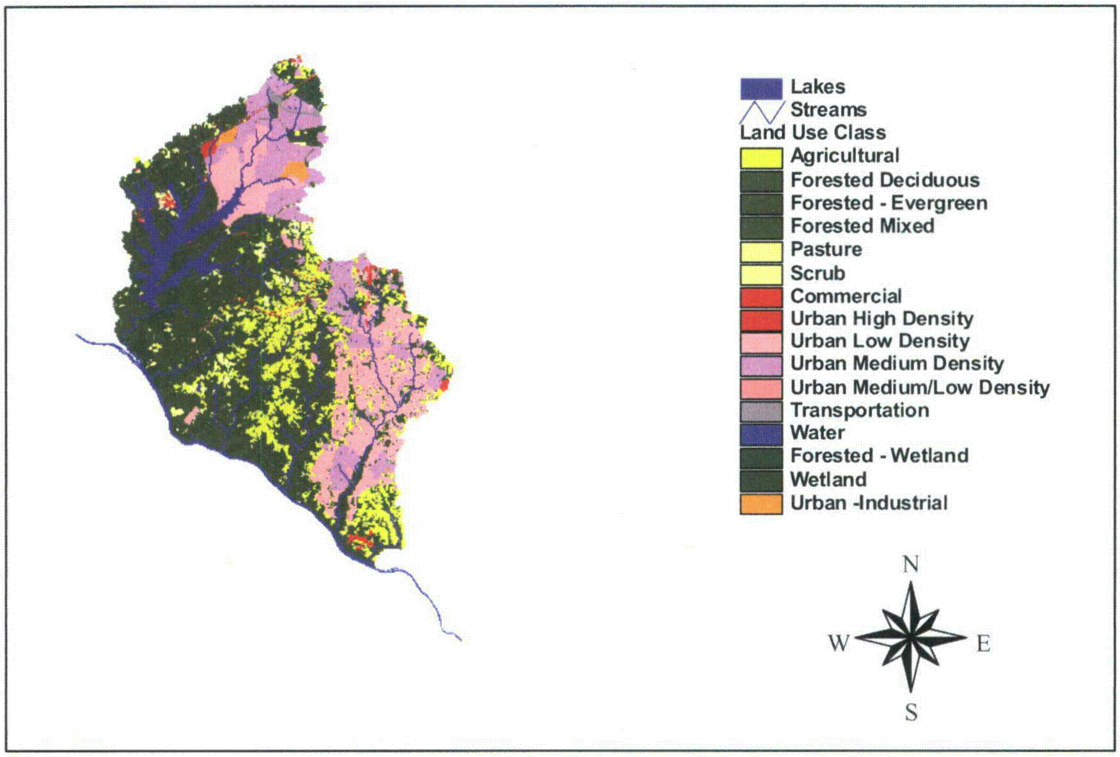


Figure 4.3 Anticipated Land Use in 2020.

Table 4.2 Existing and Anticipated Land Use of the Study Area: 2004 and 2020.

Land Use	Percent of Watershed Area		% Change
	2004	2020	
Agricultural	18.1	11.6	-6.5
Commercial	0.4	0.6	0.2
Forest-Mixed	47.9	36.2	-11.8
Industrial	0.4	0.6	0.2
Pasture	2.7	2.3	-0.4
Residential-High Density	0.8	1.0	0.2
Residential-Medium Density	2.3	11.5	9.2
Residential-Low Density	1.5	14.9	13.3
Transportation	1.4	1.7	0.3
Wetlands-Forested	18.9	14.1	-4.8
Wetlands-Mixed	0.5	0.3	-0.2

4.1.3 Likely Impacts from Anticipated Development

To determine the likely impacts from anticipated development described above, the SWAT model (see Technical Memorandum 3) was used to compare hydrologic and instream pollution conditions for existing and anticipated future land use. Model catchments were nested to report export conditions from each of the FAUs (Figure 4.4).

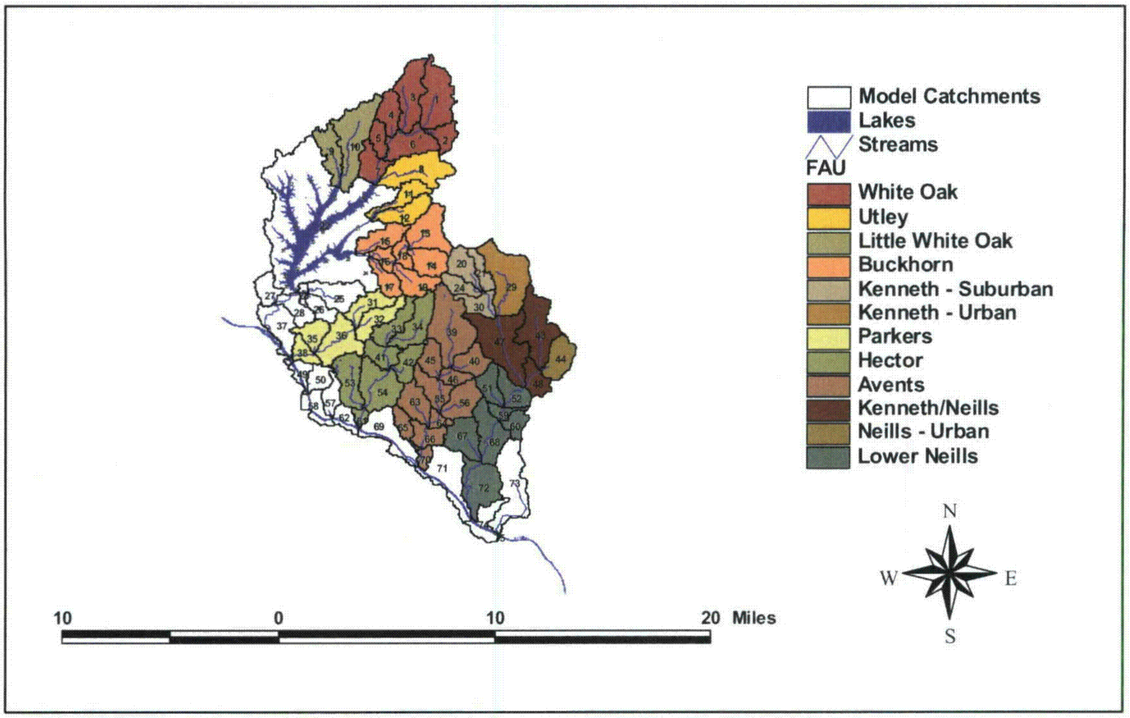


Figure 4.4 Model Catchments Nested within FAUs.

Hydrology is predicted to be significantly affected by future development. While the total discharge from the study area is unlikely to be affected, streams are predicted to become flashier, with higher peak flows and lower discharge during dry periods. In general, larger flood events in study areas streams are predicted to have peak flows 5% to 15% higher under anticipated 2020 conditions than under current lands use (Figure 4.5).

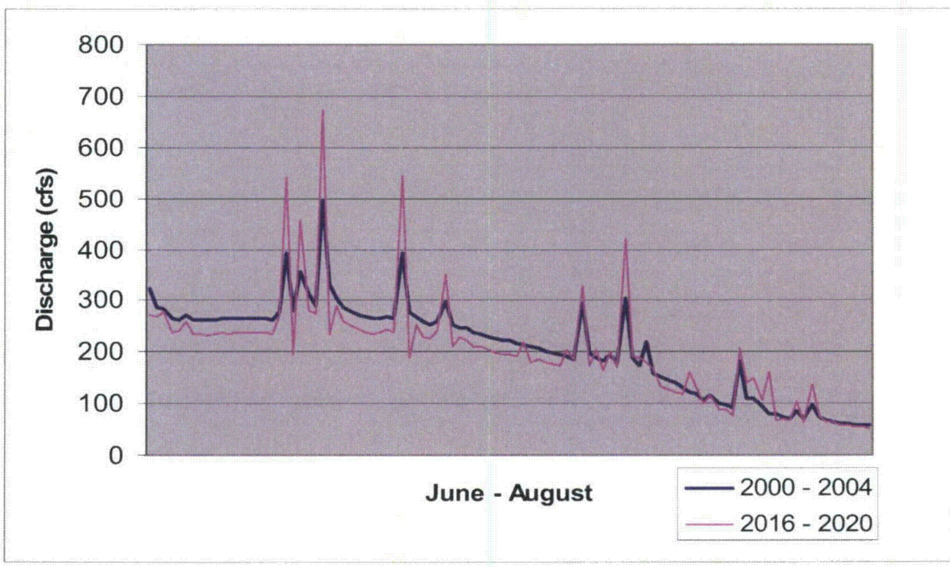


Figure 4.5 Daily Maximum Stream Discharge for the Study Area for Two Five-Year Periods.

An increase in sediment pollution is predicted to coincide with future development. To a lesser extent, nutrient pollution is also predicted to increase. Sediment yield is predicted to more than double by 2020 in the Little White Oak Creek and White Oak Creek FAUs, and there will likely also be large increases in the Kenneth Creek and Utley Creek FAUs (Table 4.3) Portions of Neills Creek area are predicted to see smaller but significant sediment yield increases under anticipated future land use conditions. Relatively large increases in nutrients, particularly phosphorus, are predicted in the Little White Oak Creek and Utley Creek FAUs (Table 4.3).

The predicted changes in pollutant yield and associated changes in instream concentrations under the anticipated development are relevant to the functional status of study area streams. Water quality and aquatic habitat in seven of the FAUs (Little White Oak Creek, White Oak Creek, Utley Creek, Middle/Lower Neills Creek, Kenneth Creek - Suburban, Upper Neills Creek and Kenneth Creek-Rural) are threatened by these large changes in pollutant loading. Harris Lake is also threatened by the predicted increase of delivered nutrients. Only the relatively undisturbed portions of the study area and the presently build out area around Kenneth Creek are unlikely to see major changes in water quality and habitat function. If development continues at its current rate, 65% of the study area will face new threats to functional qualities.

Table 4.3 Predicted Changes in Pollutant Yields by FAU, 2004 – 2020.

FAU	Sediment	Nitrogen	Phosphorus
Little White Oak Creek	105%	19%	28%
White Oak Creek	288%	20%	13%
Utley Creek	86%	15%	61%
Buckhorn Creek	-1%	-2%	4%
Parkers Creek	-4%	9%	-2%
Avents Creek	0%	-4%	-5%
Hector Creek	3%	11%	16%
Middle/Lower Neills	-8%	37%	39%
Kenneth Creek - Suburban	69%	31%	8%
Kenneth Creek - Urban	6%	6%	-4%
Upper Neills Creek - Urban	22%	17%	11%
Kenneth Creek - Rural	32%	16%	9%

4.2 Land Use Controls to Minimize Development Impacts

4.2.1 Low Impact Development

One possible solution to the impacts from new development is the implementation of low impact development (LID) design practices. LID is a suite of design practices to conserve natural systems and reduce infrastructure footprints and costs. Goals may include preserving open space, minimizing land disturbance, protecting natural features, and implementing processes that provide "green" infrastructure. LID is best suited for new suburban development. Relevant practices for the protection of functional processes within the study area include stormwater management designed to approach or achieve pre-development hydrologic conditions for the post-development period, and the preservation of riparian buffers as greenways.

LID may be implemented at different intensities and over different areas depending on need, economic feasibility, and political will. In order to evaluate the potential of LID to address functional deficits resulting from future development in the study area, two possible LID development scenarios were developed. A modest implementation of LID practices for the study area was used to represent development configurations that reduced new impervious surfaces and limited new stormwater collection systems. Under this moderate LID implementation scenario, new development would involve only 75% of the impervious surface area and only 70% of the curb length expected under standard development. Existing high value riparian buffers protected would also be protected throughout the watershed.

Aggressive implementation of LID practices would aim to protect existing hydrographs throughout the study area. Hydrographs would be maintained by the common and widespread installation of onsite infiltration devices. In addition, essentially all existing riparian buffers would be protected.

Both the moderate and aggressive LID scenarios were parameterized and used to drive SWAT model runs to determine the general potential of LID to mitigate the impacts from anticipated land use change in the study area. Results of this analysis are presented in Table 4.4.

Table 4.4 Predicted Sediment Load Reductions under LID Development Scenarios.

FAU	Standard Development	Moderate LID	Aggressive LID
Little White Oak Creek	105%	95%	28%
White Oak Creek	288%	213%	13%
Utley Creek	86%	81%	15%
Buckhorn Creek	0%	0%	0%
Parkers Creek	0%	0%	0%
Avents Creek	0%	0%	0%
Hector Creek	3%	3%	3%
Middle/Lower Neills	0%	0%	0%
Kenneth Creek - Suburban	69%	50%	8%
Kenneth Creek - Urban	6%	6%	6%
Upper Neills Creek - Urban	22%	17%	11%
Kenneth Creek - Rural	32%	16%	9%

In general, moderate LID practices, even if widespread, are not by themselves sufficient to significantly reduce the threat of future development to functional processes within the study area. However, aggressive application of LID does address the majority of impacts from future development. Given the broad range of functional conditions of the 12 FAUs, one possible solution is to consider watershed-wide implementation of moderate LID practices with aggressive LID practices prescribed in key areas.

4.2.2 <u>Stormwater Ordinances</u>

By implementing stormwater ordinances in advance of new development, watershed functions can be protected and expensive retrofit BMPs can be avoided. A sample ordinance can be found in the stormwater requirements of the Neuse River regulations (NCDENR, 2003). The requirements of this policy are applicable in the study area, with the possible exception of the nutrient loading cap. The Neuse River stormwater requirements include the following:

- Requirements for no net increase in the peak flow leaving the site from predevelopment conditions for the 1-year, 24-hour storm,
- Implementation of public education programs,
- Identification and removal of illegal discharges, and
- Identification of suitable sites for retrofit stormwater BMPs.

5 Conclusions and Action Items

This report identifies a number of opportunities to restore and protect watershed function throughout the middle Cape Fear local watershed plan study area. Prioritized project information sheets are included in Appendices 1 through 4.

Given the vulnerable condition of the natural resources in this area, it is vital to expedite implementation of the efforts recommended in this report. Many watershed functions are already degraded or threatened by current development, and future development is likely to continue at the same or, potentially, an accelerated pace. Failure to act will likely put municipalities and agencies in a reactive, rather than a proactive, position. This is a more costly and less effective approach to management, similar to the difference between retrofit stormwater BMPs and new development stormwater BMPs (Section 2.4). Additionally, it is more difficult to restore **non-functioning** habitat, hydrology, or water quality than it is to restore areas that are **at risk**.

Many of the opportunities presented in this report can be undertaken by the EEP, while others will need the involvement of local governments and other watershed stakeholders. Outlined below are a number of steps that can be taken to begin the process of implementing the recommendations in this report.

- EEP can capitalize on mitigation opportunities to fund stream and wetland restoration projects, and possibly stormwater and agriculture BMPs. EEP is in a good position to implement projects, having funded the development of the local watershed plan and formed relationships with watershed stakeholders. Initiating implementation can provide on-the-ground examples that contribute to community education and encourage additional restoration efforts.

- Local governments should undertake efforts to implement LID requirements. Since it will be necessary to obtain buy-in from town council members and county commissioners, meetings should be held to present the findings from the local watershed plan. If it is not possible to achieve community buy-in to implement aggressive LID practices throughout the towns and county, it may be feasible to adopt moderate LID practices with aggressive LID practices prescribed in key areas (e.g., headwaters).

- In addition to adoption of LID practices, local governments should adopt stormwater ordinances to alleviate the effects of development. The Neuse River stormwater requirements are a good example of a sample policy.

- Local governments should seek funding sources to implement additional watershed efforts. Funding sources include the US Environmental Protection Agency's Section 319 funds for nonpoint source management; the NC Clean Water Management Trust Fund; institution of a stormwater utility; and municipal bonds, as well as others. The former two measures may be more politically feasible because they provide outright grants, though a cost share is required. Inkind services and land donations could be used to provide cost share equivalents. The utility or bonds are both essentially taxes, but are guaranteed to provide funds.

- Local governments should decide how to allocate limited resources and choose which opportunities to pursue. For instance, they may want to focus on a particular type of opportunity - preservation, restoration, or BMPs. Such decisions are value judgments that may vary between different local governments. Limited resources may be spread between opportunity categories and locations (e.g., FAUs), or they may be combined for more targeted results.

- It will be important for all involved stakeholders to monitor before and after opportunity implementation. Documenting results validates the investment. It also allows adjustments to be made if the practice is not performing as expected. For example, maintenance or changes to vegetation types may be required.

- Efforts should be made to contact Progress Energy and other large landowners regarding preservation opportunities. These opportunities would ensure future watershed function in a number of areas. This practice is a much more cost-effective than funding restoration efforts after development has occurred.

6 References

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