# Lockwoods Folly River Local Watershed Plan

# Detailed Assessment and Targeting of Management Report

North Carolina
Ecosystem Enhancement Program

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# 1.0 Introduction

## 1.1 BACKGROUND AND PURPOSE OF LOCAL WATERSHED PLANNING

The N.C. Ecosystem Enhancement Program (NCEEP) has initiated comprehensive watershed planning efforts in certain high-priority local watersheds in order to meet the following primary objectives:

1) Assessment of historical and current watershed conditions;
2) Identification of the major causes and sources of watershed degradation;
3) Involvement of local stakeholder groups in determining major watershed issues and high-priority focus areas;
4) Prediction of future watershed conditions under alternative land use and watershed management scenarios;
5) Development of a consensus-based package of watershed restoration and protection recommendations to be brought before local decision-making bodies, including:
    a. identification of stream, wetland, and marsh restoration, enhancement, and preservation opportunities;
    b. assisting the N.C. Department of Transportation (NCDOT) in meeting future compensatory mitigation needs for stream, riparian buffer and wetland impacts;
    c. identification of non-traditional mitigation projects (e.g., stormwater Best Management Practices (BMPs), urban stormwater retrofits, agricultural practices) for targeted sites or subwatersheds; and
    d. identification of a long-term follow-up strategy to assist localities in implementation of the specific watershed protection recommendations developed during the planning process.

The NCEEP has selected the Lumber River Basin cataloging unit (CU) 03040207 as a target CU for local watershed planning efforts. Initial evaluations of restoration need and opportunity by NCEEP staff have resulted in the decision to focus efforts in the 14-digit hydrologic units, or portions thereof, within the Lockwoods Folly River watershed. The Lockwoods Folly River watershed is considered a high-priority area for watershed planning due to two primary factors: (1) documented water quality problems in selected stream segments, including segments listed on the Clean Water Act Section 303(d) list of impaired waters submitted to the U.S. Environmental Protection Agency; and (2) emerging threats to local watershed health which may be attributed to impacts from urban and suburban development, disturbance of wetlands and riparian buffers, agricultural activities, and/or other nonpoint sources.

The NCEEP Local Watershed Plan (LWP) process utilizes a watershed assessment that emphasizes lost or impaired (and restorable) functions of key watershed components (streams, riparian buffers, wetlands, and contributing uplands) within the context of an integrated landscape or ecosystem approach. These functions generally fall into three primary categories: water quality, habitat (both aquatic and terrestrial), and hydrology. These three functional areas are the focus of watershed assessment and restoration efforts associated with the LWP process. The NCEEP has funding to implement specific restoration, enhancement and preservation projects that may receive compensatory mitigation credit.

NCEEP is also seeking to work with local governments (and other agencies or non-profit groups) to fund such projects that are not traditional mitigation projects (e.g., stormwater Best Management Practices (BMPs)), under purview of “flexible mitigation” guidelines provided by pertinent regulatory agencies. As part of the development of LWPs, the NCEEP and its consultants work with local stakeholder groups to recommend feasible watershed solutions, including assistance in identifying possible funding sources for the recommended solutions.

## 1.2 MAJOR TASKS CONDUCTED BY THE WATERSHED ASSESSMENT CONSULTANTS

The NCEEP has retained Stantec to conduct a technical assessment of watershed conditions within the LWP study area of the Lockwoods Folly River and to provide other support services in the development of the final LWP for the study area. Stantec’s support services to the NCEEP for this LWP effort began in August of 2005 and were scheduled to be conducted in four phases as follows:

Phase 1 – Initial Watershed Characterization and Restoration Site Search

Phase 2 – Detailed Watershed Assessment including Modeling, Field Assessment, Water Quality and Biological Sampling, and Stakeholder Involvement

Phase 3 – Identification of Specific Strategies for Watershed Restoration and Protection

Phase 4 – Support for Implementation of Selected Strategies

The first phase of these services was completed in February 2006. The major deliverable for Phase 1 of Stantec’s watershed assessment was a Preliminary Findings Report (Stantec 2006). An overview of what was accomplished during the first phase is in the next subsection. Phases 2 and 3 are the subject of the present document.

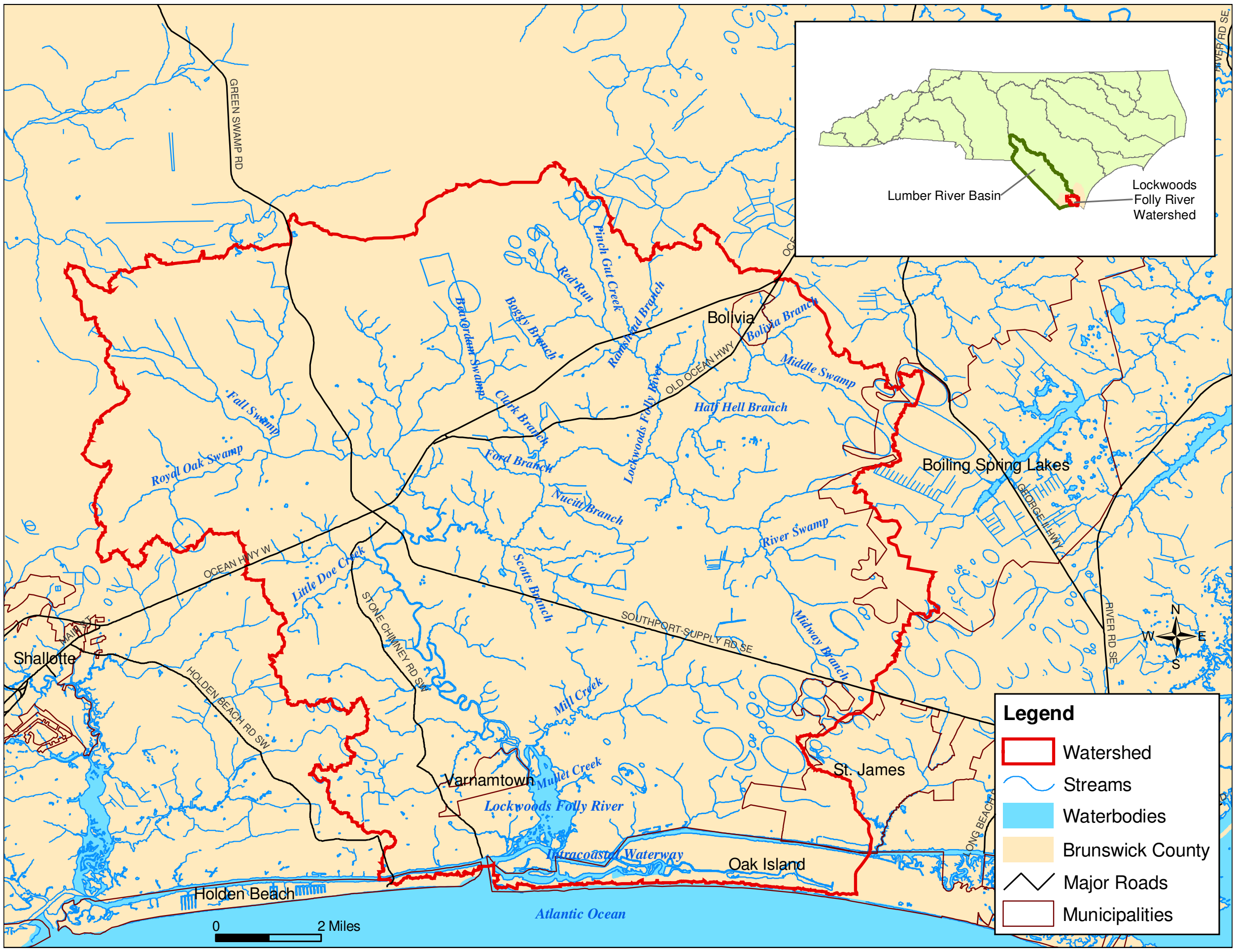


Figure 1.1. Location Map

## 1.3 BACKGROUND AND OVERVIEW OF PRELIMINARY FINDINGS REPORT

The purpose of the first phase of the LWP effort was to characterize the watershed based on pertinent and readily available sources of information from previous and ongoing assessment efforts. Based on that information, the Preliminary Findings Report identified potential key indicators of overall watershed integrity, including water quality, which provided the basis for the detailed assessment phase of the Local Watershed Planning process.

The 153-square mile watershed of the Lockwoods Folly River (Figure 1.1), including portions draining directly to the Intracoastal Waterway (ICWW), has experienced significant growth over the past decade. The growth is expected to continue, increasing the degree of threat to watershed functions from increased nonpoint source pollutant loading and loss of aquatic and terrestrial habitat. Existing stressors identified in the Preliminary Findings Report that required furthered assessment include pathogen loading, stream channelization and erosion, riparian buffer disturbance, wetland loss, and loss of coastal shoreline marsh.

Portions of the watershed are impaired and shellfishing waters are closed due to fecal coliform contamination. Data suggests frequent violations of bacterial water quality standards in the lower portion of the watershed and intermittent levels of high total suspended solids. Nutrient levels did not appear to be a major concern at the present time, but assessment of trends was hampered by the lack of recent data.

Scoping-level assessments of watershed disturbance and future risk suggested low to moderate levels of imperviousness, relatively low risk for stream channel erosion, and some areas where riparian buffer vegetation has been disturbed. Areas in the upper and southeastern portions of the watershed appeared to have the most potential for wetland restoration and enhancement based on remote data sources and limited field reconnaissance.

On the other hand, there are numerous areas containing unique and important natural communities of ecological significance from both regional and national perspectives. The NC Division of Water Quality (DWQ) uses a water quality sampling location on the Royal Oak Swamp, located in the northwest portion of the watershed, as a “least-disturbed” reference site for the ecoregion.

The watershed has been the subject of several special studies by state and federal agencies. Such efforts have resulted in an increased understanding in the local community and among its leaders that the viability of the oyster fishery and the other fragile ecosystem functions in the Lockwoods Folly River and its estuary are severely threatened by the impacts of rapid coastal development. With that understanding the Brunswick County Board of Commissioners teamed with the North Carolina Coastal Federation to obtain a grant from the USEPA in 2004 to form and support the Lockwoods Folly Watershed Roundtable. The Commissioners then appointed a diverse eight-member board of local elected officials, community leaders, environmentalists and developers to serve on the Roundtable. The Commissioners tasked the Roundtable with studying the problems affecting the Lockwoods Folly River and developing a series of recommendations to restore and protect the watershed.

## 1.4 PURPOSE OF DETAILED ASSESSMENT AND TARGETING OF MANAGEMENT

The Detailed Assessment is a comprehensive assessment of all watershed indicators that is used to identify subwatersheds having the greatest functional losses and the greatest risk for future degradation of watershed functions.

Areas with the greatest existing functional losses are targeted for stream and wetland restoration and enhancement, BMP retrofits, and other management efforts to restore watershed functions. Management alternatives identified to address the targeted areas are described in detail and prioritized. To the extent possible, solutions address both local and watershed-scale functions. Potential restoration projects within targeted subwatersheds are ranked using functional assessment results and a variety of criteria including number of landowners, feasibility, landscape position, stakeholder input, and contribution to overall watershed function.

To the extent possible, watershed management scale recommendations as well as identified site-specific BMP opportunities and restoration projects are evaluated with the watershed modeling framework developed for the Detailed Assessment. Whenever possible, opportunities are identified and highlighted to locate multiple BMP retrofits and restoration projects together in high opportunity subwatersheds to achieve additive watershed functional benefits.

## 1.5 STAKEHOLDER INPUT

Shortly after this local watershed plan was initiated, NCEEP and the Lockwoods Folly Watershed Roundtable agreed to team up in the interest of not duplicating effort and leveraging their collective resources toward a more substantial study and outcome. As a result the Roundtable has played a key role in guiding recommendations for the local watershed planning effort. Their work has culminated in the development of management and protection measures to prevent future losses of watershed function and to address local planning and development policy. The results of these efforts are incorporated into the recommended strategies for restoration and protection of the Lockwoods Folly River watershed contained in this document.

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# 2.0 Assessment of Water Quality Functions

The Preliminary Findings Report contained an overview of biological, physical, chemical, and bacteriological data that had been collected in the watershed. Pathogen, nutrient and sediment loading were all identified as stressors and a summary of each follows.

Fecal coliform contamination has been the most important water quality concern in the watershed for more than two decades. Elevated bacteria concentrations are widespread, particularly in the lower half of the watershed (Preliminary Findings Report). According to the NCDENR Division of Shellfish and Recreational Water Quality, in 1980 approximately 16% of the SA waters in the Lockwoods Folly River were closed to shellfishing due to bacterial contamination, whereas currently 55% of SA waters are closed. Current SA waters and the impaired portions of the Lockwoods Folly River are illustrated in Figure 2.1. The portion that remains open is only open conditionally, meaning that it is also closed after significant rainfall events pending testing of contamination levels. Improperly functioning septic systems and stormwater runoff are likely to be major contributors to the current impairment of Lockwoods Folly River.

While pathogen loading has been a persistent problem for many years, future development has the potential to further exacerbate that problem, and increases in stormwater from new development will contribute to higher loads of fecal coliform. Aside from septic systems, development-related sources of fecal coliform include pets, leaking sewer lines, straight piping, and sewer overflows. Wildlife is often an important source of fecal coliform contamination as well.

In addition to fecal coliform, data show that nutrient loading may become a problem. Increases in sediment and nutrient loading can be expected to accompany development in the watershed. The process of constructing roads and buildings can contribute large quantities of sediment to streams through erosion of disturbed soils. Stream channel erosion resulting from increased imperviousness and associated stormwater is another source of sediment.

Pollutants may also accumulate on hardened surfaces such as parking lots and roads. The build up and subsequent wash off of these particles during storms contributes sediment, nutrients, and other pollutants to adjacent water bodies. Another important source of nutrients in urbanizing subwatersheds of the Lockwoods Folly River is fertilizer from lawns and golf courses. Numerous golf courses and planned unit developments are situated along the lower Lockwoods Folly River and ICWW.

Eutrophication of estuaries and coastal waters is common in North Carolina and throughout the Southeast (NOAA, 1996). The estuary formed by the Lockwoods Folly River is vertically mixed and highly irregular in shape with large areas of mud flats and marsh (Evans, 1992). Its shallow depth, low freshwater inflow rates, high salinity, and low tidal range (1.28 m) suggest relatively low flushing rates and an elevated sensitivity to nutrient inputs (USEPA, 2001).

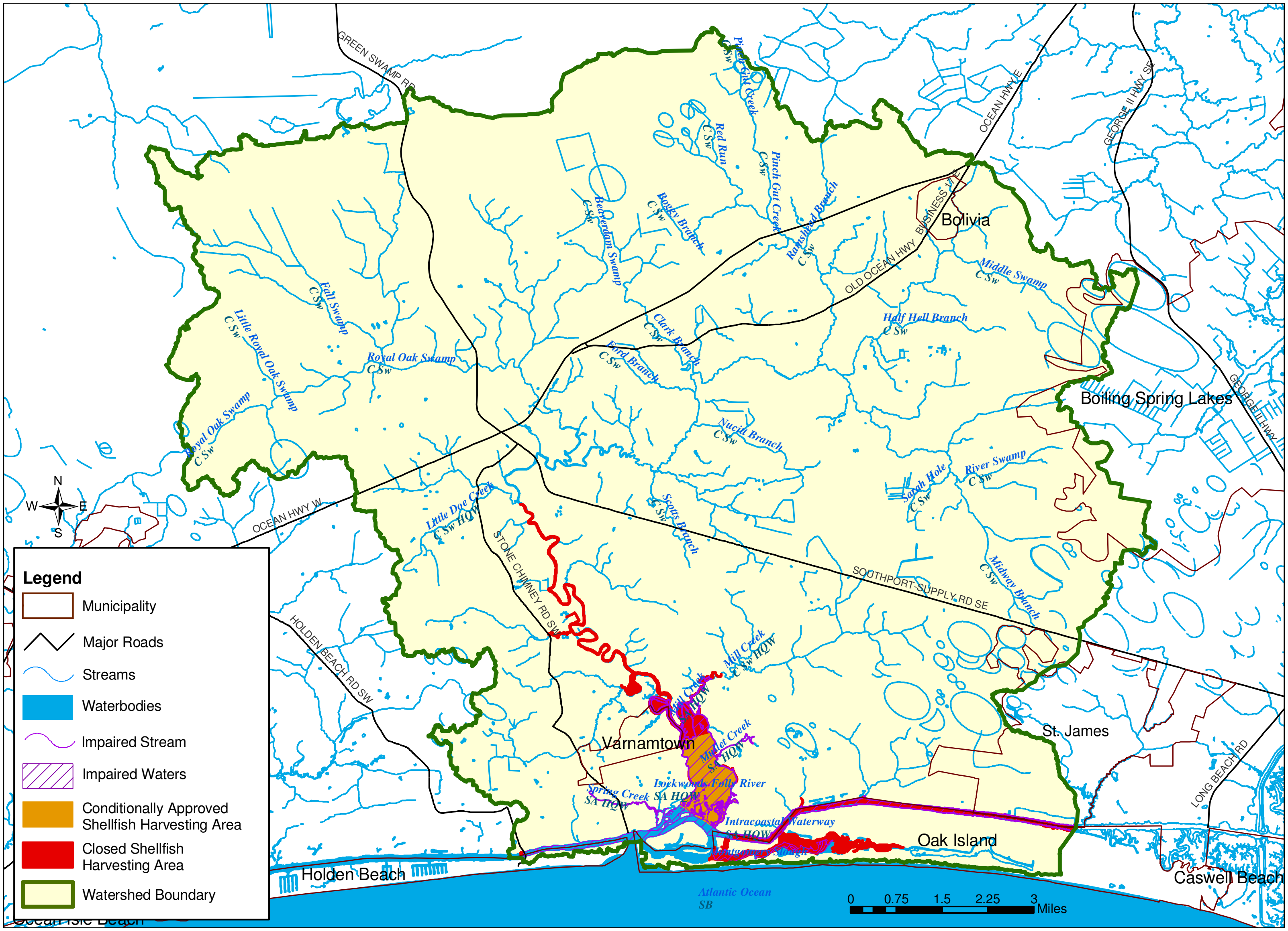


Figure 2.1. Shellfish Harvesting (SA) Waters

While NCDWQ's (2005) analysis of existing data suggests an upward trend in sediment loading near the fast-growing Oak Island, an assessment of the trends in nutrient concentrations is hampered by the lack of nutrient data since 2001.

Growth in population and development and accompanying nutrients will likely be a source of stress in the next decade. Since residence times in the estuary are much greater than algal doubling rates (½ to 1 ½ per day), the Lockwoods Folly River estuary is susceptible to eutrophication from increased nutrient loading. An understanding of baseline conditions and the future threat is an imperative.

The assumptions and conclusions above are based on existing data. In order to improve this understanding of baseline conditions, a tributary and estuary monitoring plan was developed to collect additional water quality data. The additional data led to more informed conclusions about potential stressors in the watershed as discussed later in this report.

A list of the potential stressors to water quality function along with indicators used in their assessment and the tools used to perform those assessments is presented in Table 2.1. Section 2.1 and 2.2 contain the summaries of the assessment techniques, results, and discussions.

Table 2.1. Summary of Indicators and Tools Used for Detailed Assessment of Water Quality Functions

| Watershed Function | Potential Stressor | Indicator | Scale | Assessment Technique |
|---|---|---|---|---|
| Water Quality Functions | Pathogen Loads | Fecal Coliform Loading Rates | Subwatershed | PLOAD Watershed Model |
| | | Fecal Coliform Concentrations | Watershed | Tributary Monitoring |
| | Nutrient Loads | Nitrogen and Phosphorus Loading Rates | Subwatershed | PLOAD Watershed Model |
| | | Nutrient Concentrations and Eutrophic Response | Watershed | Tributary and Estuary Monitoring |
| | Sediment Loads | Sediment Loading Rates | Subwatershed | PLOAD Watershed Model |
| | | Sediment Concentrations and Turbidity | Watershed | Tributary Monitoring |

## 2.1 WATER QUALITY MONITORING

Tributary and estuary monitoring was managed by DWQ Watershed Assessment Team (WAT). A complete copy of the report "Lockwoods Folly River Water Quality Study in support of EEP Local Watershed Plan Development" prepared by WAT can be found in Appendix A (NCDWQ

2007). Following is the executive summary from that report as well as a list of monitoring locations and parameters measured.

### 2.1.1 Data Collection

The Preliminary Findings Report identified 18 sites for water quality monitoring. These sites were a combination of historic and active existing sampling sites as well as six new locations. WAT received this information and performed a site reconnaissance. Two of the historic sites and one new location were eliminated due to accessibility issues and two other sites were added (NCDWQ 2007). Data at ten sites were collected by WAT while the staff from the Wilmington Regional Office sampled at the seven sites that are part of the Ambient Monitoring System (AMS). Data was also obtained from the Department of Health (DEH) shellfish sanitation group for one of the recommended sites as well as thirteen additional sites that are regularly monitored. Monitoring at all 31 sites occurred between April and November 2006.

Parameters measured at sites sampled by WAT, primarily tributaries to Lockwoods Folly River, included fecal coliform, nutrients, metals, suspended solids (total, volatile, and fixed), and field measurements (DO, pH, specific conductance, water temperature, and salinity where appropriate). The seven locations that are part of the AMS are on the mainstem of Lockwoods Folly River, the ICWW (station abbreviation of ICW), and Montgomery Slough. Parameters measured monthly included fecal coliform, turbidity, nutrients, chlorophyll, Secchi depth, and standard field measurements. Nutrient and chlorophyll samples were collected as composites of the photic zone (defined as twice the Secchi depth). The fourteen DEH sites are also located on the mainstem of Lockwoods Folly River, the ICWW, and Montgomery Slough. These sites were sampled for fecal coliform, and salinity and tide stage were recorded. Table 2.1 contains the monitoring locations, agency responsible for sampling, and the parameters sampled. Figure 2.2 shows the spatial distribution of the sampling locations.

Table 2.2. Monitoring Locations

| ***Watershed*** | ***LWP Station Number*** | ***Location*** | ***Sampling Agency*** | ***Field*** | ***Fecal Coliform*** | ***Nutrients*** | ***Chlorophyll*** | ***Residue & Turbidity*** | ***Metals*** |
|---|---|---|---|---|---|---|---|---|---|
| ***Tributaries*** | | | | | | | | | |
| Bolivia Branch | BB01 | Bolivia Branch at SR 1512 | WAT | X | X | X | | X | X |
| Middle Swamp | MW01 | Middle Swamp at SR 1500 | WAT | X | X | X | | X | X |
| Royal Oak Swamp | ROS01 | Royal Oak Swamp at NC 211 | WAT | X | X | X | | X | X |
| Doe Creek | DC01 | Doe Creek at SR 1115 | WAT | X | X | X | | X | X |
| Little Doe Creek | LDC01 | Little Doe Creek at SR 1115 | WAT | X | X | X | | X | X |
| Pamlico Creek | PC01 | Pamlico Creek at SR 1115 | WAT | X | X | X | | X | X |
| UT to Lower Lockwoods Folly River | UT01 | Unnamed Tributary to Lockwoods Folly R at SR 1119 | WAT | X | X | X | | X | X |
| Sandy Branch | SB01 | Sandy Branch off SR 1251 behind Winding River Clear Water Place | WAT | X | X | X | | X | X |
| ***Mainstem Lockwoods Folly River (LFR)*** | | | | | | | | | |
| Upper LFR | LFR02 | Lockwoods Folly R at SR 1501 | WAT | X | X | X | | X | X |
| Middle LFR | LFR03 | Lockwoods Folly R at NC 211 at Supply | AMS | X | X | X | X | X | X |
| | LFR06 | Lockwoods Folly R near Sandy Hill | AMS | X | X | X | X | X | X |
| Lower LFR | MC01 | Mill Creek at SR 1112 | WAT | X | X | X | | X | X |
| | LFR11 | Lockwoods Folly R at Varnamtown | AMS | X | X | X | X | X | X |
| | LFR13 | Lockwoods Folly R at CM R8 DNS of Varnamtown (west channel)/ Shellfish station 5A | SS | X | X | | | | |
| | LFR16 | Lockwoods Folly R, Shellfish station 6A | SS | X | X | | | | |
| | LFR18 | Lockwoods Folly R at CM 5/ Shellfish station 14A | SS | X | X | | | | |

| ***Watershed*** | ***LWP Station Number*** | ***Location*** | ***Sampling Agency*** | ***Field*** | ***Fecal Coliform*** | ***Nutrients*** | ***Chlorophyll*** | ***Residue & Turbidity*** | ***Metals*** |
|---|---|---|---|---|---|---|---|---|---|
| | LFR19 | Lockwoods Folly R at CM R6 NW Sunset Harbor (west channel) | AMS | X | X | X | X | X | X |
| Lower LFR | LFR20 | Lockwoods Folly R, Shellfish station 14B | SS | X | X | | | | |
| | LFR21 | Lockwoods Folly R, Shellfish station 7A | SS | X | X | | | | |
| | LFR24 | Lockwoods Folly R, Shellfish station 7 | SS | X | X | | | | |
| | LFR25 | Lockwoods Folly R, Shellfish station 8 | SS | X | X | | | | |
| ***Atlantic Intracoastal Waterway (ICW)*** | | | | | | | | | |
| Intracoastal Waterway | ICW02 | ICW, Shellfish station 11 | SS | X | X | | | | |
| | ICW03 | ICW at Sunset Harbor | AMS | X | X | X | X | X | X |
| | ICW04 | ICW, Shellfish station 10 | SS | X | X | | | | |
| | ICW06 | ICW, Shellfish station 13 | SS | X | X | | | | |
| | ICW07 | ICW at CM R42 west of Lockwoods Folly R | AMS | X | X | X | X | X | X |
| ***Montgomery Slough*** | | | | | | | | | |
| Oak Island Beach | MS01 | Montgomery Slough at SR 1105 near Long Beach | AMS | X | X | X | X | X | X |
| | MS03 | Montgomery Slough, Shellfish station 24A | SS | X | X | | | | |
| | MS04 | Montgomery Slough, Shellfish station 9 | SS | X | X | | | | |
| | MS05 | Montgomery Slough, Shellfish station 9A | SS | X | X | | | | |
| | MS06 | Montgomery Slough, Shellfish station 16 | SS | X | X | | | | |

WAT = Watershed Assessment Team; AMS = Ambient Monitoring System; SS= Shellfish Sanitation Program

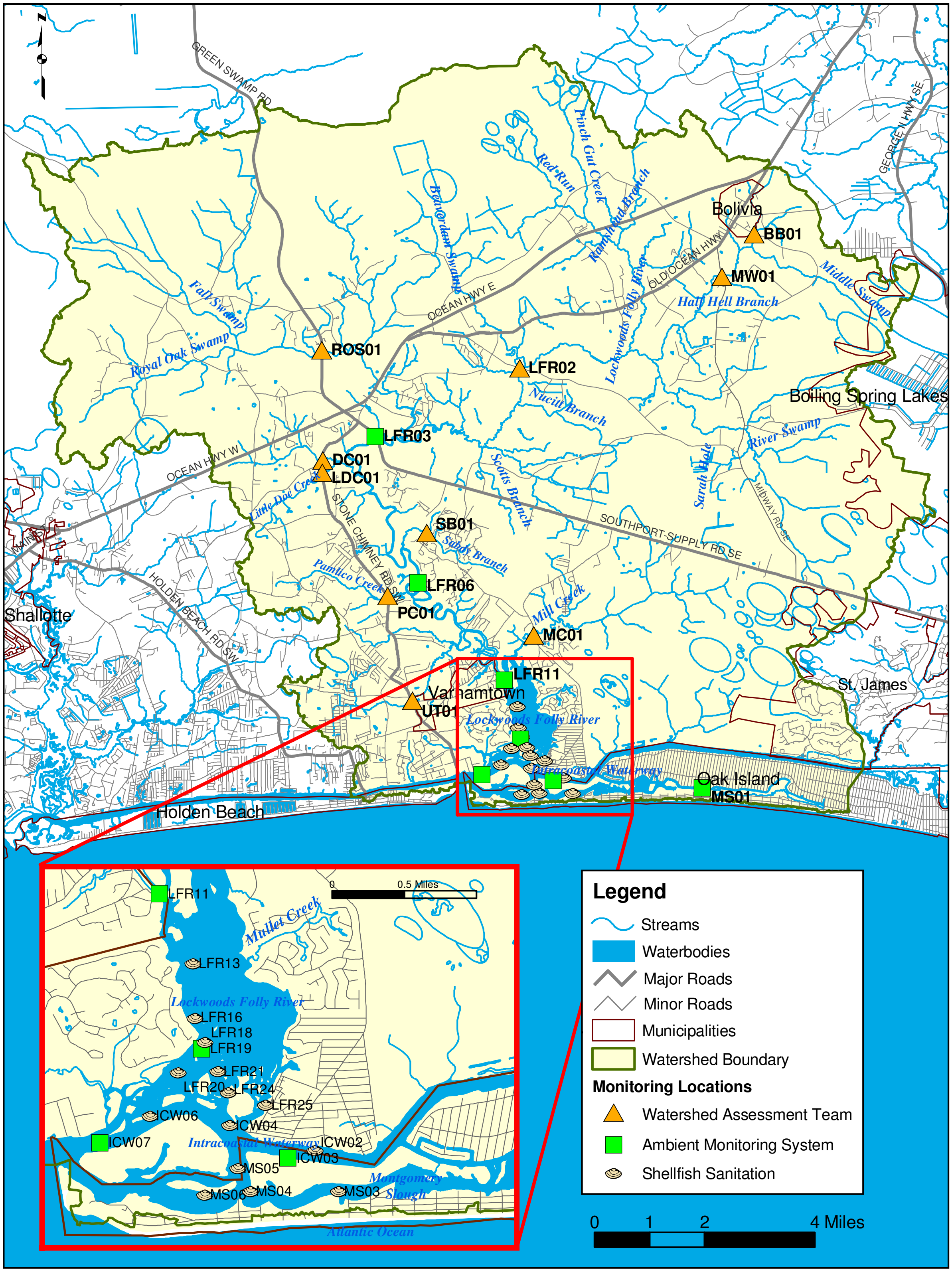


Figure 2.2. Monitoring Locations

### 2.1.2 Monitoring Data Summary

The following summary is taken from "Lockwoods Folly River Water Quality Study in support of EEP Local Watershed Plan Development" report created by WAT (NCDWQ 2007).

Fecal coliform has historically been the concern in the lower Lockwoods Folly R, ICW, and other tidal tributaries. These areas are protected for shellfishing uses, but have been closed to this use due to bacteria counts above North Carolina (NC) state water quality standards. In this study, half of the twenty sites that are protected for shellfishing had median concentrations over the screening value of 14 colonies/100 mL. The medians at these locations ranged from 17 to 80 colonies/100 mL. Included are four out of the five sampling locations on Montgomery Slough, with the highest concentrations found furthest upstream (median = 80). At this location five of seven samples exceeded the single sample screening value maximum of 43. High values were also noted on Mill Cr, a tidal saline tributary to the lower Lockwoods Folly R, with a median value of 55 colonies/100 mL and six of eight samples exceeded 43.

For the freshwater tributaries, Little Doe Cr and Sandy Br showed the highest geometric means (377 and 321 colonies/100 mL, respectively), which were well above the screening value of 200 colonies/100 mL for non-shellfishing waters. Pamlico Cr, a tidal and slightly saline tributary, showed the highest geometric mean of all sampling locations (477 colonies/100 mL).

Ammonia ($NH_3$) concentrations were highest in the tributaries and ranged from 0.02 to 0.17 mg/L as N. Bolivia Br showed the highest mean value (0.17) but this is likely due to a point source discharger. Lower values (0.02-0.04 mg/L) were seen in the Lockwoods Folly R mainstem, the ICW, and in two tributaries with unusually high flow (Little Doe Cr and Sandy Br). Mean nitrate + nitrite ($NO_2$+$NO_3$) levels were generally low throughout the entire Local Watershed Planning area (0.02-0.04 mg/L) with the exception of Bolivia Br (0.12 mg/L), again likely due to the point source discharge. Mean total Kjeldahl nitrogen (TKN) values by watershed ranged from 0.37 to 0.99 mg/L as N. The higher values were generally in the swamp stream tributaries (including Pamlico Cr with a mean of 0.99), though the Oak Island watershed (Montgomery Slough) and Sandy Br had unexpectedly high values. Mean total phosphorus ranged from 0.04-0.12 mg/L as P. The highest mean values were seen in Pamlico Cr and Oak Island watersheds (0.12 mg/L for both). A comparison of nutrient data collected at six locations from 1989- 2001 to the nutrient data that was collected in 2006 showed statistically significant increases in total phosphorus at four locations, increases in nitrate + nitrite at three locations, and an increase in TKN at one location.

Though the majority of chlorophyll-*a* samples showed relatively low values, results from two of six samples from Oak Island were above the NC water quality standard of 40 µg/L. Two other locations in the Middle Lockwoods Folly each had a single sample exceeding the standard. Three of these sampling events also showed increased turbidity levels, with two above the NC water quality standard of 25 NTU for saltwater. Two of these sampling events also showed low Secchi depths. A review of all data from these stations showed that high phosphorus and TKN results for each of these stations coincided with the exceedences of the chlorophyll water quality standard.

Dissolved oxygen concentrations were low at the many sites, likely due to natural swamp conditions. Sandy Br was unusual for its relatively high, stable DO concentrations (5.5-6.2 mg/L) throughout the study period.

Very limited benthic macroinvertebrate data were available for the study area. Royal Oak Swamp is regularly monitored by the DWQ Biological Assessment Unit (BAU) and has shown few changes over its sampling history (1998-2006). It has consistently received a bioclassification of “Natural”, though Plecoptera (stonefly) species, which are taxa that are generally intolerant to water quality stressors, were absent in the latest sample. The Lockwoods Folly River was sampled in 2006 for comparison to previous BAU estuarine benthos samples in 1999. Both of these samples received a bioclassification of “Slight Stress”, which may be more attributable to wide salinity swings than to water quality issues (DWQ 2007).

### 2.1.3 Water Quality Monitoring Conclusions

Taken collectively, these data illustrate that most of the watershed exhibits relatively good water quality, which is not surprising given that the bulk of the watershed remains undeveloped at this time (refer to Figure 2.2). However, the water quality limits for fecal coliform set forth to protect shellfishing waters are quite stringent and subject to violation from even the slightest increases in loading at a watershed scale. The data also clearly illustrates that the highest fecal coliform loads emanate from developed portions of the watershed, particularly in Montgomery Slough, Mill Creek, Little Doe Creek, Sandy Branch and Pamlico Creek. Unfortunately the data did not provide a clear enough distinction between base flow and storm event concentrations that would have supported some inference regarding the degree of partitioning between on-site septic system loads and stormwater runoff loads of fecal coliform.

The trends and occurrences regarding nutrient loads and eutrophication potential illuminated by the monitoring effort are of particular concern for the future well being of the Lockwoods Folly River ecosystem. While not conclusive, the significant increases in nutrient loads shown in current data relative to data from 1989 to 2001 and the chlorophyll-*a* spikes above the state water quality standard should raise a warning flag that the Lockwoods Folly River estuary holds a realistic potential for excess nutrient loading and associated algal blooms that can be highly detrimental to coastal river systems.

### 2.1.4 Additional Conclusions

Turbidity and suspended solids monitoring results can be used to indicate widespread sediment issues within a watershed. A watershed like Lockwoods Folly that is relatively undisturbed is not likely to have a widespread problem. Sediment issues are more likely localized in areas where the buffer has been disturbed or there is land disturbance such as that associated with construction. In addition there may be historical sediment issues related to poorly managed logging or agricultural operations. These issues are better identified by assessing sediment levels in streams throughout the watershed. The Coastal Plain Stream Assessment, discussed in section 3.1, was used to assess sediment at 120 sites throughout the watershed.

Visual observations were also made while traveling through the watershed. Sediment is most often an issue around areas that have been cleared for new construction. Many roadside drainageways in these areas had sediment buildup.

## 2.2 WATERSHED MODELING

One of the primary benefits of combining NCEEP's local watershed planning effort with those of the Watershed Roundtable was that the NCEEP project team brought with them the capability and the financial resources necessary to support development of a watershed loading model. The modeling analysis was then utilized not only to support targeting of NCEEP's watershed restoration efforts, but to examine a series of "what if" scenarios to evaluate the benefits and effectiveness of the Roundtable recommendations. Results from the watershed model as well as a synopsis of the approach and scenarios are discussed in this section. A detailed discussion of how the model was set up, development of input data, limitations, and assumptions is in Appendix B.

It should be noted that the predicted pollutant loads from PLOAD represent loading at the source and do not take into account transport and decay as the pollutants travel to the estuary. In addition, the results are based largely on inputs obtained from monitoring studies conducted elsewhere as sufficient monitoring of source loading is not available in this watershed. The actual loading could be more or less. The primary benefit and appropriate use of the model is to evaluate relative difference in pollutant loading by scenario as well as identify areas of greater (or lesser) loading within each scenario.

### 2.2.1 Technical Approach

The water quality evaluation tool chosen for use in the Lockwoods Folly watershed is the PLOAD model developed by CH2M HILL for the USEPA (2001). The tool is a simple, screening-level model that can provide estimates of nonpoint source pollutant loading on an annual average basis. This tool allows for an evaluation of the relative magnitude of change in pollutant loading associated with various future scenarios. In addition, results can be used to target management measures to those areas with the highest existing and/or future pollutant loading.

The model estimates pollutant load as a product of annual runoff volume and pollutant concentration in aggregate for a given watershed area. Runoff volume is calculated from annual rainfall and runoff coefficients based on its relationship to watershed imperviousness. Pollutant concentrations are typically estimated from local and regional data. As with all modeling approaches, there are limitations that should be considered when evaluating results from the PLOAD model analysis. Its purpose is to provide a general planning estimate of likely pollutant export from delineated regions of a watershed. This model is appropriate for assessing and comparing the changes in relative stormflow pollutant loads from various land use scenarios. The error associated with predicting actual pollutant loads and concentrations using this tool is unknown and could be considerable.

The 64 subwatersheds created for the Preliminary Findings Report were segmented into 136 subwatersheds with an average size of 1.13 square miles (Figure 2.3). Inputs include precipitation, land use, impervious factors, event mean concentrations (EMC), and contributions from septic systems. An average annual precipitation of 56.6 inches was used based on 49 years of record at nearby Southport, NC. Land use scenarios were created for existing conditions as well as a number of future conditions, explained further in the following section. Impervious cover factors were selected based on literature for each land use (Appendix B Table E.3 and E.4). The impervious factor is used to calculate a runoff coefficient, which when applied to a rainfall volume yields a corresponding runoff volume.

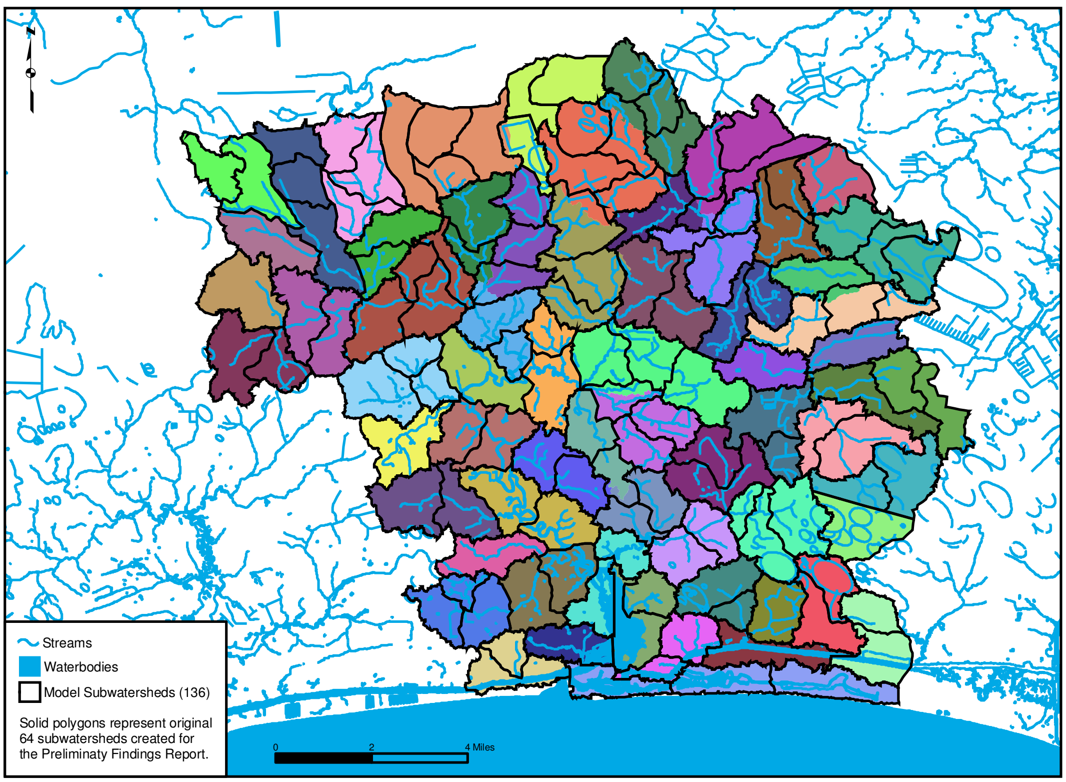


Figure 2.3 Old and New Subwatershed Delineations

EMCs represent the average concentration of a pollutant in stormwater runoff and are affected by land use, annual rainfall, percent imperviousness, season, sample collection method, watershed size, and storm event size. EMCs for fecal coliform, nitrogen, phosphorus, and total suspended solids (TSS) were derived from a number of literature sources. These numbers were adjusted for each model scenario (section 2.2.2). Each subwatershed contains a point source in the model to represent loading from septic systems which occurs year round with transport occurring during both storms and baseflow through leaching, interflow, and for ponded systems, via overland flow. The loading value is based on contributions from properly functioning and failing septic systems and takes into account the number of systems in a subwatershed, the average number of people per system, septic failure rates, and an average pollutant loading value associated with each person.

### 2.2.2 Model Scenarios

Five scenarios were simulated with the model, including an existing scenario and four future scenarios. The existing scenario incorporated existing land use which was created using the 2004 Brunswick County existing land use map, aerial imagery and parcel data (Figure 2.4 Existing Land Use). The land uses were assigned to 15 categories as shown in Table 2.3. The existing scenario also accounted for development regulations contained within the coastal stormwater management program including the requirement that 1) development with built-upon area greater than 25% and within one-half mile of and draining to SA waters or unnamed tributaries to SA waters and 2) development with built-upon area greater than 30% anywhere in the watershed have stormwater best management practices (BMPs) implemented to treat runoff from land uses. A reduction factor was applied to the EMC value to account for these mandatory stormwater BMPs.

A baseline future land use scenario was created, using the same categories as in the existing land use scenario, from the Brunswick County future land use map (Brunswick County 2006B), future land use maps from the towns of Bolivia, Varnamtown, and St. James and written communication from Oak Island (Figure 2.5 Future Land Use). Other additional sources of information included the County zoning map, the NC211 Corridor Study (Brunswick County 2006A), and the Indirect and Cumulative Impact Assessment Technical Memorandum (NCDOT 2001) for the second bridge to Oak Island. This scenario accounted for new stormwater regulations that would require treating runoff from 1) development with built-upon area greater than 12% and within one-half mile of and draining to Shellfish Resources Waters (essentially SA waters) and 2) development with built-upon area greater than 24% anywhere in the watershed. It was assumed that one or more BMPs would be implemented to treat runoff from land uses with imperviousness that exceeds the limits. A reduction factor was applied to the EMC values to account for the BMPs. The intent of this baseline future scenario was to predict the increases in pollutant loads that would result from new development within the 20-25 year planning horizon if no new management measures other than those currently in place were enacted.

The baseline future scenario also took into account the availability of sewer service to new and existing development. The future sewer service area was determined based on input from Brunswick County. Currently, all new development must put in sewer infrastructure. Existing developed areas that will connect to the sewer system in the next few years include the rest of Oak Island, Holden Beach, and Supply. EMC values were adjusted in the future scenarios to reflect the use of sewer and the decrease in septic systems. As it is unknown when other areas of existing development may connect they were not shown as having sewer in the future scenarios.

Table 2.3. Land Use and Percent Imperviousness

| Land Use Category | Percent Impervious | Model Code |
|---|---|---|
| High Density Residential Lots (0.07 - 0.22 acres) | 33 | RHD |
| Medium Density Residential Lots (0.23 - 0.33 acres) | 25 | RMD |
| Low Density Residential Lots (0.34 – 0.99 acres) | 17 | RLD |
| Very Low Density Residential Lots (1 – 5 acres) | 9 | RVL |
| Commercial/Heavy Industrial | 72 | COM |
| Office/Institutional/Light Industrial | 53 | OFF |
| Roadways (w/ right-of-way) | 63 | ROAD |
| Barren Land [1] | 32 | BARE |
| Managed Open Space [2] | 9 | OPN |
| Golf Course [2] | 9 | GOLF |
| Pasture [3] | 2 | PAS |
| Row Crop [3] | 2 | ROW |
| Forest [3] | 2 | FOR |
| Wetland [3] | 2 | WET |
| Water [4] | 90 | WAT |

1 Assumed imperviousness equal to that of a high density residential lot.

2 Based on the assumption that open space in fair condition has about the same runoff response as a low density residential lot (curve numbers are similar in SCS, 1986).

3 Based on example data set in PLOAD manual.

4 Assumes most rainfall on a water body flows to a downstream receiving water.

The three alternate future scenarios are based on the above baseline future scenario with the addition of low impact development (LID). LID is a site design strategy that seeks to minimize runoff and maintain the predevelopment hydrologic regime through the use of BMPs and landscape design techniques. LID development typically uses filtering and infiltration practices such as bioretention, sand filters, and vegetative swales. These practices can have reduction efficiencies greater than many structural practices like wet ponds and stormwater wetlands for many constituents. The first alternate future scenario assumes half of new residential development in the future will be developed using LID. The second alternate assumes all future residential development categories except the "very low density residential" category would be designed using LID techniques. The third alternate uses the assumptions from the second alternate and adds preservation of approximately 10% of the land that would otherwise be developed in an undeveloped state. The EMC values were adjusted by a reduction factor for these scenarios.

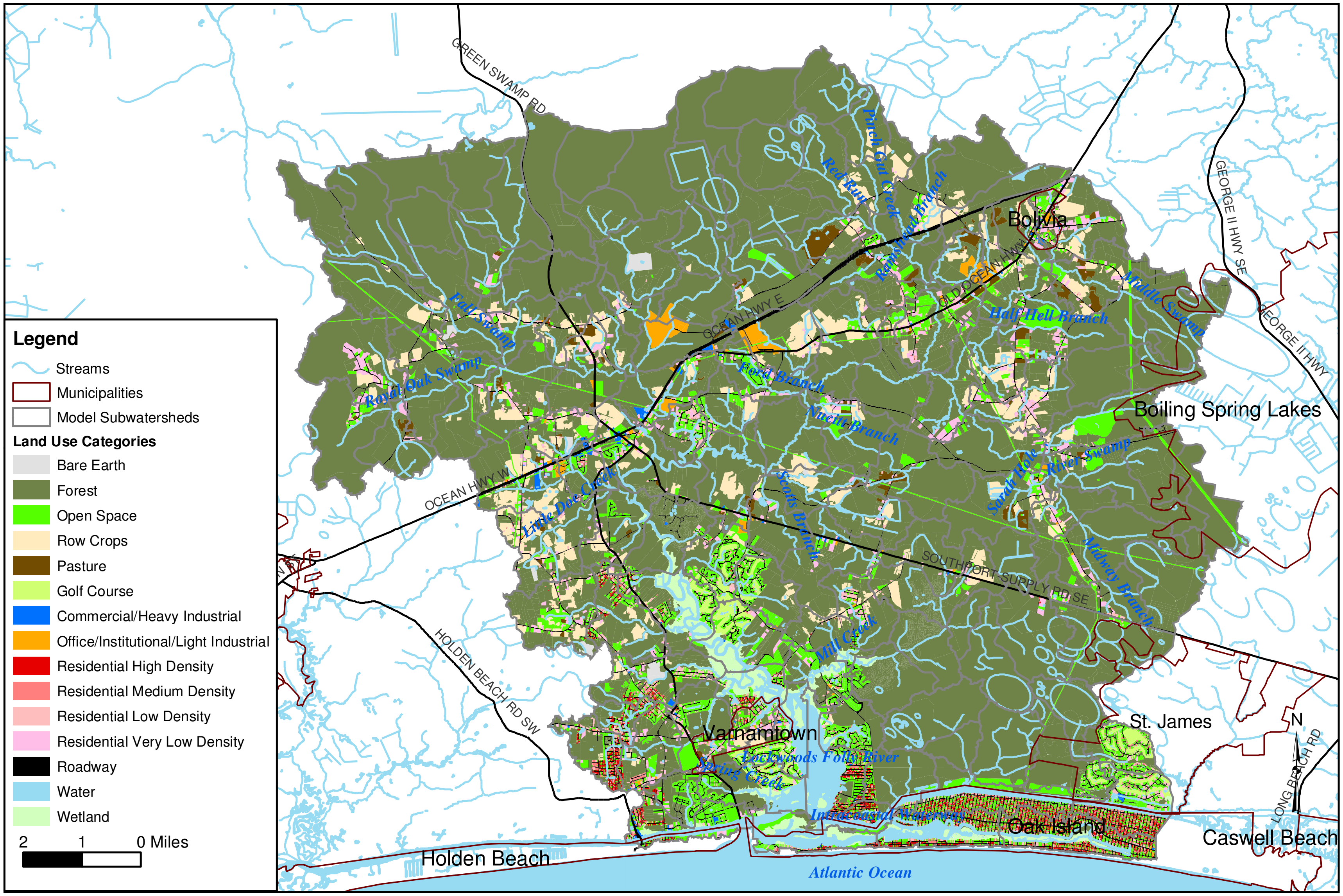


Figure 2.4. Existing Land Use

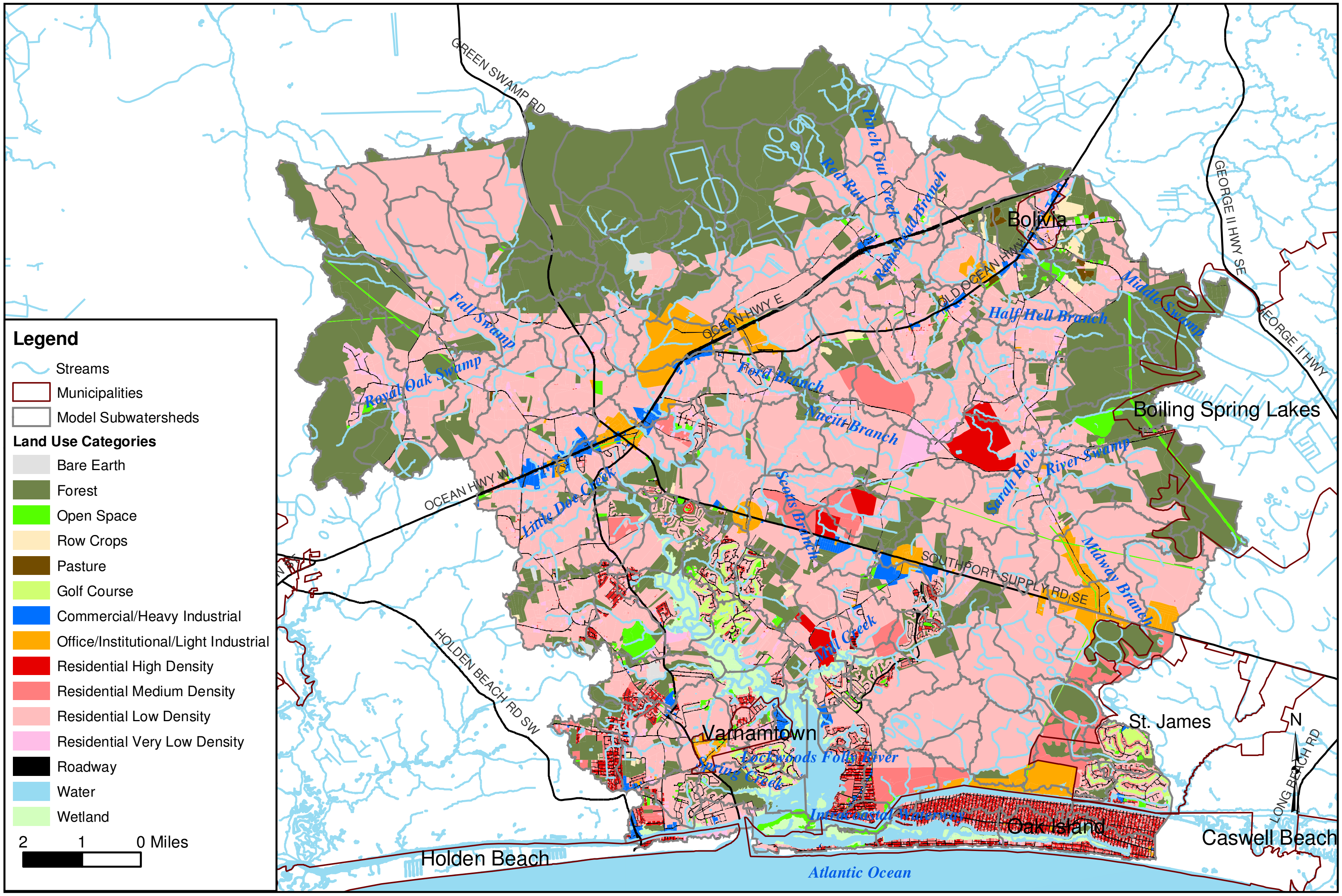


Figure 2.5. Future Land Use

### 2.2.3 Results

A summary of the results from five model scenarios is provided in Figures 2.6 and 2.7. In the baseline future scenario, increases in pollutants ranged from 81 to 360 percent. The LID scenarios lessened these increases to varying levels depending on the scenario (Table 2.4). In the case of TSS, the LID 100% scenarios resulted in levels of loading that were less than existing loading. This occurred because the assumed loading values selected for natural covers (such as forest) are slightly greater than the assumed loading value for LID treated development.

Based on the assumptions described earlier for septic systems, the model predicts that septic loads of nitrogen, phosphorus, and fecal coliform comprise 5%, 3%, and 20% of total loading under existing conditions. These percentages decrease to 3%, 2%, and 5% of total loading under the future-base scenario, because stormwater derived loading contributes a much larger percentage to the total once the watershed is mainly sewered and development occurs.

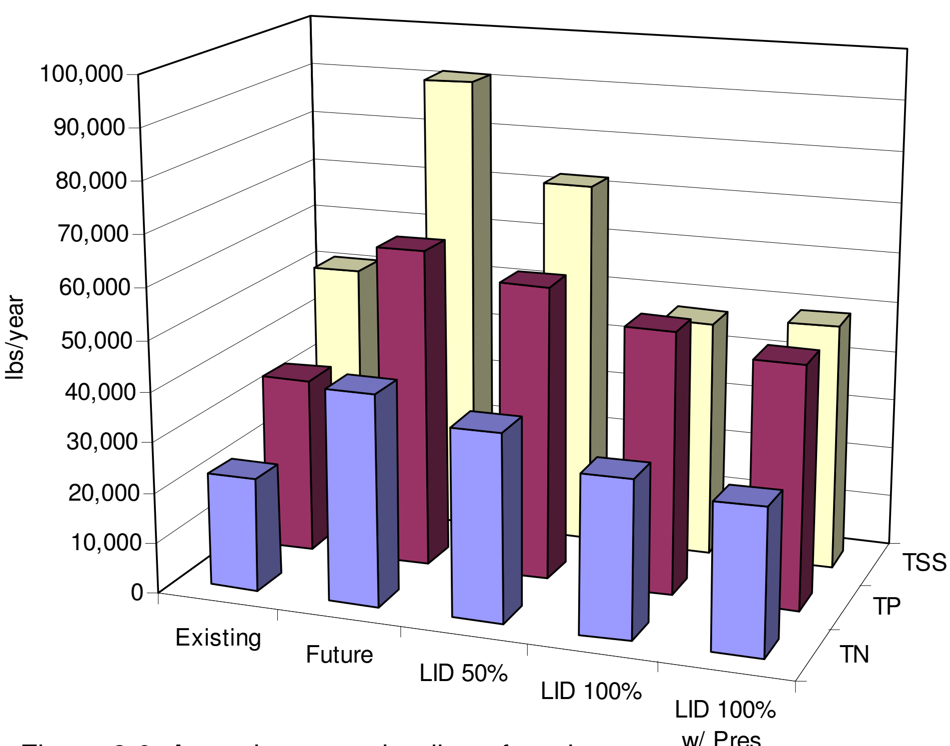


Figure 2.6. Annual average loading of nutrients and sediment totaled over the watershed

Fecal coliform loading is one of the most important parameters in this system given the current estuarine impairment and shellfish water closures. Although the LID 100% plus 10% preservation scenario led to the smallest increase in fecal loading, it was still an increase of 149% (Table 2.4 and Figure 2.7). The increases in loading for all future scenarios illustrate the difficulty of developing a coastal watershed while also protecting, and in this case restoring, its shellfish waters. However, there are additional reductions which may be achieved through management efforts not taken into account by the various modeling scenarios. For instance, the modeling analysis did not account for pollutant load reductions that may be achieved through (1) application of LID to non residential land use categories including commercial and institutional lands as well as roadways (together accounting for approximately 14% of land use in the future scenario), (2) application of LID to very low density residential development (with less than 12% imperviousness), (3) retrofitting of stormwater BMPs to existing areas of development and (4) restoration of streams and wetlands within the watershed. Though it should be noted that, even if efforts are made to take full advantage of all of these opportunities, it is likely that exerting the full extent of development currently planned for the Lockwoods Folly watershed within the next 20-25 years will still result in some increases in fecal coliform loading relative to existing loads.

Table 2.4. Increases in pollutant loading of four future scenarios over the existing land use scenario

| | Total N | Total P | TSS | Fecal Coliform |
|---|---|---|---|---|
| Future | 86% | 81% | 79% | 360% |
| LID 50%[1] | 65% | 67% | 41% | 292% |
| LID 100%[2] | 38% | 49% | -8% | 202% |
| LID 100% w/ Preservation[3] | 27% | 38% | -5% | 149% |

1 LID practices applied to approximately half of all residential development > than 12% imperviousness.

2 LID practices applied to residential development > than 12% imperviousness.

3 LID practices applied to residential development > than 12% imperviousness + 10% preservation.

Figures 2.8 through 2.12 provide color ramp graphics of predicted fecal coliform loading by subwatershed. Areas of high and low loading can be observed and compared between scenarios as the same five ranges are used in each one.

The lightest yellow category in the fecal coliform maps represents an approximate background level of loading expected from natural sources of wildlife with a daily loading rate that ranges between 4.9E+06 to 3.1E+07 counts/acre. This is comparable to a rate of 1.87E+07 counts/acre which was calculated assuming deer as the primary wildlife source, 5.0E+08 counts/acre as the value for sources of fecal coliform from deer (USEPA 2002), and an estimate of the density of deer for the area (0.035 per acre from NC Wildlife Resources Commission). The darkening of the colors between subwatersheds and scenarios represents the potential impact of development on fecal coliform loading beyond that associated with natural sources.

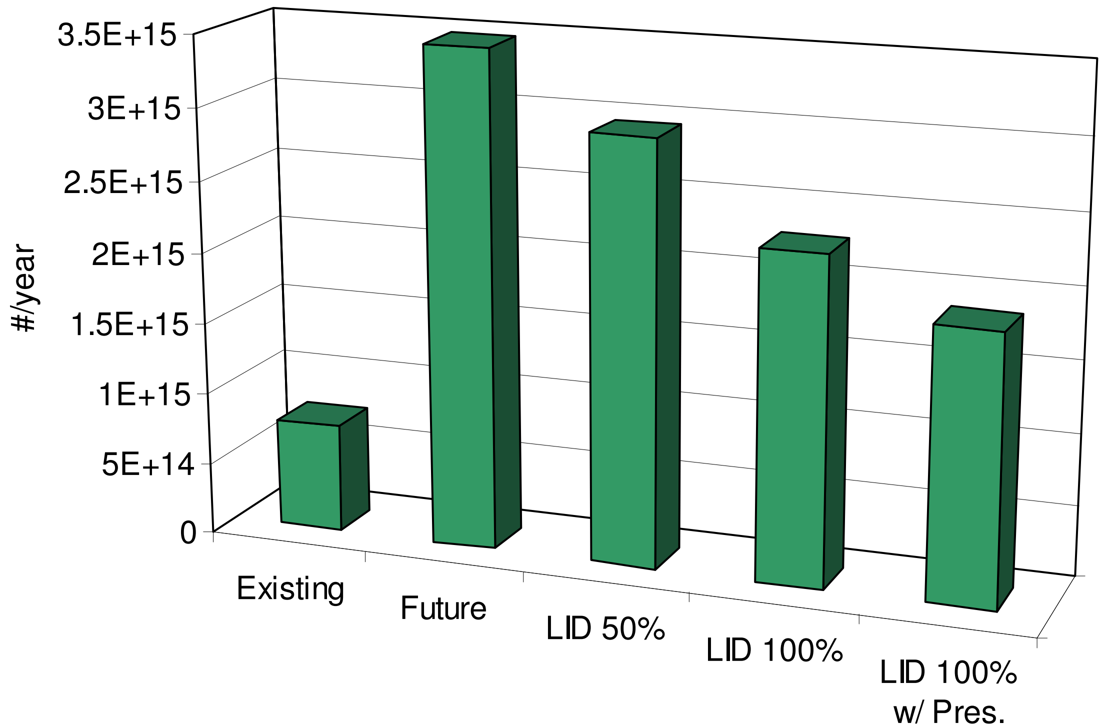


Figure 2.7. Average annual loading of fecal coliform

Under the existing fecal coliform scenario, the higher loading rates occur near the shorelines where development has already occurred. As the watershed continues to build out, new sources of pollutant loading emerge throughout the watershed. The increase in loading is seen in most of the subwatersheds as development is expected to occur throughout the area. The different alternative future scenarios help decrease the fecal load shown in the future scenario in many of the subwatersheds except for those that already have high existing loading. For example, subwatershed OI1c located on Oak Island may experience a decrease in fecal loading once it has sewer service. On the other hand, fecal loads may increase as parcels continue to be developed.

Figures 2.13 through 2.17 provide subwatershed results for nitrogen loading. For comparison purposes, existing stormwater regulations in the Neuse and Tar-Pamlico River Basins require a loading cap of 3.6 lbs/ac/yr for new development. As seen with the fecal coliform results, nitrogen loading in the existing scenario is highest along or near shorelines where most of the development has occurred to date. According to the categories used to display the model results, four of the six shades of green are above the stated loading cap. Future loading rates increase throughout the watershed as seen with the fecal loading since development is proposed in much of the area. Results for both total phosphorus and total suspended solids are not shown graphically, though the spatial trends are nearly identical to that of nitrogen.

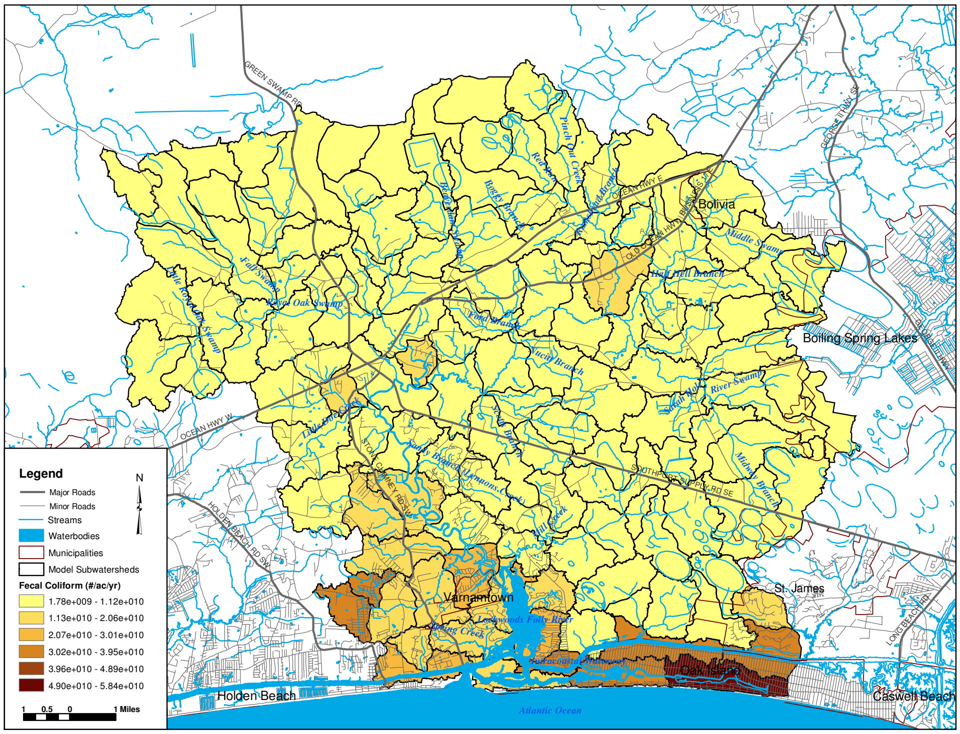


Figure 2.8. Fecal coliform model results for the existing land use scenario.

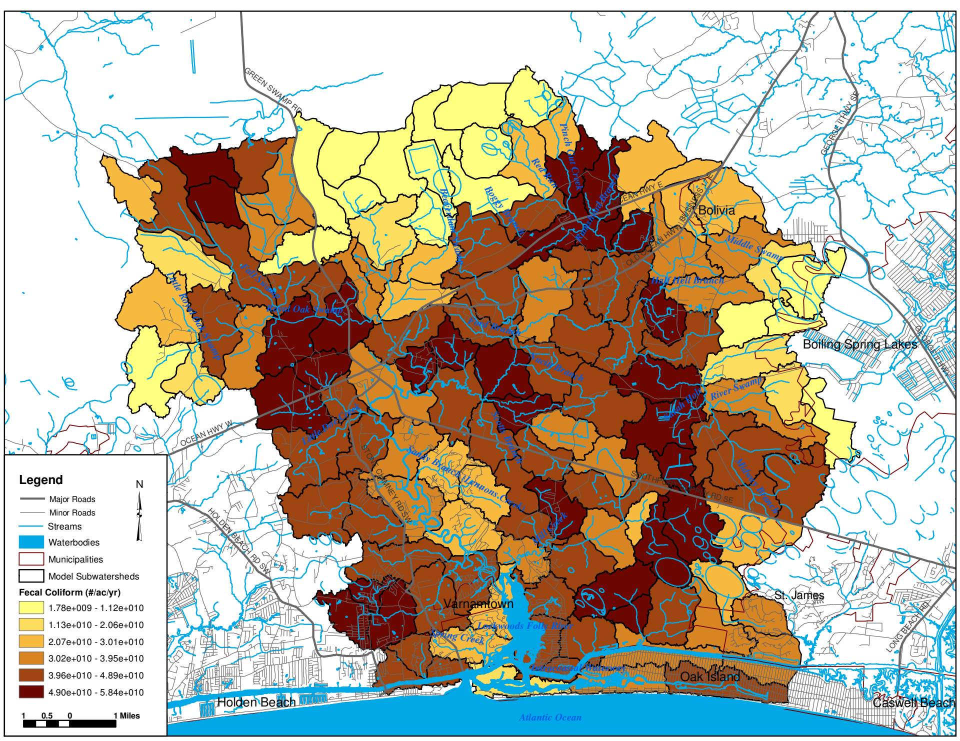


Figure 2.9. Fecal coliform model results for the future-base land use scenario.

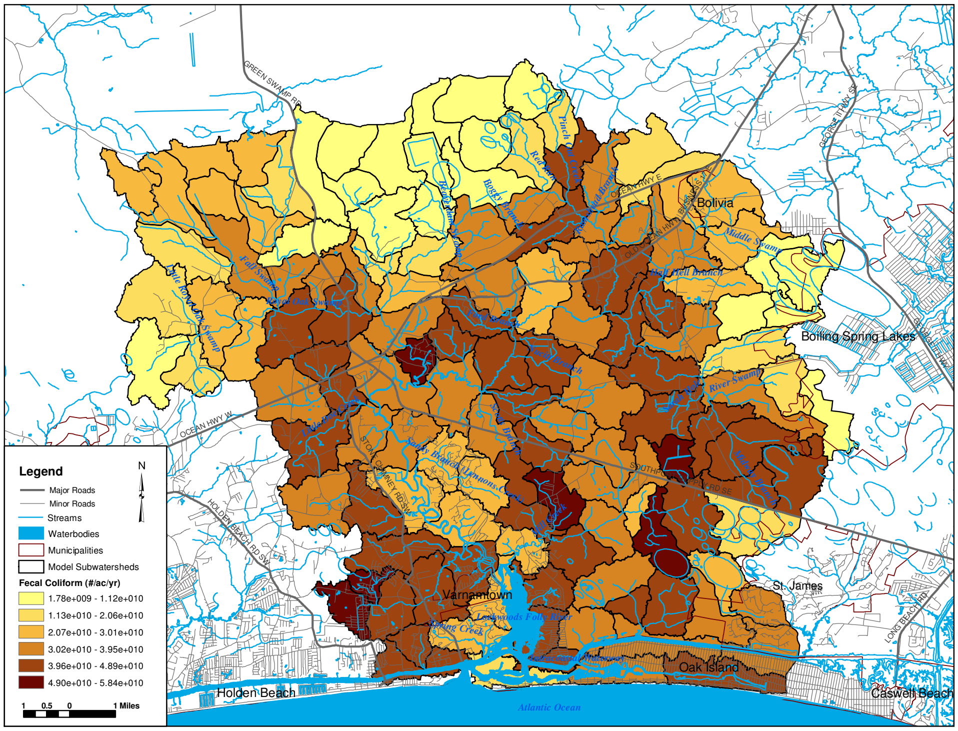


Figure 2.10. Fecal coliform model results for the future - LID 50% land use scenario

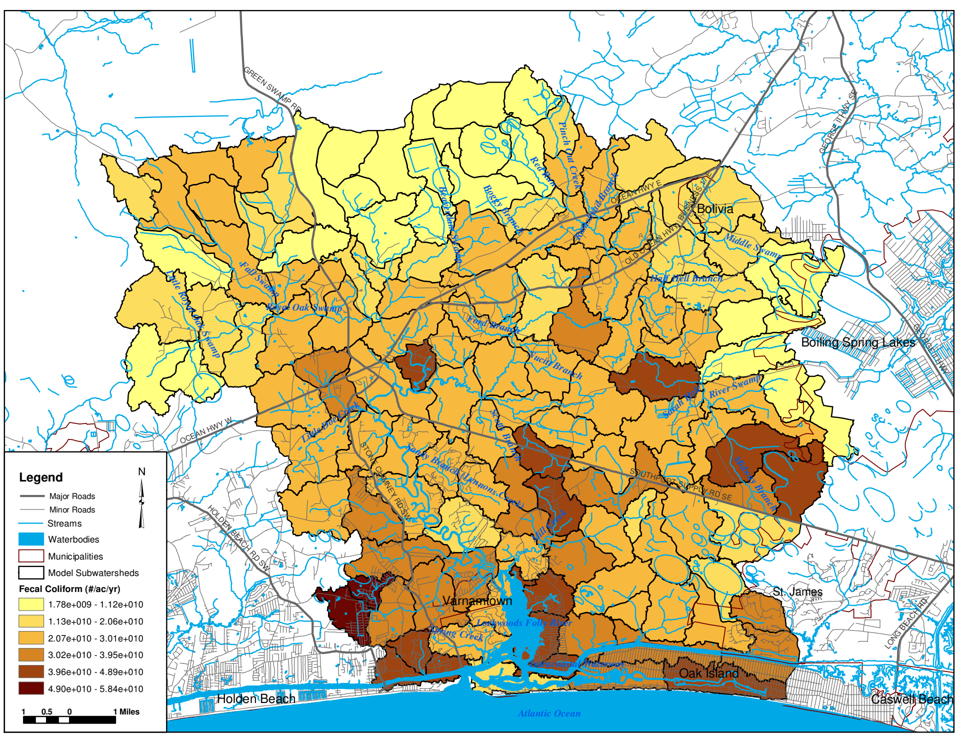


Figure 2.11. Fecal coliform model results for the future - LID 100% land use scenario

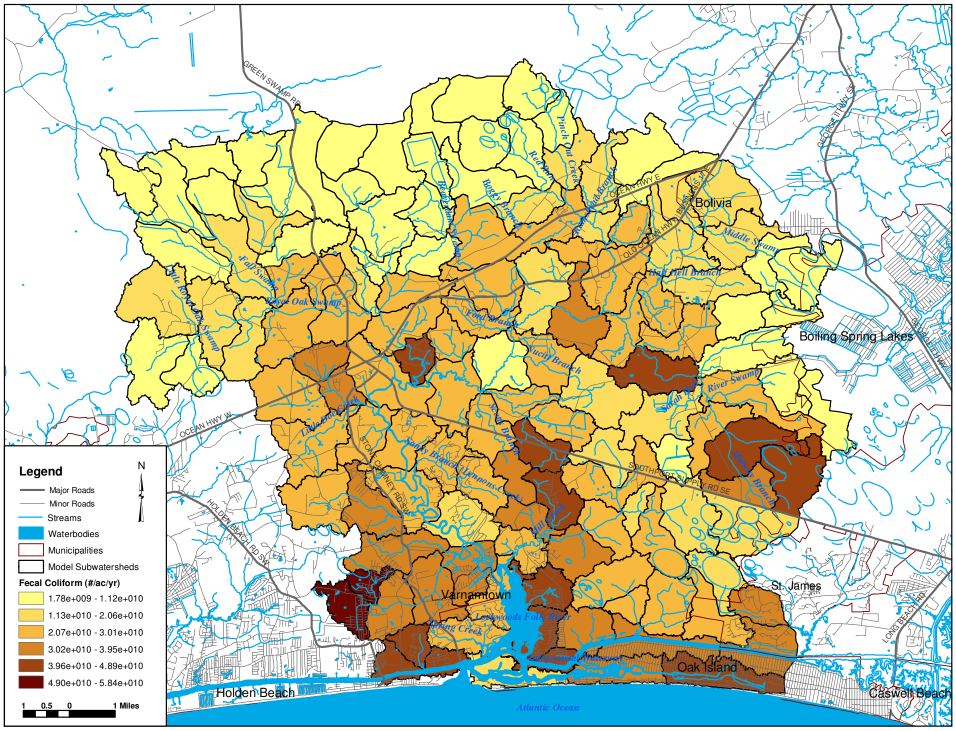


Figure 2.12. Fecal coliform model results for the future - LID 100% + 10% preservation scenario

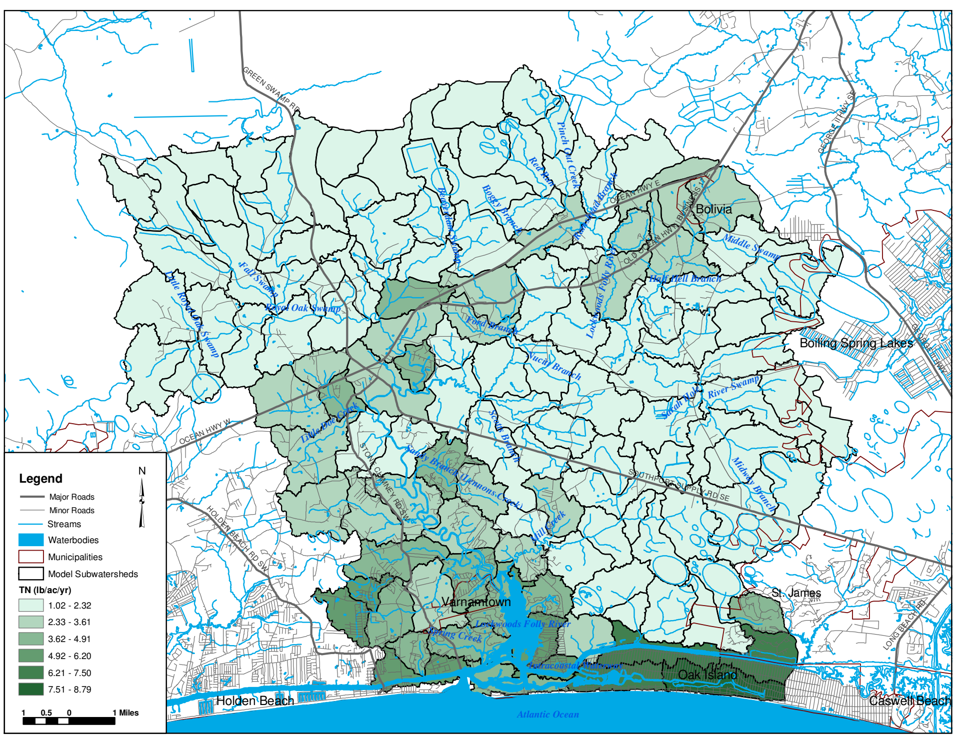


Figure 2.13. Total nitrogen model results for the existing land use scenario

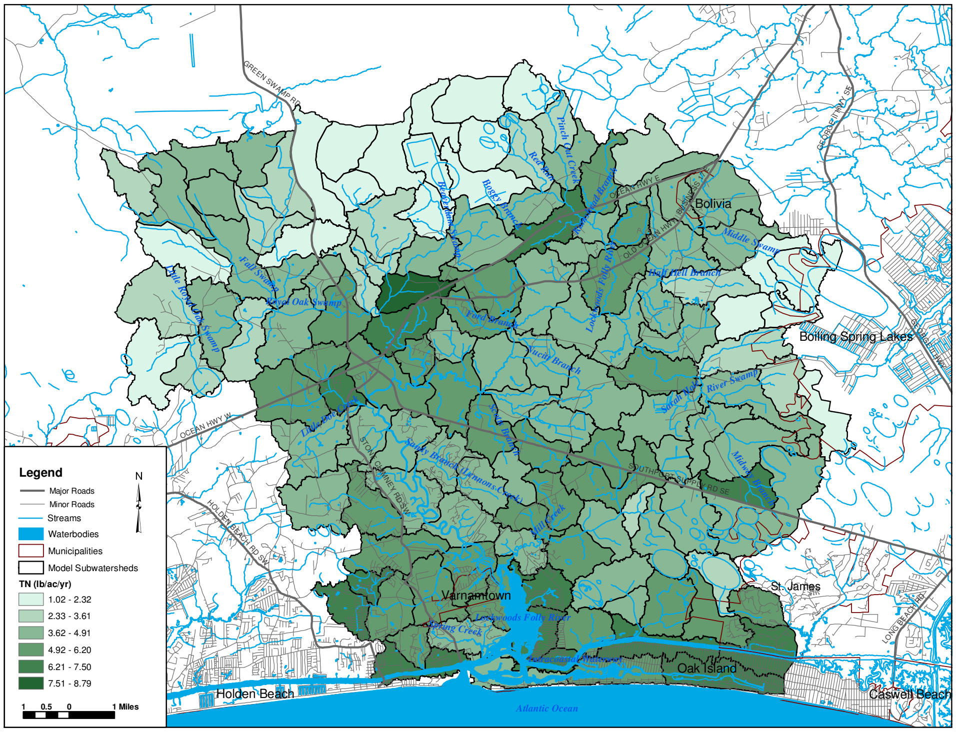


Figure 2.14. Total nitrogen model results for the future-base land use scenario

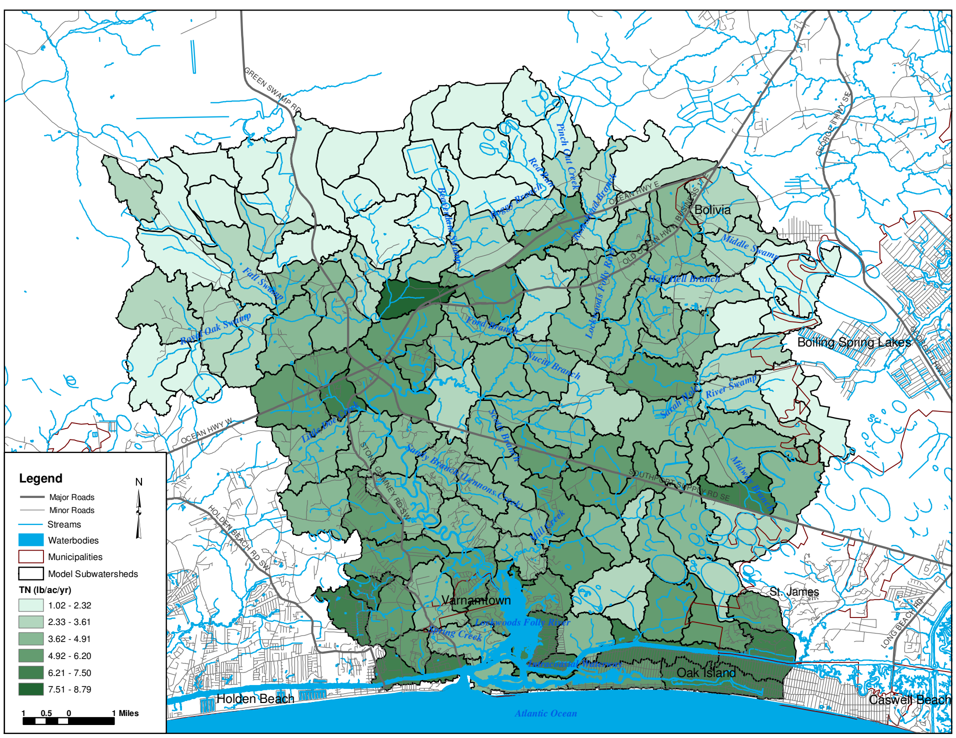


Figure 2.15. Total nitrogen model results for the future - LID 50% land use scenario

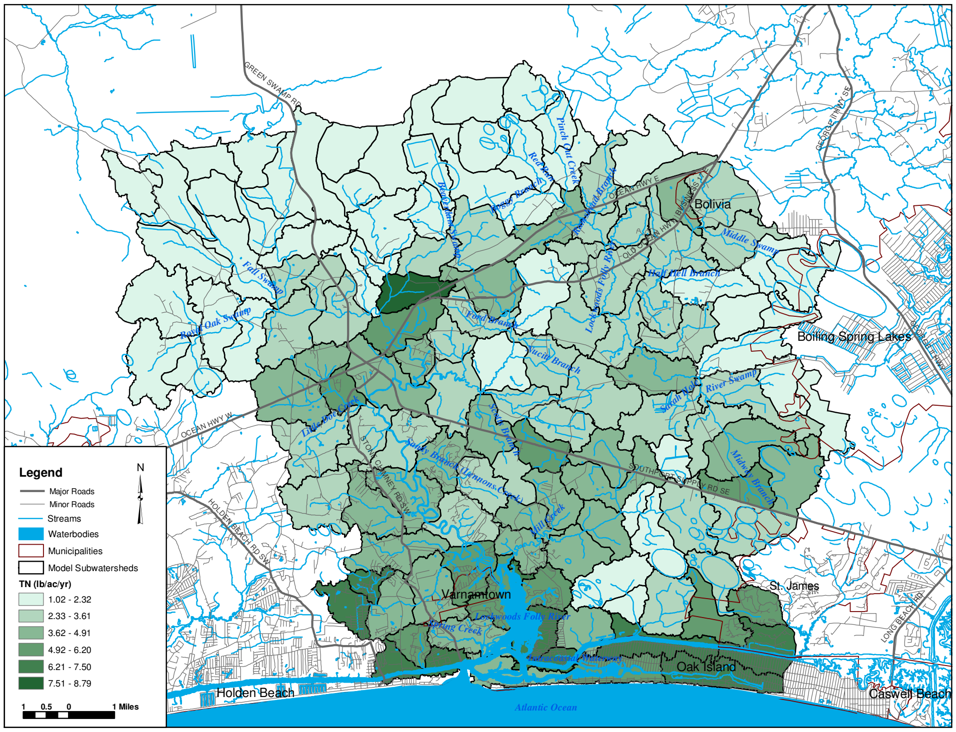


Figure 2.16. Total nitrogen model results for the future - LID 100% land use scenario

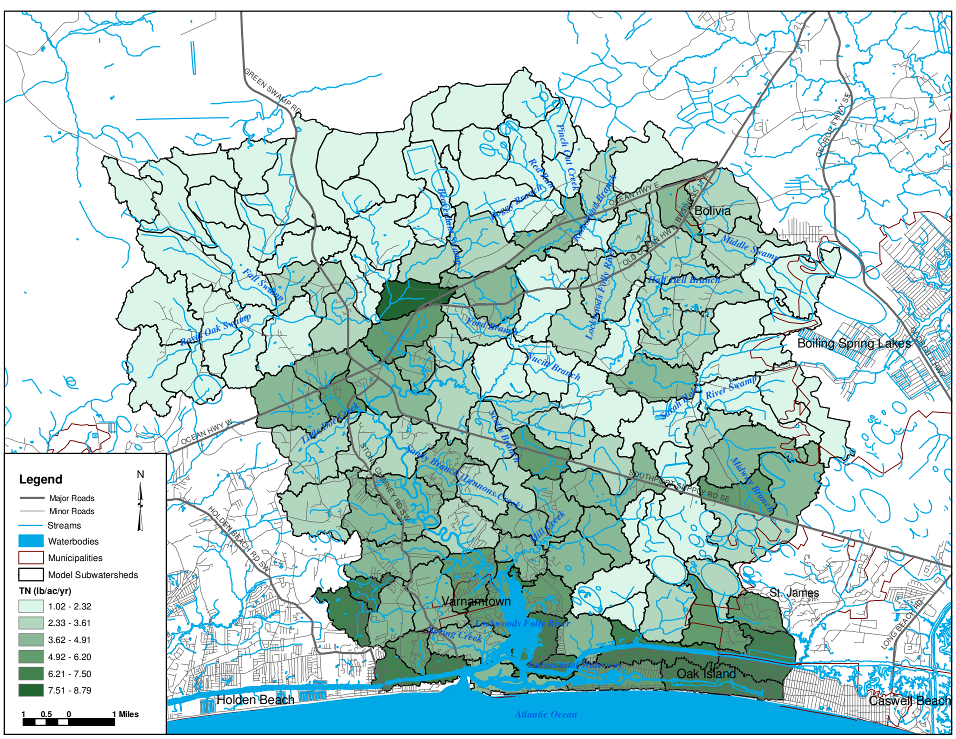


Figure 2.17. Total nitrogen model results for the future - LID 100% + 10% preservation scenario

### 2.2.4 Watershed Modeling Analysis Conclusions

The watershed modeling analysis presented here clearly illustrates that exerting the levels of development planned over the next 20-25 years in the Lockwoods Folly watershed under the current land use and stormwater management regimes will result in drastic increases in non-point source pollutant loads. Predicted results show an approximate doubling of loads for sediment and nutrients and nearly a four-fold increase in fecal coliform loads for the future baseline scenario relative to existing conditions. Unless fundamental changes are made in the ways in which land is developed and stormwater runoff is managed, the predicted increases in pollutant loads are likely to result in significant further degradation of the Lockwoods Folly River and its estuary.

However, some encouragement can be taken from the modeling results in that they also show that significant reductions in pollutant loads can be achieved through implementation of LID and strategic preservation of land that would otherwise be developed. The take-home message from this analysis is that, out of the management measures considered here, no one alone will ensure that success is achieved. Rather, an aggressive pursuit of all management opportunities together will be required to protect some vestige of shellfishing waters in the Lockwoods Folly River from increases in bacterial loading. It is also important to note that the efforts that will be undertaken to prevent or reduce fecal coliform loads in the interest of protecting shellfishing may also be required to prevent the increasing likelihood of nutrient over-enrichment and damaging eutrophication in Lockwoods Folly.

### 2.2.5 Prioritization of Subwatersheds

As previously mentioned, the model result figures displayed loading rates by assigning the same set of ranges to each scenario. This allowed for comparison of loading rates between scenarios. For example, one could track a single subwatershed through all of the scenarios and see how different management strategies may affect the loading or one could determine which areas of the watershed show an increase in loading in the future.

Stormwater BMPs are one of the management practices used to decrease fecal and nutrient loading in a watershed. In order to identify the subwatersheds with the highest loading rates under existing conditions, they were divided into quartiles using the fecal loading rate instead of the set of ranges used for comparison purposes above. The quartiles were labeled as levels of risk with the highest risk being those subwatersheds in the highest quartile. The subwatersheds were then mapped by risk categories (Figure 2.18). This observed distribution map, along with best professional judgment and stakeholder input, was used to select Tier 1 and Tier 2 subwatersheds (Figure 2.19). The result is 17 Tier 1 subwatersheds and 26 Tier 2 subwatersheds, with Tier 1 being the highest priority. Selection of the Tier 1 and 2 subwatersheds was important as they were the target of the stormwater BMP search discussed in detail in section 5. The subwatersheds are also used in section 5 to help rank stream and wetland restoration opportunities.

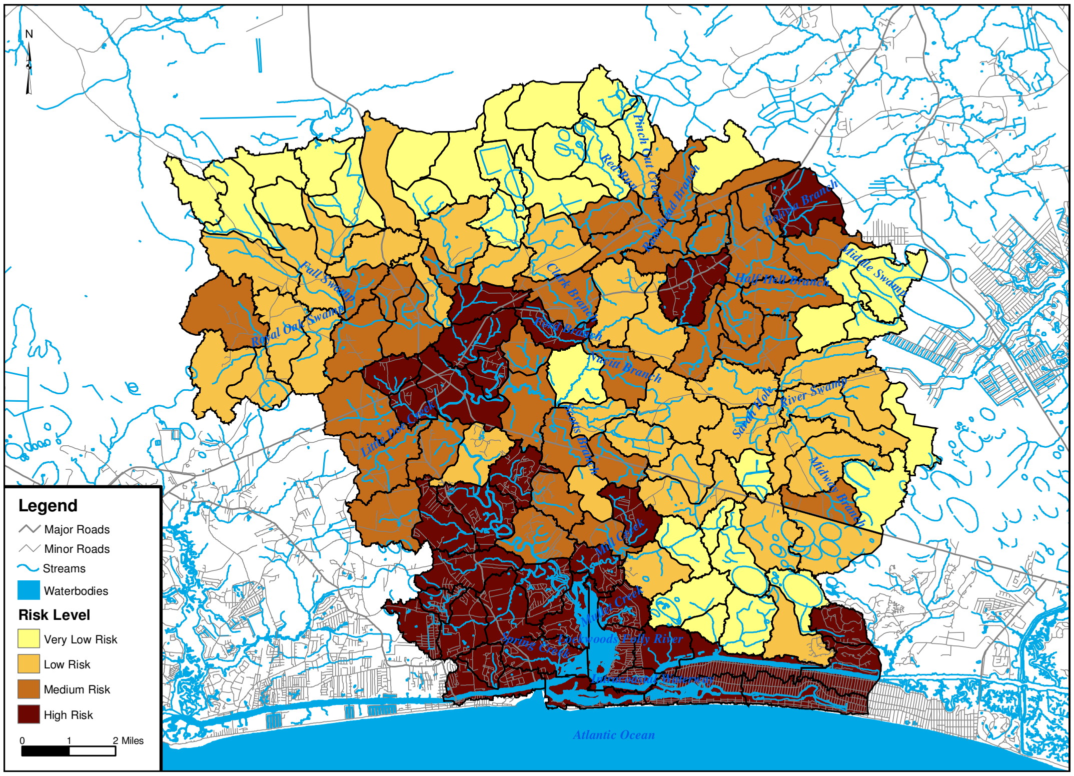


Figure 2.18. Fecal loading under existing conditions by quartile (previous figures were divided into set ranges for comparison)

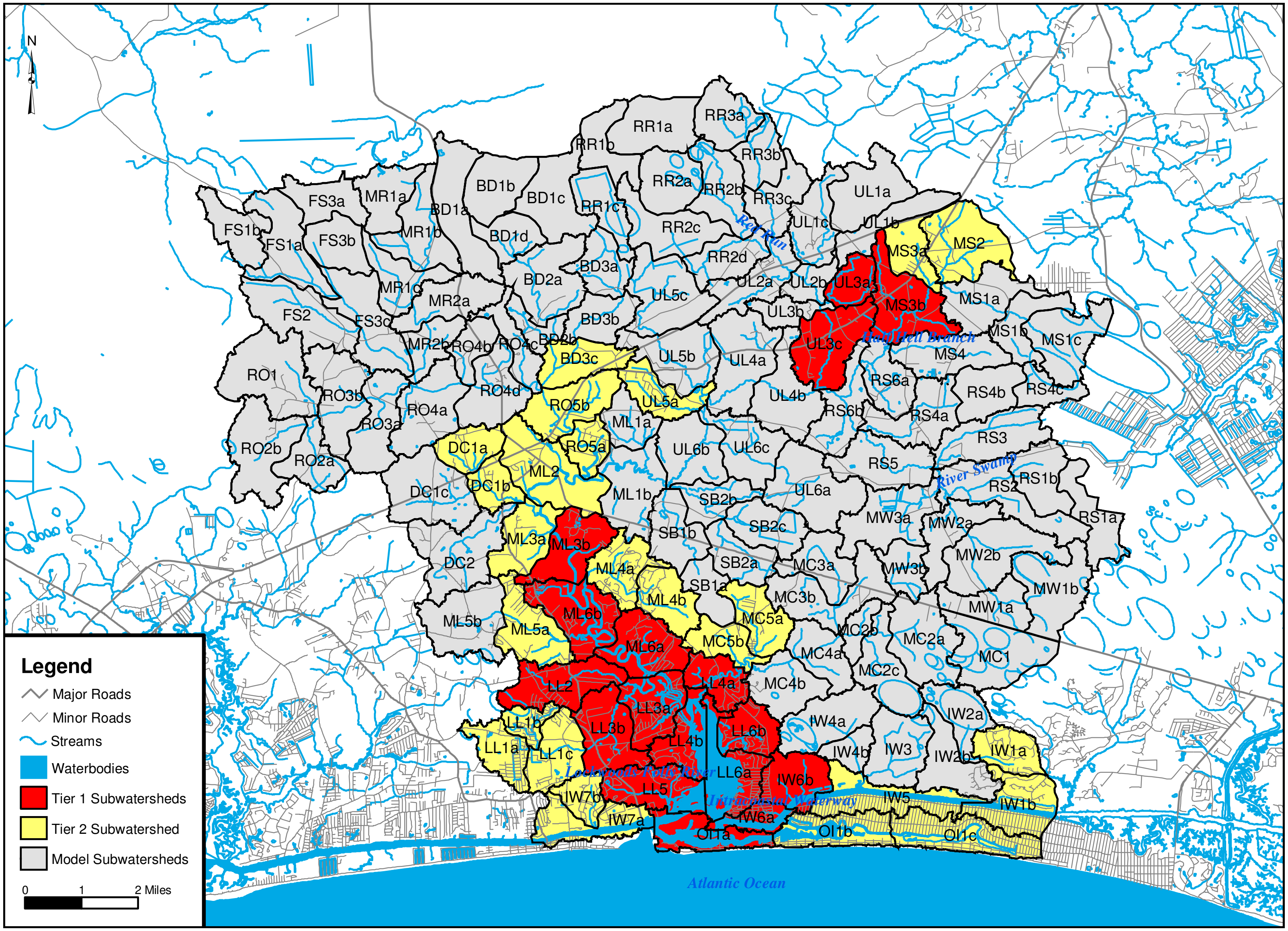


Figure 2.19. Selected Tier 1 and 2 Subwatersheds

# 3.0 Assessment of Hydrology and Aquatic and Terrestrial Habitat Functions

A summary of the key potential stressors to hydrology and aquatic and terrestrial habitat functions, along with a listing of the indicators used in their assessment and the tools used to perform those assessments are present in Table 3.1. Each of the assessment methods is discussed in Sections 3.1 through 3.5, including discussion of results divided into subbasins where possible.

To facilitate the presentation of the different assessments the 136 subwatersheds presented in section 2.2.1 were consolidated into eight subbasins. The first subbasin, Intracoastal Waterway/Atlantic Ocean, consists of two coastal 14-digit HUCs, 03040507020040 (HUC 40) and 03040507020050 (HUC 50). The HUCs were combined as they are much smaller than the other HUCs in the assessment area. The second subbasin, Royal Oak Swamp, is made up of 14-digit HUC 03040507020020 (HUC 20). HUC 03040507020010 (HUC 10) and HUC 03040507020030 (HUC 30) were each divided into three subbasins. HUC 10 includes Red Run, Upper Lockwoods Folly River (LWF), and Middle Swamp while HUC 30 includes Mill Creek, Middle LWF, and Lower LWF (Figure 3.1).

Table 3.1. Summary of Indicators and Tools used for Detailed Assessment of Hydrologic and Aquatic and Terrestrial Habitat Functions

| Watershed Function | Potential Stressor | Indicator | Scale | Assessment Technique |
|---|---|---|---|---|
| Hydrologic and Aquatic Habitat Functions | Stream Channelization and Erosion | Imperviousness and Stream Morphology | Subwatershed and Stream Reach | GIS Analysis and Coastal Plain Stream Assessment, |
| | Riparian Buffer Disturbance | Riparian Buffer Condition | Subwatershed and Stream Reach | GIS Analysis and Coastal Plain Stream Assessment |
| | Wetland Loss | Wetland Function | Subwatershed and Site | GIS Analysis and Onsite DWQ Wetland Assessment |
| | Shoreline Erosion and Loss of Shoreline Habitat | Hardening and Modification of Shoreline | Subwatershed and Site | GIS Analysis and Onsite Assessment |
| Terrestrial Habitat Functions | Degraded Riparian Buffer | Species and age of buffer | Reach | Coastal Plain Stream Assessment |

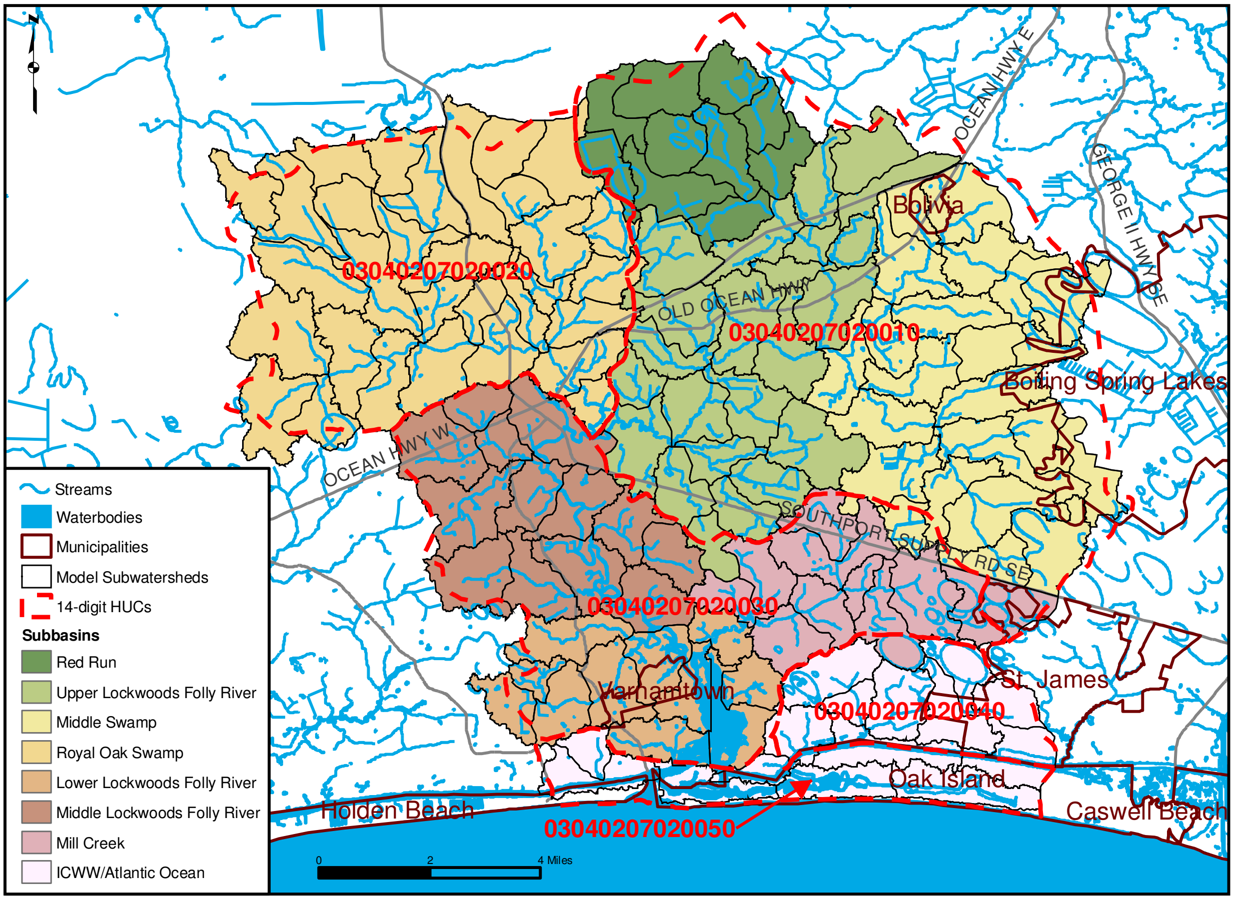


Figure 3.1. Hydrologic Units, Subbasins, and Model Subwatersheds

## 3.1 COASTAL PLAIN STREAM ASSESSMENT

One of the first versions of the Coastal Plain Stream Assessment was developed by East Carolina University (ECU) researchers as a rapid assessment procedure for assessing functions of intermittent to second order (headwater) riparian reaches in agricultural landscapes in the coastal plain. Due to the inadequacies of other stream assessment methods for use in the coastal plain, the North Carolina Ecosystem Enhancement Program (NCEEP) contracted ECU to further develop their methodology for use in local watershed planning efforts. The result is an improved Coastal Plain Stream Assessment that can be applied to low (first and second) order and high (third and fourth) order streams as well as urban stream reaches (ECU 2005). It has not been adapted for streams with tidal influences. In addition, the method was not meant to evaluate areas ponded by beaver or other impoundments.

The assessment can be used to estimate the functional condition of riparian ecosystems on a watershed scale or to evaluate an individual stream reach. In this case, the Coastal Plain Stream Assessment was used at the watershed scale and then at individual sites to assess the potential of stream restoration. ECU produced a separate report, titled Ecological Assessment of Three Coastal Stream Networks and can be found in Appendix C. It details the methodology, results from the Lockwoods Folly assessments, and provides further discussion.

The assessment sites in this analysis were targeted using the USGS 1:24,000 hyrdography GIS data layer. However, USGS 'blueline' streams in eastern North Carolina tend to include many agricultural ditches that were likely never natural streams, but instead were wet flats. Based on topography from the USGS topographic quadrangles as well as soil survey information, ECU researchers removed a number of headwater agricultural ditches from the data layer and added a few small first order streams. In general, first and second order streams were considered low order streams while third and fourth order streams were considered high order streams. There are higher order streams in the watershed but they are tidally influenced and therefore not covered in the assessment.

Once the data layer was complete, a stratified-random sampling scheme based on stream length was used to select sample sites. Approximately five percent of the streams in the watershed were assessed which equates to 140 sites or reaches each constituting 300 feet of stream length and 90 feet of riparian area on either side. The points were stratified by hydrologic unit, with 67 points in HUC10, 33 points in HUC20, and 40 points in HUC30. No points were selected in HUC 40 or HUC 50, located along the coast, as the streams in these areas are all tidally influenced. The approximate locations of the assessed points are shown on Map 3.2.

The Coastal Plain Stream Assessment is a reference-based assessment of functions. The field component involves assigning scores (0-100) to a number of indicators observed in the field. The riparian zone cover, near stream cover, and composition and structure of vegetation in the riparian zone indicator scores were all determined by the type and age of riparian zone vegetation. The instream woody structure indicator evaluated the presence of large (>4 inch diameter) downed wood within the channel and along the banks. Sediment regime was determined by observing turbidity levels as well as the amount of silt and sand deposits along the floodplain and within the channel. Channel-riparian zone connection measures the level of channel incision and overbank flooding. The on/off site factors affecting stream and riparian zone indicators were determined by evaluating the presence of pollution sources and the ability for those contaminants to access the surface water. Bank stability was assessed by evaluating the prevalence of bank erosion and is only determined for high order and urban streams.

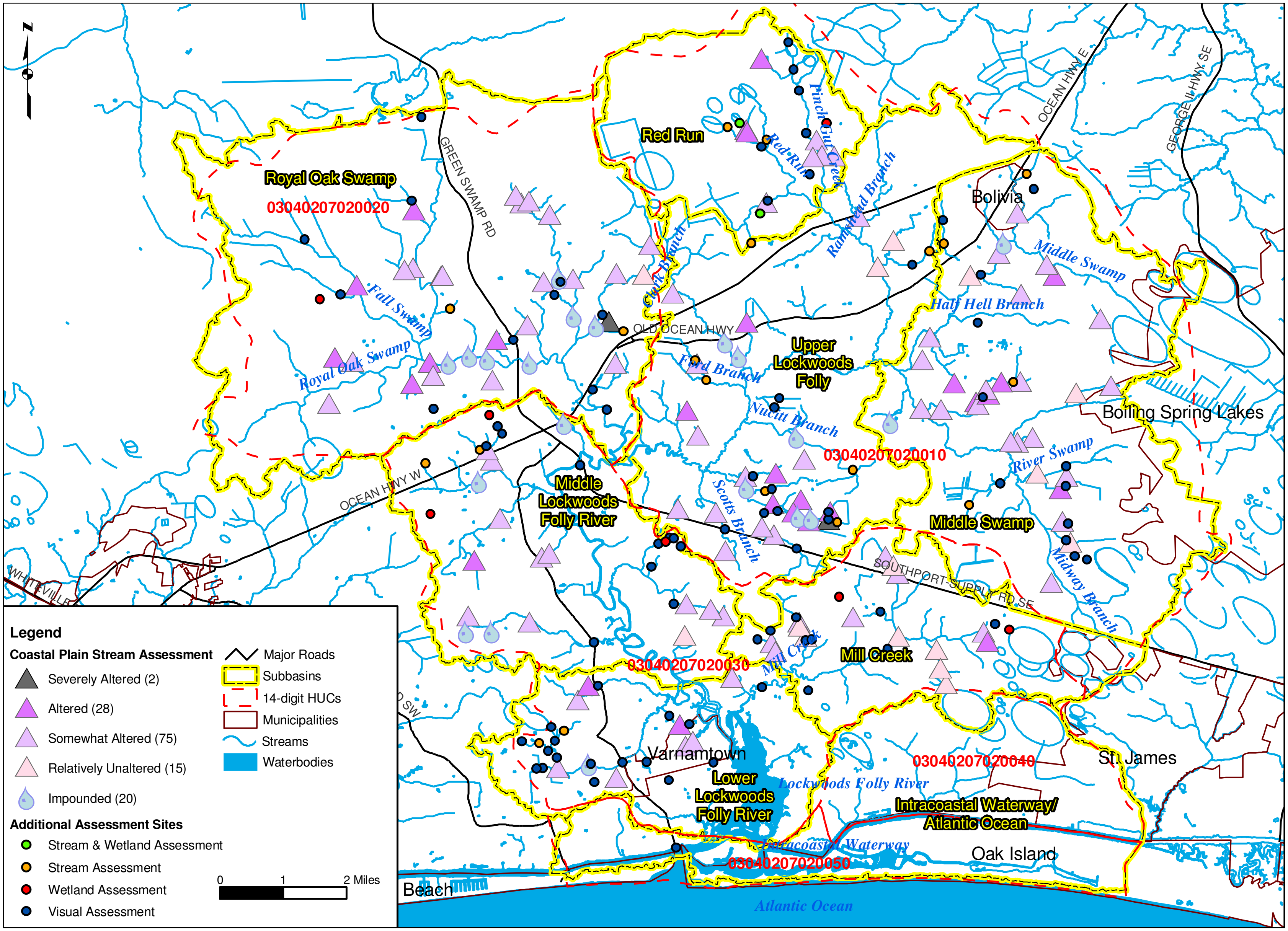


Figure 3.2. Assessment Locations by Management Unit

To evaluate the data, a matrix was generated of indicator scores for each reach. The indicator scores can be averaged to determine scores of functions such as hydrology and habitat (Table 3.2). Groups of functions can be averaged to determine the functional score of the stream channel or riparian zone. Finally all of the functional scores can be averaged to determine a composite function score for the reach. The scores are used to determine functional conditions which are from best to worst: *relatively unaltered* (90-100) followed by *somewhat altered* (60-89), *altered* (30-59), and finally *severely altered* (0-29).

Table 3.2. Function Score Determinations (X= numeric score ranging 0-100 based on the evaluation at each site) (ECU 2005)

| | Stream Channel | | | Riparian Zone | | |
|---|---|---|---|---|---|---|
| Indicators | Hydrology | Biogeo-chemistry | Habitat | Hydrology | Biogeo-chemistry | Habitat |
| Riparian zone cover (RZC) | | | | X | X | X |
| Near stream cover (NSC) | | X | X | | | |
| Instream woody structure (SRC 1) | X | X | X | | | |
| Sediment regime (SRC 2) | | X | | | | |
| Channel-riparian zone connection (SRC 3) | X | X | X | X | X | X |
| On/off site factors affecting stream (SRC 4) | X | X | X | | | |
| On/off site factors affecting riparian zone (SRC 5) | | | | X | X | X |
| Bank stability (SRC 6) | | X | X | | | |
| Composition and structure of vegetation in riparian zone (SRC 7) | | | | | | X |
| Function Score: Mean of all appropriate indicator scores for each function and location (stream vs. riparian zone) | Avg. | Avg. | Avg. | Avg. | Avg. | Avg. |
| | Mean Function Score for Stream Channel | | | Mean Function Score for Riparian Zone | | |
| | Composite Function Score | | | | | |

Beyond the reach, the data can be used to assess subbasin function or overall watershed function compared to a reference. For example, individual indicator scores can be averaged for each subbasin to be able to compare subbasins at the basic level of indicators. For this analysis, the indicators were combined and averaged by subbasin following the logic in Table

3.2 to compare subbasins by hydrologic, biogeochemical, and habitat function scores within both the stream channel and the adjacent riparian zones. The subbasins were then evaluated relative to the condition of the channel and riparian zone, by averaging the hydrology, biogeochemistry, and habitat of each component and graphing these scores. Only 120 of the reaches are graphed as the remaining 20 reaches were partially assessed due to impoundment (Table 3.3). The percent of impounded reaches per HUC is also included on each graph. The reaches are generally clustered along a line with a slope of 1 because alterations to the channel affect the riparian zone and visa versa as seen in Figures 3.3 – 3.5 (Figures from ECU 2006). Yet it is clear that the riparian condition consistently scores lower than the channel condition as evidenced by the greater number of points on the right hand side of each graph. Comparison between the three graphs shows that HUC30 had the greatest percentage of streams in the *relatively unaltered* category.

Table 3.3. Distribution of Assessment Reaches

| HUC | Total Number of Reaches | Impounded Reaches | Fully Assessed Reaches |
|---|---|---|---|
| HUC10 | 67 | 8 | 59 |
| HUC20 | 33 | 7 | 26 |
| HUC30 | 40 | 5 | 35 |
| Total | 140 | 20 | 120 |

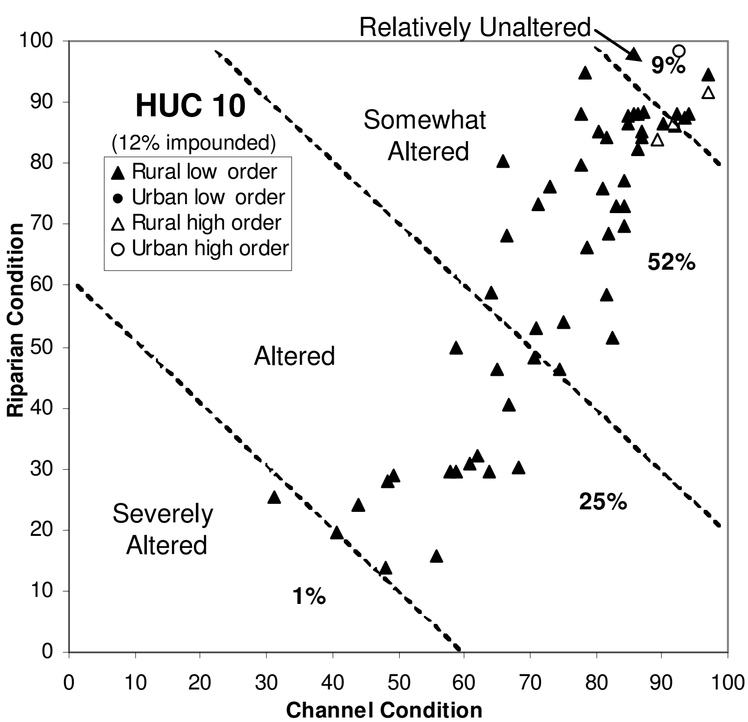


Figure 3.3. HUC 10 Channel Condition vs. Riparian Condition

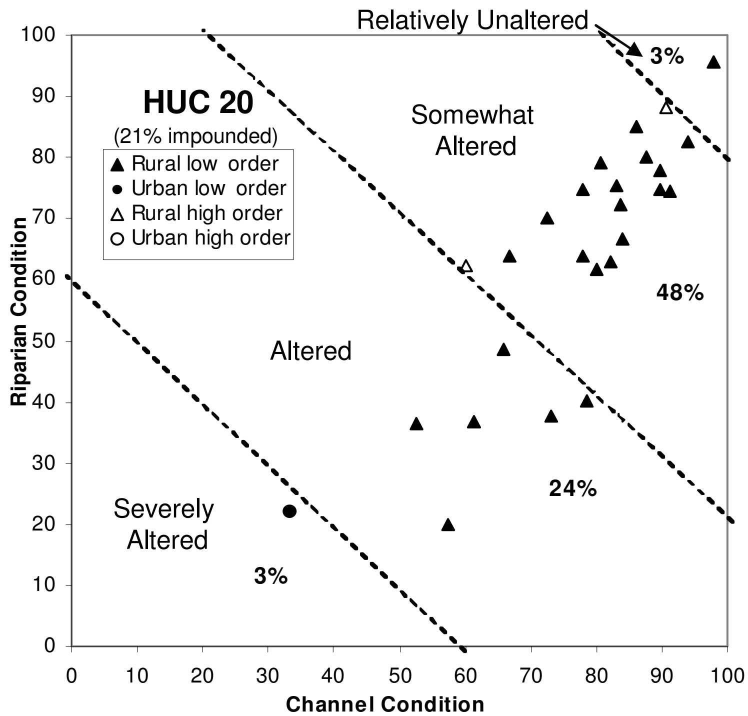


Figure 3.4. HUC 20 Channel Condition vs. Riparian Condition

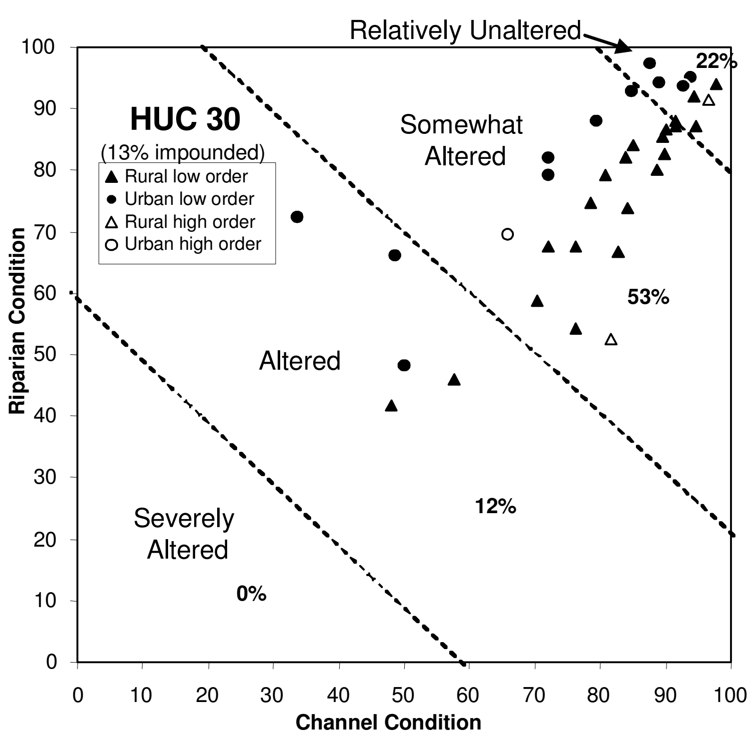


Figure 3.5. HUC 30 Channel Condition vs. Riparian Condition

A mean composite function score was then calculated for each subbasin by averaging the channel and riparian zone condition scores. Table 3.4 contains function scores as well as stream condition, riparian zone condition, and composite function scores by subbasin. In addition, the mean composite function scores for each HUC were calculated using the subbasins' scores. Each of the three HUCs scored as *somewhat altered* with HUC30 receiving the highest score of 78, followed by HUC20 with 70 and HUC30 with 69 out of 100. Figure 3.6 shows composite function scores by subbasin.

Table 3.4. Function Index by Subbasin (possible range of scores is 0-100)

| | *HUC10* | | | *HUC20* | *HUC30* | | |
|---|---|---|---|---|---|---|---|
| Function | *Red Run* | *Upper LWF* | *Middle Swamp* | *Royal Oak* | *Mill Creek* | *Lower LWF* | *Middle LWF* |
| Hydrology – Stream | *76* | *76* | *85* | *84* | *92* | *65* | *85* |
| Hydrology – Riparian Zone | *53* | *62* | *71* | *65* | *85* | *75* | *73* |
| Biogeochemistry – Stream | *64* | *67* | *74* | *73* | *85* | *65* | *71* |
| Biogeochemistry – Rip. Zone | *53* | *62* | *71* | *65* | *85* | *75* | *73* |
| Habitat – Stream | *67* | *70* | *78* | *74* | *86* | *68* | *76* |
| Habitat – Riparian Zone | *49* | *57* | *68* | *61* | *81* | *76* | *66* |
| **Overall Stream Condition** | *69* | *71* | *79* | *77* | *88* | *66* | *77* |
| **Overall Riparian Zone Condition** | *52* | *60* | *70* | *64* | *84* | *75* | *70* |
| **Composite Function Score** | *60* | *66* | *74* | *70* | *86* | *71* | *74* |
| **Overall HUC Function Score** | *69* | | | *70* | *78* | | |

Eight stream reaches were assessed in the Red Run subbasin, which had the lowest composite function score (60) and the lowest overall riparian zone score (52) of the seven units where streams were assessed. Five reaches scored as *somewhat altered* and three scored as *altered*. The Upper Lockwoods Folly subbasin had an average composite function score of 66, a ten percent increase over Red Run. Twenty-eight reaches were assessed although six were impounded. Of those assessed, half were *somewhat unaltered* and eight were *altered*. The Middle Swamp subbasin scored the highest (74) of the three subbasins in HUC10. Of the 31 sites assessed, 19 were *somewhat unaltered*.

The Royal Oak Swamp subbasin (HUC 20) had an overall composite score of 70 or *somewhat altered*. There was one *severely altered* stream reach on a small tributary near the landfill and sand mines while a reach on the main channel of Beaverdam Swamp had the highest score in the entire watershed (97). Seven of the reaches were impounded.

The Lower Lockwoods Folly subbasin had the lowest overall stream condition score of all of the subbasins at 66 although its composite score was the fourth highest. The low average stream score could be a result of the limited number of points due to the exclusion of the tidally influenced main channels. There were only nine assessment points in this subbasin and one was not scored as the stream was impounded. The highest scoring subbasin, Mill Creek, is located in the eastern side of HUC30. Fifteen reaches were assessed; with seven each scored as *somewhat altered* and *relatively unaltered* and one scored as *altered*. The Mill Creek stream hydrology score of 92 was the only function scoring in the relatively unaltered range in the entire watershed. The Middle Lockwoods Folly subbasin had the same overall composite score as the Middle Swamp subbasin (74). Ten of the sixteen reaches assessed scored as *somewhat unaltered*.

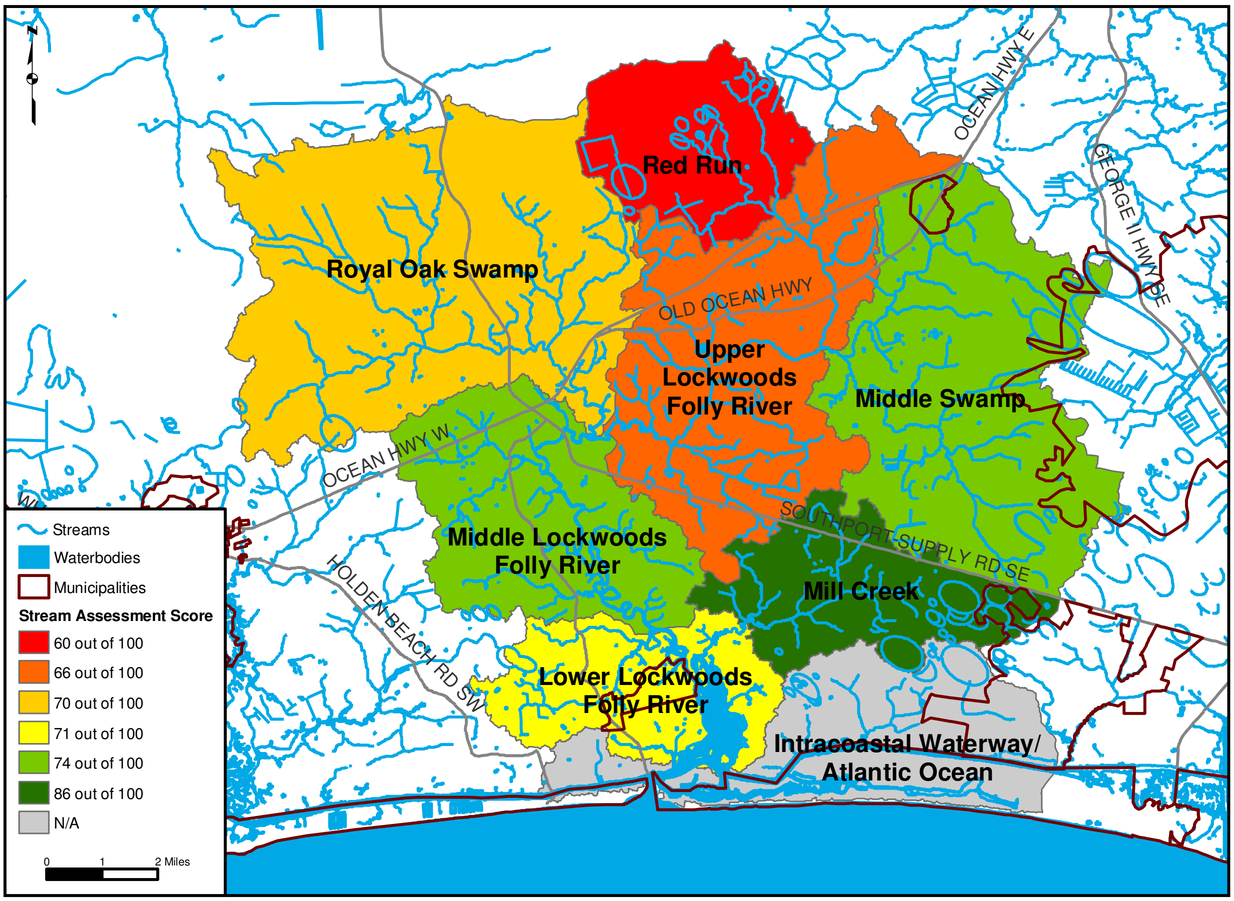


Figure 3.6. Composite Function Scores by Subbasin

### 3.1.1 Terrestrial Habitat

Four indicators from the Coastal Plain Stream Assessment (ECU 2005) are used to determine the functional score of the riparian zone habitat. The four indicators were riparian zone cover, channel-riparian zone connection, on/off site factors affecting the riparian zone, and the composition and structure of vegetation in the riparian zone.

The riparian zone cover indicator looks at the land cover found in a swath 90 feet wide on each side of the stream. The channel-riparian zone connection indicator is based on the degree to which a free-flowing stream channel is incised. The on/off site factors affecting the riparian zone indicator looks at sources of degradation within or directly adjacent to the riparian zone including alterations in the floodplain. The composition and structure of vegetation in the riparian zone indicator is related to the habitat functions of riparian zones. "Vegetation composition (evaluated relative to native forest) is a direct measure of plant habitat, which in turn affects animal habitat. It is assumed that mature to old forests represent the least altered condition that is conducive to supporting native communities. If at least four of the listed species are present in the canopy and the understory is intact with minimal cover of invasive species, then the composition and structure of the forest should be relatively unaltered" (ECU 2005). The following discussion of results considers reaches that were fully assessed, impounded reaches are excluded (Table 3.3).

Twelve of 59 (reaches scored as *severely altered* for riparian zone habitat function in HUC 10. Half of these were in the Upper LWF subbasin, while the Red Run subbasin and Middle Swamp subbasin each had 3. Approximately one third of the reaches (21 of 59) had *severely altered* composition and vegetative structure, almost half in the Upper LWF unit. This represents the quality of the habitat. Interestingly, the riparian zone cover was only *severely altered* at 11 of the reaches. This represents the quantity of cover. Some of the lack in quality as opposed to quantity of buffer could be attributed to the large number of pine plantations in the watershed. Pine plantations are not considered to provide high quality habitat. As a whole, 20% of HUC 10 has *severely altered* habitat while only 8% is *relatively unaltered*. Buffer enhancement would improve the quality of habitat in this HU.

Only one reach of 33 scored as *severely altered* for overall riparian zone habitat function in HUC 20 and one scored as *relatively unaltered*. Yet almost one third of the reaches assessed had *severely altered* composition and vegetative structure as found in HUC 10. The riparian cover at almost a third of the reaches was also *severely altered*. Low scores for both indicators show that not only is the habitat quality of the buffer low in some areas as seen in HUC 10 but also the quantity of riparian cover is low. For this HU, buffer restoration would increase the quantity of habitat as well as the quality.

There are no reaches that scored as *severely altered* for riparian zone habitat quality in HUC 30. Seven of 40 reaches had *severely altered* composition and vegetative structure, five in the Middle Lockwoods Folly subbasin and two in the Mill Creek subbasin. Only three had a riparian cover that was *severely altered*. Approximately 17% of HUC 30 has *relatively unaltered* riparian zone habitat function. These scores indicate that there are minor opportunities for buffer restoration in this HU.

## 3.2 GIS ANALYSIS SUMMARY

The GIS analysis completed in the first phase and presented in the Preliminary Findings Report, included sections on imperviousness, stream channel erodibility, and riparian vegetation disturbance. The imperviousness analysis found that areas with the highest impervious surface cover were located in Varnamtown, Oak Island, and St. James. Some of these subwatersheds are approaching or exceeding the 10% threshold in overall impervious cover which is considered detrimental to watershed health (Schueler 2003).

The stream channel erodibility analysis results showed that there was a relatively low risk of stream erosion throughout the watershed. The riparian buffer disturbance analysis revealed a number of subwatersheds with elevated levels of buffer disturbance. High risk areas were identified for each of these three analyses. In addition, GIS was used to analyze potential locations for wetland and coastal shoreline marsh restoration and enhancement.

These analyses can be evaluated in detail in the Preliminary Findings Report and were not expanded upon within this detailed assessment.

## 3.3 ADDITIONAL STREAM ASSESSMENT SITES

Based on the remote data analyses in the Preliminary Findings Report, preliminary potential restoration opportunities were identified. Each prospective site was initially screened through the use of high-resolution aerial photography to gauge the suitability of the site for restoration and determine ideal field evaluation points within the site. In addition, the majority of streams with greater than 10 percent of the buffer disturbed, streams in high risk areas, streams accessible from road crossings, and streams near prospective wetland restoration sites were visited. Select sites were assessed using the Coastal Plain Stream Assessment, especially sites that appeared to be altered or impacted.

Over 85 sites were visited and the majority were well buffered, unincised, and not channelized except for minor roadway crossing impacts. The channels thought to be at the highest relative level of risk revealed upon site visit that they were well buffered and some were ponded ruling out erosion hazards. Vegetation was regenerating at many of the reaches identified as having buffer disturbance. Harvesting of pine trees is common throughout the watershed but even in recently harvested areas, a narrow buffer of trees was left alongside the streams.

Of the 85 sites visited, only 20 were assessed using the Coastal Plain Stream Assessment. This low number reflects the small percentage of impacted streams encountered in the watershed.

Of the additional sites visited in the Red Run subbasin, four were assessed. All had composite function scores of less than 57 out of 100 and were considered *altered*. Eight sites were assessed in the Upper Lockwoods Folly River subbasin. Six scored as *altered* while two were considered *severely altered*. An additional two sites were assessed in the Middle Swamp subbasin and scored lower than the average found for that subbasin in the ECU study (composite function scores of 51 and 71 out of 100) but both were on short tributaries.

Two sites, scoring 49 and 72 out of 100, were assessed in the Royal Oak Swamp subbasin. In the Lower Lockwoods Folly River subbasin, two additional points were assessed and scored in the *altered* category (composite function scores of 54 and 58 out of 100). In the Mill Creek subbasin none of the additional sites were assessed as they all were in good condition.

## 3.4 WETLAND CONDITION ASSESSMENT

Potential wetland restoration and enhancement sites that were identified in the Preliminary Findings Report were then screened using aerial imagery and visited to evaluate function and determine feasibility. Function was assessed and evaluated using the Guidance for Rating the Values of Wetlands in North Carolina, Fifth Version Draft, produced by the Division of Water Quality (NCDWQ 1999). This method evaluates six wetland values: 1) water storage, 2) bank/shoreline stabilization, 3) pollutant removal, 4) low flow augmentation, 5) wildlife habitat, and 6) aquatic life. Over twenty sites were visited and those where restoration was deemed feasible were assessed. The nine that were assessed are identified on Figure 3.2. Scores ranged from 5 to 36 with the lowest scores associated with wet flats and the higher scores with riparian wetlands. Riverine or riparian wetlands (those associated with streams such as headwater forests) are considered to have high function and can score up to 100 using this assessment. On the other hand, non-riverine (interstream divides such as wet flats or Carolina Bays) can only score as high as 47 as they do not have the same water storage capacity or pollutant removal ability and they have no shoreline stabilization functionality.

More than half of the sites visited were wet flats and the remainder were headwater wetlands. Many of the wet flats had been identified as potential restoration sites because they had been cleared of vegetation. Field visits to many of these wet flats revealed that the vegetation was growing back. Only a few were located in active agricultural fields such as the one shown in the photo (Figure 3.7).

Figure 3.7. Wet flat drained for agriculture

The remaining drained wet flats were too small for restoration or restoration would impact too many surrounding properties. One wet flat in each of the following subbasins was assessed using the DWQ guidance and scored 5 points out of 47: Red Run, Royal Oak Swamp, and Middle Lockwoods Folly River. Two others were assessed in Mill Creek and both scored 7 out of 47 possible points.

Most of the headwater wetlands visited were drained or partially drained by enlarging their original, natural low flow channels. These systems could be restored as outlined in the coastal plain headwater stream restoration guidance. Four headwater systems were assessed in the following subbasins: Red Run (scores of 32 and 36) and Middle Lockwoods Folly River (scores of 22 and 28). Other types of riparian (riverine) wetlands were also visited such as bottomland hardwood forests, cypress-gum swamps and a variety of marshes but all were in good condition or had only been impacted by logging in the past and were recovering.

### 3.5 SHORELINE RESTORATION ASSESSMENT

The North Carolina Coastal Federation (NCCF) has a cost share program to encourage Living Shoreline projects along estuarine coasts. These projects aim to restore or preserve marshes while at the same time controlling shoreline erosion. Potential sites that could be considered for the Living Shoreline program were identified and reported in the Preliminary Findings Report. It was determined to forgo additional assessment instead seeking interested landowners via an announcement in a tabloid. The NCCF developed the tabloid explaining the Lockwoods Folly Watershed Plan and the efforts of the Lockwoods Folly Watershed Roundtable and distributed it to households throughout Brunswick County. The tabloid's contents included a description of the NCCF Living Shorelines Program and enumerated the draft watershed restoration and protection strategies under development by the Roundtable, including Strategy 6, which endorses the Living Shorelines concept (refer to Section 5.6).

### 3.6 LAND USE CHANGE

The existing and baseline future land use scenarios developed for the water quality model were used to analyze land use change on a subbasin scale (Table 3.5). A basic percent change between existing and future shows large changes, for example in Middle Lockwoods Folly River subbasin there are 287 acres of medium density residential land currently and 5,779 acres expected in the future. The percent increase of individual developed related land uses in each subbasin is large. Looking at percent change does not reveal which watershed will be impacted most by development. Instead a percent developed for each subbasin was calculated for the existing and future land uses. This shows which subbasins are currently the most developed and which ones will be in the future (Table 3.5).

Table 3.5. Percent Development by Subbasin

| Subbasin | Existing Dev (ac) | % Existing Dev | Future Dev (ac) | % Future Dev |
|---|---|---|---|---|
| Upper Lockwoods Folly River | 781 | 5% | 13167 | 81% |
| Intracoastal Waterway/Atlantic Ocean | 1329 | 16% | 6599 | 78% |
| Mill Creek | 133 | 2% | 5584 | 78% |
| Middle Lockwoods Folly River | 771 | 8% | 6929 | 70% |
| Lower Lockwoods Folly River | 985 | 17% | 4094 | 70% |
| Middle Swamp | 787 | 4% | 10460 | 60% |
| Royal Oak Swamp | 827 | 4% | 11812 | 53% |
| Red Run | 30 | <1% | 1681 | 25% |

# 4.0 Findings and Proposed Improvement Projects

### 4.1.1 Subbasins Recommended for Targeting

The Lockwoods Folly watershed is unique in that the areas with the greatest stream degradation do not coincide with the areas of the highest pollutant loading. Traditionally, the Lockwoods Folly River watershed has been impacted by logging in the northern half and development along the coast. Logging resulted in stream channelization and impacts to riparian zones while development impacted wetlands and led to higher pollutant loading. Currently the watershed is experiencing large scale change as the pace of development has increased.

In order to identify those areas that have the greatest overall risk, the subbasins described in section 3.0 were ranked by combining the results from the detailed assessment tasks, specifically the land use change analysis, the model results and the Coastal Plain Stream Assessment results. Specifically a number of points (from 1-8 for the eight subbasins) were given for each of the three tasks (Table 4.1).

To assign scores based on model results, the subbasins were listed in order with those having the greatest number of Tier 1 and Tier 2 priority subwatersheds located within it, as identified using the model loading, at the top of the list. Each subbasin then received a number of points based on the location in the list (top of the list (greatest number of targeted subwatersheds) = 8, lowest = 1. To assign scores based on the Coastal Plain Stream Assessment, the subbasins were ranked in order of highest score to lowest score in terms of composite function score from the assessment (Table 3.3). Each subbasin received a number of points based on location in the ranking (highest score = 1 point, lowest score = 8 points).

Finally, to assign scores based on the land use change analysis, subbasins were listed in order with those having the largest percentage of developed land in the future at the top of the list and those with the smallest amount at the bottom. The three scores were added together and the subbasin with the greatest score was listed as the highest priority subbasin. The one with the lowest total score has the lowest priority.

Table 4.1. Subbasin Prioritization

| Subbasin | Assessment Points | Model Points | % Developed In Future | Total Points | Priority |
|---|---|---|---|---|---|
| Upper Lockwoods Folly River | 7 | 5 | 8 | 20 | 1 |
| Lower Lockwoods Folly River | 5 | 8 | 4 | 17 | 2 |
| Middle Lockwoods Folly River | 3.5 | 6.5 | 5 | 15 | 3 |
| Intracoastal Waterway/Atlantic Ocean | 1 | 6.5 | 6 | 13.5 | 4 |
| Royal Oak Swamp | 6 | 4 | 2 | 12 | 5 |
| Mill Creek | 2 | 2 | 7 | 11 | 6 |
| Red Run | 8 | 1 | 1 | 10 | 7 |
| Middle Swamp | 3.5 | 3 | 3 | 9.5 | 8 |

Following is a discussion and map of each subbasin incorporating the water quality data, model results, Coastal Plain stream assessment, GIS analysis, wetland assessment, and land use change table as well as any additional information noted during field investigations. Restoration opportunities in each subbasin are also discussed. The number of priority (Tier 1 and 2) subwatersheds in each subbasin is noted as well as potential stormwater BMP sites. Refer to section 6 for more details regarding the restoration and stormwater BMP opportunities mentioned below.

## 4.2 SUBBASIN DISCUSSION

### 4.2.1 Royal Oak Swamp Subbasin

The Royal Oak Swamp subbasin is a mix of undeveloped land with scattered residential parcels, the county landfill and a number of active and inactive sand pits. There are large areas of pine plantations and a few scattered farm operations. A portion of the subbasin is owned by the Nature Conservancy and will be preserved. Low density residential development is expected in about half of the subbasin with the rest remaining forested. As a result. the model predicts that this area will continue to have lower loading levels than those found in the southern half of the watershed for all of the future scenarios. The GIS analysis had indicated that a portion of this subbasin was a high opportunity area for encountering restoration projects.

As in other subbasins, the main channels were in better condition than the small tributaries as evidenced from the assessment scores. The subbasin scored overall 70 out of 100 which is somewhat altered. Pine plantations along the streams cause lower scores since the available habitat is of a lower quality than other woody buffers. Some of the channels in this area are deeply incised, most likely from channelization in the past for agricultural or silvicutlural purposes. The feasibility of restoring these channels is low as many are near developed areas including paved roads and houses. Restoring the channels and the associated wetlands would impact these areas.

Some of the wet flats in the subbasin have been drained and cleared for agriculture. Wetland restoration was only feasible at one of these sites. There is a stream and riparian wetland restoration opportunity on a channel that has been cut off from its floodplain as it was filled to create a perimeter road around a now unused sand pit.

There are three Tier 2 priority subwatersheds in the subbasin (Figure 4.1). BMP opportunities were found at the Supply Elementary School, located in subwatershed RO5b, which is currently undergoing expansion. Only one water quality monitoring site, Royal Oak Swamp ROS01, is located within this subbasin. Compared to other monitoring sites, it ranked low for total phosphorous, nitrate/nitrite, and total Kjehdal nitrogen (TKN). It ranked in the middle for fecal coliform and ammonia.

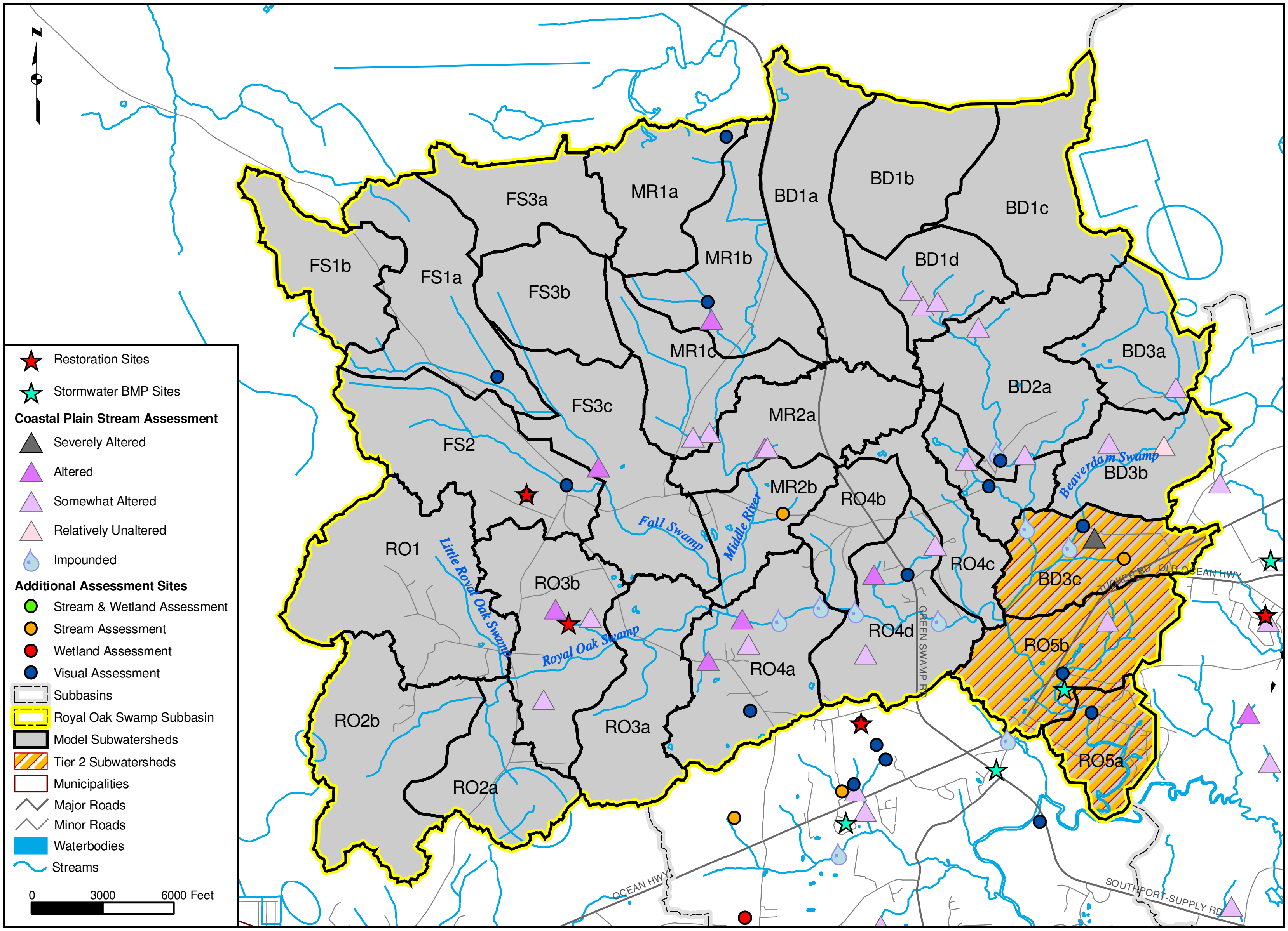


Figure 4.1. Royal Oak Subbasin

### 4.2.2 Red Run Subbasin

The Red Run subbasin consists mainly of pine plantations and agricultural lands. This is most likely the reason behind the low riparian zone condition assessment score. The streams also had low assessment scores because most are channelized and cutoff from the floodplain. In the upper two thirds of the subbasin, many of the streams are draining wet flats and Carolina Bays. Stream restoration opportunities are difficult to quantify as it is not readily apparent if the streams are natural. Additional study would be necessary to determine which of these streams are natural and which were created for drainage. Regardless, many of the streams have eroding banks that need to be stabilized to prevent degradation of downstream reaches. Large areas ditched wetlands were identified during the phase one GIS analysis. Field visits revealed that although attempts have been made to drain the wetlands, further investigation would be necessary to determine how much is actually drained. Enhancement and restoration acreage could be calculated after additional studies of the area.

Current access to the area for logging and hunting is through a network of dirt roads. These roads could be impacted if the two proposed stream and wetland restoration projects are implemented thereby severely limiting access. Alternatively, this upper region of the subbasin could be preserved as open space and the streams could be stabilized (Rosgen priority level 2) to prevent further erosion. Development in this area should be avoided as any increase in impervious surfaces will lead to further channel erosion and may impact downstream reaches.

In the lower portion of the subbasin, Boggy Branch show signs of historic channelization as evidenced by berms in the floodplain. Over time the stream has stabilized as agricultural practices declined and buffers were allowed to regenerate. There is one tributary of Boggy Branch that has been impacted by cattle and the removal of the riparian buffer. This reach and riparian wetland zone could be restored. The other two main channels, Pinch Gut Creek and Red Run, are both in good condition in the downstream reaches. The assessment scores in this lower part of the subbasin were higher than the upper area, all were somewhat unaltered.

A number of wet flats were visited in this area. Some have been cleared and drained for agriculture and one would be a good candidate for wetland restoration. Future growth consisting mainly of low density residential development is only expected in this lower portion of the subbasin. The model indicated minimal increases in pollutant loading in this subbasin for all future scenarios. None of the subwatersheds targeted for BMP retrofitting are located in this subbasin (Figure 4.2).

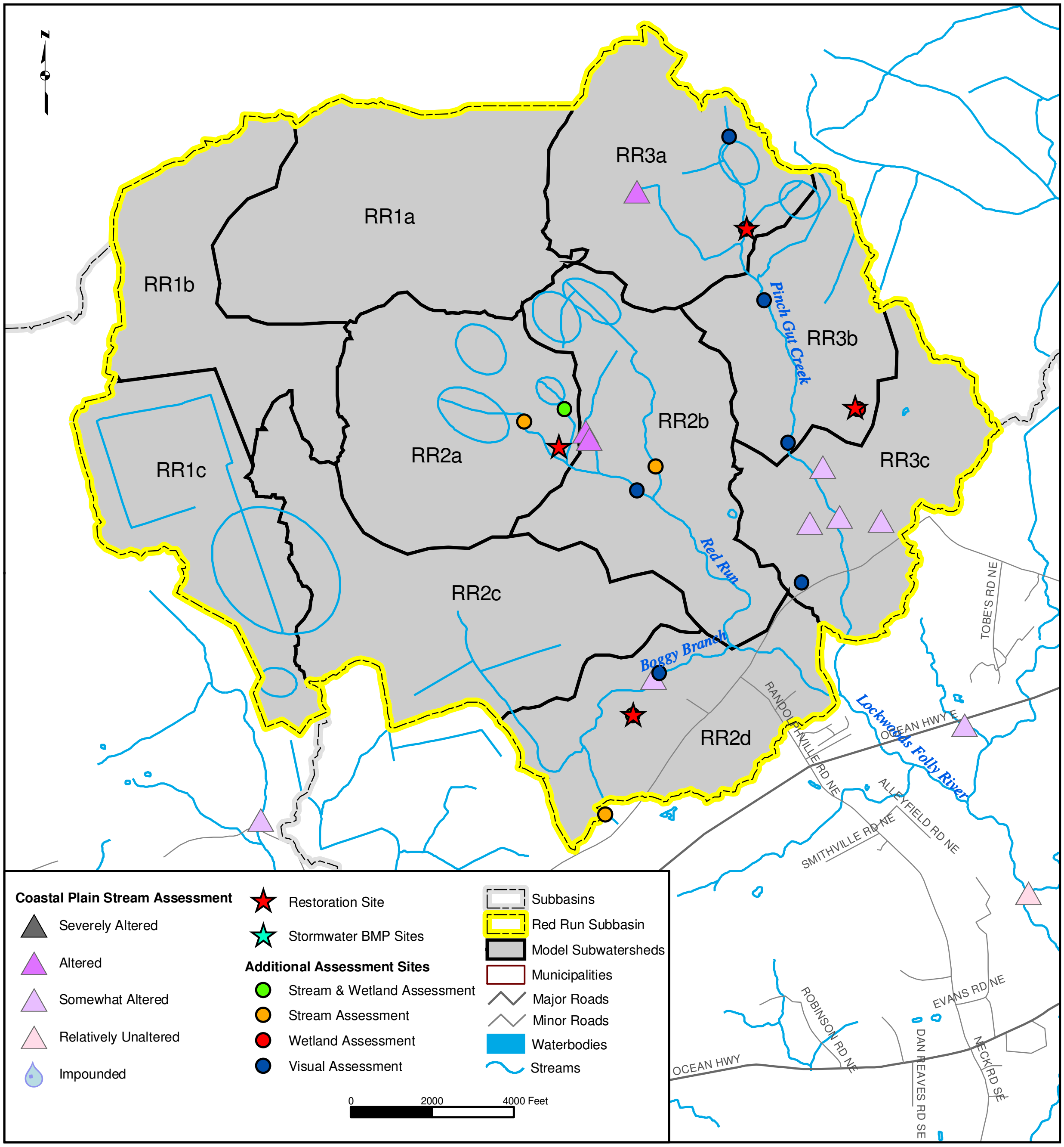


Figure 4.2. Red Run Subbasin

### 4.2.3 Upper Lockwoods Folly River Subbasin

This subbasin contains a mix of agricultural lands and pine plantations along with residential development along roadways, Brunswick Community College and part of the Brunswick County Government Complex. Significant growth is expected throughout this subbasin. Of the eight subbasins, this one has the highest potential future development consisting mainly of low density residential development. A number of residential developments ranging from high to low density have already been approved. Clearing and construction has started on some developments including one along Southport Supply Road and one on Gilbert Road. There are 3 priority subwatersheds in this subbasin, two that are Tier 1 (UL3b and UL3c) and one Tier 2 (UL5a). All three subwatersheds were searched for potential BMP retrofits but suitable locations were only found at the community college and government complex (Figure 4.3).

There was one water quality monitoring site in this subbasin. Compared to other monitoring sites, it ranked low for total phosphorous, ammonia, and total Kjehdal nitrogen (TKN). It ranked in the middle for fecal coliform and nitrate/nitrite.

Although the GIS analysis did not identify this subbasin as having opportunities for restoration, field visits and the stream assessments revealed the area is one of the more impacted subbasins.

Most of the low stream assessment scores are found on reaches of an unnamed tributary to Lockwoods Folly River. This unnamed tributary (UT) has been channelized for most of its length and there are a number of beaver dams as well as one large manmade impoundment. These impoundments have led to a loss of riparian buffer and habitat. Small tributaries are affected by backwater and vegetation has been cleared from many of them leaving only scattered trees and snags. This resulted in low riparian zone condition scores. Although restoration of this area would be beneficial it is unlikely as a large part of it and the other tributaries are located on the site of one of the approved developments. The pond formed by the manmade impoundment has been advertised as an amenity meaning it is unlikely the developer will consider woody buffers. No restoration projects are recommended for this UT and its tributaries.

Many of the small tributaries in this subbasin were channelized and some were created to drain headwater swamps. There are a few opportunities to restore these headwater streams/wetlands while small pockets of development make some of them infeasible for restoration. Other opportunities exist to restore channels that were moved and their floodplain filled to accommodate different land uses.

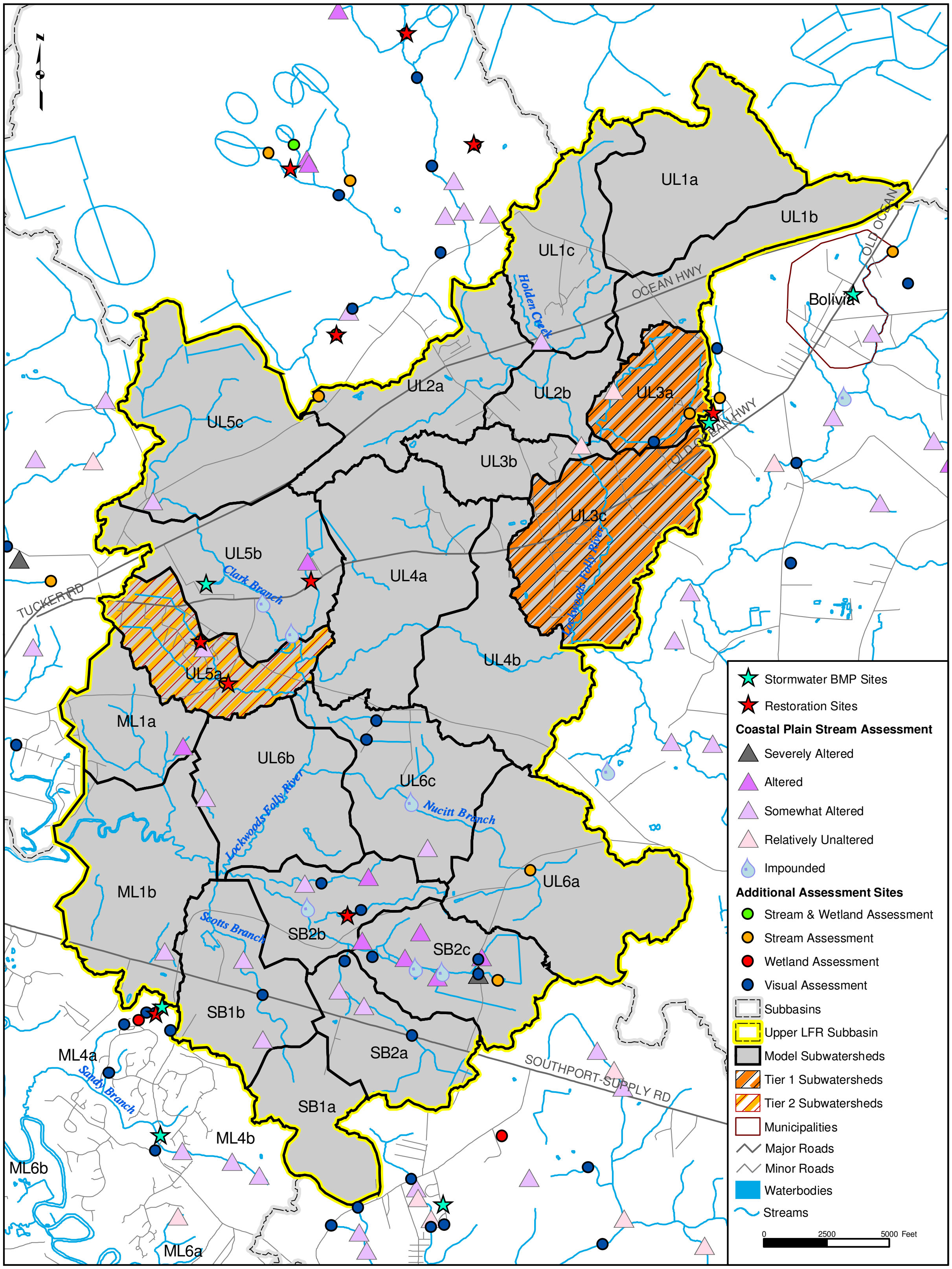


Figure 4.3. Upper Lockwoods Folly River Subbasin

### 4.2.4 Middle Swamp Subbasin

The Middle Swamp subbasin contains the other half of the Brunswick County government complex as well as the Town of Bolivia. In addition there is residential development along the roadways. A large high density residential development has already been approved in the subbasin and additional residential areas are likely to follow. Eventually Midway Road, which bisects the subbasin, will be widened to a four lane road and will also be extended south towards the coast leading to a second bridge to Oak Island. This will most likely lead to more intense development (shown as office/institutional/light industrial on Figure 2.4) along the roadway. The future model results indicate high loading rates in the subwatersheds along Midway Road due to the predicted increase in developed land. There are three high priority subwatersheds in this subbasin as well, although only one is Tier 1 (MS3b) and the others are Tier 2 (MS2 and MS3a). BMP opportunities were found at the government complex and at an elementary school in Bolivia (Figure 4.4).

Although there is plenty of impervious surface in downtown Bolivia, BMPs were infeasible in most locations as the parking lots and roads are seamless with no open space in between them and stormwater inlets set in the pavement. Subwatershed MS2 had the worst instream water quality for ammonia, nitrate and nitrite in the whole Lockwoods Folly River watershed. Phosphorous and total Kjehdal nitrogen were measured at levels that ranked in the second highest group in the watershed. Some of this could be a result of the discharge associated with the package plant that was once located at the Bolivia Elementary School. The plant was closed in October 2006 and is no longer discharging.

Most of the main channels in the Middle Swamp subbasin had large intact floodplains and buffers. Small tributaries tended to be channelized although the impacted reaches were too short for restoration purposes. There is limited ditching in the northern end of the subbasin for agricultural purposes although wetland restoration would be difficult due to adjacent development. There is some ditching as well in the eastern headwater region of the subwatershed where there are pine plantations but it does not appear to affect downstream reaches all of which scored as *relatively unaltered* or *somewhat altered*.

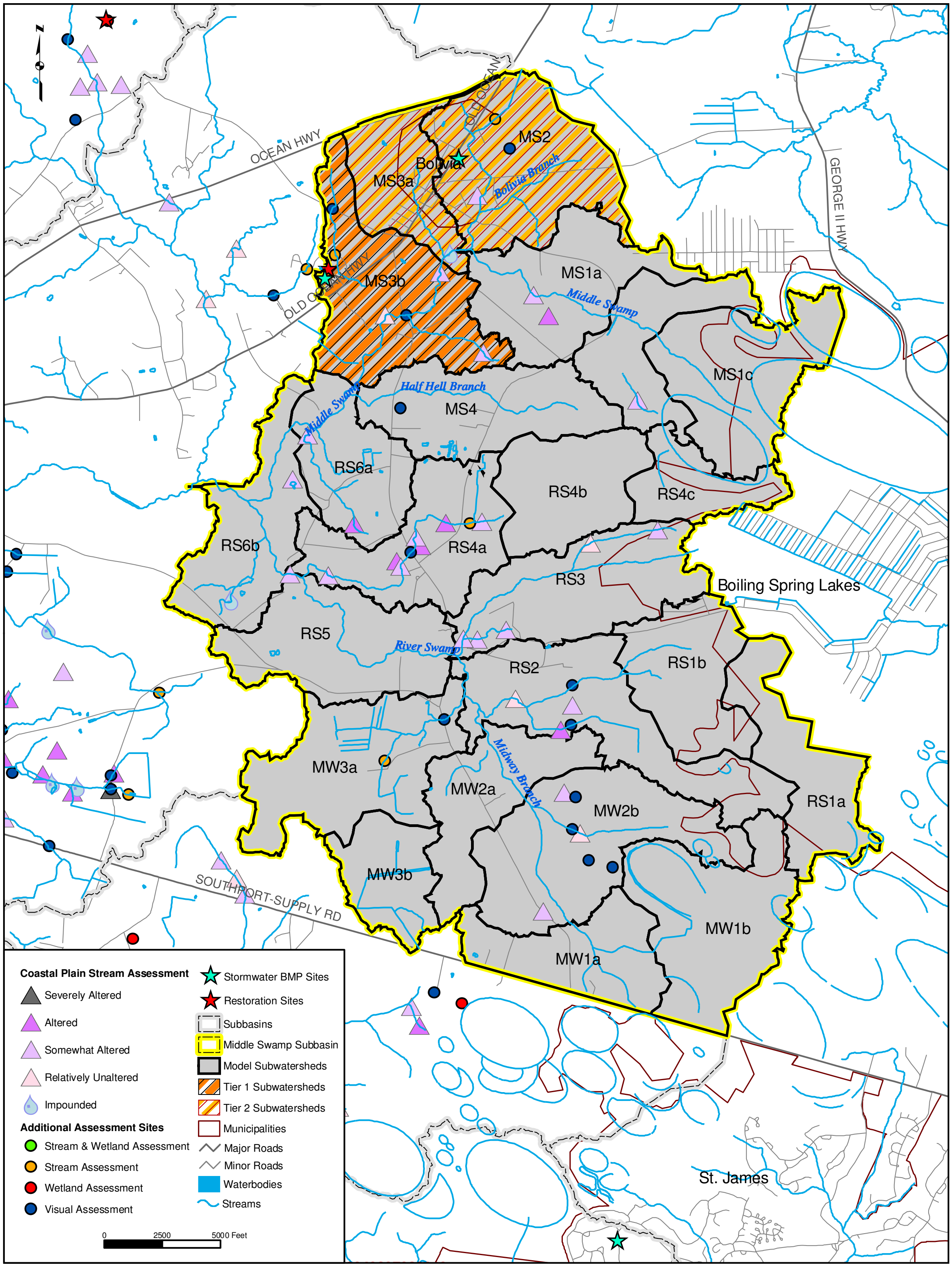


Figure 4.4. Middle Swamp Subbasin

### 4.2.5 Lower Lockwoods Folly River Subbasin

The GIS analysis from the first phase indicated high opportunities in portions of this subbasin. A large part of it was most likely wetland in the past but was extensively ditched at some point. It is not clear if ditching occurred early on for pine production or agriculture or if it occurred in the 1960s for development. Currently much of the ditched area is covered in mobile and manufactured homes (high density residential) and another portion is young pine forest. In addition, there is high density development in Sunset Harbor and Varnamtown. Although the development is considered high density due to lot size, further investigation revealed that many of the roads are unpaved and the mobile homes do not have as large of a footprint as a traditional single family house would have. Regardless of density, this subbasin is one of the most developed besides the Intracoastal Waterway subbasin. Even with the high percentage of developed areas, scores from the stream assessments were high and in the undeveloped areas the wetlands were intact making it difficult to find restoration opportunities. The two larger main tributaries have large intact floodplains, some of which are impounded. The tributaries also scored well in the assessment. A few of them have narrow buffers that could be enhanced although these projects would be very small as these tributaries are short. Other streams that appear degraded are most likely unnatural streams or they are ephemeral channels that have been enlarged for drainage. Altering these drainages is infeasible as it would affect the surrounding homes.

There were thirteen water quality monitoring stations in this subbasin although only a limited number of parameters were sampled at the majority of these sites. Results for instream water quality from the more comprehensive sites were better than other sites in the watershed.

The model indicated much of this subbasin currently has higher loading rates than the rest of the watershed with the exception of Oak Island. As a result, all of the subwatersheds in this subbasin are priority subwatersheds, eight are Tier 1 and four are Tier 2 (Figure 4.5). The Tier 2 subwatersheds are located in the western half of the subbasin which coincides with the ditched wetland area. The water table is close to the surface and there is very little topography making BMP retrofits difficult to find in this area. The small commercial area in this western section has a traditional stormwater system and intercepting runoff before it enters that system is infeasible due to high cost. The entire parking lot would have to be regraded to incorporate BMPs. In the eastern half of the subbasin, along the Lockwoods Folly River, where there is greater topographic relief, a number of retrofit opportunities were found in the Lockwoods Folly Country Club development.

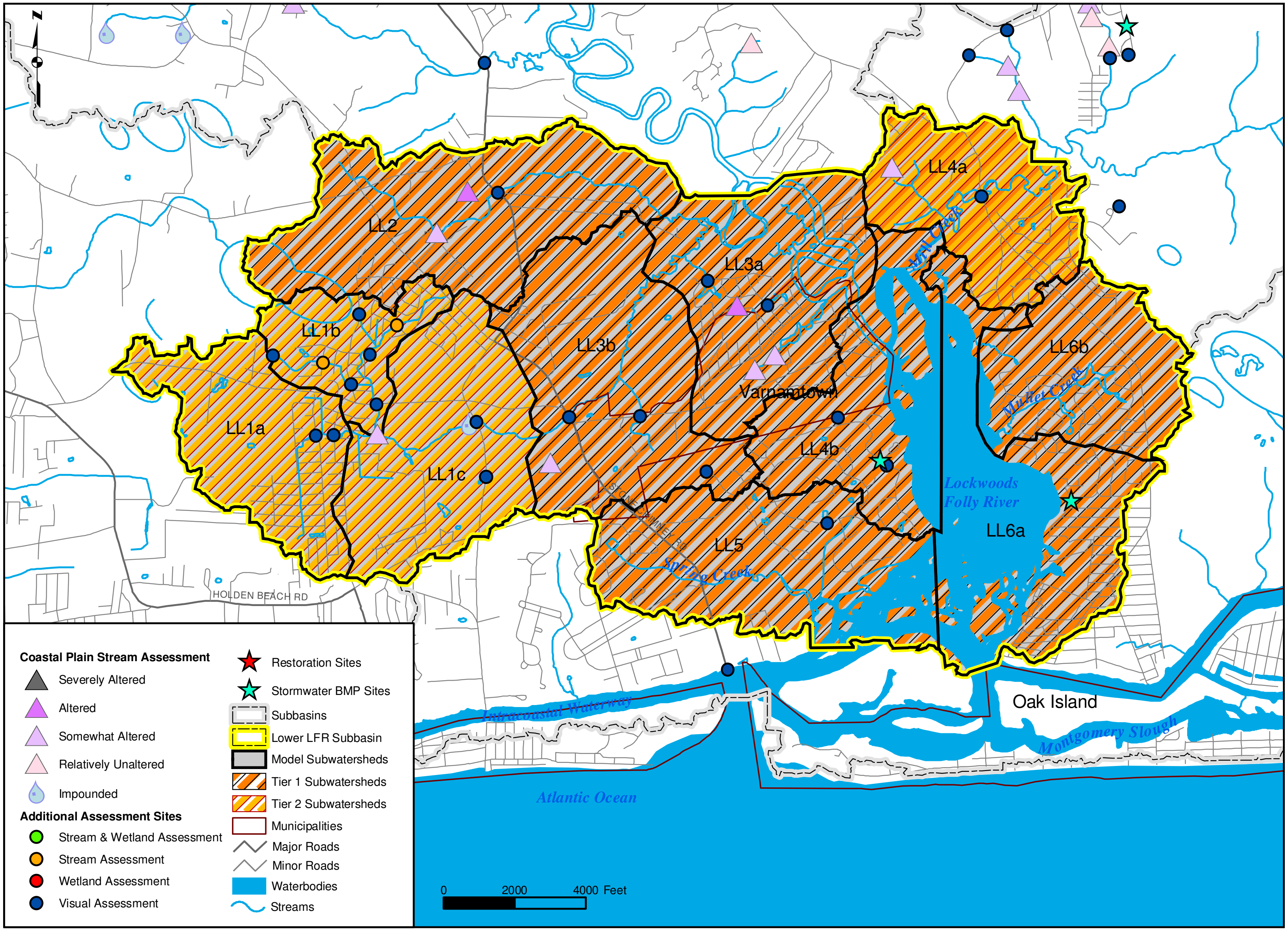


Figure 4.5. Lower Lockwoods Folly River Subbasin

### 4.2.6 Middle Lockwoods Folly River Subbasin

This subbasin is also experiencing a lot of growth. Existing land use consists of pine plantations and scattered agricultural areas as well as a few large residential developments. A number of additional residential developments of varying densities have been approved and site visits revealed that clearing and construction is underway. Eventually, much of this subbasin will be developed. There are three Tier 1 and seven Tier 2 priority subwatersheds in this subbasin (Figure 4.6). The field search for BMPs in these subwatersheds revealed a number of opportunities. Most of the opportunities are located in high density areas including an elementary school, the county hospital, and the Southport-Supply/US Highway 17 intersection. In addition, there are a number of opportunities in the Winding River neighborhood. This subbasin had one of the highest overall composite scores for the Coastal Plain assessment. Similar to other subbasins, there are large intact floodplains and buffers on the larger channels. Some of the headwater systems have been altered by ditching and two of these systems are potential restoration candidates. One is located at the elementary school and will work in conjunction with the BMP opportunities recommended there.

Although the streams were in good condition throughout this subbasin, the instream water quality data revealed three of the sampling sites in this subbasin, DC01, LC01, and PC01, had the highest levels of fecal coliform when compared with the other sampling sites. These sites were located on tributaries to Lockwoods Folly River. The sites on the river itself and on Doe Creek scored better. Subwatershed MS2 had the worst instream water quality for ammonia, nitrate and nitrite in the whole Lockwoods Folly River watershed. Phosphorous and total Kjehdal nitrogen were measured at levels that ranked in the second highest group in the watershed.

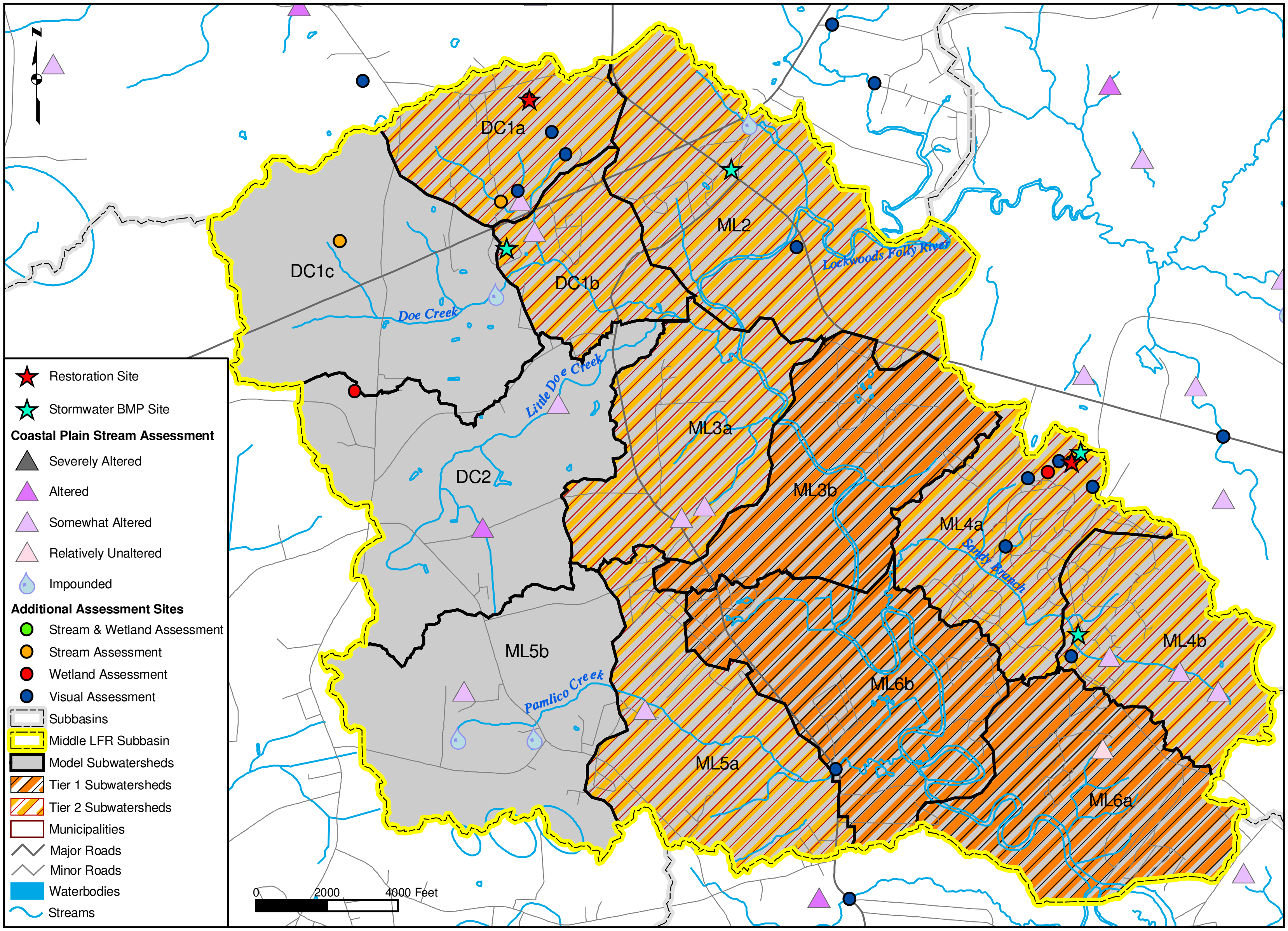


Figure 4.6. Middle Lockwoods Folly River Subbasin

### 4.2.7 Mill Creek Subbasin

Forest and pine plantations cover much of this subbasin with the exception of a few small housing developments, although a number of developments of varying densities are currently under construction that will most likely impact the streams. In addition, a second bridge and roadway to Oak Island is planned that will cross this subbasin. Eventually the entire subbasin is expected to be developed including commercial and institutional areas.

At this point there is no opportunity for restoration as most of the streams are relatively unaltered according to the stream assessment. The age and composition of the riparian buffer is evidence that large buffers were left intact when logging occurred. Some of the Carolina Bays located in the eastern portion of the subbasin were drained but the constructed drainage canals have since been plugged (Stantec 2006). Although two Tier 2 subwatersheds are located in this subbasin, only one stormwater BMP retrofit opportunity was found in a low density development that drains into a small headwater wetland (Figure 4.7).

### 4.2.8 Intracoastal Waterway/Atlantic Ocean Subbasin

Most of the mainland side of this subbasin is undeveloped except for a piece of Sunset Harbor on the western edge and a piece of St. James on the eastern end. The subwatersheds that contain these areas are all priority subwatersheds. St. James, a medium to low density residential area, already has a system of ponds that treat stormwater although one opportunity was found in a high density area. Sunset Harbor is identified as high density but field investigations revealed sand roads and small homes. No BMP opportunities were found there.

All of the streams are tidally influenced therefore no stream assessments were completed. In addition almost no feasible wetland restoration sites were identified during the GIS analysis and therefore no wetland assessments were completed. A large Carolina Bay that appears on the DCM wetland mapping layer as ditched was visited. The site visit revealed a large cypress swamp that does not appear to be ditched. The developer of Seawatch, who owns the land, has indicated it will be preserved and left as open space within the planned development. In addition, at the time of the drafting of this report indications are that the other two Carolina Bays in the subbasin will be preserved as part of the mitigation package for impacts associated with the roadway and second bridge to Oak Island that bisect this subbasin.

The island side of this subbasin consists of the Town of Oak Island. The model indicated the highest loading rates in the watershed here. Although there are many vacant parcels on the island, development continues and buildout is expected in the next twenty years. Two BMP opportunities were located that can serve as example projects (Figure 4.7). Currently, a portion of the island is ditched and stormwater enters directly into the Intracoastal Waterway. Two ditches were selected to serve as an example project of replacing ditches with enhanced water quality swales. Additional BMP opportunities were found in areas that drain to Montgomery Slough. This stream could not be assessed with the Coastal Plain stream assessment since it is tidal. The instream water quality data revealed the sampling sites in this subbasin had the highest levels of phosphrous when compared with the other sampling sites.

Lockwoods Folly River
Detailed Assessment
June 2007

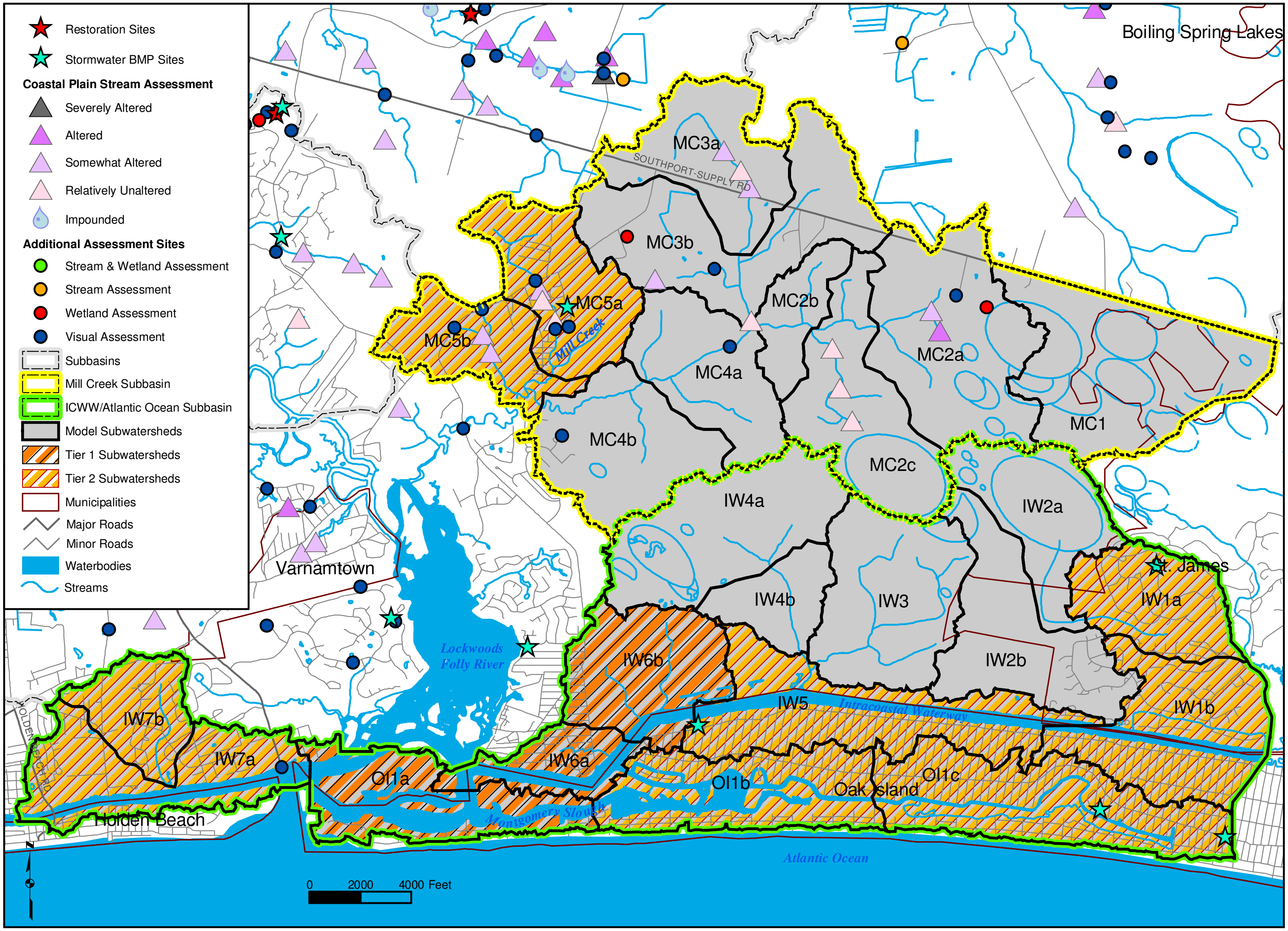


Figure 4.7. Mill Creek and Intracoastal Waterway/Atlantic Ocean Subbasins

# 5.0 Watershed Restoration and Retrofitting Strategy

Based on the collective findings of the Detailed Assessment, stream and wetland restoration efforts are recommended to help improve watershed functions and implementation of stormwater BMPs is recommended to help decrease pollutant loading from developed areas. It is important to note that most of the potential stream and wetland restoration projects were found in the less developed areas, mainly in the headwater portions of the watershed, where functional degradation has been a result of historic land use practices, primarily agriculture and forestry. Degraded watershed functions found in these areas included hydrology and/or aquatic and terrestrial habitat. Conversely, the watershed model did not identify these same areas as having the highest pollutant loading in the watershed. Rather, the watershed modeling analysis confirmed that highest pollutant loads were found to emanate from developed areas along the lower portions of the river and the ICWW, where the vast majority of the assessed streams were in good condition. Based on those modeling predictions, stormwater BMP retrofit efforts were targeted for the more developed areas in the lower portions of the watershed. While it is usually the goal of effective watershed planning to identify opportunities to implement multi-faceted management measures in high priority subwatersheds to achieve mutually additive benefits, the spatially disjunct nature of the primary stressors identified in this watershed has limited such cumulative management opportunities. In only a few cases restoration opportunities and stormwater BMP retrofit opportunities were identified in the same location.

It should be noted that all of the restoration projects are viable and will improve watershed health, yet compared to most other areas of the state, current conditions in the Lockwoods Folly watershed are not highly degraded. The projects identified reflect the best options in this watershed, and should be viewed as comprehensive in nature. Conversely the slate of BMPs identified should be view as a first pass at the potential retrofit opportunities in the watershed. The projects are further described in Appendix E, the Restoration Opportunities Atlas, which includes a project description, constraints, cost analysis, a site map for each project with parcels, hydric soils, project extent, and 2ft contours as well as a location map and directions to the site. An overview map of the project locations can also be found in Appendix E Figure 1.

## 5.1 STREAM AND WETLAND RESTORATION STRATEGY

### 5.1.1 Restoration Opportunities

There are four wetland projects including 2 non-riparian wetland restorations, 1 riparian wetland restoration that includes preservation and enhancement, and one that is a combination of riparian and non-riparian wetland restoration and enhancement. There are 9 stream restorations, 6 of which include a wetland restoration component (Table 6.1). While it is not possible to give an exact cost without a detailed engineering analysis of each restoration opportunity, to the extent possible, cost estimates were generated based on limited field reconnaissance. An estimated cost was not given for project 4 or for the wetland component of project 5 as the extent of restoration could not been determined without a more detailed assessment of the site. Constraints were identified but additional constraints and obstacles may be identified following a detailed survey of each site. This could lead to higher restoration costs.

Table 6.1. Proposed Restoration Projects

| No | Location | Recommended Activity | Length*/ Area | Observed Constraints | Estimated Cost |
|---|---|---|---|---|---|
| 1 | Alotadoe Rd | non-riparian wetland restoration | 24 ac | None | $360,000 |
| 2 | Prospect Rd | stream restoration & riparian wetland restoration | 2500 lf & 5 ac | loss of hardwood trees | $302,000 |
| 3 | Big Macedonia Headwaters | riparian wetland restoration (headwater system) | 1100 lf & 4 ac | None | $130,000 |
| 4 | Pinch Gut Creek | riparian & non-riparian wetland restoration/ enhancement | >30 ac | potential impact to logging roads | n/a |
| 5 | Red Run Bays | stream & riparian/non-riparian wetland restoration/ enhancement | >46 ac & 1600 lf | potential impact to logging roads | $320,000 (stream only) |
| 6 | Galloway Rd | non-riparian wetland restoration | 33 ac | None | $330,000 |
| 7 | Boggy Branch UT | stream & riparian wetland restoration | 1400 lf & 3 ac | proximity to spray fields | $140,000 |
| 8 | Ford Branch UT | stream restoration | 2100 lf | None | $395,000 |
| 9 | Ford Branch | stream restoration & riparian wetland restoration | 1100 lf & 3.2 ac | None | $196,000 |
| 10 | Pecan Trail Headwaters | stream restoration & riparian wetland enhancement | 1550lf & 1.4 ac | culverts in stream for Old Ocean Highway crossing | $328,000 |
| 11 | Old Lennon Rd | stream restoration | 1450 lf | None | $193,000 |
| 12 | Government Complex | stream restoration (2 reaches) (plus BMPs) | 900 lf & 900 lf | Reach 1: storage/ parking lot & county extension septic system demonstration center | $275,000 |
| 13 | Zion Hill | riparian wetland restoration/ enhancement/preservation (headwater system) (plus BMPs) | 15 ac | None | $120,000 |

* = number shown is existing stream length, restored stream length would be longer

### 5.1.2 Factors Used for Prioritization

Projects were ranked in two groups. The first group consists of the nine stream projects and the second consists of the four wetland projects that are not associated with a stream component. Projects from both groups were ranked taking into consideration a number of factors (Tables 6.2

and 6.3). Some projects are easier to implement than others while some will provide more functional uplift or have a low cost. Feasibility of restoration opportunities was used to determine which projects would be the easiest to implement relative to the others. It takes into account land ownership, site cover, and infrastructure constraints.

Projects located on sites where multiple landowners have a stake can be costly and time consuming to negotiate. Projects on public land are often easier to implement as agreements can be made to use the site whereas land acquisition is necessary on private land. Sites where the vegetative cover is wooded require greater effort for clearing and grubbing than sites with few or no trees. This factor is not included in the wetland group. In addition there may be more public opposition to a project if mature trees will be removed. Finally infrastructure such as roadways and water or sewer lines can limit the space available for restoration and thereby restrict the design. Culverts can also restrict design unless the culvert will be replaced during restoration but this option can be costly. These three components were used to determine feasibility at each site by assigning a score to each one and then taking an average of the three.

Feasibility is just one factor used to prioritize the two groups of restoration projects. Cost is another factor as well as the functional uplift associated with each project. Total cost for each stream project was divided by the length of stream to determine a cost per linear foot. The range of cost per linear foot is $100 to $212. This calculation includes the cost associated with planting and grading any associated riparian wetlands. Since wetlands are an added benefit, these projects were given extra points. The project also received extra points if they are associated with stormwater BMPs.

Wetland project costs were divided by the area of the project to determine cost per acre. Some projects appear to be less expensive per acre but may include enhancement or preservation which may be worth a smaller amount of mitigation credit. To determine function uplift for stream restorations, the Coastal Plain Assessment was filled out at each site. Sites with lower existing scores will have a greater uplift than sites with higher existing scores. The DWQ wetland rating guidance (see section 3.4) was used to determine functional uplift for the wetland projects. Those functioning less than 33% received the highest score. Finally, additional points were given to a project based on which subbasin it is located in. More points are given to projects in high priority subbasins.

Table 6.2. Factors for Ranking Stream Projects

| Factors | Feasibility (average of three) | | | Cost | Associated with BMP or wetland | Functional Uplift* | Subbasin Priority |
|---|---|---|---|---|---|---|---|
| Score | Land Ownership | Vegetative Cover | Infrastructure Constraints | | | | |
| 1 | Private – many owners | Wooded | Numerous | High (175-212) | None | Low (score >52) | Priority 6-8 |
| 2 | Private – few owners | Scattered Trees | Minimal | Medium (138-174) | BMP or wetland | Medium (score 45-51) | Priority 3-5 |
| 3 | Public | Herbaceuos | None | Low (100-137) | Both | High (score <44) | Priority 1-2 |

*Coastal Plain Stream Assessment

Table 6.3. Factors for Ranking Wetland Projects

| Factors | Feasibility (average of two) | | Cost | Functional Uplift* | Subbasin Priority |
|---|---|---|---|---|---|
| Score | Land Ownership | Infrastructure Constraints | | | |
| 1 | Private – many owners | Numerous | High | Low (score >67%) | Priority 6-8 |
| 2 | Private – few owners | Minimal | Medium | Medium (score 34-66%) | Priority 3-5 |
| 3 | Public | None | Low | High (score <33) | Priority 1-2 |

*DWQ Wetland Ranking

### 5.1.3 Ranking of Restoration Projects

The stream projects were ranked according to the method described above with the points received for each factor displayed in Table 6.4. The highest ranked project is the stream restoration at the county government complex which consists of two separate stream reaches. These streams are channelized and incised with no access to the floodplain. A few patches of existing wetlands would be reconnected with the stream as a result of this project. A number of stormwater BMPs are also proposed for this project site. The restoration and BMPs together would help improve water quality as well as terrestrial and aquatic habitat. The entire site could be used for education and demonstration purposes.

Table 6.4. Stream Project Ranking

| No | Location | Feasibility | Cost | Associated wetland or BMP | Uplift | Subbasin | Total |
|---|---|---|---|---|---|---|---|
| 12 | Government Complex | 3 | 2 | 2 | 3 | 3 | 13 |
| 11 | Old Lennon Rd | 3 | 3 | 1 | 2 | 3 | 12 |
| 2 | Prospect Rd | 2 | 3 | 2 | 2 | 2 | 11 |
| 3 | Big Macedonia Headwaters | 2 | 3 | 2 | 2 | 2 | 11 |
| 7 | Boggy Branch UT | 2 | 3 | 2 | 3 | 1 | 11 |
| 10 | Pecan Trail Headwaters | 1.3 | 1 | 2 | 3 | 3 | 10.3 |
| 9 | Ford Branch | 2.3 | 1 | 2 | 1 | 3 | 9.3 |
| 5 | Red Run Bays | 1.8 | 1 | 2 | 3 | 1 | 8.8 |
| 8 | Ford Branch UT | 1.3 | 1 | 1 | 1 | 3 | 7.3 |

The range of scores is narrow and a number of projects ranked the same or within one point of each other. In addition to the ranking, potential stream restoration length and acres of riparian wetlands could be used to further prioritize and select projects for implementation. For example, project 2 has the same score as 2 and 7 but is almost twice the length. Projects 8 and 9 did not rank high yet these projects could be combined which would also include some stream preservation. These projects combined may make them more desirable despite the low ranking.

Projects can be prioritized based on any of the factors used in the ranking. These factors can be used as individual tools or in any combination to help inform selection and prioritization of restoration projects.

Of the four wetland projects, the Zion Hill project scored the highest (Table 6.5). This project is located in an area undergoing rapid development. The project would restore a small piece of terrestrial habitat in what will become a sea of residential developments. The project includes a stormwater wetland to treat runoff from the adjacent school and roadway thereby improving water quality. A boardwalk could also be installed along the wetland to be used for educational purposes by the school or as a greenway for the adjacent neighborhoods. Once again, these projects can be prioritized based on any of the factors using in the ranking.

Table 6.5. Wetland Project Ranking

| No | Location | Feasibility | Cost | Uplift | Subbasin | Total |
|---|---|---|---|---|---|---|
| 13 | Zion Hill | 2.5 | 3 | 3 | 2 | 10.5 |
| 6 | Galloway Rd | 2.5 | 2 | 3 | 1 | 8.5 |
| 1 | Alotadoe Rd | 2.5 | 1 | 3 | 2 | 8.5 |
| 4 | Pinch Gut Creek | 2 | n/a | 2 | 1 | n/a |

## 5.2 STORMWATER BMP RETROFIT STRATEGY

### 5.2.1 BMP Opportunities

Once the Tier 1 and 2 subwatersheds were identified, potential BMP retrofits were located using aerial imagery. Each potential site was visited to determine the quantity, size, and location of the potential BMPs as well as constraints and feasibility. In addition to visiting specific sites, each subwatershed was canvassed for additional potential projects (Table 6.6).

The cost to install a BMP varies widely depending on site features including soil. An average price for each BMP type was used base on cost found in stormwater literature and best professional judgment. The estimated cost listed here only includes construction cost and does not include design fees or easement costs (Table 6.6). The average cost of a bioretention cell is $10 square foot (LID Center 2007), a water quality swale is $9 a linear foot (USEPA 1999), and a stormwater wetland is $8 a cubic yard plus $0.30 per square foot for vegetation (Hunt 2000). A wier structure for the wetland would be an additional cost and in this case a lump sum of $3000 was used. A number of projects involve retrofitting existing ponds or adding stormwater wetlands to these ponds. Cost for these retrofits cannot be estimated as an engineer's assessment is required to determine the necessary actions to repair or expand and improve each pond. Minor constraints were identified at three sites but additional constraints and obstacles may be identified following a detailed survey of each site. This could lead to higher costs.

Table 6.6. Stormwater BMP Opportunities

| No | Location | Recommended Stormwater BMP | Estimated Cost |
|---|---|---|---|
| 12 | Government Complex | bioretention | $100,000 |
| | | stormwater wetland | $6,070 |
| | | swales (front) | $3,780 |
| | | swales (back) | $3,150 |
| | | pond retrofit | n/a |
| 13 | Zion Hill | stormwater wetland | $2,600 |
| 14 | Bolivia Elementary School | bioretention (3 cells) (*constraint: potential loss of a few parking spaces*) | $52,000 |
| 15 | Brunswick Technical College | bioretention (2 cells) | $80,000 |
| | | retrofit pond | n/a |
| 16 | Supply Intersection | stormwater wetland | $18,600 |
| 17 | Brunswick Community Hospital | stormwater wetland | $7,050 |
| | | swales (front) | $2,970 |
| | | swales (back) | $1,350 |
| | | retrofit pond | n/a |
| 18 | River Run Plantation | stormwater wetland | $14,050 |
| 19 | Harbor Ridge | swales (*constraint: potential high # landowners if right-of-way not wide enough for swale*) | $16,740 |
| 20 | Supply Elementary School | bioretention (2 cells) | $155,000 |
| 21 | St. James | stormwater wetland | $6,400 |
| 22 | Lockwoods Folly County Club | swales | $25,200 |
| | | retrofit pond | n/a |
| 23 | Oak Island Northwest | swale (2) | $6,075 |
| 24 | Oak Island Recreation Center | stormwater wetland (*constraint: may require removal of some pavement*) | $10,590 |
| 25 | Oak Island Hospital | bioretention (2 cells) | $31,000 |

### 5.2.2 Factors Used for Prioritization

Stormwater BMP opportunities were prioritized by ranking the projects based on a number of factors similar to those discussed in section 6.1.2. As with the wetland projects, only two feasibility factors are used, land ownership and infrastructure constraints. The land ownership categories are somewhat different. Public land still receives three points, parcels owned by a community (for example a homeowners association) receive two points and private, individual owner parcels receive one point. Once again, points were given to a project based on the subbasin in which it is located, with more points given to projects in high priority subbasins. Projects associated with restoration opportunities were also given additional points (Table 6.7).

BMPs were also analyzed in terms of potential nutrient removal capacity. The analysis was performed using the PLOAD model (discussed in Section 2). Nutrient loads to BMPs were generated by delineating the contributing catchment for each practice and applying the loading rates used in the existing land use scenario. Research-based levels of nutrient reduction for each of the recommended BMPs were then applied to those loads.

Nitrogen was the nutrient chosen to determine a cost per pound of nutrient removed. Unfortunately, due to model limitations, all BMPs found in a model subwatershed had to be combined. Therefore there is only one removal efficiency per project instead of per BMP. Projects 24 and 25 are in the same model subwatershed and therefore the pounds of nitrogen removed takes into account both project sites. Nitrogen removal was used as the principle measure of BMP performance because consistent removal rates for fecal coliform were not available in the research literature for all the BMP types considered. Phosphorus removal was not utilized in addition to that for nitrogen because it is expected that reduction patterns in total phosphorus would mirror those exhibited for nitrogen.

Table 6.7. Factors for Ranking Stormwater BMP Projects

| Factors | Feasibility (average of three) | | Cost/lb of N removed | Associated with restoration project | Subbasin Priority |
|---|---|---|---|---|---|
| Score | Land Ownership | Infrastructure Constraints | | | |
| 1 | Private | Numerous | High (top third) | None | Priority 6-8 |
| 2 | Community | Minimal | Medium (middle third) | Stream or wetland | Priority 3-5 |
| 3 | Public | None | Low (lower third) | Both | Priority 1-2 |

### 5.2.3 Ranking of Stormwater BMP Projects

The stormwater projects were ranked according to the method described above with the points received for each factor displayed in Table 6.8. It should be noted that bioretention cells are more expensive than other BMPs and therefore the projects involving them will rank lower. Yet bioretention cells are often the only BMP option if space is limited or the water table is close to the surface. If cost is the limiting factor, sites may be reevaluated in more detail to determine if other BMP types may work.

On the other hand, when bioretention is included in a suite of BMPs such as that found at the county government complex (project 12), the overall cost is lower. The proposed project includes three types of BMPs including one bioretention cell (see Appendix E Project 12). The other less expensive BMPs help offset the higher price associated with the bioretention cell. This project ranked the highest among all of the BMP opportunities. The BMPs associated with this project will serve as demonstration projects for the county and beyond. Project 23, Oak

Island swales and project 17 at the county hospital project ranked the next highest of the projects. The Oak Island project involves replacing stormwater ditches with water quality swales along two roads. Currently stormwater is discharged directly into the Intracoastal Waterway. These two water quality swales will also serve as demonstration projects. Similar ditches are located along many other roads in the northwest quadrant of Oak Island. If these two are implemented and successful, swales can be constructed along the other roads.

Table 6.8. Stormwater BMP Project Rankings

| No | Location | Feasibility | Cost/lb N removed | Associated w/ restoration project | Subbasin | Total |
|---|---|---|---|---|---|---|
| 12 | Government Complex | 2.5 | 2 | 2 | 3 | 9.5 |
| 17 | Brunswick Community Hospital | 3 | 3 | 1 | 2 | 9 |
| 23 | Oak Island Northwest | 3 | 3 | 1 | 2 | 9 |
| 22 | Lockwoods Folly County Club | 2.5 | 2 | 1 | 3 | 8.5 |
| 18 | River Run Plantation | 2.5 | 2 | 1 | 3 | 8.5 |
| 15 | Brunswick Technical College | 3 | 1 | 1 | 3 | 8 |
| 16 | Supply Intersection | 2 | 3 | 1 | 2 | 8 |
| 21 | St. James | 2.5 | 2 | 1 | 2 | 7.5 |
| 19 | Harbor Ridge | 2 | 3 | 1 | 1 | 7 |
| 20 | Supply Elementary School | 3 | 1 | 1 | 2 | 7 |
| 25 | Oak Island Hospital | 2 | 1 | 1 | 2 | 6 |
| 14 | Bolivia Elementary School | 2.5 | 1 | 1 | 1 | 5.5 |
| 24 | Oak Island Recreation Center | 1.5 | 1 | 1 | 2 | 5.5 |
| 13 | Zion Hill | 2 | n/a | 2 | 2 | n/a |

# 6.0 Lockwoods Folly Watershed Roundtable Strategies

Recognizing the decline in overall heath of the river and its estuary, Brunswick County officials teamed with the North Carolina Coastal Federation in 2004 to secure grant funding from the US Environmental Protection Agency (EPA) to develop a watershed plan to protect and restore water quality in Lockwoods Folly. Several groups provided components of the plan, including a survey of water pollution sources by the state Shellfish Sanitation Section of the Division of Environmental Health and an economic analysis comparing the cost of conventional development to that of low impact development conducted by North Carolina State University.

To oversee this effort, the county created an advisory group known as the Lockwoods Folly Roundtable. The Roundtable consists of eight members, including town officials, developers, fishermen and engineers. They were charged with assessing the state of the river and developing a comprehensive plan for its recovery and protection.

Coincident with the formation of the Roundtable, NCEEP targeted the Lockwoods Folly River watershed for the local watershed planning initiative described in this document. Through initial investigations toward potential development of a stakeholder group for the LWP effort, NCEEP staff became aware of the ongoing Roundtable process and attended some of the Roundtable's initial meetings. Upon becoming fully aware of each others' efforts, the Roundtable and NCEEP formed a partnership in the interest of avoiding duplication and leveraging their resources toward development of a more robust watershed plan.

With the active participation of NCEEP and Stantec staff, the Roundtable met every one to two months for approximately two years and performed the following tasks:

1) *Evaluated current state and federal water quality programs.* During their assessment, several agency officials noted that despite the current federal and state laws, water quality has continued to decline and more waters are closed to shellfishing. These officials have said that local leadership is necessary to ensure the protection and restoration of the river's uses.
2) *Commissioned a land suitability analysis,* in order to tailor future land use policies to water quality risk factors. This means guiding development into areas at low risk for harming water quality.
3) *Conducted a special water quality survey* to identify actual and potential sources of stormwater pollution and heard presentations from local and state experts about specific problems they've identified.
4) *Devised a draft set of strategies designed to protect water quality* as the area continues to grow while taking steps to fix the current problems. The watershed strategies will aid the county in planning for the future wise development of the area while balancing the need to protect the resources that make it a desirable place to live and visit.

The majority of the strategies developed through the Roundtable process are aimed at protecting the watershed from the adverse ecological impacts of future development in the watershed. The watershed modeling analysis supported by NCEEP (described in Chapter 2) provided a strong impetus for several of the strategies. In addition to addressing the impacts of future development, some of the strategies are aimed at restoring the watershed under existing conditions and essentially reflect the Roundtable's endorsement of NCEEP's programmatic activities in the watershed. The Roundtable strategies are summarized below and are presented in full detail in Appendix D.

## 6.1 ROUNDTABLE STRATEGY 1

*(A) Assess water quality risk according to natural systems in watershed and develop future land use policies and ordinances that fit land use density and landscape design to the level of water quality risk.*

*(B) Sewer extension policies that: (1) give priority services to communities with malfunctioning septic tanks, and (2) ensure that land use and development policies in sewer service areas are consistent with risks to water quality.*

### 6.1.1 Strategy 1 Findings

The Roundtable reviewed the results of a Land Suitability Assessment – Water Quality Risk Model, which was developed as part of the project. This model relies on four factors to assess water quality risk from land development activities: Soil Characteristics, Land Cover, Presence of Wetlands, and Proximity to Surface Water. Mapping produced by the model and (Figure 5.1) shows areas in the following four risk categories:

*High-value Water Quality Protection Areas* – contain coastal wetlands or non-coastal wetlands that have significant or exceptional water quality protection functions. These areas have only limited development potential.

*Highest Water Quality Risk Areas* – due to the soil conditions and land cover found here, land-disturbing activities in these areas may cause serious damage to natural systems and water quality. These areas are suited only for the very lowest intensity development.

*Moderate Water Quality Risk Areas* – these areas contain soils and land cover types that have significant limitations for development activities, but these limitations may be mitigated by methods such as controls on development density, open space preservation, tree preservation, and the range of low intensity development techniques.

*Lowest Water Quality Risk Areas* – these areas have the least limitations for development from a water quality protection standpoint. These limitations can generally be addressed by commonly accepted land use and development practices.

The availability of sewer is another important land use planning consideration from the standpoint of built-upon surfaces and stormwater runoff. Sewers have the potential to facilitate intensive sprawling development. Studies in other watersheds have shown that in the absence of effective land use plans and ordinances (that are designed specifically to protect water

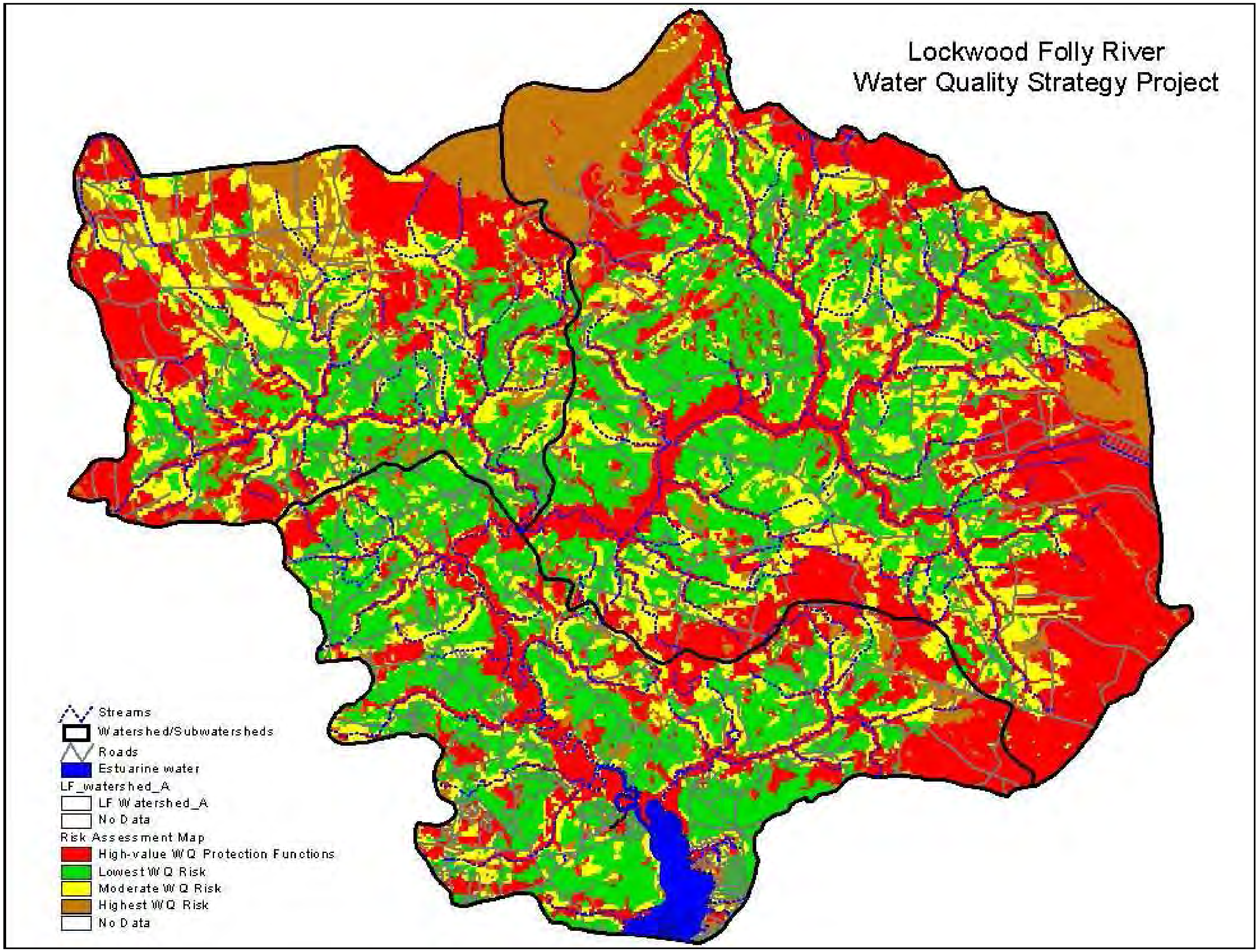


Figure 5.1. Results from Lockwoods Folly Watershed Roundtable's Water Quality Risk Model

quality) the availability of sewer can contribute to significant increases in development density with resulting increases in impervious surfaces. Land use policies should recognize this possibility and where sewer is available or is extended the policies should be designed to achieve appropriate density, location, siting and/or landscape designs.

### 6.1.2 Strategy 1 Recommendations

1. A range of low impact development (LID) techniques are the preferred approach to managing stormwater in the watershed. The LID approach can also be a central component of the land use management process in the watershed. The county should include specific policies in its Coastal Area Management Act (CAMA) land use plan update that make clear LID is the preferred approach for new development. In addition, it should include a chapter or section on in the proposed Unified Development Ordinance clarifying that LID techniques are the preferred approach to land use within the watershed and that such approaches comply with county, state, and federal performance measures. This approach should provide regulatory incentives (reduced road widths, density credits, etc.) that encourage the development community to use LID techniques as an alternative to traditional development designs.

2. The county should reduce the amount of impervious surface required by its development management policies to the maximum extent practical.

3. The county's development review process should incorporate a system, such as the Water Quality Risk Assessment Model, to identify sensitive areas where land development activities have a reasonable probability of degrading water quality.

4. The county should adopt land use and development policies in its CAMA land use plan to protect water quality. These policies should be implemented through its development management program. The policies should also reflect new regulatory requirements adopted by the North Carolina General Assembly for NPDES Phase II counties such as whether the site drains to SA waters and its proximity to SA waters. The following are key aspects of these policies.

5. Cluster development should be considered as a development practice to the maximum extent feasible as a means to manage stormwater and to protect valuable water quality features. The density levels on the cluster area of the site should be consistent with the density allowed by the zoning of the site. The open space created by the cluster approach should be planned as part of the overall water quality protection scheme for the site. In addition, the site should include a green space system that incorporates sensitive areas such as wetlands, stream corridors and naturally vegetated areas. This development option should be available for small parcels as well as large tracts and should not require significant additional review processes.

6. The county should develop a sewer extension policy consistent with land use policies that are designed to protect water quality.

## 6.2 ROUNDTABLE STRATEGY 2

*Incorporate low impact development (LID) technology into county site design and development policies. The strategy will include methods to integrate this tool into the County's existing development management program.*

### 6.2.1 Strategy 2 Findings

Low impact development (LID) is an ecologically friendly approach to site development and stormwater management that aims to minimize development impacts to land, water, and air. The approach emphasizes the integration of site design and planning techniques that conserve natural systems and hydrologic functions on a site. Low impact development is not a land use control, but a management and design strategy that is integrated into the proposed land use. It has also been shown to decrease costs to developers and to increase the desirability and value of the property. The practice has been successfully integrated into many municipal development codes and storm water management ordinances throughout the United States.

The goals of LID are to:

1) Preserve open space and minimize land disturbance.
2) Protect natural systems and processes (drainage ways, vegetation, soils, sensitive areas).
3) Reexamine the use and sizing of traditional site infrastructure (lots, streets, curbs, gutters, sidewalks) and customize site design to each site.
4) Incorporate natural site elements (wetlands, stream corridors, mature forests) as design elements.
5) Decentralize and micromanage stormwater at its source.

### 6.2.2 Strategy 2 Recommendations

1. Brunswick County should publicly support low impact development as a more effective means, than that of the typical current practice of managing stormwater and protecting water quality. This public support will encourage developers to utilize LID techniques and will encourage the public to purchase homes in LID developments.

2. The county should incorporate LID as a preferred strategy to meet post construction stormwater requirements for the Phase II NPDES permit requirements.

3. The county should review and update the County Stormwater Manual to reflect the latest LID technology.

4. Brunswick County should also incorporate low impact development into their local ordinances, similar to the town of Huntersville, which has incorporated low impact development into the town's zoning ordinance. Developers would have the option to use LID

or conventional development, as LID would not be required, just recommended. Local ordinances that contain potentially excessive impervious surfaces, such as a minimum street widths, are often the biggest obstacles to low impact development. The incorporation of LID principles into local county ordinances will help to encourage developers to utilize these environmentally friendly principles.

5. Conduct a demonstration project that will showcase low impact development principles to developers and the public. This project will educate developers and citizens about both the economic and environmental benefits of low impact development and encourage the use of these techniques throughout the county.

6. A staff specialist in the Brunswick County Department of Engineering Services should be trained in LID. In addition, the county should sponsor periodic training in LID for both staff and the county's development community.

## 6.3 ROUNDTABLE STRATEGY 3

*Coordination of state, local, and federal regulatory programs with Brunswick County taking lead enforcement role. Suggest policy changes and financial plan to accomplish.*

### 6.3.1 Strategy 3 Findings

Currently there are three major permitting processes in place: the county's stormwater ordinance and related stormwater manual; the NC Land Quality Section's Soil Erosion and Sedimentation Control regulations that have been in place since the 1970s; and NC Division of Water Quality's coastal stormwater regulations. The county's subdivision and site plan (zoning) programs are linked to the county stormwater regulations and the state's soil erosion/sedimentation control requirements.

Three major benefits derive from consolidation of plan approval, permitting, and inspections: (1) the Brunswick County development community will see efficiencies in the review process through 1-stop permitting and possibly some reduction in plan review time; (2) there will be greater consistency among the 3 permit systems; and (3) the county's post-permit inspections will improve the effectiveness of the state coastal stormwater program.

### 6.3.2 Strategy 3 Recommendations

1. The Roundtable recommends that the Board of Commissioners take necessary steps to coordinate stormwater permitting in Brunswick County. The Roundtable concludes that permit coordination will increase efficiency and will improve the effectiveness of the permitting system in protecting water quality.

2. The Phase II NPDES permit should be adopted as the primary tool for coordinating stormwater permitting by the county. The Phase II permit provides for local soil erosion and sedimentation control plan review and may provide for coastal stormwater plan review.

3. The county should establish a fee schedule for plan review and inspection that makes the program financially self-sufficient to the extent feasible.

## 6.4 ROUNDTABLE STRATEGY 5

*Action plan to acquire strategic sites and parcels to protect and restore water quality.*

### 6.4.1 Strategy 4 Findings

As part of the Lockwoods Folly River Water Quality Strategy, land acquisition of strategic sites within the Lockwoods Folly River Watershed were proposed in order to reduce projected future increases of pollutant load into the River due to stormwater runoff, as well as prevent increased impervious surface from development of these lands. This should assist in reduction of three key environmental health threats: fecal coliform, freshwater inundation of estuarine areas, and increased runoff from impervious surfaces.

Reports and presentations to the Roundtable (Lynch, 2005) described a three-step for formulating the land acquisition strategy.

1) Eliminate parcels that do not meet acreage criteria and development criteria.
2) Rank remaining parcels based on hydrologic criteria—risk to water quality if developed, percent highly saturated soil, and stream index.
3) Select from ranked parcels based on values of three different organizations.

The parcels and sites identified through this process constitute the land acquisition strategy.

### 6.4.2 Strategy 4 Recommendations

1. The priority sites identified as a result of the Land Acquisition Strategy Process should be the basis for selecting potential sites for acquisition.

2. The county should establish partnerships with NGOs (North Carolina Coastal Conservation League, North Carolina Coastal Land Trust, The Nature Conservancy, etc.) to pursue targeted land acquisition to preserve high priority properties.

3. Through these partnerships where NGOs and EEP will take the lead, the county should actively encourage at least one major property acquisition (from willing sellers) every two years within the watershed.

4. The county should work with NCEEP to promote the restoration of degraded lands with EEP taking the lead on these projects.

5. Brunswick County should also seek to elevate the status of the Lockwoods Folly River as an important location to invest land acquisition funds by:

- Supporting Wild and Scenic Designation of the upper Lockwoods Folly River
- Supporting the NC Oyster plan that places high priority on the watershed for oyster protection and restoration
- Including policy statements in its CAMA land use plan that promote land acquisition within the watershed
- Encouraging the NC Division of Coastal Management to include the Lockwoods Folly Watershed in its CELCP (Coastal and Estuarine Land Conservation Program) plan.

6. The county, through its planning process, should develop and map an open space system and use open space values as a factor in the final selection of sites scheduled for acquisition.

## 6.5 ROUNDTABLE STRATEGY 5

*(A) Develop a public education, information, and outreach program.*

*(B) Recognize the environmental and cultural significance of the Lockwoods Folly River through Wild and Scenic River designation.*

### 6.5.1 Strategy 5 Findings

The effectiveness of the water quality strategy will be greatly enhanced by the active participation and support of the residents, property owners, and visitors of the watershed. The strategy aims to increase public understanding and awareness, promote better stewardship of private lands, and develop funding to help sustain watershed programs.

An informed and knowledgeable community is crucial to the success of the Lockwoods Folly Watershed Strategy. A public education and outreach program will ensure *greater support* for the program as the public gains a greater understanding of the reasons why it is necessary and important. This will also ensure *greater compliance* with the program as the public becomes aware of the personal responsibilities expected of them and others in the community, including the individual actions they can take to protect or improve the quality of area waters.

The components of the public education, information, and outreach strategy are as follows:

1) technical assistance
2) advocacy
3) education
4) pollution prevention
5) maintenance

6) water quality monitoring
7) assistance with restoration

A river is eligible for Wild and Scenic River (WSR) designation if it is a free-flowing river with "outstandingly remarkable" values (ORV) as described in the Wild and Scenic River Act of 1968. These values include outstanding and remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values.

WSR designations seek to maintain and enhance a river's *current* natural condition and provide for public use consistent while retaining those values. The designation prohibits the federal government from licensing or permitting hydroelectric dams or major diversions on these streams, and federal agencies are prohibited in assisting any water resource projects that may directly affect designated rivers. However, the designation *does not* affect private land and *does not* give additional power to the federal government over private landowners.

In other words, scenic or recreational designation will allow current river and land uses to continue while preventing federal projects that will degrade the outstanding qualities of the river. In addition, the designation will bring local and regional attention to the beauty and pristine nature of the river, and it will support the county's education, information, and outreach program.

The primary benefit of the designation of the Lockwoods Folly River is the increased opportunities of public money that might be available to buy land or easements from willing property owners. Having more land available for public uses such as hunting and camping will help accommodate growing public demand for such areas and reduce pressures and conflicts with private property owners.

### 6.5.2 Strategy 5 Recommendations

1. Brunswick County should create a permanent staff position to assist in implementation of the Lockwoods Folly River water quality strategy, including the education and outreach program. The position will be in charge of implementing and overseeing the various Lockwoods Folly River water quality strategies: include low impact development, land acquisition, coordination with other programs such as coastal management and non-coastal wetlands, a living shorelines program, a working waterfront program, and so on.

2. The county should establish an adequate annual budget to support the education and outreach program activities.

3. The Board of Commissioners should adopt a resolution stating that it is the intent of the county to pursue the WSR designation.

4. The Board of Commissioners should enlist the support of its congressional delegation to move the project through the federal study and WSR designation process.

## 6.6 ROUNDTABLE STRATEGY 6

*Protect stream edges in the watershed by implementing a **Living Shorelines** program.*

### 6.6.1 Strategy 6 Findings

A *living shoreline* is an innovative approach to shoreline stabilization that combines various stabilization bioengineering methods to control shoreline erosion, while restoring and/or preserving the characteristics of the estuarine marshes and upland buffers. Living shoreline design typically uses a low rock sill to absorb wave energy. Behind the sill, wetland vegetation is planted to restore the lost habitat, provide a stormwater buffer, and reduce erosion.

Living Shoreline approaches allow property owners to choose a protection method that will provide effective erosion control with the least negative impact on the environment. Living Shoreline projects avoid a "hardened" shoreline, which results from the traditional approaches of vertical walls or riprap. Vertical walls and rip-rap revetments do not absorb wave energy like sloping vegetation. Instead, the energy is reflected back along the shoreline, which can increase the erosion in these areas and scour marshes that naturally grow here. Bulkheads replace the broad, diverse tidal area with a vertical surface, greatly reducing the potential habitat for numerous estuarine animals that rely on these fringes to survive.

### 6.6.2 Strategy 6 Recommendations

1. Brunswick County should support the EEP Living Shorelines Program and help promote it to the public. Potential cost sharing for restoration projects should be a centerpiece of the promotion program.

2. The county should consider conducting a public living shoreline demonstration project that could be showcased as a public education facility.

3. Brunswick County should consider incorporating language supporting living shorelines in policy documents such as the CAMA land use plan.

## 6.7 ROUNDTABLE STRATEGY 7

*Identify sites for water quality "retrofit" to reduce or eliminate unwanted runoff.*

### 6.7.1 Strategy 7 Findings

The Lockwoods Folly River is currently on the 303(d) list of impaired waters in North Carolina due to levels of fecal coliform bacteria that exceed standards for SA waters. The *Lockwoods Folly Local Watershed Plan - Preliminary Findings Report* (Stantec, 2005) identified fecal coliform loading and the potential for excess nutrient loading as primary stress factors to watershed functions in the Lockwoods Folly Local Watershed Plan study area.

All the primary stress factors identified in the watershed can be attributed to the adverse impacts of urban stormwater runoff. Reduction of these factors offers a strong opportunity to realize multiple benefits through the retrofitting of stormwater BMPs, primarily stormwater wetlands and detention ponds, which can reduce fecal coliform and nutrient loads, as well as reduce peak storm flow and stream erosion.

### 6.7.2 Strategy 7 Recommendations

1. Support the development of, and give high priority to, the implementation of targeted stormwater BMPs identified in the NCEEP Local Watershed Plan.

2. Identify a central county staff position (see Strategy 6B) that, in conjunction with NCEEP efforts, will explore the feasibility and funding for retrofitting the County Government Complex with appropriate stormwater BMPs as a demonstration project.

## 6.8 ROUNDTABLE STRATEGY 8

*Develop financial incentive program that encourages developers to take alternative approaches that support water quality objectives.*

### 6.8.1 Strategy 8 Findings

The Round Table identified three potential options for providing financial incentives. One of these options is the traditional donation of fee simple title or a conservation easement to a qualified land trust or conservancy. Such a donation qualifies for federal income tax deductions and in North Carolina, the donation brings either a tax deduction or a tax credit.

A second option is to purchase land or development rights using a public or NPO trust fund. Even if the purchase price is limited to a portion of the appraised value, say 50%, the ability to generate cash may be more attractive to a development organization than a tax deduction or tax credit. Some local governments have been successful in using the NC Clean Water Trust Fund to purchase land in this manner.

A third option is a process called transfer of development rights, or TDR. TDR is a method for protecting land by transferring the “rights to develop” from one area and giving them to another. What is actually occurring is a consensus to place conservation easements on property in critical water quality areas while allowing for an increase in development densities or “bonuses” in other areas that are being developed. The costs of purchasing the easements are recovered from the developers who receive the building bonus.

The transfer of development rights is not a new concept. TDRs have been used in other areas of the country for the preservation or protection of open space, natural resources, farmland, and urban areas of historical importance. TDRs also have been used to secure land for solid waste facilities and for the protection of golf courses. More than 20 states have enacted or amended statutes accommodating the TDR concept.

TDRs are regulatory tools designed to facilitate land-use planning. Unlike most land use plans, the transfer of development rights requires much more certainty of where development will happen and where it will not. TDR programs cannot be established in the absence of a detailed land use plan.

### 6.8.2 Strategy 8 Recommendations

1. The county should develop a simple, effective mechanism that encourages donation of conservation land to appropriate non-profit conservation organizations. In conjunction with this strategy, the county should consider designating and training a staff person to provide this assistance.

2. The county tax office should ensure that designated conservation lands within subdivisions receive maximum favorable ad valorem tax treatment.

3. The county should work with its state and national organizations to explore the feasibility of increasing the percentage of value and the tax credit caps on the conservation land tax credit program. By increasing these levels it is more likely the program will be utilized.

4. Developers should have access to a streamlined development review process to encourage cluster development, flexible site planning and development, and other LID techniques that support water quality objectives.

5. As a long-term option, the county should consider a TDR program. Preparation of a detailed operation plan is a first step in this process. The plan will provide significant details on operation and the requirements for state and local legislation.

6. The county should assess the feasibility of a conservation land trust fund for fee simple purchase or to purchase development rights for key properties in the watershed.

## 6.9 ROUNDTABLE STRATEGY 9

*Develop a working waterfront program that assists in the preservation of traditional waterfront businesses, such as fish houses and commercial marinas, and public access, such as boat ramps and fishing piers.*

### 6.9.1 Strategy 9 Findings

As development pressures and land values increase along the Lockwoods Folly River, it will be more difficult for traditional waterfront uses to continue. This strategy will involve land use policies and incentives that will assist water dependent owners and business operators with remaining in place. The strategy will also take advantage of funding sources for the preservation of public access points.

A working waterfront, such as the Varnamtown waterfront shown in Figure 5.2, is property that provides access for water dependent commercial activities or property that provides access for the public to public trust waters of the state. Working waterfronts include commercial marinas, boatyards, wet and dry storage, fish houses, commercial fishing vessel dockage and marine-related industries such as boat dealers, boat repair and maintenance services, commercial fishing and tourism. A limited supply of waterfront land and an increasing demand by different uses is leading to a loss of the working waterfront.

In coastal, and largely rural, Brunswick County, fishing and shellfishing functions of the Lockwoods Folly River and estuary are integral to the economy and natural heritage of the residents.

### 6.9.2 Strategy 9 Recommendations

1. Brunswick County is currently updating their land-use plan as required by the CAMA. Specific policies on working waterfronts should be included in this plan, as well as in municipal plans, such as the Varnamtown Workbook Plan.

2. The county should quickly develop a public access plan that identifies and utilizes sources of funding for land acquisition of priority areas.


Figure 5.2. Working Waterfront at Varnamtown

3. Public access is one of the keys to maintaining a working waterfront. In addition, CAMA requires counties to address and develop a plan for public access. The county must encourage varied waterfront uses, such as commercial fish houses, industrial and recreational marinas and recreational fishing piers. The Brunswick County local government should consider using their zoning and subdivision authority to require that new development set aside space for public and commercial access.

4. The Brunswick County local government should consider establishing a fund, through activities such as bond referendums, which provide money to buy development rights or conservation easements to land that is ecologically or culturally significant or that provide waterfront access to commercial or recreational fishermen and the public.

5. Support Senate Bill 1352 that would create a Waterfront Access Study Committee. This bill would create a 17-member committee that will prepare a report by early next year. The report would include information about land use management and zoning, shoreline development trends and tax assessment trends. It would also review incentives and management tools to preserve waterfront diversity. Brunswick County should also push to get representation on the committee.

6. The county should support efforts that allow people with moderate incomes to continue to live in the Lockwoods Folly Watershed. This may be done through a workforce housing plan that will allow moderate income residents to continue to live within the watershed.

# 7.0 Conclusions and Next Steps

The Lockwoods Folly River watershed was chosen for local watershed planning efforts by NCEEP because of its 303(d) list impaired status resulting from loss of shellfishing waters due to excess fecal coliform loads. Beyond that particular problem, the assessment tools utilized in the Detailed Assessment have revealed a relatively undeveloped watershed with ecological functions largely intact. The comprehensive assessments of coastal streams and wetlands indicated that the vast majority of the hydrologic resources of the watershed are healthy and functioning and some exhibit fairly pristine conditions. The watershed modeling analysis indicated that, with the exceptions of the few developed areas near the coat and the estuary, the bulk of the watershed yields pollutant loads that could be characterized as natural background loading under existing conditions.

The future land use scenario developed for this effort represents major changes in watershed conditions when compared to existing levels of development. The watershed modeling analysis strongly reinforced the expectation that those land use changes have the potential to result in drastic increases in nonpoint source pollutant loads under existing development and stormwater management guidelines. In addition, increased stormwater runoff volumes have the potential to destabilize and degrade the headwater streams and wetlands that have the imperative ecologic functions of providing critical habitat and reducing pollutant loads at the watershed scale. Clearly, relative to that of existing conditions, the adverse impacts of future development pose the greatest threats to the health in this watershed. This concern is heightened by the fact that development has been occurring very rapidly within the watershed, and given that Brunswick County is the 29$^{th}$ fastest growing county in the nation (*reference*), this rapid growth is expected to continue for the foreseeable future.

The threat posed by future development puts particular emphasis on the strategies set forth by the Lockwoods Folly River Watershed Roundtable in that the majority of their recommendations are aimed at reducing the impacts of development. The watershed modeling analysis also confirmed that significant water quality benefits could be achieved through implementation of the Roundtable's recommendations to institute low impact development and strategic preservation of lands with high importance to water quality. Their recommendations to use a water quality risk analysis to direct development away from areas or positions in the landscape where it is less suitable and toward more suitable areas also hold promise within a comprehensive land use planning context.

In spite of the benefits predicted to result form the recommended management actions, restoring shellfishing waters and/or protecting the remaining shellfishing opportunities in the Lockwoods Folly will be at best a challenging endeavor with the levels of development predicted for the watershed. Taken collectively the results of this watershed planning effort have shown that no one measure or strategy alone will achieve the desired results, but rather, an aggressive pursuit of all restoration and protection opportunities will be required to achieve a modicum of success.

The endeavor to restore and protect shellfishing also places particular emphasis on the restoration and BMP retrofitting opportunities set forth in this plan in order to reduce existing pollutant loads and restore watershed functions. It should be noted, that while the list of restoration opportunities presented in this plan can be viewed as comprehensive, the list of stormwater BMP retrofit opportunities should be viewed as a first-pass in an overall strategy that should be consistently and diligently pursued over the coming years.

The North Carolina Coastal Federation has been awarded federal grant funding under Section 319 of the Clean Water Act to support development of a fecal coliform total maximum daily load (TMDL) allocation for the Lockwoods Folly watershed. It is expected that work on the TMDL will begin in summer or fall of 2007, and this effort will bring the opportunity to develop a more sophisticated set of management tools for the watershed including a more robust watershed loading model for fecal coliform and a water quality response model for the river and its estuary. The TMDL will also spur another round of identification of stormwater BMP retrofit opportunities. If funding sources can be identified, the scope of the TMDL development project should be expanded to include modeling of watershed nutrient loading and the predicted eutrophic response in the river. The need for these additional assessments and management tools is spurred by results from the NCDWQ water quality monitoring effort associated with this plan. The results show that the Lockwoods Folly River may be approaching the threshold where nutrient loads have the potential to cause significant degradation of overall aquatic ecology of the system through excess eutrophication manifested as nuisance blooms.

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**Appendix A. Lockwoods Folly River Water Quality Study**

**Appendix B. Watershed Modeling**

**Appendix C. Ecological Assessment of Three Coastal Stream Networks**

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**Appendix E. Restoration Opportunities Atlas**

# Appendix A

## Lockwoods Folly River Water Quality Study

## in support of

## EEP Local Watershed Plan Development

**DRAFT Final Report**

**March 16, 2007**

***Prepared by Division of Water Quality***

***Watershed Assessment Team***

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## *Acronyms*

AMS: Ambient Monitoring System
BAU: Biological Assessment Unit
BIMS: Basinwide Information Management System
BOD: Biological Oxygen Demand
CFU: Colony Forming Units
DEH: Division of Environmental Health
DEM: Division of Environmental Management (now known as DWQ)
DENR: Department of the Environment and Natural Resources
DMR: Discharge Monitoring Report
DO: Dissolved Oxygen
DWQ: Division of Water Quality
EEP: (NC) Ecosystem Enhancement Program
EPA: Environmental Protection Agency
HUC: Hydrologic Unit Code
ICW: Intracoastal Waterway
ISU: Intensive Survey Unit
LFR: Lockwoods Folly River
LULC: Land Use/Land Cover
LWP: Local Watershed Plan
MDL: Method Detection Limit
MPN: Most Probable Number
NH3: Ammonia
NLCD: National Land Cover Database
NO2+NO3: Nitrate + nitrite
NPDES: National Pollutant Discharge Elimination System
NTU: Nephelometric Turbidity Units
PQL: Practical Quantitation Limit
QA/QC: Quality Assurance/Quality Control
QAM: Quality Assurance Manual
QAPP: Quality Assurance Project Plan
RL: Reporting Limit
SOP: Standard Operating Procedures
SS: Shellfish Sanitation Program
SU: Standard Units (pH)
TIN: Total Inorganic Nitrogen
TKN: Total Kjeldahl Nitrogen
TN: Total Nitrogen
TON: Total Organic Nitrogen
TP: Total Phosphorus
UT: Unnamed Tributary
WAT: Watershed Assessment Team

## *Executive Summary*

Water quality data for the Lockwoods Folly River study were collected from the period of April through October 2006 at a total of 31 locations on the mainstem Lockwoods Folly River, the Intracoastal Waterway (ICW), Montgomery Slough on Oak Island, and nine tributaries (both fresh- and saltwater). The parameters that were sampled or measured include fecal coliform, nutrients, residues, turbidity, chlorophyll-a, metals, and field measurements (dissolved oxygen, temperature, specific conductance, pH, and salinity).

Fecal coliform has historically been the concern in the lower Lockwoods Folly R, ICW, and other tidal tributaries. These areas are protected for shellfishing uses, but have been closed to this use due to bacteria counts above North Carolina (NC) state water quality standards. In this study, half of the twenty sites that are protected for shellfishing had median concentrations over the screening value of 14 colonies/100 mL. The medians at these locations ranged from 17 to 80 colonies/100 mL. Included are four out of the five sampling locations on Montgomery Slough, with the highest concentrations found furthest upstream (median = 80). At this location five of seven samples exceeded the single sample screening value maximum of 43. High values were also noted on Mill Cr, a tidal saline tributary to the lower Lockwoods Folly R, with a median value of 55 colonies/100 mL and six of eight samples exceeded 43.

For the freshwater tributaries, Little Doe Cr and Sandy Br showed the highest geometric means (377 and 321 colonies/100 mL, respectively), which were well above the screening value of 200 colonies/100 mL for non-shellfishing waters. Pamlico Cr, a tidal and slightly saline tributary, showed the highest geometric mean of all sampling locations (477 colonies/100 mL).

Ammonia ($NH_3$) concentrations were highest in the tributaries and ranged from 0.02 to 0.17 mg/L as N. Bolivia Br showed the highest mean value (0.17) but this is likely due to a point source discharger. Lower values (0.02-0.04 mg/L) were seen in the Lockwoods Folly R mainstem, the ICW, and in two tributaries with unusually high flow (Little Doe Cr and Sandy Br). Mean nitrate + nitrite ($NO_2$+$NO_3$) levels were generally low throughout the entire Local Watershed Planning area (0.02-0.04 mg/L) with the exception of Bolivia Br (0.12 mg/L), again likely due to the point source discharge. Mean total Kjeldahl nitrogen (TKN) values by watershed ranged from 0.37 to 0.99 mg/L as N. The higher values were generally in the swamp stream tributaries (including Pamlico Cr with a mean of 0.99), though the Oak Island watershed (Montgomery Slough) and Sandy Br had unexpectedly high values. Mean total phosphorus ranged from 0.04-0.12 mg/L as P. The highest mean values were seen in Pamlico Cr and Oak Island watersheds (0.12 mg/L for both). A comparison of nutrient data collected at six locations from 1989- 2001 to the nutrient data that was collected in 2006 showed statistically significant increases in total phosphorus at four locations, increases in nitrate + nitrite at three locations, and an increase in TKN at one location.

Though the majority of chlorophyll-*a* samples showed relatively low values, results from two of six samples from Oak Island were above the NC water quality standard of 40 µg/L. Two other locations in the Middle Lockwoods Folly each had a single sample exceeding the standard. Three of these sampling events also showed increased turbidity levels, with two above the NC water quality standard of 25 NTU for saltwater.  Two of these sampling events also showed low Secchi depths.  A review of all data from these stations showed that high phosphorus and TKN results for each of these stations coincided with the exceedences of the chlorophyll water quality standard.

Dissolved oxygen concentrations were low at the many sites, likely due to natural swamp conditions.  Sandy Br was unusual for its relatively high, stable DO concentrations (5.5-6.2 mg/L) throughout the study period.

Correlation analysis performed with land use and chemistry results showed that total suspended solids and zinc show the most correlations to individual land use categories and therefore may be the most useful indicators for determining instream impacts due to differing land uses.  However, a comparison of the results from a cluster analysis of land use to the results from a cluster analysis of actual chemistry data showed no obvious relationships, suggesting that for these data and/or watersheds, land use was not a good predictor of instream conditions or chemical concentrations.

Very limited benthic macroinvertebrate data were available for the study area.  Royal Oak Swamp is regularly monitored by the DWQ Biological Assessment Unit (BAU) and has shown few changes over its sampling history (1998-2006).  It has consistently received a bioclassification of “Natural”, though Plecoptera (stonefly) species, which are taxa that are generally intolerant to water quality stressors, were absent in the latest sample.  The Lockwoods Folly R was sampled in 2006 for comparison to previous BAU estuarine benthos sample in 1999.  Both of these samples received a bioclassification of “Slight Stress”, which may be more attributable to wide salinity swings than to water quality issues.

# Introduction and Watershed Overview

## *Introduction*

The North Carolina (NC) Ecosystem Enhancement Program (EEP) selected the Lockwoods Folly River watershed for development of a Local Watershed Plan (LWP). The LWP is meant as a guide for future efforts within the watershed that will provide functional uplift to the waters of the area. As part of this plan development, a characterization of the current state of the watershed was conducted.

In coordination with EEP and Stantec Consulting Services, water quality data were collected by NC Department of the Environment and Natural Resources (DENR), Division of Water Quality (DWQ) staff from both the Watershed Assessment Team (WAT) and Wilmington Regional Office from April to November 2006. Results from these data collections are summarized in this report. In addition to these project-specific data collections, results from the Shellfish Sanitation monitoring program managed by the NC Division of Environmental Health (DEH) were obtained for inclusion in this report.

## *LWP area overview and water quality concerns*

The Lockwoods Folly River watershed is located in the Lumber River Basin in the southeastern portion of North Carolina in coastal Brunswick County. The LWP area, which contains the entire Lockwoods Folly River drainage, is approximately 153 square miles. An overview of the watershed is shown in Figure 1.

Municipalities within the area include Bolivia, Varnamtown, Oak Island, Long Beach, and Holden Beach. The bulk of the area is relatively undeveloped at this time. According to land use data obtained from Brunswick County, as of 2004 73% of the watershed was still forested or undeveloped, though much of this is managed timberland. Development is clustered in areas along the coast, barrier islands (such as Oak Island), Intracoastal Waterway (ICW), and major rivers.

The watershed was initially delineated by four hydrologic units (HU): Upper Lockwoods Folly River (HU 03040207020010), Royal Oak Swamp (HU 03040207020020), Lower Lockwoods Folly River (HU 03040207020030), Unnamed Tributaries (HU 03040207020040), and the ICW (HU 03040207020050). Stantec further delineated the LWP area into 30 watersheds (Figure 2), and these were delineated into 64 catchments. In this report, results will often be grouped by watersheds. For reference, a list of all watersheds and their areas is included in Appendix 1.

Historically, bacteria has been the primary water quality concern in the LWP area: the designated shellfishing areas in the Lockwoods Folly River and the ICW are closed due to fecal coliform counts above the state water quality standard. As more of the area is developed and land use transitions from a rural setting to golf course communities and retirement and vacation homes, new concerns also arise over sediment and nutrient inputs from non-point sources.

There was only one point source discharger in the LWP area. Bolivia Elementary School (NPDES permit NC0045250) was a minor, 100% domestic wastewater treatment facility that discharged to Bolivia Br, which drains into Middle Swamp. The facility has had a number of exceedences of its permit limits since 1994. However, the facility was connected to the recently expanded municipal sanitary sewer system during the study period. In October 2006 the permit for this facility was rescinded by DWQ after it was confirmed that the school is no longer discharging to Bolivia Br.

More detailed information on the LWP area and water quality concerns are available in previous reports (NC DENR DWQ 2005; Stantec Consulting Services, 2006).

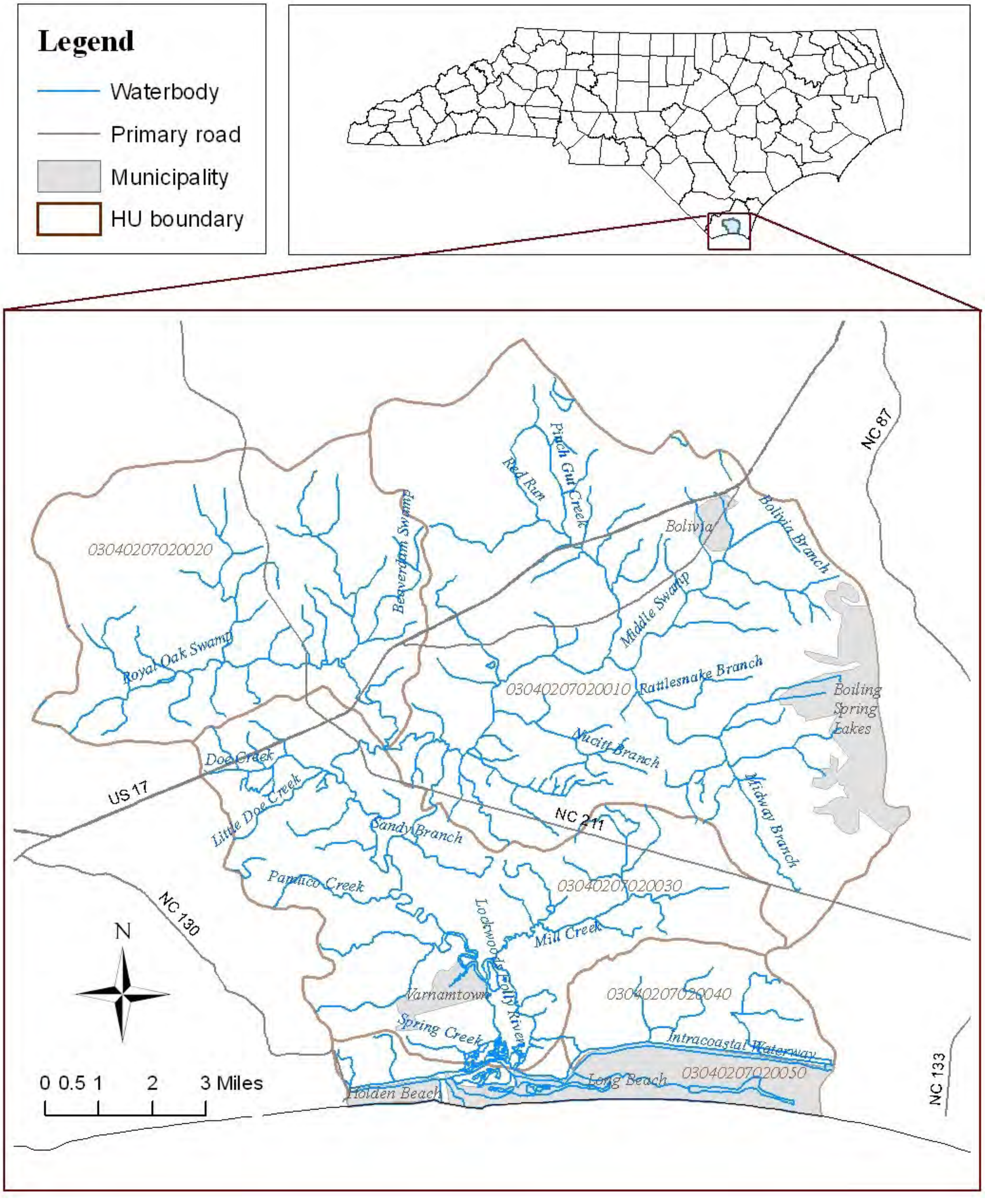


**Figure 1: Lockwoods Folly River Local Watershed Planning Area**


**Figure 2: Watersheds of the Lockwoods Folly River LWP Area**

Dark grey outlines indicate watersheds and are labeled with their name.
Light grey outlines indicate catchments.

### *Land use*

The most significant impacts on water quality are generally non-point sources, including runoff from developed areas as well as agricultural areas. Water quality cannot be discussed without placing it into the context of land use within the drainage area.

The most recent land use/land cover (LULC) data available from the National Land Cover Database (NLCD) is from 1992. A more recent source for land use data is available from Brunswick County; this information was generated in 2004. It is based on parcel data, so is not entirely comparable to the NLCD data since land use was assigned on a parcel-by-parcel basis. In particular, wetlands seem to be severely underrepresented. However, for residential, commercial, agricultural, and recreational (e.g., golf courses) uses this more recent dataset may actually be preferable, as newer developments are not represented in the older NLCD data collected in 1992.

There are limitations to the Brunswick County data. As it was developed for county planning, a single land use type is assigned to each parcel. This naturally will lead to gross overestimations or underestimations of land use in individual parcels. Certain land use categories, particularly Forested and Wetland, were assigned as would be expected from data collected primarily for planning uses. “Forested” was applied to any area that was generally undeveloped, and appears to include managed timberland, wetlands, as well as natural areas (including some significant Carolina Bays). It appears that the use “Wetland, marsh” was only used to identify salt marsh areas along the ICW, lower Lockwoods Folly R, and on the barrier islands (Stantec, 2006).

Though these caveats are significant, any water quality assessment of the LWP area should take into consideration the impacts of impervious area, homes, golf courses, and other development on instream conditions. Since much of this growth has occurred in recent years, it is preferable to use the Brunswick County data as it most accurately reflects current development.

**Table 1: Land use in LWP area, based on 2004 Brunswick County data**

| Land use group | Area (square miles) | Percent of total area |
|---|---|---|
| Forested | 111.7 | 73.0 |
| Undeveloped Lots | 10.1 | 6.6 |
| Residential | 8.4 | 5.5 |
| Agriculture | 7.6 | 5.0 |
| Transportation | 4.2 | 2.8 |
| Water | 3.3 | 2.2 |
| Salt Marsh | 2.9 | 1.9 |
| Other | 1.6 | 1.1 |
| Pasture | 1.0 | 0.7 |
| Golf | 1.0 | 0.6 |
| Institutional | 0.9 | 0.6 |
| Commercial | 0.3 | 0.2 |
| ***Total*** | ***153.1 sq. mi.*** | ***100%*** |

The data were provided as an ArcGIS layer and used to determine land use for the LWP area as a whole, as well as for each of the watersheds. Due to the large number of available land use categories (n=38), they were grouped into twelve broader categories. These Land Use Groups were roughly based on those used previously by Stantec (Stantec, 2005). Individual categories and their groupings can be found in Appendix 1.

Area and percent of total area for each group are shown in Table 1 in descending order of prevalence.  The great majority of the watershed is Forested (73%).  Undeveloped Lots, Residential, and Agriculture uses are next in prevalence, though each only contributes to 5-7% of the total LWP area.  Transportation (e.g., roads and right-of-ways), Water, Salt Marsh, and Other (e.g., manufacturing, communication towers, cemeteries) are each about 1-3% to total area. Pasture, Golf, Institutional (e.g., schools, churches), and Commercial uses each make up <1% of total area.

In spite of the seemingly low contributions of most types of land use in the LWP area overall, when reviewed on a watershed-by-watershed basis, there is great variability (Appendix 1).  For example, the Forested land use ranges from 3% in the Oak Island Beach watershed to 95% in the Red Run watershed.  On the other end of the scale, the Golf land use is only found in five watersheds; in Sandy Br, it makes up 10% of the land use.

# Study Design and Methods Overview

## *Monitoring locations*

Monitoring locations were selected by Stantec based on data needs for water quality modeling and included sites on the mainstem Lockwoods Folly R and tributaries, the Intracoastal Waterway, and Montgomery Slough, which drains Oak Island. These efforts will focus on bacteria and nutrients. During site reconnaissance, several locations that were requested by Stantec had to be excluded due to accessibility or logistical issues.

In response to field observations, two additional monitoring locations were identified. One site was added on Bolivia Br, since this is the receiving stream of the sole NPDES discharger in the watershed. Another site was added on Little Doe Cr, as it seemed an unusual stream type for the watershed in that it had a very distinctly defined, unchannelized and sinuous channel, with a very sandy substrate and consistently higher flows. Many of the freshwater streams in the study showed evidence of channelization and/or had predominantly organic/muck substrates, likely due to lower flows.

A map of station locations is shown in Figure 3. Site descriptions and station numbers are included in Table 2. More detailed information on station locations (including latitude/longitude, stream class, etc.) is included in Appendix 2.

Results are often presented on a watershed scale in this report. Generalizing site-specific results to an entire watershed can be questionable. In general, however, the author believes that in most cases site selections were made in such a way that they should reasonably assess the predominant land use in the watershed. Exceptions exist, such as the presence of point source discharges, but an attempt has been made to highlight these exceptions where appropriate. In some cases watersheds contain more than one sampling location, which allows an assessment of a wider range of values within that watershed. Also, as an ancillary analysis, relationships between land use and actual instream concentrations of constituents of concern were examined to determine the predictive power of land use patterns on water quality.

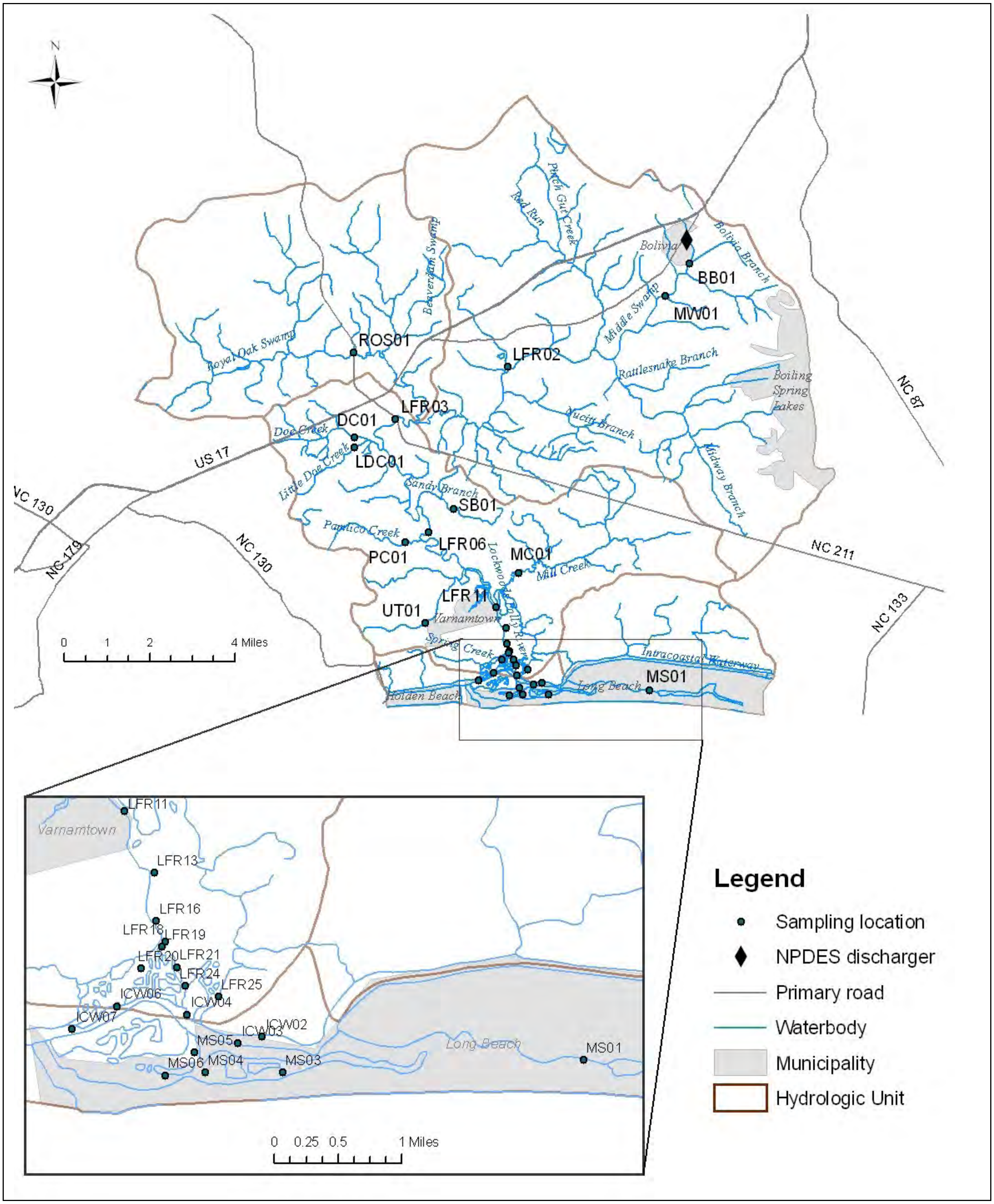


**Figure 3: Monitoring station locations**

**Table 2: Monitoring station locations by watershed**

| Watershed | LWP Station Number | Location |
|---|---|---|
| *Tributaries to Lockwoods Folly River (LFR)* | | |
| Bolivia Branch | BB01 | Bolivia Branch at SR 1512 |
| Middle Swamp | MW01 | Middle Swamp at SR 1500 |
| Royal Oak Swamp | ROS01 | Royal Oak Swamp at NC 211 |
| Doe Creek | DC01 | Doe Creek at SR 1115 |
| Little Doe Creek | LDC01 | Little Doe Creek at SR 1115 |
| Pamlico Creek | PC01 | Pamlico Creek at SR 1115 |
| UT to Lower LFR | UT01 | Unnamed Tributary to Lockwoods Folly R at SR 1119 |
| Sandy Branch | SB01 | Sandy Branch off SR 1251 behind Winding River Clear Water Place |
| *Mainstem Lockwoods Folly River (LFR)* | | |
| Upper LFR | LFR02 | Lockwoods Folly R at SR 1501 |
| Middle LFR | LFR03 | Lockwoods Folly R at NC 211 at Supply |
| | LFR06 | Lockwoods Folly R near Sandy Hill |
| Lower LFR | MC01 | Mill Creek at SR 1112 |
| | LFR11 | Lockwoods Folly R at Varnamtown |
| | LFR13 | Lockwoods Folly R at CM R8 DNS of Varnamtown (west channel)/ Shellfish station 5A |
| | LFR16 | Lockwoods Folly R, Shellfish station 6A |
| | LFR18 | Lockwoods Folly R at CM 5/ Shellfish station 14A |
| | LFR19 | Lockwoods Folly R at CM R6 NW Sunset Harbor (west channel) |
| | LFR20 | Lockwoods Folly R, Shellfish station 14B |
| | LFR21 | Lockwoods Folly R, Shellfish station 7A |
| | LFR24 | Lockwoods Folly R, Shellfish station 7 |
| | LFR25 | Lockwoods Folly R, Shellfish station 8 |
| *Intracoastal waterway (ICW)* | | |
| Intracoastal Waterway | ICW02 | ICW, Shellfish station 11 |
| | ICW03 | ICW at Sunset Harbor |
| | ICW04 | ICW, Shellfish station 10 |
| | ICW06 | ICW, Shellfish station 13 |
| | ICW07 | ICW at CM R42 west of Lockwood Folly R |
| *Montgomery Slough* | | |
| Oak Island Beach | MS01 | Montgomery Slough at SR 1105 near Long Beach |
| | MS03 | Montgomery Slough, Shellfish station 24A |
| | MS04 | Montgomery Slough, Shellfish station 9 |
| | MS05 | Montgomery Slough, Shellfish station 9A |
| | MS06 | Montgomery Slough, Shellfish station 16 |

***Indicators measured and overview of sampling methods***

Chemical data were collected by two programs within the NC Division of Water Quality: the Watershed Assessment Team (WAT) and regional Ambient Monitoring System (AMS) staff. Useful secondary data sources, such as NC Division of Environmental Health (DEH) Shellfish Sanitation monitoring, were identified and included in this report.

WAT sampling occurred only during the defined study time period, April through October 2006. For AMS and Shellfish Sanitation monitoring programs, sampling at most locations is an ongoing effort. To minimize concerns over differences due to seasonal or climatic variations, only samples collected during the study period were included in this report.

In order to assess impacts from non-point sources, all results must be put into the context of current and/or recent precipitation ("flow regime"). Three terms are used in this report:

1. Baseflow: no measurable rainfall was recorded in the 48 hours previous to sampling;
2. Stormflow (first flush): sampling was initiated during a storm event once sheet flow was noted on impervious surfaces;
3. Other: measurable rainfall ($\geq$0.01 inch) was recorded in the 48 hours previous to sampling.

An overview of sampling methods for each monitoring program is given below, with more detailed information for each parameter included in the Results and Discussion section. A summary of the number of samples (grouped by Bacteria, Field Measurements, Nutrients, Chlorophyll, Turbidity, Residues, and Metals) that were taken under different flow regimes is given in Table 3. As the parameters measured by each program differed slightly, more detailed descriptions are given below and in the station summaries in Appendix 5.

- NC DWQ, WAT: Chemical, physical, and bacteria data were collected from ten locations, primarily tributaries to the Lockwoods Folly R. In addition to locations specified in Stantec's *Preliminary Findings Report* (2006), two locations were monitored due to their status as a receiving water for the sole NPDES discharger in the LWP area (Bolivia Br) or to evaluate an unique stream that appeared to have few historic modifications (e.g., channelization) and an unusually sandy substrate (Little Doe Cr) as compared to the organic/muck substrates common in other streams in the LWP area.

  All samples were taken as surface grabs (depth = 0.1m) and all field measurements were taken *in situ* just below the water surface. All sites were accessible from land, generally near bridge crossings. Most of these locations have no past data available, or at least very limited data. Sampling was performed in accordance with the Standard Operating Procedures (SOP) used by the DWQ Intensive Survey Unit (ISU), applicable WAT SOPs, and DWQ Laboratory Section sample collection, preservation, and handling requirements. All laboratory analyses were performed by the DWQ Laboratory Section.

  Parameters measured included fecal coliform, nutrients ($NH_3$, TKN, $NO_2$+$NO_3$, TP), total metals (Al, As, Ca, Cd, Cr, Cu, Fe, Hg, Mg, Mn, Ni, Pb, and Zn), suspended solids (total, volatile, and fixed), and field measurements (DO, pH, specific conductance, water temperature, and salinity where appropriate). WAT staff aimed to collect monthly samples during baseflow, though due to scheduling issues 1-2 of these sampling trips actually occurred after rain events (i.e., "Other" flow). WAT also obtained stormflow, ("first flush") samples by hand collection during storm events where possible.

- NC DWQ, AMS: Chemical, physical, and bacteria data were collected from seven locations on the mainstem Lockwoods Folly R, the ICW, and Montgomery Slough. These locations are current or inactive monitoring locations in the AMS program. In addition to temporarily reinstating sampling at inactive AMS stations, staff also collected additional parameters (particularly chlorophyll-*a* and nutrients) to assist with this study's objectives. All locations except Montgomery Slough were accessed by boat. Sampling occurred under baseflow or "Other" flow conditions; no storm samples were collected.

  Parameters that were measured monthly included fecal coliform, turbidity, nutrients ($NH_3$, TKN, $NO_2$+$NO_3$, total P), chlorophyll-*a*, Secchi depth, and standard field measurements. Nutrient and chlorophyll samples were collected as composites of the photic zone (defined as twice the Secchi depth) where sufficient depth existed. All other samples were collected as grab samples just below the water surface. Field measurements were taken at the surface, at mid-depth, and at the bottom of the water column, where there was sufficient depth. If there was not sufficient depth, measurements would be taken at the surface only. The AMS program also collects total metals (Al, As, Cd, Cr, Cu, Fe, Hg, Ni, Pb, and Zn) and total suspended residue quarterly, so a limited number of observations are available for these parameters.

  All sampling and measurements were done in accordance with the ISU SOP, AMS Quality Assurance Project Plan (QAPP), and Laboratory Section sample handling and preservation requirements. All laboratory analyses were performed by the DWQ Laboratory Section.

  All of the locations sampled by AMS staff have a relatively robust historic data set, as they have been, and in some cases continue to be, part of the AMS program, which is an ongoing water quality monitoring program that supports DWQ's watershed planning and assessment (use support, impairment, etc.) activities.

- **Secondary data sources**
  - *NC DENR, DEH, Shellfish Sanitation Section monitoring program*: As part of DEH's ongoing monitoring of shellfishing waters, fourteen locations located in the LWP area were sampled for fecal coliform, and salinity and tide stage were recorded. Sampling and measurements were performed in accordance with the Shellfish Sanitation SOP. A total of six sampling events occurred at each location in 2006, as required by their program. However, only three occurred during the time period of this study and only those data were included in this report.

  - *NPDES discharger monitoring reports*: As part of the requirements of NPDES permits, dischargers are required to monitor the quality and quantity of their effluent. In the LWP area there is one discharger, Bolivia Elementary School. Monitoring results from the Discharge Monitoring Reports (DMRs) were obtained from DWQ's

Basinwide Information Management System (BIMS). Only results from effluent sampling are readily available, so any instream monitoring that may be required in their permit are not included here. However, the WAT monitoring location on Bolivia Br. provides similar information.

- *Precipitation*: To determine flow regime (baseflow, stormflow, other) for each sampling event, rainfall totals for the 48 hours prior to sampling were obtained from The Weather Underground website (www.wunderground.com). Precipitation was obtained from the Southport Airport location (airport code KSUT), which is situated just east of the LWP area.

**Table 3: Summary of number of chemistry results by flow regime at each monitoring station.**

See text for more detailed descriptions of monitoring program's methods, flow regimes, and parameter groups. Duplicate samples were averaged for analysis and are counted as a single sample.

| Location type | LWP Station Number | Monitoring program | Field | | | Bacteria | | | Nutrients | | | Chlorophyll | | Residues | | | Turbidity | | | Metals | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Baseflow | Other | Stormflow | Baseflow | Other | Stormflow | Baseflow | Other | Stormflow | Baseflow | Other | Baseflow | Other | Stormflow | Baseflow | Other | Stormflow | Baseflow | Other | Stormflow |
| Tributaries | BB01 | WAT | 5 | 1 | - | 5 | 1 | - | 5 | 1 | - | - | - | 5 | 1 | - | 5 | 1 | - | 5 | 1 | - |
| | MW01 | WAT | 2 | 2 | 2 | 2 | 2 | 2 | - | - | 2 | - | - | - | - | 2 | - | - | 2 | - | - | 2 |
| | ROS01 | WAT | 5 | 2 | 1 | 5 | 2 | 1 | 5 | 1 | 1 | - | - | 5 | 1 | 1 | 5 | 1 | 1 | 5 | 1 | 1 |
| | DC01 | WAT | 5 | 2 | 1 | 5 | 2 | 1 | 5 | 1 | 1 | - | - | 5 | 1 | 1 | 5 | 1 | 1 | 5 | 1 | 1 |
| | LDC01 | WAT | 5 | 1 | 1 | 5 | 1 | 1 | 5 | 1 | 1 | - | - | 5 | 1 | 1 | 5 | 1 | 1 | 5 | 1 | 1 |
| | SB01 | WAT | 2 | 2 | 2 | 2 | 2 | 2 | - | 1 | 2 | - | - | - | - | 2 | - | - | 2 | - | - | 2 |
| | PC01 | WAT | 2 | 2 | 2 | 2 | 2 | 2 | - | - | 2 | - | - | - | - | 2 | - | - | 2 | - | - | 2 |
| | UT01 | WAT | 2 | 2 | 2 | 2 | 2 | 2 | - | - | 2 | - | - | - | - | 2 | - | - | 2 | - | - | 2 |
| | MC01 | WAT | 5 | 2 | 1 | 5 | 2 | 1 | 5 | 1 | 1 | - | - | 5 | 1 | 1 | 5 | 1 | 1 | 5 | 1 | 1 |
| LFR mainstem | LFR02 | WAT | 5 | 1 | 1 | 5 | 1 | 1 | 5 | 1 | 1 | - | - | 5 | 1 | 1 | 5 | 1 | 1 | 5 | 1 | 1 |
| | LFR03 | AMS | 4 | 3 | - | 5 | 2 | - | 4 | 3 | - | 4 | 3 | 3 | - | - | 5 | 2 | - | - | 2 | - |
| | LFR06 | AMS | 4 | 3 | - | 4 | 3 | - | 4 | 3 | - | 4 | 3 | 2 | 1 | - | 4 | 3 | - | 1 | 1 | - |
| | LFR11 | AMS | 4 | 3 | - | 4 | 3 | - | 4 | 3 | - | 4 | 3 | 1 | 1 | - | 4 | 3 | - | 1 | 1 | - |
| | LFR13 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | LFR16 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | LFR18 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | LFR19 | AMS | 4 | 3 | - | 4 | 3 | - | 4 | 3 | - | 4 | 3 | 2 | 1 | - | 4 | 2 | - | 1 | 1 | - |
| | LFR20 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | LFR21 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | LFR24 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | LFR25 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| ICW | ICW02 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | ICW03 | AMS | 4 | 3 | - | 4 | 3 | - | 4 | 3 | - | 4 | 3 | 1 | 2 | - | 4 | 3 | - | - | - | - |
| | ICW04 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | ICW06 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | ICW07 | AMS | 4 | 3 | - | 4 | 3 | - | 4 | 3 | - | 4 | 3 | 1 | 2 | - | 4 | 3 | - | - | - | - |
| Montgomery Slough | MS01 | AMS | 3 | 4 | - | 2 | 5 | - | 2 | 4 | - | 2 | 4 | - | 2 | - | 2 | 5 | - | - | 2 | - |
| | MS03 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | MS04 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | MS05 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |
| | MS06 | SS | 2 | 1 | - | 2 | 1 | - | - | - | - | - | - | - | - | - | - | - | - | - | - | - |

## *Analytical methods, NC stream classifications, and water quality standards*

For samples collected by AMS and WAT staff, the DWQ Laboratory Section performed all analyses. The reporting limits (RLs) provided by the Laboratory are based on Practical Quantitation Limits (PQLs), which were derived from Method Detection Limit (MDL) studies, performed by the Laboratory most recently in 2001. U.S. Environmental Protection Agency (EPA) approved methods and RLs for each analysis are provided in Table 4.

NC has a series of classifications that apply to all waters of the state, including streams, rivers, and lakes. These classifications are each meant to protect for certain specified uses, such as aquatic life survival and reproduction, secondary recreation, primary recreation, shellfishing, and water supply. For the Lockwoods Folly River LWP area, streams have one of three classifications:

- **C Sw**: Freshwater that is protected for aquatic life and secondary recreation uses. The "Sw" supplemental classification indicates that these are swamp streams, and so they will likely have lower dissolved oxygen and pH than non-swamp streams due to natural conditions.
  *This classification applies to most tributary sampling stations: BB01, MW01, ROS01, DC01, LDC01, UT01, SB01, and LFR02.*

- **SC**: Saline waterbodies that are protected for aquatic life and secondary recreation uses. Standards will be slightly different from freshwater systems due to differences in aquatic life to be supported and toxicity of priority pollutants in a saline environment.
  *This classification applies to sampling stations PC01, LFR03, and LFR06.*

- **SA**: Saline waterbodies that are protected for shellfishing uses. This use requires a more stringent standard for fecal coliform. Protection for this use is in addition to protections for the uses specified by the "lower" classifications of SC and SB, which include aquatic life, secondary recreation, and primary recreation.
  *This classification applies to all sampling stations in the Lower LFR, ICW, and Oak Island Beach watersheds: MC01, LFR11, LFR13, LFR16, LFR18, LFR19, LFR20, LFR21, LFR24, LFR25, ICW02, ICW03, ICW04, ICW06, ICW07, MSO1, MS03, MS04, MS05, and MS06.*

Water quality standards have been identified legislatively for each of these classifications to ensure protection of these uses. These water quality standards and classifications are described in NC Adminstrative Code, sections 15A NCAC 2H .0100 and 15A NCAC 2B .0200. A summary of applicable standards is shown in Table 4. Where applicable, these values will be used as benchmark criteria throughout this report.

**Table 4: Analytical methods, reporting limits, and NC water quality standards**

| *Parameter* | *EPA method* | *Reporting limit* | *NC standard for each classification* [1] | | |
|---|---|---|---|---|---|
| | | | *C Sw* | *SC* | *SA* |
| Fecal coliform (DWQ) | 600/8-78-017 | 1 colony/ 100mL | Geomean <200; <20% samples >400 | Geomean <200; <20% samples >400 | Median of <14; <10% of samples >43 |
| Fecal coliform (DEH) | 600/8-78-017 | 1 MPN/ 100mL | | | |
| Turbidity | 180.1 | 1 NTU | 50 | 25 | 25 |
| Suspended residue, total | 160.2 | 2.5 mg/L | -- | -- | -- |
| Suspended residue, volatile | 160.4 | 2.5 mg/L | -- | -- | -- |
| Suspended residue, fixed | 160.4 | 2.5 mg/L | -- | -- | -- |
| $NH_3$ as N | 350.1, 350.2 | 0.02 mg/L | -- | -- | -- |
| $NO_2$+$NO_3$ as N | 353.2 | 0.02 mg/L | -- | -- | -- |
| TKN as N | 350.1, 351.2 | 0.20 mg/L | -- | -- | -- |
| TP | 365.1 | 0.02 mg/L | -- | -- | -- |
| Chlorophyll-*a* | 445.0 | 1 ug/L | 40 | 40 | 40 |
| Aluminum (Al) | 200.7 | 50µg/L | -- | -- | -- |
| Arsenic (As) | 200.8 /200.9 | 5µg/L | 50 | 50 | 50 |
| Calcium (Ca) | 200.7 | 0.10 mg/L | -- | -- | -- |
| Cadmium (Cd) | 200.8 /200.9 | 2.0µg/L | 2.0 | 5.0 | 5.0 |
| Chromium (Cr) | 200.8 /200.7 | 25µg/L | 50 | 20 | 20 |
| Copper (Cu) | 200.8 /200.9 | 2.0µg/L | 7 | 3 | 3 |
| Iron (Fe) | 200.7 | 50µg/L | 1000 | -- | -- |
| Nickel (Ni) | 200.8 /200.9 | 10µg/L | 88 | 8.3 | 8.3 |
| Lead (Pb) | 200.8 /200.9 | 10µg/L | 25 | 25 | 25 |
| Magnesium (Mg) | 200.7 | 0.10 mg/L | -- | -- | -- |
| Manganese (Mn) | 200.8/200.7 | 10µg/L | -- | -- | -- |
| Mercury (Hg) | 245.1 | 0.2µg/L | 0.012 | 0.025 | 0.025 |
| Zinc (Zn) | 200.8 /200.7 | 10µg/L | 50 | 86 | 86 |
| Field measurements | | | | | |
| Dissolved oxygen (DO) | -- | 0.1 mg/L | 4.0 [2] | 5.0 [3] | 5.0 [3] |
| pH | -- | 0.1 S.U. | 6.0-9.0 [4] | 6.8-8.5 [4] | 6.8-8.5 [4] |
| Specific conductance | -- | 1 us/cm at 25°C | -- | -- | -- |
| Salinity | -- | 0.1 ppt | -- | -- | -- |
| Water temperature | -- | 0.1°C | 32 | -- | -- |
| Secchi depth | -- | 0.05 m | -- | -- | -- |

[1] “--" indicates there is no NC standard for that parameter. Units for standard limits are the same as listed under “Reporting Limit”.
[2] This is the standard for instantaneous readings. Swamp waters may have lower values if caused by natural conditions.
[3] Swamp waters, poorly flushed tidally influenced streams or embayments, or estuarine bottom waters may have lower values if caused by natural conditions.
[4] For swamp streams, pH may be as low as 4.3 if due to natural conditions

### *Data management and analysis*

Data collected by WAT and AMS staff during the study period are warehoused in an MS Access database. Data were analyzed using SAS JMP v.6.0. Statistical data exploration tools included quantiles, distribution plots, correlations, student t-tests, Wilcoxon rank sum tests, and clustering analyses. Unless otherwise noted in the text, results reported as being less than the RL were analyzed using the RL in the calculation. For duplicate samples, the average of the two results was used in all calculations.

Results are shown as tabular presentations of distributions, graphical presentations of distributions (box and whisker plots), tables of correlations, clustering dendrograms, and graphed over time. Certain summary statistics (e.g., means, medians) were imported into ESRI ArcGIS 9 software for examination for spatial patterns of results. ArcGIS was also used to calculate information such as watershed areas.

A standardized set of symbols for monitoring stations is used in all graphs. Unless otherwise noted on individual graphs, these are the symbols used. A key is provided in Table 5.

**Table 5: Graph symbols legend**

| Tributaries | Mainstem LFR | ICW | Montgomery Slough |
|---|---|---|---|
| BB01 | LFR02 | ICW02 | MS01 |
| MW01 | LFR03 | ICW03 | MS03 |
| ROS01 | LFR06 | ICW04 | MS04 |
| DC01 | LFR11 | ICW06 | MS05 |
| LDC01 | LFR13 | ICW07 | MS06 |
| SB01 | LFR16 | | |
| UT01 | LFR18 | | |
| PC01 | LFR19 | | |
| MC01 | LFR20 | | |
| | LFR21 | | |
| | LFR24 | | |
| | LFR25 | | |

### *QA/QC*

Quality assurance and quality control methods were performed in accordance with program SOP. Lab QA/QC is outlined in the laboratory's Quality Assurance Manual (QAM). Analytical results not meeting QA/QC criteria were reported using standard qualifier codes, as per the QAM.

Field QA/QC included daily calibration (pre- and post-sampling) of field meters. One day's pH values were discarded when the pH meter did not meet precision criteria during final calibration. Duplicate samples were collected at one out of every ten sites by WAT for calculation of relative percent difference (RPD) for an ongoing study of QA/QC of WAT sampling methods.

# Results and Discussion

## ***Fecal coliform***

Fecal coliform samples were taken at 17 locations by WAT and DWQ. Coliform results from an additional 14 locations were obtained from the DEH Shellfish Sanitation monitoring program and are included in this summary. Differences in methods between the two Divisions exist: DWQ analyses use a membrane filtration technique and report results in colonies/100 mL (or CFU), and DEH uses the fermentation tube method and reports results in most-probable-number (MPN)/100 mL. Though not exactly identical, it was felt that these different methods and units were reasonably equivalent for the watershed screening objectives of this study (Griffith, 2006), though generally the fermentation tube method is considered more accurate.

Table 6 shows summaries of all results (baseflow, storm, and other) and the appropriate fecal coliform screening values (dependent on stream class) for each sampling location. Please note that the “single sample max” and “central tendency max” values are taken from the appropriate NC water quality standard, but are only provided as screening values. Since the standards as written have minimum requirements as to number of samples taken over a 30-day period, these data are not appropriate for use support or impairment decisions. These are only provided as guidelines to identify areas that may be having issues with bacteria. Results that exceed the screening values for central tendency (geometric mean or median, as appropriate) are shown in bold, red type in the table.

Several tributaries (Little Doe Cr, Sandy Br, and Pamlico Cr) have fairly high geometric means. Note that these geometric means include storm as well as baseflow samples. Little Doe Cr seems to show larger increases in instream concentrations in response to stormflow, a pattern that will be repeated in discussions of other parameters. Sandy Br seems to have this sensitivity as well. Pamlico Cr shows high coliform counts, but this stream is tidal at the sampling point yet has poor flow and likely poor flushing as well. High bacteria counts therefore may be due to hydrology more than land use in the watershed.

Of the waters that are classified as SA for protection of shellfishing uses, 10 of 20 locations have a median greater than the screening value of 14 colonies/100 mL. The worst case is Montgomery Slough (Oak Island watershed), with a median of 80 at the most upstream site (MS01). The median shows a gradual decrease going downstream, but four of the five sites on the slough exceed the screening criteria of 14 colonies/100 mL. Mill Cr (MC01) also shows elevated values, with a median of 55. This site is tidal, but appears to flush well.

Geometric means were calculated for each watershed using all available results (Table 7). To determine if there are any spatial patterns, the geometric means were used to assign the display characteristics of each watershed in ArcGIS (Figure 5). This allows the easy identification of several “hotspots” in the LWP area: Sandy Br, Little Doe Cr, and Pamlico Cr watersheds.

**Table 6: Fecal coliform concentrations by sampling location**

Exceedences of evaluation level are shown in bold, red typeface. All results are in colonies/100mL. "NA" indicates that that standard does not apply to that stream classification.

| Watershed name | NC stream class | LWP Station | Total # samples | Single sample maximum[1] | N>Single sample maximum | Central tendency maximum[1] | Geomean | Median |
|---|---|---|---|---|---|---|---|---|
| Bolivia Br | C Sw | BB01 | 6 | 400 | 2 | 200 | 103 | NA |
| Middle Sw | C Sw | MW01 | 6 | 400 | 0 | 200 | 91 | NA |
| Royal Oak Sw | C Sw | ROS01 | 8 | 400 | 1 | 200 | 108 | NA |
| Doe Creek | C Sw HQW | DC01 | 8 | 400 | 1 | 200 | 96 | NA |
| Little Doe Cr | C Sw HQW | LDC01 | 7 | 400 | 2 | 200 | **377** | NA |
| Sandy Br | C Sw HQW | SB01 | 6 | 400 | 2 | 200 | **321** | NA |
| Pamlico Cr | SC HQW | PC01 | 6 | 400 | 3 | 200 | **477** | NA |
| UT to Lower LFR | C Sw HQW | UT01 | 6 | 400 | 0 | 200 | 127 | NA |
| Upper LFR | C Sw | LFR02 | 7 | 400 | 0 | 200 | 110 | NA |
| Middle LFR | SC HQW | LFR03 | 7 | 400 | 0 | 200 | 94 | NA |
| | | LFR06 | 7 | 400 | 0 | 200 | 46 | NA |
| Lower LFR | SA HQW | LFR11 | 7 | 43 | 2 | 14 | 25 | **33** |
| | | LFR13 | 3 | 43 | 0 | 14 | 25 | **33** |
| | | LFR16 | 3 | 43 | 0 | 14 | 9 | 5 |
| | | LFR18 | 3 | 43 | 0 | 14 | 6 | 7 |
| | | LFR19 | 7 | 43 | 0 | 14 | 4 | 1 |
| | | LFR20 | 3 | 43 | 0 | 14 | 27 | **33** |
| | | LFR21 | 3 | 43 | 0 | 14 | 5 | 4 |
| | | LFR24 | 3 | 43 | 0 | 14 | 7 | 7 |
| | | LFR25 | 3 | 43 | 1 | 14 | 20 | 14 |
| | SA HQW | MC01 | 8 | 43 | 6 | 14 | 73 | **55** |
| ICW | SA HQW | ICW02 | 3 | 43 | 1 | 14 | 22 | **17** |
| | | ICW03 | 7 | 43 | 0 | 14 | 4 | 4 |
| | | ICW04 | 3 | 43 | 2 | 14 | 23 | **46** |
| | | ICW06 | 3 | 43 | 0 | 14 | 8 | 6 |
| | | ICW07 | 7 | 43 | 0 | 14 | 2 | 1 |
| Oak Island Beach | SA HQW | MS01 | 7 | 43 | 5 | 14 | 51 | **80** |
| | | MS03 | 3 | 43 | 0 | 14 | 22 | **31** |
| | | MS04 | 3 | 43 | 0 | 14 | 12 | **27** |
| | | MS05 | 3 | 43 | 0 | 14 | 18 | **22** |
| | | MS06 | 3 | 43 | 0 | 14 | 11 | 8 |

[1] These values were taken from the appropriate NC water quality standards. For C and SC stream classifications, the single sample maximum is 400 and the central tendency maximum is a geometric mean of 200. For SA stream classifications the single sample maximum is 43 and the central tendency maximum is a median of 14.

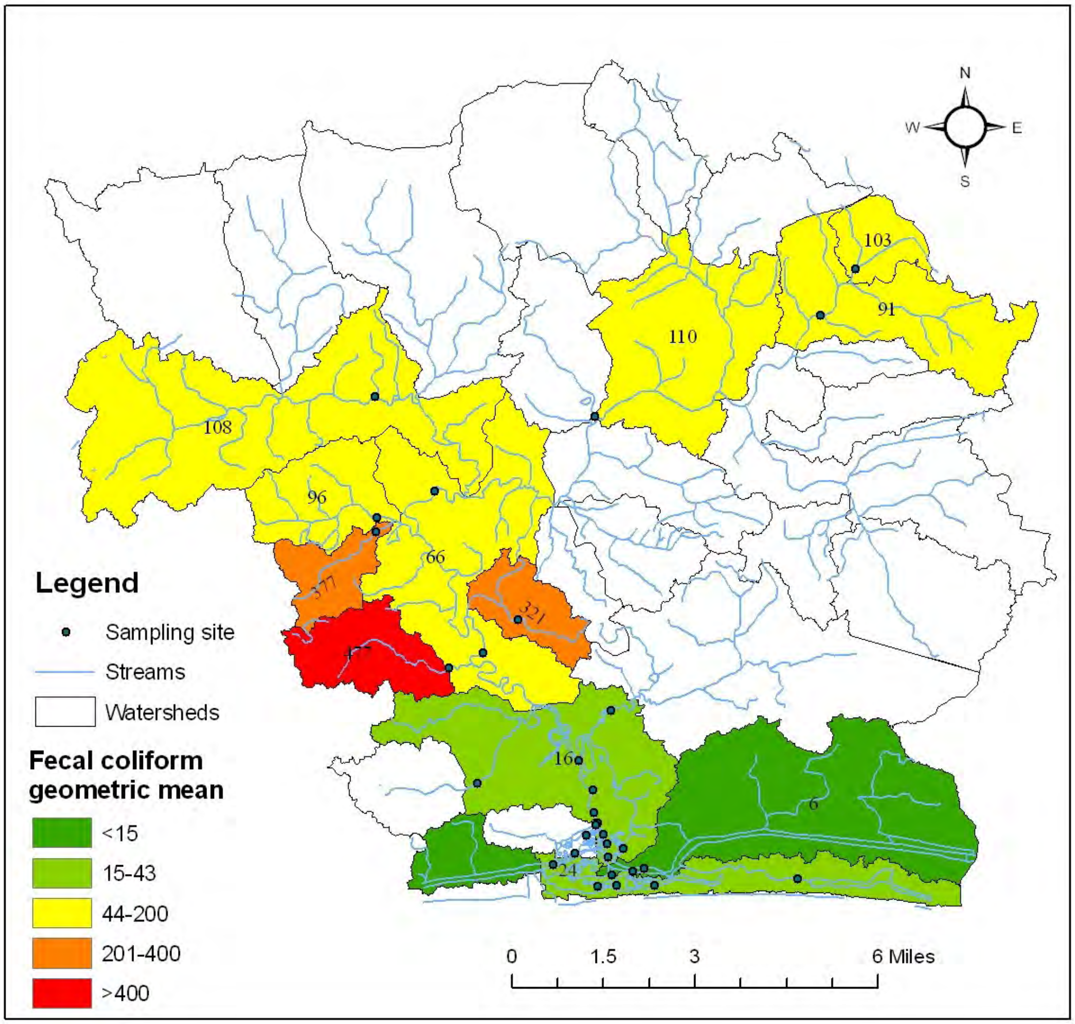


**Figure 4: Fecal coliform geometric means by watershed.** Watersheds shown in white have no data.

**Table 7: Fecal coliform geometric means by watershed**

| Watershed | NC Stream classification | Geometric mean (N results) |
|---|---|---|
| Bolivia Branch | C Sw | 103 (6) |
| Middle Swamp | C Sw | 91 (6) |
| Royal Oak Swamp | C Sw | 108 (8) |
| Doe Creek | C Sw HQW | 96 (8) |
| Little Doe Creek | C Sw HQW | 377 (7) |
| Sandy Branch | C Sw HQW | 321 (6) |
| Pamlico Creek | SC HQW | 477 (6) |
| UT to Lower LFR | C Sw HQW | 126 (6) |
| Upper LFR | C Sw | 110 (7) |
| Middle LFR | SC HQW | 66 (14) |
| Lower LFR | SA HQW | 16 (43) |
| ICW | SA HQW | 6 (23) |
| Oak Island Beach | SA HQW | 24 (19) |

In order to examine any effects of tidal direction on bacteria concentrations, a simple plot of distributions was made (Figure 5) of all results from tidal sites (all sites from the Pamlico Cr, Middle LFR, Lower LFR, ICW, and Oak Island Beach watersheds) during ebb (outgoing) and flood (incoming) tides under varying flow regimes. At this large of a grouping it appears that under baseflow conditions coliform levels may be higher during incoming tides, and after recent rains outgoing tides may have slightly higher levels. However, a Wilcoxon rank sum test did not show statistically significant differences between "Baseflow, ebb" and "Baseflow, flood" conditions. Significant differences were found using the Wilcoxon rank sum test between "Other, ebb" and "Other, flood".

Figure 6 further breaks out the data by monitoring location type: mainstem LFR (Middle LFR and Lower LFR watersheds), ICW (ICW watershed), tributary (Pamlico Cr watershed), or Montgomery Slough (Oak Island Beach watershed). This level of division gives sample sizes of only one to three observations in certain categories, which is too small to allow for definitive statements. It is intended to provide an additional line of evidence that may suggest a likely source for coliform.

No patterns are noted over all station types. However, at Montgomery Slough (Oak Island Beach watershed) stations there is a significant difference between ebb and flood tides for samples taken after recent rains (flow = "other"). The higher values during outgoing tides suggest that overland runoff may be the more predominant issue here. Due to the small sample size for baseflow samples, though, it is difficult to determine if coliform levels during "other" flow regimes are actually statistically different from levels at baseflow. Being able to make this distinction would provide evidence as to whether bacteria sources are on land or may be due to failing septic systems.

In order to further examine the relationship between flow regime, tidal direction, and fecal coliform concentrations, analyses were repeated on data collected by the AMS program at monitoring location MS01 (Oak Island Beach watershed) from September 2001 through August 2005. Though older coliform results are available, precipitation data were only readily available going back to 2001. Analyses were repeated (data not shown) for all available data as well as for only those collected during the growing season (April-October). No significant differences were found using Wilcoxon rank sum.

It should be noted that examining bacteria (or any other constituent of concern) in relation to tides can be extremely difficult, as tides are not strictly a one-way event. Poorly flushing tidal areas, such as in the middle LFR and Oak Island watersheds, may require several tidal cycles before complete turnover occurs. In addition, a major source of bacteria may be the bottom sediments. When these sediments are disturbed, due to tidal movements or boat traffic, the bacteria may be resuspended.

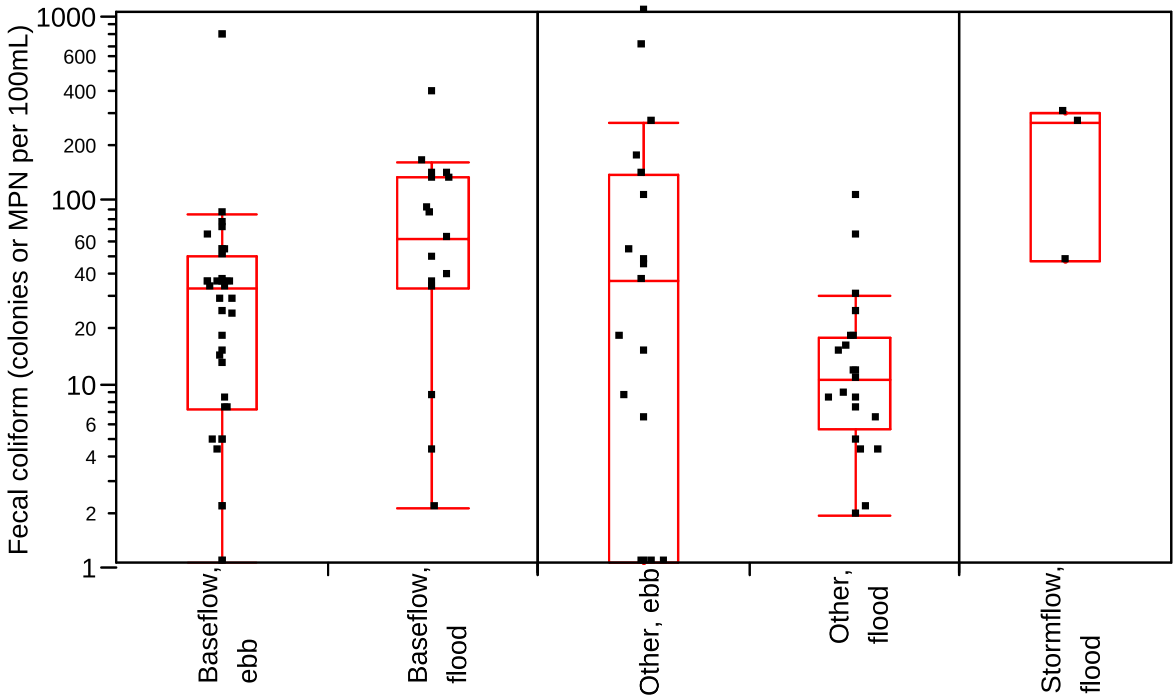


**Figure 5: Fecal coliform distributions at different flow regimes and tide stages**

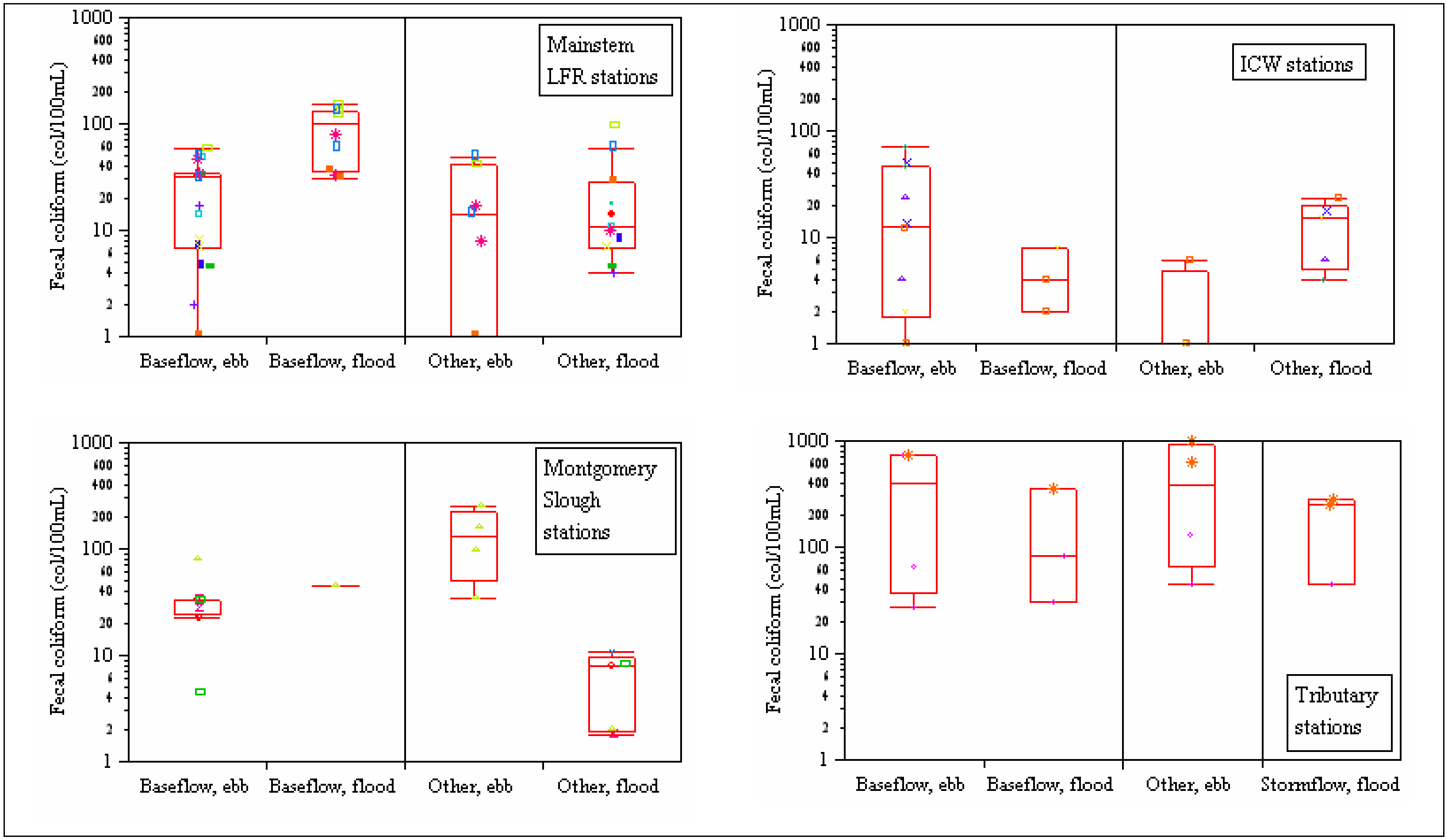


**Figure 6: Fecal coliform distributions at varying flow regimes and tide direction by monitoring location type**

## ***Chlorophyll-*a**

Chlorophyll-*a* sampling was performed to obtain baseline data on possible nutrient enrichment in the estuary. Historically no indications of enrichment, such as algal blooms or fish kills, have been documented in the estuary. No historic chlorophyll data were available for comparison. However, this watershed is facing immediate and future development pressures and is one of the fastest growing counties in the nation in percent growth (Christie, 2006) as coastal areas continue to be developed for vacation, retirement, and recreational areas. In particular, as areas transition from undeveloped, agriculture, and silviculture uses to golf courses, vacation homes, and more impervious area, it is to be expected that nutrient inputs, and possibly enrichment in the estuary, will likely rise due to additional sources and runoff.

Chlorophyll-*a* was collected at seven locations, including one location in the Oak Island Beach watershed, two on the ICW, and four in the Middle and Lower LFR watersheds. Distributions are shown in Table 8 and Figure 7. For the majority of samples, no issues with chlorophyll levels were noted. However, a few high values occurred sporadically at different locations throughout the spring and summer (Figure 8). Chlorophyll levels were elevated overall at MS01 (Oak Island Beach watershed), with two separate occurrences in June and July that exceeded the NC water quality standard of 40µg/L. Exceedences were also seen in the Middle LFR watershed at LFR03 (late July) and LFR06 (late April). Field staff noted no indications of algal blooms, such as unusual pH or DO measurements or visual indicators, during these site visits.

Since higher levels were noted in the Oak Island watershed and only the middle section of the estuary, flushing problems may be an issue, allowing nutrients to build up and feed the phytoplankton community. Past reports have noted that the Lockwoods Folly River flushes poorly (NC DENR DEM, 1989b). This may also be the case for Montgomery Slough, the sole waterbody sampled in the Oak Island watershed. The Slough runs down the middle of Oak Island, which is very densely populated primarily with vacation homes with septic systems.

If nutrient enrichment in Montgomery Slough were due primarily to failing septic systems on Oak Island, a source suggested in previous NC Div. of Environmental Management reports (NC DENR DEM, 1989a), it would be expected that algal response, as represented by chlorophyll-*a*, would continue increasing (or at least stay at a higher level) into peak beach season (July, August, and early September). This does not appear to be the case. However, chlorophyll-*a* can be a notoriously poor indicator of actual algal productivity, depending on the species present.

**Table 8: Distributions of chlorophyll-a (µg/L) by monitoring station and watershed**

| Watershed | Station | N | Min | 10$^{th}$ | 25$^{th}$ | Median | 75$^{th}$ | 90$^{th}$ | Max |
|---|---|---|---|---|---|---|---|---|---|
| Intracoastal Waterway | ICW03 | 7 | 4 | 4 | 4 | 10 | 12 | 13 | 13 |
| | ICW07 | 7 | 3 | 3 | 4 | 5 | 9 | 9 | 9 |
| Lower LFR | LFR11 | 7 | 3 | 3 | 4 | 10 | 13 | 14 | 14 |
| | LFR19 | 7 | 3 | 3 | 4 | 7 | 11 | 15 | 15 |
| Middle LFR | LFR03 | 7 | 1 | 1 | 1 | 7 | 10 | 46 | 46 |
| | LFR06 | 7 | 2 | 2 | 2 | 8 | 18 | 44 | 44 |
| Oak Island | MS01 | 6 | 6 | 6 | 7.5 | 18 | 46.5 | 60 | 60 |

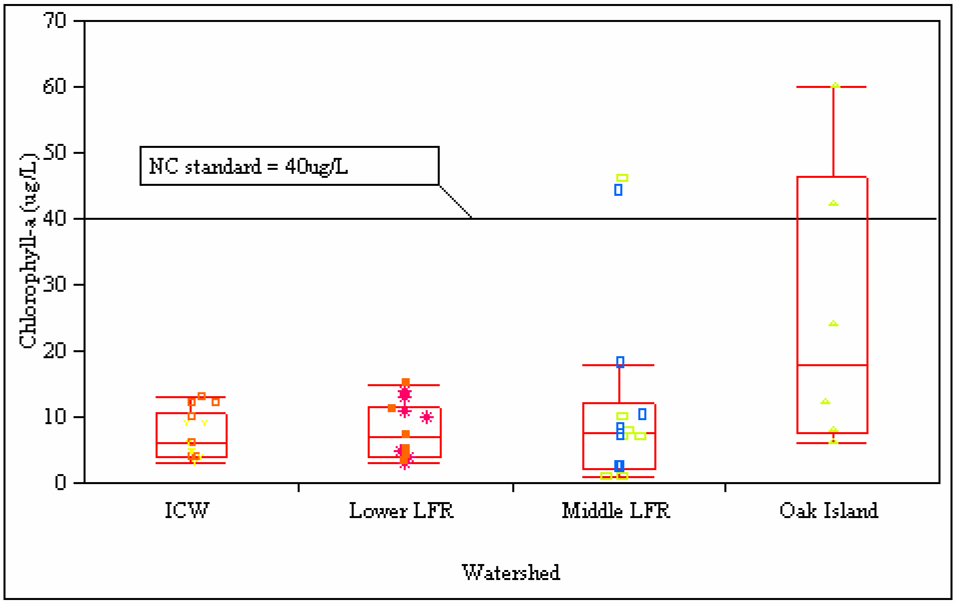


**Figure 7: Distributions of chlorophyll-a (µg/L) by watershed**

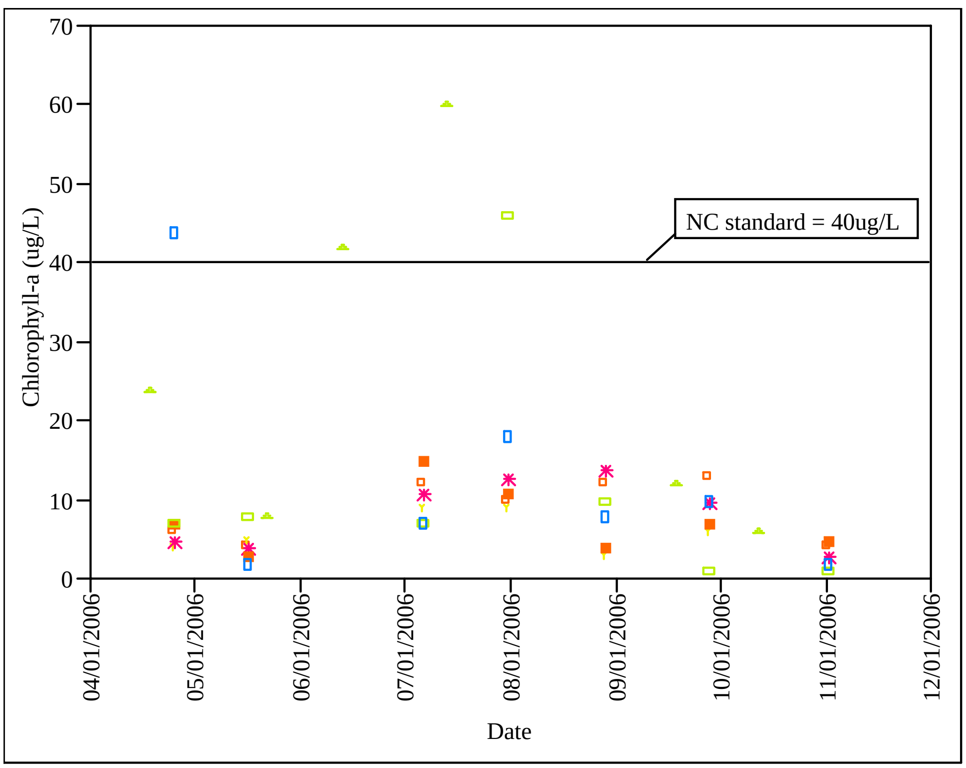


**Figure 8: Chlorophyll-a concentrations over time**

***Nutrients***

Assessing nutrient levels in any aquatic system can be difficult, as different systems react very differently to nutrient inputs.  The analysis is further complicated in certain situations, as in this LWP area, where many of the tributaries are blackwater, have a relatively high content of volatile (organic) suspended matter, riparian wetland areas, little flow during certain times of the year, naturally lower DO and pH levels, and other factors that may prevent what is considered a typical biological response to enrichment (e.g., phytoplankton, periphyton, or macrophyte overgrowth).  It is, after all, this response and its aftereffects (e.g., bloom die off leading to increased biological oxygen demand [BOD] and depressed DO levels) that are considered deleterious to the aquatic ecosystem.  However, nutrient inputs in the tributaries may eventually lead to increases in nutrient loads in the estuaries, where light penetration of the water column, flow, and other components are not as much of an inhibitor to algal blooms.

In this study, samples were analyzed for ammonia ($NH_3$), nitrate + nitrite ($NO_2$+$NO_3$), total Kjeldahl nitrogen (TKN), and total phosphorus (TP).  Distributions of nutrients are grouped by watershed and presented as box plots in Figure 9.  All nitrogen species are reported as mg/L as N.  Phosphorus is reported as mg/L as P.

Bolivia Br shows marked increases in $NH_3$ and $NO_2$+$NO_3$ as compared to other watersheds.  This is not unexpected, given that this is the receiving stream for effluent from the Bolivia Elementary School (NPDES permit #  NC0045250).  It is a minor, 100% domestic discharger, and is a package plant with a history of violations of its fecal coliform, ammonia, DO, pH, and BOD limits.  This discharger is further discussed in a later section.  In addition to possible point source impacts, this stream has very little flow, as it is relatively narrow and deep, and therefore nutrient inputs likely are not flushed very quickly.  It is very much a blackwater stream with high suspended organic content.  It is also situated in one of the (relatively) more developed areas in the upper watershed, draining the town of Bolivia.  This area still has fairly low density development, but is more developed than other portions of the upper LWP area, such as some of the tributaries to Royal Oak Swamp, which drain the Green Swamp.

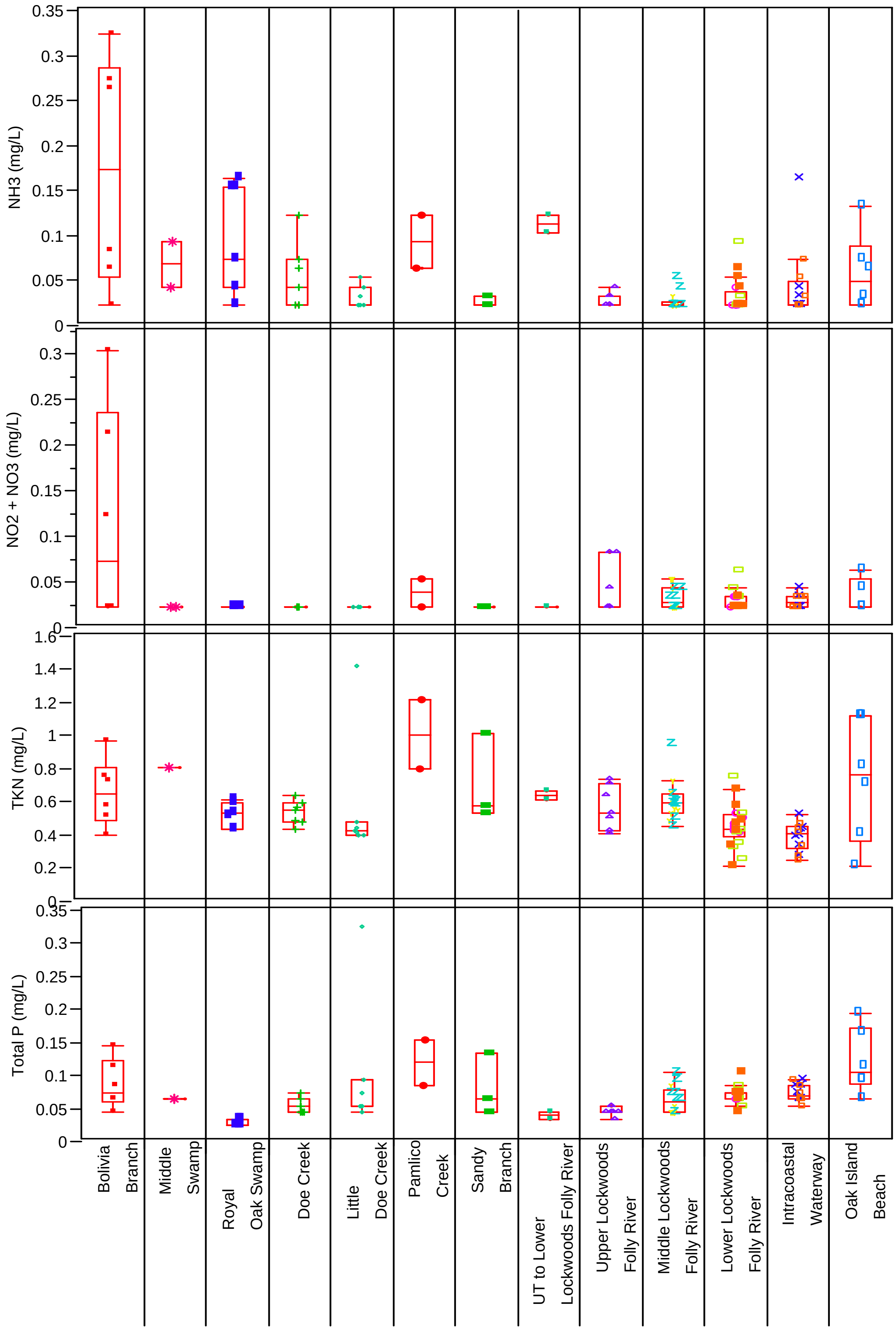


**Figure 9: Nutrient distributions by watershed**

The Oak Island Beach and the Middle Lockwoods Folly River watersheds were noted previously to have higher chlorophyll-*a* levels than in the ICW and Upper or Lower Lockwoods Folly watersheds. As phosphorus is often considered to be a limiting nutrient to algal growth, a comparison of phosphorus between these watersheds is warranted. When looking at the individual results from the three locations with chlorophyll results above the NC water quality standard of 40 µg/L (MS01, LFR03, and LFR06), the dates of these exceedences coincided with the highest total phosphorus values (Table 9) at each of these locations. Three of the four sampling events also showed the highest TKN levels for those stations. No patterns were noted for $NH_3$ or $NO_2$+$NO_3$. It should be noted that increased phosphorus or TKN levels cannot be identified as a cause of the elevated chlorophyll-*a* using these data; increased phosphorus or TKN levels may be solely a reflection of increased algal biomass.

At the watershed level, median phosphorus levels are highest in Oak Island Beach and Pamlico Cr watersheds (Figure 9). Oak Island Beach contained the site with the highest chlorophyll-*a* results (MS01). The Pamlico Cr sampling site did not have any accompanying chlorophyll-*a* results, but is a tidal creek that was sampled fairly close to the confluence with the Lockwoods Folly R mainstem. The confluence with Pamlico Cr is just downstream of sampling site LFR06, which was one of the locations showing higher levels of chlorophyll-*a*.

**Table 9: Chlorophyll and nutrient results from stations LFR03, LFR06, and MS01**

Values in bold indicate maximum values for each parameter at each station

| LWP Station | Date | Chlorophyll-a µg/L | Total P (mg/L) | TKN (mg/L) | $NH_3$ (mg/L) | $NO_2$+$NO_3$ (mg/L) |
|---|---|---|---|---|---|---|
| LFR03 | 04/25/2006 | 7 | 0.04 | 0.52 | **0.03** | **0.05** |
| LFR03 | 05/16/2006 | 8 | 0.04 | 0.53 | 0.02 | **0.05** |
| LFR03 | 07/06/2006 | 7 | 0.05 | 0.54 | 0.02 | 0.02 |
| LFR03 | 07/31/2006 | **46** | **0.08** | 0.64 | 0.02 | 0.02 |
| LFR03 | 08/28/2006 | 10 | 0.04 | 0.58 | 0.02 | 0.04 |
| LFR03 | 09/27/2006 | 1 | 0.04 | **0.71** | 0.02 | 0.02 |
| LFR03 | 11/01/2006 | 1 | 0.04 | 0.47 | 0.02 | 0.02 |
| LFR06 | 04/25/2006 | **44** | **0.10** | **0.93** | 0.02 | **0.04** |
| LFR06 | 05/16/2006 | 2 | 0.04 | 0.49 | **0.05** | **0.04** |
| LFR06 | 07/06/2006 | 7 | 0.06 | 0.63 | 0.02 | 0.03 |
| LFR06 | 07/31/2006 | 18 | 0.07 | 0.58 | 0.04 | 0.03 |
| LFR06 | 08/28/2006 | 8 | 0.06 | 0.44 | 0.02 | 0.02 |
| LFR06 | 09/27/2006 | 10 | 0.07 | 0.57 | 0.02 | 0.02 |
| LFR06 | 11/01/2006 | 2 | 0.09 | 0.59 | 0.02 | 0.02 |
| MS01 | 04/18/2006 | 24 | 0.09 | 0.8 | 0.02 | 0.02 |
| MS01 | 05/22/2006 | 8 | 0.09 | 0.2 | 0.03 | 0.02 |
| MS01 | 06/13/2006 | **42** | **0.16** | **1.1** | 0.06 | 0.02 |
| MS01 | 07/13/2006 | **60** | **0.19** | **1.1** | 0.02 | 0.04 |
| MS01 | 09/18/2006 | 12 | 0.11 | 0.69 | 0.13 | **0.06** |
| MS01 | 10/12/2006 | 6 | 0.06 | 0.39 | **0.07** | 0.04 |

The mean value of all results for each watershed is shown in Table 10 and on the maps in Figures 10-13. The mean, as opposed to median, value was used as a measure of central tendency in this case to ensure that the effect of extremely high or low values were not diluted, as instream concentrations due to runoff and other periodic events may be critical to planning restoration activities. In the figures, the watersheds are color-coded by mean value, providing an easy way to identify relative differences or "hot spots".

Ammonia levels seem to be higher in the tributaries (Figure 10), such as Bolivia Br, Middle Swamp, Royal Oak Swamp, Pamlico Cr, and the UT to LFR watersheds. Moderate levels were also noted in Oak Island.

Nitrate + nitrite levels showed very little variability across watersheds and were generally quite low (Figure 11) with the exception of Bolivia Br, where levels were three to six times higher than any other watershed. This is likely due to the NPDES discharge upstream of the sampling site, which ceased discharging in fall 2006.

The TKN analysis measures ammonia as well as organic nitrogen. In many inland streams organic sources are low and therefore TKN and ammonia show similar patterns. However, higher levels of organic nitrogen will be seen in areas with large concentrations of decaying matter, such as the swamp streams that are found in much of the LWP area. As can be seen in Figure 12, a slightly different pattern from ammonia is evident. Relatively high values are seen in almost all watersheds and this may likely be a natural condition. The highest concentrations are clustered around the Middle LFR watershed and its tributaries, the Bolivia Br and Middle Swamp watersheds, and Oak Island watershed.

The patterns seen with median (Figure 9) total phosphorus are repeated when looking at means (Figure 13). Higher values are also seen in Little Doe Cr (especially striking when compared to its neighbor, Doe Cr), Sandy Br, and Bolivia Br.

**Table 10: Mean nutrient results by watershed**

| Watershed name | Total no. of results (all parameters) | Mean $NH_3$ (mg/L) | Mean $NO_2$+$NO_3$ (mg/L) | Mean TKN (mg/L) | Mean TP (mg/L) |
|---|---|---|---|---|---|
| Bolivia Branch | 24 | 0.17 | 0.12 | 0.64 | 0.08 |
| Middle Swamp | 8 | 0.07 | 0.02 | 0.79 | 0.06 |
| Royal Oak Swamp | 28 | 0.09 | 0.02 | 0.52 | 0.02 |
| Doe Creek | 28 | 0.05 | 0.02 | 0.52 | 0.05 |
| Little Doe Creek | 28 | 0.03 | 0.02 | 0.55 | 0.1 |
| Sandy Branch | 12 | 0.02 | 0.02 | 0.69 | 0.08 |
| Pamlico Creek | 8 | 0.09 | 0.04 | 0.99 | 0.12 |
| UT to Lower LFR | 8 | 0.11 | 0.02 | 0.63 | 0.04 |
| Upper LFR | 28 | 0.03 | 0.04 | 0.55 | 0.04 |
| Middle LFR | 56 | 0.02 | 0.03 | 0.59 | 0.06 |
| Lower LFR | 84 | 0.03 | 0.04 | 0.44 | 0.07 |
| ICW | 56 | 0.04 | 0.04 | 0.37 | 0.07 |
| Oak Island Beach | 24 | 0.06 | 0.03 | 0.71 | 0.12 |

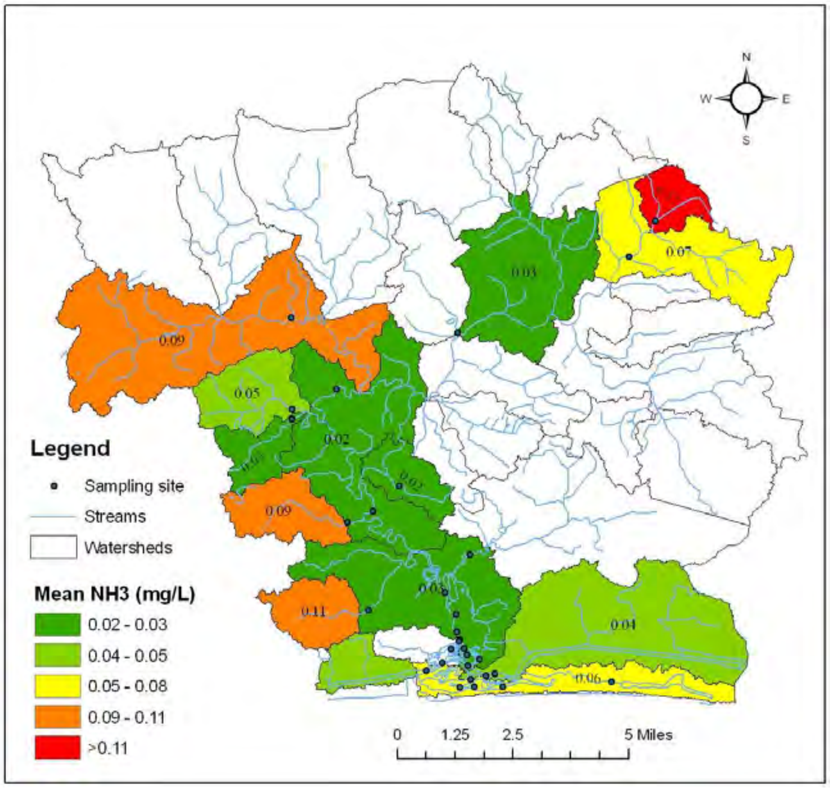


**Figure 10: Mean NH3 results by watershed.** Areas in white have no data**.**

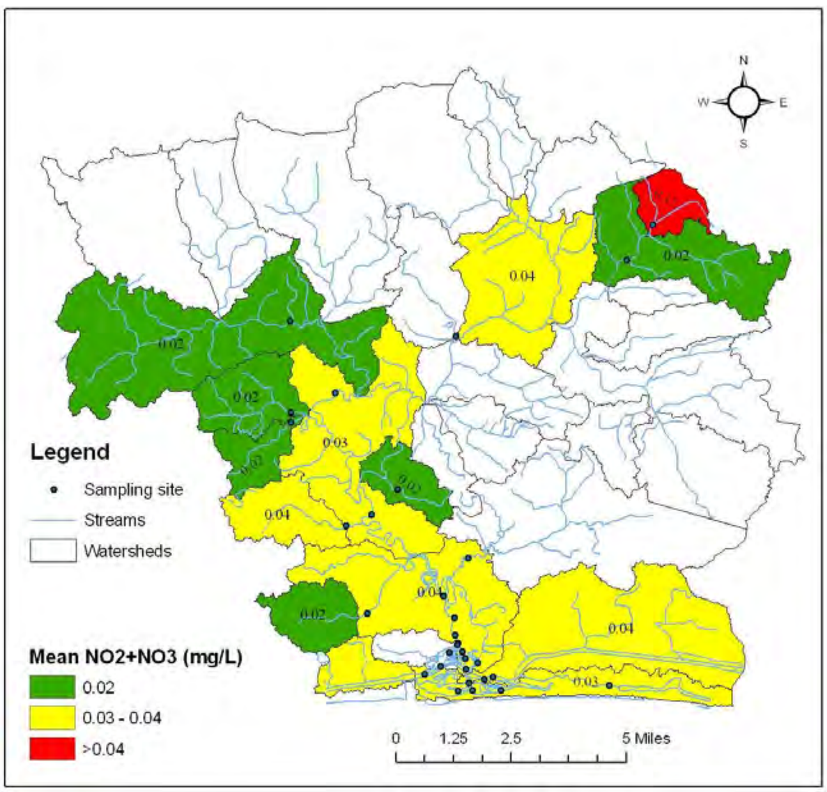


**Figure 11: Mean NO2+NO3 results by watershed.** Areas in white have no data.

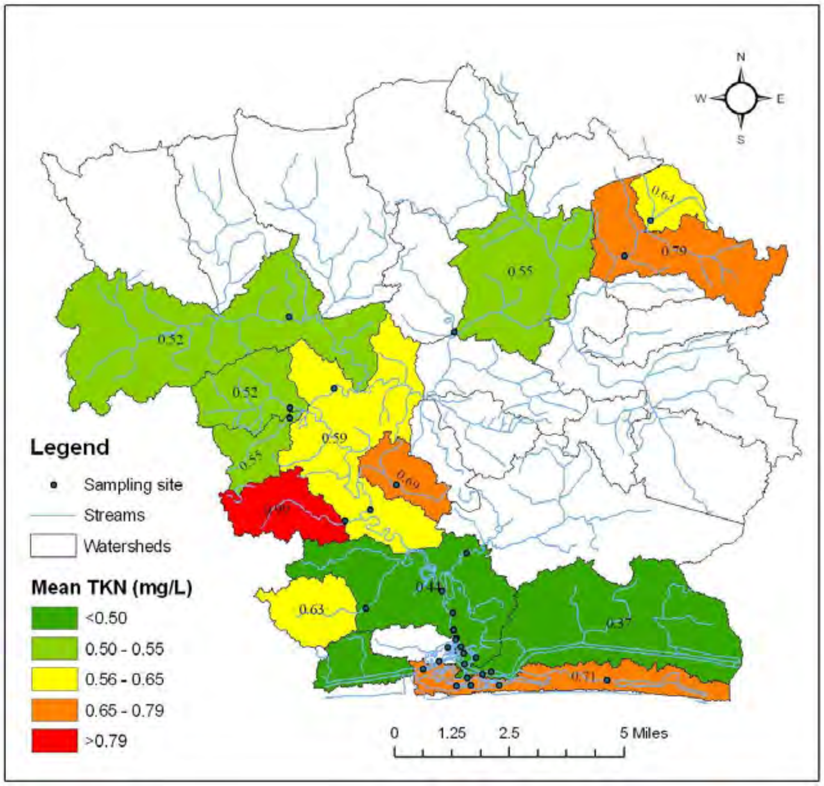


**Figure 12: Mean TKN results by watershed.** Areas in white have no data.

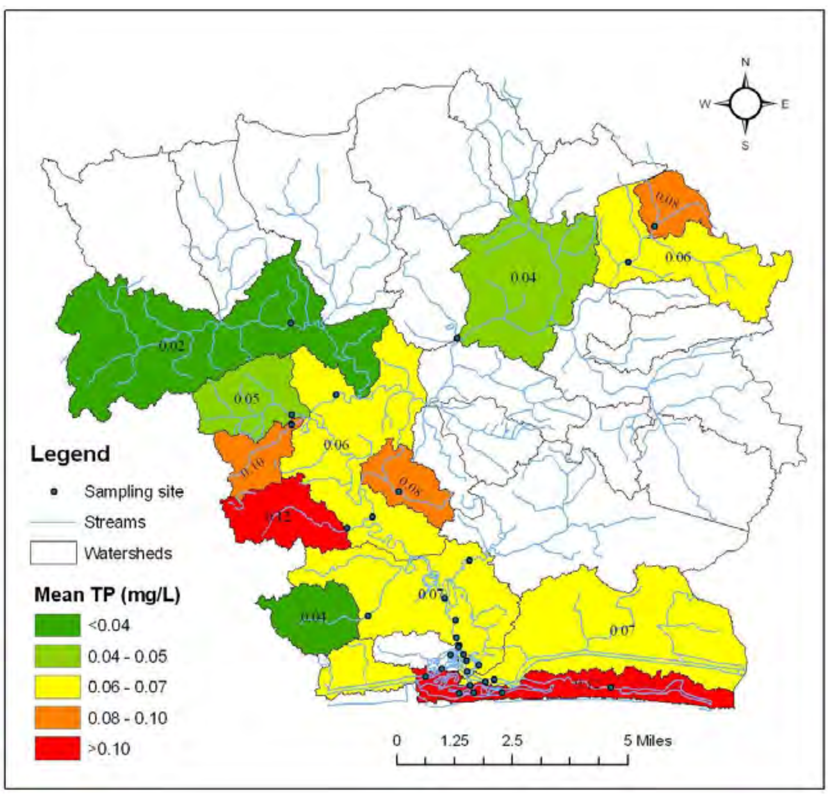


**Figure 13: Mean total P results by watershed.** Areas in white have no data.

There is an historical data set for nutrients for six monitoring locations (ICW03, ICW07, LFR03, LFR11, LFR19, and MS01) that were part of this study. These locations were part of the DWQ AMS program for several decades, and previous data collections for nutrients were made from 1989 through 2001. These historic data were previously summarized (NC DENR DWQ, 2005). This provides a unique opportunity to explore changes in nutrient levels from the former concentrations.

Only data collected during the growing season (April through October) were used from the previous data set (1989-2001) in order to make comparisons to the 2006 results. Comparisons of the distributions for total P, $NH_3$, $NO_2$+$NO_3$, TKN, total nitrogen (TN), total inorganic nitrogen (TIN), and total organic nitrogen (TON) for each of the time periods are shown in Figures 14-16.

Though difficult to make strong conclusions on such a small data set and using a gross analysis that does not consider other factors such as drought effects, it appears that there may have been an increase in phosphorus, TKN, and $NO_2$+$NO_3$ levels at several sampling locations. It should be noted that $NO_2$+$NO_3$ levels are still extremely low in most of the watershed. As environmental data are generally not normally distributed, nonparametric analyses were used for comparison of historic data vs. the data collected in this study. Using the Kruskal-Wallis nonparametric one-way analysis of variance, a number of sites' 2006 results showed significant ($p<0.05$) differences from data collected previously:

- MS01: Increase in TP
- ICW03 and ICW07: Increases in $NO_2$+$NO_3$ and TP
- LFR03: Increases in $NO_2$+$NO_3$ and TKN
- LFR11: Increase in TP
- LFR19: Increases in $NO_2$+$NO_3$ and TP

As stated above, these results are not conclusive and more in-depth analyses and/or further data collections would be required before making definitive statements about changes in nutrient concentrations over time.

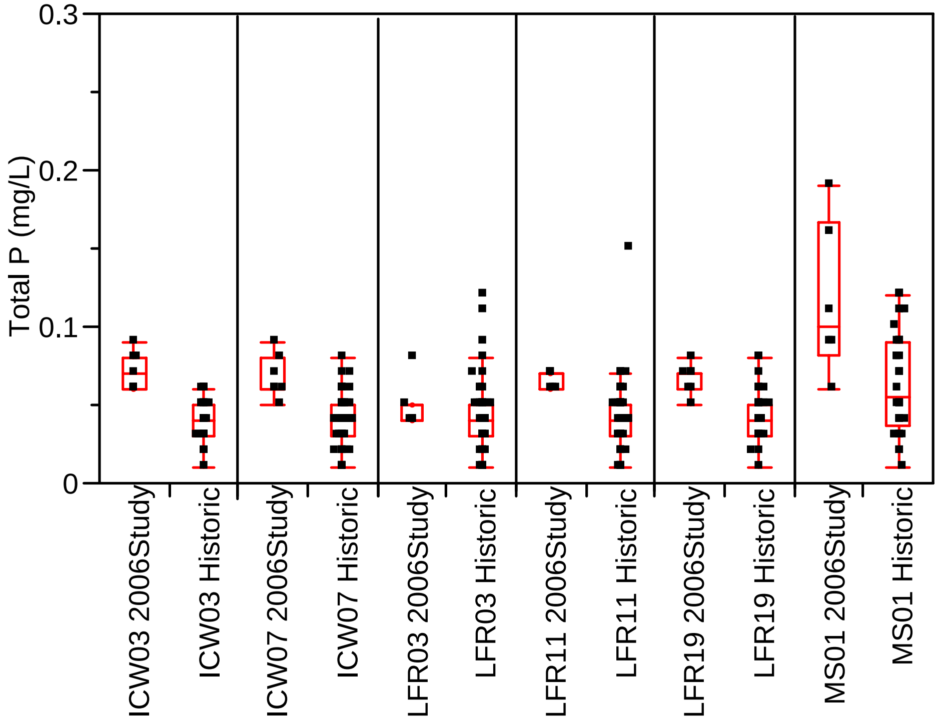


**Figure 14: Recent (2006) vs. historic (1989-2001) total phosphorus concentrations by station**

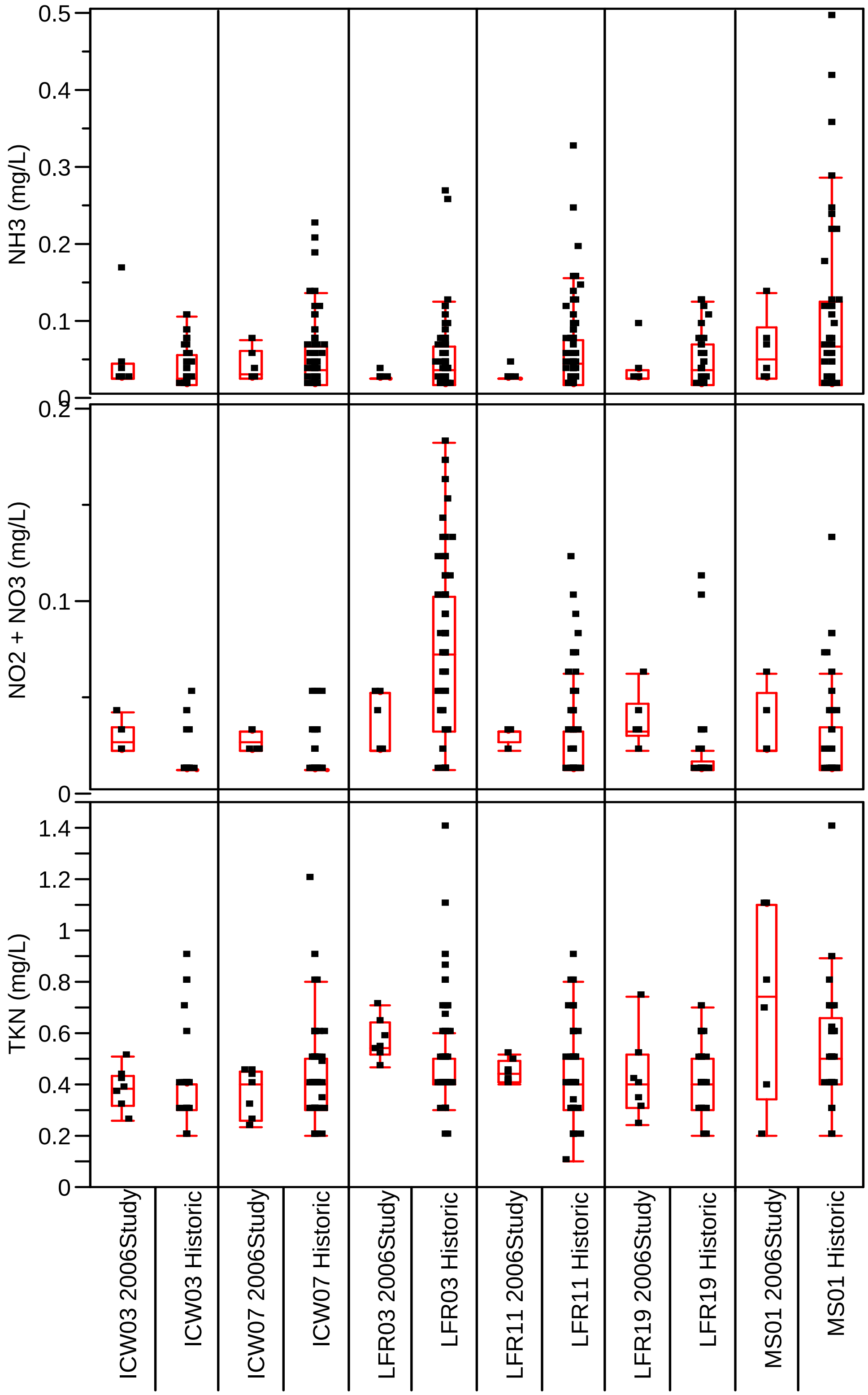


**Figure 15: Recent (2006) vs. historic (1989-2001) $NH_3$, $NO_2$+$NO_3$, and TKN concentrations by station**

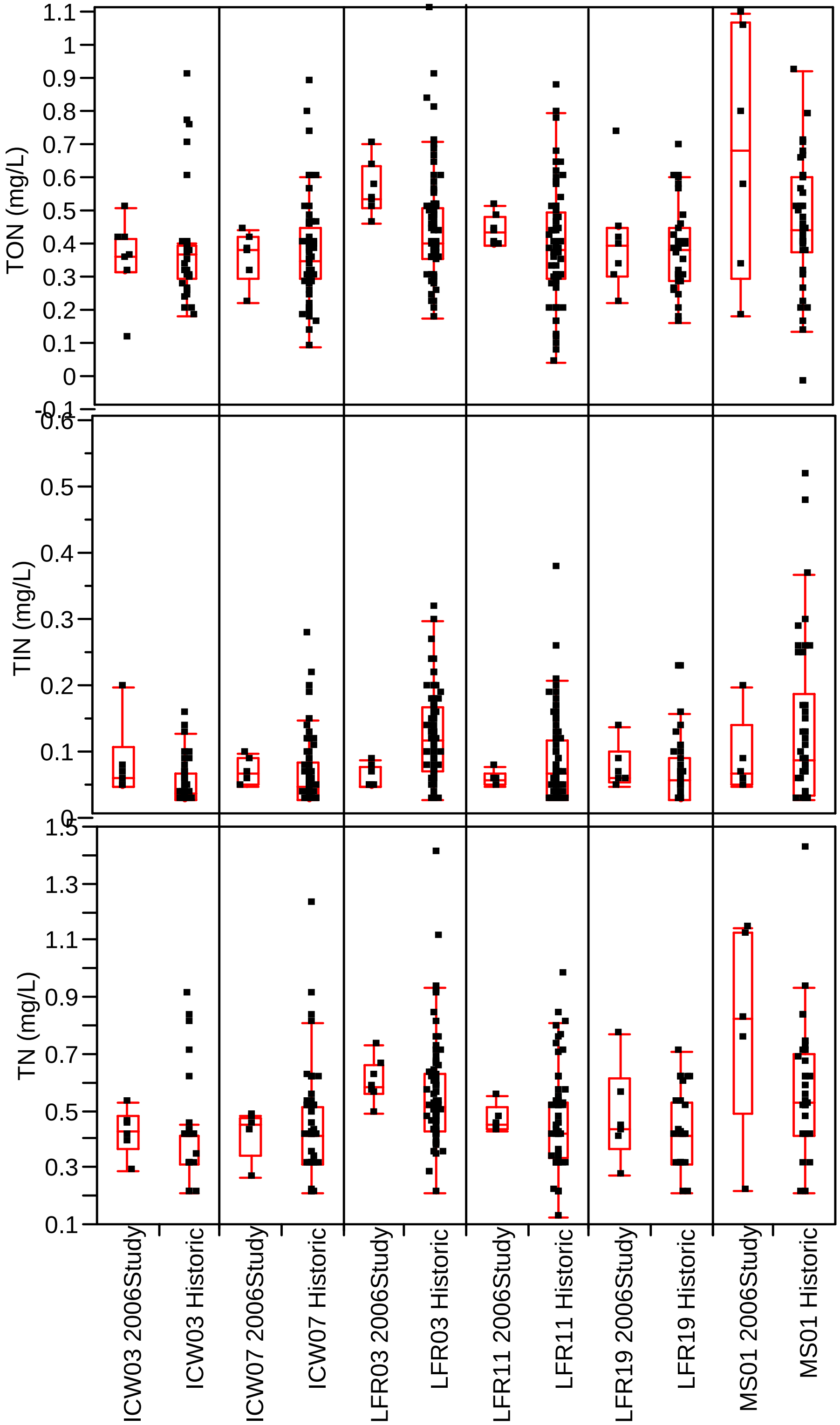


**Figure 16: Recent (2006) vs. historic (1989-2001) TON, TIN, and TN concentrations by station**

***Field measurements***

Dissolved oxygen, pH, and specific conductance were taken at all locations sampled by WAT and AMS staff. Salinity measurements were taken only at saltwater (class SC and SA) sites. For tributary sites, including the Oak Island Beach watershed, measurements were only taken at the water surface (depth = 0.1m).

Field measurements were taken at the surface, at mid-depth, and at the bottom of the water column in most of the mainstem LFR stations and at the ICW stations. Secchi depth readings were also taken at these locations. No stratification was noted at any location, indicating that the water column stays reasonably well mixed and salt wedges are likely not present. Unless otherwise noted, mid-depth and bottom measurements are excluded from the analyses, i.e., graphs show only surface readings. Results from all flow regimes (baseflow, stormflow, other) are combined in the following analyses.

The DEH Shellfish Sanitation monitoring program only records salinity at its monitoring locations. These data are included with DWQ results in the appropriate section.

*Dissolved oxygen concentrations*

Distributions of DO concentrations at each monitoring site are shown in Figure 17. Results below the NC standard of 4.0 mg/L (class C Sw) for instantaneous readings were common at tributary stations. In most cases this is likely natural and due to the swamp stream characteristics of these streams, including little or no flow especially during the summer months. Sluggish or no flow was often noted at Doe Cr (DC01) due to beaver dams. At the UT to the lower Lockwoods Folly R (UT01), flowing water was never seen and appears to be more of a tidal marsh than a flowing stream. Low or non-existent flow was noted at almost all locations, with the exception of Sandy Br (SB01) and Little Doe Cr (LDC01). These streams are both very different in character from the other tributaries, and both had consistently good flow throughout the study period. The low DO values at Little Doe Cr are actually somewhat unexpected, especially when compared to Sandy Br.

In addition to being a swamp stream, Bolivia Br (BB01) was the receiving stream for the effluent from a minor wastewater treatment facility. The additional inputs of organic material from the effluent may have depressed the DO even further than normal, though this data set does not allow for definitive determination. Flow was rarely noted on this stream.

Saltwater classifications (SC and SA) have a more stringent DO standard of 5.0 mg/L. Results below this value were common, though values below this threshold value were not as prevalent as in the freshwater tributaries. The DO concentrations generally are depressed in upstream tidal areas, as indicated by low values on Mill Cr (MC01), Pamlico Cr (PC01), Montgomery Slough (MS01), and the two most upstream saltwater sites on the Lockwoods Folly R (LFR03 and LFR06). This reinforces the theory proposed in the discussion on chlorophyll-*a* that these areas may be poorly flushed. For Mill Cr and Pamlico Cr, extensive salt marshes are also present, which may impact instream DO concentrations as tides flush out low DO water that is “stored” in these marshes during low tide. However, a cursory examination of DO concentrations during ebb and flood stage did not show any significant differences.

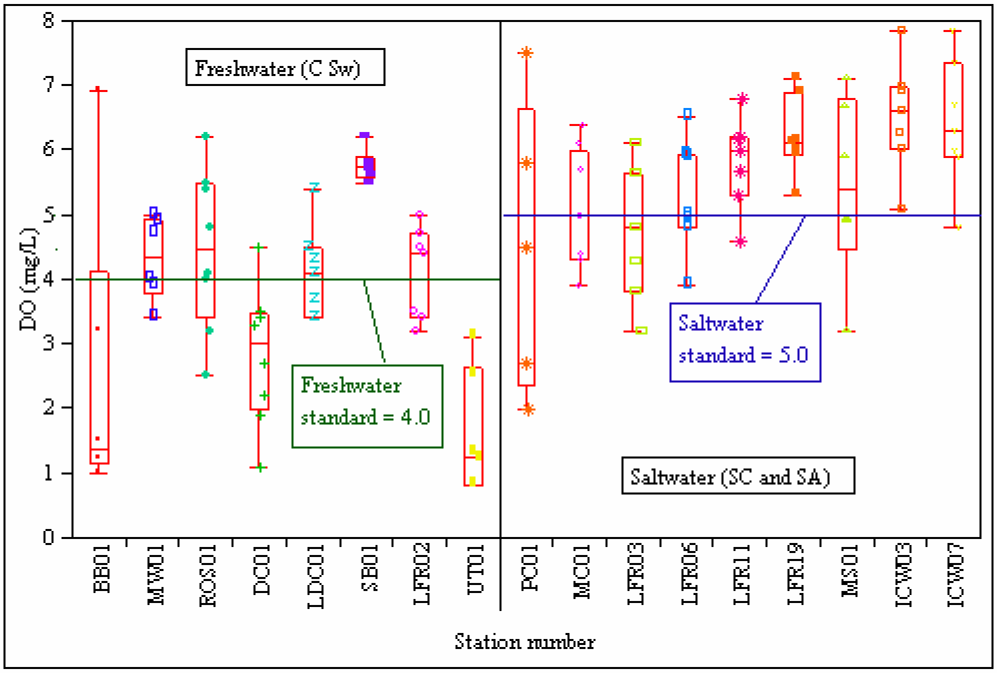


**Figure 17: Dissolved oxygen concentrations by monitoring station**

*pH*

Distributions of pH values for each monitoring site are shown in Figure 18. For freshwater sites, no pH values were recorded below the water quality standard of 4.3 that is applicable to swamp streams. All of the observations that were at or below 6.0 (the standard for non-swamp freshwater) occurred during the final sampling visit in October (Appendix 6). On this day, it was noted that in most cases the streams had re-established good connections with their riparian wetland areas due to heavy rains during the previous week. This may have led to a flushing of these wetland areas into the adjacent streams. This pattern was not noted in any other field measurements. This pattern of lower pH readings was also seen during visits to tributary sites in January 2007, indicating that this may be a winter condition, as opposed to the more neutral pH levels found during the rest of the year.

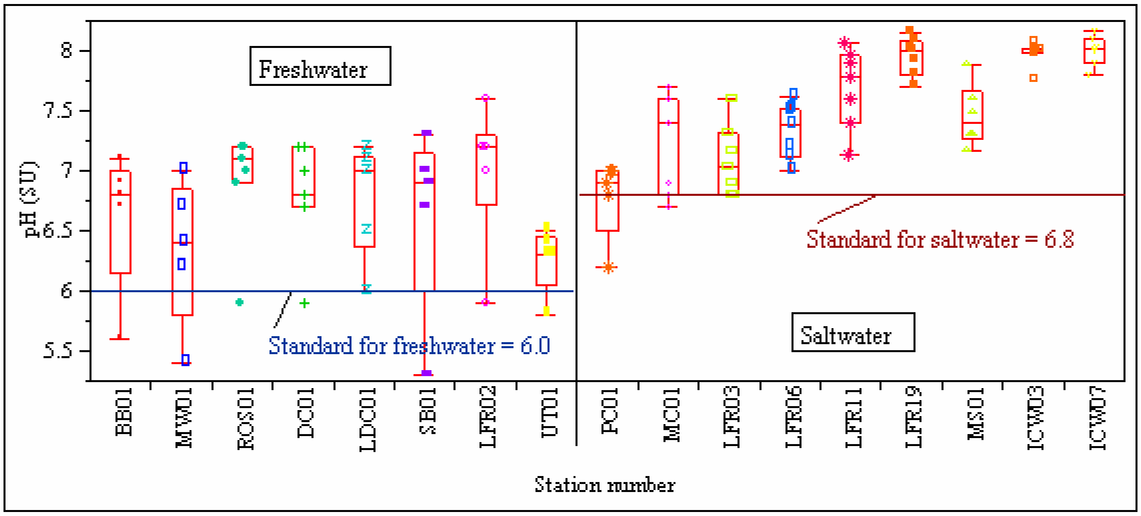


**Figure 18: pH distributions by monitoring station.**

NOTE: Standard of 4.3 for freshwater swamp streams not shown on graph.

*Specific conductance and salinity*

Distributions of specific conductance for all locations are shown in Figure 19. Distributions of salinity data are shown in Figure 20. Note that salinity was only recorded for class SC and SA waters. The graph also includes stations sampled by DEH, so stations shown differ from those shown on graphs of other field measurements.

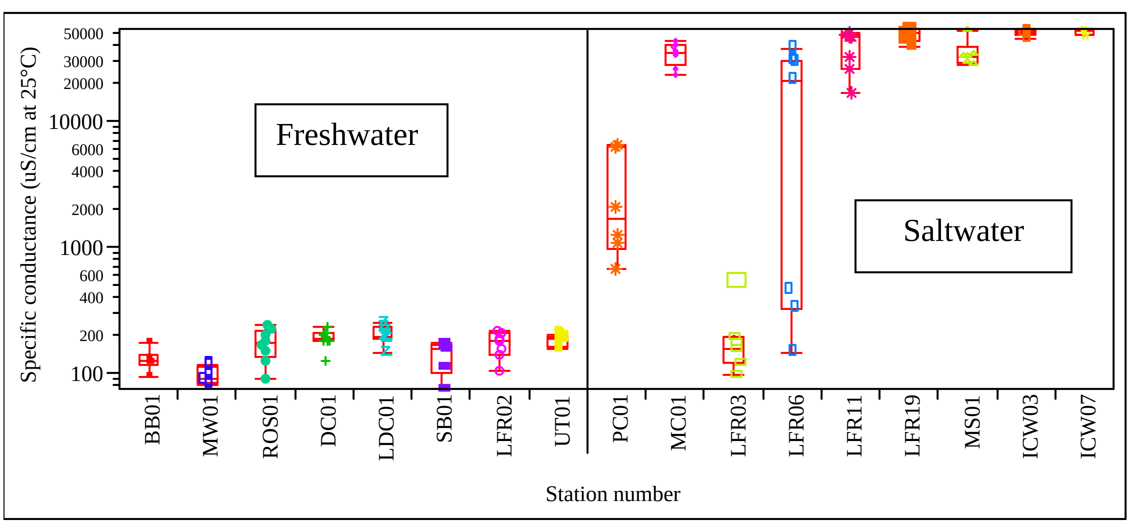


**Figure 19: Specific conductance distributions by monitoring station**

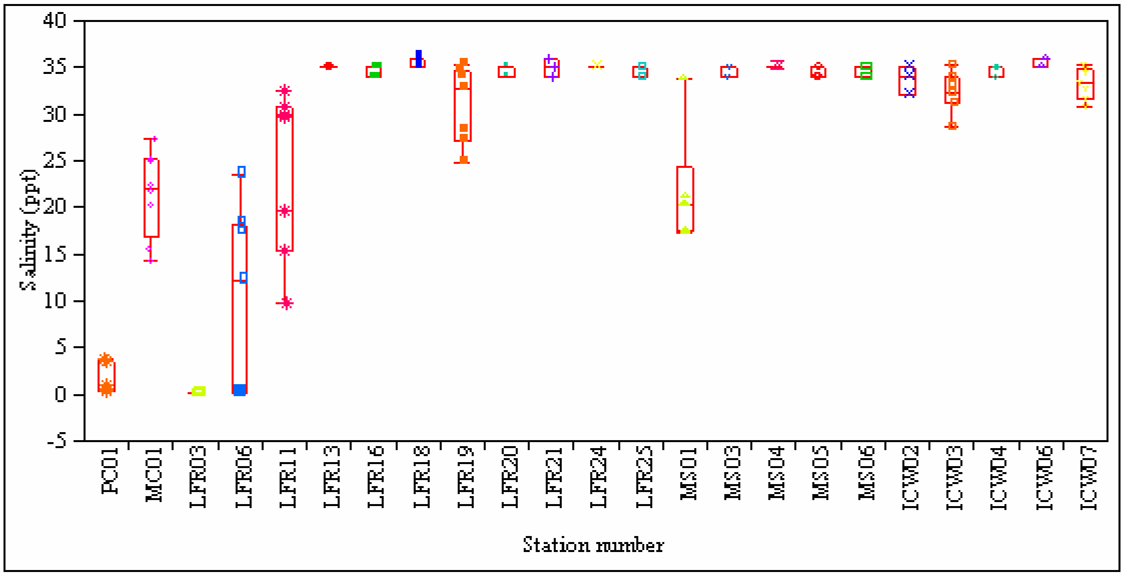


**Figure 20: Salinity distributions by monitoring station**

*Secchi depth*

Secchi transparency was measured in the lower Lockwoods Folly R and ICW only. Distributions of depth in meters are shown in Figure 21. There is an increase in transparency as well as range of readings going downstream on the Lockwoods Folly. The minimum values for LFR03 and LFR06 correspond to April 25, the date when chlorophyll results exceeded the state water quality standard.

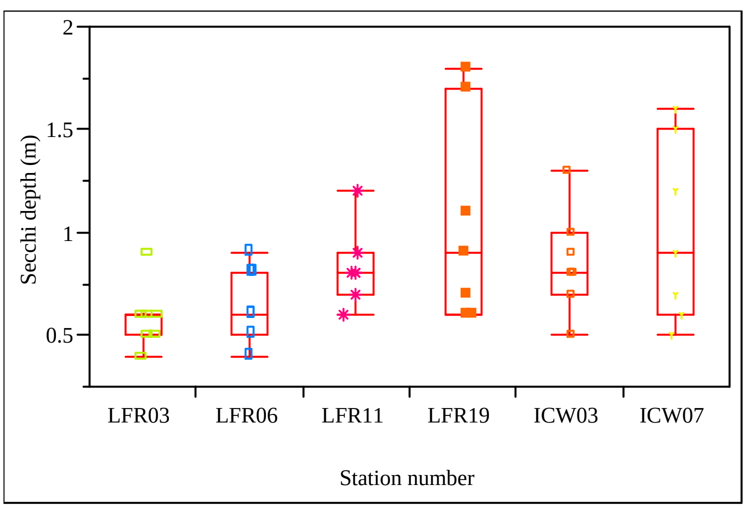


**Figure 21: Secchi depth by monitoring station**

### *Metals*

Metals were sampled at 15 locations in the watershed. Analyses included aluminum (Al), arsenic (As), cadmium (Cd), chromium (Cr), copper (Cu), iron (Fe), lead (Pb), manganese (Mn), mercury (Hg), nickel (Ni), and zinc (Zn) at all locations, with the addition of calcium (Ca) and magnesium (Mg) at tributary locations. For all 236 analyses for Cr, Pb, Hg, and Ni, results were reported as below the laboratory's reporting limit (RL). For As, Cu, and Cd, there were only four results (out of 177 analyses total) above the RL. The few exceptions are listed in Table 11, and almost all are from a single storm sampling event. There was only one exceedence of any NC water quality standard or action level: the Cu value of 3.6 from PC01 on August 21 is over the standard of 3.0 for SC waters.

**Table 11: Arsenic, copper, and cadmium samples with results over the reporting limit**

| Watershed | Site | Location | Date | Metal | Result (ug/L) | Flow | Tide |
|---|---|---|---|---|---|---|---|
| Lower LFR | MC01 | Mill Cr. | 07/11/2006 | As | 7.5 | Base | ebb |
| UT to Lower LFR | UT01 | UT to LFR | 08/21/2006 | As | 5 | Storm | n/a |
| Pamlico Creek | PC01 | Pamlico Cr. | 08/21/2006 | Cu | 3.6 | Storm | flood |
| Doe Creek | DC01 | Doe Cr. | 08/21/2006 | Cd | 2 | Storm | n/a |

For the remaining metals (Al, Fe, Mn, and Zn) distributions are shown in Figure 22, grouped by flow regime (baseflow, storm, other) and watershed. The number of storm samples is too few to illuminate differences between different flow regimes in each watershed. In the case of Zn it is especially difficult, since only about half of results were non-censored (i.e., at or above the reporting limit).

It appears that Little Doe Cr may show larger variations in Al, Fe, and Mn in response to precipitation/run-off. This may be due to more suspended inorganic soils in this creek, given that it has fewer coastal swamp stream characteristics and a sandy substrate. It also tended to have higher flow, therefore greater energy to carry larger/heavier suspended particles.

There were no exceedences of the applicable NC action level for Zn. Al and Mn do not have standards or action levels in C, SC, or SA waters. There is an action level for Fe, but only in freshwaters (class C). Almost all of the results from freshwater sites exceeded the action level of 1000 µg/L, as shown in Table 12. This is extremely common in NC waters, likely due to suspended soils. No exceedences were found at estuarine sites.

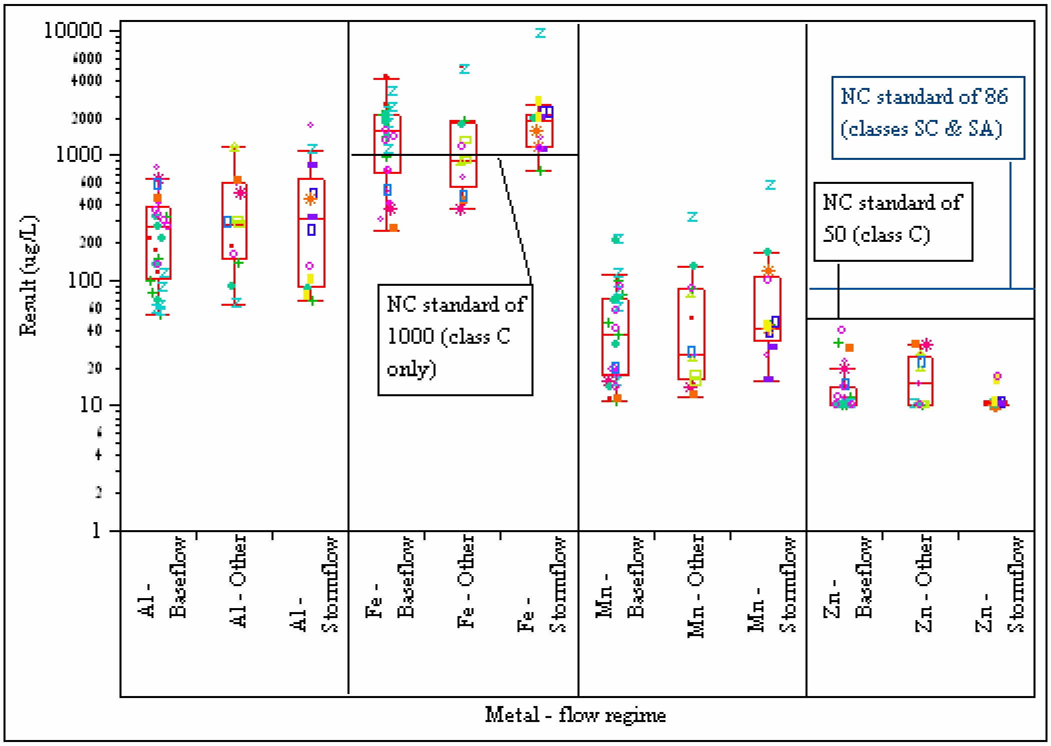


**Figure 22: Aluminum, iron, manganese, and zinc distributions by flow regime and watershed**

**Table 12: Number of exceedences of Fe standard for freshwater monitoring locations.**

NC water quality standard = 1000 ug/L

| LWP Station Number | Description | No. of samples | No. of exceedences |
|---|---|---|---|
| BB01 | Bolivia Br. | 6 | 5 |
| DC01 | Doe Cr. | 7 | 5 |
| LDC01 | Little Doe Cr. | 7 | 7 |
| LFR02 | Lockwoods Folly R. at SR 1501 | 7 | 6 |
| MW01 | Middle Sw. | 2 | 2 |
| ROS01 | Royal Oak Sw. | 7 | 7 |
| SB01 | Sandy Br. | 2 | 2 |
| UT01 | UT to LFR | 2 | 2 |

### *Turbidity*

Turbidities are, in general, fairly low throughout the study area (Figure 23). Three observations exceeded the applicable NC water quality standard. For Little Doe Cr, this corresponded to a storm sampling event. For the two exceedences at saltwater locations (Middle LFR and Oak Island), chlorophyll-*a* also exceeded the standard during these sampling visits, so the elevated turbidity may be due to increased algal densities.

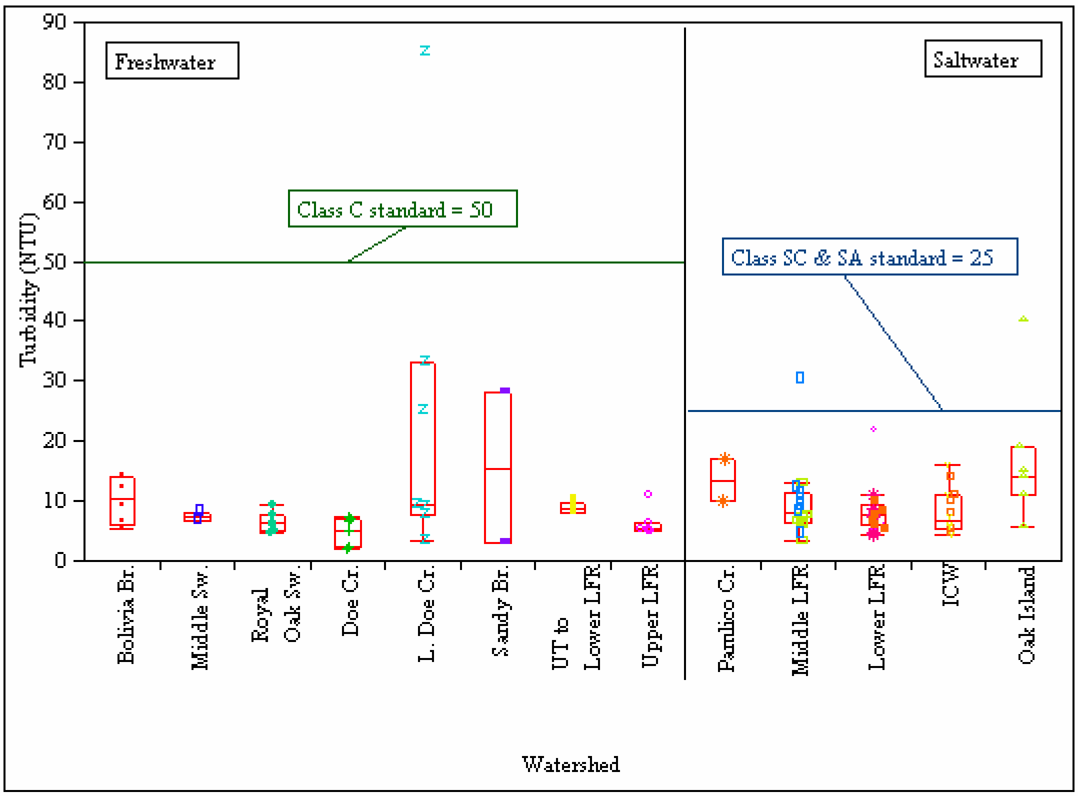


**Figure 23: Turbidity distributions by watershed**

## *Suspended residues*

Distributions of suspended residues (total, fixed, and volatile) under different flow regimes are shown in Figure 24. Baseflow concentrations are generally low in tributary stations. In tributary stations suspended residues tend have higher percentages of volatile than fixed solids, indicating higher suspended organic content. An exception exists for Little Doe Cr., which also shows a much bigger increase in residues in response to storm events than any other tributary.

Higher values are seen in watersheds with class SC and SA waters (Pamlico Cr., Middle and Lower LFR, ICW, and Montgomery Slough). This is to be expected since dissolved salts will increase the total suspended and total fixed suspended residues.

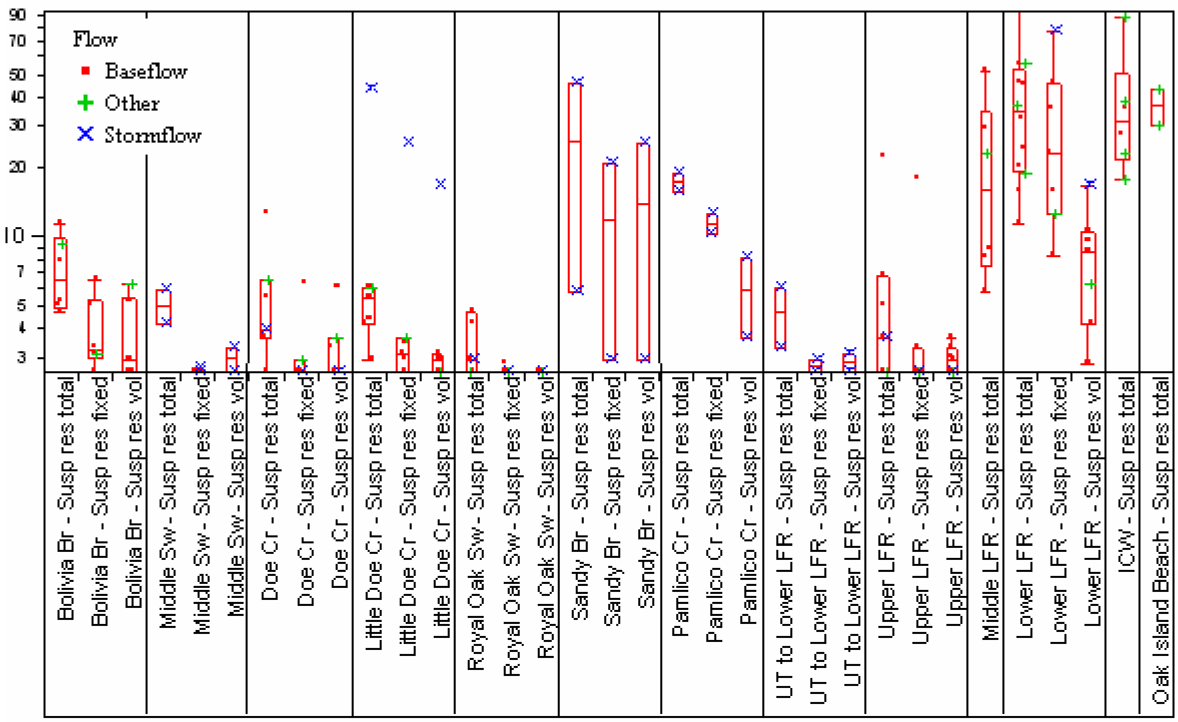


**Figure 24: Suspended residues by watershed and flow regime**

***NPDES Discharger***

As previously noted, there was one NPDES-permitted discharger in the LWP area: Bolivia Elementary School (NPDES permit #NC0045250). It was a package plant-type wastewater treatment facility and a minor, 100% domestic discharger. Effluent was discharged into Bolivia Br, which feeds into Middle Swamp. As seen in earlier sections, mean nutrient levels ($NH_3$, $NO_2$+$NO_3$, and TP) in this watershed were some of the highest seen in all of the monitored watersheds in the LWP area.

A brief discussion of results from effluent monitoring is provided in this report in order to provide possible explanations for unusual instream results seen downstream at station BB01 during this study. It should be noted that in October 2006 the permit for this facility was rescinded by DWQ after it was confirmed that the school is now connected to the municipal sanitary sewer system, and therefore is no longer discharging to Bolivia Br. Field notes indicate that sewer lines were observed being installed in the area in late August and early September.

As part of the NPDES permit, limits are placed on concentrations of certain parameters of concern (Appendix 3). The permittee is required to perform regular sampling for these constituents and report monthly to DWQ. In reviewing temporal patterns of this self-monitoring data, a distinct shift in results occurs from June through August, likely due to the fact that the permitted facility is an elementary school, and so is nearly vacant during the summer months.

Time series graphs of effluent monitoring results reported by the permittee in their monthly reports are shown in Appendix 4. Distributions are shown in Table 13. A quick review of these data showed that ammonia levels are within permit levels but are very high when compared to instream concentrations found elsewhere within the LWP area. The median ammonia value reported for the effluent was 1.7 mg/L, and it ranged from 0.1-10.5 mg/L. The amount of effluent being discharged on a daily basis was generally fairly low (median = 3000 gal/day).

**Table 13: Distributions of Bolivia ES effluent self-monitoring data**

| Parameter | No. of results | Min | $25^{th}$ percentile | Median | $75^{th}$ percentile | Max |
|---|---|---|---|---|---|---|
| Temperature (°C) | 68 | 14.6 | 16.4 | 18.2 | 24.7 | 31.4 |
| Specific conductance (uS/cm) | 59 | 7.45 | 804 | 945.5 | 1036.5 | 1690 |
| DO, Oxygen, Dissolved (mg/L) | 67 | 6.1 | 6.5 | 6.8 | 8.3525 | 11.7 |
| BOD, 5-Day (20°C) (mg/L) | 24 | 2 | 2 | 2 | 3 | 7 |
| pH (su) | 52 | 6.2 | 6.6 | 6.7 | 6.9 | 7.1 |
| Solids, Total Suspended (mg/L) | 25 | 1 | 1 | 2 | 2 | 3 |
| Ammonia Total (mg/L as N) | 26 | 0.1 | 0.55 | 1.7 | 3.5 | 10.5 |
| Fecal coliform (#/100ml) | 24 | 1 | 2 | 4 | 59.5 | 3000 |
| Flow (mgd) | 318 | 0.0001 | 0.001 | 0.003 | 0.004 | 0.008 |

***Cluster analyses***

Cluster analysis allows grouping of objects with similar characteristics, and can be useful for management decisions. Clustering on known characteristics may allow the reader to make inferences on similarities between locations based on unknown or unmeasured characteristics. For example, clustering monitoring sites based on results from chemical and physical measurements may provide an additional line of evidence that clustered sites may share similarities in geomorphology, hydrology, land use, instream conditions, etc. since many of these measurements are tied to these other characteristics. The process could also work in reverse: watershed land use and drainage area are often used for remote sensing, i.e., predicting water quality characteristics based on maps and/or aerial photographs.

Cluster analysis was used as an exploratory tool to identify monitoring sites and/or watersheds with similar characteristics as a way to identify groups that may benefit from similar types of water quality management, restoration, preservation, or mitigation activities within their drainage areas. Several groups of characteristics were used for clustering: mean chemical and physical results; watershed land use; and watershed area.

In cluster analysis, a critical decision must be made when deciding where to break out the groups. To assist with this, a “scree diagram” is included with the dendrogram; this is the graph in blue in the bottom right of Figure 25. Each point on the scree diagram indicates a relative difference between two clusters. When the slope of the graph shows a sudden change, this indicates that there is a relatively large difference between the two groups being clustered (i.e., they are “less alike” than groups previously clustered) at that point and is likely an ideal place to cut the clusters. In this case, that breakpoint produces four groups.

In addition to the groups identified through cluster analysis, the relative value for each parameter at each station can be easily seen: the wider the horizontal bar for a particular parameter at a particular station, the higher the mean. For example, Figure 25 makes it very easy to identify that the highest results for $NH_3$ and $NO_2$+$NO_3$ (NOx) occurred at BB01.

The cursory analyses that were performed for this report showed that grouping by these characteristics generally do not match up with grouping based on all chemistry results. In other words, in this study area, land use within watersheds was not a good predictive tool for actual instream conditions. However, when watersheds are clustered on land use and represent a gradient of development, water quality indicators associated with urbanization (residue, nutrients, turbidity, and zinc) seem to show some predictable patterns, though the statistical significance of these differences was not determined.

*Monitoring location clusters based on chemical and physical results*

Shellfish Sanitation stations were not used as part of this cluster analysis since only results for fecal coliform and salinity were available. Additionally, parameters with all or almost all results reported as less than the laboratory's reporting limits were not used. For the remaining monitoring locations and parameters, mean values were calculated and used for the analysis. The resulting dendrogram and Chemistry Cluster Groups are shown in Figure 25.

Group A contains many of the tributary sites, particularly those in the upper LWP area, and two mainstem LFR sites, including LFR03, which shows minimal salinity but has a stream classification of SC. These sites all show relatively low values for most parameters (particularly suspended residue), but have moderate levels of iron.

Group B contains only one site: BB01. This site shows similar characteristics to Group A (including MW01, which is located downstream of BB01). BB01 would likely have been included in Group A, except for the much higher nutrient values, likely due to the NPDES discharger.

High fecal coliform counts and low zinc levels characterize Group C. On the ground, the sampling locations LDC01 and SB01 appear very similar, in that they are smaller streams with sandier substrates and much better flow than others in this study. The land uses in their drainage areas are drastically different, though, as will be seen in the next section. They also seem to react similarly to storm events (i.e., instream concentrations rose much more in these streams in response to storms than the swamp-type streams). PC01 is also included in this group. This very slightly saline, tidal location was likely grouped with LDC01 and SB01 based on the high mean fecal coliform counts, high TP, and low zinc. All of these watersheds are also fairly small (1.8-2.8 square miles).

All of the remaining saltwater sites, including all of the SA class waters (Lower LFR and Oak Island watersheds), are clustered in Group D. These sites have higher concentrations for metals (particularly Zn), suspended residue, DO, pH, and lower levels of Fe and fecal coliform than the other Chemistry Cluster Groups. These patterns are fairly typical in aquatic systems with higher salinities. Though coliform levels are lower in this group, it should be noted that they also have much more stringent standards for bacteria.

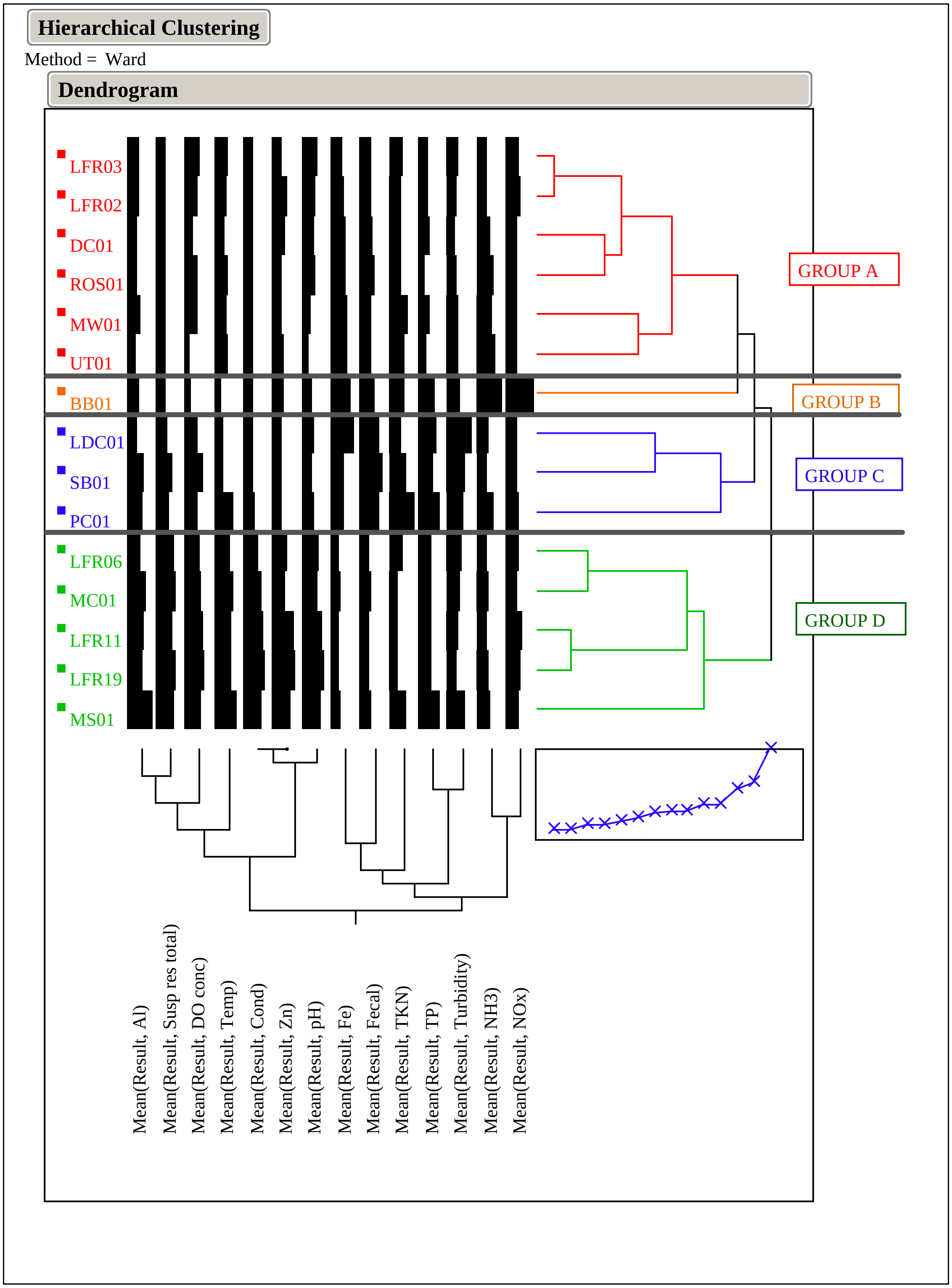


**Figure 25: Clustering of monitoring locations by means showing Chemistry Cluster Groups**

*Watershed clustering based on land use data*

The source for land use information was the ArcGIS shapefile "landuse_2004" that was developed by Brunswick County. Other land use and/or land cover data sources were considered, but these other data sets (NLCD; NC GAP) were based on 1992 or 1996 information. The older land cover data provided more detailed categories, but due to its age it is not accurate in watersheds that have seen recent development (e.g., Sandy Br). Given the importance of looking at impacts of golf courses, housing, etc., on water quality in the LWP area, the Brunswick County layer was selected for use in data analysis. Watershed boundaries were developed by Stantec and supplied as a shapefile named "phase_II_watersheds_62006". The field "STREAM" was used to determine the watershed for each sampling location, with slight adjustments made as necessary based on field observations/experience.

Using the watershed boundary and land use data, ArcGIS was used to calculate the percent contribution of each type of land use to the total area of each watershed (Appendix 1). Watersheds were then clustered in JMP by using Ward's method (SAS, 2005) based on percent of each land use type within the watersheds. Five groups were identified. Results from the cluster analysis are shown in Figure 26. A representation of the geographical distribution of the clusters is shown in Figure 27.

*LU Cluster 1* shows high amounts of Pasture, higher Residential and Transportation, and the presence of Institutional. Also, it has a higher amount of Undeveloped Lots, which may indicate that development will be continuing in the near future. As per a previous analysis (Stantec, 2006), most development will be focused in the watersheds south of NC 211 (Scotts Br, UT to LFR, Mill Cr). Of all of the clusters, Cluster 1 is unique in that it has "moderate amounts of everything" except for Golf, Water, and Salt marsh (identified as Wetland in Figure 26).

*LU Cluster 2* is very similar to Cluster 1 in that they are both relatively undeveloped. However, Cluster 2 could be characterized as being the "least developed" watersheds in the LWP area. It is highly Forested, has low Residential, few Undeveloped Lots, and very little Commercial or Institutional.

*LU Cluster 3* includes only one watershed: Doe Creek. Land use in this watershed shows a unique combination of high Agriculture, high Commercial, and high Other. Highway NC 17 cuts through the watershed and the intersection with NC 211 is nearby; the watershed has a high but very localized concentration of gas stations, fast food restaurants, etc. in this area. The remainder of the watershed is predominantly Agriculture.

*LU Cluster 4* contains watersheds that have reasonable access to the lower mainstem of the LFR or to the ICW. Also included is the Sandy Br watershed, which is the site of the River's Edge golf community. Golf is found in almost all watersheds in this cluster, and Residential, Transportation, and Undeveloped Lot uses are prevalent as well. Sandy Br has the highest percentage of Undeveloped Lots of all watersheds, and as can be seen when driving through this area new housing continues to be built. Water and Salt marsh (identified as Wetland in Figure 26) uses appear at low to moderate levels in this cluster.

*LU Cluster 5* contains the most "desirable" property from a real estate perspective. These watersheds are on the barrier island (Oak Island Beach) and along the ICW, with easy access to beaches and recreational boating. These watersheds show dense development as reflected by high percentages of both Transportation and Undeveloped Lots (suggesting significant future development). Golf is present in most watersheds. This cluster also contains the highest levels of Water and Salt marsh (identified as Wetland in Figure 26). Forested land use is very low.

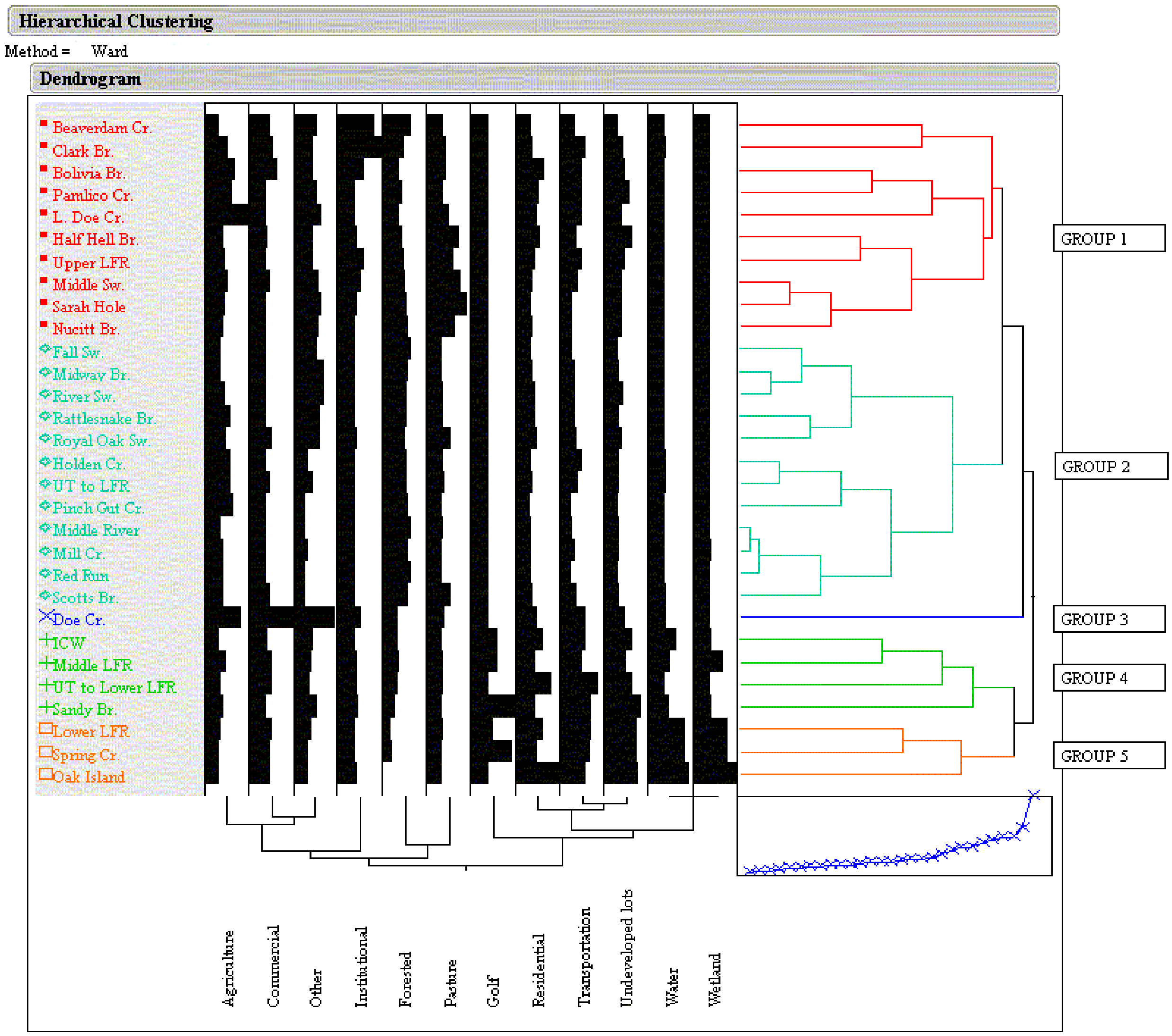


**Figure 26: Grouping watersheds based on clustering by land use**

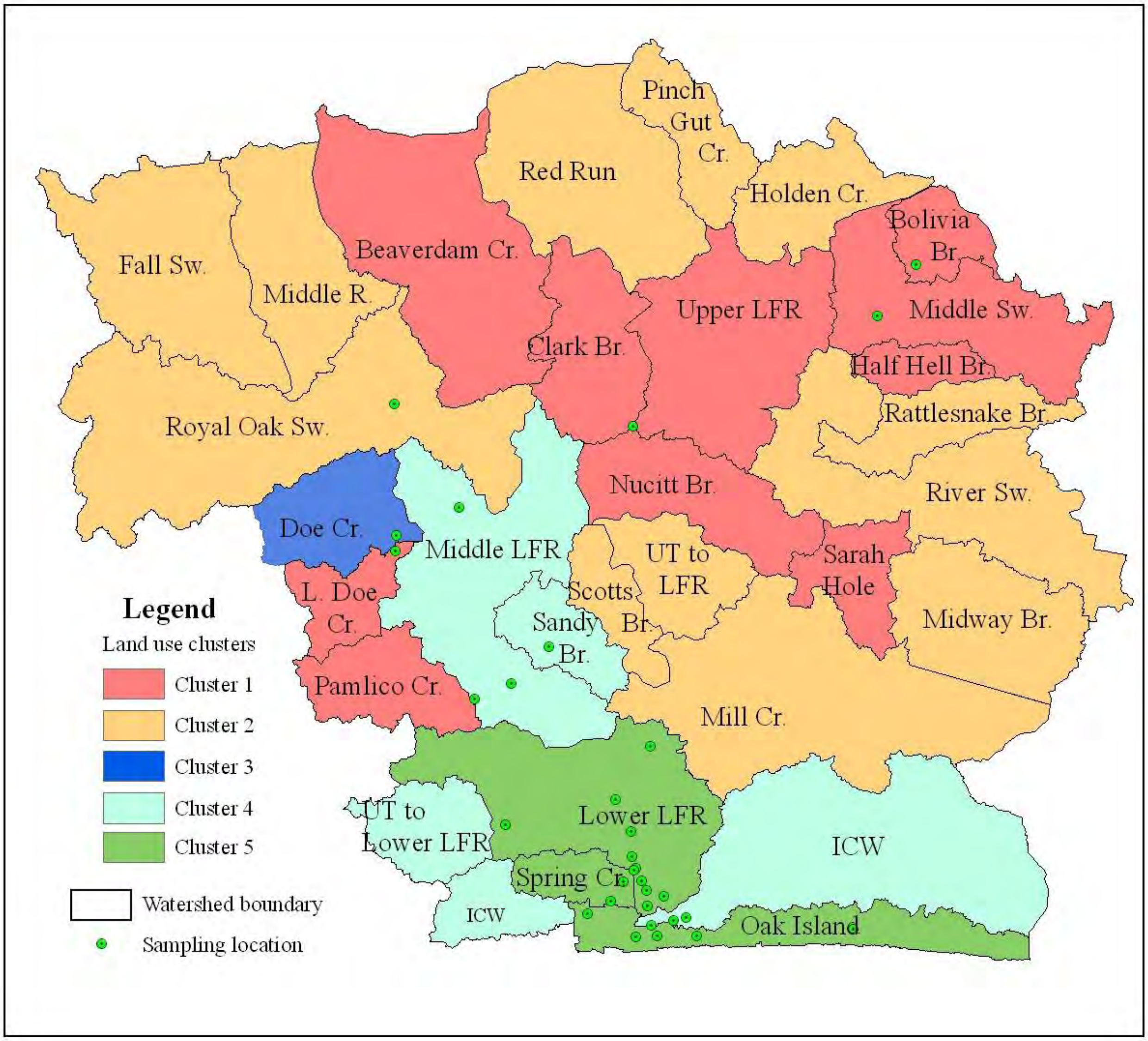


**Figure 27: Watershed cluster groups based on land use characteristics**

*Correlations between land use and chemistry data for all flow regimes*

Chemical parameters used in the correlation analysis were limited to those with more than half of results greater than the laboratory reporting limit (RL), or were field measurements performed at the majority of locations. These include: chlorophyll-*a*, specific conductance (Cond), DO concentration, fecal coliform, nutrients ($NH_3$, $NO_2$+$NO_3$, TKN, TP), pH, residues (total, volatile, and fixed), turbidity and select metals (Al, Fe, and Zn).

Statistically significant ($p<0.05$) correlations for land use group, watershed drainage area, and mean chemistry values from all flow regimes are shown in Table 14. Some obvious patterns exist:

- Higher percentages of Forested land use showed inverse correlations with aluminum, conductance, suspended resides (fixed, volatile, and total), and zinc concentrations. Watersheds with large percentages (>70%) of Forested land use include Middle Swamp, Royal Oak Swamp, and Upper LFR (Clusters 1 and 2). All are located in the upper watershed, are freshwater, and have moderate to large drainage areas.

- Water land use showed eight significant correlations: aluminum, conductance, DO concentration, iron, pH, suspended residue (fixed and total), and Zn. Water is only prevalent (>5% of watershed area) in three watersheds: Lower LFR, ICW, and Oak Island (Clusters 4 and 5). These are all saltwater/estuarine, which is the likely cause of most of these correlations. The monitoring sites in these watersheds are also not located in swamp streams, which would account for a correlation with higher DO and pH.

- Salt marsh land use was correlated with aluminum, conductance, iron, pH, suspended residues (fixed and total), and Zn, nearly identical to those found with Water land use. Salt marsh was only noted in five watersheds, with only four showing >1% of area as Salt marsh. Not surprisingly, as for the Water land use discussion, these are saltwater/estuarine watersheds: Middle LFR, Lower LFR, ICW, and Oak Island (Clusters 4 and 5).

- Golf land use shows a very strong positive correlation with volatile suspended residue (organics). This is counterintuitive, but may be due to some golf course management practices, such as mulching grass clippings when mowing. One of the watersheds with significant Golf land use was Sandy Br; this location also showed unexpectedly high organic nitrogen.

- The chemical parameters that showed significant correlations with the most land use types were total suspended residue (6 land use types) and zinc (4 land use types).

- No land use categories had statistically significant correlations with nutrients, fecal coliform, or turbidity.

**Table 14: Pairwise Correlations- land use group, watershed size, and mean of results from all flow regimes**

| Variable | by Variable | Correlation | Count | Signif Prob | Correlation Plot -1 ← 0 → 1 |
|---|---|---|---|---|---|
| Agriculture | Mean Fe | 0.6725 | 12 | 0.0166 | |
| Forested | Mean Al | -0.8056 | 12 | 0.0016 | |
| Forested | Mean Cond | -0.5713 | 13 | 0.0414 | |
| Forested | Mean Susp res fixed | -0.7225 | 10 | 0.0183 | |
| Forested | Mean Susp res total | -0.7076 | 13 | 0.0068 | |
| Forested | Mean Susp res vol | -0.6631 | 10 | 0.0366 | |
| Forested | Mean Zn | -0.7347 | 12 | 0.0065 | |
| Golf | Mean Susp res vol | 0.9133 | 10 | 0.0002 | |
| Institutional | Mean Susp res total | -0.5532 | 13 | 0.0499 | |
| Other | Mean Chlorophyll | -0.9796 | 4 | 0.0204 | |
| Pasture | Mean Susp res total | -0.6185 | 13 | 0.0242 | |
| Residential | Mean Al | 0.5907 | 12 | 0.0432 | |
| Residential | Mean Zn | 0.6805 | 12 | 0.0149 | |
| Undeveloped lots | Mean Al | 0.6587 | 12 | 0.0198 | |
| Undeveloped lots | Mean Susp res total | 0.7490 | 13 | 0.0032 | |
| Undeveloped lots | Mean Susp res vol | 0.8380 | 10 | 0.0025 | |
| Water | Mean Al | 0.8759 | 12 | 0.0002 | |
| Water | Mean Cond | 0.8481 | 13 | 0.0002 | |
| Water | Mean DO conc | 0.5981 | 13 | 0.0308 | |
| Water | Mean Fe | -0.5943 | 12 | 0.0416 | |
| Water | Mean pH | 0.7384 | 13 | 0.0039 | |
| Water | Mean Susp res fixed | 0.9448 | 10 | <.0001 | |
| Water | Mean Susp res total | 0.8538 | 13 | 0.0002 | |
| Water | Mean Zn | 0.8536 | 12 | 0.0004 | |
| Watershed area (sq. miles) | Mean pH | 0.5794 | 13 | 0.0380 | |
| Salt marsh | Mean Al | 0.8413 | 12 | 0.0006 | |
| Salt marsh | Mean Cond | 0.6371 | 13 | 0.0192 | |
| Salt marsh | Mean Fe | -0.6295 | 12 | 0.0283 | |
| Salt marsh | Mean pH | 0.5804 | 13 | 0.0376 | |
| Salt marsh | Mean Susp res fixed | 0.9253 | 10 | 0.0001 | |
| Salt marsh | Mean Susp res total | 0.6887 | 13 | 0.0092 | |
| Salt marsh | Mean Zn | 0.8583 | 12 | 0.0004 | |

*Comparison of Chemical Cluster Groups and Land Use Cluster Groups*

Generally speaking, Land Use Cluster groups as determined for this report showed very poor predictive power in terms of actual instream water quality, i.e., similar land uses within a watershed do not imply that instream water chemistries are similar (Table 15). However, land use within a watershed shows statistically significant correlations with only a handful of chemical and physical measurements. The measurements showing the highest number of correlations with individual land uses were total suspended residue and zinc.

Chemistry Cluster Groups were developed based on additional chemical measures, such as nutrients, that did not show any correlations with land use. It may be that effects attributable to land uses may only be measurable using total suspended residue and zinc. However, when the cluster analysis was repeated using only these two chemical parameters, the “new” chemistry cluster groups did not correspond any better with the Land Use Cluster groups (data not shown).

This disconnect between similarities of watersheds based on land use and actual instream conditions could have many possible explanations. It could simply be that land use within a watershed is not a good predictor of the chemical and/or physical characteristics of its waterbodies. Perhaps a different set of land use data, further subgroupings (e.g., % Developed vs. % Undeveloped), or fewer subgroupings may provide better predictive power. These results also bring into question the applicability of extrapolating results from a single site (even if it is at or near the exit point of the watershed) to a larger area, and random sampling points may be a preferable study design. Finally, the differences between the “predicted” (land use clusters) and “actual” (chemistry clusters) may be a key to identifying watersheds with possible issues.

**Table 15: Monitoring site and watershed cluster groups**

| Monitoring site | Watershed | Land Use Cluster Group | Chemistry Cluster Group |
|---|---|---|---|
| BB01 | Bolivia Br | 1 | B |
| LDC01 | L Doe Cr | 1 | C |
| MW01 | Middle Sw | 1 | A |
| PC01 | Pamlico Cr | 1 | C |
| LFR02 | Upper LFR | 1 | A |
| MC01 | Lower LFR | 2 | D |
| ROS01 | Royal Oak Sw | 2 | A |
| DC01 | Doe Cr | 3 | A |
| LFR03 | Middle LFR | 4 | A |
| LFR06 | Middle LFR | 4 | D |
| SB01 | Sandy Br | 4 | C |
| UT01 | UT to Lower LFR | 4 | A |
| LFR11 | Lower LFR | 5 | D |
| LFR19 | Lower LFR | 5 | D |
| MS01 | Oak Island Beach | 5 | D |

## ***Biological monitoring***

Biological data are scarce for the LWP area. This is due to the fact that the majority of freshwater streams have swamp characteristics, such as low flow, and the lower LFR watershed is predominantly estuarine, both of which preclude the use of standard collection methods of the DWQ Biological Assessment Unit (BAU). There is one freshwater site (Royal Oak Sw at NC 211) that is regularly sampled as part of BAU's basinwide monitoring cycle. Basinwide monitoring supports DWQ basin planning programs and 303(d)/305(b) reporting to the U.S. EPA; see http://h2o.enr.state.nc.us/basinwide/ for more information on these activities. This site was sampled in February 2006 and the results are provided here as ancillary evidence of any impacts or changes in water quality in the upper LWP area.

In addition to the regular BAU basinwide sampling site, there is a site on the lower Lockwoods Folly River that was part of DWQ studies from the 1990s to develop assessment methods appropriate for estuarine waters. This method, though not part of BAU's standard methods, was previously published (Eaton, 2001).

*BAU Basinwide sampling- Royal Oak Swamp at NC 211*

Royal Oak Swamp was sampled at NC 211 in February 2006 by BAU as part of regular basinwide sampling of the Lumber River basin in accordance with BAU SOPs (NC DENR DWQ, 2006b). This site is used as a "least-impacted" reference site for the ecoregion. It has been sampled five times previously. These previous sampling events supported the development of the recently approved criteria for rating swamp streams based on benthic macroinvertebrate communities. BAU now recommends that only samples collected during the winter months be used for assessments. Therefore, only the winter samples from 1998, 1999, and 2001 will be discussed in this report and two summer samples will be excluded.

Since the swamp stream criteria have been finalized after the last round of basinwide sampling in 2001, results from the 2006 sampling are the first that will allow a "rating" or bioclassification to be applied to the stream. In this report this rating system will be applied to the past samples, but this is only for comparison purposes; this information is not appropriate for use support determination or other regulatory work without conferring further with BAU staff.

A summary of results for each sampling event is shown in Table 16. This includes the number of taxa (generally species) that were found in each taxonomic Order, the total taxa richness (i.e., number of taxa found), EPT richness (total number of taxa from the more intolerant orders Ephemeroptera, Plecoptera, and Trichoptera), the Biotic Index (BI, calculated as per BAU SOPs using swamp stream criteria), and the Bioclassification. For swamp streams, there are only three bioclassifications: Natural, Moderate Stress, and Severe Stress.

Royal Oak Swamp scores have consistently yielded "Natural" bioclassifications with BI scores well below the threshold value of 6.8, indicating that few stressors are noted in the benthic macroinvertebrate community. This latest sampling yielded a slightly higher Biotic Index value than the previous sampling, possibly indicating a slightly more stressed community. Also, no

Plecoptera taxa (stoneflies) were found in this latest sampling, though they tended to be rare (1-2 individuals per taxa) or common (3-9 individuals/taxa) during past samplings. These species are generally considered to be less tolerant of water quality stressors. It appears that no significant changes in land use have occurred over the previous five years, so the reason for the decline of Plecoptera taxa and slight increase in the BI are currently unknown.

**Table 16: BAU benthic macroinvertebrate sampling results**

| | Sampling date | | | |
|---|---|---|---|---|
| | 2/21/2006 | 2/5/2001 | 2/18/1999 | 3/3/1998 |
| *Number of taxa by Order* | | | | |
| Ephemeroptera | 9 | 8 | 7 | 7 |
| Plecoptera | 0 | 1 | 2 | 3 |
| Trichoptera | 8 | 9 | 12 | 8 |
| Coleoptera | 5 | 6 | 6 | 3 |
| Crustacea | 8 | 6 | 5 | 7 |
| Diptera: Chironomidae | 18 | 12 | 20 | 17 |
| Misc. Diptera | 1 | 2 | 2 | 3 |
| Gastropoda | 6 | 4 | 6 | 3 |
| Megaloptera | 1 | 0 | 0 | 0 |
| Odonata | 9 | 6 | 10 | 3 |
| Oligochaeta | 5 | 2 | 3 | 1 |
| Other | 5 | 0 | 2 | 0 |
| Pelecypoda | 0 | 2 | 0 | 0 |
| *Summary statistics* | | | | |
| Total taxa richness | 75 | 58 | 75 | 55 |
| EPT Richness | 17 | 18 | 21 | 18 |
| EPT Abundance | 90 | 86 | 126 | 75 |
| Biotic Index | 6.63 | 6.02 | 6.41 | 6.25 |
| Bioclassification | Natural | Natural | Natural | Natural |

*WAT Estuarine sampling- Lockwoods Folly River at Channel Marker 14*

In the 1990s, BAU staff, including an aquatic entomologist currently on the WAT, developed methods appropriate for sampling and rating estuarine sites based on macroinvertebrate communities. These methods were published (Eaton 2001), though they are not included in the current BAU SOP.

One location on the Lockwoods Folly River near channel marker (CM) 14 was part of this previous study, and was sampled in June 1996. At that time, this location was given a bioclassification of "Slight Stress" based on a total score of 11 points (out of 15, with higher values indicating less stressed benthic communities). It should be noted that 2 bonus points were added during calculation of the bioclassification, as per the method, since annual salinity swings >26 ppt can stress estuarine communities, irregardless of water quality stressors. Based on DWQ

AMS data collected in 1996 at LFR11 (AMS station number I9440000), located just downstream of CM14, the range of salinity had a minimum recorded value of 0.6 ppt and maximum of 28.9 ppt. Taxa found at the time included freshwater midges.

Sampling was repeated in July 2006 by WAT staff. This also resulted in a score of 11 and a bioclassification of Slight Stress, as in 1996, but without adjustments due to wide salinity swings, though salinity continues to be highly variable. Data from LFR11 from the 2006 study period (April-October) show a salinity range of 9.8-35 ppt, which is just shy of the criteria of 26 ppt mentioned above. Note that the minimum salinity in 2006 was appreciably higher than in 1996. For the 2006 sample, freshwater taxa were not present and taxa indicative of higher salinities were also found.

The report for this sample (NC DENR DWQ, 2006a) concluded that the few minor differences between the two sets of results were likely due more to differences in salinity regime than to water quality. The changes in salinity may be due to climatic issues such as drought, or may reflect enhanced flushing of the river in response to dredging in the Lockwoods Folly Inlet.[1] The bioclassification of Slight Stress is reinforced in both cases by the low incidence of intolerant taxa, such as amphipods.

[1] History of dredging in the inlet was requested from the U.S. Corps of Engineers but was not provided.

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## *Appendix 1: Land use by LWP area and by watersheds*

The table below shows the codes, descriptions, total area in square miles, and percent of total area for each of the 38 land uses included in the Brunswick County GIS layer "landuse_2004". An additional column indicates the more general groupings assigned by WAT that were used for correlation analyses shown in this report. The groups were roughly based on categories used by Stantec in their Preliminary Findings Report (Stantec, 2005).

| Land use code | Land use description | Land use group | Area (sq. miles) | % of total area |
|---|---|---|---|---|
| AN | Agricultural Land, confined animal operation | Agriculture | 0.34 | 0.22 |
| AG-C | Agricultural Land, cultivated fields | Agriculture | 7.24 | 4.73 |
| NUR | Agricultural Land, ornamental horticulture | Agriculture | 0.01 | 0.01 |
| CEM | Cemetery | Other | 0.04 | 0.03 |
| HOT | Commercial hotel, motel | Commercial | 0.01 | 0.01 |
| OP | Commercial office and professional | Commercial | 0.03 | 0.02 |
| CR | Commercial retail | Commercial | 0.29 | 0.19 |
| CW | Commercial wholesale | Commercial | 0.01 | 0.01 |
| CT | Communication Towers | Other | 0.02 | 0.01 |
| UT | Communications & Utilities Facilities | Other | 1.08 | 0.70 |
| REC | Developed Outdoor Recreational, camper, RV parks, putt-putt | Other | 0.14 | 0.09 |
| GOLF | Developed Outdoor Recreational, golf course | Golf | 0.99 | 0.64 |
| COL | Educational Facility, college or higher learning | Institutional | 0.18 | 0.11 |
| DC | Educational Facility, day care | Institutional | 0.01 | 0.01 |
| SCH | Educational Facility, grade school | Institutional | 0.10 | 0.06 |
| MO | Institional, membership organization | Institutional | 0.01 | 0.00 |
| CH | Institutional, church & related religious facility | Institutional | 0.08 | 0.05 |
| GOV | Institutional, government services | Institutional | 0.50 | 0.32 |
| HOS | Institutional, hospital & health clinic | Institutional | 0.03 | 0.02 |
| MFG-H | Manufacturing, heavy | Other | 0.01 | 0.00 |
| MFG-L | Manufacturing, light | Other | 0.01 | 0.01 |
| MIN | Mining & extraction | Other | 0.31 | 0.20 |
| MHP | Mobile Home Park | Residential | 0.05 | 0.03 |
| F | Pasture/Clear fields | Pasture | 0.99 | 0.65 |
| DU | Residential, Duplex | Residential | 0.00 | 0.00 |
| CAMP | Residential, campers, single or grouping | Residential | 0.01 | 0.00 |
| LC | Residential, cleared lot | Undeveloped lots | 5.87 | 3.84 |
| DMH | Residential, double-wide mobile home | Residential | 0.62 | 0.40 |
| MF | Residential, multi-family | Residential | 0.03 | 0.02 |
| NB | Residential, neighborhood business | Residential | 0.03 | 0.02 |
| SF | Residential, single family site built detached | Residential | 5.96 | 3.89 |
| SMH | Residential, single-wide mobile home | Residential | 1.70 | 1.11 |
| LV | Residential, vegetated lot | Undeveloped lots | 4.24 | 2.77 |
| ROW | Road Right of Way | Transportation | 4.16 | 2.72 |
| T-WAT | Transportation, water-related facilities | Transportation | 0.05 | 0.03 |
| WAT | Water | Water | 3.33 | 2.17 |
| WT | Wetland, marsh | Salt marsh | 2.91 | 1.90 |
| W | Wooded Area | Forested | 111.71 | 72.98 |
| | | **TOTAL:** | **153.10 sq. miles** | **99.97%** |

The following table shows the percent of each land use group found in each watershed in the LWP area. Values were calculated from the Brunswick County GIS layer "landuse_2004". Land use was assigned on a parcel by parcel basis, and so underrepresents certain groups. See main text for details and caveats.

| Watershed | Watershed area (sq. miles) | % of watershed area by land use group "--" indicates that land use group is not found in that watershed | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | Agriculture | Commercial | Forested | Golf | Institutional | Other | Pasture | Residential | Transportation | Undeveloped lots | Water | Wetland |
| Beaverdam Cr. | 9.55 | 0.54 | 0.25 | 92.88 | -- | 3.00 | 1.33 | 0.16 | 0.35 | 1.28 | 0.02 | 0.18 | -- |
| Bolivia Br. | 1.62 | 14.36 | 0.90 | 56.41 | -- | 1.53 | 0.79 | 0.92 | 13.20 | 3.70 | 8.17 | 0.01 | -- |
| Clark Br. | 3.94 | 7.73 | 0.55 | 69.99 | -- | 4.75 | 0.83 | 0.75 | 3.68 | 4.98 | 6.06 | 0.67 | -- |
| Doe Cr. | 3.09 | 19.32 | 2.86 | 52.75 | -- | 1.18 | 3.45 | 0.66 | 6.51 | 5.07 | 7.53 | 0.67 | -- |
| Fall Sw. | 7.32 | 2.60 | -- | 94.17 | -- | 0.01 | 1.29 | -- | 0.97 | 0.76 | 0.17 | 0.02 | -- |
| Half Hell Br. | 1.23 | 3.69 | 0.18 | 64.12 | -- | 0.33 | 0.78 | 2.97 | 9.66 | 1.89 | 16.08 | 0.31 | -- |
| Holden Cr. | 3.27 | 10.29 | -- | 81.34 | -- | -- | 0.13 | 0.30 | 1.52 | 3.75 | 1.42 | 1.25 | -- |
| ICW | 11.96 | -- | 0.11 | 55.31 | 2.63 | 0.01 | 0.78 | -- | 11.22 | 4.83 | 16.93 | 7.12 | 1.07 |
| L. Doe Cr. | 1.76 | 26.83 | -- | 56.10 | -- | 0.14 | 2.01 | 1.21 | 6.41 | 3.43 | 3.43 | 0.44 | -- |
| Lower LFR | 7.85 | 2.43 | 0.48 | 30.06 | 1.38 | 0.19 | 0.73 | 0.21 | 11.40 | 6.25 | 20.51 | 13.53 | 12.83 |
| Middle LFR | 9.10 | 6.00 | 0.37 | 59.71 | 2.84 | 0.33 | 0.54 | 0.36 | 4.74 | 3.62 | 9.48 | 3.20 | 8.81 |
| Middle River | 5.07 | 2.09 | -- | 93.77 | -- | 0.04 | -- | 0.16 | 1.89 | 1.11 | 0.91 | 0.02 | -- |
| Middle Sw. | 5.81 | 7.60 | 0.24 | 75.67 | -- | 1.21 | 1.54 | 3.31 | 3.40 | 2.65 | 4.28 | 0.11 | -- |
| Midway Br. | 5.19 | 2.10 | 0.02 | 90.11 | -- | 0.07 | 2.21 | -- | 2.75 | 1.23 | 1.49 | 0.01 | -- |
| Mill Cr. | 11.24 | 3.17 | 0.04 | 89.46 | -- | 0.07 | 0.24 | -- | 1.94 | 1.47 | 2.44 | 0.22 | 0.95 |
| Nucitt Br. | 4.21 | 3.69 | -- | 85.47 | -- | -- | 1.52 | 2.39 | 2.79 | 0.90 | 2.99 | 0.23 | -- |
| Oak Island | 3.61 | -- | 0.24 | 3.25 | -- | 0.33 | 0.27 | -- | 32.82 | 5.03 | 21.70 | 16.84 | 19.53 |
| Pamlico Cr. | 2.83 | 12.19 | 0.01 | 62.07 | -- | -- | 1.33 | 0.18 | 8.95 | 3.63 | 11.53 | 0.11 | -- |
| Pinch Gut Cr. | 2.70 | 12.42 | -- | 86.89 | -- | -- | -- | -- | 0.29 | 0.26 | 0.13 | -- | -- |
| Rattlesnake Br. | 2.83 | 10.35 | -- | 79.77 | -- | -- | 1.65 | 0.13 | 5.29 | 1.31 | 1.50 | 0.01 | -- |
| Red Run | 7.66 | 3.97 | -- | 95.04 | -- | -- | 0.01 | -- | 0.50 | 0.23 | 0.16 | 0.09 | -- |
| River Sw. | 8.45 | 4.74 | 0.03 | 81.67 | -- | 0.01 | 2.26 | 0.30 | 4.08 | 1.22 | 5.50 | 0.17 | -- |
| Royal Oak Sw. | 13.12 | 6.12 | 0.37 | 78.20 | -- | 0.46 | 1.77 | 1.30 | 5.73 | 2.30 | 3.28 | 0.46 | -- |
| Sandy Br. | 1.98 | 4.09 | -- | 41.67 | 10.46 | 0.71 | 1.32 | 0.04 | 5.22 | 6.30 | 27.27 | 2.62 | 0.29 |
| Sarah Hole | 2.20 | 5.68 | -- | 81.88 | -- | 0.47 | 1.92 | 4.08 | 2.02 | 0.84 | 3.07 | 0.03 | -- |
| Scotts Br. | 1.75 | 2.90 | 0.24 | 88.23 | -- | -- | -- | 1.42 | 2.70 | 2.28 | 1.55 | 0.66 | -- |
| Spring Cr. | 1.24 | -- | 0.28 | 32.79 | 7.91 | -- | 0.20 | -- | 6.24 | 6.18 | 20.09 | 13.54 | 12.76 |
| Upper LFR | 7.41 | 5.80 | 0.05 | 73.50 | -- | 1.56 | 0.91 | 2.09 | 5.51 | 3.49 | 7.06 | 0.03 | -- |
| UT to LFR | 2.69 | 9.72 | 0.29 | 79.87 | -- | 0.13 | 0.77 | 0.60 | 3.52 | 2.35 | 1.88 | 0.86 | -- |
| UT to Lower LFR | 2.38 | 1.15 | 0.40 | 51.18 | -- | 0.31 | 0.35 | 0.22 | 20.87 | 8.54 | 16.62 | 0.36 | -- |

## *Appendix 2: Monitoring station location information*

| Watershed name | LWP Station Number | Location | Latitude (decimal degrees) | Longitude (decimal degrees) | NC stream index | NC stream class | Tidal (y/n) |
|---|---|---|---|---|---|---|---|
| *Tributaries* | | | | | | | |
| Bolivia Branch | BB01 | Bolivia Branch at SR 1512 | 34.0630 | -78.1430 | 15-25-1-6-4-1 | C Sw | no |
| Middle Swamp | MW01 | Middle Swamp at SR 1500 | 34.0520 | -78.1531 | 15-25-1-6-4 | C Sw | no |
| Royal Oak Swamp | ROS01 | Royal Oak Swamp at NC 211 | 34.0335 | -78.2805 | 15-25-1-14 | C Sw | no |
| Doe Creek | DC01 | Doe Creek at SR 1115 | 34.0047 | -78.2803 | 15-25-1-13 | C Sw HQW | no |
| Little Doe Creek | LDC01 | Little Doe Creek at SR 1115 | 34.0014 | -78.2805 | 15-25-1-13-1 | C Sw HQW | no |
| Sandy Branch | SB01 | Sandy Branch off SR 1251 behind Winding River Clear Water Place | 33.9801 | -78.2402 | 15-25-1-14 | C Sw HQW | no |
| UT to Lower Lockwoods Folly River | UT01 | Unnamed Tributary to Lockwoods Folly R at SR 1119 | 33.9412 | -78.2522 | none | C Sw HQW | no |
| Pamlico Creek | PC01 | Pamlico Creek at SR 1115 | 33.9688 | -78.2599 | 15-25-1-15-(2) | SC HQW | yes |
| *Mainstem Lockwoods Folly River (LFR)* | | | | | | | |
| Upper LFR | LFR02 | Lockwoods Folly R at SR 1501 | 34.0283 | -78.2177 | 15-25-1-(1) | C Sw | no |
| Middle LFR | LFR03 | Lockwoods Folly R at NC 211 at Supply | 34.0108 | -78.2636 | 15-25-1-(11) | SC HQW | yes |
| | LFR06 | Lockwoods Folly R near Sandy Hill | 33.9722 | -78.2503 | 15-25-1-(11) | SC HQW | yes |
| Lower LFR | LFR11 | Lockwoods Folly R at Varnamtown | 33.9465 | -78.2232 | 15-25-1-(16) | SA HQW | yes |
| | LFR13 | Lockwoods Folly R at CM R8 DNS of Varnamtown (west channel)/ Shellfish station 5A | 33.9395 | -78.2192 | 15-25-1-(16) | SA HQW | yes |
| | LFR16 | Lockwoods Folly R, Shellfish station 6A | 33.9340 | -78.2190 | 15-25-1-(16) | SA HQW | yes |
| | LFR18 | Lockwoods Folly R at CM 5/ Shellfish station 14A | 33.9316 | -78.2178 | 15-25-1-(16) | SA HQW | yes |

| Watershed name | LWP Station Number | Location | Latitude (decimal degrees) | Longitude (decimal degrees) | NC stream index | NC stream class | Tidal (y/n) |
|---|---|---|---|---|---|---|---|
| | LFR19 | Lockwoods Folly R at CM R6 NW Sunset Harbor (west channel) | 33.9310 | -78.2183 | 15-25-1-(16) | SA HQW | yes |
| | LFR20 | Lockwoods Folly R, Shellfish station 14B | 33.9286 | -78.2211 | 15-25-1-(16) | SA HQW | yes |
| | LFR21 | Lockwoods Folly R, Shellfish station 7A | 33.9287 | -78.2163 | 15-25-1-(16) | SA HQW | yes |
| | LFR24 | Lockwoods Folly R, Shellfish station 7 | 33.9266 | -78.2151 | 15-25-1-(16) | SA HQW | yes |
| | LFR25 | Lockwoods Folly R, Shellfish station 8 | 33.9253 | -78.2106 | 15-25-1-(16) | SA HQW | yes |
| | MC01 | Mill Creek at SR 1112 | 33.9582 | -78.2139 | 15-25-1-18-(2) | SA HQW | yes |
| *Intracoastal waterway (ICW)* | | | | | | | |
| Intracoastal Waterway | ICW02 | ICW, Shellfish station 11 | 33.9207 | -78.2047 | 15-25 | SA HQW | yes |
| | ICW03 | ICW at Sunset Harbor | 33.9200 | -78.2080 | 15-25 | SA HQW | yes |
| | ICW04 | ICW, Shellfish station 10 | 33.9233 | -78.2149 | 15-25 | SA HQW | yes |
| | ICW06 | ICW, Shellfish station 13 | 33.9243 | -78.2245 | 15-25 | SA HQW | yes |
| | ICW07 | ICW at CM R42 west of Lockwood Folly R | 33.9217 | -78.2306 | 15-25 | SA HQW | yes |
| *Montgomery Slough* | | | | | | | |
| Oak Island Beach | MS01 | Montgomery Slough at SR 1105 near Long Beach | 33.9178 | -78.1609 | 15-25 | SA HQW | yes |
| | MS03 | Montgomery Slough, Shellfish station 24A | 33.9166 | -78.2019 | 15-25 | SA HQW | yes |
| | MS04 | Montgomery Slough, Shellfish station 9 | 33.9167 | -78.2125 | 15-25 | SA HQW | yes |
| | MS05 | Montgomery Slough, Shellfish station 9A | 33.9190 | -78.2140 | 15-25 | SA HQW | yes |
| | MS06 | Montgomery Slough, Shellfish station 16 | 33.9164 | -78.218 | 15-25 | SA HQW | yes |

## *Appendix 3: NPDES Permit Limits*

The permit limits for Bolivia Elementary School are shown in the table below. For Sample Location E = Effluent; D = Downstream of outfall; U = Upstream of outfall

**A (1). EFFLUENT LIMITATIONS AND MONITORING REQUIREMENTS** **Permit Number: NC0045250**

During the period beginning on the effective date of the permit and lasting until expiration, the permittee is authorized to discharge treated wastewater from Outfall 001. Such discharges shall be limited and monitored by the Permittee as specified below:

| EFFLUENT CHARACTERISTICS | EFFLUENT LIMITS | | | MONITORING REQUIREMENTS | | |
|---|---|---|---|---|---|---|
| Parameter Description - PCS Code | Monthly Average | Weekly Average | Daily Maximum | Measurement Frequency | Sample Type | Sample Location |
| Flow, in conduit or thru treatment plant - 50050 | 0.01 mgd | | | Weekly | Instantaneous | E |
| Flow, in conduit or thru treatment plant - 50050 | 0.01 mgd | | | Weekly | Instantaneous | E |
| BOD, 5-Day (20 Deg. C) - 00310 - Winter | 10 mg/l | | 15. mg/l | 2 X month | Grab | E |
| BOD, 5-Day (20 Deg. C) - 00310 - Summer | 5 mg/l | | 7.5 mg/l | 2 X month | Grab | E |
| BOD, 5-Day (20 Deg. C) - 00310 - Winter | 10 mg/l | | 15. mg/l | 2 X month | Grab | E |
| BOD, 5-Day (20 Deg. C) - 00310 - Summer | 5 mg/l | | 7.5 mg/l | 2 X month | Grab | E |
| Solids, Total Suspended - 00530 | 30 mg/l | | 45. mg/l | 2 X month | Grab | E |
| Solids, Total Suspended - 00530 | 30 mg/l | | 45. mg/l | 2 X month | Grab | E |
| Nitrogen, Ammonia Total (as N) - 00610 - Winter | 4 mg/l | | 20. mg/l | 2 X month | Grab | E |
| Nitrogen, Ammonia Total (as N) - 00610 - Summer | 2 mg/l | | | 2 X month | Grab | E |
| Nitrogen, Ammonia Total (as N) - 00610 - Winter | 4 mg/l | | | 2 X month | Grab | E |
| Nitrogen, Ammonia Total (as N) - 00610 - Summer | 2 mg/l | | 10. mg/l | 2 X month | Grab | E |
| Coliform, Fecal MF, M-FC Broth,44.5C - 31616 (geom.mean) | 200 #/100ml | | 400. #/100ml | 2 X month | Grab | E |
| Coliform, Fecal MF, M-FC Broth,44.5C - 31616 (geom.mean) | 200 #/100ml | | 400. #/100ml | 2 X month | Grab | E |
| Chlorine, Total Residual - 50060 | | | | Once per discharge | Grab | E |
| Temperature, Water Deg. Centigrade - 00010 | | | | 5 X week | Grab | E |
| Temperature, Water Deg. Centigrade - 00010 | | | | Weekly | Grab | D,E,U |
| DO, Oxygen, Dissolved - 00300 | | | | Weekly | Grab | E |
| DO, Oxygen, Dissolved - 00300 | | | | Weekly | Grab | E |
| Specific Conductance - 00095 | | | | Weekly | Grab | E |
| Specific Conductance - 00095 | | | | Weekly | Grab | E |
| Temperature, Water Deg. Centigrade - 00010 | | | | Weekly | Grab | D,U |
| DO, Oxygen, Dissolved - 00300 | | | | Weekly | Grab | D,U |
| DO, Oxygen, Dissolved - 00300 | | | | Weekly | Grab | D,U |

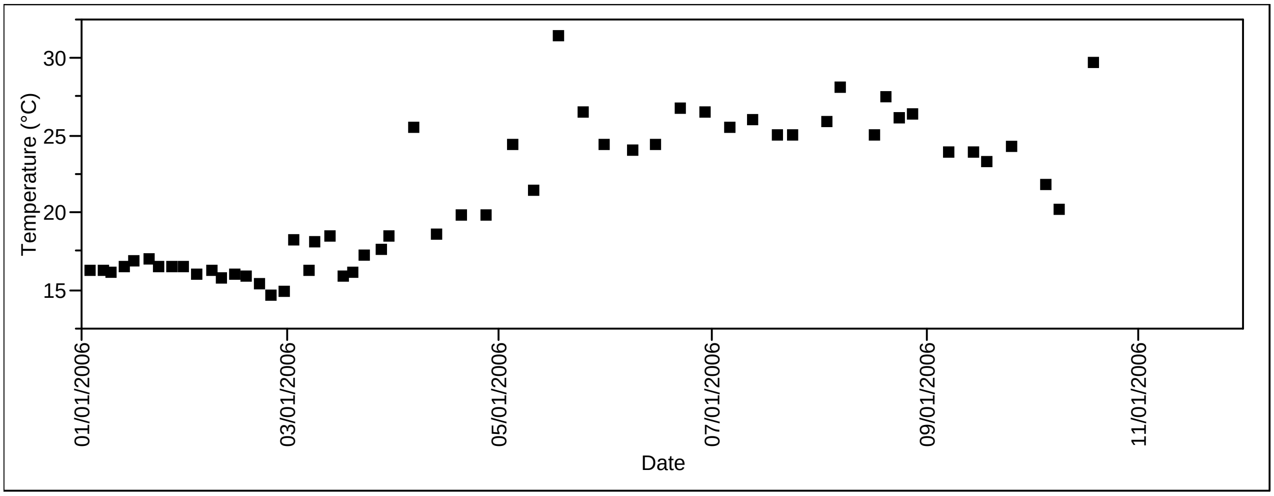
Winter: November 1 - March 31

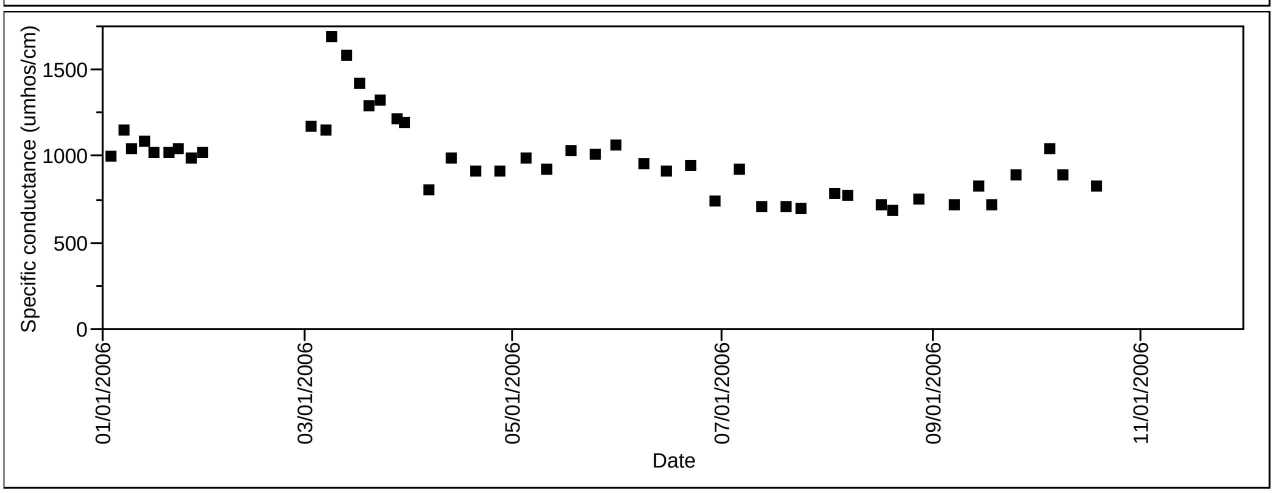
Summer: April 1 - October 31

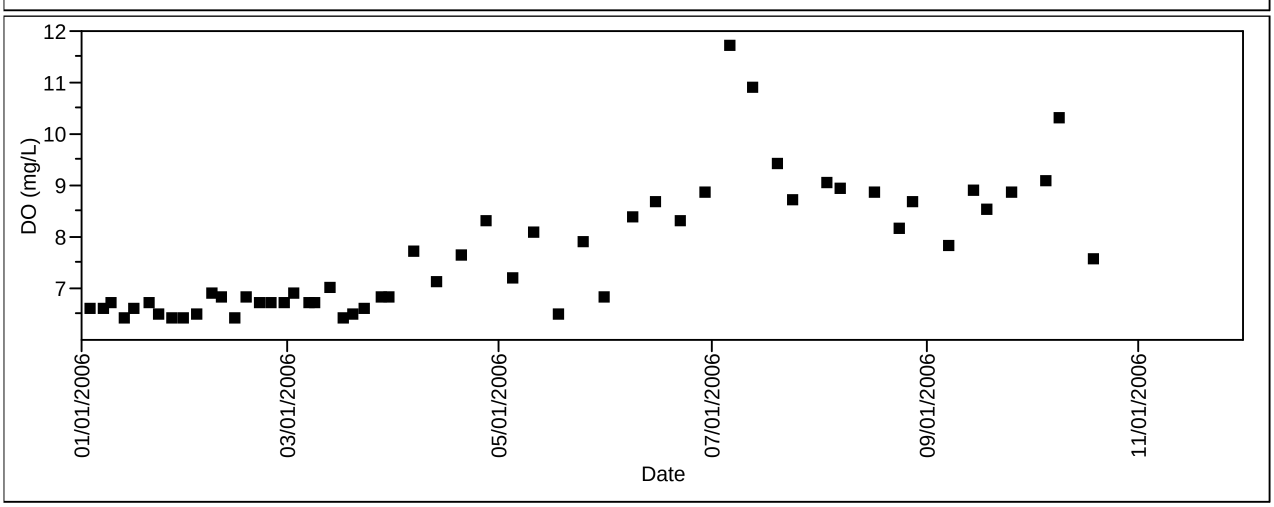
There shall be no discharge of floating solids or visible foam in other than trace amounts.

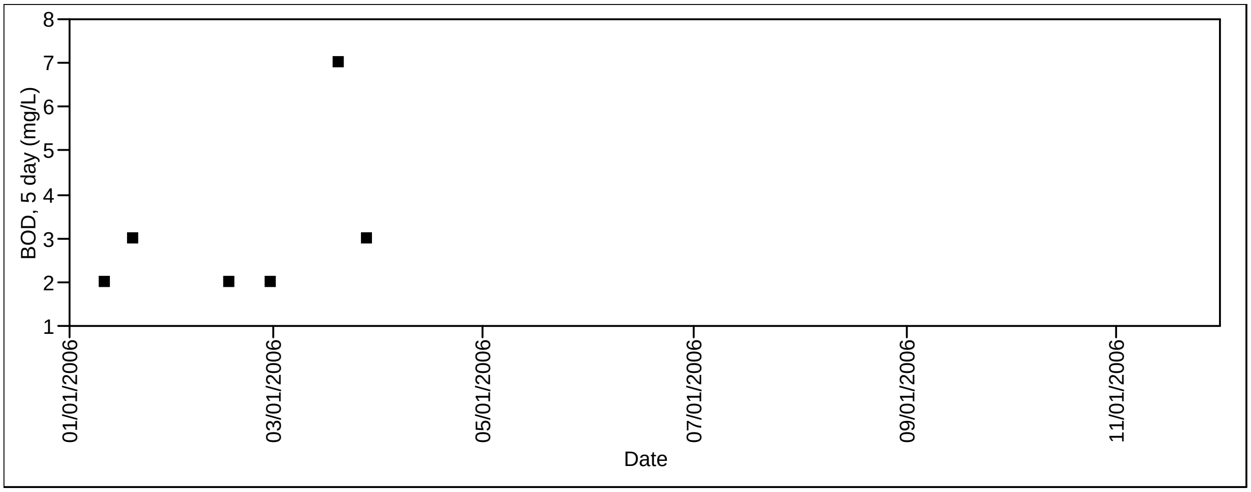
*Appendix 4: Bolivia Elementary School Effluent Monitoring Data*

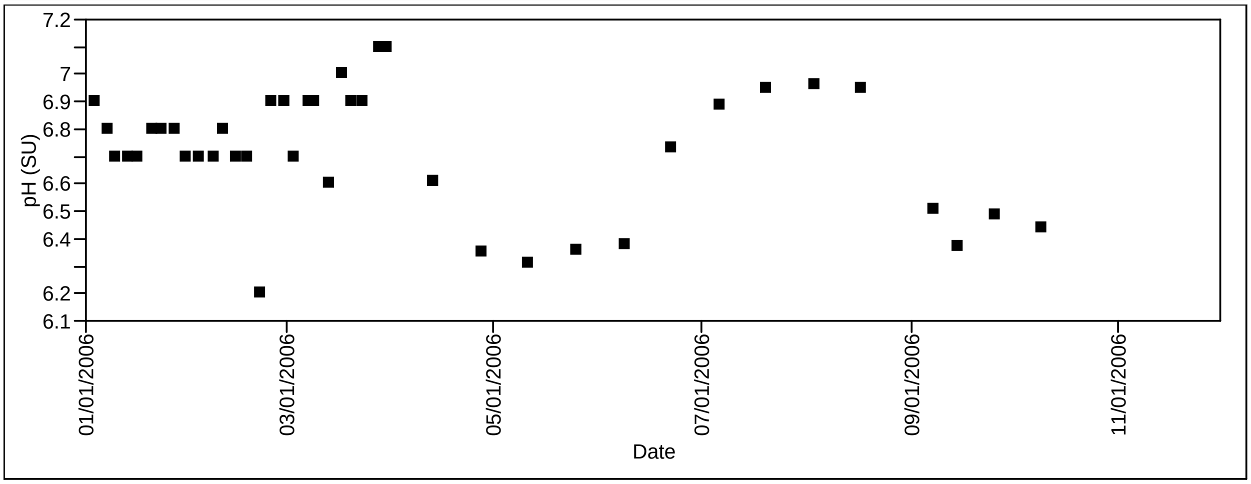
The effluent monitoring results reported by the Bolivia Elementary School (NPDES permit #0045250) are shown in the graphs below. Data were obtained from the NC Division of Water Quality Basinwide Information Management Systems (BIMS).

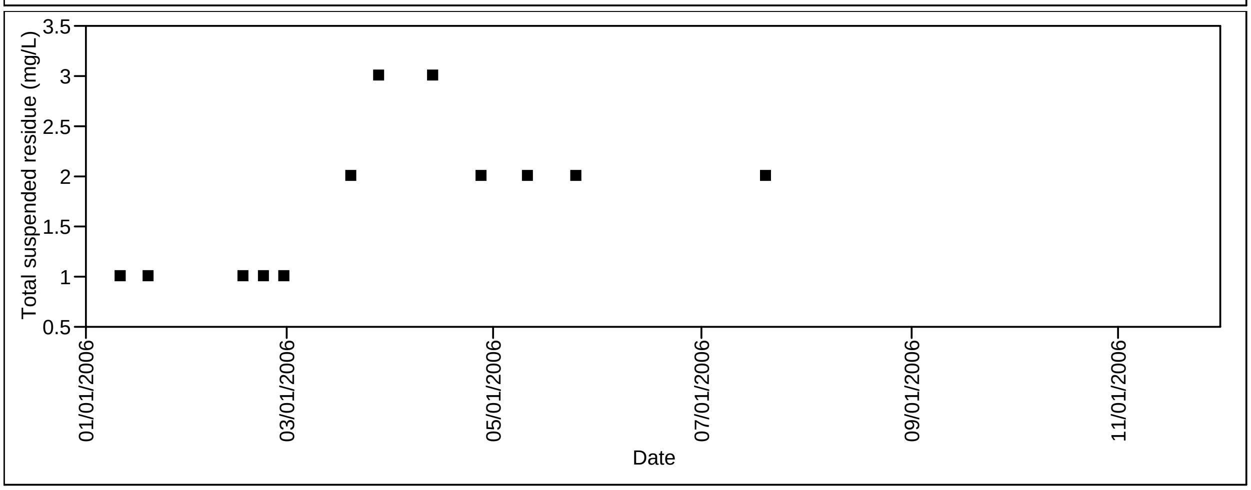


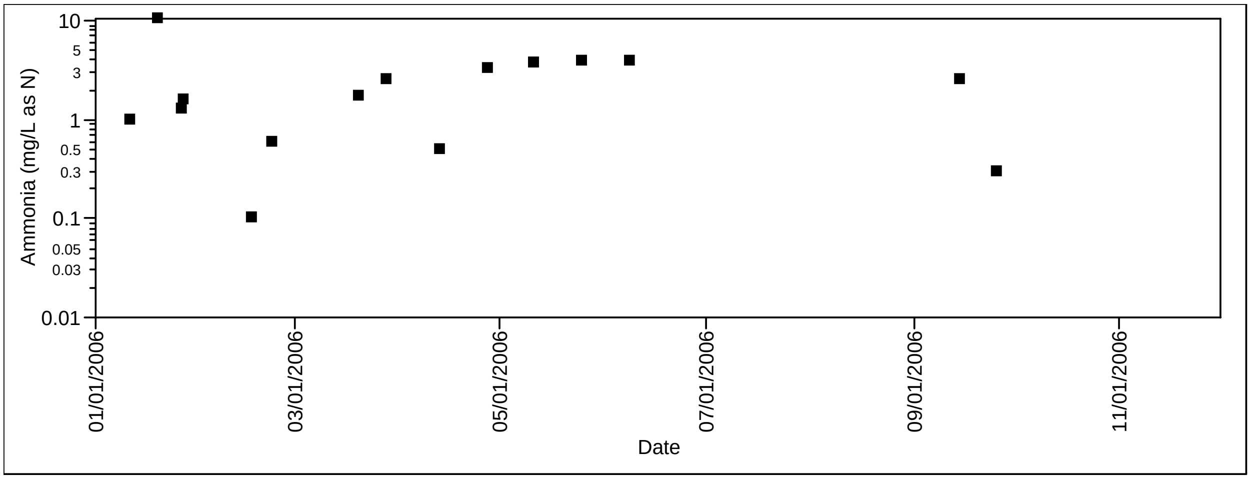



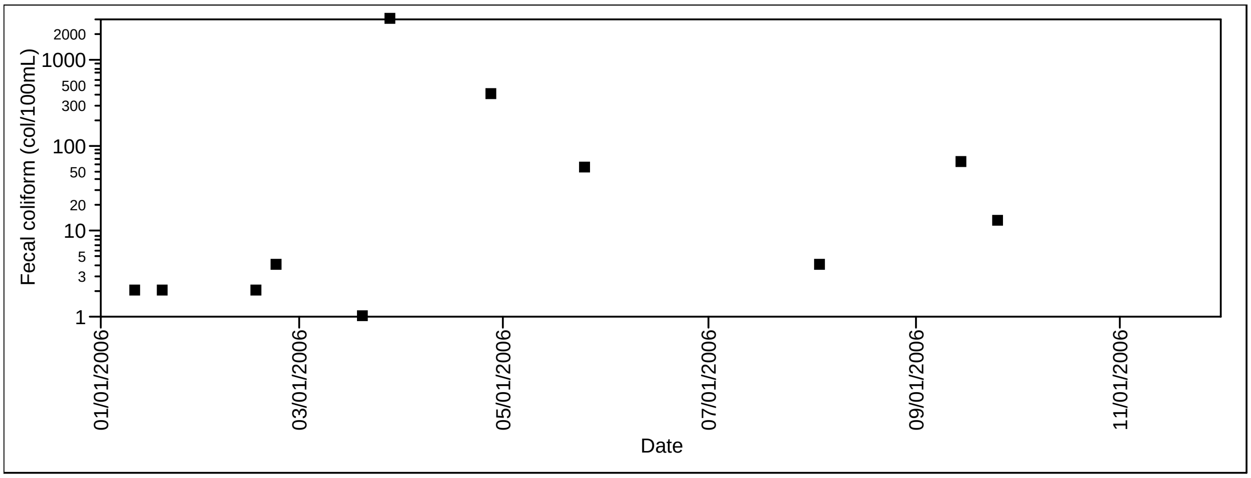



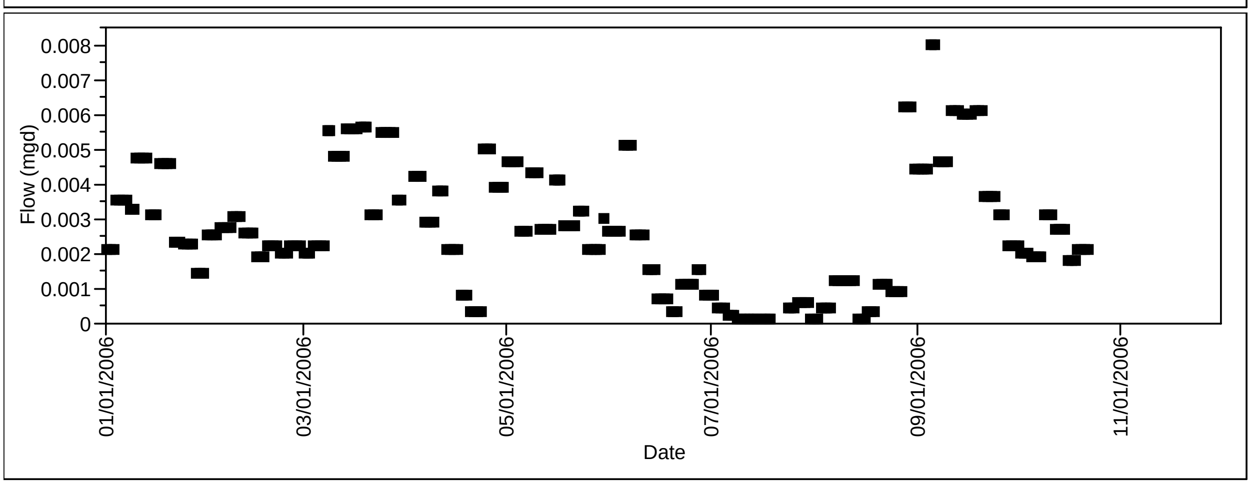

BOD, 5 day (mg/L)
8
7
6
5
4
3
2
1
01/01/2006
03/01/2006
05/01/2006
07/01/2006
09/01/2006
11/01/2006
Date


pH (SU)
7.2
7
6.9
6.8
6.6
6.5
6.4
6.2
6.1
01/01/2006
03/01/2006
05/01/2006
07/01/2006
09/01/2006
11/01/2006
Date


Total suspended residue (mg/L)
3.5
3
2.5
2
1.5
1
0.5
01/01/2006
03/01/2006
05/01/2006
07/01/2006
09/01/2006
11/01/2006
Date


Ammonia (mg/L as N)
10
5
3
1
0.5
0.3
0.1
0.05
0.03
0.01
01/01/2006
03/01/2006
05/01/2006
07/01/2006
09/01/2006
11/01/2006
Date


Fecal coliform (col/100mL)
2000
1000
500
300
100
50
20
10
5
3
1
01/01/2006
03/01/2006
05/01/2006
07/01/2006
09/01/2006
11/01/2006
Date


Flow (mgd)
0.008
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
01/01/2006
03/01/2006
05/01/2006
07/01/2006
09/01/2006
11/01/2006
Date

*Appendix 5: Monitoring station summary pages*

The following pages provide site-by-site summaries of the chemical and physical data collected by NC Division of Water Quality's Watershed Assessment Team (WAT), NC DWQ's Ambient Monitoring System (AMS), and NC Division of Environmental Health's Shellfish Sanitation (SS) programs in the Lockwoods Folly River Local Watershed Planning area from April 1, 2006 through November 1, 2006.

**HUC:** Hydrologic Unit Code
**Watershed:** Watershed site is located in, from Stantec ArcGIS watershed delineations
**Latitude/longitude:** Georeference in decimal degrees
**Sampling start/end date:** Date first/last sample or measurement occurred
**LWP Station #:** Site identifier used in this report, as well as past reports by WAT and Stantec
**Monitoring Program:** Program that collected data/samples from the site (WAT, AMS, or SS)
**Program Station #:** Site identifier used by Monitoring Program
**NC stream index:** Unique identifier for stream reach, assigned and used by NC DWQ
**NC stream class:** Stream classification assigned by NC DWQ; determines which uses are protected and which water quality standards are applicable.
**Parameter:** Chemical or physical constituent that was sampled or measured. NOTE: Hardness was calculated from Ca and Mg. All other parameters represent analyses specific for that constituent.
**N Results:** Number of results for that parameter at that sampling site. NOTE: Results from duplicate samples were averaged and reported as a single result.
**N NDs:** Number of non-detects, i.e., number of results reported as being less than the laboratory's reporting limit for that analysis.
**% NDs:** Percent of results reported as being less than the laboratory's reporting limit
**Min, 10$^{th}$, 25$^{th}$, Median, 75$^{th}$, 90$^{th}$, Max:** Percentiles; distribution of results. For some parameters, "-" is entered in all of these columns since 100% of all results were NDs.

## Bolivia Branch at Green Lewis Rd. (SR 1512)

| | | | |
|---|---|---|---|
| HUC: | 03040207020010 | LWP Station #: | BB01 |
| Watershed: | Bolivia Branch | Monitoring Program: | DWQ- WAT |
| Latitude/longitude: | 34.0630 / -78.1430 | Program Station #: | BB1512 |
| Sampling start date: | 5/18/2006 | NC stream index: | 15-25-1-6-4-1 |
| Sampling end date: | 10/11/2006 | NC stream class: | C Sw |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 6 | 0 | 0 | 14 | 14 | 17 | 96.5 | 695 | 770 | 770 |
| DO concentration (mg/L) | 6 | 0 | 0 | 1 | 1 | 1.15 | 1.35 | 4.125 | 6.9 | 6.9 |
| DO saturation (%) | 6 | 0 | 0 | 12 | 12 | 12 | 15.5 | 47.25 | 75 | 75 |
| pH (SU) | 5 | 0 | 0 | 5.6 | 5.6 | 6.15 | 6.8 | 7 | 7.1 | 7.1 |
| Spec. conductance (uS/cm at 25°C) | 6 | 0 | 0 | 93 | 93 | 113.25 | 125 | 139.5 | 171 | 171 |
| Water temperature (°C) | 6 | 0 | 0 | 16.7 | 16.7 | 18.5 | 20.9 | 23.275 | 23.5 | 23.5 |
| Aluminum total (ug/L) | 6 | 0 | 0 | 110 | 110 | 155 | 195 | 330 | 420 | 420 |
| Arsenic total (ug/L) | 6 | 6 | 100 | - | - | - | - | - | - | - |
| Cadmium total (ug/L) | 6 | 6 | 100 | - | - | - | - | - | - | - |
| Calcium total (mg/L) | 6 | 0 | 0 | 8.2 | 8.2 | 11.8 | 14 | 18 | 21 | 21 |
| Chromium total (ug/L) | 6 | 6 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 6 | 6 | 100 | - | - | - | - | - | - | - |
| Hardness (mg/L) | 6 | 0 | 0 | 27 | 27 | 38 | 44 | 53 | 62 | 62 |
| Iron total (ug/L) | 6 | 0 | 0 | 710 | 710 | 1527.5 | 3250 | 4300 | 4900 | 4900 |
| Lead total (ug/L) | 6 | 6 | 100 | - | - | - | - | - | - | - |
| Magnesium total (mg/L) | 6 | 0 | 0 | 1.5 | 1.5 | 1.8 | 2.1 | 2.325 | 2.4 | 2.4 |
| Manganese total (ug/L) | 6 | 0 | 0 | 11 | 11 | 16.25 | 38.5 | 66.25 | 70 | 70 |
| Mercury total (ug/L) | 6 | 6 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 6 | 6 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 6 | 3 | 50 | 10 | 10 | 10 | 10.5 | 17 | 23 | 23 |
| NH3 as N (mg/L) | 6 | 1 | 17 | 0.02 | 0.02 | 0.05 | 0.17 | 0.2825 | 0.32 | 0.32 |
| NO2+NO3 as N (mg/L) | 6 | 3 | 50 | 0.02 | 0.02 | 0.02 | 0.07 | 0.2325 | 0.3 | 0.3 |
| Phosphorus total (mg/L) | 6 | 0 | 0 | 0.04 | 0.04 | 0.055 | 0.07 | 0.1175 | 0.14 | 0.14 |
| TKN as N (mg/L) | 6 | 0 | 0 | 0.38 | 0.38 | 0.47 | 0.635 | 0.7925 | 0.95 | 0.95 |
| Residue susp. (mg/L) | 6 | 0 | 0 | 4.5 | 4.5 | 4.725 | 6.25 | 9.5 | 11 | 11 |
| Residue susp., fixed (mg/L) | 6 | 1 | 17 | 2.5 | 2.5 | 2.875 | 3.1 | 5.15 | 6.2 | 6.2 |
| Residue susp., volatile (mg/L) | 6 | 2 | 33 | 2.5 | 2.5 | 2.5 | 2.8 | 5.25 | 6 | 6 |
| Turbidity (NTU) | 6 | 0 | 0 | 5.3 | 5.3 | 5.975 | 10.45 | 14 | 14 | 14 |

## Doe Creek at Stone Chimney Rd. (SR 1115)

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | DC01 |
| Watershed: | Doe Creek | Monitoring Program: | DWQ- WAT |
| Latitude/longitude: | 34.0047 / -78.2803 | Program Station #: | DC1115 |
| Sampling start date: | 5/18/2006 | NC stream index: | 15-25-1-13 |
| Sampling end date: | 10/11/2006 | NC stream class: | C Sw HQW |

| ***Parameter*** | ***N Results*** | ***N NDs*** | ***% NDs*** | ***Min*** | ***10th*** | ***25th*** | ***50th*** | ***75th*** | ***90th*** | ***Max*** |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 8 | 0 | 0 | 43 | 43 | 45.5 | 51 | 220 | 1200 | 1200 |
| DO concentration (mg/L) | 8 | 0 | 0 | 1.1 | 1.1 | 1.975 | 3 | 3.475 | 4.5 | 4.5 |
| DO saturation (%) | 8 | 0 | 0 | 12 | 12 | 24.25 | 34 | 39.25 | 52 | 52 |
| pH (SU) | 7 | 0 | 0 | 5.9 | 5.9 | 6.7 | 6.8 | 7.2 | 7.2 | 7.2 |
| Spec. conductance (uS/cm at 25°C) | 8 | 0 | 0 | 124 | 124 | 176 | 185 | 205.25 | 230 | 230 |
| Water temperature (°C) | 8 | 0 | 0 | 18.1 | 18.1 | 19.675 | 23.6 | 24.225 | 27.1 | 27.1 |
| Aluminum total (ug/L) | 7 | 0 | 0 | 53 | 53 | 68 | 100 | 150 | 320 | 320 |
| Arsenic total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Cadmium total (ug/L) | 7 | 6 | 86 | 2 | 2 | 2 | 2 | 2 | 2 | 2 |
| Calcium total (mg/L) | 7 | 0 | 0 | 16 | 16 | 25 | 30 | 31 | 32 | 32 |
| Chromium total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Hardness (mg/L) | 7 | 0 | 0 | 48 | 48 | 73 | 86 | 88 | 93 | 93 |
| Iron total (ug/L) | 7 | 0 | 0 | 770 | 770 | 970 | 1700 | 2100 | 2500 | 2500 |
| Lead total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Magnesium total (mg/L) | 7 | 0 | 0 | 1.9 | 1.9 | 2.6 | 2.6 | 3 | 3.3 | 3.3 |
| Manganese total (ug/L) | 7 | 0 | 0 | 11 | 11 | 37 | 46 | 85 | 100 | 100 |
| Mercury total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 7 | 4 | 57 | 10 | 10 | 10 | 10 | 12 | 32 | 32 |
| NH3 as N (mg/L) | 7 | 3 | 43 | 0.02 | 0.02 | 0.02 | 0.04 | 0.07 | 0.12 | 0.12 |
| NO2+NO3 as N (mg/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Phosphorus total (mg/L) | 7 | 0 | 0 | 0.04 | 0.04 | 0.04 | 0.05 | 0.06 | 0.07 | 0.07 |
| TKN as N (mg/L) | 7 | 0 | 0 | 0.42 | 0.42 | 0.46 | 0.53 | 0.58 | 0.62 | 0.62 |
| Residue susp. (mg/L) | 7 | 0 | 0 | 2.5 | 2.5 | 3.5 | 3.8 | 6.2 | 12 | 12 |
| Residue susp., fixed (mg/L) | 7 | 5 | 71 | 2.5 | 2.5 | 2.5 | 2.5 | 2.8 | 6 | 6 |
| Residue susp., volatile (mg/L) | 7 | 4 | 57 | 2.5 | 2.5 | 2.5 | 2.5 | 3.5 | 5.8 | 5.8 |
| Turbidity (NTU) | 7 | 0 | 0 | 2.1 | 2.1 | 2.3 | 5.1 | 6.9 | 7.3 | 7.3 |

## ICW, Shellfish Sanitation Station 11

| | | | |
|---|---|---|---|
| HUC: | 03040207020050 | LWP Station #: | ICW02 |
| Watershed: | Intracoastal Waterway | Monitoring Program: | DEH- SS |
| Latitude/longitude: | 33.9207 / -78.2047 | Program Station #: | 11 |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25 |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| ***Parameter*** | ***N Results*** | ***N NDs*** | ***% NDs*** | ***Min*** | ***10th*** | ***25th*** | ***50th*** | ***75th*** | ***90th*** | ***Max*** |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 13 | 13 | 13 | 17 | 49 | 49 | 49 |
| Salinity (ppt) | 3 | 0 | 0 | 32 | 32 | 32 | 34 | 35 | 35 | 35 |

## ICW at Sunset Harbor

| | | | |
|---|---|---|---|
| HUC: | 03040207020050 | LWP Station #: | ICW03 |
| Watershed: | Intracoastal Waterway | Monitoring Program: | DWQ - AMS |
| Latitude/longitude: | 33.9200 / -78.2080 | Program Station #: | I9390000 |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25 |
| Sampling end date: | 11/1/2006 | NC stream class: | SA HQW |

| ***Parameter*** | ***N Results*** | ***N NDs*** | ***% NDs*** | ***Min*** | ***10th*** | ***25th*** | ***50th*** | ***75th*** | ***90th*** | ***Max*** |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 7 | 2 | 29 | 1 | 1 | 1 | 4 | 12 | 23 | 23 |
| Chlorophyll-a (ug/L) | 7 | 0 | 0 | 4 | 4 | 4 | 10 | 12 | 13 | 13 |
| DO concentration (mg/L) | 19 | 0 | 0 | 4.71 | 4.93 | 5.67 | 6.26 | 6.98 | 7.85 | 7.88 |
| pH (SU) | 19 | 0 | 0 | 7.76 | 7.77 | 7.99 | 8.01 | 8.01 | 8.09 | 8.11 |
| Salinity (ppt) | 19 | 0 | 0 | 28.72 | 29.44 | 31.5 | 32.67 | 34.05 | 35.19 | 35.2 |
| Secchi depth (m) | 7 | 0 | 0 | 0.5 | 0.5 | 0.7 | 0.8 | 1 | 1.3 | 1.3 |
| Spec. conductance (uS/cm at 25°C) | 19 | 0 | 0 | 44380 | 45376 | 48202 | 49791 | 51666 | 53219 | 53228 |
| Water temperature (°C) | 19 | 0 | 0 | 20.11 | 20.12 | 20.8 | 25.1 | 29.57 | 29.98 | 30.01 |
| NH3 as N (mg/L) | 7 | 1 | 14 | 0.02 | 0.02 | 0.02 | 0.02 | 0.04 | 0.16 | 0.16 |
| NO2+NO3 as N (mg/L) | 7 | 2 | 29 | 0.02 | 0.02 | 0.02 | 0.03 | 0.04 | 0.1 | 0.1 |
| Phosphorus total (mg/L) | 7 | 0 | 0 | 0.06 | 0.06 | 0.06 | 0.07 | 0.08 | 0.09 | 0.09 |
| TKN as N (mg/L) | 7 | 0 | 0 | 0.26 | 0.26 | 0.32 | 0.38 | 0.43 | 0.51 | 0.51 |
| Residue susp. (mg/L) | 3 | 0 | 0 | 17 | 17 | 17 | 34 | 37 | 37 | 37 |
| Turbidity (NTU) | 7 | 0 | 0 | 4.6 | 4.6 | 5.2 | 8.1 | 11 | 14 | 14 |

## ICW, Shellfish Station 10

| | | | |
|---|---|---|---|
| HUC: | 03040207020050 | LWP Station #: | ICW04 |
| Watershed: | Intracoastal Waterway | Monitoring Program: | DEH - SS |
| Latitude/longitude: | 33.9233 / -78.2149 | Program Station #: | 10 |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25 |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| ***Parameter*** | ***N Results*** | ***N NDs*** | ***% NDs*** | ***Min*** | ***10th*** | ***25th*** | ***50th*** | ***75th*** | ***90th*** | ***Max*** |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 4 | 4 | 4 | 46 | 70 | 70 | 70 |
| Salinity (ppt) | 3 | 0 | 0 | 34 | 34 | 34 | 35 | 35 | 35 | 35 |

## ICW, Shellfish Station 13

| | | | |
|---|---|---|---|
| HUC: | 03040207020050 | LWP Station #: | ICW06 |
| Watershed: | Intracoastal Waterway | Monitoring Program: | DEH - SS |
| Latitude/longitude: | 33.9243 / -78.2245 | Program Station #: | 13 |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25 |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| ***Parameter*** | ***N Results*** | ***N NDs*** | ***% NDs*** | ***Min*** | ***10th*** | ***25th*** | ***50th*** | ***75th*** | ***90th*** | ***Max*** |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 4 | 4 | 4 | 6.1 | 23 | 23 | 23 |
| Salinity (ppt) | 3 | 0 | 0 | 35 | 35 | 35 | 35 | 36 | 36 | 36 |

# ICW at CM R42 west of Lockwood Folly River

| | | | |
|---|---|---|---|
| HUC: | 03040207020050 | LWP Station #: | ICW07 |
| Watershed: | Intracoastal Waterway | Monitoring Program: | DWQ - AMS |
| Latitude/longitude: | 33.9217 / -78.2306 | Program Station #: | I9510000 |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25 |
| Sampling end date: | 11/1/2006 | NC stream class: | SA HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 7 | 3 | 43 | 1 | 1 | 1 | 1 | 8 | 15 | 15 |
| Chlorophyll-a (ug/L) | 7 | 0 | 0 | 3 | 3 | 4 | 5 | 9 | 9 | 9 |
| DO concentration (mg/L) | 19 | 0 | 0 | 4.65 | 4.81 | 5.9 | 6.14 | 7.22 | 7.65 | 7.84 |
| pH (SU) | 19 | 0 | 0 | 7.8 | 7.8 | 8 | 8.01 | 8.1 | 8.17 | 8.17 |
| Salinity (ppt) | 19 | 0 | 0 | 30.76 | 30.78 | 32.62 | 33.32 | 34.77 | 35.24 | 35.24 |
| Secchi depth (m) | 7 | 0 | 0 | 0.5 | 0.5 | 0.6 | 0.9 | 1.5 | 1.6 | 1.6 |
| Spec. conductance (uS/cm at 25°C) | 19 | 0 | 0 | 47186 | 47214 | 49721 | 50674 | 52613 | 53272 | 53282 |
| Water temperature (°C) | 19 | 0 | 0 | 19.69 | 19.69 | 20.65 | 25.5 | 29.18 | 29.99 | 30 |
| NH3 as N (mg/L) | 7 | 2 | 29 | 0.02 | 0.02 | 0.02 | 0.03 | 0.05 | 0.07 | 0.07 |
| NO2+NO3 as N (mg/L) | 7 | 3 | 43 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.1 | 0.1 |
| Phosphorus total (mg/L) | 7 | 0 | 0 | 0.05 | 0.05 | 0.06 | 0.06 | 0.08 | 0.09 | 0.09 |
| TKN as N (mg/L) | 7 | 0 | 0 | 0.23 | 0.23 | 0.26 | 0.4 | 0.45 | 0.45 | 0.45 |
| Residue susp. (mg/L) | 3 | 0 | 0 | 22 | 22 | 22 | 26 | 84 | 84 | 84 |
| Turbidity (NTU) | 7 | 0 | 0 | 4.3 | 4.3 | 5.6 | 6.1 | 11 | 16 | 16 |

## Little Doe Creek at Stone Chimney Rd. (SR1115)

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | LDC01 |
| Watershed: | Little Doe Creek | Monitoring Program: | DWQ - WAT |
| Latitude/longitude: | 34.0014 / -78.2805 | Program Station #: | LDC1115 |
| Sampling start date: | 5/18/2006 | NC stream index: | 15-25-1-13-1 |
| Sampling end date: | 10/11/2006 | NC stream class: | C Sw HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 7 | 0 | 0 | 160 | 160 | 180 | 330 | 630 | 1600 | 1600 |
| DO concentration (mg/L) | 7 | 0 | 0 | 3.4 | 3.4 | 3.4 | 4.1 | 4.5 | 5.4 | 5.4 |
| DO saturation (%) | 7 | 0 | 0 | 40 | 40 | 40 | 43 | 50 | 66 | 66 |
| pH (SU) | 6 | 0 | 0 | 6 | 6 | 6.375 | 7 | 7.125 | 7.2 | 7.2 |
| Spec. conductance (uS/cm at 25°C) | 7 | 0 | 0 | 143 | 143 | 184 | 192 | 229 | 246 | 246 |
| Water temperature (°C) | 7 | 0 | 0 | 17.8 | 17.8 | 19.3 | 23.2 | 24.3 | 25.9 | 25.9 |
| Aluminum total (ug/L) | 7 | 0 | 0 | 55 | 55 | 57 | 64 | 110 | 1100 | 1100 |
| Arsenic total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Cadmium total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Calcium total (mg/L) | 7 | 0 | 0 | 16 | 16 | 24 | 30 | 35 | 39 | 39 |
| Chromium total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Hardness (mg/L) | 7 | 0 | 0 | 48 | 48 | 70 | 86 | 99 | 111 | 111 |
| Iron total (ug/L) | 7 | 0 | 0 | 1100 | 1100 | 1800 | 2400 | 4800 | 9400 | 9400 |
| Lead total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Magnesium total (mg/L) | 7 | 0 | 0 | 2 | 2 | 2.5 | 2.8 | 2.9 | 3.2 | 3.2 |
| Manganese total (ug/L) | 7 | 0 | 0 | 15 | 15 | 60 | 110 | 310 | 570 | 570 |
| Mercury total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 7 | 6 | 86 | 10 | 10 | 10 | 10 | 10 | 10 | 10 |
| NH3 as N (mg/L) | 7 | 3 | 43 | 0.02 | 0.02 | 0.02 | 0.02 | 0.04 | 0.05 | 0.05 |
| NO2+NO3 as N (mg/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Phosphorus total (mg/L) | 7 | 0 | 0 | 0.04 | 0.04 | 0.05 | 0.05 | 0.09 | 0.32 | 0.32 |
| TKN as N (mg/L) | 7 | 0 | 0 | 0.38 | 0.38 | 0.38 | 0.41 | 0.46 | 1.4 | 1.4 |
| Residue susp. (mg/L) | 7 | 0 | 0 | 2.8 | 2.8 | 4 | 5.2 | 5.8 | 41 | 41 |
| Residue susp., fixed (mg/L) | 7 | 2 | 29 | 2.5 | 2.5 | 2.5 | 3 | 3.5 | 24 | 24 |
| Residue susp., volatile (mg/L) | 7 | 3 | 43 | 2.5 | 2.5 | 2.5 | 2.8 | 3 | 16 | 16 |
| Turbidity (NTU) | 7 | 0 | 0 | 3.2 | 3.2 | 7.7 | 9.4 | 33 | 85 | 85 |

## Lockwoods Folly River at Gilbert Rd. (SR1501)

| | | | |
|---|---|---|---|
| HUC: | 03040207020010 | LWP Station #: | LFR02 |
| Watershed: | Upper Lockwoods Folly River | Monitoring Program: | DWQ - WAT |
| Latitude/longitude: | 34.0283 / -78.2177 | Program Station #: | LFR1501 |
| Sampling start date: | 5/18/2006 | NC stream index: | 15-25-1-(1) |
| Sampling end date: | 10/11/2006 | NC stream class: | C Sw |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 7 | 0 | 0 | 67 | 67 | 75 | 87 | 135 | 360 | 360 |
| DO concentration (mg/L) | 7 | 0 | 0 | 3.2 | 3.2 | 3.4 | 4.4 | 4.7 | 5 | 5 |
| DO saturation (%) | 7 | 0 | 0 | 40 | 40 | 43 | 48 | 54 | 54 | 54 |
| pH (SU) | 6 | 0 | 0 | 5.9 | 5.9 | 6.725 | 7.2 | 7.3 | 7.6 | 7.6 |
| Spec. conductance (uS/cm at 25°C) | 7 | 0 | 0 | 104 | 104 | 137 | 181 | 208 | 216 | 216 |
| Water temperature (°C) | 7 | 0 | 0 | 19.6 | 19.6 | 19.9 | 23.9 | 25.9 | 27.6 | 27.6 |
| Aluminum total (ug/L) | 7 | 0 | 0 | 130 | 130 | 135 | 270 | 340 | 360 | 360 |
| Arsenic total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Cadmium total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Calcium total (mg/L) | 7 | 0 | 0 | 14 | 14 | 22 | 31 | 34 | 35 | 35 |
| Chromium total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Hardness (mg/L) | 7 | 0 | 0 | 41 | 41 | 62 | 85 | 89 | 96 | 96 |
| Iron total (ug/L) | 7 | 0 | 0 | 750 | 750 | 1150 | 1300 | 1600 | 1600 | 1600 |
| Lead total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Magnesium total (mg/L) | 7 | 0 | 0 | 1 | 1 | 1.4 | 1.9 | 1.9 | 2.1 | 2.1 |
| Manganese total (ug/L) | 7 | 0 | 0 | 14 | 14 | 41 | 58 | 88 | 99 | 99 |
| Mercury total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 7 | 3 | 43 | 10 | 10 | 10 | 12 | 17 | 40 | 40 |
| NH3 as N (mg/L) | 7 | 1 | 14 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.04 | 0.04 |
| NO2+NO3 as N (mg/L) | 7 | 3 | 43 | 0.02 | 0.02 | 0.02 | 0.02 | 0.08 | 0.08 | 0.08 |
| Phosphorus total (mg/L) | 7 | 0 | 0 | 0.03 | 0.03 | 0.04 | 0.04 | 0.05 | 0.05 | 0.05 |
| TKN as N (mg/L) | 7 | 0 | 0 | 0.39 | 0.39 | 0.41 | 0.52 | 0.69 | 0.72 | 0.72 |
| Residue susp. (mg/L) | 7 | 1 | 14 | 2.5 | 2.5 | 2.5 | 3.5 | 6.5 | 21 | 21 |
| Residue susp., fixed (mg/L) | 7 | 5 | 71 | 2.5 | 2.5 | 2.5 | 2.5 | 3.2 | 17 | 17 |
| Residue susp., volatile (mg/L) | 7 | 2 | 29 | 2.5 | 2.5 | 2.5 | 2.8 | 3.2 | 3.5 | 3.5 |
| Turbidity (NTU) | 7 | 0 | 0 | 4.9 | 4.9 | 5.1 | 5.3 | 6.3 | 11 | 11 |

## Lockwoods Folly River at NC 211 at Supply

| | | | |
|---|---|---|---|
| HUC: | | LWP Station #: | LFR03 |
| Watershed: | Middle Lockwoods Folly River | Monitoring Program: | DWQ - AMS |
| Latitude/longitude: | 34.0107 / -78.2634 | Program Station #: | I9420000 |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25-1-(11) |
| Sampling end date: | 11/1/2006 | NC stream class: | SC HQW |

| ***Parameter*** | ***N Results*** | ***N NDs*** | ***% NDs*** | ***Min*** | ***10th*** | ***25th*** | ***50th*** | ***75th*** | ***90th*** | ***Max*** |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 7 | 0 | 0 | 41 | 41 | 59 | 120 | 130 | 150 | 150 |
| Chlorophyll-a (ug/L) | 7 | 1 | 14 | 1 | 1 | 1 | 7 | 10 | 46 | 46 |
| DO concentration (mg/L) | 19 | 0 | 0 | 3 | 3.1 | 3.8 | 4.8 | 5.64 | 5.88 | 6.1 |
| pH (SU) | 19 | 0 | 0 | 6.7 | 6.7 | 6.88 | 7.03 | 7.21 | 7.56 | 7.6 |
| Salinity (ppt) | 19 | 0 | 0 | 0.04 | 0.04 | 0.05 | 0.07 | 0.09 | 0.27 | 0.27 |
| Secchi depth (m) | 7 | 0 | 0 | 0.4 | 0.4 | 0.5 | 0.6 | 0.6 | 0.9 | 0.9 |
| Spec. conductance (uS/cm at 25°C) | 19 | 0 | 0 | 94.6 | 94.7 | 121 | 154 | 191.5 | 534.9 | 539.9 |
| Water temperature (°C) | 19 | 0 | 0 | 15.77 | 15.84 | 20.93 | 23.4 | 28.7 | 30.02 | 30.2 |
| Aluminum total (ug/L) | 2 | 0 | 0 | 280 | 280 | 280 | 290 | 300 | 300 | 300 |
| Arsenic total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Cadmium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Chromium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Iron total (ug/L) | 2 | 0 | 0 | 900 | 900 | 900 | 1100 | 1300 | 1300 | 1300 |
| Lead total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Manganese total (ug/L) | 2 | 0 | 0 | 15 | 15 | 15 | 16.5 | 18 | 18 | 18 |
| Mercury total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| NH3 as N (mg/L) | 7 | 5 | 71 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 |
| NO2+NO3 as N (mg/L) | 7 | 3 | 43 | 0.02 | 0.02 | 0.02 | 0.02 | 0.05 | 0.05 | 0.05 |
| Phosphorus total (mg/L) | 7 | 0 | 0 | 0.04 | 0.04 | 0.04 | 0.04 | 0.05 | 0.08 | 0.08 |
| TKN as N (mg/L) | 7 | 0 | 0 | 0.47 | 0.47 | 0.52 | 0.54 | 0.64 | 0.71 | 0.71 |
| Residue susp. (mg/L) | 3 | 0 | 0 | 5.5 | 5.5 | 5.5 | 7.8 | 8.5 | 8.5 | 8.5 |
| Turbidity (NTU) | 7 | 0 | 0 | 3.2 | 3.2 | 6 | 6.8 | 7.7 | 13 | 13 |

## Lockwoods Folly River near Sandy Hill

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | LFR06 |
| Watershed: | Middle Lockwoods Folly River | Monitoring Program: | DWQ - AMS |
| Latitude/longitude: | 33.9722 / -78.2503 | Program Station #: | I9430000 |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25-1-(11) |
| Sampling end date: | 11/1/2006 | NC stream class: | SC HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 7 | 0 | 0 | 14 | 14 | 31 | 49 | 59 | 130 | 130 |
| Chlorophyll-a (ug/L) | 7 | 0 | 0 | 2 | 2 | 2 | 8 | 18 | 44 | 44 |
| DO concentration (mg/L) | 19 | 0 | 0 | 3.9 | 3.9 | 4.36 | 4.9 | 5.88 | 5.93 | 6.5 |
| pH (SU) | 19 | 0 | 0 | 6.96 | 7 | 7.1 | 7.43 | 7.6 | 7.67 | 7.7 |
| Salinity (ppt) | 19 | 0 | 0 | 0.06 | 0.06 | 0.15 | 15.26 | 20.63 | 26.57 | 27.51 |
| Secchi depth (m) | 7 | 0 | 0 | 0.4 | 0.4 | 0.5 | 0.6 | 0.8 | 0.9 | 0.9 |
| Spec. conductance (uS/cm at 25°C) | 19 | 0 | 0 | 144.1 | 145.2 | 318 | 25043 | 33006 | 41395 | 42706 |
| Water temperature (°C) | 19 | 0 | 0 | 15.69 | 15.69 | 21.25 | 24.6 | 29.76 | 30.22 | 30.39 |
| Aluminum total (ug/L) | 2 | 0 | 0 | 280 | 280 | 280 | 425 | 570 | 570 | 570 |
| Arsenic total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Cadmium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Chromium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Iron total (ug/L) | 2 | 0 | 0 | 450 | 450 | 450 | 475 | 500 | 500 | 500 |
| Lead total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Manganese total (ug/L) | 2 | 0 | 0 | 19 | 19 | 19 | 22.5 | 26 | 26 | 26 |
| Mercury total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 2 | 0 | 0 | 14 | 14 | 14 | 17.5 | 21 | 21 | 21 |
| NH3 as N (mg/L) | 7 | 4 | 57 | 0.02 | 0.02 | 0.02 | 0.02 | 0.04 | 0.05 | 0.05 |
| NO2+NO3 as N (mg/L) | 7 | 2 | 29 | 0.02 | 0.02 | 0.02 | 0.03 | 0.04 | 0.04 | 0.04 |
| Phosphorus total (mg/L) | 7 | 0 | 0 | 0.04 | 0.04 | 0.06 | 0.07 | 0.09 | 0.1 | 0.1 |
| TKN as N (mg/L) | 7 | 0 | 0 | 0.44 | 0.44 | 0.49 | 0.58 | 0.63 | 0.93 | 0.93 |
| Residue susp. (mg/L) | 3 | 0 | 0 | 22 | 22 | 22 | 28 | 50 | 50 | 50 |
| Turbidity (NTU) | 7 | 0 | 0 | 4.2 | 4.2 | 8.1 | 9.9 | 12 | 30 | 30 |

# Lockwoods Folly River at Varnamtown

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | LFR11 |
| Watershed: | Lower Lockwoods Folly River | Monitoring Program: | DWQ - AMS |
| Latitude/longitude: | 33.9465 / -78.2232 | Program Station #: | I9440000 |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25-1-(16) |
| Sampling end date: | 11/1/2006 | NC stream class: | SA HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 7 | 0 | 0 | 8 | 8 | 10 | 33 | 46 | 80 | 80 |
| Chlorophyll-a (ug/L) | 7 | 0 | 0 | 3 | 3 | 4 | 10 | 13 | 14 | 14 |
| DO concentration (mg/L) | 19 | 0 | 0 | 4.1 | 4.2 | 5.68 | 6.1 | 6.41 | 6.78 | 6.87 |
| pH (SU) | 19 | 0 | 0 | 7.13 | 7.4 | 7.6 | 7.96 | 8.02 | 8.14 | 8.14 |
| Salinity (ppt) | 19 | 0 | 0 | 9.75 | 15.31 | 19.7 | 30.84 | 33.36 | 34.66 | 35.01 |
| Secchi depth (m) | 7 | 0 | 0 | 0.6 | 0.6 | 0.7 | 0.8 | 0.9 | 1.2 | 1.2 |
| Spec. conductance (uS/cm at 25°C) | 19 | 0 | 0 | 16651 | 25205 | 31663 | 47294 | 50737 | 52487 | 52967 |
| Water temperature (°C) | 19 | 0 | 0 | 18.19 | 18.64 | 20.68 | 25.2 | 29.95 | 30.6 | 31.24 |
| Aluminum total (ug/L) | 2 | 0 | 0 | 510 | 510 | 510 | 580 | 650 | 650 | 650 |
| Arsenic total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Cadmium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Chromium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Iron total (ug/L) | 2 | 0 | 0 | 370 | 370 | 370 | 375 | 380 | 380 | 380 |
| Lead total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Manganese total (ug/L) | 2 | 0 | 0 | 14 | 14 | 14 | 15 | 16 | 16 | 16 |
| Mercury total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 2 | 0 | 0 | 20 | 20 | 20 | 25.5 | 31 | 31 | 31 |
| NH3 as N (mg/L) | 7 | 5 | 71 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.04 | 0.04 |
| NO2+NO3 as N (mg/L) | 7 | 3 | 43 | 0.02 | 0.02 | 0.03 | 0.03 | 0.1 | 0.1 | 0.1 |
| Phosphorus total (mg/L) | 7 | 0 | 0 | 0.06 | 0.06 | 0.06 | 0.07 | 0.07 | 0.07 | 0.07 |
| TKN as N (mg/L) | 7 | 0 | 0 | 0.4 | 0.4 | 0.41 | 0.44 | 0.49 | 0.52 | 0.52 |
| Residue susp. (mg/L) | 2 | 0 | 0 | 15 | 15 | 15 | 25 | 35 | 35 | 35 |
| Turbidity (NTU) | 7 | 0 | 0 | 4.5 | 4.5 | 4.7 | 7.7 | 11 | 11 | 11 |

## Lockwoods Folly River, Shellfish Sanitation Station 5A

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | LFR13 |
| Watershed: | Lower Lockwoods Folly River | Monitoring Program: | DEH - SS |
| Latitude/longitude: | 33.9395 / -78.2192 | Program Station #: | 5A |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25-1-(16) |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| ***Parameter*** | ***N Results*** | ***N NDs*** | ***% NDs*** | ***Min*** | ***10th*** | ***25th*** | ***50th*** | ***75th*** | ***90th*** | ***Max*** |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 14 | 14 | 14 | 33 | 33 | 33 | 33 |
| Salinity (ppt) | 3 | 0 | 0 | 35 | 35 | 35 | 35 | 35 | 35 | 35 |

## Lockwoods Folly River, Shellfish Sanitation Station 6A

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | LFR16 |
| Watershed: | Lower Lockwoods Folly River | Monitoring Program: | DEH - SS |
| Latitude/longitude: | 33.9340 / -78.2190 | Program Station #: | 6A |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25-1-(16) |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| ***Parameter*** | ***N Results*** | ***N NDs*** | ***% NDs*** | ***Min*** | ***10th*** | ***25th*** | ***50th*** | ***75th*** | ***90th*** | ***Max*** |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 4.5 | 4.5 | 4.5 | 4.5 | 33 | 33 | 33 |
| Salinity (ppt) | 3 | 0 | 0 | 34 | 34 | 34 | 35 | 35 | 35 | 35 |

## Lockwoods Folly River, Shellfish Sanitation Station 14A

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | LFR18 |
| Watershed: | Lower Lockwoods Folly River | Monitoring Program: | DEH - SS |
| Latitude/longitude: | 33.9316 / -78.2178 | Program Station #: | 14A |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25-1-(16) |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| ***Parameter*** | ***N Results*** | ***N NDs*** | ***% NDs*** | ***Min*** | ***10th*** | ***25th*** | ***50th*** | ***75th*** | ***90th*** | ***Max*** |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 4.5 | 4.5 | 4.5 | 6.8 | 7.8 | 7.8 | 7.8 |
| Salinity (ppt) | 3 | 0 | 0 | 35 | 35 | 35 | 35 | 36 | 36 | 36 |

## Lockwoods Folly River at CM R6 northwest of Sunset Harbor (West Channel)

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | LFR19 |
| Watershed: | Lower Lockwoods Folly River | Monitoring Program: | DWQ - AMS |
| Latitude/longitude: | 33.9310 / -78.2183 | Program Station #: | I9480000 |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25-1-(16) |
| Sampling end date: | 11/1/2006 | NC stream class: | SA HQW |

| ***Parameter*** | ***N Results*** | ***N NDs*** | ***% NDs*** | ***Min*** | ***10th*** | ***25th*** | ***50th*** | ***75th*** | ***90th*** | ***Max*** |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 7 | 2 | 29 | 1 | 1 | 1 | 1 | 31 | 36 | 36 |
| Chlorophyll-a (ug/L) | 7 | 0 | 0 | 3 | 3 | 4 | 7 | 11 | 15 | 15 |
| DO concentration (mg/L) | 19 | 0 | 0 | 4.6 | 4.7 | 5.8 | 6.08 | 7.05 | 7.13 | 7.28 |
| pH (SU) | 19 | 0 | 0 | 7.7 | 7.7 | 7.91 | 8 | 8.09 | 8.16 | 8.17 |
| Salinity (ppt) | 19 | 0 | 0 | 24.71 | 26.63 | 28.22 | 33.2 | 34.67 | 35.23 | 35.24 |
| Secchi depth (m) | 7 | 0 | 0 | 0.6 | 0.6 | 0.6 | 0.9 | 1.7 | 1.8 | 1.8 |
| Spec. conductance (uS/cm at 25°C) | 19 | 0 | 0 | 38805 | 41492 | 43687 | 50661 | 52507 | 53280 | 53285 |
| Water temperature (°C) | 19 | 0 | 0 | 19.83 | 19.88 | 21.04 | 25.6 | 29.7 | 30.08 | 30.5 |
| Aluminum total (ug/L) | 2 | 0 | 0 | 440 | 440 | 440 | 525 | 610 | 610 | 610 |
| Arsenic total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Cadmium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Chromium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Iron total (ug/L) | 2 | 0 | 0 | 250 | 250 | 250 | 335 | 420 | 420 | 420 |
| Lead total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Manganese total (ug/L) | 2 | 0 | 0 | 11 | 11 | 11 | 11.5 | 12 | 12 | 12 |
| Mercury total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 2 | 0 | 0 | 28 | 28 | 28 | 29 | 30 | 30 | 30 |
| NH3 as N (mg/L) | 7 | 4 | 57 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.09 | 0.09 |
| NO2+NO3 as N (mg/L) | 7 | 2 | 29 | 0.02 | 0.02 | 0.03 | 0.03 | 0.06 | 0.1 | 0.1 |
| Phosphorus total (mg/L) | 7 | 0 | 0 | 0.05 | 0.05 | 0.06 | 0.07 | 0.07 | 0.08 | 0.08 |
| TKN as N (mg/L) | 7 | 0 | 0 | 0.24 | 0.24 | 0.31 | 0.4 | 0.52 | 0.74 | 0.74 |
| Residue susp. (mg/L) | 3 | 0 | 0 | 23 | 23 | 23 | 43 | 54 | 54 | 54 |
| Turbidity (NTU) | 6 | 0 | 0 | 5.1 | 5.1 | 5.625 | 6.7 | 8.525 | 9.8 | 9.8 |

## Lockwoods Folly River, Shellfish Sanitation Station 14B

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | LFR20 |
| Watershed: | Lower Lockwoods Folly River | Monitoring Program: | DEH - SS |
| Latitude/longitude: | 33.9286 / -78.2211 | Program Station #: | 14B |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25-1-(16) |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 17 | 17 | 17 | 33 | 33 | 33 | 33 |
| Salinity (ppt) | 3 | 0 | 0 | 34 | 34 | 34 | 35 | 35 | 35 | 35 |

## Lockwoods Folly River, Shellfish Sanitation Station 7A

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | LFR21 |
| Watershed: | Lower Lockwoods Folly River | Monitoring Program: | DEH - SS |
| Latitude/longitude: | 33.9287 / -78.2163 | Program Station #: | 7A |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25-1-(16) |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 2 | 2 | 2 | 4 | 17 | 17 | 17 |
| Salinity (ppt) | 3 | 0 | 0 | 34 | 34 | 34 | 35 | 36 | 36 | 36 |

## Lockwoods Folly River, Shellfish Sanitation Station 7

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | LFR24 |
| Watershed: | Lower Lockwoods Folly River | Monitoring Program: | DEH - SS |
| Latitude/longitude: | 33.9266 / -78.2151 | Program Station #: | 7 |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25-1-(16) |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 6.8 | 6.8 | 6.8 | 6.8 | 7.8 | 7.8 | 7.8 |
| Salinity (ppt) | 3 | 0 | 0 | 35 | 35 | 35 | 35 | 35 | 35 | 35 |

## Lockwoods Folly River, Shellfish Sanitation Station 8

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | LFR25 |
| Watershed: | Lower Lockwoods Folly River | Monitoring Program: | DEH - SS |
| Latitude/longitude: | 33.9253 / -78.2106 | Program Station #: | 8 |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25-1-(16) |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 11 | 11 | 11 | 14 | 49 | 49 | 49 |
| Salinity (ppt) | 3 | 0 | 0 | 34 | 34 | 34 | 34 | 35 | 35 | 35 |

# Mill Creek at Sunset Harbor Rd. (SR1112)

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | MC01 |
| Watershed: | Lower Lockwoods Folly River | Monitoring Program: | DWQ- WAT |
| Latitude/longitude: | 33.9582 / -78.2139 | Program Station #: | MC1112 |
| Sampling start date: | 5/18/2006 | NC stream index: | 15-25-1-18-(2) |
| Sampling end date: | 10/11/2006 | NC stream class: | SA HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 8 | 0 | 0 | 27 | 27 | 34.25 | 55 | 118.25 | 730 | 730 |
| DO concentration (mg/L) | 8 | 0 | 0 | 3.9 | 3.9 | 4.325 | 5 | 6 | 6.4 | 6.4 |
| DO saturation (%) | 8 | 0 | 0 | 54 | 54 | 60.5 | 68 | 85.5 | 95 | 95 |
| pH (SU) | 7 | 0 | 0 | 6.7 | 6.7 | 6.8 | 7.4 | 7.6 | 7.7 | 7.7 |
| Salinity (ppt) | 8 | 0 | 0 | 14.2 | 14.2 | 16.775 | 22.05 | 25.225 | 27.3 | 27.3 |
| Spec. conductance (uS/cm at 25°C) | 8 | 0 | 0 | 23300 | 23300 | 27200 | 34900 | 39200 | 42500 | 42500 |
| Water temperature (°C) | 8 | 0 | 0 | 20.3 | 20.3 | 22.35 | 27.4 | 29.975 | 31.2 | 31.2 |
| Aluminum total (ug/L) | 7 | 0 | 0 | 275 | 275 | 420 | 540 | 820 | 1800 | 1800 |
| Arsenic total (ug/L) | 7 | 6 | 86 | 5 | 5 | 5 | 25 | 25 | 25 | 25 |
| Cadmium total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Calcium total (mg/L) | 7 | 0 | 0 | 200 | 200 | 210 | 310 | 330 | 340 | 340 |
| Chromium total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Hardness | 7 | 0 | 0 | 2929 | 2929 | 3078 | 4686 | 4942 | 5379 | 5379 |
| Iron total (ug/L) | 7 | 0 | 0 | 310 | 310 | 415 | 520 | 760 | 1400 | 1400 |
| Lead total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Magnesium total (mg/L) | 7 | 0 | 0 | 590 | 590 | 620 | 950 | 1000 | 1100 | 1100 |
| Manganese total (ug/L) | 7 | 0 | 0 | 18 | 18 | 19 | 20 | 26 | 26 | 26 |
| Mercury total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 7 | 2 | 29 | 10 | 10 | 10 | 12 | 19 | 23 | 23 |
| NH3 as N (mg/L) | 7 | 4 | 57 | 0.02 | 0.02 | 0.02 | 0.02 | 0.05 | 0.06 | 0.06 |
| NO2+NO3 as N (mg/L) | 7 | 4 | 57 | 0.02 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 |
| Phosphorus total (mg/L) | 7 | 0 | 0 | 0.04 | 0.04 | 0.06 | 0.07 | 0.07 | 0.1 | 0.1 |
| TKN as N (mg/L) | 7 | 1 | 14 | 0.2 | 0.2 | 0.32 | 0.45 | 0.56 | 0.66 | 0.66 |
| Residue susp. (mg/L) | 7 | 0 | 0 | 11 | 11 | 18 | 31 | 53 | 90 | 90 |
| Residue susp., fixed (mg/L) | 7 | 0 | 0 | 8 | 8 | 12 | 22 | 44 | 74 | 74 |
| Residue susp., volatile (mg/L) | 7 | 0 | 0 | 2.7 | 2.7 | 4 | 8.2 | 10 | 16 | 16 |
| Turbidity (NTU) | 7 | 0 | 0 | 5.4 | 5.4 | 6.1 | 7.9 | 10 | 22 | 22 |

## Montgomery Slough At SR 1105 near Long Beach

| | | | |
|---|---|---|---|
| HUC: | 03040207020050 | LWP Station #: | MS01 |
| Watershed: | Oak Island Beach | Monitoring Program: | DWQ- AMS |
| Latitude/longitude: | 33.9178 / -78.1609 | Program Station #: | I9385000 |
| Sampling start date: | 4/18/2006 | NC stream index: | 15-25 |
| Sampling end date: | 10/12/2006 | NC stream class: | SA HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 7 | 0 | 0 | 2 | 2 | 34 | 80 | 160 | 250 | 250 |
| Chlorophyll-a (ug/L) | 6 | 0 | 0 | 6 | 6 | 7.5 | 18 | 46.5 | 60 | 60 |
| DO concentration (mg/L) | 6 | 0 | 0 | 3.19 | 3.19 | 4.4725 | 5.41 | 6.785 | 7.1 | 7.1 |
| pH (SU) | 6 | 0 | 0 | 7.16 | 7.16 | 7.265 | 7.395 | 7.6725 | 7.89 | 7.89 |
| Salinity (ppt) | 6 | 0 | 0 | 17.23 | 17.23 | 17.4025 | 20.31 | 24.28 | 33.76 | 33.76 |
| Spec. conductance (uS/cm at 25°C) | 6 | 0 | 0 | 28054 | 28054 | 28304.5 | 32511 | 38092 | 51274 | 51274 |
| Water temperature (°C) | 6 | 0 | 0 | 23.5 | 23.5 | 24.4 | 28.665 | 30.9225 | 31.5 | 31.5 |
| Aluminum total (ug/L) | 2 | 0 | 0 | 1100 | 1100 | 1100 | 1150 | 1200 | 1200 | 1200 |
| Arsenic total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Cadmium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Chromium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Iron total (ug/L) | 2 | 0 | 0 | 850 | 850 | 850 | 860 | 870 | 870 | 870 |
| Lead total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Manganese total (ug/L) | 2 | 0 | 0 | 23 | 23 | 23 | 48.5 | 74 | 74 | 74 |
| Mercury total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 2 | 0 | 0 | 19 | 19 | 19 | 22.5 | 26 | 26 | 26 |
| NH3 as N (mg/L) | 6 | 2 | 33 | 0.02 | 0.02 | 0.02 | 0.045 | 0.085 | 0.13 | 0.13 |
| NO2+NO3 as N (mg/L) | 6 | 2 | 33 | 0.02 | 0.02 | 0.02 | 0.03 | 0.045 | 0.06 | 0.06 |
| Phosphorus total (mg/L) | 6 | 0 | 0 | 0.06 | 0.06 | 0.0825 | 0.1 | 0.1675 | 0.19 | 0.19 |
| TKN as N (mg/L) | 6 | 1 | 17 | 0.2 | 0.2 | 0.3425 | 0.745 | 1.1 | 1.1 | 1.1 |
| Residue susp. (mg/L) | 2 | 0 | 0 | 29 | 29 | 29 | 35 | 41 | 41 | 41 |
| Turbidity (NTU) | 7 | 0 | 0 | 5.8 | 5.8 | 11 | 14 | 19 | 40 | 40 |

## Montgomery Slough, Shellfish Sanitation Station 24A

| | | | |
|---|---|---|---|
| HUC: | 03040207020050 | LWP Station #: | MS03 |
| Watershed: | Oak Island Beach | Monitoring Program: | DEH - SS |
| Latitude/longitude: | 33.9166 / -78.2019 | Program Station #: | 24A |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25 |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 11 | 11 | 11 | 31 | 33 | 33 | 33 |
| Salinity (ppt) | 3 | 0 | 0 | 34 | 34 | 34 | 35 | 35 | 35 | 35 |

## Montgomery Slough, Shellfish Sanitation Station 9

| | | | |
|---|---|---|---|
| HUC: | 03040207020050 | LWP Station #: | MS04 |
| Watershed: | Oak Island Beach | Monitoring Program: | DEH - SS |
| Latitude/longitude: | 33.9167 / -78.2125 | Program Station #: | 9 |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25 |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 1.8 | 1.8 | 1.8 | 27 | 33 | 33 | 33 |
| Salinity (ppt) | 3 | 0 | 0 | 35 | 35 | 35 | 35 | 35 | 35 | 35 |

## Montgomery Slough, Shellfish Sanitation Station 9A

| | | | |
|---|---|---|---|
| HUC: | 03040207020050 | LWP Station #: | MS05 |
| Watershed: | Oak Island Beach | Monitoring Program: | DEH - SS |
| Latitude/longitude: | 33.9190 / -78.2140 | Program Station #: | 9A |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25 |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 7.8 | 7.8 | 7.8 | 22 | 33 | 33 | 33 |
| Salinity (ppt) | 3 | 0 | 0 | 34 | 34 | 34 | 34 | 35 | 35 | 35 |

## Montgomery Slough, Shellfish Sanitation Station 16

| | | | |
|---|---|---|---|
| HUC: | 03040207020050 | LWP Station #: | MS06 |
| Watershed: | Oak Island Beach | Monitoring Program: | DEH - SS |
| Latitude/longitude: | 33.9164 / -78.2180 | Program Station #: | 16 |
| Sampling start date: | 4/25/2006 | NC stream index: | 15-25 |
| Sampling end date: | 7/31/2006 | NC stream class: | SA HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (MPN/100mL) | 3 | 0 | 0 | 4.5 | 4.5 | 4.5 | 8.3 | 33 | 33 | 33 |
| Salinity (ppt) | 3 | 0 | 0 | 34 | 34 | 34 | 35 | 35 | 35 | 35 |

## Middle Swamp at Midway Rd. (SR1500)

| | | | |
|---|---|---|---|
| HUC: | 03040207020010 | LWP Station #: | MW01 |
| Watershed: | Middle Swamp | Monitoring Program: | DWQ- WAT |
| Latitude/longitude: | 34.0520 / -78.1531 | Program Station #: | MS1500 |
| Sampling start date: | 6/8/2006 | NC stream index: | 15-25-1-6-4 |
| Sampling end date: | 10/11/2006 | NC stream class: | C Sw |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 6 | 0 | 0 | 27 | 27 | 58.5 | 79.5 | 207.5 | 260 | 260 |
| DO concentration (mg/L) | 6 | 0 | 0 | 3.4 | 3.4 | 3.775 | 4.35 | 4.925 | 5 | 5 |
| DO saturation (%) | 6 | 0 | 0 | 42 | 42 | 46.5 | 50.5 | 54.75 | 60 | 60 |
| pH (SU) | 5 | 0 | 0 | 5.4 | 5.4 | 5.8 | 6.4 | 6.85 | 7 | 7 |
| Spec. conductance (uS/cm at 25°C) | 6 | 0 | 0 | 81 | 81 | 83.25 | 89 | 110.25 | 114 | 114 |
| Water temperature (°C) | 6 | 0 | 0 | 19.6 | 19.6 | 20.05 | 24.55 | 26.65 | 26.8 | 26.8 |
| Aluminum total (ug/L) | 2 | 0 | 0 | 240 | 240 | 240 | 352.5 | 465 | 465 | 465 |
| Arsenic total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Cadmium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Calcium total (mg/L) | 2 | 0 | 0 | 10 | 10 | 10 | 12.5 | 15 | 15 | 15 |
| Chromium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Hardness (mg/L) | 2 | 0 | 0 | 31 | 31 | 31 | 37 | 44 | 44 | 44 |
| Iron total (ug/L) | 2 | 0 | 0 | 2100 | 2100 | 2100 | 2125 | 2150 | 2150 | 2150 |
| Lead total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Magnesium total (mg/L) | 2 | 0 | 0 | 1.4 | 1.4 | 1.4 | 1.5 | 1.6 | 1.6 | 1.6 |
| Manganese total (ug/L) | 2 | 0 | 0 | 37 | 37 | 37 | 40.5 | 44 | 44 | 44 |
| Mercury total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| NH3 as N (mg/L) | 2 | 0 | 0 | 0.04 | 0.04 | 0.04 | 0.065 | 0.09 | 0.09 | 0.09 |
| NO2+NO3 as N (mg/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Phosphorus total (mg/L) | 2 | 0 | 0 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 | 0.06 |
| TKN as N (mg/L) | 2 | 0 | 0 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 | 0.79 |
| Residue susp. (mg/L) | 2 | 0 | 0 | 4 | 4 | 4 | 4.8 | 5.6 | 5.6 | 5.6 |
| Residue susp., fixed (mg/L) | 2 | 0 | 0 | 2.5 | 2.5 | 2.5 | 2.55 | 2.6 | 2.6 | 2.6 |
| Residue susp., volatile (mg/L) | 2 | 1 | 50 | 2.5 | 2.5 | 2.5 | 2.85 | 3.2 | 3.2 | 3.2 |
| Turbidity (NTU) | 2 | 0 | 0 | 6.7 | 6.7 | 6.7 | 7.4 | 8.1 | 8.1 | 8.1 |

## Pamlico Creek at Stone Chimney Rd. (SR 1115)

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | PC01 |
| Watershed: | Pamlico Creek | Monitoring Program: | DWQ- WAT |
| Latitude/longitude: | 33.9688 / -78.2599 | Program Station #: | PC1115 |
| Sampling start date: | 6/8/2006 | NC stream index: | 15-25-1-15-(2) |
| Sampling end date: | 10/11/2006 | NC stream class: | SC HQW |

| Parameter | N Results | N NDs | % NDs | Min | 10th | 25th | 50th | 75th | 90th | Max |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 6 | 0 | 0 | 250 | 250 | 272.5 | 500 | 797.5 | 1000 | 1000 |
| DO concentration (mg/L) | 5 | 0 | 0 | 2 | 2 | 2.35 | 4.5 | 6.65 | 7.5 | 7.5 |
| DO saturation (%) | 5 | 0 | 0 | 26 | 26 | 31.5 | 50 | 88.5 | 95 | 95 |
| pH (SU) | 5 | 0 | 0 | 6.2 | 6.2 | 6.5 | 6.9 | 7 | 7 | 7 |
| Salinity (ppt) | 5 | 0 | 0 | 0.3 | 0.3 | 0.42 | 1.03 | 3.65 | 3.8 | 3.8 |
| Spec. conductance (uS/cm at 25°C) | 6 | 0 | 0 | 672 | 672 | 970.5 | 1630 | 6200 | 6500 | 6500 |
| Water temperature (°C) | 6 | 0 | 0 | 19.7 | 19.7 | 20.3 | 27.55 | 30.075 | 31.8 | 31.8 |
| Aluminum total (ug/L) | 2 | 0 | 0 | 450 | 450 | 450 | 455 | 460 | 460 | 460 |
| Arsenic total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Cadmium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Calcium total (mg/L) | 2 | 0 | 0 | 30 | 30 | 30 | 53.5 | 77 | 77 | 77 |
| Chromium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 2 | 1 | 50 | 2 | 2 | 2 | 2.8 | 3.6 | 3.6 | 3.6 |
| Hardness | 2 | 0 | 0 | 219 | 219 | 219 | 473 | 728 | 728 | 728 |
| Iron total (ug/L) | 2 | 0 | 0 | 1200 | 1200 | 1200 | 1400 | 1600 | 1600 | 1600 |
| Lead total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Magnesium total (mg/L) | 2 | 0 | 0 | 35 | 35 | 35 | 82.5 | 130 | 130 | 130 |
| Manganese total (ug/L) | 2 | 0 | 0 | 41 | 41 | 41 | 80.5 | 120 | 120 | 120 |
| Mercury total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| NH3 as N (mg/L) | 2 | 0 | 0 | 0.06 | 0.06 | 0.06 | 0.09 | 0.12 | 0.12 | 0.12 |
| NO2+NO3 as N (mg/L) | 2 | 1 | 50 | 0.02 | 0.02 | 0.02 | 0.035 | 0.05 | 0.05 | 0.05 |
| Phosphorus total (mg/L) | 2 | 0 | 0 | 0.08 | 0.08 | 0.08 | 0.115 | 0.15 | 0.15 | 0.15 |
| TKN as N (mg/L) | 2 | 0 | 0 | 0.78 | 0.78 | 0.78 | 0.99 | 1.2 | 1.2 | 1.2 |
| Residue susp. (mg/L) | 2 | 0 | 0 | 15 | 15 | 15 | 16.5 | 18 | 18 | 18 |
| Residue susp., fixed (mg/L) | 2 | 0 | 0 | 9.8 | 9.8 | 9.8 | 10.9 | 12 | 12 | 12 |
| Residue susp., volatile (mg/L) | 2 | 0 | 0 | 3.5 | 3.5 | 3.5 | 5.65 | 7.8 | 7.8 | 7.8 |
| Turbidity (NTU) | 2 | 0 | 0 | 10 | 10 | 10 | 13.5 | 17 | 17 | 17 |

# Royal Oak Swamp at NC 211

| | | | |
|---|---|---|---|
| HUC: | 03040207020020 | LWP Station #: | ROS01 |
| Watershed: | Royal Oak Swamp | Monitoring Program: | DWQ- WAT |
| Latitude/longitude: | 34.0335 / -78.2805 | Program Station #: | ROS211 |
| Sampling start date: | 5/18/2006 | NC stream index: | 15-25-1-12 |
| Sampling end date: | 10/11/2006 | NC stream class: | C Sw |

| ***Parameter*** | ***N Results*** | ***N NDs*** | ***% NDs*** | ***Min*** | ***10th*** | ***25th*** | ***50th*** | ***75th*** | ***90th*** | ***Max*** |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 8 | 0 | 0 | 24 | 24 | 48 | 61.5 | 260 | 1400 | 1400 |
| DO concentration (mg/L) | 8 | 0 | 0 | 2.5 | 2.5 | 3.4 | 4.45 | 5.475 | 6.2 | 6.2 |
| DO saturation (%) | 8 | 0 | 0 | 31 | 31 | 41.75 | 52 | 67.75 | 68 | 68 |
| pH (SU) | 7 | 0 | 0 | 5.9 | 5.9 | 6.9 | 7.1 | 7.2 | 7.2 | 7.2 |
| Spec. conductance (uS/cm at 25°C) | 8 | 0 | 0 | 90 | 90 | 130.75 | 171.5 | 217.5 | 238 | 238 |
| Water temperature (°C) | 8 | 0 | 0 | 18.6 | 18.6 | 19.925 | 25.75 | 26.45 | 29.1 | 29.1 |
| Aluminum total (ug/L) | 7 | 0 | 0 | 69 | 69 | 86 | 135 | 270 | 330 | 330 |
| Arsenic total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Cadmium total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Calcium total (mg/L) | 7 | 0 | 0 | 13 | 13 | 20 | 33 | 39 | 39 | 39 |
| Chromium total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Hardness (mg/L) | 7 | 0 | 0 | 37 | 37 | 56 | 91 | 107 | 108 | 108 |
| Iron total (ug/L) | 7 | 0 | 0 | 1400 | 1400 | 1750 | 2000 | 2100 | 2100 | 2100 |
| Lead total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Magnesium total (mg/L) | 7 | 0 | 0 | 1.2 | 1.2 | 1.5 | 2 | 2.4 | 2.5 | 2.5 |
| Manganese total (ug/L) | 7 | 0 | 0 | 14 | 14 | 31 | 72 | 170 | 210 | 210 |
| Mercury total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| NH3 as N (mg/L) | 7 | 0 | 0 | 0.02 | 0.02 | 0.04 | 0.07 | 0.15 | 0.16 | 0.16 |
| NO2+NO3 as N (mg/L) | 7 | 7 | 100 | - | - | - | - | - | - | - |
| Phosphorus total (mg/L) | 7 | 0 | 0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 |
| TKN as N (mg/L) | 7 | 0 | 0 | 0.42 | 0.42 | 0.42 | 0.52 | 0.58 | 0.6 | 0.6 |
| Residue susp. (mg/L) | 7 | 2 | 29 | 2.5 | 2.5 | 2.5 | 2.8 | 4.5 | 4.5 | 4.5 |
| Residue susp., fixed (mg/L) | 7 | 6 | 86 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.7 | 2.7 |
| Residue susp., volatile (mg/L) | 7 | 4 | 57 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 | 2.5 |
| Turbidity (NTU) | 7 | 0 | 0 | 4.7 | 4.7 | 4.9 | 6.2 | 7.6 | 9.3 | 9.3 |

## Sandy Branch off Goley Hewitt Rd. (SR1251) behind Winding River Clear Water Place

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | SB01 |
| Watershed: | Sandy Branch | Monitoring Program: | DWQ- WAT |
| Latitude/longitude: | 33.98007 / -78.24018 | Program Station #: | SB1251 |
| Sampling start date: | 6/8/2006 | NC stream index: | 15-25-1-14 |
| Sampling end date: | 10/11/2006 | NC stream class: | C Sw HQW |

| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 6 | 0 | 0 | 77 | 77 | 135.5 | 270 | 1090 | 3100 | 3100 |
| DO concentration (mg/L) | 6 | 0 | 0 | 5.5 | 5.5 | 5.575 | 5.75 | 5.9 | 6.2 | 6.2 |
| DO saturation (%) | 6 | 0 | 0 | 63 | 63 | 63 | 65 | 68.25 | 75 | 75 |
| pH (SU) | 5 | 0 | 0 | 5.3 | 5.3 | 6 | 6.9 | 7.15 | 7.3 | 7.3 |
| Spec. conductance (uS/cm at 25°C) | 6 | 0 | 0 | 74 | 74 | 100.25 | 156 | 165.5 | 173 | 173 |
| Water temperature (°C) | 6 | 0 | 0 | 19.3 | 19.3 | 19.525 | 22.2 | 23.575 | 24.7 | 24.7 |
| Aluminum total (ug/L) | 2 | 0 | 0 | 310 | 310 | 310 | 570 | 830 | 830 | 830 |
| Arsenic total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Cadmium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Calcium total (mg/L) | 2 | 0 | 0 | 26 | 26 | 26 | 27.5 | 29 | 29 | 29 |
| Chromium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Hardness (mg/L) | 2 | 0 | 0 | 72 | 72 | 72 | 75 | 79 | 79 | 79 |
| Iron total (ug/L) | 2 | 0 | 0 | 1100 | 1100 | 1100 | 1550 | 2000 | 2000 | 2000 |
| Lead total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Magnesium total (mg/L) | 2 | 0 | 0 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 | 1.6 |
| Manganese total (ug/L) | 2 | 0 | 0 | 16 | 16 | 16 | 22.5 | 29 | 29 | 29 |
| Mercury total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| NH3 as N (mg/L) | 3 | 0 | 0 | 0.02 | 0.02 | 0.02 | 0.02 | 0.03 | 0.03 | 0.03 |
| NO2+NO3 as N (mg/L) | 3 | 3 | 100 | - | - | - | - | - | - | - |
| Phosphorus total (mg/L) | 3 | 0 | 0 | 0.04 | 0.04 | 0.04 | 0.06 | 0.13 | 0.13 | 0.13 |
| TKN as N (mg/L) | 3 | 0 | 0 | 0.52 | 0.52 | 0.52 | 0.56 | 1 | 1 | 1 |
| Residue susp. (mg/L) | 2 | 0 | 0 | 5.5 | 5.5 | 5.5 | 24.75 | 44 | 44 | 44 |
| Residue susp., fixed (mg/L) | 2 | 0 | 0 | 2.8 | 2.8 | 2.8 | 11.4 | 20 | 20 | 20 |
| Residue susp., volatile (mg/L) | 2 | 0 | 0 | 2.8 | 2.8 | 2.8 | 13.4 | 24 | 24 | 24 |
| Turbidity (NTU) | 2 | 0 | 0 | 3.1 | 3.1 | 3.1 | 15.55 | 28 | 28 | 28 |

# Unnamed Tributary to Lockwoods Folly River at Stanley Rd. (SR1119)

| | | | |
|---|---|---|---|
| HUC: | 03040207020030 | LWP Station #: | UT01 |
| Watershed: | UT to Lower Lockwoods Folly River | Monitoring Program: | DWQ- WAT |
| | | Program Station #: | UTLFR1119 |
| Latitude/longitude: | 33.9412 / -78.2522 | | |
| | | NC stream index: | none |
| Sampling start date: | 6/8/2006 | NC stream class: | C Sw HQW |
| Sampling end date: | 10/11/2006 | | |

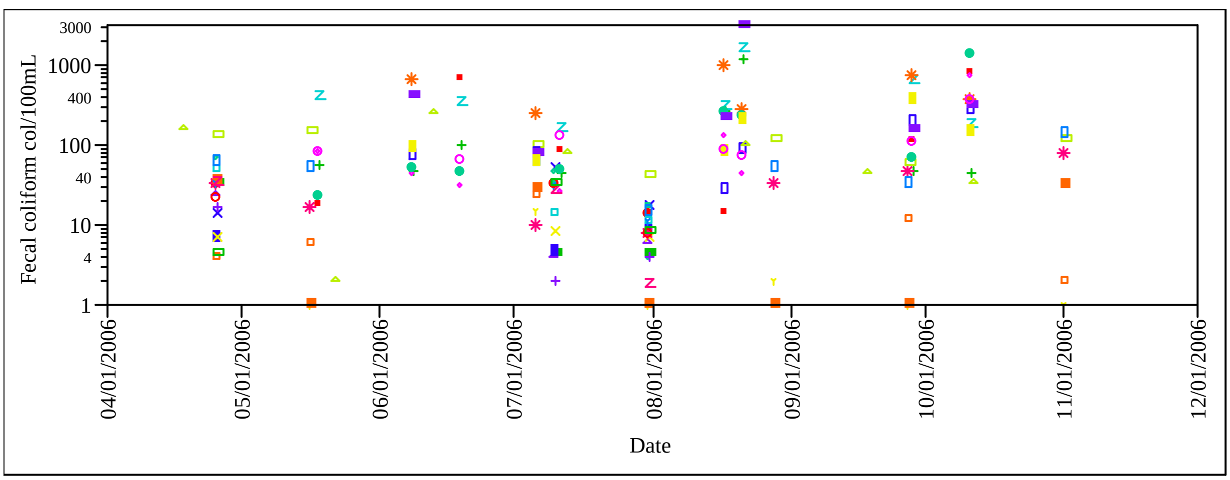
| *Parameter* | *N Results* | *N NDs* | *% NDs* | *Min* | *10th* | *25th* | *50th* | *75th* | *90th* | *Max* |
|---|---|---|---|---|---|---|---|---|---|---|
| Fecal coliform (col/100mL) | 6 | 0 | 0 | 60 | 60 | 75 | 113.5 | 237.5 | 350 | 350 |
| DO concentration (mg/L) | 6 | 0 | 0 | 0.8 | 0.8 | 0.8 | 1.25 | 2.65 | 3.1 | 3.1 |
| DO saturation (%) | 6 | 0 | 0 | 9 | 9 | 9.75 | 14.5 | 31 | 34 | 34 |
| pH (SU) | 5 | 0 | 0 | 5.8 | 5.8 | 6.05 | 6.3 | 6.45 | 6.5 | 6.5 |
| Spec. conductance (uS/cm at 25°C) | 6 | 0 | 0 | 154 | 154 | 157.75 | 183.5 | 191.25 | 195 | 195 |
| Water temperature (°C) | 6 | 0 | 0 | 20.3 | 20.3 | 20.75 | 24.85 | 27.75 | 28.2 | 28.2 |
| Aluminum total (ug/L) | 2 | 0 | 0 | 73 | 73 | 73 | 84 | 95 | 95 | 95 |
| Arsenic total (ug/L) | 2 | 1 | 50 | 5 | 5 | 5 | 5 | 5 | 5 | 5 |
| Cadmium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Calcium total (mg/L) | 2 | 0 | 0 | 18 | 18 | 18 | 18.5 | 19 | 19 | 19 |
| Chromium total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Copper total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Hardness (mg/L) | 2 | 0 | 0 | 54 | 54 | 54 | 56 | 57 | 57 | 57 |
| Iron total (ug/L) | 2 | 0 | 0 | 1900 | 1900 | 1900 | 2250 | 2600 | 2600 | 2600 |
| Lead total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Magnesium total (mg/L) | 2 | 0 | 0 | 2.2 | 2.2 | 2.2 | 2.3 | 2.4 | 2.4 | 2.4 |
| Manganese total (ug/L) | 2 | 0 | 0 | 40 | 40 | 40 | 40.5 | 41 | 41 | 41 |
| Mercury total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Nickel total (ug/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Zinc total (ug/L) | 2 | 1 | 50 | 10 | 10 | 10 | 12.5 | 15 | 15 | 15 |
| NH3 as N (mg/L) | 2 | 0 | 0 | 0.1 | 0.1 | 0.1 | 0.11 | 0.12 | 0.12 | 0.12 |
| NO2+NO3 as N (mg/L) | 2 | 2 | 100 | - | - | - | - | - | - | - |
| Phosphorus total (mg/L) | 2 | 0 | 0 | 0.03 | 0.03 | 0.03 | 0.035 | 0.04 | 0.04 | 0.04 |
| TKN as N (mg/L) | 2 | 0 | 0 | 0.6 | 0.6 | 0.6 | 0.625 | 0.65 | 0.65 | 0.65 |
| Residue susp. (mg/L) | 2 | 0 | 0 | 3.2 | 3.2 | 3.2 | 4.5 | 5.8 | 5.8 | 5.8 |
| Residue susp., fixed (mg/L) | 2 | 1 | 50 | 2.5 | 2.5 | 2.5 | 2.65 | 2.8 | 2.8 | 2.8 |
| Residue susp., volatile (mg/L) | 2 | 1 | 50 | 2.5 | 2.5 | 2.5 | 2.75 | 3 | 3 | 3 |
| Turbidity (NTU) | 2 | 0 | 0 | 8.1 | 8.1 | 8.1 | 8.85 | 9.6 | 9.6 | 9.6 |

## *Appendix 6: Time series for all parameters*

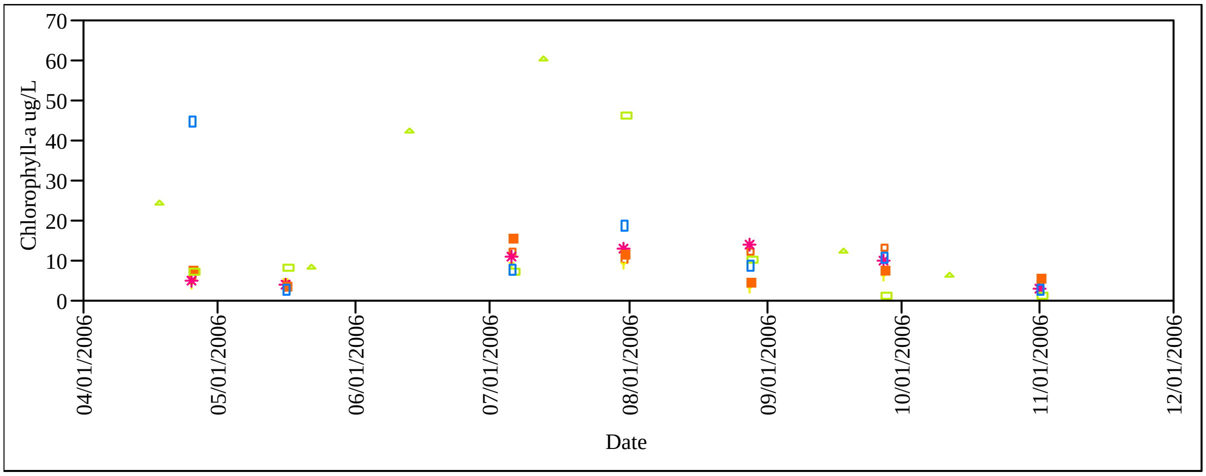
Many chemical parameters show natural seasonal fluctuations, so time series for each parameter are shown in this Appendix. Certain parameters have been omitted since all or nearly all results were less than the reporting limit. The graphs use the same set of standard symbols for monitoring stations that was used in the main portion of the report, as shown in the table below.

| Tributaries | Mainstem LFR | ICW | Montgomery Slough |
|---|---|---|---|
| BB01 | LFR02 | ICW02 | MS01 |
| MW01 | LFR03 | ICW03 | MS03 |
| ROS01 | LFR06 | ICW04 | MS04 |
| DC01 | LFR11 | ICW06 | MS05 |
| LDC01 | LFR13 | ICW07 | MS06 |
| SB01 | LFR16 | | |
| UT01 | LFR18 | | |
| PC01 | LFR19 | | |
| MC01 | LFR20 | | |
| | LFR21 | | |
| | LFR24 | | |
| | LFR25 | | |

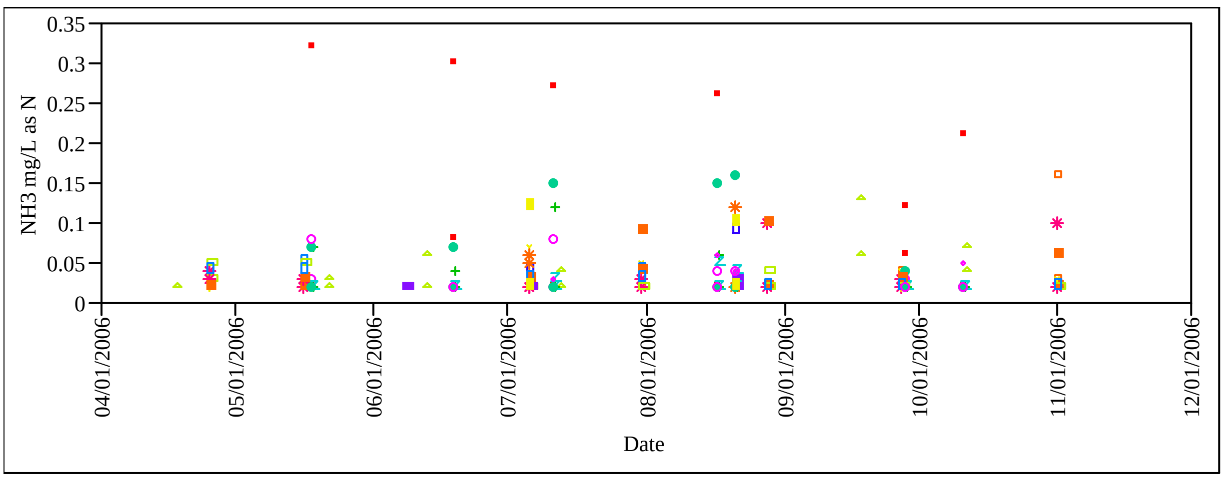
Bacteria

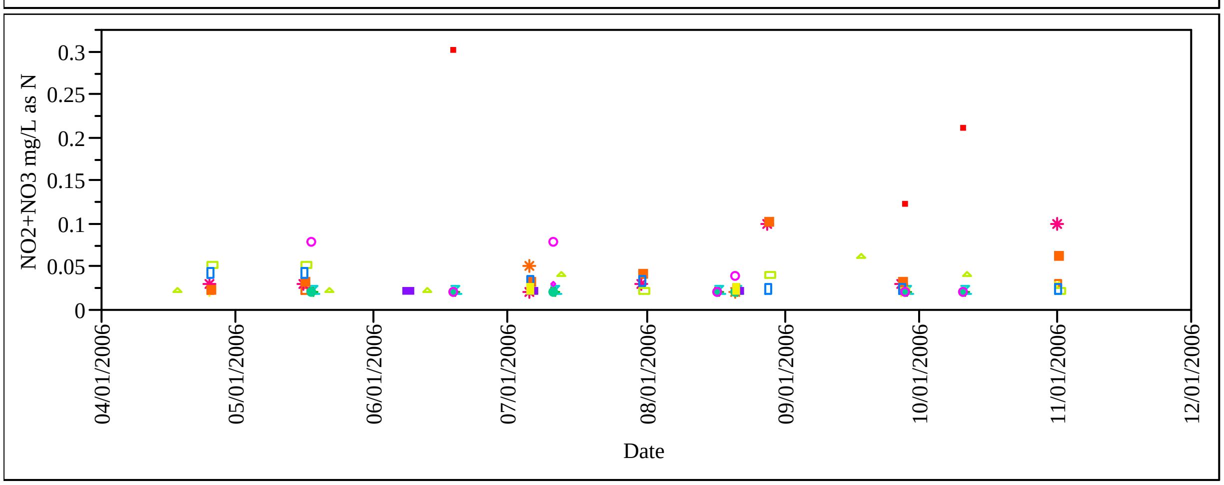


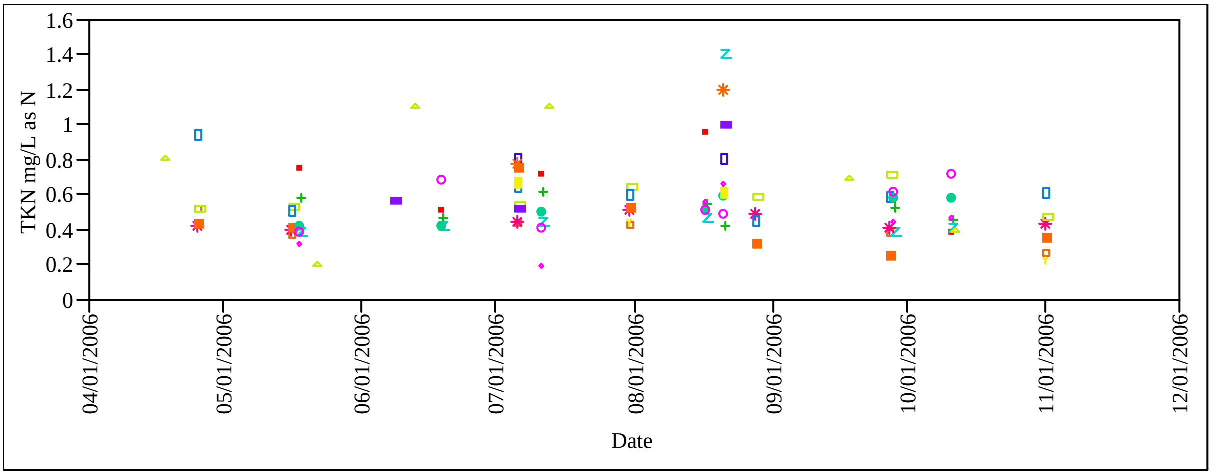
## Chlorophyll

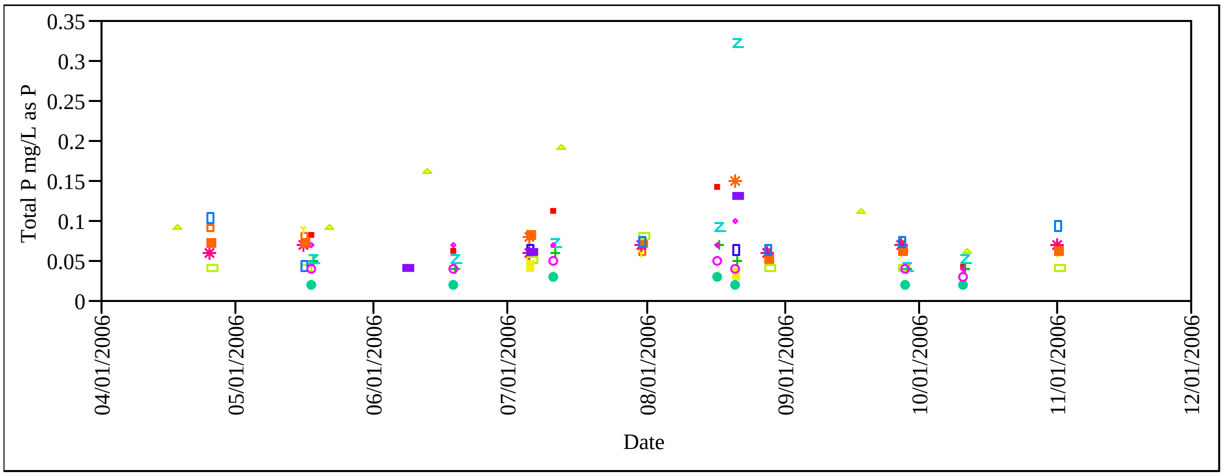



## Nutrients

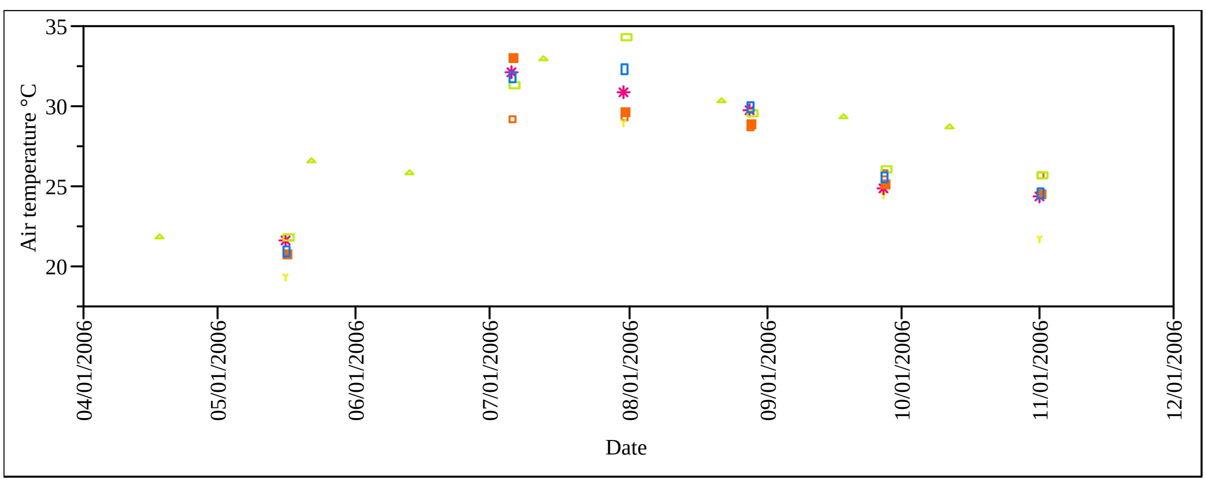


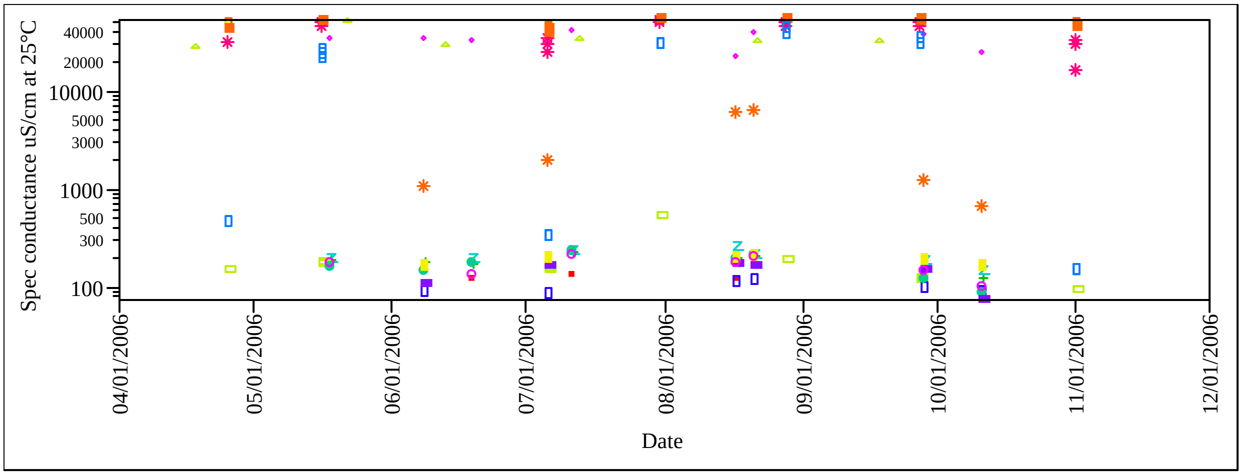





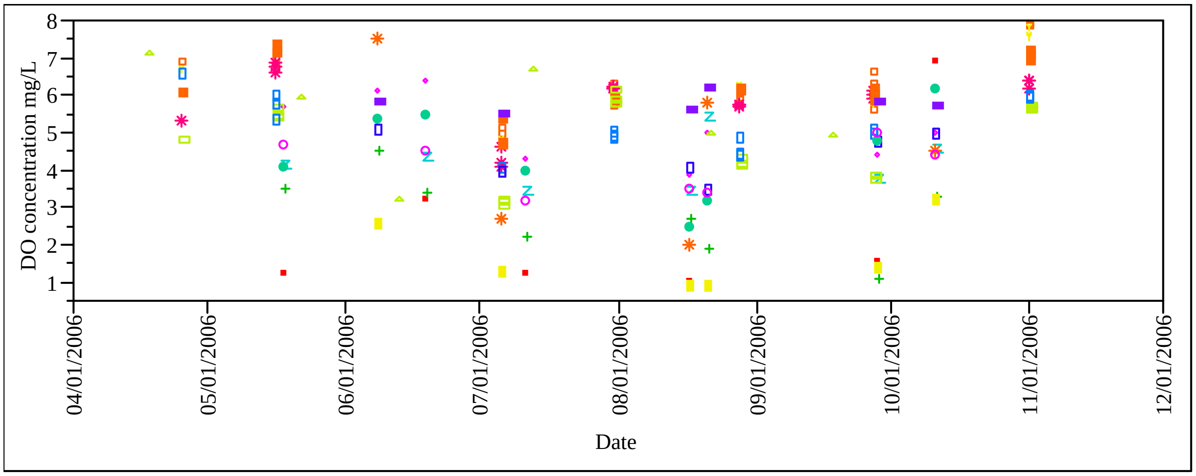




Field measurements

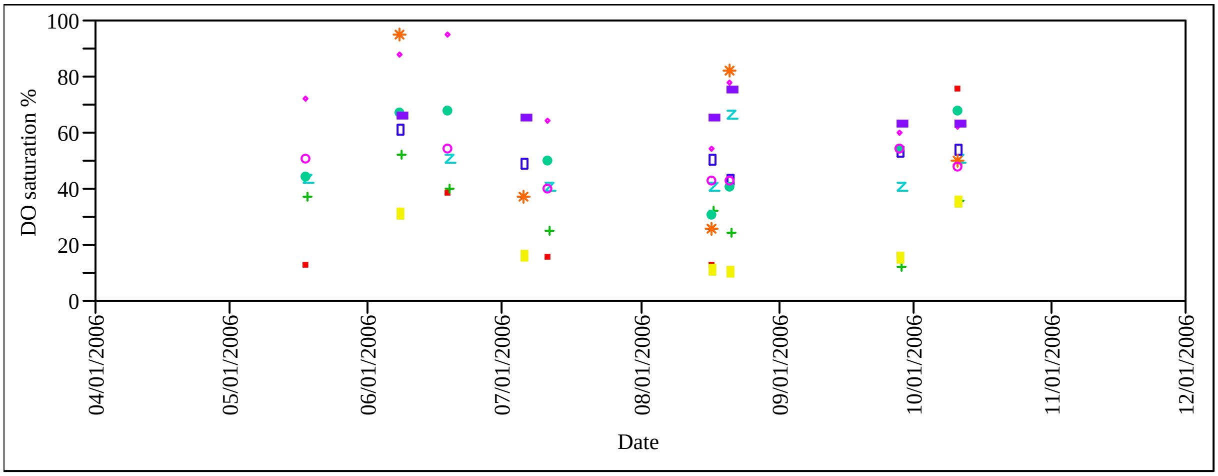




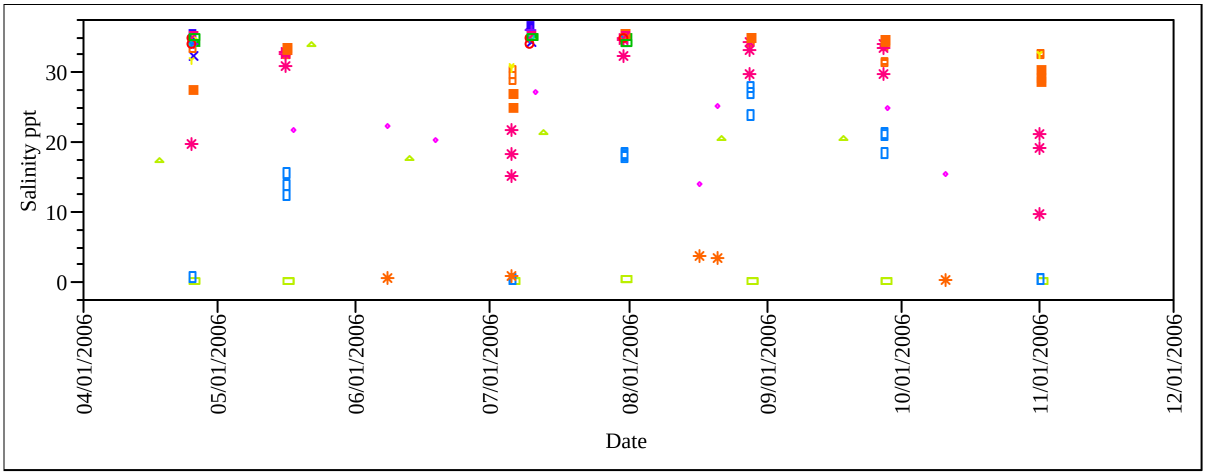
Spec conductance uS/cm at 25°C
40000
20000
10000
5000
3000
1000
500
300
100
04/01/2006
05/01/2006
06/01/2006
07/01/2006
08/01/2006
09/01/2006
10/01/2006
11/01/2006
12/01/2006
Date

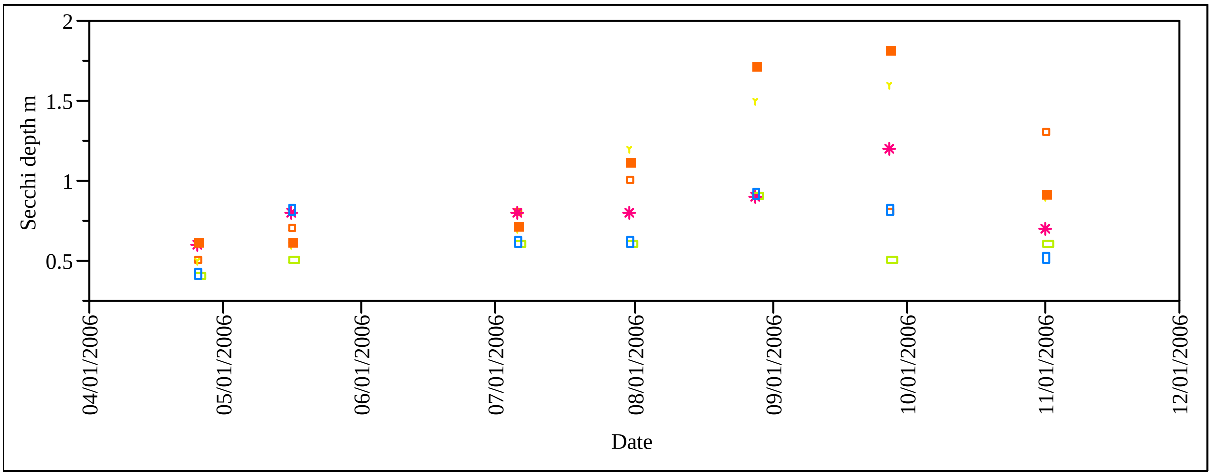
DO concentration mg/L
8
7
6
5
4
3
2
1
04/01/2006
05/01/2006
06/01/2006
07/01/2006
08/01/2006
09/01/2006
10/01/2006
11/01/2006
12/01/2006
Date

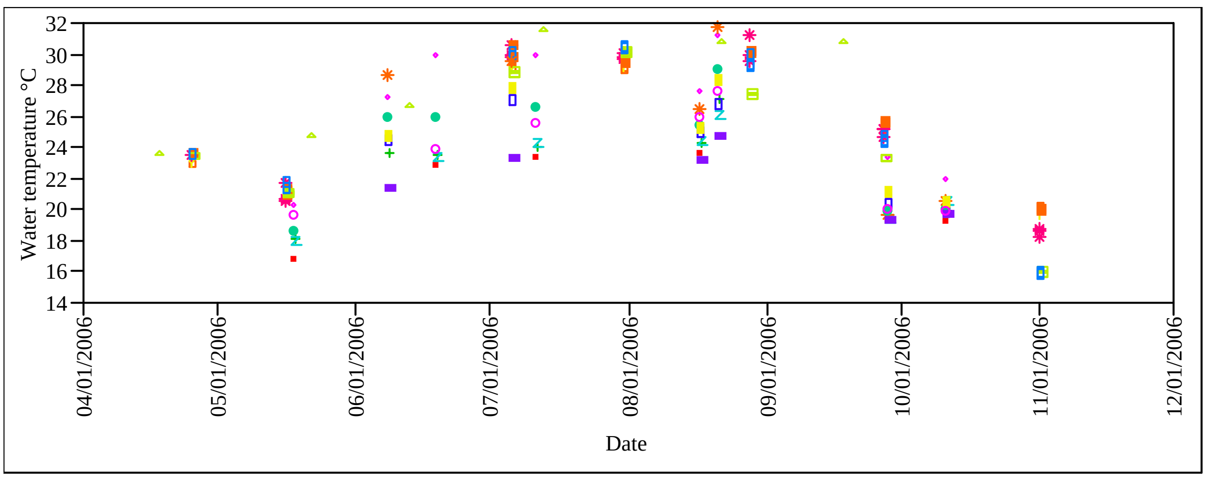
DO saturation %
100
80
60
40
20
0
04/01/2006
05/01/2006
06/01/2006
07/01/2006
08/01/2006
09/01/2006
10/01/2006
11/01/2006
12/01/2006
Date



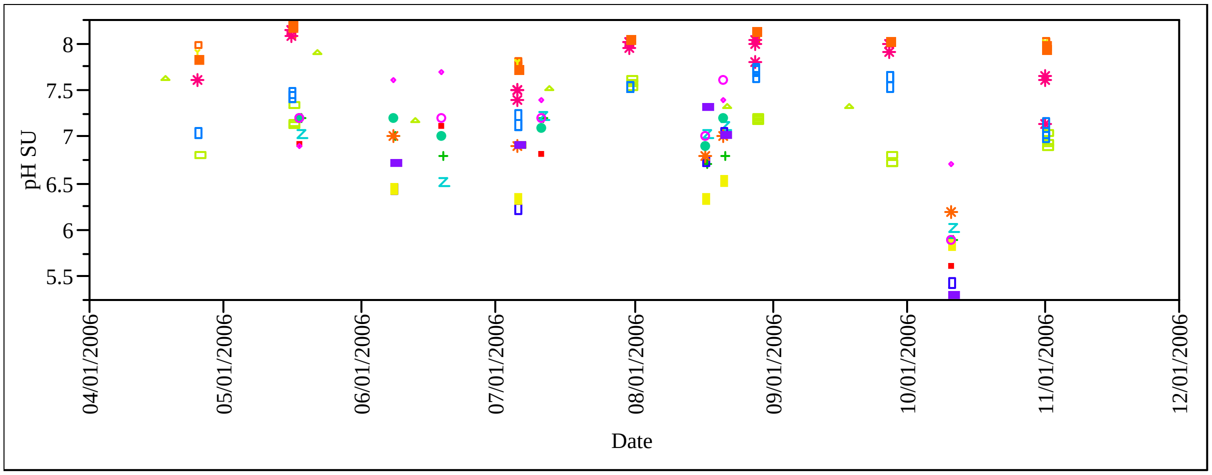
Salinity ppt
0
10
20
30
04/01/2006
05/01/2006
06/01/2006
07/01/2006
08/01/2006
09/01/2006
10/01/2006
11/01/2006
12/01/2006
Date

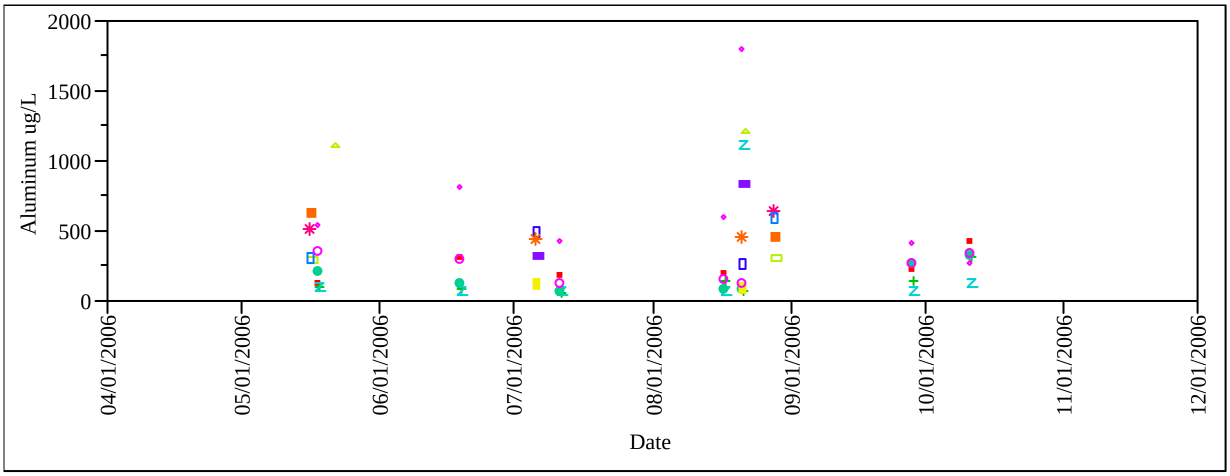
Secchi depth m
0.5
1
1.5
2
04/01/2006
05/01/2006
06/01/2006
07/01/2006
08/01/2006
09/01/2006
10/01/2006
11/01/2006
12/01/2006
Date

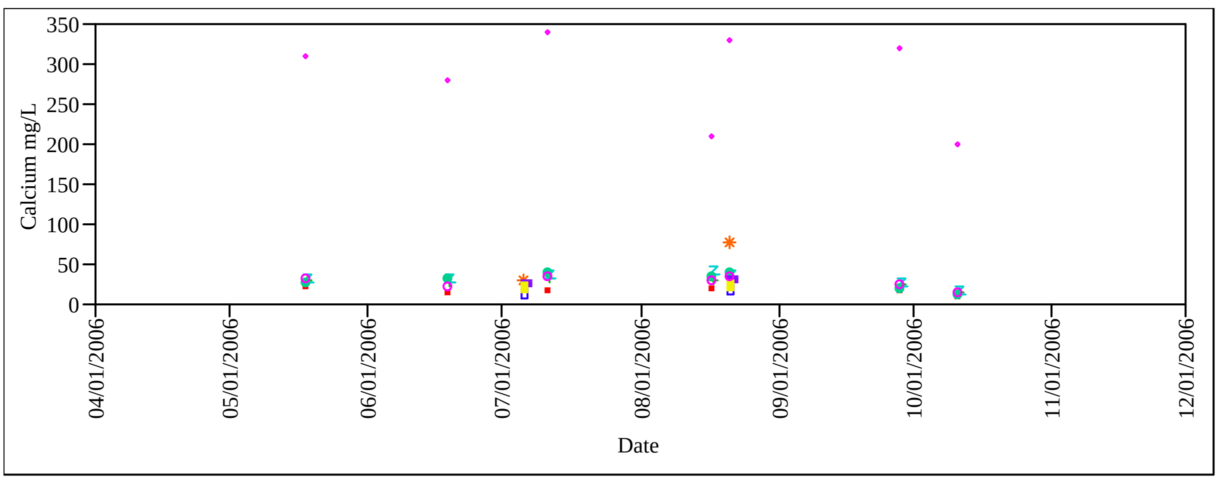



Water temperature °C
14
16
18
20
22
24
26
28
30
32
04/01/2006
05/01/2006
06/01/2006
07/01/2006
08/01/2006
09/01/2006
10/01/2006
11/01/2006
12/01/2006
Date


pH SU
8
7.5
7
6.5
6
5.5
04/01/2006
05/01/2006
06/01/2006
07/01/2006
08/01/2006
09/01/2006
10/01/2006
11/01/2006
12/01/2006
Date

## Metals


Aluminum ug/L
2000
1500
1000
500
0
04/01/2006
05/01/2006
06/01/2006
07/01/2006
08/01/2006
09/01/2006
10/01/2006
11/01/2006
12/01/2006
Date


Calcium mg/L
350
300
250
200
150
100
50
0
04/01/2006
05/01/2006
06/01/2006
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09/01/2006
10/01/2006
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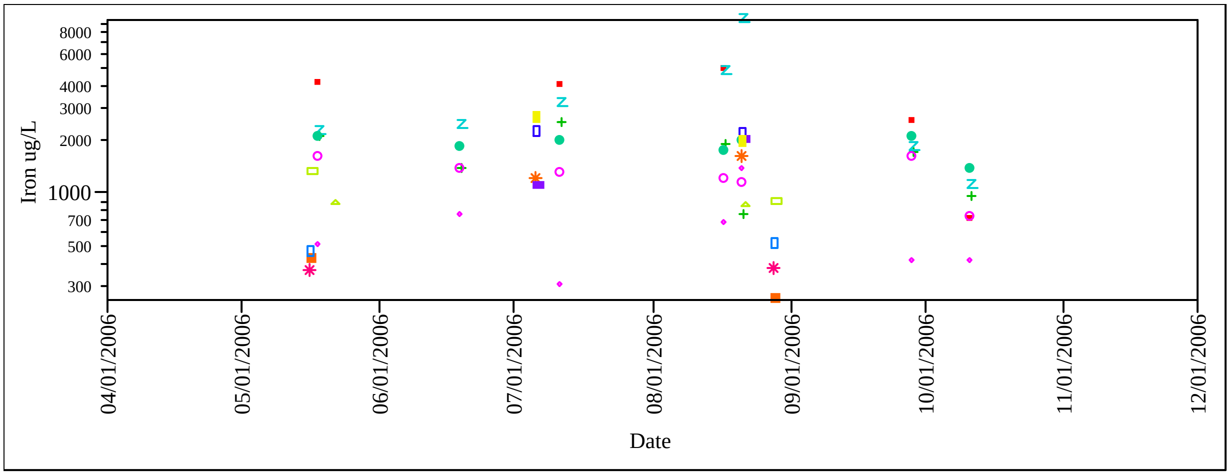
12/01/2006
Date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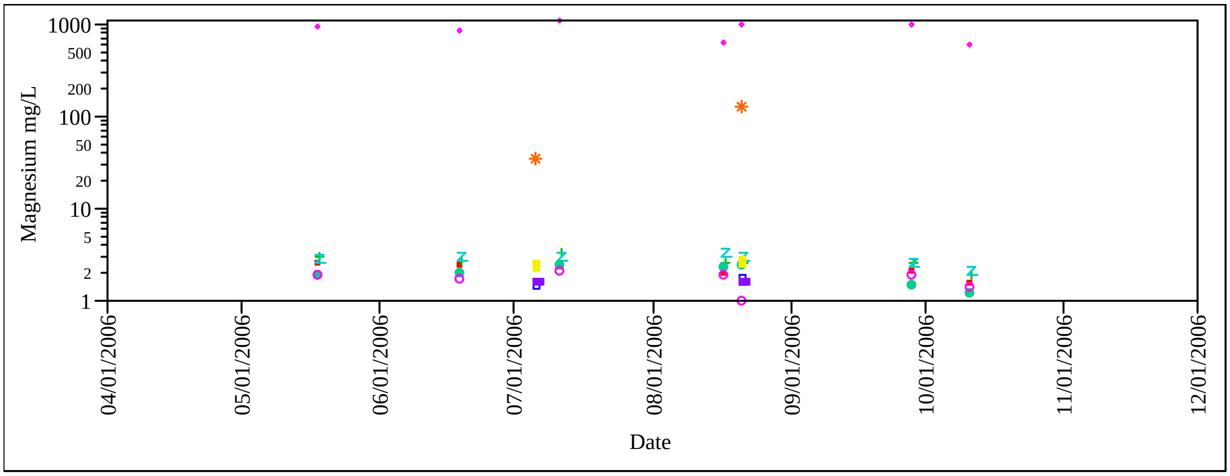
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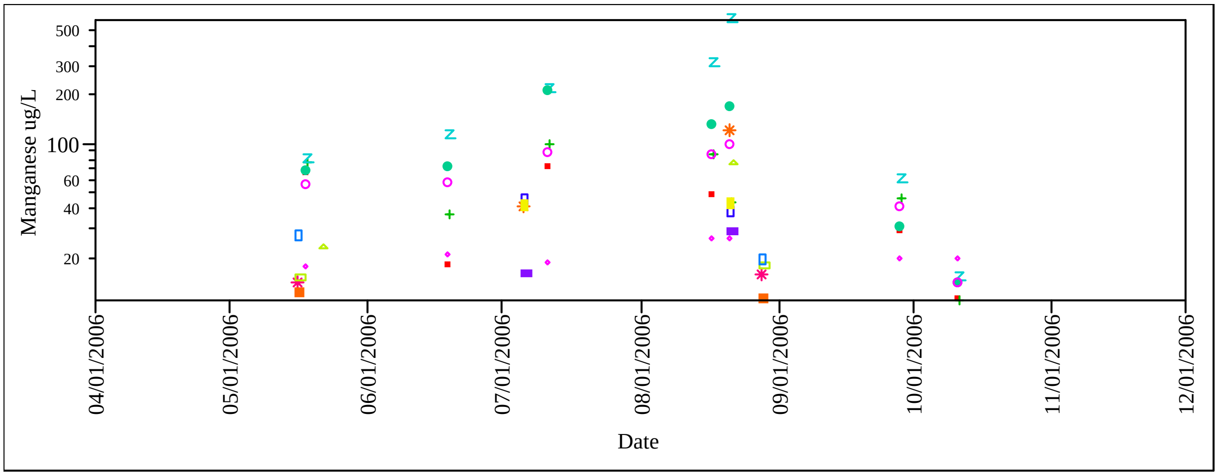
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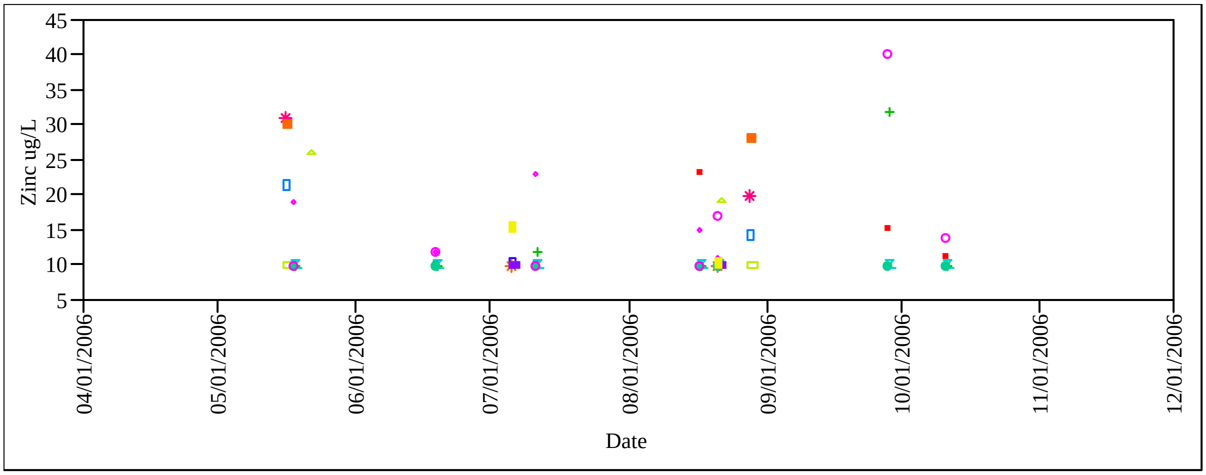


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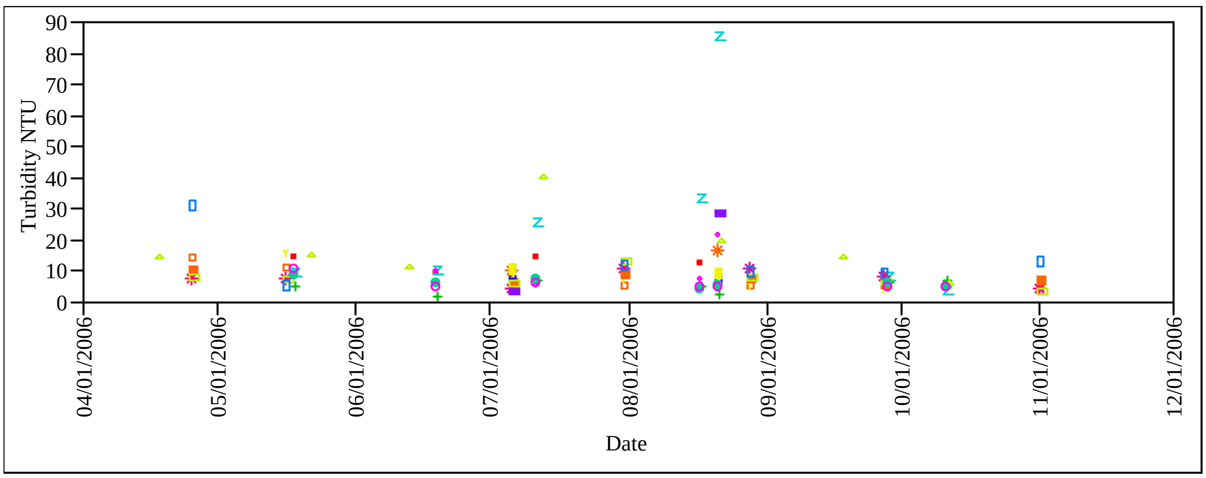


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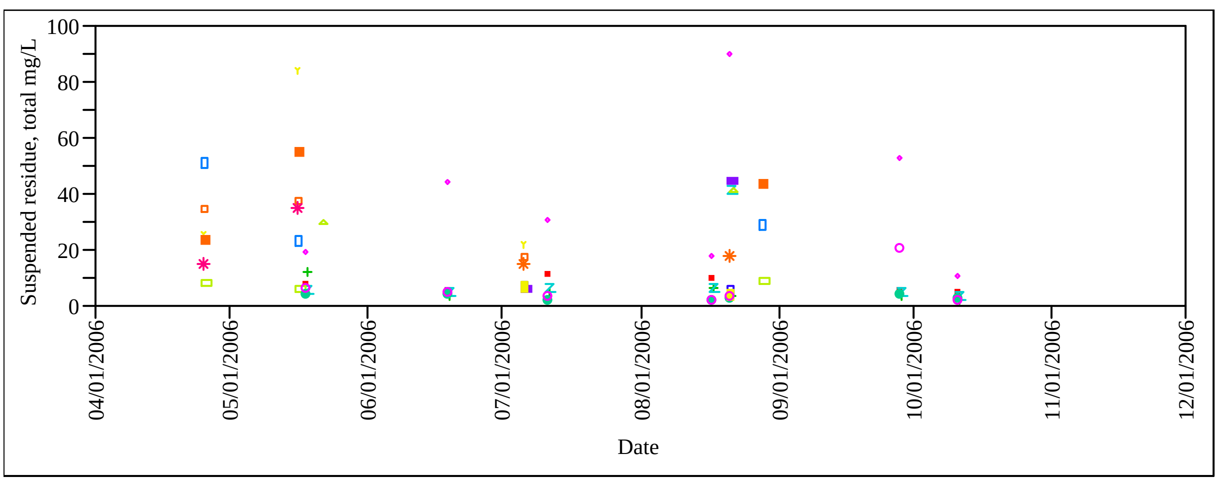

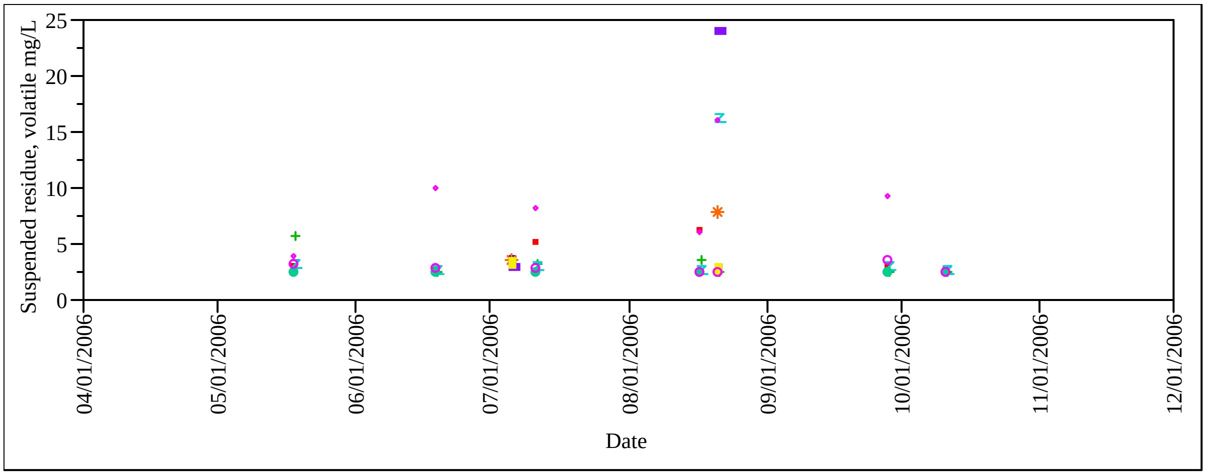


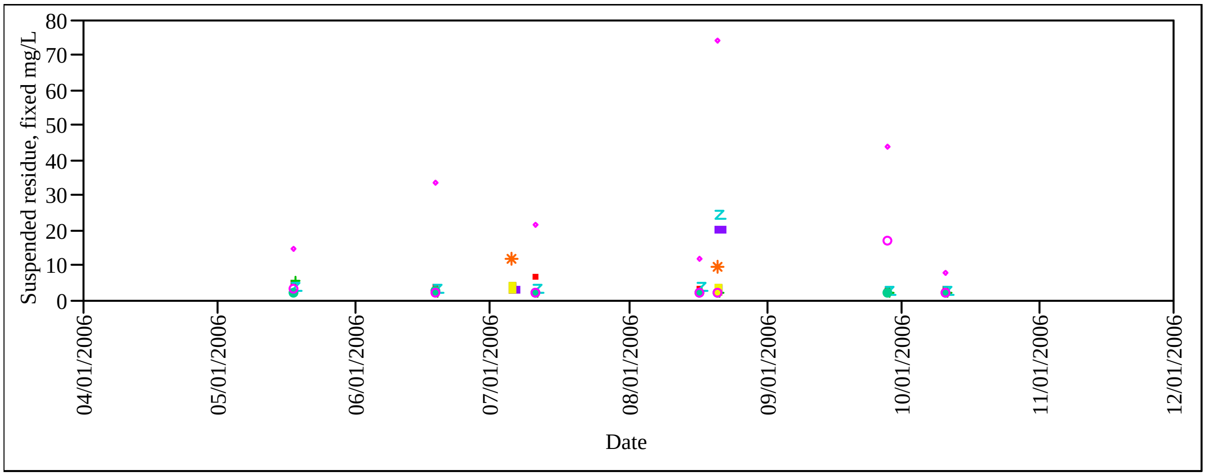


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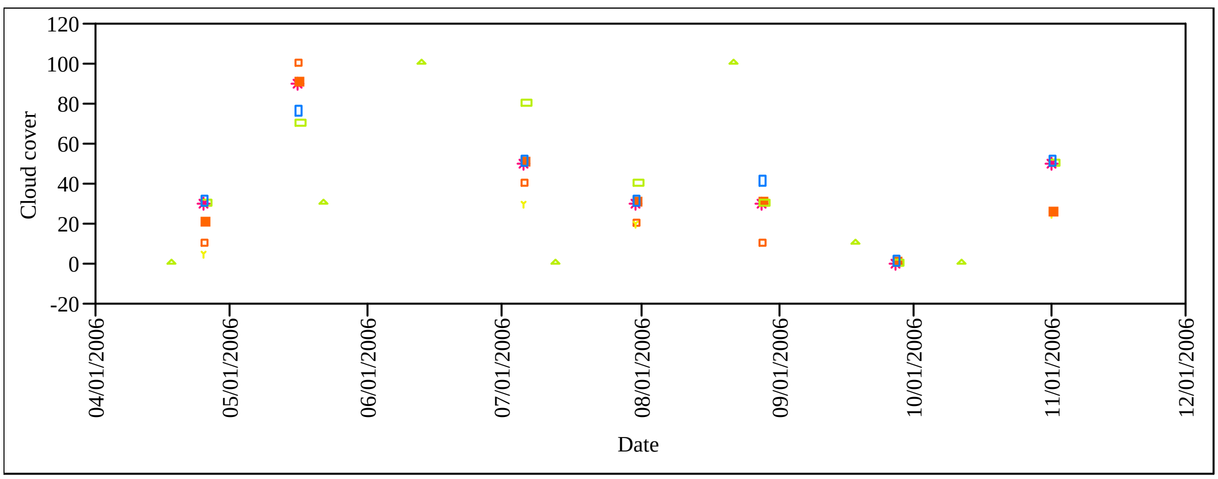

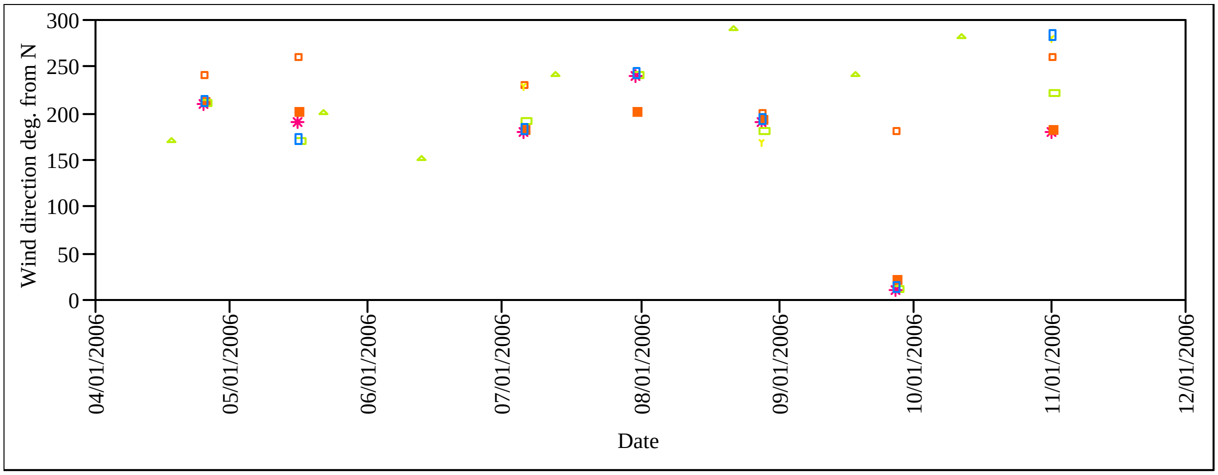
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100
150
200
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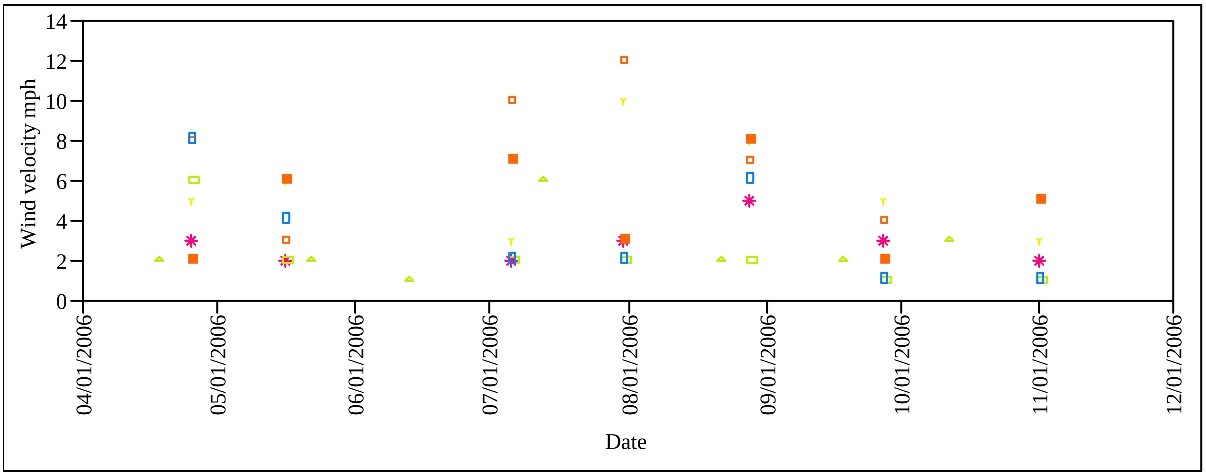
11/01/2006
12/01/2006
Date


Wind velocity mph
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6
8
10
12
14
04/01/2006
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07/01/2006
08/01/2006
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Date

# Lockwoods Folly River Local Watershed Plan

# APPENDIX B

# Modeling Methods

North Carolina
Ecosystem Enhancement Program

June 2007

Prepared by:

Stantec

Stantec Consulting Services Inc.
801 Jones Franklin Road, Suite 300
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## 1.1 WATERSHED MODELING

Watershed and water quality models are essential planning tools for evaluating potential future conditions and the impact of management alternatives in a watershed. There exists a wide range of models based on their complexity, modeled processes and constituents, and spatial and temporal detail. The evaluation tool chosen for use in the Lockwoods Folly watershed is the PLOAD model developed by CH2M HILL for the EPA (2001). The tool is a simple, screening-level model that can provide estimates of nonpoint source pollutant loading on an annual average basis. This tool will allow for an evaluation of the relative magnitude of change in pollutant loading associated with various future scenarios. In addition, results can be used to target management measures to those areas with the highest existing and/or future pollutant loading.

### 1.1.1 Model Description

The PLOAD tool allows for analysis based on one of two empirical approaches: the Simple Method (Schueler, 1987) or export coefficient method. The former method, chosen for the present study, estimates pollutant load as a product of annual runoff volume and pollutant concentration in aggregate for a given watershed area. Runoff volume is calculated from annual rainfall and runoff coefficients based on its relationship to watershed imperviousness. Pollutant concentrations are typically estimated from local and regional data.

As with all modeling approaches, there are limitations that should be considered when evaluating results from the PLOAD model analysis. Its purpose is to provide a general planning estimate of likely pollutant export from delineated regions of a watershed. This model is appropriate for assessing and comparing the changes in relative stormflow pollutant loads from various land use scenarios. The error associated with predicting actual pollutant loads and concentrations using the tool is unknown and could be considerable. Additional limitations of the PLOAD model and the Simple Method are provided below:

- Baseflow contributions to pollutant loading are not considered.
- Instream transport and transformations are not incorporated.
- The model cannot predict loading on short time intervals.
- As a screening tool, the model is not formally calibrated to local, observed data.

### 1.1.2 Model Setup

Since the Simple Method was developed for application to small drainage areas of less than one square mile, the 64 subwatersheds created for the Preliminary Findings Report were segmented into 136 subwatersheds with an average size of 1.13 square miles. The subwatersheds form the basis on which the model is applied and results are given. In order to be consistent with the original intent of Simple Method, The model uses a value of average annual precipitation based on Southport and 49 years of record (56.6 inches). No point sources were included in the model since all wastewater systems in the watershed are non-discharge. Additional parameters and input data developed include land use, impervious factors, event mean concentrations (EMC), and contributions from septic systems. Development of these data is described in the following sections.

### 1.1.3 Existing Land Use

Future and existing land use scenarios were developed for the watershed model. The existing land use map (Figure 7.1) is based on the 2004 Brunswick County existing land use map.

The 2004 Brunswick County existing land use map contains eighteen classes. Each class contains a number of sub-classes. The model existing land use scenario has 15 categories. To convert the existing land use map to the existing land use scenario for input into the watershed model, classes that had similar amounts of impervious cover based on literature were combined to form the categories. For example, the institutional class and the educational facility class were combined with the office and professional sub-class to form the Office/Institutional/Light Industrial category. Other categories that contain developed land are Commercial/Heavy Industrial, four categories of residential land use, Golf Courses, and Roadways. The Pasture and Row Crop categories include all agricultural practices in the watershed including animal operations. Categories based on land cover that may have minimal impervious surfaces include Water, Wetland, Bare Earth, and Forest. The final category is Open Space, which includes cemeteries, recreation centers, and common areas in residential subdivisions.

Although the 2004 Brunswick County existing land use map was created using parcel data, in some areas large numbers of residential parcels were combined and assigned a land use class or sub-class based on the type of house, i.e. single-family residential, double wide mobile home, etc. Residential land use for the watershed model land use scenario is based on density rather than type of house. Therefore all residential classes were initially assigned to the same class regardless of type. Then, the 2004 Brunswick County existing land use map was intersected with county parcel data. This resulted in a parcel based land use map that was then clipped to the watershed boundary. All residential parcels with a building value greater than two hundred dollars and with an area between 0.07 acres and 5 acres were selected. These parcels were then assigned a residential land use dependent on lot size (see Table E.1). A parcel size of 0.07 acres is the smallest allowable parcel for residential buildings according to Brunswick County zoning.

Table E.1. Residential land use categories

| Lot Size (acres) | Residential Category | Residential Category Code |
|---|---|---|
| 0.07 – 0.2249 | Residential high density | RHD |
| 0.2250 – 0.3349 | Residential medium density | RMD |
| 0.3350 – 0.9950 | Residential low density | RLD |
| 0.995 – 5.0 | Residential very low density | RVL |

All residential parcels over five acres were reviewed using 2004 aerial imagery (obtained from Brunswick County) and were then assigned a land use of Forest, Row crop, Pasture, Bare or Open based on land cover. The land cover is the dominant land use in these situations as a house on these large parcels does not contribute a significant amount of impervious surface. All other categories were assigned based on the 2004 Brunswick County existing land use map.

### 1.1.4 Future Land Use

The future land use scenario has the same categories as the existing land use scenario. Brunswick County is in the process of completing a CAMA land use plan. The plan includes a future land use map (Brunswick County 2004). The map was the primary source of information used to determine the future land use scenario for the water quality model. The future land use map did not include the towns of Oak Island, St. James, Varnamtown, or Bolivia. To help determine future land use for these areas the following documents and information were acquired: the future land use map of Varnamtown (Varnamtown 2005), the Bolivia Land Use Plan Amendment (Town of Bolivia 1999), the St. James development plan (lots approved by the county), and written communication with Jerry Walters, the town manager of Oak Island. Other sources of information used to augment the CAMA plan were the NC211 Corridor Study done by the Brunswick County planning department (2006) and the Indirect and Cumulative Impact Assessment Technical Memorandum for the second bridge to Oak Island (NCDOT 2006) as well as the Brunswick County Zoning Map.

Brunswick County

The following table illustrates how the CAMA land use classes were assigned to the model land use categories. All Water, Wetlands, Golf Courses and Roadways in the existing land use scenario were kept the same in the future land use scenario. In addition if existing land use equaled Office/Institutional/Light Industrial or Commercial/Heavy Industrial it was not changed.

Table E.2. Land Use Classes

| CAMA Future Land Use Map | Model Land Use Scenario |
|---|---|
| Commercial | Commercial/Heavy Industrial |
| Industrial | Office/Institutional/Light Industrial |
| Office and Institutional | Office/Institutional/Light Industrial |
| Recreation | Open Space |
| Protected Land | Forest |
| Conservation Land | Existing land use category (see below) |
| High Density Residential | Residential High Density |
| Middle Density Residential | Residential Medium Density |
| Low Density Residential | Residential Low Density |
| Mixed Use | Variable (see below) |

According to the CAMA land use plan, Conservation Land equals land that is undesirable to build on due to proximities to wetlands, flood hazards, storm surge inundation. Areas were located using a land suitability model where all lands in the least suitable category are assigned to conservation land. Original land use categories of Bare, Forest, Golf, Open Space, Pasture, Row Crop, Wetland, and Water were maintained for these areas. Some areas had residential land uses in the existing land use scenario and were not changed to conservation, as it is unlikely existing houses will be removed. In addition all parcels in the Conservation Land category between 0.07 and 1 acre were assigned a residential land use category based on Table E.2. The majority of these small parcels were empty lots in existing subdivisions that will most likely be developed over time.

There were four mixed use circles in the Lockwoods Folly watershed according to the CAMA future land use map. The first one is located at the intersection of US17 and NC211. Existing Commercial/Heavy Industrial and Office/Institutional/Light Industrial as well as Water areas were left in the same category. The rest of the circle was changed to Office/Institutional/Light Industrial if it was zoned as commercial. One area, in the northwest corner of the intersection, was designated as Residential Low Density as it is a proposed development according to the NC211 Corridor Study.

The largest circle is located at the intersection of Midway Road and NC211. For this mixed use area, Office/Institutional/Light Industrial was assigned to parcels along the roadways and Low Density Residential was assigned to the rest of the area with the exception of a wetland area identified on the St James master plan which was assigned to the Wetland category. Two remaining circles were located on NC211 as well, one at the intersection with Sunset Harbor Road and one at Zion Hill/Old Lennon Road. Both of these areas were assigned to the Office/Institutional/Light Industrial category.

The CAMA land use plan includes the area covered by the NC211 Corridor Study. The CAMA plan shows large areas of low-density residential development and conservation land. The NC211 Study shows denser development and very few conservation areas. The Brunswick County Planning Department advised that the NC211 Study illustrates what will happen better than the CAMA plan because most of the developments have already been approved. In addition the Division of Coastal Management has not approved the CAMA plan and there are no ordinances currently in place to ensure the plan will be followed. An average residential density was determined for each approved development in the study area using site plans. Commercial areas were assigned to the Commercial/Heavy Industrial category unless it conflicted with approved developments or existing development. Developments not yet approved, and therefore with no site plan to determine lot size, were assigned to the Residential Low Density category.

<u>Town of Varnamtown</u>

The Varnamtown CAMA land use plan and future land use map were used to determine future land use for all of the area under Varnamtown jurisdiction. As previously noted all Water, Wetlands, Golf Courses and Roadways in the existing land use scenario were kept the same in the future land use scenario. Residential areas were assigned to RHD, RMD, RLD, or RVL based on parcel size. For parcels greater than 5 acres in size, it was assumed they would be divided in the future and developed as Residential Low Density. Neighborhood Business District parcels were assigned to Office/Institutional/Light Industrial and Waterfront District (mixed use) parcels were assigned to Commercial/Heavy Industrial. Finally Conservation parcels were assigned to Forest or Open Space based on visual inspection of 2004 aerial imagery.

Town of Bolivia and Extraterritorial Jurisdiction

All existing developed land uses, water, wetlands, and roadways were maintained in the future land use scenario. To determine future land use for the remaining areas the Town of Bolivia Land Use Plan Amendment from 1999 and the Land Classification Map were used. The map contains a transition zone and a rural zone. All parcels outside of the transition zone as depicted on the Classification Map were given the same land use as in the existing land use scenario. Within the transition zone, the strip along US17 Business was assigned to the Commercial/Heavy Industrial and the remainder of the area was assigned Residential Low Density.

Town of Oak Island and Extraterritorial Jurisdiction (ETJ)

In 2005 the Indirect and Cumulative Impact Assessment for the second bridge to Oak Island was amended. The assessment included a future land use scenario for much of the area south of NC211 including the Town of Oak Island and its ETJ. The assessment along with written correspondence with Jerry Walters, the Town Manager was used to determine the future land use scenario. All of the parcels from the existing land use scenario between 0.07 and 1 acre and categorized as Open Space on the island were assigned a residential land use dependent on lot size. Commercial/Heavy Industrial, Office/Institutional/Light Industrial, Roadways, Forest, Water, and Wetland areas remained unchanged. On the mainland (ETJ), half of the area was assigned to Residential Medium Density and the other half to Office/Institutional/Light Industrial as a government complex and recreation area for Oak Island may be built there in the future.

St. James

For the Town of St. James the development plan that was submitted to the county was used to determine the extent of development and the density of the lots as well as the location of wetlands and open space.

### 1.1.5 Sewer Service

All areas that had sewer service in 2005 were identified on the land use layer. Sewer service was determined based on current NPDES permits as well as input from Brunswick County and the Town of Oak Island staff. Existing sewer in the Lockwoods Folly watershed consisted of a number of package plants that served large subdivisions or municipalities including St. James, Winding River, and a small portion of Oak Island. The Brunswick County Government Complex, Brunswick Community College, and an elementary school in Bolivia all had sewer systems. In

2006 the county opened a new tertiary water reclamation facility. This facility began treating wastewater from the above listed systems (personal communication, Jeff Phillips, Brunswick County).

The future sewer service area was determined based on input from Brunswick County. There have been a number of plans for sewer treatment in the area and plans continue to change. Therefore it is somewhat speculative where sewer will be available in the next twenty years. Currently, all new development must put in sewer infrastructure. Existing developed areas that will connect to the sewer system in the next few years include the rest of Oak Island, Holden Beach, and Supply. Further into the future the Lockwoods Folly Country Club development and the Town of Bolivia will be able to connect. Besides these areas, it is unknown when other existing development may be able to connect to the sewer system. The current policy will allow houses with failing septic tanks to connect to the high-pressure mains but they are required to put in a 200-gallon holding tank (to hold a days worth of sewage).

### 1.1.6 Septic Systems

On-site wastewater systems can be a contributor of nutrients and bacteria to surface waters. Given the prevalence of these systems in Brunswick County and the Lockwoods Folly watershed (Figure E.1), a consideration of the impacts of septic systems within the modeling approach is prudent. The PLOAD modeling framework does not make explicit allowance for septic systems. However, their impacts have been incorporated into the model as point sources: each model subwatershed contains a point source representing loading from septic systems (EPA, 2000). Loading occurs year round with transport occurring during both storms and baseflow through leaching, interflow, and for ponded systems, via overland flow.

The procedure for calculating an annual loading value for each subwatershed point source is based on contributions from both properly functioning and failing septic systems. The calculation is based on the number septic systems, the average number of persons per septic system (or household), septic failure rates, and an average pollutant loading value associated with each person. The loading rate will vary based on whether it is a properly functioning system or not.

Losses of nutrients and bacteria occur in septic systems through denitrification, plant uptake and other soil processes. Fecal coliform is effectively reduced through filtration and other die off mechanisms in properly functioning systems. A large portion of total phosphorus is bound to soil particles, this inhibiting its transport to surface or groundwater in most cases. Nitrogen, however, is highly mobile in the soil profile. Therefore, in addition to loading from failing systems, a value for nitrogen export is added to the annual loading. A loading value selected was 0.21 kg N/person/yr based on a monitoring and modeling study conducted in the Hoods Creek watershed near New Bern, North Carolina (Pradhan et al., 2005).

Septic systems exhibit variable failure rates depending on the type of system, maintenance regime, and environmental factors such as soil type and groundwater level. In a study of septic systems in Brunswick County, Uebler et al. (1983) found that systems on poorly drained Leon soils had a 13% higher rate of failure (20.5% versus 7.5%) compared to other systems. A statewide survey conducted in 1982 and cited in NCDEH (2000) found an average 11.4% failure rate. Data collected by Brunswick County shows 1,091 unique repairs in the watershed based on data from 1980 to mid-2006. Staff with the County Department of Health suggested that the tracking system has evolved over time and the numbers may not represent an exact accounting of the number of repairs conducted. In addition, there may be some systems with failure that are never reported.

Approximately 30 percent of soils within developed parcels on septic fall into the following drainage classes: excessively drained, poorly drained, or very poorly drained. Some of the remaining soils have limited suitability for septic tanks as well. The failure rate used for this study is based on a weighted average of data from Uebler et al. (1983) and county soils data, resulting in a 12% failure rate. In addition, it was assumed that only 50% of these systems are sufficiently close to a waterbody to cause direct loading, resulting in a 6% failure contributing to pollutant loading (Caraco, 2001).

Annual loading rates for TN (4.5 kg/person), TP (0.64 kg/person), and fecal coliform (9.67e10 counts/person) were based on literature sources and local data. It was assumed that septic tanks would not be a significant contributor of TSS. Values for nutrient loading were based on values developed by Beutow (2002) and used for a statewide study in NC of potential nutrient loading from onsite systems (Pradhan et al. 2004). Fecal coliform content in septic effluent ranges $10^4$ to $10^7$ counts/100ml according to Horsely and Whitten (1996) and $10^4$ to $10^6$ counts/100ml according to Schueler (2000). A fecal coliform concentration of $10^5$ counts/100ml was selected for this study.

Additional assumptions used to estimate the impacts of septic systems are as follows:

- Each building unit associated with a parcel without sewer is assumed to have one septic tank.
- The number of people per septic is assumed to be 2.38 persons based on US Census (2000) data from Brunswick County.
- A septic system has an average daily discharge of 70 gal/person/day Horsely and Whitten (1996).

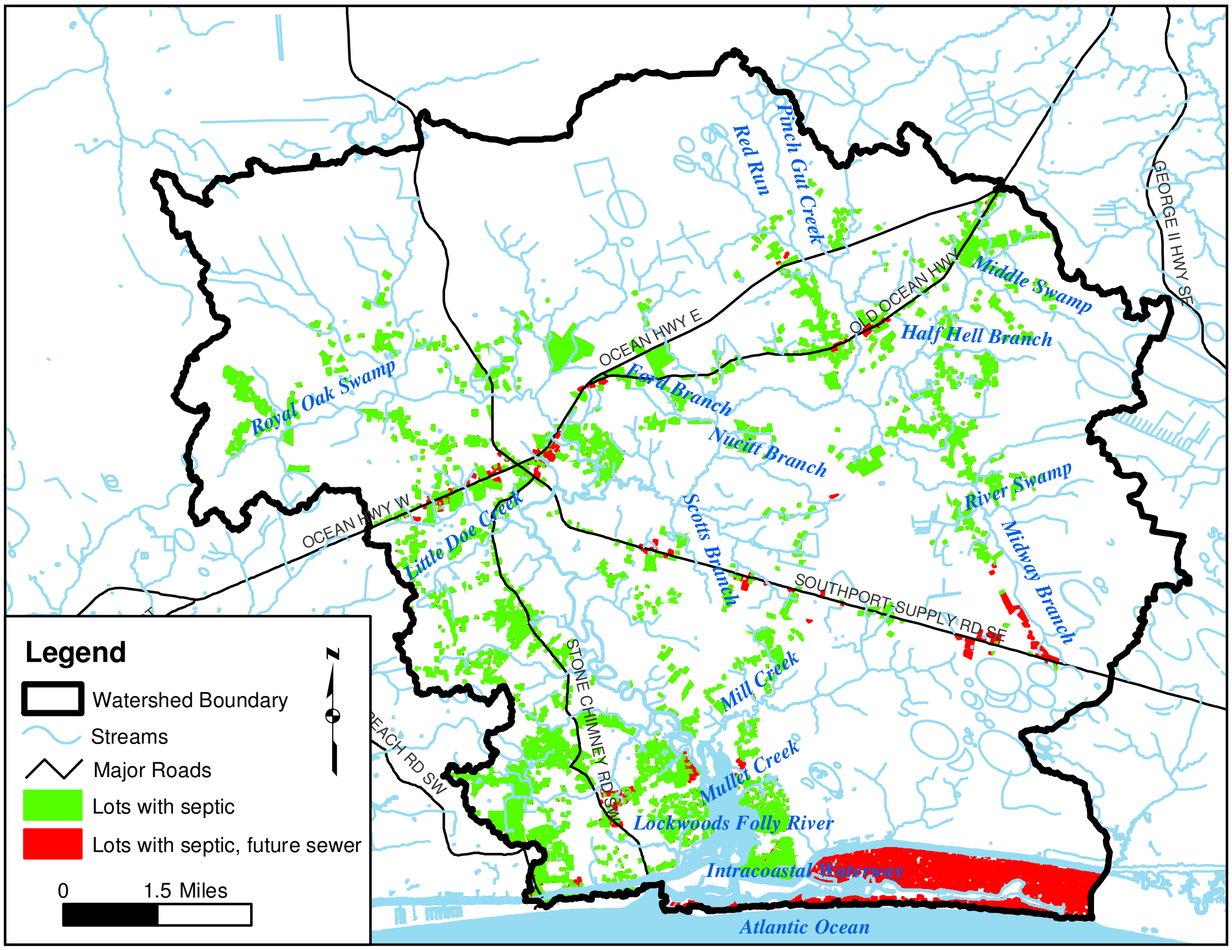


Figure E.1. Parcels with septic systems current and future

### 1.1.7 Impervious Cover Factors

The method used to calculate pollutant loading in PLOAD requires specification of assumed impervious factors for each land use. The impervious factor is subsequently used to calculate a runoff coefficient, which when applied to a rainfall volume yields a corresponding runoff volume.

Site-specific impervious factors were not readily available for the Lockwoods Folly watershed. Therefore, literature-based estimates were adapted to the watershed. Table E.3 below shows values from three literature sources: SCS (1986), Hunt and Lucas (2003), and Cappiella and Brown (2001). Impervious estimates from Hunt and Lucas (2003) and Cappiella and Brown (2001) are close in value, whereas estimates from SCS (1986) are high in comparison, particularly for small residential lots.

Values selected for the Lockwoods Folly model are based on Cappiella and Brown (2001) since they are available for a wide range of land uses (Table E.4). Residential values were calculated using a regression equation based on a strong relationship between average lot size and imperviousness.

Roadway imperviousness is based on the average of the light industrial and commercial categories. This value (63) is close to the value (61) of a semi-rural highway studied in Wu et al. (1998). Impervious values for less developed land uses are also specified in the Table 6.

Table E.3. Estimates of land use imperviousness from the literature

| Land Use Category | Percent Impervious | | |
|---|---|---|---|
| Residential 1/8 acre lot | 38 | 33 | 65 |
| Residential 1/4 acre lot | 30 | 28 | 38 |
| Residential 1/2 acre lot | 22 | 21 | 25 |
| Residential 1acre lot | 14 | 14 | 20 |
| Residential 2 acre lot | 11* | 11 | 12 |
| MultiFamily/Townhome | | 41-44 | 65 |
| Institutional | | 34 | |
| Light Industrial | | 53 | |
| Industrial | | | 72 |
| Commercial | | 72 | 85 |
| | | | |
| Reference | Hunt and Lucas (2003) | Cappiella and Brown (2001) | SCS (1986) |
| Regression Equation | $y=0.148x^{-0.48}$ | $y=14.669x^{-0.42}$ | $y=17.895x^{-0.5707}$ |
| $R^2$ | 0.98 | 0.98 | 0.98 |
| Location | Raleigh, NC | Chesapeake Bay, Va/Md | National Estimate |

* Calculated with regression equation.

Table E.4. Selected imperviousness factors

| Land Use Category | Midpoint | Percent Impervious | Model Code |
|---|---|---|---|
| High Density Residential Lots 0.07 - 0.22 acres | 0.15 | 33 | RHD |
| Medium Density Residential Lots 0.23 - 0.33 acres | 0.28 | 25 | RMD |
| Low Density Residential Lots 0.34 – 0.99 acres | 0.67 | 17 | RLD |
| Very Low Density Residential Lots 1 – 5 acres | 3 | 9 | RVL |
| Commercial/Heavy Industrial | | 72 | COM |
| Office/Institutional/Light Industrial | | 53 | OFF |
| Roadways (w/ right-of-way) | | 63 | ROAD |
| Barren Land [1] | | 32 | BARE |
| Managed Open Space [2] | | 9 | OPN |
| Golf Course [2] | | 9 | GOLF |
| Pasture [3] | | 2 | PAS |
| Row Crop [3] | | 2 | ROW |
| Forest [3] | | 2 | FOR |
| Wetland [3] | | 2 | WET |
| Water [4] | | 90 | WAT |

1 Assumed imperviousness equal to that of a high density residential lot.
2 Based on the assumption that open space in fair condition has about the same runoff response as a low density residential lot (curve numbers are similar in SCS, 1986).
3 Based on example data set in PLOAD manual.
4 Assumes most rainfall on a water body flows to a downstream receiving water.

### 1.1.8 Selection of EMC Values

The PLOAD model calculates annual pollutant loads based on runoff and pollutant event mean concentrations (EMCs) for each land use. EMCs represent the average concentration of a pollutant in stormwater runoff usually reported in mass per unit volume (mg/l). Many factors may affect EMC values including landuse, annual rainfall, percent imperviouness, season, sample collection method, watershed size, and storm event size. Appropriate selection of EMC values is an important step in development of the model application.

Regional differences in EMCs are largely determined by the amount and frequency of rainfall. Pitt et al. (2004) reporting on findings from the National Stormwater Quality Database (NSQD) found that residential areas located in the wettest parts of the country such as the Southeast appear to have lower EMCs for many stormwater pollutants. The result most likely stems from the reduced time between rainfall events allowing for less accumulation of pollutants on impervious surfaces available for washoff during storm event. Regression analyses by Driver (1988) and Maestre and Pitt (2005) have supported similar conclusions. Driver (1988) found that annual rainfall depth was the best overall predictor of stormwater EMCs.

The relative impact of land use and imperviousness is less clear. The National Urban Runoff Program (NURP) findings showed no significant differences in urban runoff concentrations as a function of common urban land uses (EPA, 1983). Maestre and Pitt (2005) conducted a statistical analysis of data from the NSQD focusing on EPA Rain Zone 2, which includes North Carolina, Virginia, Maryland, Tennessee, Kentucky, and West Virginia. They found that only nitrate-nitrite exhibited a significant regression relationship (negative) with percent imperviousness in residential land use categories. A lack of data in the study prevented a full analysis for commercial and industrial land uses.

Several studies have suggested a positive linear relationship between fecal coliform concentrations and impervious cover (Young and Thackston, 1999; Mallin et al., 2000, Tufford and Marshall, 2002). Schueler in CWP (2003) suggested an indirect relationship between bacteria and imperviousness.

Median concentrations of fecal coliforms from the NSWD (Pitt et al., 2005) were higher in residential and open space categories compared to commercial and industrial land uses. The study has also found that the first flush phenomenon is more prevalent in high impervious land uses of commercial development.

EMCs selected for the present study are derived based on a number of sources (see Tables E.5 through E.8). Fecal coliform values tend to be highly variable from storm to storm with a number or sources including both of wild and domestic animals (e.g. geese, deer, livestock, and pets), incidence of septic failure, and sewer overflows or leaks. Table E.5 demonstrates variability between studies and locations as well. Values for the model were based on Zone 2 data in Pitt et al. (2004) and EPA (2001). Texas values were high, perhaps explained by lower rainfall levels (~30 inches per year). However, data from Mecklenburg County suggests that highly urbanized areas of the Southeast can also exhibit high concentrations of fecal coliform.

Climate and physiographic characteristics contribute to high variability in nutrient export from both urban and agricultural watersheds (Beaulac and Reckhow, 1982). In undeveloped watersheds of the southeast, background concentrations of nitrogen (0.5 to 1.0 mg/l) is controlled predominately by atmospheric deposition, whereas phosphorus concentrations (0.014 to 0.037 mg/l) appear to be controlled by rates of organic decomposition and mineral weathering (Clark et al., 2000).

EMC values for nitrogen and phosphorus by land use are presented in Tables E.6 and E.7. National data is shown for perspective, though only regional values were considered for selection.

Regional nitrogen values for residential land uses fell between 1.2 and 3.2 mg/l, while phosphorus EMCs ranged 0.2 to 0.7 mg/l. Nonresidential development fell in about the same range. Final selection was based on an average of the regional values. The lowest selected values were for forested land use: 0.2 mg/l TP and 1.3 mg/L TN. Golf courses, pasture land, and row crop agriculture (conventional is assumed) had the highest nutrient concentrations. Values selected for these rural land uses were based on compressing the range of average values.

Literature estimates of EMCs for total suspended solids (TSS) are presented in Table E.8. TSS exhibits a higher level of variability than do nutrients. Excluding the high values from Driver (1988) and CDM (1993) compresses the range considerably. The selected values are based on the average of the regional values excluding Driver (1988) and CDM (1993). Values for residential and office/light industrial land uses are based directly on the average value, while TSS values for the remaining land uses were reduced from the average to compress the range slightly.

Table E.5. Literature review of fecal coliform EMC values (cfu/100ml)

| Source | Location | Low Density Residential | Medium Density Residential | High Density Residential | Office and Light Industrial | Commercial and Heavy Industrial | Road | Forest | Golf and Managed Open Space | Pasture | Row Crop |
|---|---|---|---|---|---|---|---|---|---|---|---|
| Pitt et al. (2004) | US | 8345 | 8345 | 8345 | 2500 | 4300 | | | | | |
| NURP (1983) | US | 101 | 101 | 101 | | 21000 | | | | | |
| Pitt et al. (2004) | EPA Rain Zone 2 | 1600 | 1600 | 1600 | 1377 | 2400 | | | | | |
| Pitt et al. (2004) | EPA Rain Zone 3 | 2800 | 2800 | 2800 | 210 | 2000 | | | | | |
| Tetra Tech (2005) [1] | NC | | | | | 1540 | 1540 | 252 | 100 | 12500 | 414 |
| Young and Thackston (1999) [2, 3] | TN | 12182 | | | | | | | | | |
| EPA (2001) [1] | GA | 8700 | 8700 | 8700 | 1400 | 1850 | 1400 | 500 | 500 | | |
| Newell et al. (1992) [1] | TX | 22000 | 22000 | 22000 | 22000 | 22000 | | 1600 | 2500 | 2500 | 2500 |
| Baird et al. (1996) | TX | 20000 | 20000 | 20000 | 9700 | 6900 | 53000 | | | | |
| Bales et al. (1999) | NC | | 29000 | | 27500 | 14600 | | | | | |
| **Selected Value** | | **5150** | **5150** | **5150** | **1389** | **2125** | **1400** | **500** | **500** | **1000** | **500** |

All values are medians unless otherwise noted.

1 Literature review and/or BPJ

2 Mean value

3 Average of winter and summer storms

Table E.6. Literature review of total nitrogen EMC values (mg/l)

| Source | Location | Low Density Residential | Medium Density Residential | High Density Residential | Office and Light Industrial | Commercial and Heavy Industrial | Road | Forest | Golf | Pasture | Row Crop | Managed Open Space |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NURP (1983) | US | 2.64 | 2.64 | 2.64 | | 1.75 | | 1.51 | | | | |
| Smullen and Cave (1998) | US | 2.00 | 2.00 | 2.00 | | 2.00 | | 2.00 | | | | |
| Schueler (1987) | US | 2.20 | 2.20 | 2.20 | | 2.25 | 3.00 | 0.78 | | | | |
| Pitt et al. (2004) | US | | | 2.00 | 2.04 | 2.20 | 2.28 | | | | | 1.33 |
| Driscoll et al. (1990) | US | | | | | | 2.14 | | | | | |
| Driver (1988) | Region 3 | 2.15 | 2.15 | 2.15 | | | | | | | | |
| CDM (1993) | GA | 3.05 | 2.06 | 1.93 | 2.25 | 3.15 | | 0.71 | | | | |
| Baird et al. (1996) | TX | 1.82 | 1.82 | 1.82 | 1.26 | 1.34 | 1.86 | 1.50 | | | 4.40 | |
| Harper (1994) | FL | 1.77 | 2.29 | 2.42 | | 1.93 | 2.08 | 1.60 | | 2.48 | 2.68 | 1.25 |
| Pitt et al. (2004) | EPA Rain Zone 3 | 1.60 | 1.60 | 1.60 | 1.24 | 1.55 | | | | | | |
| Pitt et al. (2004) | EPA Zone 2 | 1.97 | 1.97 | 1.97 | 1.95 | 2.18 | | | | | | 2.19 |
| Wu et al. (1998) | NC | | | | | | 1.14 | | | | | |
| Line et al. (2002) | NC | | 1.97 | | | 1.30 | | 1.47 | 6.13 | 3.61 | | |
| Hunt and Lucas (2003) [1] | NC | 1.65 | 2.02 | 1.61 | 2.02 | 2.09 | | 1.05 | | | | |
| Tetra Tech (2005) [2] | NC-Neuse | | | | | 3.48 | 3.48 | 1.45 | 6.23 | 2.59 | 2.59 | 6.23 |
| Tetra Tech (2004) [2] | NC-Cary | 3.00 | 2.30 | 2.00 | 2.10 | 3.50 | | 1.50 | | | | |
| Bales et al. (1999) | NC-Mecklenburg | | 2.10 | | 1.10 | 1.60 | | | | | | |
| CH2M HILL (2000) [3] | NC | 1.20 | 1.70 | 2.70 | 2.40 | 3.10 | 3.30 | 1.10 | 1.10 | 1.10 | 1.10 | 1.10 |
| **Selected Value** | | **2.0** | **2.0** | **2.0** | **1.8** | **2.3** | **2.4** | **1.3** | **3.0** | **2.7** | **2.7** | **2.7** |

All values are medians unless otherwise noted.

1 Mean value

2 Literature review and/or BPJ

3 Regression analysis

Table E.7. Literature review of total phosphorus EMC values (mg/l)

| Source | Location | Low Density Residential | Medium Density Residential | High Density Residential | Office and Light Industrial | Commercial and Heavy Industrial | Road | Forest | Golf | Pasture | Row Crop | Managed Open Space |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| NURP (1983) | US | 0.38 | 0.38 | 0.38 | | 0.20 | | 0.12 | | | | |
| Smullen and Cave (1998) | US | 0.26 | 0.26 | 0.26 | | 0.26 | 0.26 | | | | | |
| Schueler (1987) | US | 0.40 | 0.40 | 0.40 | | 0.30 | 0.50 | 0.15 | | | | |
| Pitt et al. (2004) | US | | | 0.30 | 0.22 | 0.22 | 0.25 | | | | | 0.31 |
| Driscoll et al. (1990) | US | | | | | | 0.29 | | | | | |
| Driver (1988) | Region III | 0.31 | 0.31 | 0.31 | | | | | | | | |
| CDM (1993) | GA | 0.67 | 0.47 | 0.19 | 0.17 | 0.45 | | | | | | |
| Baird et al. (1996) | TX | 0.57 | 0.57 | 0.57 | 0.28 | 0.32 | 0.22 | 0.12 | | | 1.3 | |
| Harper (1994) | FL | 0.18 | 0.30 | 0.49 | | 0.33 | 0.34 | 0.19 | | 0.48 | 0.56 | 0.05 |
| Pitt et al. (2004) | EPA Rain Zone 3 | 0.18 | 0.18 | 0.18 | 0.16 | 0.11 | | | | | | |
| Pitt et al. (2004) | EPA Zone 2 | 0.29 | 0.29 | 0.29 | 0.21 | 0.22 | | | | | | 0.15 |
| Wu et al. (1998) | NC | | | | | | 0.37 | | | | | |
| Line et al. (2002) | NC | | 0.40 | | | 0.23 | | 0.25 | 0.82 | 1.56 | | |
| Hunt and Lucas (2003) [1] | NC | 0.26 | 0.37 | 0.24 | 0.32 | 0.33 | | 0.17 | | | | |
| Tetra Tech (2005) [2] | NC-Neuse | | | | | 0.49 | 0.49 | 0.25 | 1.13 | 0.4 | 0.4 | 1.13 |
| Tetra Tech (2004) [2] | NC-Cary | 0.50 | 0.40 | 0.30 | 0.17 | 0.50 | | 0.25 | | | | |
| Bales et al. (1999) | Mecklenburg | | 0.29 | | 0.20 | 0.26 | | | | | | |
| CH2M HILL (2000) [3] | NC | 0.20 | 0.30 | 0.40 | 0.30 | 0.40 | 0.40 | 0.2 | 0.2 | 0.2 | 0.2 | 0.2 |
| **Selected Value** | | **0.4** | **0.4** | **0.3** | **0.3** | **0.3** | **0.4** | **0.2** | **0.7** | **0.7** | **0.6** | **0.4** |

All values are medians unless otherwise noted.

1 Mean value

2 Literature review and/or BPJ

3 Regression analysis

Table E.8. Literature review of total suspended solids (TSS) EMC values (mg/l)

| Source | Location | Low Density Residential | Medium Density Residential | High Density Residential | Office and Light Industrial | Commercial and Heavy Industrial | Road | Forest | Golf plus Managed Open Space | Pasture | Row Crop |
|---|---|---|---|---|---|---|---|---|---|---|---|
| NURP (1983) | US | 101 | 101 | 101 | | 69 | | 70 | | | |
| Smullen and Cave (1998 | US | 55 | 55 | 55 | | 55 | | 55 | | | |
| Schueler (1987) | US | 100 | 100 | 100 | | 98 | 150 | | | | |
| Driscoll et al. (1990) | US | | | | | | 93 | | | | |
| Pitt et al. (2004) | US | | | 49 | | 42 | 99 | | 11 | | |
| Driver (1988) [1] | Region III | 120 | 120 | 120 | | | | | | | |
| CDM (1993) | GA | 280 | 140 | 109 | 93 | 243 | | 216 | | | |
| Baird et al. (1969) | TX | 41 | 41 | 41 | 61 | 56 | 74 | 70 | | | 107 |
| Harper (1994) | FL | 19 | 27 | 72 | | 90 | 50 | 10 | 11 | 94 | 55 |
| Pitt et al. (2004) | EPA Rain Zone 3 | 41 | 41 | 41 | 66 | 34 | | | 49 | | |
| Pitt et al. (2004) | EPA Rain Zone 2 | 43 | 43 | 43 | 37 | 39 | | | | | |
| Wu et al. (1998) | NC | | | | | | 88 | | | | |
| Line et al. (2002) | NC | | 42 | | 48 | 170 | | 113 | 150 | 84 | |
| Hunt and Lucas (2003) [1] | NC | | | | | | | | | | |
| Tetra Tech (2005) [2] | NC-Neuse | | | | | 70 | 70 | 49 | 25 | 400 | 400 |
| Tetra Tech (2004) [2] | NC-Cary | 25 | 42 | 75 | | 69 | | 50 | | | |
| CH2M HILL (2000) [3] | NC | 22 | 52 | 48 | 42 | 54 | 58 | 20 | 20 | 19 | 19 |
| **Selected Value** | | **32** | **41** | **53** | **51** | **60** | **60** | **40** | **32** | **80** | **100** |

All values are medians unless otherwise noted.

1 Mean value

2 Literature review and/or BPJ

3 Regression analysis

### 1.1.9 Consideration of Water Quality Regulations

Existing and future water quality regulations were incorporated into the analysis to the extent possible allowed by the PLOAD framework.

In the existing land use scenario, the development regulations contained within the coastal stormwater management program were used (15A NCAC 02H .1005). The local ordinances for the County and its municipalities are largely based on the requirements of this state regulation. The regulations applicable to the Lockwoods Folly watershed and considered in the model application are as follows:

- Within one-half mile of and draining to SA waters or unnamed tributaries to SA waters: development activities with built-upon area greater than 25% must use stormwater control systems to treat runoff from 1.5 inches of rainfall. No direct outlet channels or pipes are allowed to SA waters (unless permitted via 15A NCAC 2H .0126).

- Within all other areas of Brunswick County, a coastal CAMA county: development activities with built-upon area greater than 30% must treat runoff from the one inch rainfall.

Session Law 2006-246 was approved by the NC Legislature and signed into law in late summer of 2006. The act provides for the implementation of the federal Phase II stormwater program and additional stormwater management provisions. Beginning 1 July 2007, any new development that cumulatively disturbs one acre or more of land located in Brunswick County or municipalities contained therein must comply with the standards set forth in Section 9 of Session Law 2006-246. The future scenarios in the model include consideration of these requirements. In addition, Leland, Navassa, and Oak Island will be issued Phase II NPDES permits. In the Lockwoods Folly watershed, Section 9 would require the following:

- Within one-half mile of and draining to Shellfish Resources Waters (essentially SA waters): development activities with built-upon area greater 12% must use stormwater control systems to treat runoff from the one-year, 24 hour rainfall (~3.5 inches). Prohibits new points of stormwater discharge.

- Within all other areas of the watershed: development activities with built-upon area greater than 24% must treat runoff from the 1.5-inch rainfall.

For land uses with assumed imperviousness that exceed the limits applicable to existing and future scenarios, it was assumed that one or more BMPs would be implemented to treat runoff from the developed land area. A reduction factor, applied to the EMC value, was calculated based on an assumed BMP treatment efficiency and a discount for storm capture. The storm capture discount is based on the design storm required by the regulation. For the one-inch design storm, since approximately 80% of storms that occur on an annual basis are one inch or less (NCDWQ, 2005), a discount factor of 80% is applied to the BMP efficiencies. Discount factors of 90% and 98% are applied for the 1.5-inch and 3.5-inch design storms, respectively.

The following BMP efficiencies were incorporated into the analysis to simulate application of existing and future regulations (Table E.9).

Table E.9. BMP reduction efficiencies from the literature

| | Range of Values for Various BMPs[1] | Efficiency Selected | Literature Reference |
|---|---|---|---|
| Total Suspended Solids | 76 to 95% | 85%[2] | Winer (2000) |
| Total Nitrogen | 20 to 40% | 30% | NCDWQ (2004) |
| Total Phosphorus | 20 to 45% | 35% | NCDWQ (2004) |
| Fecal Coliform | 37 to 78% | 50% | Winer (2000) |

1 Excludes consideration of dry detention

2 TSS efficiency based on design standard set forth in the regulation

While important to preserve the physical integrity of a watercourse, consideration of the 30-foot vegetative buffer required for low density developments under the coastal stormwater rules is not directly incorporated into the model. The setback, alone, is unlikely to result in significant nutrient reductions from urban stormwater runoff due to the amount of land it would treat combined with its minimal width. For urban runoff, Claytor and Schueler (1996) suggest that the filter strip can only treat an impervious are approximately equivalent to its own area. For higher density development, the setback required under the Brunswick County stormwater program is considered to be included in the reductions factors applied to the EMC values.

Brunswick County requires peak discharge control for the 1-year, 24-hour storm for developments with greater or equal to 15% built-upon area. This provision is not incorporated into the model scenarios for the following reasons: limitations of the modeling tool, mitigating peak flow will have little impact on long term runoff, and that part of the pollutant treatment provided by peak flow control is already incorporated in the controls provided by higher density developments.

### 1.1.10 Future LID Management Scenarios

Low impact development (LID) is a site design strategy that seeks to minimize runoff and maintain the predevelopment hydrologic regime through the use of BMPs and landscape design techniques. LID development typically uses filtering and infiltration practices such as bioretention, sand filters, and vegetative swales. These practices can have reduction efficiencies greater than many structural practices like wet ponds and stormwater wetlands for many constituents. Three LID scenarios were developed for the model. The first assumed that approximately half of the residential area identified in the first scenario would be developed using LID. The second was based on the assumption that all future residential development categories except for RVL would be designed using LID techniques. A third LID scenario uses the assumptions in scenario 2 above and adds preservation of approximately 10% of the land that would otherwise be developed in an undeveloped state.

The preservation parcels were selected based on a study done in 2005 that used logistic and hydrologic criteria to identify and recommend properties in the watershed that should be protected and/or acquired (Lynch). In this study all tax parcels larger than 50 acres with no buildings located on them were selected. This resulted in 174 eligible parcels. Factors considered in ranking the 174 parcels included acreage, risk to water quality, percent highly saturated soil, and proximity to streams. The study focused on the top ten parcels for preservation in the watershed (Lynch 2005). In order to increase the preservation area to 10% of the watershed to be used in the third LID scenario, undeveloped parcels with stream frontage greater than 3,851 feet were selected as well as parcels with greater than 31% of soils in hydrologic group D and those that scored greater than 2.71 on the risk to water quality if developed (scores ranged from 1.67 to 3.87).

A similar method of adjusting the EMC values by multiplying them by a reduction factor was used to simulate the LID-based scenarios. Reductions were based on data for LID practices described in Winer (2000) and Schueler (1999) and categorized as filtering practices, infiltration practices and water quality swales (Table e.10). The average reduction value was used and adjusted by discount factors described earlier.

Table E.10. LID-type BMP efficiencies from the literature

| | Range of Values for LID-Type BMPs | Efficiency Selected | Literature Reference |
|---|---|---|---|
| Total Suspended Solids | 81 to 95% | 87% | Winer (2000) |
| Total Nitrogen | 35 to 84% | 57% | Winer (2000) |
| Total Phosphorus | 34 to 70% | 54% | Winer (2000) |
| Fecal Coliform | 51 to 55%[1] | 55% | Winer (2000)<br>Schueler (1999) |

1 Excludes efficiencies for water quality swales, which were based on limited data according to both Winer (2000) and Schueler (1999).

# Appendix C

## Ecological Assessment of Three Coastal Stream Networks in the Lockwoods Folly Basin, North Carolina

Draft Report to the Ecosystem Enhancement Program
North Carolina Department of Environment
and Natural Resources*

December 2006

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***Draft report for Contract Number D06025 between East Carolina University and the North Carolina Department of Environment and Natural Resources.**

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**ABSTRACT**

The ecological condition of stream-riparian condition (SRC) was assessed for drainage networks in three coastal sub-basins of the Lockwoods Folly, North Carolina, watershed. The protocol used was a reference-based assessment that had been developed for inner coastal plain watersheds. Like the earlier study, it used a random selection of stream reaches 100 yards in length, consisted of 8 or 9 indicators, and could be completed in the field in less than 1 hour each. Modifications included the need to apply different criteria for extending mapped channels upstream and removing downstream reaches that were tidally influenced. The former modification was influenced by the generally sandier soils, and thus resulted in a relatively lower projected drainage density than the earlier study. Removal of tidally influenced reaches was needed because tidal inundation interfered with the way indicators would be scored and because we wanted to compare the two studies. Indicators were aggregated logically into scores reflective of the current understanding between indicators and ecosystem functioning for the riparian zone and channel. Assessments were applied to an average of 3.4 percent of total stream length.

Of the 140 randomly chosen reaches, 80 percent were low order (1$^{st}$ and 2$^{nd}$), 6 percent high order (3$^{rd}$ and 4$^{th}$), and the remaining 14 percent impounded by beaver, and thus not assessed. Each of the coastal sub-basins were in better condition than those of the inner coastal plain study. Moreover, channel condition in the Lockwoods Folly network was better relative to SRC than the previous study. Some of the difference can be attributed to a lesser amount and intensity of agriculture in the Lockwoods Folly basin, which, in turn, may be influenced by the sandier, less fertile soils. The watersheds are currently undergoing rapid development toward retirement community land use, however, but thus far these activities have had little observable effect on SRC. Good agreement was achieved between the team that developed the protocol and the consulting team that collected the data. The results may be used to track net change over time in response to stream and riparian improvement (from restoration) and degradation (from continuing alterations). The approach could be useful as part of a broader assessment method for coastal watersheds that includes additional indicators of shoreline, nearshore, and offshore condition.

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## INTRODUCTION

### Channel-riparian assessment protocols

In 2000, the North Carolina Wetlands Restoration Program, since reorganized as part of the Ecosystem Enhancement Program (EEP), recognized that it needed a functionally-based tool for assessing riparian ecosystems. To contribute toward this effort, EEP contracted with East Carolina University (ECU) scientists to develop a series of reference-based rapid assessment procedures for riparian ecosystems (Rheinhardt et al. 2005, Brinson et al. 2006). Protocols were developed for each of the four types of streams that occur in the inner coastal plain: (1) rural low ($1^{st}$-$2^{nd}$) order reaches, (2) rural high ($3^{rd}$-$4^{th}$) order, (3) urban low order, and (4) urban high order reaches. The protocol for each reach type was designed to quantify ecological condition along a designated 100-yd reach of a stream and its 180-ft-wide riparian zone (Figure 1) by evaluating 8-9 indicators (Table 1) of stream and riparian zone condition. Information from condition assessments were intended to be used to diagnose problems with stream reaches, provide quantitative information on network condition that could be used to determine the relative contribution of stream networks to downstream water quality, particularly in receiving estuaries, and track changes over time to evaluate the effectiveness of restoration in watersheds.


**Figure 1. Various riparian zones and their boundaries. Condition is evaluated for each zone on each side of stream before being combined to provide one condition score (maximum score, 100).**

**Table 1. Indicators adopted for the riparian assessment protocol and examples of rationale for adoption. Each indicator is scored between 0 and 100 based on measurements and narrative descriptions, but calibrations of indicators differed among the four reach types. Detailed rationale are provided in Rheinhardt et al. (2006). "Stream bank stability" was not assessed in rural low order reach type.**

| | | Associated function | |
|---|---|---|---|
| **Indicator** | **Rationale** | **Channel** | **Riparian Zone** |
| Near-stream cover (0-3 m) | Plants nearest the stream channel contribute organic matter to the channel from litterfall, stabilize banks to reduce sediments from entering stream, contribute organic matter for denitrifying bacteria, and assimilate nutrients through plant growth. | Biogeochemistry<br>Habitat quality | |
| Riparian zone cover (0-30 m) | Vegetated riparian zones contribute to infiltration of precipitation, groundwater storage, and evapotranspiration. Refers to quality of cover (forested cover is most effective) and weighted distance (cover closest to channel is most effective). | | Hydrology<br>Biogeochemistry<br>Habitat quality |
| Instream woody structure | Wood in channel creates riffle and pool sequences that dissipate energy of flowing water and store water in pools during low flows. | Hydrology<br>Biogeochemistry<br>Habitat quality | |
| Sediment regime | Excessive sediment may transport phosphorus and heavy metals to the channel. | Biogeochemistry | |
| Channel-riparian zone connection | Overbank flow dissipates energy, thus reducing channel incision and bank erosion. Storage of water in floodplains reduces downstream flood peaks and contributes to de-synchronization of flood pulses at watershed scales. | Hydrology<br>Biogeochemistry<br>Habitat quality | Hydrology<br>Biogeochemistry<br>Habitat quality |
| Pollution affecting stream | Pollution from roadside ditches and ditches draining agricultural fields, both upstream and within a reach, degrades instream habitat and interferes with normal biogeochemical cycling. Impervious surfaces and channelized tributaries increase flashiness of flow and may lead to channel incision, bank erosion, and a decrease in groundwater discharge. | Hydrology<br>Biogeochemistry<br>Habitat quality | |
| Factors affecting riparian zone | Alterations, ranging from conversion to impervious surface to filling with spoil, interfere with hydrologic functioning. | | Hydrology<br>Biogeochemistry<br>Habitat quality |
| Habitat quality of riparian zone | Forest species composition, forest age, and 3-D structure contribute to nesting, foraging, and denning opportunities that are otherwise absent in altered forests. | | Habitat quality |
| Stream bank stability | Degree of bank erosion, when excessive, increases suspended sediments downstream. (Not used in rural low order streams because of difficulty in assessing.) | Biogeochemistry<br>Habitat quality | |

Each stream-riparian condition (SRC) indicator score was partitioned into four condition categories, 0-29 (Severely altered), 30-59 (Altered), 60-89 (Somewhat altered), and 90-100 (Relatively unaltered). Narratives were provided for each indicator to allow field crews to score the condition of SRC indicators within each of the four condition categories. Descriptors of indicator conditions were derived from a ranking of reference data along a gradient of alteration from least to most altered. In this way, indicator scores were calibrated using variations in conditions among real (reference) sites of the same type. SRC indicators used to evaluate condition are multivariate, in the sense that the score of each indicator relies on one or more field observations. By explicitly describing variations in conditions within each category based on reference conditions, the amount of “best professional judgment” that could be interjected into scoring indicators is minimized (Rheinhardt et al. 2006).

After scoring the SRC indicators, each indicator score is aggregated with the other indicator scores based on its relationship to hydrologic, biogeochemical, and/or habitat quality functioning (Figure 2). In so doing, the suite of condition indicators provides a more encompassing indicator of reach condition in relation to function. However, indicator and/or function scores can be aggregated still further, at the watershed level, by averaging condition scores of randomly chosen reaches within a stream network. Ultimately, indicators and function scores should be useful for tracking net change over time in response to stream-riparian improvement (from restoration) and degradation (from continuing alterations). This could provide information to help prioritize restoration in and among stream networks and to track changes over time.

**Field testing protocols**

The four assessment protocols were field tested in 2005 by teams of consultants contracted by EEP as part of an initiative to develop watershed plans for targeted watersheds. The stream networks for assessment were primarily chosen based on anticipated compensatory mitigation needs for highway construction projects in the targeted watersheds. EEP used the watershed planning process as an opportunity to provide a forum for local communities to contribute to the watershed plans. Tests of the protocols in the targeted watersheds had two main objectives: (1) to determine how closely indicator scores obtained by trained resource professionals matched the scores obtained by the ECU team that developed the method and (2) to provide a case study on how assessment scores from randomly-chosen reaches could be used to evaluate stream network condition as one tool for determining a network’s potential for providing compensatory mitigation needs.

Test results showed that the rural protocols were robust in consistency of scoring among test groups, i.e., users tended to score indicators as intended (similar to the ECU scientists). However, scoring consistency was less robust for urban reaches for some indicators. Lack of consistency was partly due to problems associated with the specific wording of the narratives, but was also related to inadequate calibration of the indicators. Following the testing, improvements were made to data sheets to help clarify narrative descriptions for the urban and rural protocols. Additional research is currently underway that will help better calibrate indicator scoring for urban reaches. Results of the urban reach research will be the subject of a separate report.

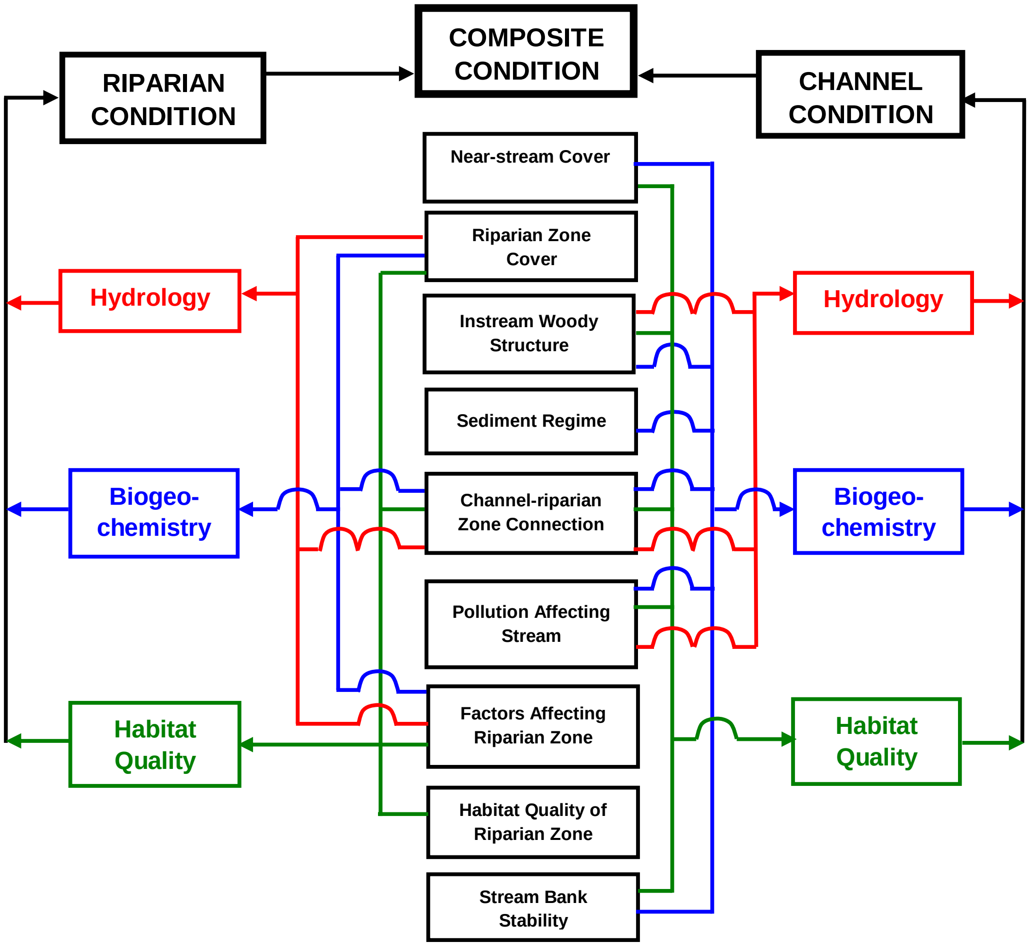



**Figure 2. Aggregation of indicators that characterize functions and the condition of channels and riparian zones. For each randomly chosen reach, the function scores for riparian zone and stream channel reflect the mean of the indicators attributed to them (sorted by color), with the exception that the indicator "Stream bank stability" was not measured in rural low order reaches, nor were "Sediment regime," "Channel-riparian zone connection," and "Stream bank stability" in reaches where the channel was backed up by an impoundment. This aggregation provides a de facto weighting of indicator scores. The three function scores are averaged for channel and riparian zone separately to obtain condition scores for each.**

**Coastal watershed assessments**

Once the assessment protocols were shown to work in inner coastal plain watersheds, NC-EEP became interested in expanding condition assessments to coastal watersheds, i.e., those adjoining estuaries. Coastal watersheds include both their tributary streams (stream network) and their nearshore zones. Therefore, it became obvious that assessments of aquatic resource condition in coastal watersheds would require different procedures that those developed for inland watersheds. Coastal watersheds require different protocols for several reasons: (1) coastal stream networks flow directly into estuarine waters rather than to larger freshwater rivers (such as the Chowan, Roanoke, Neuse, Tar, etc.) and so contribute flow that directly affects shallow estuarine embayments (receptor habitats) associated with the watersheds and (2) coastal watersheds are also affected by shoreline modifications and by the conditions in the estuary proper.

We hypothesized that the protocol developed for assessing inner coastal plain stream networks would likely be useful for assessing one aspect of coastal resource condition. However, since the SRC assessment protocols were developed from reference sites in the inner coastal plain, we were not sure to what extent the indicators would incorporate potential alterations to coastal streams. Therefore, one objective of this study was to determine if the protocols were appropriate for coastal watersheds, and if not, how they could be changed to be more robust. Another objective was to compare the variation in indicator scores between consultant teams and the ECU team to see if further refinement of narratives was needed. A third objective was to evaluate assessment data collected by consultant teams from three coastal watersheds to identify causes and sources of degradation and identify potential restoration opportunities. This would represent a case study of coastal watershed condition analogous to an earlier study of six inner coastal plain watersheds (Rheinhardt et al. 2005, Rheinhardt et al. in review).

We recognized that the riparian protocols lacked the capacity to evaluate the effects of alterations to the coastal watersheds that occur in the near shore zone and estuary proper. In a companion report, we proposed a potential framework for developing a functionally-based, condition assessment protocol for coastal watersheds (Rheinhardt and Brinson in review), of which the stream network protocol would be one part.

## METHODS

EEP identified the Lockwoods Folly drainage basin (Figure 3) as the focus of a coastal watershed planning effort where the SRC assessment protocol would be applied and further tested. As in the previous study by Rheinhardt et al. (2005), randomly chosen points in the stream network were the focal point of reach-scale assessments conducted by consultants. In the Lockwoods Folly basin, Stantec scientists were contracted by EEP to conduct the assessments. However, before assigning points, we first had to produce a digital hydrographic layer that accurately represented the true stream network. For the coastal plain (inland) watersheds, we had used line shapefiles derived from USGS

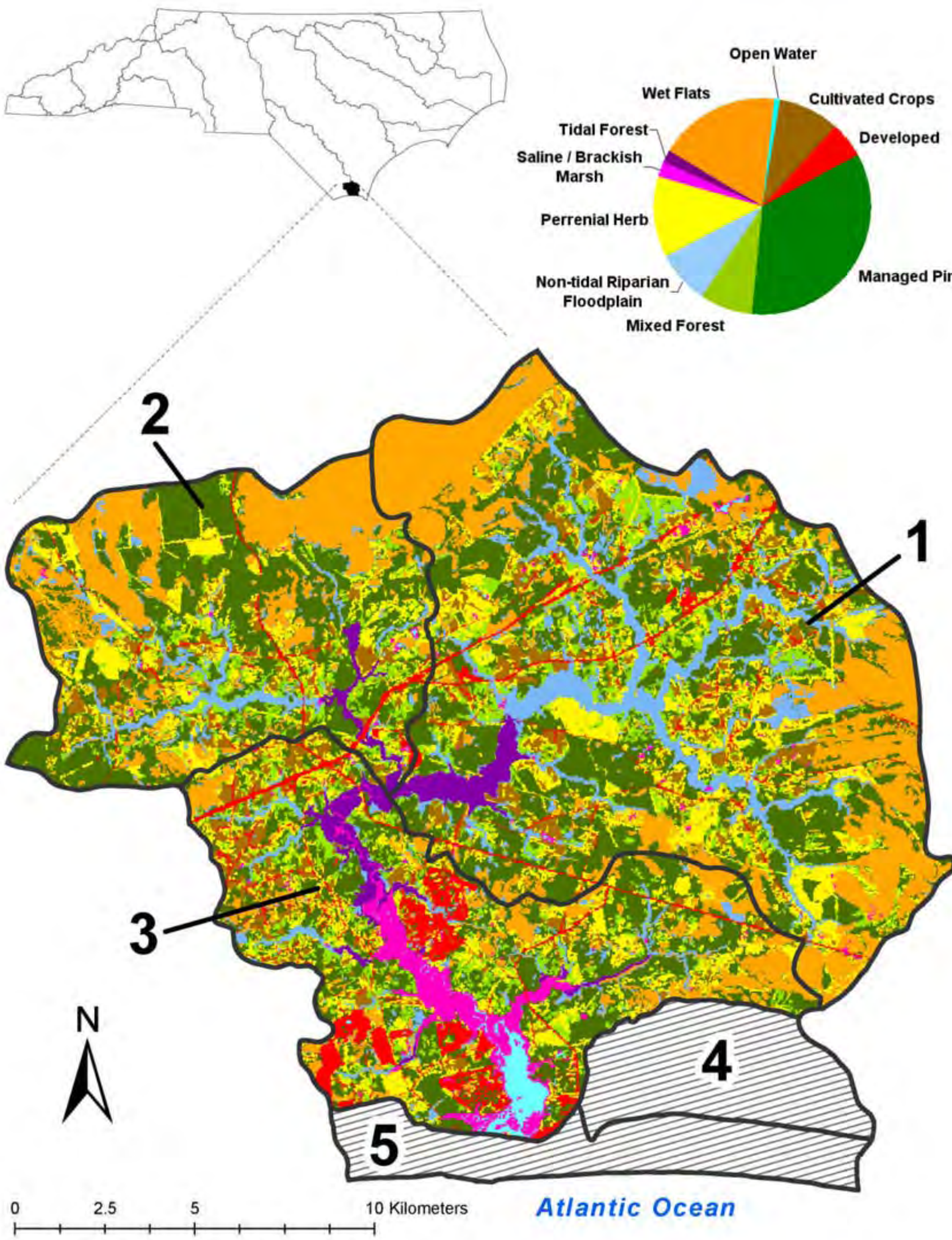



**Figure 3. Landuse map of the three sub-basins of the Lockwoods Folly study area. Landuse data modified from 2001 National Land Cover Dataset (Homer et al. 2004).**

1:24,000 scale maps (7.5-minute quadrangle series) as our base map and then developed criteria for extending or deleting headwater stream segments to match the true network (Rheinhardt et al. 2005). However, those criteria had not been tested in coastal watersheds, so we had to field test them before proceeding, and then modify the criteria based on results of the field testing.

**Amended criteria for revising hydrographic maps**

From field visits to numerous locations, we concluded that there were several differences between the Lockwoods Folly watershed and the inland watersheds previously sampled. These differences affected how we would have to revise the hydrographic layer to better reflect the true stream network. One difference is that soils in Lockwoods Folly watershed were much sandier than those in inner coastal plain watersheds. The sandier soils resulted in less extensive agricultural landuse in the watershed, which in turn led to less intensive field ditching and stream channelization. We found that when the original rules for extending stream hydrography headward were applied, many bifurcations (junctions) and streams lines were added to the hydrographic layer that did not in fact exist. A plausible explanation for this phenomenon is that groundwater driven streams arise further downgradient in watersheds with sandier soils (due to increased infiltration rates) than topography alone would indicate. Therefore, to correct for the discrepancy between the true network and the hydrographic network, we further modified the added streams as follows: (1) for added 1$^{st}$ order stream segments above a bifurcation that were shorter than their downstream (2$^{nd}$ order) segment, both segments were removed and (2) for any added 1$^{st}$ order segments above a bifurcation that were longer than their downstream (2$^{nd}$ order) segment, the segment with the least slope or the one that crossed more obtuse topographic lines was removed (the other segment was retained). Stream orders were then re-calculated. Based on field reconnaissance, these criteria seemed to be sufficient to correct for most of the discrepancies between the true stream networks and the revised digital hydrographic layer.

The other main difference between the coastal and inland stream networks was the long tidal section at the lower end of the coastal networks. Therefore, we also had to develop criteria for deleting tidal sections. The full extent of the tidal portions was impossible to predict from examining topographic maps (topos) or aerial photos. Although salt and brackish marshes could be differentiated fairly easily, tidal freshwater sections dominated by forests could not. From our field reconnaissance in the lower sections of Lockwoods Folly, we determined that the 3-ft topographic contour represented the approximate extent of upriver tidal incursion. Stantec used 20-m LIDAR data to identify the 3-ft topographic contour and then we deleted the portion of the hydrographic layer downstream from this contour. As was the case for the inland watersheds, we wanted the hydrographic layer to provide a slightly conservative estimate of the stream network, i.e., we preferred that sites be rejected in the field for being tidal rather than being excluded from the sampled universe because they had been deleted from the map.

**Reach assessments**

Due to the large size of the Lockwoods Folly basin, approximately 1 point was sampled for each 2.9 km of stream length. This ratio was lower than the approximately 1:1 ratio used for the Rheinhardt et al. (2005) study of smaller inner coastal plain watersheds. A separate set of random points was assigned to the hydrographic layer of each of the three 14 digit HUC (Hydrologic Unit Code) sub-basins identified as 1-3 in Figure 3. Random selection of points was performed using the same algorithm applied in the previous Rheinhardt et al. (2005) study. As in that study, each random point identified the center of a 100-yard reach (Figure 1), which was then assessed with one of the 4 SRC assessment protocols. A total of 140 primary points and 140 alternate points were assigned to the three sub-basins. Some points were rejected (not assessed) for not meeting the definition of an intermittent to perennial channel and so were sequentially replaced by the random points in the alternate list. Points that identified reaches in which channel and floodplain were inundated by a beaver impoundment were not sampled, but they were not replaced by an alternate point either.

We spent several days testing the developed protocol in Lockwoods Folly to make sure that it was applicable there. (Our field tests did not reveal any problems with applying the method.) We also spent a day in the field with Stantec scientists to insure that they were comfortable with the criteria for rejecting headwater reaches and could recognize tidal reaches (which were also to be rejected). During the course of their fieldwork, Stantec scientists identified some reaches about which they were unsure how to classify. We visited those sites as well and provided feedback on proper classification.

**Data analysis**

We evaluated SRC scores from the randomly chosen reaches assessed by Stantec scientists to determine the condition of the three sub-basins. These data constitute the core of this report. A subset of sites (10%) assessed by Stantec were also re-assessed by the ECU team. We compared the degree to which consultant SRC indicators scores agreed with the ECU scores of the same reaches and determined the lower threshold of the 90% confidence interval, i.e., based on sample size, the least agreement in SRC indicator scores that would have been expected (90% probability) had all reaches been resampled.

**Indicator analysis --** A matrix was generated of SRC indicator scores for each reach. Individual indicator scores were averaged for each watershed to compare watersheds at the basic level of indicators. Indicators were then combined and averaged following the logic in Figure 2. The three resulting function scores for Stream Channel and for Riparian Zone were averaged to obtain a mean function score for those two components. A Composite Condition score was calculated by averaging all function scores for each reach.

**Stream network analysis –** Stream networks were evaluated relative to the condition of the Stream Channel and Riparian Zone by graphing the distribution of Stream Channel and Riparian condition scores for all reaches in a watershed. Composite Condition scores were delineated by dashed lines into condition categories carried over from SRC categories in the field sheets: 0-29 (severely altered), 30-59 (altered), 60-89 (somewhat altered), and 90-100 (relatively unaltered).

## RESULTS AND DISCUSSION

One hundred forty (140) randomly chosen reaches were assessed by Stantec scientists in three sub-basins of Lockwoods Folly (Table 2). The three sub-basins together comprise about 360 km,[2] with unimpounded low order reaches comprising close to 80% of total stream length (409 km) and higher order reaches comprising about 6%. The remaining 14% of stream length was impounded by beaver to such a degree that the reaches' floodplains were flooded. Impounded reaches were not assessed, but the percentage of impounded stream length is included in summaries to provide a direct estimate of stream length associated with various conditions. For example, the 27.5% of Sub-basin 3 identified as urban low order equates to 30 km of stream length in that stream network.

**Table 2. Characteristics of the Lockwoods Folly drainage basin, by sampled sub-basin. Number of reaches (n) assessed in each basin does not include rejected reaches, except rejections for being beaver impoundments (n=21).**

| Sub-watershed | n | Watershed area ($km^2$) | Stream length (km) | % Reach Type: Rural low order | % Reach Type: Urban low order | % Reach Type: Rural high order | % Reach Type: Urban high order | % Low order | % High order | % Beaver impounded |
|---|---|---|---|---|---|---|---|---|---|---|
| Sub-basin 1 | 67 | 175.51 | 213.2 | 82.1 | 0.0 | 4.5 | 1.5 | 82.1 | 6.0 | 11.9 |
| Sub-basin 2 | 33 | 84.37 | 85.5 | 69.7 | 3.0 | 6.1 | 0.0 | 72.7 | 6.1 | 21.2 |
| Sub-basin 3 | 40 | 97.94 | 109.9 | 52.5 | 27.5 | 5.0 | 2.5 | 80.0 | 7.5 | 12.5 |
| Total | 140 | 357.8 | 408.6 | | | | | | | |
| | | Weighted Average | | 71.5 | 8.0 | 4.9 | 1.5 | 79.6 | 6.4 | 14.0 |

Most (76.5%) of the un-impounded reaches of the Lockwoods Folly basin were identified as rural with only about 9.5% considered to be urban or suburban. Most urban/suburban reaches were concentrated in Sub-basin 3, in which 30% of its total length was urban. Low order reaches in this sub-basin comprised 80% of total stream length, similar to the two more rural sub-basins. This suggests that urban reaches in Sub-basin 3 were more suburban or suburbanizing in character than urban, with little of no truncation of the headwater sections due to piping (burial) of channels, a condition common in more intensely urban watersheds. From our reconnaissance of Lockwoods Folly, it seemed that most of the expansion of golf retirement communities in Lockwoods Folly was concentrated in Sub-basin 3, which is consistent with the results showing higher percentage of urban stream length in that basin.

Causes for rejecting reaches for assessment varied among sub-basin, but overall about 24% (33/140) of all assigned reaches were rejected for reasons other than being impounded. Of rejected reaches, 42% were rejected for being ephemeral channels, 38% for being impounded, 15% for being a wet flat (no channel), and 6% for being tidal (Table 3). Apparently, eliminating reaches below the 3-ft contour was effective in deleting most tidal reaches from the randomly assigned points in Lockwoods Folly. However, corrections made to the hydrographic layer to trim added headwater segments was somewhat conservative because 10% of all reaches sampled were still rejected for being ephemeral. This discrepancy between adjusted hydrography and true hydrography may have resulted from soils in Lockwoods Folly being much sandier than the Little Contentnea basin and the other inland watersheds where criteria for rejection were originally developed and fine-tuned. Perhaps instead of extending streams headward using criteria developed for inland watersheds, we should have first tested the baseline hydrographic layers mapped in NRCS soil surveys and UGGS topographic maps or invoked a more stringent slope criterion for headward extension.

**Table 3. Number of rejected reaches in each sub-basin, by type of rejection.**

| Sub-basins | Ephemeral channel | Ditch | Beaver impound-ment | Lack of access | Tidal | Wet flat | Total |
|---|---|---|---|---|---|---|---|
| Sub-basin 1 | 10 | 0 | 8 | 0 | 2 | 4 | 24 |
| Sub-basin 2 | 3 | 0 | 7 | 0 | 0 | 2 | 12 |
| Sub-basin 3 | 9 | 0 | 5 | 0 | 1 | 2 | 17 |
| Total number | 22 | 0 | 20 | 0 | 3 | 8 | 53 |
| Percentage | 42 | 0 | 38 | 0 | 6 | 15 | 100 |

**Watershed-scale assessments**

Impoundments occurred in 12-21% of stream length in Lockwoods Folly, with Sub-basin 2 being the most impounded basin of the three (Figure 4). Along un-impounded reaches, approximately 63% of the Lockwoods Folly network was in relatively unaltered to somewhat altered condition. Of the 3 sub-basins, channel/riparian condition of Sub-basin 3 was relatively better than the other two other stream networks (Figure 5). About half of the reaches in Sub-basin 3 that were determined to be in a relatively unaltered condition were urban/suburban low order and most of the urban/suburban reaches in Lockwoods Folly were in this basin.

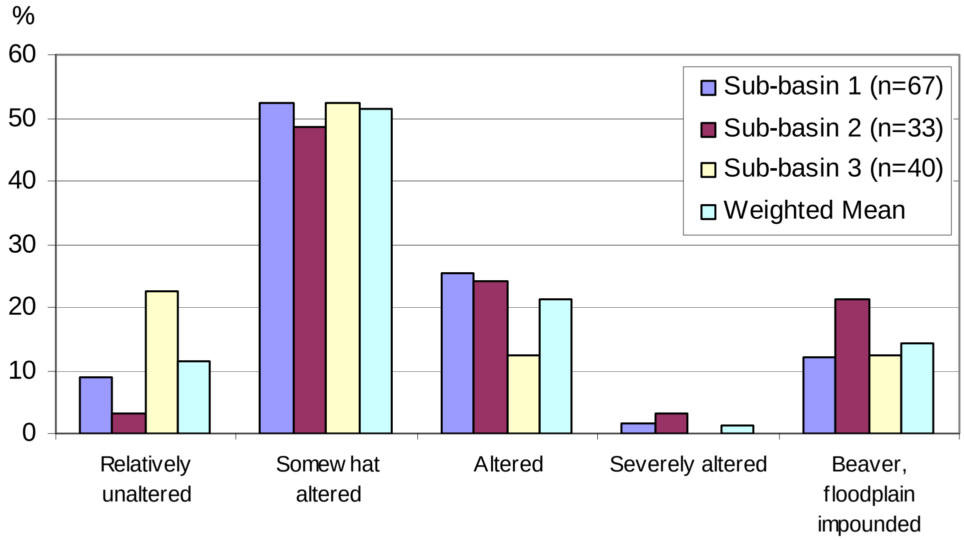



**Figure 4. Percentage of reaches in Lockwoods Folly sorted by condition category and sub-basin. Number of reaches (n) assessed in each basin includes those rejected for being beaver impoundments.**

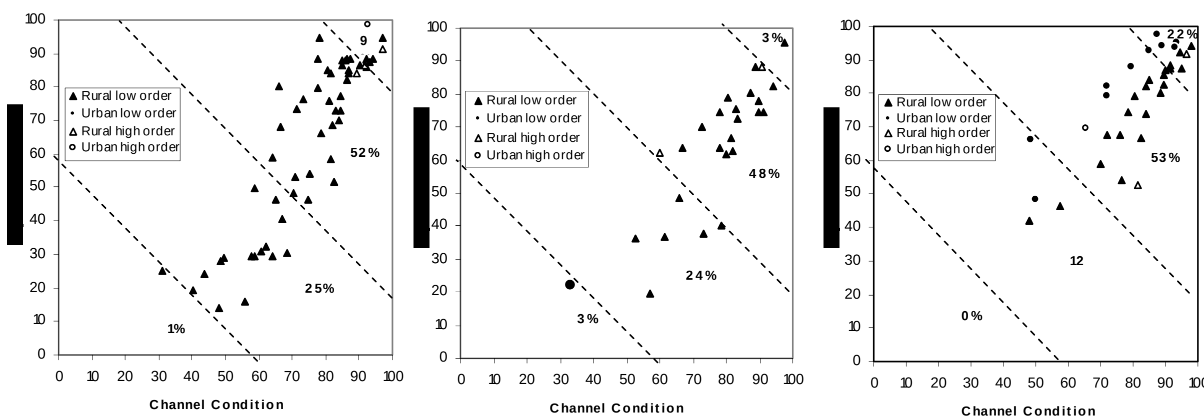



**Figure 5. Condition of the three Lockwoods Folly sub-basins. Each point on the graphs represents an assessed reach. Channel and Riparian conditions for each reach were derived from averaging function scores for channel and riparian zone. Dashed lines compartmentalize reaches by condition category, based on composite function scores, ranging from relatively unaltered (upper right) to severely altered (lower left). Percent of reaches for each condition category is equivalent to percent stream length in the category.**

Compared to the inner coastal plain watersheds assessed in the Rheinhardt et al. (2005) study, the Lockwoods Folly basin is in better condition (Figure 6), with both low and higher order streams in better condition. Even within a condition category, channel condition seems to be better in the Lockwoods Folly network than in the inner coastal plain networks previously studied, i.e., reaches tended to be shifted further to the right of a line that would represent a 1:1 ratio between channel condition and riparian condition.

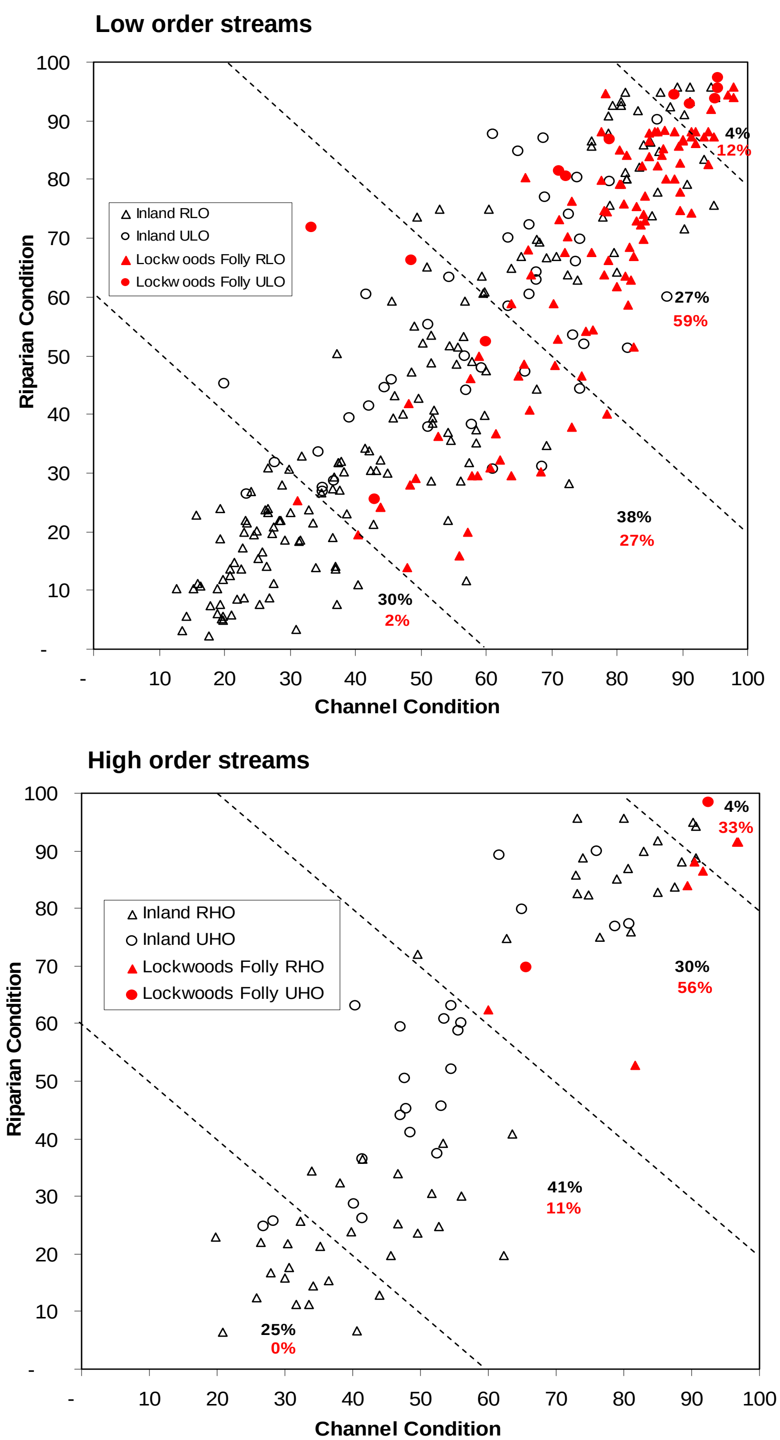



**Figure 6. Comparison between the condition of the Lockwoods Folly basin (red or solid points) and the condition of basins assessed in the inner coastal plain (hollow points), by stream order. Percentages represent reaches in each condition category (top = low order reaches; bottom= high order reaches). From top right to bottom left: Relatively unaltered, Somewhat altered, Altered, Severely altered. Abbreviations: RLO= rural low order, ULO=Urban low order, RHO=rural high order, UHO=urban high order. Inner coastal plain data from Rheinhardt et al. (2005).**

The sandier soils in Lockwoods Folly means that infiltration rates are higher, perhaps reducing the demand for channelizing streams to increase drainage. Sandy soils also may have made agriculture a less desirable land use, another factor reducing the demand for channelization. Both factors are likely reasons that Lockwoods Folly had better channel condition scores than the less sandy, inner coastal plain stream networks previously sampled.

Many of the urban/suburban areas in Lockwoods Folly are relatively new, gated retirement communities, with additional large-scale development underway. However, few data points fell within the severely altered category for any of the three stream networks. Therefore, it appears that either the new developments have successfully avoided degrading stream condition or development has been so recent that there has been too little time for stream condition to have deteriorated much. In any case, the Lockwoods Folly watershed is undergoing rapid changes in landuse and the current assessment data provide a useful baseline from which stream network condition can be monitored over time. If future assessments of the stream network show a deterioration in condition, such data could provide justification for more strictly managing new development within the watershed.

## Indicator condition

For Lockwoods Folly as a whole, indicator scores ranged from 52 for “Riparian zone cover” to 87 for “Pollution affecting stream” (weighted means in Table 4). “Riparian zone cover” and “Near-stream cover” were consistently the lowest scoring indicators, with the exception of the urban low order reaches in Sub-basin 3. This suggests that there are abundant opportunities for restoring streamside buffers in the Lockwoods Folly basin.

**Table 4. Mean indicator scores, by sub-basin and riparian type. The number of reaches sampled within a type influenced the resulting scores for the sub-basins. Generalizations are not meaningful in riparian types where there are only a few points, e.g., urban reaches in Sub-basins 1 and 2. Mean scores based on 120 un-impounded reaches. "Bv" means that only the channel was impounded by beaver, but not the floodplain.**

| Riparian type, by Sub-basin | *n* | Riparian zone cover | Near-stream cover | Instream woody structure | Sediment regime | Channel-riparian zone connection | Pollution affecting stream | Factors affecting riparian zone | Habitat quality of riparian zone | Stream bank stability |
|---|---|---|---|---|---|---|---|---|---|---|
| **Sub-basin 1** | | | | | | | | | | |
| Rural Low Order | 55 | 48 | 51 | 76 | 56 | 75 | 87 | 70 | 49 | NA |
| Urban Low Order | 0 | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| Rural High Order | 3 | 68 | 68 | 93 | 80 | 100 | 100 | 100 | 67 | 93 |
| Urban High Order | 1 | 100 | 100 | 100 | 50 | 100 | 80 | 100 | 80 | 100 |
| **Sub-basin 2** | | | | | | | | | | |
| Rural Low Order | 23 | 41 | 44 | 85 | 67 | 81 | 93 | 76 | 47 | NA |
| Urban Low Order | 1 | 44 | 44 | 30 | 60 | 0 | 70 | 10 | 70 | 10 |
| Rural High Order | 2 | 39 | 38 | 55 | 55 | 95 | 90 | 100 | 45 | 95 |
| Urban High Order | 0 | NA | NA | NA | NA | NA | NA | NA | NA | NA |
| **Sub-basin 3** | | | | | | | | | | |
| Rural Low Order | 20 | 50 | 51 | 83 | 69 | 93 | 91 | 87 | 59 | NA |
| Urban Low Order | 11 | 91 | 93 | 73 | 53 | 82 | 65 | 77 | 80 | 68 |
| Rural High Order | 2 | 61 | 60 | 95 | Bv | Bv | 100 | 90 | 45 | Bv |
| Urban High Order | 1 | 90 | 90 | 40 | 10 | 75 | 70 | 50 | 50 | 90 |
| Weighted mean | 120 | 52 | 55 | 79 | 60 | 81 | 87 | 76 | 54 | 74 |

“Habitat quality of riparian zone” also tended to score lower in rural low order reaches (47-59, in the altered range) than other indicators. This was not surprising since the condition of this indicator is partially related to “Riparian zone cover” condition, i.e., although “Habitat quality of riparian zone” could be low. For example, when “Riparian zone cover” is high, “Habitat quality of riparian zone” is always low when “Riparian zone cover” is low. This is because high scores for “Habitat quality of riparian zone” must not only have high biomass (i.e., age), but must consist of a variety of species typical of mature forests. The only other indicator that scored somewhat low was "Sediment regime," scoring as "Altered" or "Severely altered" in 5 of the 9 categories of sub-basin and riparian type. "Sediment regime" scores may have reflected the condition of the stream networks, but it may also have been an artifact of Stantec scientists using Version 1.1 of the data sheets, rather than Version 2.0 because revisions made to the "Sediment regime" narrative were more substantive than revisions to the other indicator narratives. We will address this in more detail below when comparisons are made between Stantec and ECU scores of indicators from a subset of reaches.

The Lockwoods Folly stream network was only "Somewhat altered" overall, scoring a weighted mean composite condition score of 72 (Table 5). The relatively high condition of the Lockwoods Folly networks is reflected in the weighted mean function scores for the sub-basins. Weighted function scores ranged from 65 (Riparian zone habitat) to 82 (Stream channel hydrology), both within the "Somewhat altered" range. ("Riparian zone habitat" was the lowest scoring function in all three sub-basins while "Stream channel hydrology" scored highest in all three sub-basins.)

The Lockwoods Folly stream network scored higher than any of the six previously assessed inner coastal plain stream networks (Rheinhardt et al. 2005). However, a more meaningful comparison would be to compare Lockwoods Folly with other coastal watersheds. This is because stream network condition is only one aspect of the aquatic resource condition in coastal watersheds. Other unmeasured factors in the sea-level portion of the watershed, such as shoreline condition and nearshore condition, also affect coastal watersheds (Rheinhardt and Brinson in review). These other factors should be considered when evaluating the condition of the basin's aquatic resources.

**Table 5. Mean Function scores and mean Composite Condition scores, by watershed. Composite Condition scores are derived from the average of all function scores within a reach or from the average of stream channel condition and riparian zone condition (Figure 2). Relatively unaltered watersheds would score 90 or greater for all mean Composite Condition scores.**

| | STREAM CHANNEL | | | RIPARIAN ZONE | | | Mean Composite Condition scores |
|---|---|---|---|---|---|---|---|
| | Hydrology | Biogeo-chemistry | Habitat | Hydrology | Biogeo-chemistry | Habitat | |
| Sub-basin 1 | 80 | 70 | 73 | 65 | 65 | 61 | 69 |
| Sub-basin 2 | 84 | 72 | 74 | 65 | 65 | 61 | 70 |
| Sub-basin 3 | 83 | 76 | 78 | 79 | 79 | 75 | 78 |
| Weighted Mean | 82 | 72 | 75 | 69 | 69 | 65 | 72 |

**Test of the assessment method**

Nineteen of the 120 reaches assessed by Stantec were selected for re-assessment by ECU scientists. This was done to determine the degree to which the indicator scores recorded by Stantec scientists matched scores recorded by ECU scientists. The intent was to determine where narratives of the SRC protocol might be improved upon to better insure both precision (repeatability among users) and accuracy (comparison with ECU scientist scores). Of the 19 reaches re-sampled, three reaches were rejected correctly according to criteria defined by the protocol, one was rejected that should not have been rejected, two were not rejected that should have been rejected, and 13 were correctly assessed as true streams. Thus, 3/19 reaches (15% error rate) were either rejected when they should not have been or were not rejected when they should have been. However, because the sample size was so small, we cannot be statistically confident that 15% represents a true error rate.

Of the 13 re-assessed reaches, two were identified as rural low order by ECU, but as urban low and urban high order by Stantec. Therefore, these two reaches were excluded from further analysis; only scores for the 11 remaining reaches were compared, all of which were rural low order reaches. In addition, because all compared reaches were rural low order and "Stream bank stability" was not measures in such reaches, "Stream bank stability" was not tested. Figure 7 shows the lower 90% confidence limit of the maximum expected difference in scores, arranged in cumulative 10-point intervals. This represents the maximum expected difference in scores that would be expected had all 120 reaches had been re-sampled. For example, for "Instream woody structure" we could be 90% confident that at least 77% of reaches would have been scored by both groups within 10 points of one another. In contrast, for "Sediment regime" we could be 90% confident that only 13% of reaches would have been scored within 20 points of each other.

Most of the indicators, with the exception of "Sediment regime," were scored similarly by both Stantec and ECU. This similarity occurred in spite of the fact that slightly different indicator narratives were used by each group. Although the "Sediment regime" indicator was scored differently between the groups, we expect that differences in scores would only minimally influence differences in function scores. This is because "Sediment regime" is only pertinent to stream channel biochemistry, where it is only one of five indicators used to evaluate channel biogeochemical condition.

To compare the overall effect of the "Sediment regime" indicator on reach condition, we compared Composite Condition scores between groups (ECU vs. Stantec) with and without "Sediment regime" included in composite function calculations (Figure 8). With "Sediment regime" included, one could be 90% confident that the two groups would have Composite Condition scores within 10 points of each other 51-95% of the time and within 20 points 77-100% of the time. Without "Sediment regime" included, Composite Condition scores for the two groups would be expected to be within 10 points 63-100% of the time and within 20 points 100% of the time. Thus, similarity in Composite Condition scores could be improved somewhat by eliminating the "Sediment regime" indicator, although agreement among groups was still high. Much of this agreement was

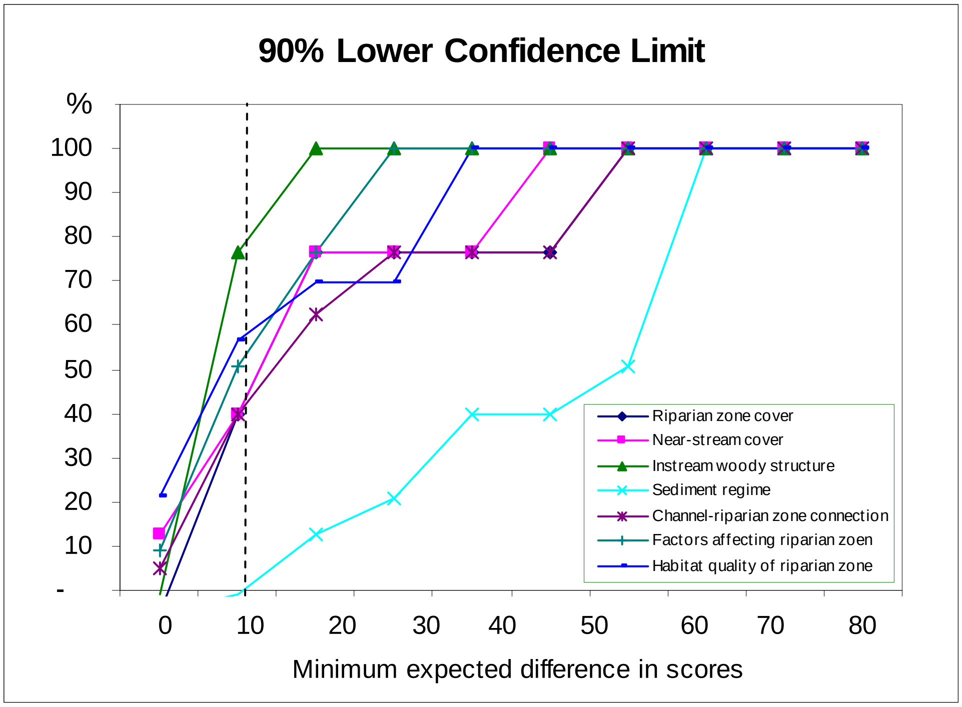
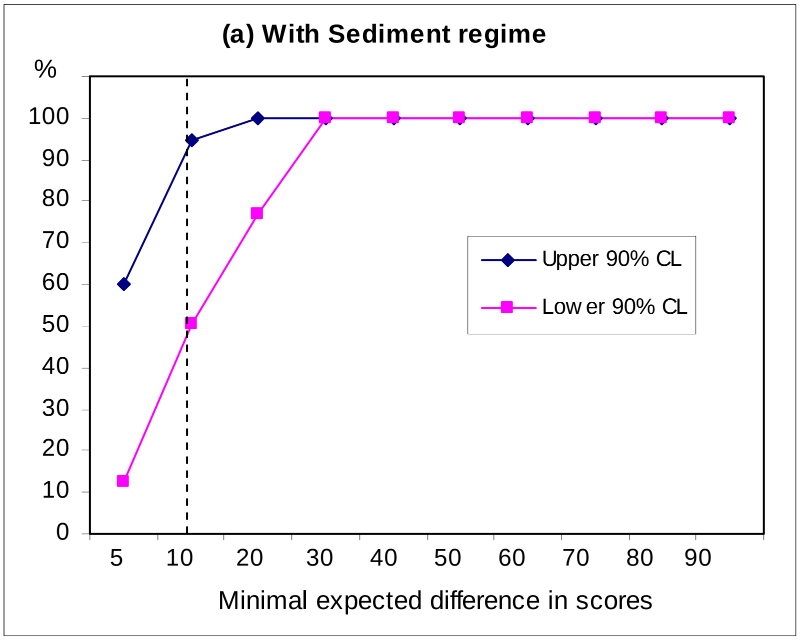



**Figure 7. Lower 90% confidence limit of the maximum expected difference in indicator scores, arranged in cumulative 10-point intervals, between Stantec and ECU scientists. For example, one can be 90% confident that "Instream woody structure" was scored within 10 points of one another for 77% of reaches or within 20 points of one another for 100% of reaches.**



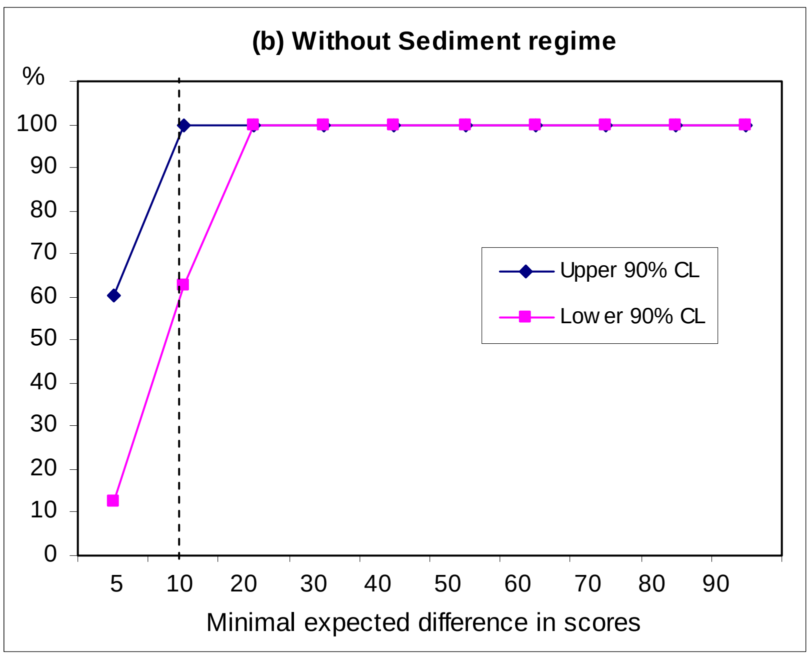




**Figure 8. Upper and lower 90% confidence limits (CL) for Composite Condition scores with (a) and without (b) "Sediment regime" included as a component of condition. Without sediment regime, one can be 90% confident that Composite Condition scores are in within 10 points 63-100% of the time and within 20 points 100% of the time.**

due to the teams scoring the other indicators similarly and part was due to the fact a slightly lower score for one indicator might be compensated for by a slightly higher score for another indicator.

Although composite function scores were not altered much when “Sediment regime” was removed from the aggregated scoring, we decided to see how much reaches in stream networks would shift in the distribution of channel-riparian scores with “Sediment regime” removed (Figure 9). Overall, scores improved somewhat relative to condition categories (compare Figure 5 vs. Figure 9). This was probably because sediment regime tended to be scored lower in all reaches than other indicators, thus improving overall scores somewhat when it was removed. The take home message is that either the “Sediment regime” indicator needs further testing to improve it or it should be removed altogether as an indicator of channel condition.

**Management implications**

The Lockwoods Folly basin differs from the inner coastal plain basins in several respects: (1) its soils are much sandier; hence agriculture and channelization have been far less extensive than in inner coastal plain watersheds and (2) because it is a coastal watershed, a significant portion its stream network is tidally influenced. Less agricultural influence is probably the main reason that Lockwoods Folly is in better condition than the previously assessed inner coastal plain stream networks. However, even though channelization is less extensive, there are still opportunities for restoring channel-riparian connections. There are also ample opportunities for restoring riparian condition and near stream condition and for preserving currently well-buffered riparian zones. Preservation should be particularly attractive in light of rapidly changing landuse in the watershed in the wake of the rapid expansion of golfing retirement communities. Regulations protecting buffer zones and purchasing conservation easements along streams could proactively inhibit further degradation of riparian zone condition.

Many of the strategies devoted to improving the condition of inland riparian ecosystems have been developed ultimately to protect aquatic resources in receiving estuaries. This is because much of the impairment of estuarine resources has been attributed to the poor condition of contributing tributary streams in general (Bricker et al. 1999, Dauer et al. 2000, Howarth et al. 2000) and for North Carolina estuaries in particular (Street et al. 2005). However, estuarine resources are also affected by factors originating in or near the estuary proper. Thus, additional indicators of shoreline, nearshore, and offshore condition need to be considered when assessing the condition of small coastal watersheds (Deaton et al. 2006). For example, although the Lockwoods Folly estuary receives almost all of its freshwater input from the coastal watersheds of the Lockwoods Folly basin, estuarine resources are also affected by alterations to the tidal portions of its basin, alterations of its shorelines, and alterations of its subtidal areas. Thus, information in this report on the condition of stream networks of the Lockwoods Folly basin provides only part of the picture of the condition of aquatic resources.

Developing a reference-based assessment approach for coastal watersheds will require a preliminary research-level effort to identify appropriate coastal indicators and determine the relationships between the indicators and ecosystem health. An outline of essential elements of a protocol for assessing coastal watersheds is provided in Rheinhardt and Brinson (in review).

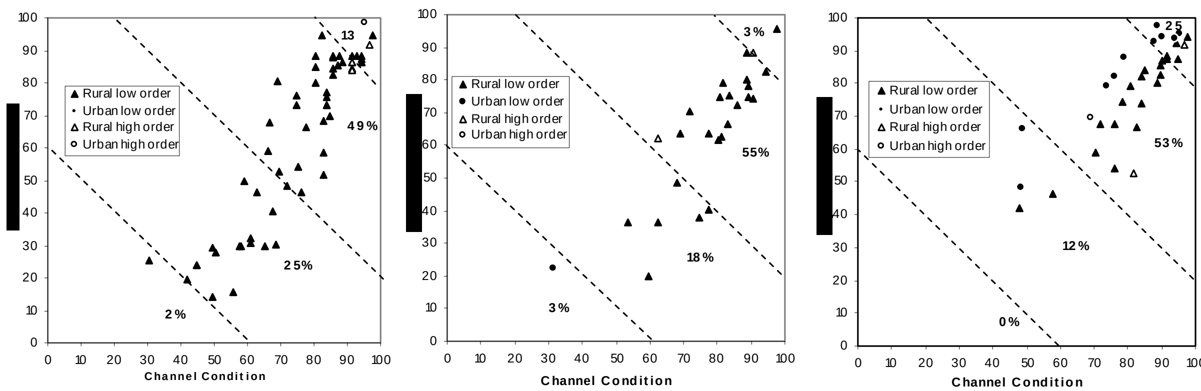



**Figure 9. Condition of the three Lockwoods Folly sub-basins with "Sediment regime" indicator score removed from calculations. Each point on the graphs represents an assessed reach. Channel and Riparian conditions for each reach were derived from averaging function scores for channel and riparian zone. Dashed lines compartmentalize reaches by condition category, based on composite function scores, ranging from relatively unaltered (upper right) to severely altered (lower left). Percent of reaches for each condition category is equivalent to percent stream length in the category.**

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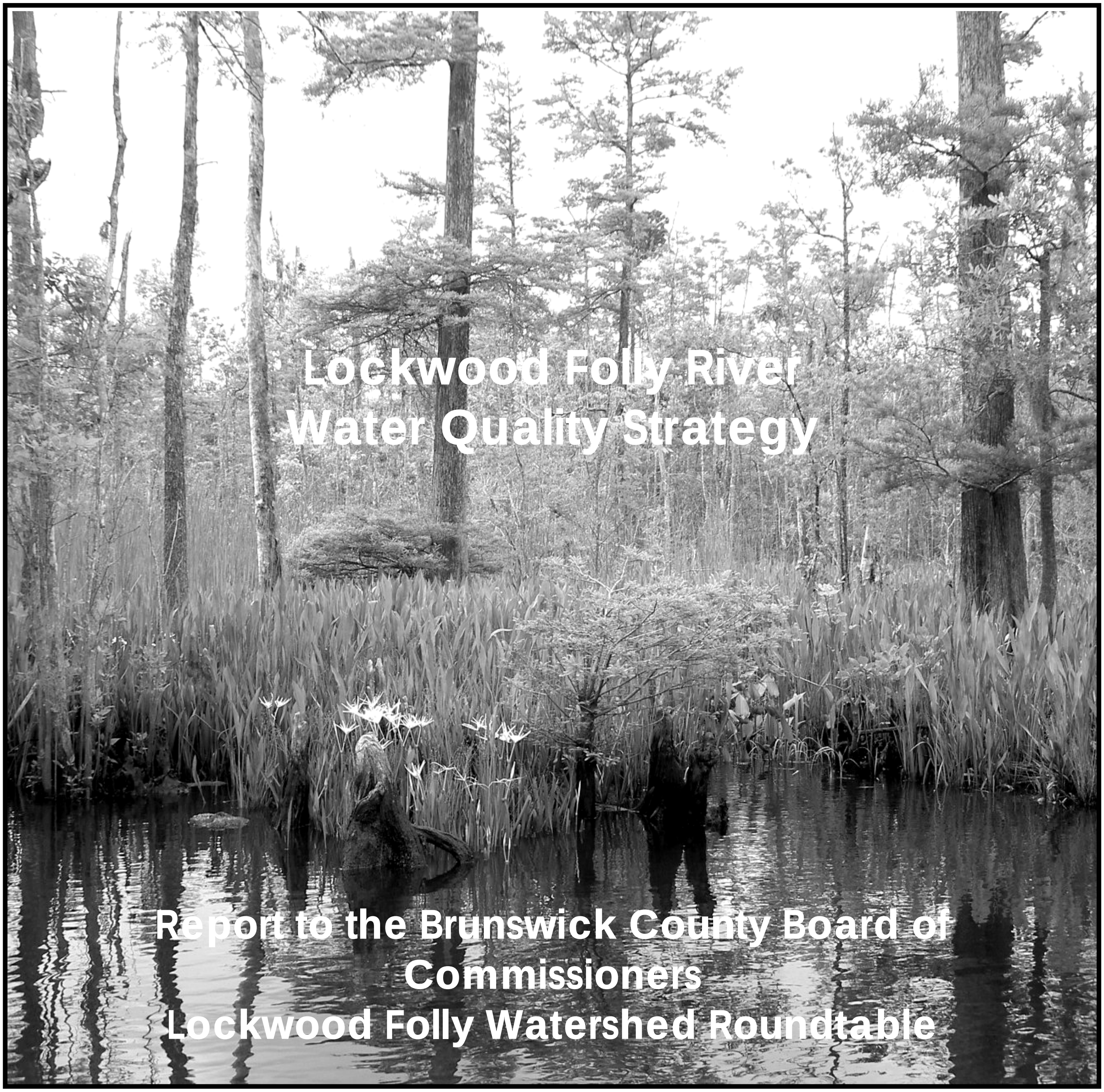
Appendix D




February 2007

## Overview

This report outlines a group of ten strategies recommended for implementation by the Lockwood Folly Watershed Roundtable to help preserve and, where feasible, to restore water quality in the Lockwood Folly River.

The strategies are the result of a long series of deliberations by the citizens Roundtable, which was appointed by the Board of Commissioners in 2005. Roundtable Members heard presentations by water quality professionals and reviewed reports that documented water quality trends and conditions and that laid out methods to address the project's goals. Early in the program, the Roundtable partnered with the NC Environmental Enhancement Program that brought water quality modeling and watershed planning expertise to the process. In addition, the Environmental Enhancement Program provides access to financial resources to help implement some of the strategies.

The Roundtable also considered an economic study that demonstrated the financial feasibility of implementing the low impact development strategy when compared to conventional land development approaches.

The strategies provide the county with a range of options, including changes in land development policies, education programs, and site preservation and retrofit techniques.

Roundtable Members and the planning team that assisted them through this process are grateful for the opportunity to assist the county with this important work.

**Strategy 1**

(A) Assess water quality risk according to natural systems in watershed and develop future land use policies and ordinances that fit land use density and landscape design to the level of water quality risk.

(B) Sewer extension policies that: (1) give priority services to communities with malfunctioning septic tanks, and (2) ensure that land use and development policies in sewer service areas are consistent with risks to water quality.

**Findings**


Water quality experts from a number of state agencies presented the Roundtable with convincing statement that demonstrated a long-term deterioration of water quality in the Lockwood Folly River. These presentations showed that, between 1980 and the present, widespread areas in the Lockwood Folly failed to meet basic water quality standards set for shellfishing. As a result, the percentage of the river's shellfishing areas that are closed increased from 18% in 1980 to the current level of 55%. Increasing turbidity and increasing levels of fecal coliform, an indicator of waste from warm-blooded animals that is more efficiently transported into the river by alterations in watershed hydrology, are the culprits. Increasing turbidity and increasing levels of fecal coliform are a direct result of increased stormwater runoff due to the effects of urbanization and ditching in the watershed. It is also suspected that poorly maintained and failing septic tanks are resulting in water quality impairment.* Prevention of stormwater runoff and proper sewage treatment are necessary components of the overall water quality strategy for the watershed.

The volume and intensity of stormwater runoff in the watershed are strongly linked to built-upon surfaces that are connected through drainage systems to surface waters. These are the harder surfaces such as

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* Studies that may support these linkages are underway through the state's NCEEP program.

asphalt, concrete, rooftops, and highly compacted soils that come with community development. These built-upon surfaces have a major impact on the watershed's natural water balance. They reduce evapo-transpiration and infiltration of rainwater, and thereby increase- the volume, velocity, and timing of storm water runoff entering receiving waters. The increased stormwater runoff carries with it sediment, nutrients, heavy metals, chemical pollutants, and bacteria and viruses. As the watershed develops, these impacts will become more pronounced.

The state Division of Water Quality has determined that traditional stormwater management practices such as curb and gutter, storm drains, pipes and ponds are failing to protect water quality.

To address the impact of stormwater on water quality, a major goal of the county's water quality strategy should be to maintain the watershed's natural hydrology at or near the natural state in the watershed. Within the watershed, the natural landscape has very little surface runoff since most rainfall infiltrates into the groundwater table or is used by vegetation. Traditional development approaches generally do not utilize the natural environment as means for preventing and treating stormwater runoff. New development that is properly designed, sited and landscaped so that it does not directly connect built-upon surfaces with the downstream surface waters within the watershed, can treat stormwater at its original source before it reaches sensitive waters of the Lockwood Folly watershed. The county's land use policies and its development management program are major tools that are available to accomplish this goal.

Development density, location and landscape design are three of the fundamental variables that determine the effect of built-upon surfaces on water quality within the watershed. Logically, as overall development density increases, built-upon surfaces increase. There are two basic ways to control the impact of these built-upon surfaces on water quality: (1) maximize pervious areas where water can infiltrate either by minimizing development density, and/or (2) maximizing areas where stormwater can infiltrate into the groundwater.

Transportation facilities are another major variable that influence water quality. According to information from the US EPA, transportation systems – roads, parking lots, driveways, and the like – can account for a significant amount of the impervious surface in developed areas. Water quality policies that set appropriate development standards for highways, streets, parking lots, and driveways are an essential part of the strategy.

A study* by the US EPA demonstrates that *for a given amount of development*, more compact and higher density development may be preferable to lower density alternatives. The study concluded the following:

- Higher-density development scenarios generate less storm water runoff per house at all scales;
- Higher-density development produces less runoff and less impervious cover than low-density development for the same amount of development; and
- Lower-density development impacts more of the watershed for a given amount of growth.

These finding suggest that "clustering" of appropriately sited development in higher density nodes combined with low impact development techniques may be the preferred development pattern from the standpoint of water quality protection as long as the overall development density that would occur does not increase substantially. This means that the success of "cluster" strategies depend upon using non-built upon areas as part of green space systems that are designed to protect water quality.

As part of its study of the watershed, the Roundtable reviewed the results of a Land Suitability Assessment – Water Quality Risk Model, which was developed as part of the project. This model relies on four factors to assess water quality risk from land development activities: Soil Characteristics, Land Cover, Presence of Wetlands, and Proximity to Surface Water. Mapping produced by the model shows areas in the following four risk categories:

1. **High-value Water Quality Protection Areas** – contain coastal wetlands or non-coastal wetlands that have significant or exceptional water quality protection functions. These areas have only limited development potential.
2. **Highest Water Quality Risk Areas** – due to the soil conditions and land cover found here, land-disturbing activities in these areas may cause serious damage to natural systems and water quality. These areas are suited only for the very lowest intensity development.
3. **Moderate Water Quality Risk Areas** – these areas contain soils and land cover types that have significant limitations for

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* US Environmental Protection Agency, *Protecting Water Resources with Higher Density Development*, 2006.

development activities, but these limitations may be mitigated by methods such as controls on development density, open space preservation, tree preservation, and the range of low intensity development techniques.

4. **Lowest Water Quality Risk Areas** – these areas have the least limitations for development from a water quality protection standpoint. These limitations can generally be addressed by commonly accepted land use and development practices.

The water quality risk model and associated mapping is not intended to be a site-specific system. It is intended only as a planning tool and as an early warning system that indicates where more intensive site analysis and more sensitive site planning and development are necessary to protect water quality. (A map that illustrates the location of these risk areas is found on page 8.)

The availability of sewer is another important land use planning consideration from the standpoint of built-upon surfaces and stormwater runoff. Sewers have the potential to facilitate intensive sprawling development. Studies in other watersheds have shown that in the absence of effective land use plans and ordinances (that are designed specifically to protect water quality) the availability of sewer can contribute to significant increases in development density with resulting increases in impervious surfaces. Land use policies should recognize this possibility and where sewer is available or is extended the policies should be designed to achieve appropriate density, location and or siting and/or landscape designs.

**Recommendations**

1. The range of low impact development (LID) techniques are the preferred approach to managing stormwater in the watershed; however, the LID approach can also be a central component of the land use management process in the watershed. The county should include specific policies in its Coastal Area Management Act (CAMA) land use plan update that make clear that LID is the preferred approach for new development. In addition, it should include a chapter or section in the proposed Unified Development Ordinance clarifying that LID techniques are the preferred approach to land use within the watershed and that such approaches comply with county, state, and federal performance measures. This approach should provide regulatory incentives (reduced road widths, density credits, etc.) that encourage LID as an alternative to traditional development

designs so that the development community is encouraged to use these techniques in their new projects.

2. The county should reduce the amount of impervious surface required by its development management policies to the maximum extent practical.
   a) The county should review the development standards contained in its current zoning ordinance and subdivision regulations to ensure that the minimum level of impervious surface is required for development. This review should extend to the Unified Development Ordinance that is currently under development.
   b) Since the transportation system accounts for a significant percentage of the impervious surface in the watershed, the county should strongly encourage the NCDOT to incorporate LID techniques to manage stormwater associated with the development of new facilities and the upgrade or expansion of existing facilities. The county should encourage NCDOT to use LID approaches for all new and expanded transportation projects within the watershed by including a LID transportation policy in its CAMA land use plan update.
3. The county's development review process should incorporate a system, such as the Water Quality Risk Assessment Model, to identify sensitive areas where land development activities have a reasonable probability of degrading water quality.
4. The county should review the existing zoning ordinance and adjust density limits upward or downward based on the land suitability analysis, transportation and sewer infrastructure, population projections, land use compatibility goals, and other local needs.
5. The county should adopt land use and development policies in its CAMA land use plan to protect water quality and these policies should be implemented through its development management program. These policies should reflect new regulatory requirements adopted by the North Carolina General Assembly for NPDES Phase II counties such as whether the site drains to SA waters and its proximity to SA waters. The following are key aspects of these policies.
   a) Watershed-wide policies
      i) Coastal wetlands are part of the watershed's most sensitive natural system and they should not be used or developed for any purpose other than those water dependent uses that are allowed by the CRC rules. As an aid for managing the creation of surfaces in the watershed, these coastal wetlands should not be considered when calculating total development yield.
      ii) Throughout the watershed, non-coastal wetlands that have *significant or exceptional water quality protection functions* are vital systems and should be maintained as close to their natural

state as possible. These wetlands may be regulated by state of federal agencies, but the county should apply its own development guidelines to ensure the proper level of protection. Jurisdictional non-coastal wetlands should not be provided with sewer service; however, these areas may be included for calculations of total development yield.

iii) Hydrologic soil group (HSG) D soils, all of which are classified as *hydric* and have a high probability of being wetlands, should not be developed but rather should be incorporated into site green space systems. This policy should be included in the CAMA land use plan.

iv) HSG C soils contain a significant percentage of *hydric* soils. These soils have limited development potential and sites that contain predominantly "C" soils should be limited to *very low development* density. These sites should also have significant areas dedicated to green space. This policy should be included in the CAMA land use plan.

b) Sites within ½ mile and draining to SA waters and unnamed tributaries of SA waters:

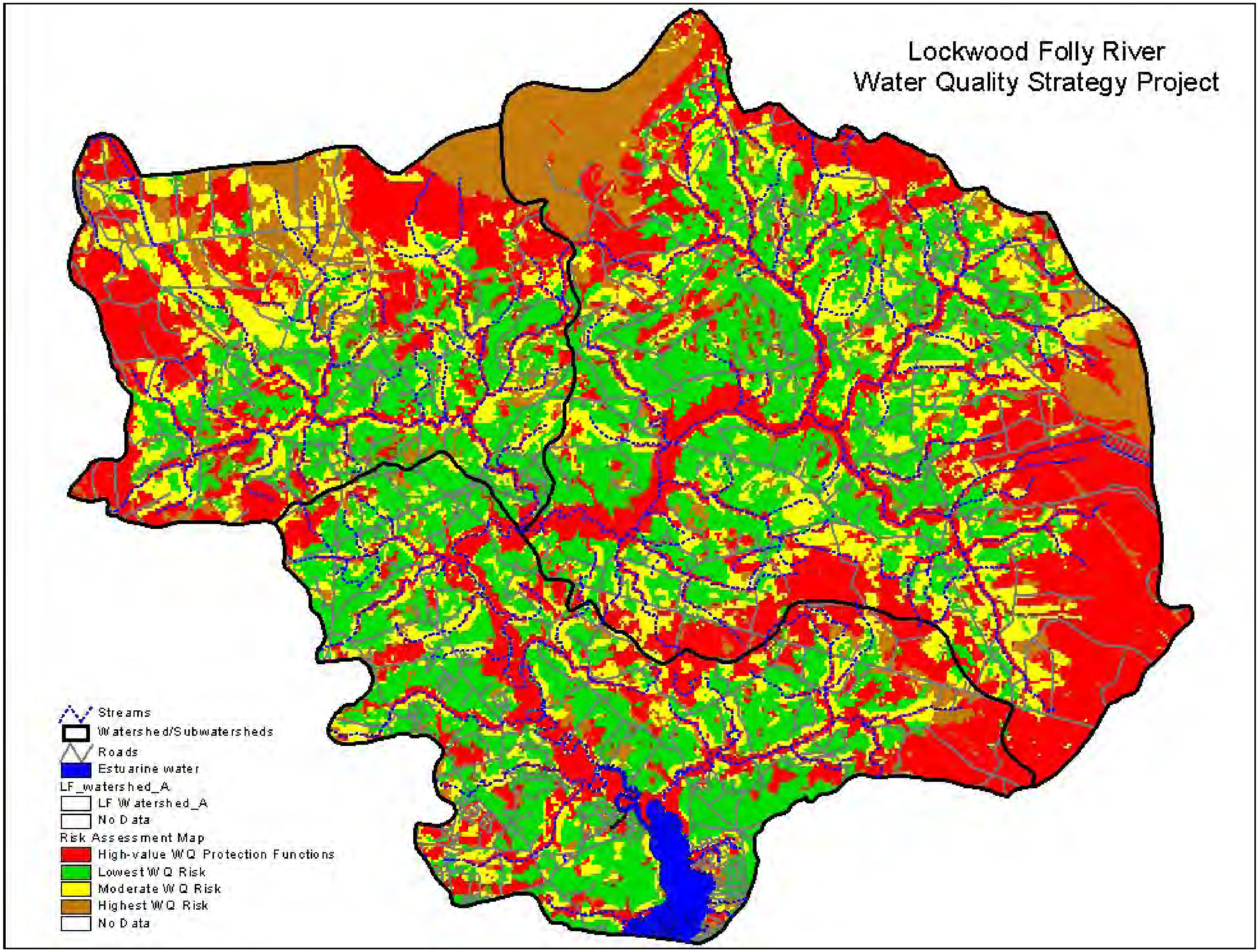
i) While HSG A and B soils are well drained, they are a major factor in the amount of rainfall that infiltrates the soil rather than runs off. Even though they have minimal development limitations, creation of built-upon surfaces on these soils will significantly increase stormwater runoff. In addition, these soils offer the best locations for installation of low impact development techniques. "A" and "B" soils should be: (1) limited to *low- development density* as defined by the Phase II NPDES Stormwater program (12% built-upon area); or (2) developed at higher density using LID measures that control stormwater runoff to pre-development conditions. The county should reflect these policies in its CAMA land use plan update as well as incorporate this strategy directly into its NPDES Phase II Stormwater program.

ii) Mature tree cover plays a major role in managing storm water runoff. Tree cover should be protected to the extent feasible.

6. Cluster development should be considered as a development practice to the maximum extent feasible as a means to manage stormwater and to protect valuable water quality features. The density levels on the cluster area of the site should be consistent with the density allowed by the zoning of the site. The open space created by the cluster approach should be planned as part of the overall water quality protection scheme for the site. In addition, the site should include a green space system that incorporates sensitive areas such as wetlands, stream corridors and naturally vegetated areas. This development option should be available for small parcels as well as

large tracts and should not require significant additional review processes.

7. The county should develop a sewer extension policy that is consistent with its land use policies that are designed to protect water quality.
   a) The county's sewer service extension policies and programs should give priority to service for existing development within the unincorporated area, particularly those developed areas that may be shown to have septic tank failures. Service to existing areas may encourage development in close-by areas that can be served by existing infrastructure and thereby reduce the need for additional impervious surfaces. Extension policies should encourage low impact development.
   b) The county's sewer service extension policies should discourage land uses and development intensities that produce impervious surface areas that are not consistent with water quality objectives.


Lockwood Folly River
Water Quality Strategy Project
Streams
Watershed/Subwatersheds
Roads
Estuarine water
LF_watershed_A
LF Watershed_A
No Data
Risk Assessment Map
High-value WQ Protection Functions
Lowest WQ Risk
Moderate WQ Risk
Highest WQ Risk
No Data

**Strategy 2**

*Incorporate low impact development (LID) technology into county site design and development policies. The strategy will include methods to integrate this tool into the County's existing development management program.*

**Findings**

Low impact development (LID) is an ecologically friendly approach to site development and storm water management that aims to minimize development impacts to land, water, and air. The approach emphasizes the integration of site design and planning techniques that conserve natural systems and hydrologic functions on a site. Low impact development is not a land use control, but a management and design strategy that is integrated into the proposed land use. It has also been shown to decrease costs to developers and to increase the desirability and value of the property. The practice has been successfully integrated into many municipal development codes and storm water management ordinances throughout the United States.

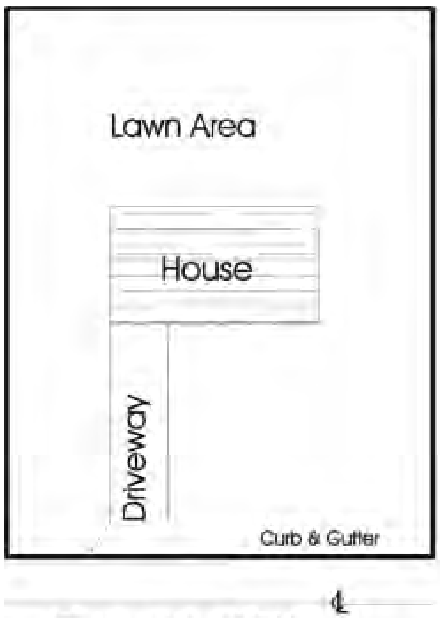
The goals of LID are to:

(1) Preserve open space and minimize land disturbance.
(2) Protect natural systems and processes (drainage ways, vegetation, soils, and sensitive areas).
(3) Reexamine the use and sizing of traditional site infrastructure (lots, streets, curbs, gutters, sidewalks) and customize site design to each site.
(4) Incorporate natural site elements (wetlands, stream corridors, and mature forests) as design elements.
(5) Decentralize and micromanage stormwater at its source.

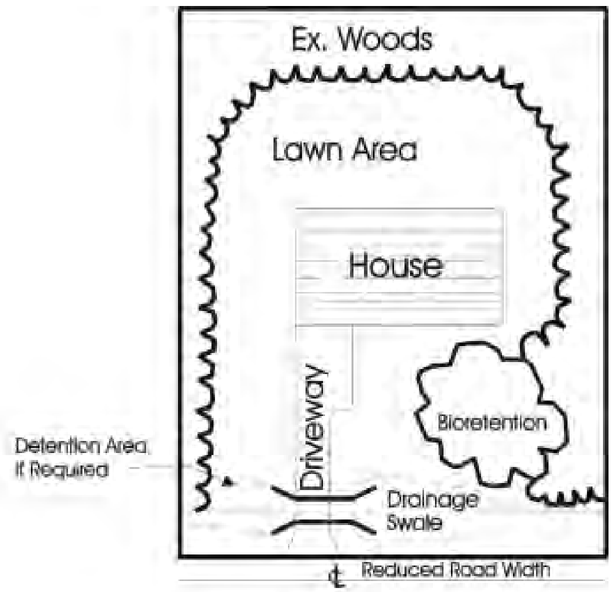
Low impact development techniques can provide a variety of benefits to municipalities, developers, homeowners and the environment. Some of these benefits include:

- Universally applicable
- Economically sustainable
- Ecologically sustainable
- Added values (lot premiums)
- Increased sales velocity and volume
- Lower costs (construction, maintenance and operation)
- Multiple benefits (air, water, energy and property values)

- Silent on growth management
- Ideal for urban retrofit
- Common sense approach
- Public acceptance




Conventional CN for 1-Acre Lot




Typical Low-Impact Development Lot

North Carolina State University prepared a comparison study on the costs of traditional development versus the costs of low impact development in Brunswick County. The result shows that the low impact approach is can actually be less costly than traditional development techniques. A few cost comparison studies have been conducted in other parts of the country, especially Maryland, support this finding.

**Recommendations**

1. Brunswick County should publicly support low impact development as a more effective means, compared to typical current practice, of managing stormwater and protecting water quality. This public support will encourage developers to utilize LID techniques and will encourage the public to purchase homes in LID developments.

2. The county should incorporate low impact development as a preferred strategy to meet post construction stormwater requirements for the Phase II NPDES permit requirements.

3. The county should review and update the County Stormwater Manual to reflect the latest low impact development technology.

4. Brunswick County should also incorporate low impact development into their local ordinances. Developers would have the option to use LID or conventional development, as LID would not be required, just recommended. Local ordinances that contain potentially excessive impervious surfaces, such as a minimum street widths, are often the biggest obstacles to low impact development. Therefore, the incorporation of LID principles into local county ordinances will help to encourage developers to utilize these environmentally friendly principles.

5. Conduct a demonstration project that will showcase low impact development principles to developers and to the public. This project will educate developers and citizens about both the economic and environmental benefits of low impact development and encourage the use of these techniques throughout the county. For example, future developments or expansions of county and public buildings should incorporate low impact development technologies into the building plans.

6. A staff specialist in the Brunswick County Department of Engineering Services should be trained in low impact development. In addition, the county should sponsor periodic training in low impact development for both staff and the county's development community.

7. The county should seek to establish an internship program in partnership with Brunswick Community College that involves students in coordination in implementation of the overall watershed strategy and with the public education and outreach program.

**Strategy 3**

*Coordination of state, local, and federal regulatory programs with Brunswick County taking lead enforcement role and fostering interlocal cooperation . Suggest policy changes and financial plan to accomplish.*

**Findings**

Information provided to the Round Table and discussions by Round Table members indicate that coordination of stormwater and water quality regulations and enforcement between federal, state, and local agencies and departments is less than optimal.

Figure 1 illustrates the stormwater permitting system.  Currently there are three major permitting processes in place: the county's stormwater ordinance and related stormwater manual; the NC Land Quality Section's Soil Erosion and Sedimentation Control regulations that have been in place since the 1970s; and NC Division of Water Quality's coastal stormwater regulations.  The county's subdivision and site plan (zoning) programs are linked to the county stormwater regulations and the state's soil erosion/sedimentation control requirements.

Each of these regulatory programs has some overlap but they tend to be mutually reinforcing.  The county stormwater ordinance conditions county permits on receipt of a soil erosion and sedimentation control permit.  The county ordinance does not make reference to the state's coastal stormwater permit requirements.

The county ordinance provides for a maintenance agreement for all facilities constructed to meet its requirements.  These agreements are typically between the county and homeowners associations.  The county inspects facilities at least one time per year after construction.

Typical review times for permit applications and stormwater plans are 30 days for soil erosion/sedimentation control; 45 to 60 days for coastal stormwater plans; and 30 days for the county stormwater permit.  These reviews can take place concurrently.

The county may be authorized to approve soil erosion and sedimentation control plans and issues permits after making application to the NC Land Quality Section.  The Division of Water Quality is presently developing regulations for a Universal Stormwater Management Program with goals of improving the effectiveness of the current regulations and streamlining the administration of the program.  By adopting a model ordinance provided by DWQ, the county may administer this program locally. This program will be implemented in summer 2007. The NC Division of Water Quality has submitted a preliminary draft Phase II NPDES permit that contains provisions similar to the new Universal Stormwater Management Program. NC DWQ is not able to provide details on this provision at the present time.

Currently the county has a staff of three individuals involved in plan review and inspections required by the local ordinance. Assuming administrative responsibility for soil erosion/sedimentation control and the universal stormwater program would require additional plan reviewers and inspectors. The following is a reasonable expectation:

| | |
|---|---|
| Engineer/supervisor | $60,000 |
| Assistant/Plan review | $38,000 |
| 4 Inspectors | $144,000 |

These costs are salary only and do not include benefit costs and typical overhead.

Three major benefits derive from consolidation of plan approval, permitting, and inspections: (1) the Brunswick County development community will see efficiencies in the review process through 1-stop permitting and possibly some reduction in plan review time; (2) there will be greater consistency among the 3 permit systems; and (3) the county's post-permit inspections will improve the effectiveness of state coastal stormwater program.

### Recommendations

1. The Round Table recommends that the Board of Commissioners take necessary steps to coordinate stormwater permitting in Brunswick County. The Round Table concludes that permit coordination will increase efficiency and will improve the effectiveness of the permitting system in protecting water quality.
2. The Phase II NPDES permit should be adopted as the primary tool for coordinating stormwater permitting by the county. The Phase II permit provides for local soil erosion and sedimentation control plan review and may provide for coastal stormwater plan review.
3. The county should establish a fee schedule for plan review and inspection that makes the program financially self-sufficient to the extent feasible.

4. The county will pursue partnerships with the local governments in the watershed to ensure the strategy and related programs are implemented uniformly.

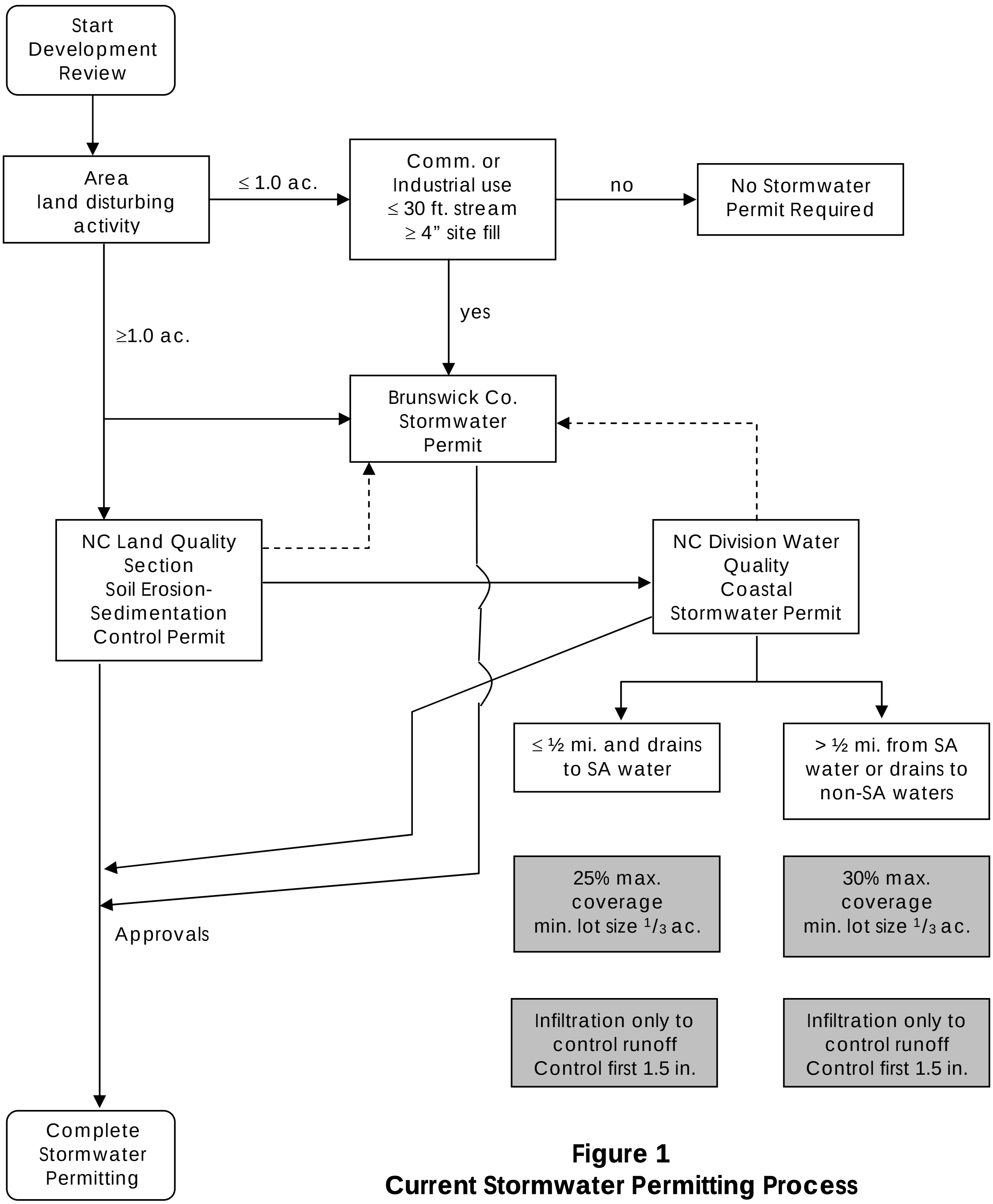



**Figure 1**
**Current Stormwater Permitting Process**

**Strategy 4**

*Action plan to acquire strategic sites and parcels to protect and restore water quality.*

**Findings**

As part of the Lockwood Folly River Water Quality Strategy, land acquisition of strategic sites within the Lockwood Folly River Watershed is proposed in order to reduce pollutant load into the River due to stormwater runoff, as well as prevent increased impervious surface from development of these lands. This should assist in reduction of three key environmental health threats: fecal coliform, freshwater inundation of estuarine areas, and increased runoff from impervious surfaces.

In reports and presentations to the Roundtable, Amy Lynch (Duke University) described a three-step for formulating the land acquisition strategy.

(1) Eliminate parcels that do not meet acreage criteria and development criteria.
(2) Rank remaining parcels based on hydrologic criteria—risk to water quality if developed, percent highly saturated soil, and stream index.
(3) Select from ranked parcels based on values of three different organizations.

The parcels and sites identified through this process constitute the land acquisition strategy.

The strategy identifies a number of funding organizations, agencies, and programs that are available options for funding of the Lockwood Folly Land Acquisition Strategy.

(1) Clean Water Management Trust Fund
(2) EPA—Targeted Watershed Grant Program

(3) EPA—Assessment and Watershed Protection Program Grants (AWPPGs)
(4) Environmental Finance Center Network: Directory of Watershed Resources
(5) The Conservation Trust Land Conservation
(6) The Compton Foundation Environmental Grants
(7) NOAA Community-Based Restoration (CRP)—National and Regional Partnerships
(8) NCEEP Funding

**Recommendations**

The county should work to preserve and restore key properties that are identified. Acquisition priorities should be based on the property selection criteria developed by the Roundtable. To implement this strategy, the county should pursue the following steps:

1. The priority sites identified as a result of the Land Acquisition Strategy Process should be the basis for selecting potential sites for acquisition.
2. The county should establish partnerships with NGOs (North Carolina Coastal Conservation League, North Carolina Coastal Land Trust, The Nature Conservancy, etc.) to pursue targeted land acquisition to preserve high priority properties.
3. Through these partnerships where NGOs and EEP will take the lead, the county should actively encourage at least one major property acquisition (from willing sellers) every two years within the watershed
4. The county should work with the NCEEP to promote the restoration of degraded lands with EEP taking the lead on these projects.
5. Brunswick County should also seek to elevate the status of the Lockwood Folly River as an important location to invest land acquisition funds by:
   - Supporting Wild and Scenic Designation of the upper Lockwood Folly River
   - Supporting the NC Oyster plan that places high priority on the watershed for oyster protection and restoration
   - Including policy statements in its CAMA land use plan that promotes land acquisition within the watershed
   - Encouraging the NC Division of Coastal Management to include the Lockwood Folly Watershed in its CELCP plan (there is no mention in the current plan)

6. The county, through its planning process, should develop and map an open space, or green space, system and use open space values as a factor in the final selection of sites scheduled for acquisition.

**Strategy 5A**

*Develop a public education, information, and outreach program.*

**Findings**

The effectiveness of the water quality strategy will be greatly enhanced by the active participation and support of the residents, property owners, and visitors of the watershed. The strategy aims to increase public understanding and awareness, promote better stewardship of private lands, and develop funding to help sustain watershed programs.

An informed and knowledgeable community is crucial to the success of the Lockwood Folly Watershed Strategy. A public education and outreach program will ensure *greater support* for the program as the public gains a greater understanding of the reasons why it is necessary and important. The program will also ensure *greater compliance* with the program as the public becomes aware of the personal responsibilities expected of them and others in the community, including the individual actions they can take to protect or improve the quality of area waters.

The components of the public education, information, and outreach strategy are as follows:

(1) technical assistance
(2) advocacy
(3) education
(4) pollution prevention
(5) maintenance
(6) water quality monitoring
(7) assistance with restoration

There are two main sources of funding opportunities for a public education and outreach strategy. The *319 Grant Program* federal grant funding from the Environmental Protection Agency to implement non-point source pollution management projects. The U.S. Environmental Protection Agency provides funds to state and tribal agencies, which are then allocated via a competitive grant process to organizations to address current or potential non-point source pollution concerns. In North Carolina, the 319 Grant Program is administered by the Division of Water Quality of the Department of Environment and Natural Resources.

A second source of funding for a public education and outreach program is the *North Carolina Coastal Non-point Source Program Grant (CNPSP).* This grant program is jointly administered by the Division of Coastal Management and the Division of Water Quality to strengthen the links between Federal and State coastal zone management and water quality management programs to enhance State and local efforts to manage land use activities that degrade coastal waters and coastal habitats.

**Recommendations**

1. Brunswick County should create a permanent staff position to assist in implementation of the Lockwood Folly River water quality strategy, including the education and outreach program. The position will be in charge of implementing and overseeing the various Lockwood Folly River water quality strategies: include low impact development, land acquisition, coordination with other programs such as coastal management and non-coastal wetlands, a living shorelines program, a working waterfront program, and so on.

2. The county should establish an adequate annual budget to support the education and outreach program activities.

**Strategy 5B**

*Recognize the environmental and cultural significance of the Lockwood Folly River through Wild and Scenic River designation.*

**Findings**

A river is eligible for the Wild and Scenic River designation if it is a free-flowing river with "outstandingly remarkable" values (ORV) as described in the Wild and Scenic River Act of 1968. These values include outstanding and remarkable scenic, recreational, geologic, fish and wildlife, historic, cultural, or other similar values. There are three classifications of WSRs: (1) wild, (2) scenic, and (3) recreational. Each of these classifications is described below:

(1) WILD: Rivers, or sections of rivers, that are free of impoundments, generally inaccessible, except by trail (no roads), with watershed or shorelines essentially primitive, and having unpolluted waters.

(2) SCENIC: Rivers having the same characteristics as *wild,* but accessible in places by roads. These rivers are usually more developed than *wild* rivers and less developed than *recreational* rivers.

(3) RECREATIONAL: Rivers, or sections of rivers that remain largely natural in appearance but are readily accessible by road or railroad. These rivers may have some development along the shoreline and may have had some impoundment or diversion in the past.

The upper Lockwood Folly River will be eligible for the *scenic* and *recreational* river designation.

WSR designations seek to maintain and enhance a river's *current* natural condition and provide for public use consistent with retaining those values. The designation prohibits the federal government from licensing or permitting hydroelectric dams or major diversions on these streams, and federal agencies are prohibited in assisting any water resource projects that may directly affect designated rivers. However, the designation *does not* affect private land and *does not* give additional power to the federal government over private landowners.

In other words, scenic or recreational designation will allow current river and land uses to continue while preventing Federal projects that will degrade the outstanding qualities of the river. In addition, the designation will bring local and regional attention to the beauty and pristine nature of the river, and it will support the county's education, information, and outreach program.

In coastal, and largely rural, Brunswick County, fishing, shellfishing, and tourism functions of the Lockwood Folly River and estuary are integral to the economy and natural heritage of residents. However, some of the most rapid population growth in coastal North Carolina is taking place in Brunswick County. More and more people will be using the river in coming years whether the designation is made or not. The designation will raise awareness about the special values of the river and will help us all (landowners and the general public) be better stewards of this remarkable river. For example, one of these special values is the presence of the American alligator in the Lockwood Folly River. This inhabitance is considered rare because the alligator is at the northernmost part of its range.

The primary benefit of the designation of the Lockwood Folly River is the increased opportunities that public money might be available to buy land or easements from willing property owners. Having more land available for public uses such as hunting and camping will help accommodate growing public demand for such areas and reduce pressures and conflicts with private property owners. The designation also assures that activities on federal lands are consistent with *Scenic* and *Recreational* qualities of the river.

In addition, the North Carolina Wetlands Restoration Program (NCWRP) has identified the Lockwood Folly River watershed as an area with the greatest need and opportunity for stream and wetland restoration efforts. The Lockwood Folly River has also been designated as a primary nursery area for fish, shrimp, and shellfish. This watershed is still relatively undeveloped and further degradation can be prevented. The designation will recognize the environmental and cultural significance of the Lockwood Folly River.

**Recommendations**

Brunswick County should take steps to designate the Upper Lockwood Folly River and a *Wild and Scenic River*:

1. The Board of Commissioners should adopt a resolution stating that it is the intent of the county to pursue the designation.
2. The Board of Commissioners should enlist the support of its congressional delegation to move the project through the federal study and designation process.

**Strategy 6**

*Protect stream edges in the watershed by implementing a* ***Living Shorelines*** *program.*

A *living shoreline* is an innovative approach to shoreline stabilization that combines various stabilization methods to control shoreline erosion, while restoring and/or preserving the characteristics of the estuarine marshes and upland buffers. Living shoreline typically use a low rock sill to absorb wave energy. Behind the sill, wetland vegetation is planted to restore the lost habitat, provide a stormwater buffer, and reduce erosion.

Brunswick County's coastal marsh systems provide critical nursery habitat for many recreationally and commercially valuable fisheries. Wetlands provide direct and indirect food sources for countless animals, and they filter out pollution and sediment from stormwater runoff. In this way, wetlands protect the water quality, by acting as the "kidneys" of the estuary. Because they absorb stormwater and wave energy, marshes provide flood protection and erosion control. Coastal marshes are also a very important part of North Carolina's natural heritage and beauty, and are closely associated with the health of the estuaries' shellfish areas.

The county's coastal marshes are declining, and will continue to do so in the coming decades due to storms, boat wakes, development impacts and sea level rise. The North Carolina Ecosystem Enhancement Program is encouraging demonstration of "Living Shorelines" projects along the estuarine coasts of North Carolina. Broadly refined, a "Living Shorelines" project is an innovative approach that combines various stabilization methods to control shoreline erosion, while restoring and/or preserving the characteristics of the estuarine marshes and upland buffers.

Living Shoreline approaches allow property owners to choose a protection method that will provide effective erosion control with the least negative impact on the environment. Living Shoreline projects incorporate bioengineering techniques to avoid a "hardened" shoreline, which results from the traditional approaches of vertical walls or riprap. Vertical walls and riprap revetments do not absorb wave energy like sloping vegetation. Instead, the energy is reflected back along the shoreline, which can increase the erosion in these areas and scour marshes that naturally grow here. Bulkheads replace the broad, diverse tidal area with a vertical surface, greatly reducing the potential habitat for numerous estuarine animals that rely on these fringes to survive.

The Ecosystem Enhancement Program is seeking opportunities to restore coastal marsh along coastal Brunswick County by encouraging people to participate in a living shorelines program.

**Recommendations**

1. Brunswick County should support the EEP Living Shorelines Program and help promote it to the public. Potential cost sharing for restoration projects should be a centerpiece of the promotion program.

2. The county should consider conducting a public living shoreline demonstration project that could be showcased as a public education facility.

3. Brunswick County should consider incorporating language supporting living shorelines in policy documents such as the CAMA land use plan.

**Strategy 7**

*Identify sites for water quality "retrofit" to reduce or eliminate unwanted runoff.*

**Findings**

Retrofitting and restoration are possibly the most challenging aspects of water quality protection and improvement. However, given that portions of the Lockwood Folly River are already degraded under exiting land use conditions, diligent efforts must be made to reduce stormwater runoff and pollutant loads from the areas already developed.

The Lockwood Folly River is currently on the 303(d) list of impaired waters in North Carolina due to levels of fecal coliform bacteria that exceed standards for SA waters. The *Lockwood(s) Folly LWP - Preliminary Findings Report* prepared by NCEEP identified fecal coliform loading and the potential for excess nutrient loading as primary stress factors to watershed functions in the Lockwood(s) Folly LWP study area.

There is still significant potential to guide new growth so as to avoid and minimize new water quality problems in the areas of the watershed that have yet to be developed. However, existing sources of impairment of the river have not yet been fully evaluated or addressed. The Roundtable Water Quality Process is an outgrowth of the County's recognition that existing federal, state and local land use management in the watershed will need to be improved if the river is to be restored and adequately protected. The County's Phase II NPDES permit application supports this effort.

In addition to the efforts of the County, the North Carolina Ecosystem Enhancement Program (NCEEP) selected the Lockwood(s) Folly Watershed for development of a Local Watershed Plan (LWP). The LWP will identify and prioritize restoration and management opportunities to protect and improve the functions of the watershed. Specifically these efforts will include identification and prioritization of opportunities to retrofit stormwater BMPs to already developed areas of the watershed to reduce non-point source pollutant loads of nutrient and fecal coliform.

All the primary stress factors identified in the watershed can be attributed to the adverse impacts of urban stormwater runoff. Reduction of these factors offers a strong opportunity to realize multiple benefits through the retrofitting of stormwater BMPs, primarily stormwater wetlands and detention ponds, which can reduce fecal coliform and nutrient loads, as well as reducing peak storm flow and stream erosion.

NCEEP will conduct a detailed assessment of the watershed as part of the LWP effort. This assessment will allow for identification of those portions of the study area having the greatest potential to deliver pathogens and nutrients to the River under both existing and future land use conditions. The LWP will identify a list of potential BMP retrofit sites in those areas identified as high-risk sources for fecal coliform and nutrient loading. The suitability of potential retrofit sites will be further evaluated through field reconnaissance and/or the input of local planners and stormwater managers, and opportunities will be prioritized on the basis of feasibility and cost-effectiveness. Also, the LWP will describe potential sources of funding and assistance for implementation will be identified.

**Recommendations**

1. Support the development of, and give high priority to, the implementation of targeted stormwater BMPs identified in the NCEEP Local Watershed Plan.

2. Identify a central county staff position (see Strategy 6B) that, in conjunction with NCEEP efforts, will explore the feasibility and funding for retrofitting the County Government Complex with appropriate stormwater BMPs as a demonstration project.

**Strategy 8**

*Develop financial incentive program that encourages developers to take alternative approaches that support water quality objectives.*

**Findings**

Round Table Members have discussed the concept of a financial incentive program that encourages the real estate development community to use alternative site design and development approaches that are consistent with the water quality goals in the watershed. Such a program recognizes that there may be both monetary and organizational costs associated with formulating new site planning and development models to address the issues necessary to protect water quality.

The Round Table identified three potential options for providing financial incentives. One of these options is the traditional donation of fee simple title or a development easement to conservation land to a qualified land trust or conservancy. Such a donation qualifies for federal income tax deductions and in North Carolina, the donation brings either a tax deduction or a tax credit. The tax credit is limited to 25% of the value of the donation up to $500,000 for a corporation and $250,000 for an individual. Other tax credit programs, such as the historic preservation tax credit and the low income housing tax credit, generate immediate cash for the donor entity through a syndication process. However, syndication of the conservation tax credit is not feasible due to the limit of 25% of value and the caps on individuals and corporations.

One of the difficulties with donations is that they may be paper-work intensive and require the services of real estate appraisers and attorneys. In addition, it may be difficult to find an organization to accept donations of small tracts of land. Creation of a county trust that could coordinate the donation of property and easements, transfer suitable property to an established land trust, and retain and manage donated property and easements not suited for transfer.

Related to tax-advantaged donations, the ad valorem tax treatment of conservation land can be a major factor in the owners decision-making concerning development. The county tax office has the ability to assign use-values that can defer property taxes.

A second option is to purchase land or development rights using a public or NPO trust fund. Even if the purchase price is limited to a portion of the appraised value, say 50%, the ability to generate cash may be more attractive to a development organization than a tax deduction or tax credit. Some local governments have been successful in using the NC Clean Water Trust Fund to purchase land in this manner.

A third option is a process called transfer of development rights, or TDR. TDR is a method for protecting land by transferring the "rights to develop" from one area and giving them to another. What is actually occurring is a consensus to place conservation easements on property in critical water quality areas while allowing for an increase in development densities or "bonuses" in other areas that are being developed. The costs of purchasing the easements are recovered from the developers who receive the building bonus.

The transfer of development rights is not a new concept. TDRs have been used in other areas of the country for the preservation or protection of open space, natural resources, farmland, and urban areas of historical importance. TDRs also have been used to secure land for solid waste facilities and for the protection of golf courses. More than 20 states have enacted or amended statutes accommodating the TDR concept.

TDRs are regulatory tools designed to facilitate land-use planning. Unlike most land use plans, the transfer of development rights requires much more certainty of where development will happen and where it will not. TDR programs cannot be established in the absence of a detailed land use plan.

Cluster development is a simpler, on-site version of the TDR concept. Essentially, the cluster development concept allows owners and developers to relocate permitted residential units from conservation areas to on-site areas that have higher levels of development suitability. The result is to protect sensitive areas and increase density in more suitable areas.

**Recommendations**

1. The county should develop a simple, effective mechanism encourages donation of conservation land to appropriate non-

profit conservation organizations. In conjunction with this strategy, the county should consider designating and training a staff person to provide this assistance:

a. Property owners should be informed about the benefits and requirements for donating conservation land;
b. Assistance should be available to help property owners complete the *due diligence* process required for donations; and

2. The county tax office should ensure that designated conservation lands within subdivisions receive maximum favorable ad valorem tax treatment.
3. The county should work with its state and national organizations to explore the feasibility of increasing the percentage of value and the tax credit caps on the conservation land tax credit program. Increasing these levels will it more likely that the program will be utilized.
4. Developers should have access to a streamlined development review process to encourage cluster development, flexible site planning and development, and other LID techniques that support water quality objectives.
5. As a long-term option, the county should consider a TDR program. Preparation of a detailed operation plan is a first step in this process. The plan will provide significant details on operation and the requirements for state and local legislation.
6. The county should assess the feasibility of a conservation land trust fund for fee simple purchase or to purchase development rights for key properties in the watershed.

**Strategy 9**

*Develop a working waterfront program that assists in the preservation of traditional waterfront businesses, such as fish houses and commercial marinas, and public access, such as boat ramps and fishing piers.*

**Findings**

As development pressures and land values increase along the Lockwood Folly River, it will be more difficult for traditional waterfront uses to continue. This strategy will involve land use policies and incentives that will assist water dependent owners and business operators with remaining in place. The strategy will also take advantage of funding sources for the preservation of public access points.

A working waterfront is property that provides access for water dependent commercial activities or property that provides access for the public to public trust waters of the state. A working waterfront includes commercial marinas, boatyards, wet and dry storage, fish houses, commercial fishing vessel dockage and marine-related industries such as boat dealers, boat repair and maintenance services, commercial fishing and tourism. A limited supply of waterfront land and an increasing demand by different uses is leading to a loss of the working waterfront.

In coastal, and largely rural, Brunswick County, fishing and shellfishing functions of the Lockwood Folly River and estuary are integral to the economy and natural heritage of the residents. However, some of the most rapid population growth in coastal North Carolina is taking place in Brunswick County. Good planning is the key to saving the working waterfront. These plans involve people from the area sitting down and coming up with a vision for their communities. In other words, the community needs to decide what's worth saving. Local governments can then fashion ordinances that enforce the goals and polices of the land-use plan. Optional categories in zoning ordinances can protect commercial fish houses or allow people to build boats in their front yards. Special cultural or conservation overlays can protect water quality or a place's ethnic or cultural identity.

There is a variety of funding sources available to help save the working waterfront, including loans, municipal bonds, grants, donations, and local taxes. For example, Brunswick County can seek financial assistance for public access from the state through the North Carolina Park and Recreation Trust Fund. This fund provides annual dollar-for-dollar matching grants. In addition, the local government can purchase land by issuing general obligation bonds. General obligation bonds require approval by the public and are backed by the full faith and credit of the local jurisdiction issuing the bonds. Several local jurisdictions in North Carolina have successfully issued bonds for open space preservation. Local governments can spend the money on public boat access as well as the purchase of development rights from marinas and boatyards.

The Division of Coastal Management, under the Coastal Area Management Act (CAMA) is one of the largest sources of public access grants, awarding about $1 million a year in matching grants to local governments. Local governments may use access grants to construct low-cost public access facilities, including parking areas, restrooms, dune crossovers and piers. Towns and counties may also use the grants to replace aging access facilities. In addition, local governments can use the funds to help acquire land for access sites or to revitalize urban waterfronts.

### Recommendations

1. Brunswick County is currently updating their land-use plan as required by the Coastal Area Management Act (CAMA). Specific policies on working waterfronts should be included in this plan, as well as in municipal plans, such as the Varnamtown Workbook Plan.

The first step in this process is to complete an inventory of what currently exists, in terms of public access points and commercial businesses, such as fish houses. CAMA allows for the protection of traditional access, but these access points must first be inventoried before they can be protected. The county should also look at models from other states, such as Maine and Florida, which have incorporated a variety of working waterfront policies into their land-use plans. For example, the state of Maine has developed waterfront ordinances that specify how municipal waters and waterfront facilities will be managed. By delineating what activities will occur where, ordinances establish consistent rules and help to minimize conflicts. Maine's Working Waterfronts Initiative also includes the outright purchase of shorefront lands as well as securing easements that provide permanent guaranteed access for working fishermen. The Working Waterfront Initiative also supports water-dependent businesses through the private sector, such as commercial loans, leases and new markets, and through the public sector, such as low-interest loans, guarantee funds, and technical assistance. In addition, the state of Florida has developed a Marine Management Strategic Plan to address their working waterfront concerns. Brunswick County can use other states' programs, such as Maine's Working Waterfront Initiative and Florida's Marine Management Strategic Plan, as models for their own working waterfront program.

2. The county should quickly develop a public access plan that identifies and utilizes sources of funding for land acquisition of priority areas. For example, the town of Emerald Isle is in the process of buying a local fishing pier to save it from development and to keep it open for public use. There are a variety of funding sources available for priority land acquisition, including CAMA and the North Carolina Park and Recreation Trust Fund. These funds will allow the county to purchase working waterfront land, such as piers and boat ramps, and to keep this land available to the public and to working fishermen.

   The county should expand its paddle trail and access plan to include projects in the Lockwood Folly River and its tributaries.

3. Public access is one of the keys to maintaining a working waterfront. In addition, CAMA requires counties to address and develop a plan for public access. The county should encourage varied waterfront uses, such as commercial fish houses, industrial and recreational marinas and recreational fishing piers. The

Brunswick County local government should consider using their zoning and subdivision authority to require that new development set aside space for public and commercial access. For example, local governments have the authority to require access for commercial fishermen in any new marina—even those built for private real estate development.

4. The Brunswick County local government should consider establishing a fund, through activities such as bond referendums, that provide money to buy development rights or conservation easements to land that is ecologically or culturally significant or that provide waterfront access to commercial or recreational fishermen and the public.

5. Oak Island Mayor John W. Wereen and Lockwood Folly Roundtable member and developer Buddy Milliken will represent Brunswick County interests on the recently appointed *Waterfront Access Study Committee* created by Senate Bill 1352. The committee is charged with preparing a report for the Joint Legislative Commission on Seafood and Aquaculture by early next year. The report will include information about land use management and zoning, shoreline development trends and tax assessment trends. The report will also include possible incentives and management tools to preserve waterfront diversity.

6. The county should support efforts that allow people with moderate incomes to continue to live in the Lockwood Folly Watershed. This may be done through a workforce housing plan that will allow moderate income residents to continue to live within the watershed.

# Lockwoods Folly River Local Watershed Plan

# APPENDIX E

# Restoration Opportunities Atlas

North Carolina
Ecosystem Enhancement Program

June 2007

Prepared by:

Stantec

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# Table of Contents

# Figures

# 1 Introduction

## 1.1 BACKGROUND

The Detailed Assessment and Targeting of Management Report is the result of the second and third phases of the local watershed planning effort for the Lockwoods Folly River. In the second phase, areas with the greatest functional loss were identified including those with the greatest stream and wetland degradation as well as those with the highest pollutant loading rate. In order to address these losses, stream and wetland restoration opportunities, retrofitting opportunities for best management practices (BMPs) and other management opportunities were identified. Management and protection measures to prevent future degradation were also identified through the efforts of the Lockwoods Folly Watershed Roundtable.

This Restoration Opportunities Atlas provides site-scale information and characterization details for each of the individual opportunities identified. Users of this atlas should be cautioned that it is not intended as a stand-alone document. Rather, it should be used as a companion to the primary Detailed Assessment and Targeting of Management Report which describes the overall watershed context and priorities within which these potential individual projects should be approached.

## 1.2 APPROACH

A search for stream and wetland restoration sites occurred throughout the watershed as five percent of all non tidal streams were visited and assessed. In addition, remote sensing and aerial imagery was used to identify other potential areas that were then visited.

Little opportunity was found in the southern half of the watershed as many of the streams are protected by large buffers. Streams have been impacted by road crossings and impoundments but the affected areas are small.

Within the Tier 1 and Tier 2 priority subwatersheds, a comprehensive search was conducted to identify suitable locations for stormwater BMPs such as stormwater wetlands, bioretention, and water quality swales. Opportunities to improve existing BMPs that showed signs of failure were also located. The search focused on commercial and institutional areas as well as community facilities in residential developments although all of the priority subwatersheds were canvassed and some BMPs were identified in residential areas.

Most of the development in the Lockwoods Folly River is residential. Older neighborhoods most often have roads without curb and gutters and there are multiple ponds that were originally constructed for aesthetics. Runoff can infiltrate in the grassy areas lining the road or is contained in the ponds. In some neighborhoods, as more houses have been constructed, stormwater runoff volumes have increased leading to erosion along roadsides and in some places down cut ditches are forming. Most of the newer neighborhoods are designed with traditional stormwater infrastructure where inlets catch most of the runoff from roads and houses. Stormwater BMPs, including ponds, are often located in these neighborhood but it is difficult to determine how much of the runoff they recieve. In addition, many of the neighborhoods are still under construction and there are still large areas of uncleared land. Opportunities for BMP retrofits are limited in these neighborhoods.

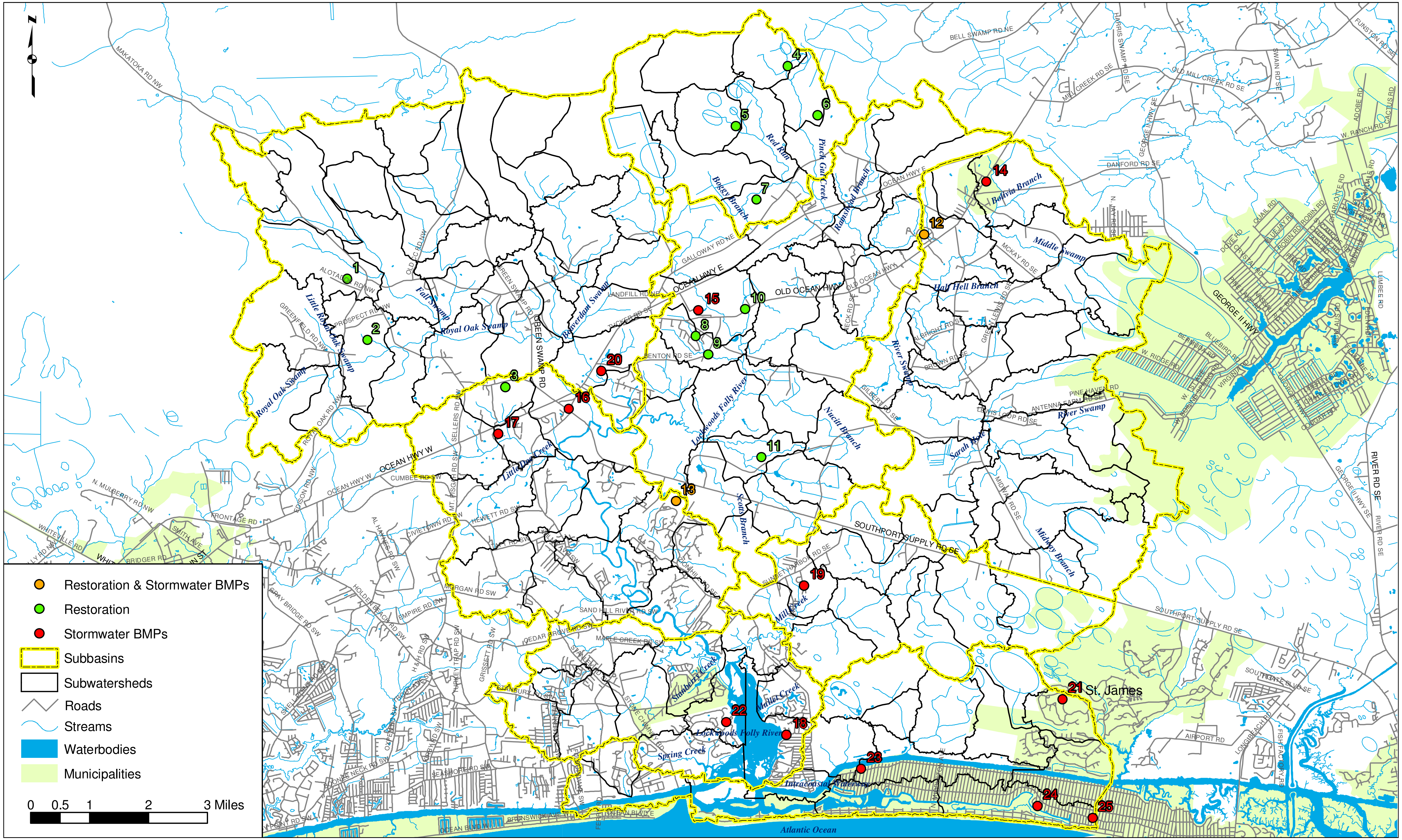
# 2 List of Projects

Stream and Wetland Projects:

| No | Location | Recommended Activity | Length*/ Area | Observed Constraints | Estimated Cost |
|---|---|---|---|---|---|
| 1 | Alotadoe Rd | non-riparian wetland restoration | 24 ac | None | $360,000 |
| 2 | Prospect Rd | stream restoration & riparian wetland restoration | 2500 lf & 5 ac | loss of hardwood trees | $302,000 |
| 3 | Big Macedonia Headwaters | riparian wetland restoration (headwater system) | 1100 lf & 4 ac | None | $130,000 |
| 4 | Pinch Gut Creek | riparian & non-riparian wetland restoration/ enhancement | >30 ac | potential impact to logging roads | n/a |
| 5 | Red Run Bays | stream & riparian/non-riparian wetland restoration/ enhancement | >46 ac & 1600 lf | potential impact to logging roads | $320,000 (stream only) |
| 6 | Galloway Rd | non-riparian wetland restoration | 33 ac | None | $330,000 |
| 7 | Boggy Branch UT | stream & riparian wetland restoration | 1400 lf & 3 ac | proximity to spray fields | $140,000 |
| 8 | Ford Branch UT | stream restoration | 2100 lf | None | $395,000 |
| 9 | Ford Branch | stream restoration & riparian wetland restoration | 1100 lf & 3.2 ac | None | $196,000 |
| 10 | Pecan Trail Headwaters | stream restoration & riparian wetland enhancement | 1550lf & 1.4 ac | culverts in stream for Old Ocean Highway crossing | $328,000 |
| 11 | Old Lennon Rd | stream restoration | 1450 lf | None | $193,000 |
| 12 | Government Complex | stream restoration (2 reaches) *(plus BMPs – see next table)* | 900 lf & 900 lf | Reach 1: storage/ parking lot & county extension septic system demonstration center | $275,000 |
| 13 | Zion Hill | riparian wetland restoration/ enhancement/preservation (headwater system) *(plus BMPs – see next table)* | 15 ac | None | $120,000 |

* = number shown is existing stream length, restored stream length would be longer


Stantec




Project Overview Map

Stormwater BMPs:

| No | Location | Recommended Stormwater BMP | Estimated Cost |
|---|---|---|---|
| 12 | Government Complex *(in addition to stream restoration listed above)* | bioretention | $100,000 |
| | | stormwater wetland | $6,070 |
| | | swales (front) | $3,780 |
| | | swales (back) | $3,150 |
| | | pond retrofit | n/a |
| 13 | Zion Hill *(in addition to stream restoration listed above)* | stormwater wetland | $2,600 |
| 14 | Bolivia Elementary School | bioretention (3 cells) (*constraint: potential loss of a few parking spaces*) | $52,000 |
| 15 | Brunswick Technical College | bioretention (2 cells) | $80,000 |
| | | retrofit pond | n/a |
| 16 | Supply Intersection | stormwater wetland | $18,600 |
| 17 | Brunswick Community Hospital | stormwater wetland | $7,050 |
| | | swales (front) | $2,970 |
| | | swales (back) | $1,350 |
| | | retrofit pond | n/a |
| 18 | River Run Plantation | stormwater wetland | $14,050 |
| 19 | Harbor Ridge | swales (*constraint: potential high # landowners if right-of-way not wide enough for swale*) | $16,740 |
| 20 | Supply Elementary School | bioretention (2 cells) | $155,000 |
| 21 | St. James | stormwater wetland | $6,400 |
| 22 | Lockwoods Folly County Club | swales | $25,200 |
| | | retrofit pond | n/a |
| 23 | Oak Island Northwest | swale (2) | $6,075 |
| 24 | Oak Island Recreation Center | stormwater wetland (*constraint: may require removal of some pavement*) | $10,590 |
| 25 | Oak Island Hospital | bioretention (2 cells) | $31,000 |

# 3 Potential Restoration Projects

## 3.1 PROJECT 1 ALOTADOE RD WETLAND

### 3.1.1 Location

The proposed area is on the north side of Alotadoe Road near the intersection of Royal Oak Road (SR 1345) and Makatoka Road (SR 1342).

### 3.1.2 Project Description

The project involves approximately 24 acres of non-riparian wetland restoration in agriculture fields that have been ditched and drained. The ditches currently drain to a UT of Fall Swamp. The potential restoration area shown on the map is approximate and is based on mapped hydric soils, location of the ditches, topography, and aerial photograph interpretation. Woodington fine sandy loam (Hydric A) is mapped in the western half of the potential project area. Hydric B soils cover most of the field.

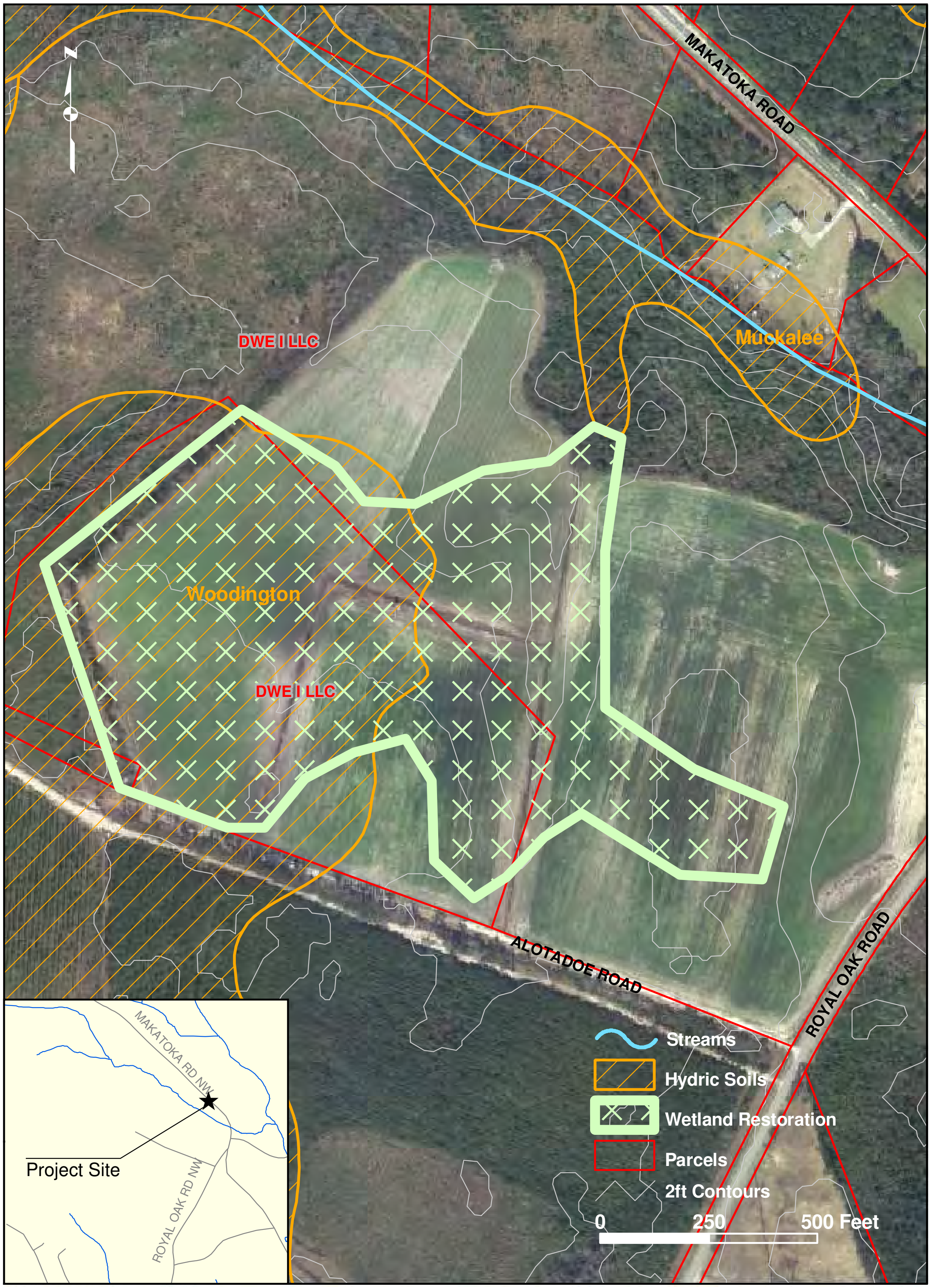
The functional benefit of this wetland restoration is to improve habitat. The restoration will also help improve water quality by eliminating runoff from the agriculture field as well as any sediment erosion from the ditches.

### 3.1.3 Constraints

None

### 3.1.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---|
| Construction Cost | $240,000 |
| Project Design and Consulting Services | $120,000 |
| Total Cost Estimate | $360,000 |
| Approximate Yield | 24 acres |
| Estimated Cost/Acre | $15,000 |




Project 1. Alotadoe Rd Wetland Restoration

### 3.1.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 1360002302,<br>13600023 | DWE I, LLC<br>2618 New Village Way<br>Wilmington, NC 28405 |

### 3.1.6 Photos

1. West ditch looking north

2. Presence of organic soil material

## 3.2 PROJECT 2 PROSPECT RD STREAM & WETLAND

### 3.2.1 Location

The proposed project is located on the south side of Prospect Road (SR 1353) approximately 250 yards east of the intersection with Royal Oak Road (SR 1345).

### 3.2.2 Project Description

The proposed project is located on a first order stream that is a UT to Royal Oak Swamp. The stream is channelized and incised with eroding banks. The right bank is a steep berm that may double as an access road. It has been cleared of all woody vegetation and the herbaceous vegetation appears to be mowed. Priority 1 stream restoration is recommended for approximately 2,500 linear feet. The channel can be realigned within the adjacent property, although this property is wooded. Restoring the stream and floodplain would result in at least 5 acres of riparian wetland based on a fifty foot buffer on each side of the stream. Soils along the reach include Leon fine sand for the majority of the length and Pantego mucky loam at the upstream end of the project site. Part of this stream length may fall under the Coastal Plain Headwater Stream Guidance.

The main functional benefit of this project is an improvement in water quality and aquatic habitat by reducing sediment erosion. In addition, restoration of the riparian buffer will also help improve aquatic and terrestrial habitat. Runoff from Prospect Road currently enters the stream via roadside ditches. Floodplain restoration will enable overbank flow during rain events allowing short term storage of stormwater and thereby improving water quality.

### 3.2.3 Constraints

The left bank and beyond is currently hardwood forest; some trees would be lost.

### 3.2.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---|
| Construction Cost | $202,000 |
| Project Design and Consulting Services (33%) | $100,000 |
| Total Cost Estimate | $302,000 |
| Approximate Yield | 2,500 linear feet<br>5 acres |
| Estimated Cost/Linear Foot (including riparian wetland buffer) | $120 |


Project 2. Prospect Rd Stream & Wetland Restoration

### 3.2.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 15100004 | Love, Virginia ET ALS<br>2618 New Village Way<br>Wilmington, NC 28405 |
| 15100047 | Gore, J W (Heirs)<br>c/o Robert Gore<br>102-01 32nd Avenue<br>Apt 1-B<br>East Elmhurst, NY 11369 |
| 15100009 | Varnam, Samuel N ET Lisa<br>1574 Monster Buck Estate<br>Supply, NC 28462 |

### 3.2.6 Photos

1. Channelized stream with berms

## 3.3 PROJECT 3 BIG MACEDONIA HEADWATER WETLAND

### 3.3.1 Location

The proposed project is located on the south side of Big Macedonia Road (SR 1342) approximately 0.5 miles west from the intersection with Green Swamp Road (NC 211).

### 3.3.2 Project Description

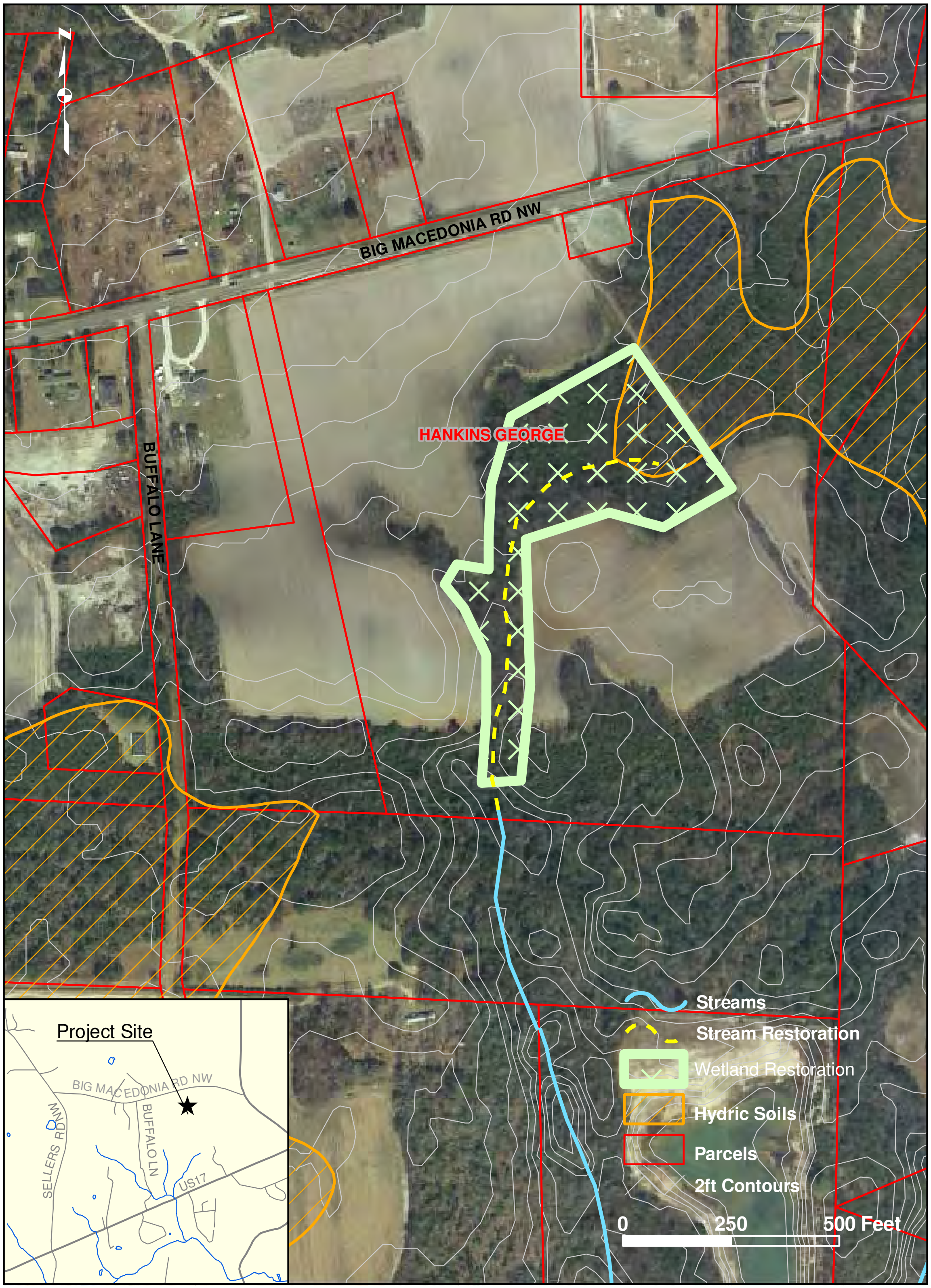
This coastal plain headwater area has been channelized and now contains an oversized channel (UT to Big Doe Creek). An old farm pond is located within the woods adjacent to the stream and would be incorporated into the headwater riparian wetland restoration. Restoration would include approximately four acres of riparian wetland restoration with a 1,100 linear foot low flow channel. During field visits for this project the channel has contained water, but it is possible it is only an intermittent or ephemeral stream due to its location in the landscape. This may affect mitigation credit. The soils in the project area are Baymeade and Lynchburg, both hydric B soils. Restoration of this area will increase aquatic and terrestrial habitat.

### 3.3.3 Constraints

The farm pond could be a constraint if it is not drained and incorporated into the design.

### 3.3.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---|
| Construction Cost | $ 78,000 |
| Project Design and Consulting Services (40%) | $ 52,000 |
| Total Cost Estimate | $130,000 |
| Approximate Yield | 1,100 linear feet<br>4 acres |
| Estimated Cost/Linear Foot | $ 100 |
| Estimated Cost/Acre | $5,000 |




Project 3. Big Macedonia Headwater Wetland Restoration

### 3.3.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 16800067 | Hankins, George<br>290 Big Macedonia Road<br>Supply, NC  28462 |

### 3.3.6 Photos

1. Upstream reach

2. Downstream reach

## 3.4 PROJECT 4 PINCH GUT CREEK

### 3.4.1 Location

The project area is located along a network of dirt roads approximately 1.8 miles to the northwest of Galloway Road (SR 1401). The turn off for the dirt road is at the 90 degree turn in Galloway Road 1.2 miles northwest of the intersection with US 17.

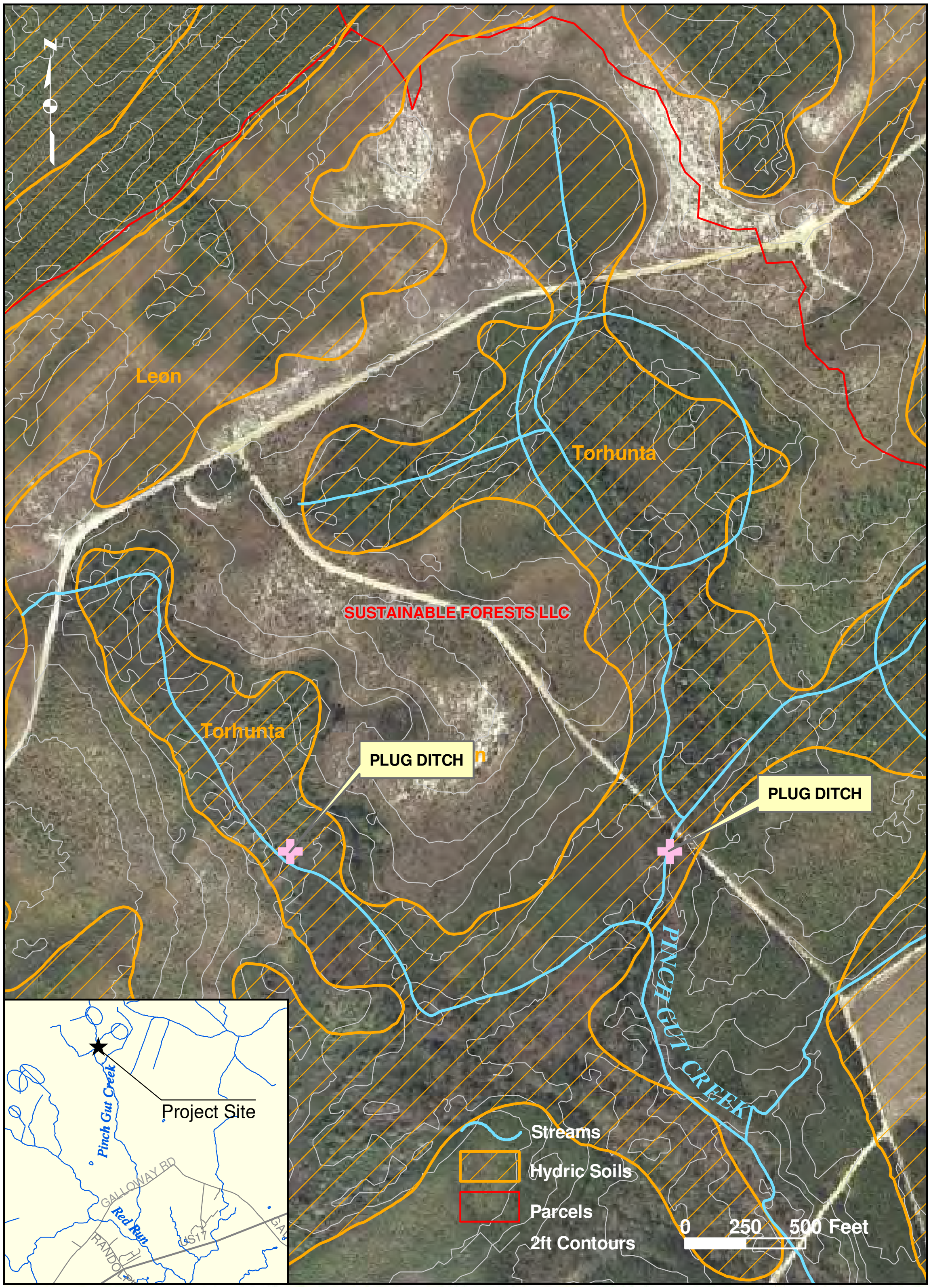
### 3.4.2 Project Description

This headwater area, including Carolina Bays, has been ditched extensively in an attempt to drain the area. Most of the area has been logged and is now pine plantation. Plugging the oversized channels, Pinch Gut Creek and a UT to Pinch Gut Creek, would restore and enhance hydrology to the area. Additional study would be necessary to determine if any of the channel reaches are natural in order to determine the best location for the plugs. It is difficult to quantify the acreage of wetland restoration and enhancement without further field investigations as it is unclear how much of the area has been successfully drained. For this reason, restoration opportunities are not shown on the site map nor are cost estimates given for this project. The map does show the bays which cover approximately 30 acres. The entire project area consists of hydric A and B soils including Leon fine sand, Mandarin fine sand, and Torhunta mucky fine sandy loam.

One functional benefit of restoring this area is an increase in quantity and quality of terrestrial habitat. This area is holding a lot of water and if it were to be developed, the impacts would include increased flooding and streambank erosion. If restoration is not pursued at this site, it should be preserved.

### 3.4.3 Constraints

Logging roads may be impacted if the channels are plugged.




Project 4. Pinch Gut Creek Wetland Restoration/Enhancement

### 3.4.4 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 11000003 | Sustainable Forests LLC<br>c/o Mary Sheffield<br>865 John L Riegel Road<br>Riegelwood, NC 28456 |

### 3.4.5 Photos

1. Eastern ditch at road crossing

## 3.5 PROJECT 5 RED RUN BAYS

### 3.5.1 Location

The project area is located along a network of dirt roads approximately 3 miles to the northwest of Galloway Road (SR 1401). The turn off for the dirt road is at the 90 degree turn in Galloway Road 1.2 miles northwest of the intersection with US 17.

### 3.5.2 Project Description

This project site is located adjacent to Project 4. The stream in this area, a UT to Red Run, is channelized and deeply incised. If the road can be removed, priority 1 restoration can be undertaken on 1,600 linear feet of stream, and if not, then priority 2 restoration would be appropriate. In addition, the ditches draining the Carolina Bays could be plugged to enhance hydrology and return the area to a more natural condition. It is difficult to quantify the acreage of wetland restoration and enhancement without further field investigation but at a minimum the there would be 46 acres of wetland area (the total area of the two bays). The bay area could be a combination of restoration and enhancement. In addition, other areas adjacent to the bays that are mapped as hydric A soils may yield additional restoration acres. The bays and adjacent areas are mapped as Croatan muck and Dorovan muck. Specific wetland restoration areas are not shown on the site map below due to the difficulty in determining restoration extent and, for this reason, cost estimates are provided only for the stream project.

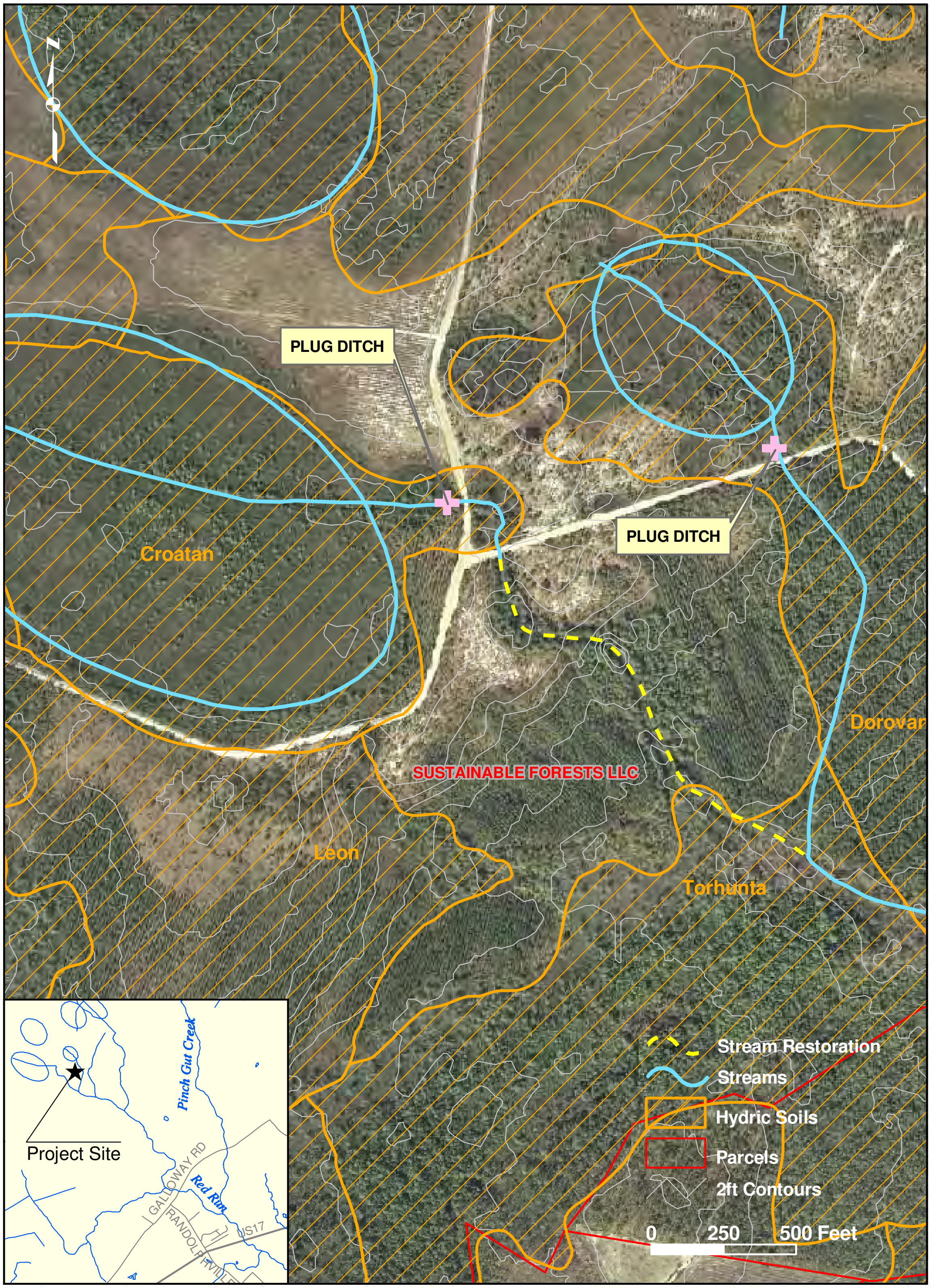
Functional benefits are similar to Project 4 in that restoring the area will increase the quantity and quality of terrestrial habitat. In addition stream restoration would decrease the sediment entering the stream and improve aquatic habitat. As mentioned above, this area is also holding a lot of water and if it were to be developed, the impacts would include increased flooding and streambank erosion. If restoration is not pursued at this site, it should also be preserved.

### 3.5.3 Constraints

Two logging roads will be impacted if priority 1 restoration is undertaken.

### 3.5.4 Cost Analysis

| Item | Estimated Cost |
|---|---|
| Construction Cost | $192,000 |
| Project Design and Consulting Services (40%) | $128,000 |
| Total Cost Estimate | $320,000 |
| Approximate Yield | 1,600 |
| Estimated Cost/Linear Foot | $200 |




Project 5. Red Run Bays Stream & Wetland Restoration

### 3.5.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 11000003 | Sustainable Forests LLC<br>c/o Mary Sheffield<br>865 John L Riegel Road<br>Riegelwood, NC 28456 |

### 3.5.6 Photos

1. Incised channel looking downstream

2. Incised channel – active erosion

## 3.6 PROJECT 6 GALLOWAY RD WETLAND

### 3.6.1 Location

The project area is located on the east side of a dirt road approximately 0.5 miles north of Galloway Road. The turn off for the dirt road is at the 90 degree turn in Galloway Road 1.2 miles northwest of the intersection with US 17.

### 3.6.2 Project Description

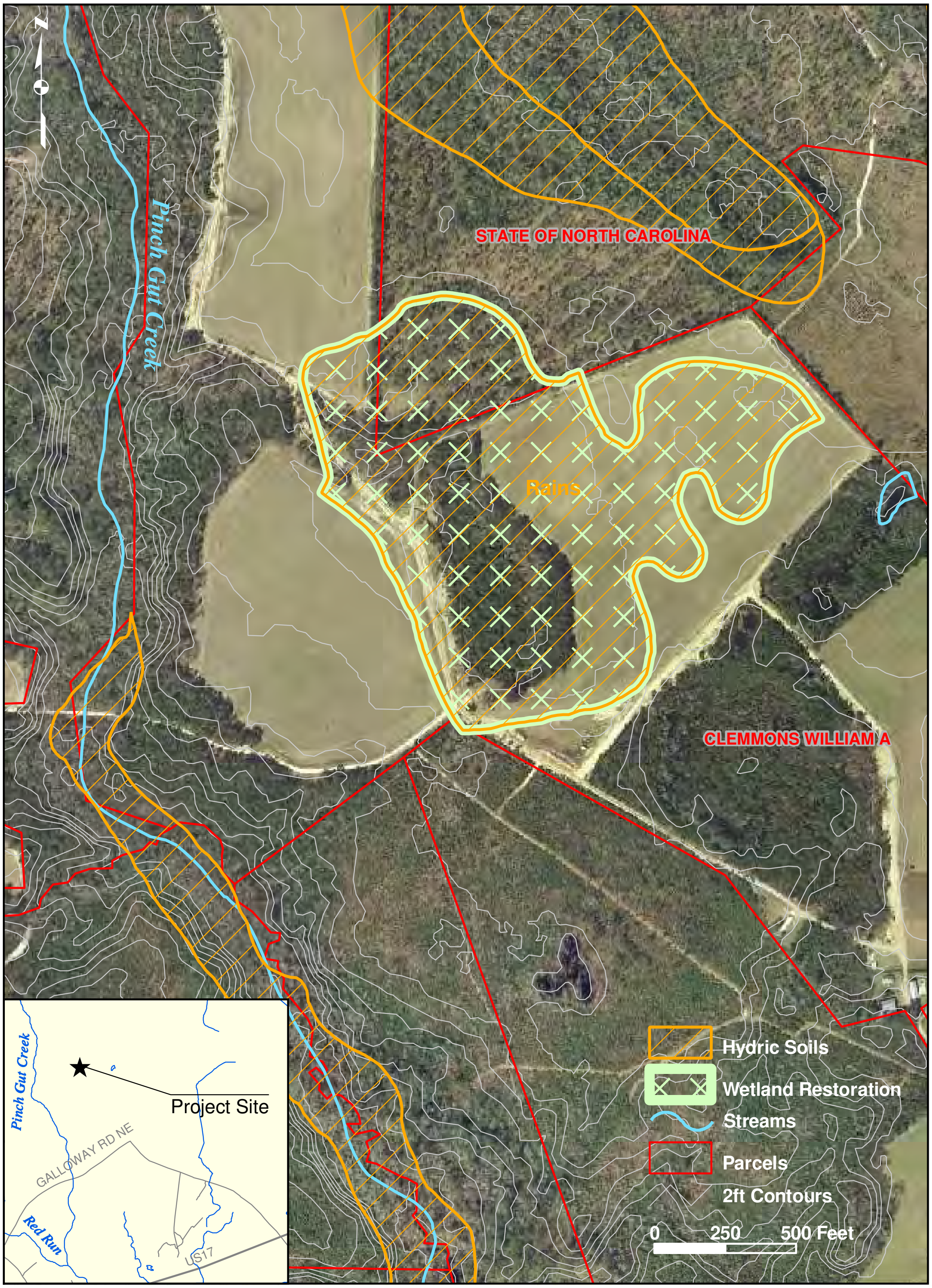
This historic wetland flat and headwater area, which drains to Pinch Gut Creek, has been ditched and drained for agricultural purposes. The mapped soil, Rains find sandy loam, is a hydric A soil. Wetland restoration can be undertaken on approximately 33 acres to restore hydrology and habitat. Part of the project area is owned by the State of North Carolina. The restoration will result in an increase of terrestrial habitat. In addition the removal of agriculture fields will decrease nutrient inputs into surface water thereby improving water quality.

### 3.6.3 Constraints

None

### 3.6.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---:|
| Construction Cost | $330,000 |
| Project Design and Consulting Services (40%) | $165,000 |
| Total Cost Estimate | $495,000 |
| Approximate Yield | 33 acres |
| Estimated Cost/Acre | $15,000 |




Project 6. Galloway Rd Wetland Restoration

### 3.6.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 12400002 | Clemmons, William A.<br>1140 Galloway Road NE<br>Bolivia, NC 28422 |
| 11000002 | State of North Carolina<br>c/o State Property Office<br>1321 Mail Service Center<br>Raleigh, NC 27699 |

### 3.6.6 Photos

1. Ditch along western edge of field

2. Looking east across the field

## 3.7 PROJECT 7 BOGGY BRANCH UT

### 3.7.1 Location

The proposed project is a UT to Boggy Branch and is located on a hog farm on the northwest side of Galloway Road (SR 1401) approximately 0.4 miles southwest of the intersection with Randolphville Road (SR 1402).

### 3.7.2 Project Description

The channel is shown as a first order stream on the Brunswick County Soil Survey. Currently the stream has minimal woody vegetation in the riparian zone and is open to cattle on the east side. In March 2005 the stream was filled with algae indicating nutrient inputs. Coastal plain first order stream restoration would be pursued on approximately 1400 linear feet along the length of the valley. Approximately 3 acres of wetlands and riparian buffers would be restored along each side of the stream and cattle would be excluded from the channel.

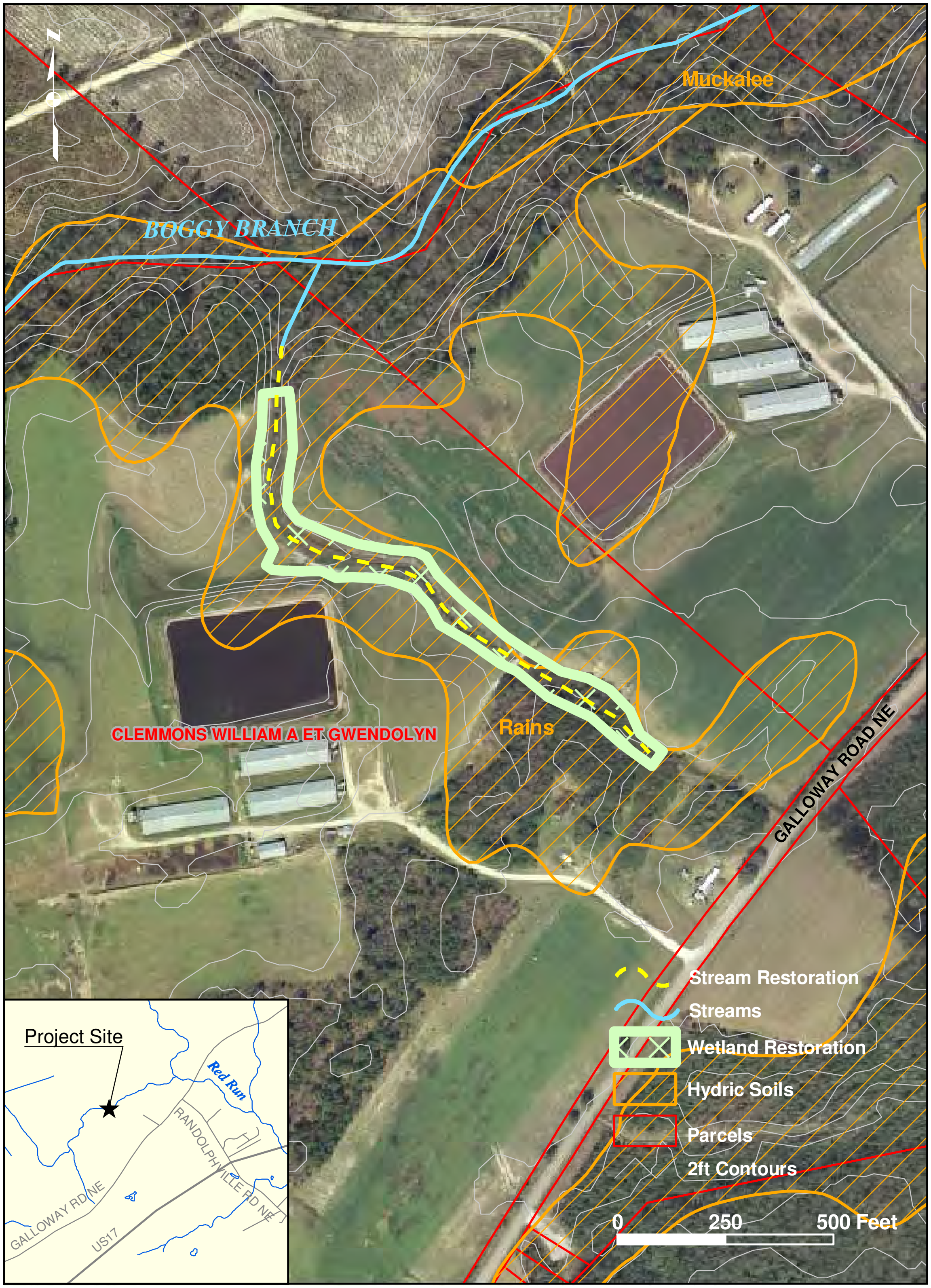
Restoring this stream and wetland system would improve water quality directly by reducing fecal inputs from cattle and indirectly as riparian buffers decreased the amount of nutrients to reach the stream from the spray fields. In addition, the project will improve terrestrial and aquatic habitat.

### 3.7.3 Constraints

Proximity to spray field irrigation systems may limit wetland restoration extent.

### 3.7.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---|
| Construction Cost | $ 85,000 |
| Project Design and Consulting Services (40%) | $ 57,000 |
| Total Cost Estimate | $140,000 |
| Approximate Yield | 1,400 linear feet<br>3 acres |
| Estimated Cost/Linear Foot (including riparian wetland buffer) | $100 |




Project 7. Boggy Branch UT Stream & Wetland Restoration

### 3.7.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 13800009 | Clemmons, William A. & Gwendolyn<br>1140 Galloway Road NE<br>Bolivia, NC  28422 |

### 3.7.6 Photos

1. Cattle have access to east side of channel

2. Nutrient-laden channel looking downstream

## 3.8 PROJECT 8 FORD BRANCH UT

### 3.8.1 Location

The project is located on the south side of Gilbert Road (SR 1501) approximately 140 yards south of the intersection with Old Ocean Highway (US 17 Business).

### 3.8.2 Project Description

This UT to Ford Branch, a first order stream, has been ditched and is now incised. Remnant spoil berms can be found on both banks. A crossing has been constructed consisting of multiple pipes and a sandy fill material. The stream crossing contributes sediment to the stream as do the unstable banks. Priority 1 restoration can be undertaken on approximately 2,100 linear feet of stream in its natural valley.

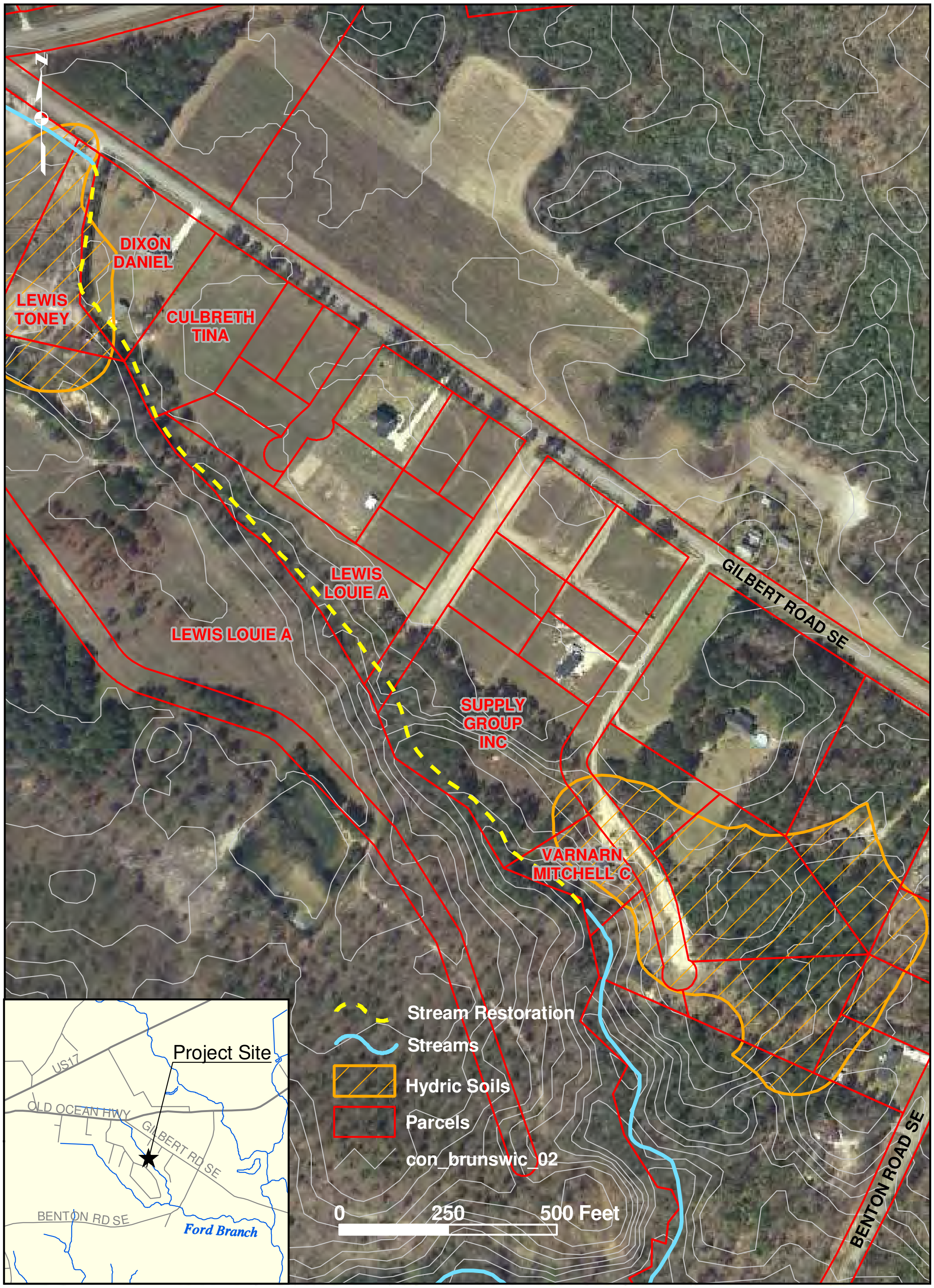
Improving water quality is the main functional benefit of this project as creating a stable channel will greatly reduce sediment inputs. Reducing sediment inputs will also benefit aquatic habitat.

### 3.8.3 Constraints

It is unclear if the crossing will be permanent or is temporary to allow access for construction equipment. The crossing is in the middle of the proposed restoration reach. The high number of property owners could be a constraint although of the six property owners listed, it appears three are part of one business as they have the same address.

### 3.8.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---|
| Construction Cost | $ 264,000 |
| Project Design and Consulting Services (33%) | $ 131,000 |
| Total Cost Estimate | $ 395,000 |
| Approximate Yield | 2,100 linear feet |
| Estimated Cost/Linear Foot | $ 188 |




Project 8. Ford Branch UT Stream Restoration

### 3.8.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 1530003069 | Culbreth, Tina & Sheppard<br>2445 S Boonesboro Road<br>Supply, NC 28462 |
| 1530003068 | Dixon, Daniel & Michele<br>15 Gilbert Road<br>Bolivia, NC 28422 |
| 1530003034,<br>1530003021 | Lewis, Louie A<br>237 Ocean Hwy 17<br>Supply, NC 28462 |
| 15300040 | Lewis, Toney Glenn<br>237 Ocean Hwy 17<br>Supply, NC 28462 |
| 15300044 | Supply Group, Inc<br>237 Ocean Hwy 17<br>Supply, NC 28462 |
| 1530003022 | Varnarn, Mitchell C<br>1221 Jonathan Street<br>Supply, NC 28462 |

### 3.8.6 Photos

1. Channel looking upstream of crossing


2. Channel looking downstream

## 3.9 PROJECT 9 FORD BRANCH

### 3.9.1 Location

The project area is located on the east side of Benton Road (SR 1502) approximately 0.3 miles south of the intersection with Gilbert Road (SR 1501).

### 3.9.2 Project Description

This project is located downstream of Project 8 and Benton Road. The stream appears to have been channelized and relocated to the edge of the Boldt property. The banks are steep and eroding especially just downstream of the culvert under Benton Road. The majority of the Boldt property is horse pasture although the area adjacent to the stream has been saturated during both field visits (March 2006 and November 2006). A priority 1 restoration is recommended for approximately 1,100 linear feet of stream. Relocating the stream to the valley center will also result in approximately 3.2 acres of riparian wetland restoration and buffer restoration. The soils in the stream valley are Baymeade which is a hydric B soil.

The functional benefits of this project include an improvement in water quality as the sediment input from the eroding streambanks will be eliminated. In addition, the project will add terrestrial habitat and improve aquatic habitat.

Project 8 and 9 could be grouped as one project for a total of 3,200 linear feet stream restoration plus a 1,300 linear foot section of preservation and 3.2 acres of riparian wetland restoration

### 3.9.3 Constraints

None

### 3.9.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---|
| Construction Cost | $120,400 |
| Project Design and Consulting Services (40%) | $ 75,600 |
| Total Cost Estimate | $196,000 |
| Approximate Yield | 1,100 linear feet<br>3.2 acres |
| Estimated Cost/Linear Foot | $ 167 |
| Estimated Cost/Acre | $3,750 |


Project 9. Ford Branch Stream Restoration

### 3.9.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 15300018 | Anderson, Elbert C MD & Martha S<br>5224 Clear Run Drive<br>Wilmington, NC 28403 |
| 1530001903 | Boldt, Terrence D & Lori W<br>751 Benton Road<br>Bolivia, NC 28422 |
| 1530001902 | Willetts, Harold Dale & George<br>250 Green Ridge Trail<br>Bolivia, NC 28422 |

### 3.9.6 Photos

1. Horse farm looking upstream from Benton Road

2. Eroding banks

## 3.10 PROJECT 10 PECAN TRAIL HEADWATERS

### 3.10.1 Location

The project is located on either side of Old Ocean Highway (US 17 Business) approximately 200 yards southwest of the intersection with Pecan Place.

### 3.10.2 Project Description

This stream, a UT to Clark Branch, is channelized and incised. Based on USGS mapping, the project reaches are second order. Agriculture fields are located upstream of the proposed restoration reach but the property was recently purchased and rezoned for residential development by the Red Apple Group. The property owners along the restoration reach are concerned about increased runoff and flooding. During a site visit, Lee Thorton expressed interest in learning more about the proposed project. Downstream of Old Ocean Highway cattle have access to the stream as evident by the trampled banks. Priority 2 restoration is proposed for the approximately 1,300 feet of headwater stream north of the road and priority 1 restoration is recommended downstream of the road on approximately 250 feet of stream. Below this stream portion the 1.4 acre wetland area (Norfolk soils – hydric B) has been disturbed and should be enhanced with additional buffer plantings.

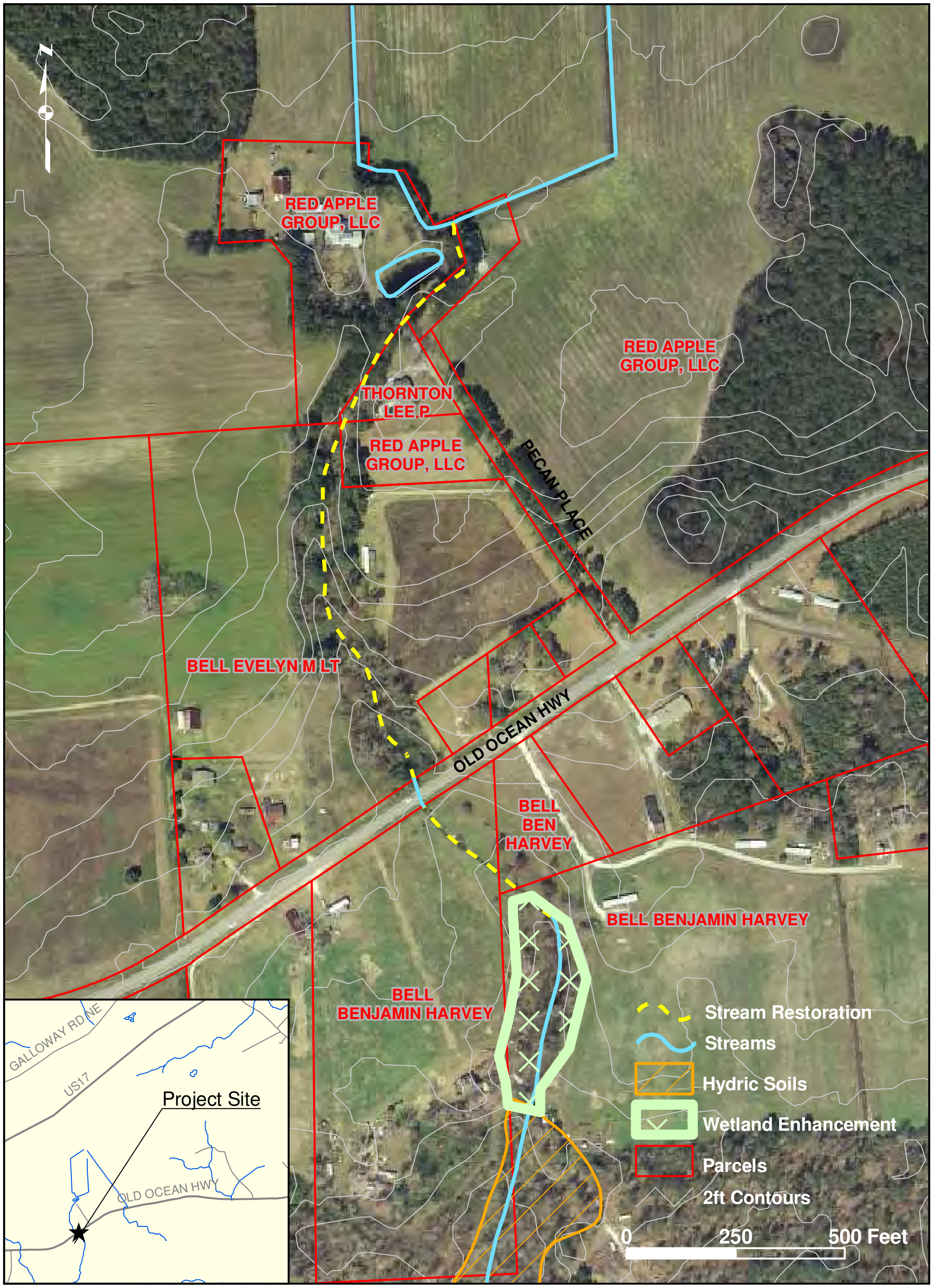
Stream restoration will improve aquatic habitat, decrease erosion, and may help reduce flooding. In addition, excluding cattle will decrease nutrient input in to the stream and wetland enhancement will improve habitat.

### 3.10.3 Constraints

Culverts located under Old Ocean Highway are the only constraint for this project although restoration could be designed without impacting the culvert.

### 3.10.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---|
| Construction Cost | $197,00 |
| Project Design and Consulting Services (40%) | $131,000 |
| Total Cost Estimate | $328,000 |
| Approximate Yield | 1,550 linear feet<br>1.4 acres |
| Estimated Cost/Linear Foot | $ 209<br>$2,900 |




Project 10. Pecan Trail Stream Restoration & Wetland Enhancement

### 3.10.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 15300011,<br>1530000901,<br>1530001007 | Bell, Benjamin Harvey<br>1690 Old Ocean Highway<br>Bolivia, NC 28422 |
| 1530001005 | Bell, Evelyn M LT<br>c/o Julian R Bell<br>1745 Old Ocean Highway<br>Bolivia, NC 28422 |
| 15300004;<br>1530001003 | Red Apple Group, LLC<br>712 Village Rd, SW<br>Shallotte, NC 28470<br>(866)754-7104 |
| 15300003 | Thorton, Lee P<br>59 Pecan Place<br>Bolivia, NC 28422 |

### 3.10.6 Photos

1. Eroding banks downstream of US 17 Bus

2. Incised channel upstream of road

## 3.11 PROJECT 11 OLD LENNON RD

### 3.11.1 Location

The project site is located north of Old Lennon Road (SR 1504) approximately one mile west of the intersection with Clemmons Road (SR 1505).

### 3.11.2 Project Description

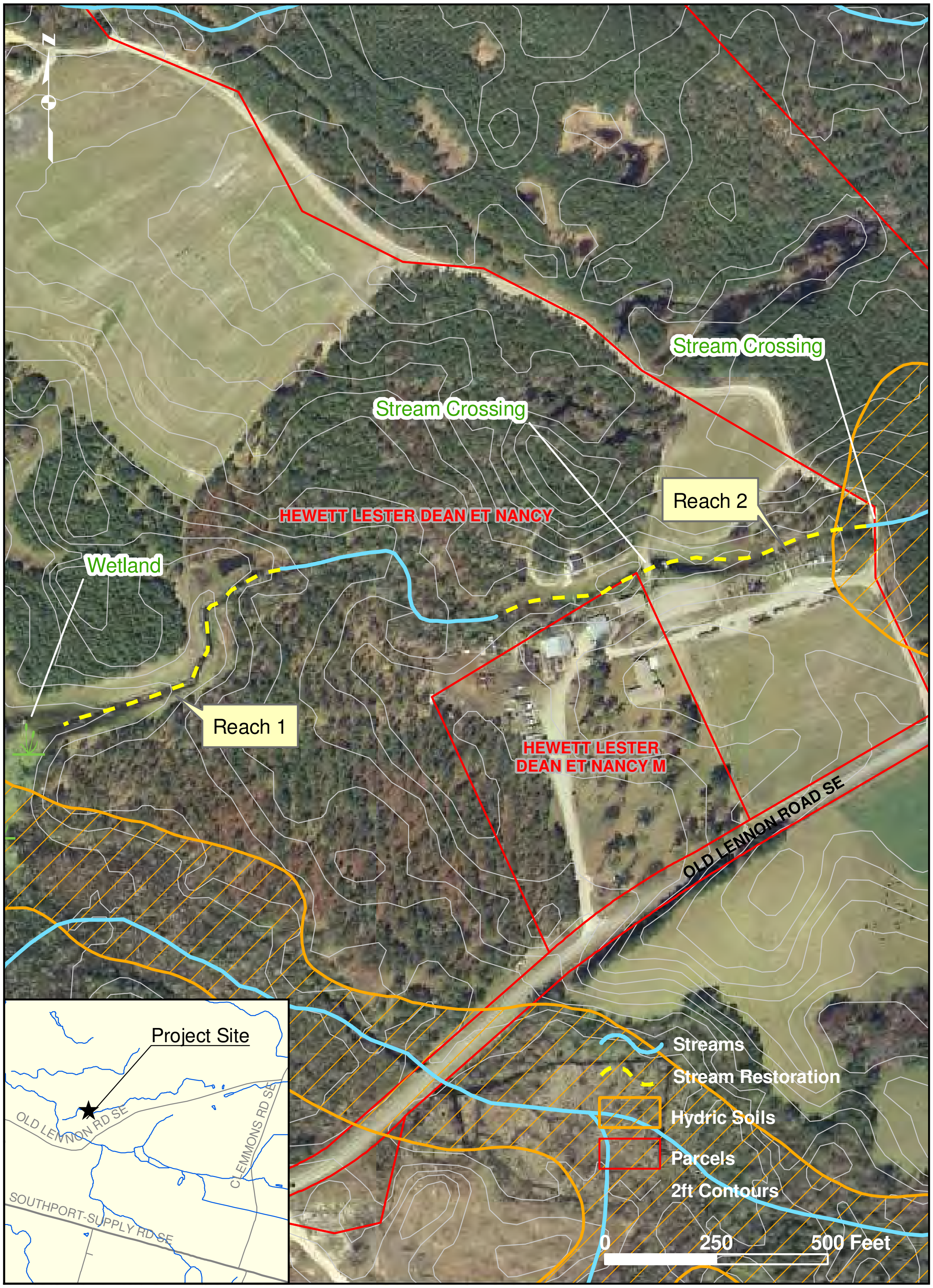
This first order stream, a UT to Lockwoods Folly River, has no woody riparian buffer and has been straightened in two sections. A crossing with a small culvert has dammed the stream and created a small, linear pond. Priority 1 stream restoration is recommended on 600 feet of reach 1 and 850 feet of reach 2 in the natural stream valley. An improvement of terrestrial and aquatic habitat is the main functional benefit of this restoration.

### 3.11.3 Constraints

The crossing is in the middle of reach 2 although it appears to be unused. The crossing could be removed as there is another crossing just upstream of the project reach. Although there are buildings on both sides of the stream they are above the natural stream valley.

### 3.11.4 Cost Analysis

| Item | Estimated Cost |
|---|---|
| Construction Cost | $116,000 |
| Project Design and Consulting Services (40%) | $ 77,500 |
| Total Cost Estimate | $193,500 |
| Approximate Yield | 1,450 linear feet |
| Estimated Cost/Linear Foot | $133 |




Project 11. Old Lennon Rd Stream Restoration

### 3.11.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 1690000105<br>1690000104 | Hewett, Lester Dean & Nancy<br>PO Box 192<br>Supply, NC 28462 |

### 3.11.6 Photos

1. Reach 2 – looking downstream

2. Reach 2 – pond upstream from photo 1

## 3.12 PROJECT 12 GOVERNMENT COMPLEX

### 3.12.1 Location

Both proposed areas are on the north side of Government Center Drive in the Brunswick County Government Complex on Old Ocean Highway (US 17 Business).

### 3.12.2 Project Description – add BMP description here

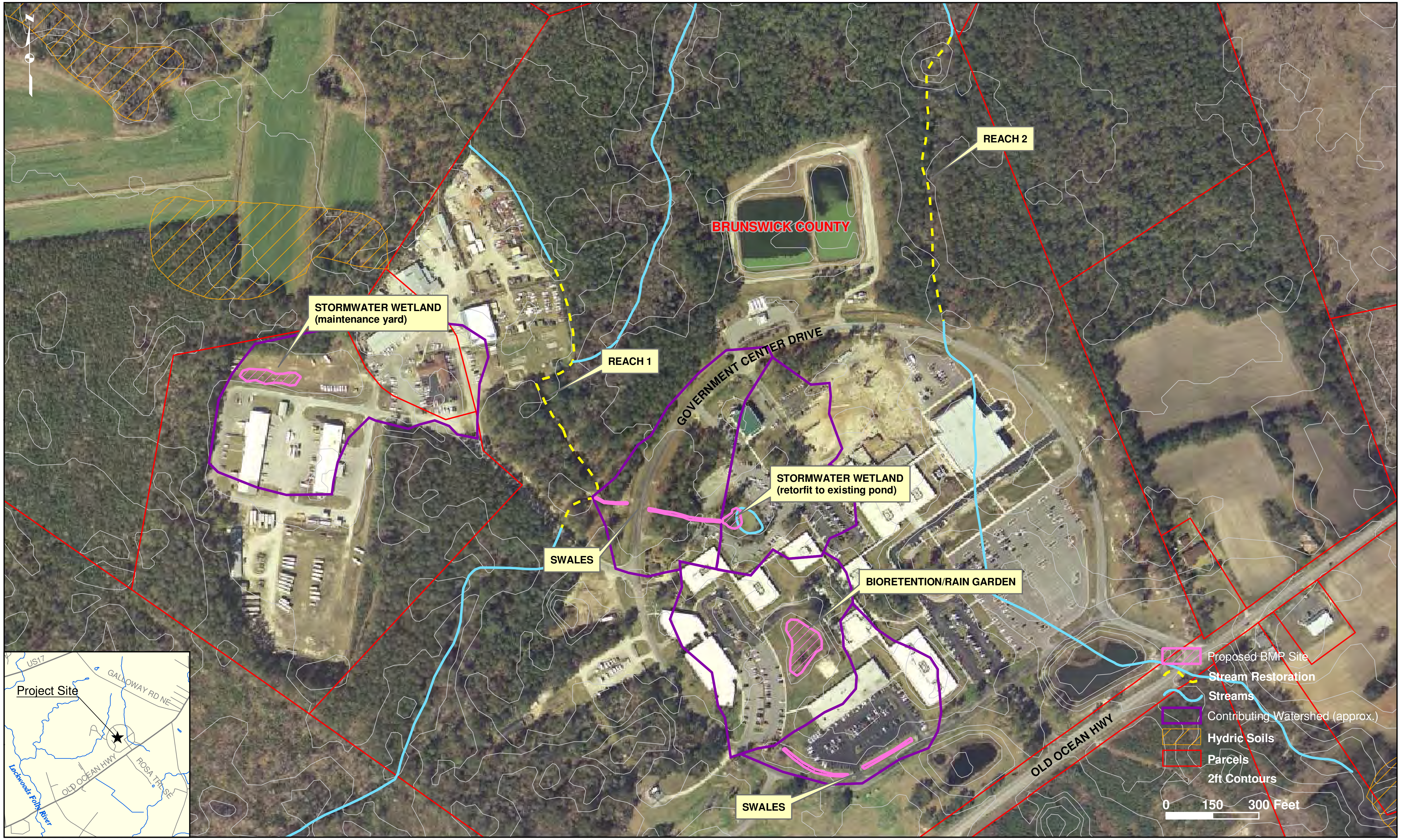
Reach 1 and Reach 2 are both channelized and incised. Reach 1, a UT to Lockwoods Folly River, is mapped as a first and second order stream. It is likely a first order stream as the area is heavily impacted and the USGS map does not truly reflect what is on the ground. Currently Reach 1 is cut off from its floodplain throughout the government complex. Remnant floodplain pockets exist. Reach 2, a first order stream, has spoil berms on both banks. The reach is a UT to Middle Swamp.

The reaches are both on county property and would serve as demonstrations of priority 1 stream restoration. Each reach is approximately 900 feet in length. In addition there are many opportunities for BMPs throughout the government complex that would complement the restoration.

A bioretention cell could be constructed in the middle of the complex to treat runoff from a number of buildings. Water quality swales in place of some of the roadside ditches would help treat runoff from the roads. A small pond found on the backside of the complex could be improved by adding a small stormwater wetland cell on one side. Currently the pond discharges directly into a stream via a ditch. The ditch could be replaced with a water quality swale. Finally, there is a large open area near the maintenance yard that could be used to construct a stormwater wetland to treat runoff from the buildings and parking lots there. All of these proposed projects would serve as examples for the county and could be used for educational purposes.

### 3.12.3 Constraints

Possible constraints on Reach 1 include a storage/parking lot and a county extension septic system demonstration center. Reach 2 has no constraints.




Project 12. Brunswick County Government Complex Stream Restoration &BMPs

### 3.12.4 Cost Analysis – add BMP cost to this

| **Item - restoration** | **Estimated Cost** |
|---|---|
| Total Construction Cost | $183,400 |
| Project Design and Consulting Services (33%) | $ 92,000 |
| Total Cost Estimate | $275,400 |
| Approximate Yield | 1,800 linear feet |
| Estimated Cost/Linear Foot | $153 |
| **Item - BMPs** | |
| Construction Cost bioretention | $100,000 |
| Approximate Area | 10,000 $ft^2$ |
| Estimated Cost/Square Foot | $10 |
| Construction Cost stormwater wetland (maintenance area) | $ 6,070 |
| Approximate Area | 6,800 $ft^2$ |
| Estimated Cost/Square Foot | $0.90 |
| Construction Cost swales (front of complex) | $ 3,780 |
| Approximate Area | 420 ft |
| Estimated Cost/Linear Foot | $9 |
| Construction Cost swales (back of complex) | $ 3,150 |
| Approximate Area | 350 ft |
| Estimated Cost/Linear Foot | $9 |

Cost for the detention pond retrofit cannot be estimated as an engineer's assessment is required to determine the necessary actions to expand and improve it.

### 3.12.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 13900059 | Brunswick County<br>c/o Finance Dept.<br>PO Box 249<br>Bolivia, NC 28422 |

### 3.12.6 Photos

1. Reach 1 – severe right turn in stream

2. Reach 1 – looking upstream

3. Reach 1 – upstream end of restoration reach

4. Parking lot at maintenance yard

5. Reach 2 – looking upstream

6. Reach 2 – looking downstream

## 3.13 PROJECT 13 ZION HILL HEADWATER & BMPS

### 3.13.1 Location

The project is located on the west side of Zion Hill Road (SR 1114) on the property adjacent to Virginia Williamson Elementary School on the southwest corner of the intersection with Southport-Supply Road (NC 211).

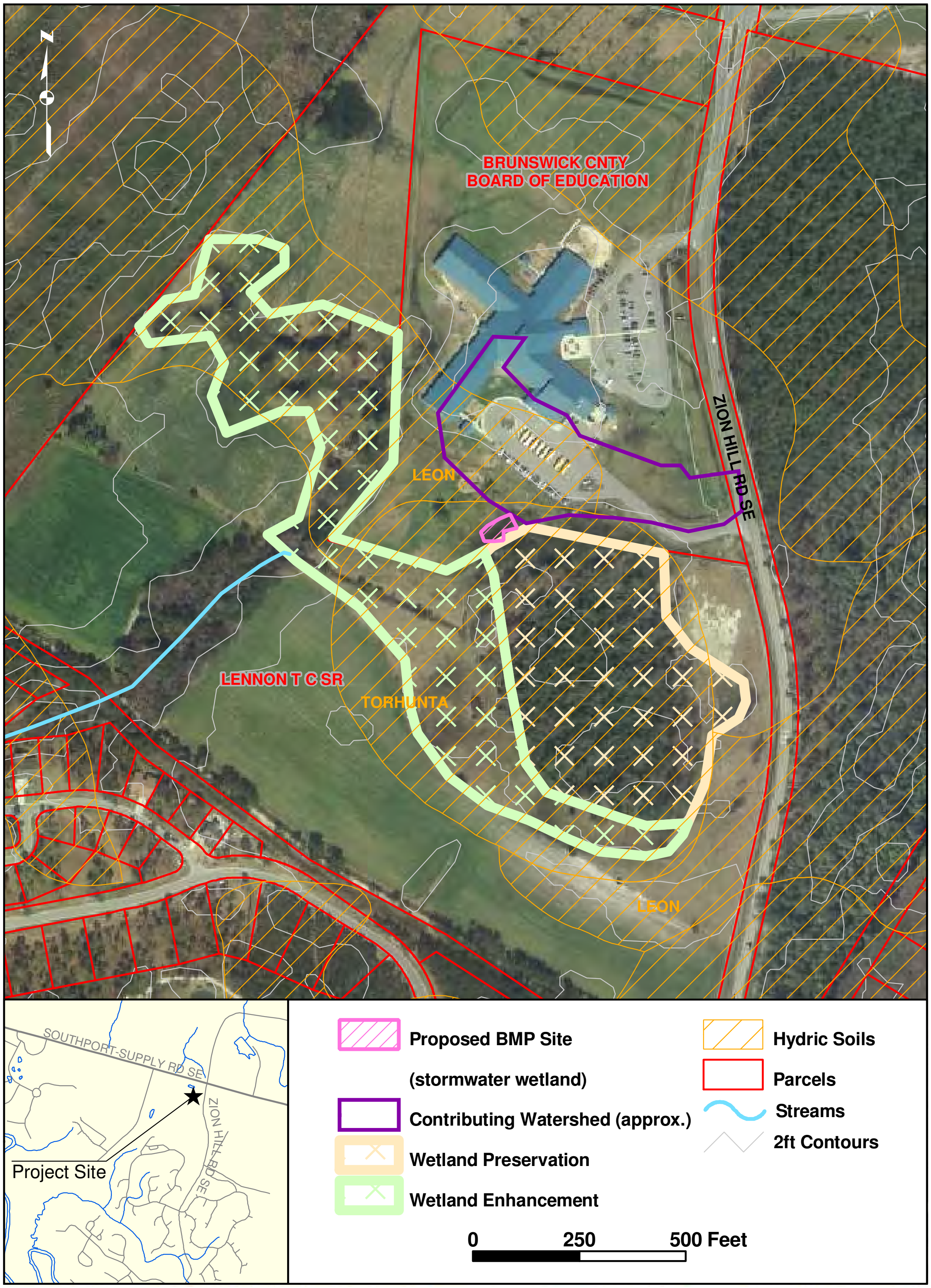
### 3.13.2 Project Description

The project area is currently used as pasture although evidence of cattle was only found during one of two site visits. A small wetland pocket drains to a channelized stream. Downstream of the project site, spoil berms are evident alongside the stream. There are enough breaks in the berm to allow the stream access to the floodplain. Proposed restoration would include restoring and enhancing approximately 9 acres of wetlands on the open fields where there are hydric A soils as well as preservation of 5.6 acres of adjacent gum swamp. A low flow channel could be restored through the restored wetlands although this may not increase mitigation credit. The project site is upstream of Sandy Branch and the hydric soils include Leon find sand and Torhunta mucky fine sandy loam.

The school playground and parking lots also sit on hydric A soils but it is not feasible to restore these areas. Instead a swale could be constructed from the school to a stormwater wetland to treat runoff from the building and parking lot. Fill from the restoration site could be used to improve the playground which was partially covered in standing water during both field visits. A boardwalk could be built along the playground perimeter in order to use the restored wetlands as an outdoor classroom.

### 3.13.3 Constraints

None. The school would not be affected by the proposed restoration.




Project 13. Wetland restoration/enhancement & BMPs

### 3.13.4 Cost Analysis – add BMP cost, remove stream

| **Item - restoration** | **Estimated Cost** |
|---|---|
| Construction Cost | $ 90,000 |
| Project Design and Consulting Services (33%) | $ 45,000 |
| Total Cost Estimate | $120,000 |
| Approximate Yield | 9 Acres |
| Estimated Cost/Acre | $15,000 |
| **Item - BMPs** | |
| Construction Cost stormwater wetland | $ 2,600 |
| Approximate Area | 2,900 $ft^2$ |
| Estimated Cost/Square Foot | $1.92 |

### 3.13.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 1850001505 | Brunswick County Board of Education<br>35 Referendum Drive NE<br>Bolivia, NC 28422 |
| 18500015 | Lennon, TC Sr<br>1094 Southport Supply Road SE<br>Bolivia, NC 28422 |

### 3.13.6 Photos

1. Flooded playground at elementary school

2. Coastal plain stream restoration area

## 3.14 PROJECT 14 BOLIVIA ELEMENTARY SCHOOL BMPS

### 3.14.1 Location

The project site is located on the Bolivia Elementary School campus on Old Ocean Highway (US 17 Business) in the Town of Bolivia.

### 3.14.2 Project Description

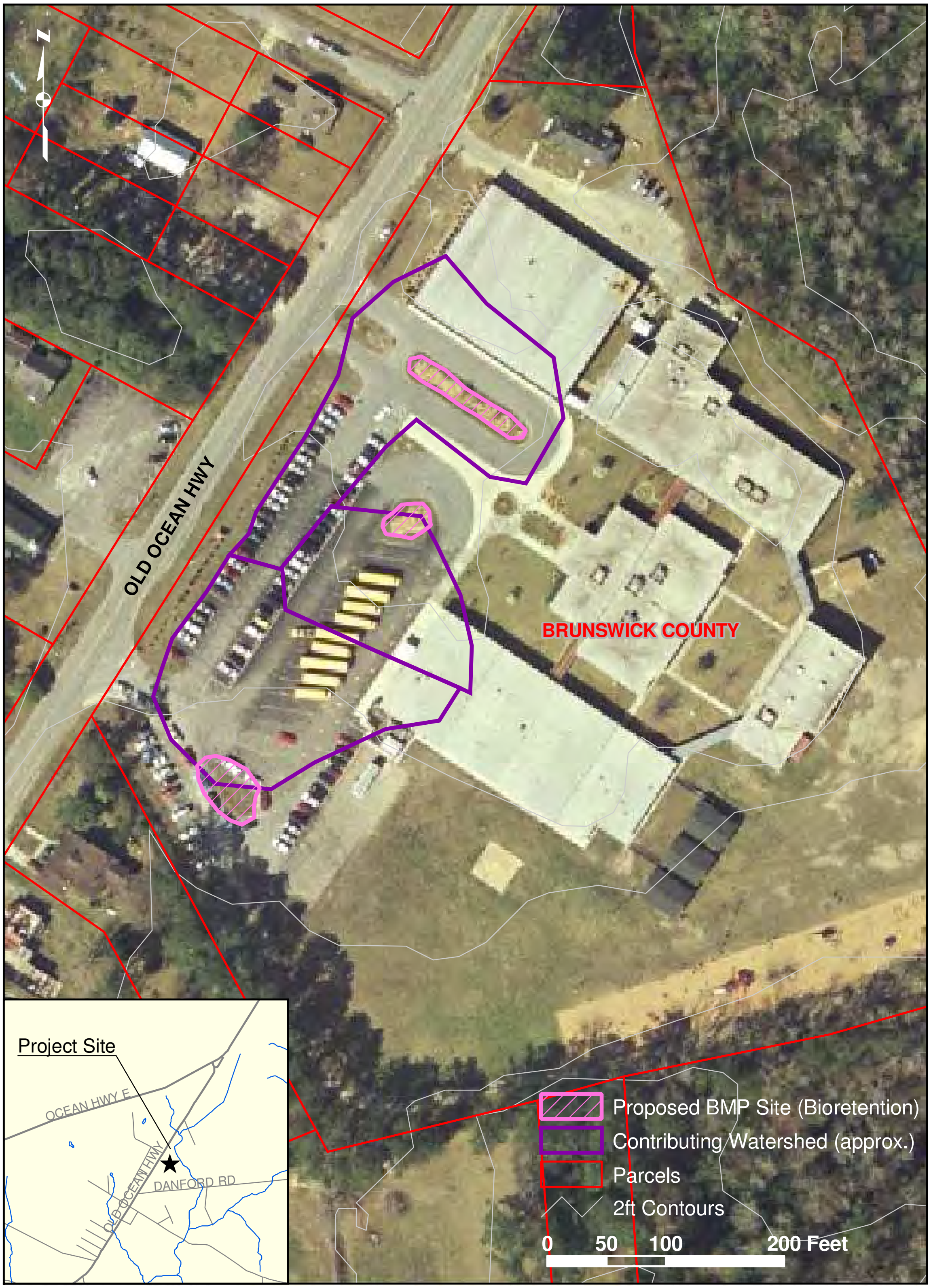
The construction of three bioretention cells is proposed in the school parking lot on three existing parking islands (Photos 1-3). Although these islands do not have curbing, they are all mounded, which prevents stormwater from flowing into them. The bioretention cells would intercept stormwater flow before it entered the existing stormwater inlets. These inlets are located in the parking lot and outlet to a small channel behind the school before flowing into Bolivia Branch. The bioretention cells would help reduce nutrient and fecal coliform inputs into Bolivia Branch.

### 3.14.3 Constraints

The parking islands may not be sufficient to treat stormwater from all local impervious surfaces. The southern island may be expanded to improve water quality treatment (Photo 3). This would result in the loss of a few parking spaces.

### 3.14.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---|
| Construction Cost (three bioretention cells) | $ 52,000 |
| Approximate Area | 5,200 $ft^2$ |
| Estimated Cost/Square Foot | $10 |




Project 14. Bolivia Elementary School BMP Retrofit

### 3.14.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 125PC003 | Brunswick County<br>c/o Finance Dept<br>PO Box 249<br>Bolivia, NC 28422 |

### 3.14.6 Photos

Photo 1. Parking island

Photo 2. Parking island with stormwater inlet in foreground

Photo 3. Southern parking island

## 3.15 PROJECT 15 BRUNSWICK TECHNICAL COLLEGE BMPS

### 3.15.1 Location

The project site is located on the Brunswick Technical College campus between Old Ocean Highway (US 17 Business) and US 17 on College Road. Three BMP retrofits are proposed on the campus, two near the auditorium (Map 1) and one behind the classroom buildings near the basketball court (Map 2).

### 3.15.2 Project Description

Stormwater from the auditorium and parking areas discharges into a headwater wetland area that divides the campus. This wetland area has immature vegetation and appears to have been altered in the past (Photo 1 and area within blue circle on Map Project 15A). The stormwater can be treated in two small bioretention areas to be located in natural areas at the end of the parking lot and auditorium (Map1). It is possible that runoff from US 17 is contributing to the stormwater, therefore the bioretention cells may need to be larger or an additional BMP may be needed.

Currently stormwater from a number of parking lots and buildings is piped to a stormwater pond behind the classroom buildings near the outdoor basketball court (Map Project 15B). There is evidence of overflow on the west end of the pond which appears to be lower than the east end where the outlet is located. The pond is ringed with young pine trees (Photo 2). This pond could be retrofitted to handle the flow from the contributing watershed without overflowing into the nearby channel. Water from an additional pond in front of the classroom buildings also discharges to this channel. There are signs of erosion that should be addressed.

### 3.15.3 Constraints

None

### 3.15.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---:|
| Construction Cost (two bioretention cells) | $ 80,000 |
| Approximate Area | 8,000 $ft^2$ |
| Estimated Cost/Square Foot | $10 |

Cost for the detention pond retrofit cannot be estimated as an engineer’s assessment is required to determine the necessary actions to repair it.


Project 15A. Brunswick Technical College BMP Retrofit


Project 15B. Brunswick Technical College BMP Retrofit

### 3.15.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 1530000105 | Brunswick Technical College<br>The Board of Trustees<br>Supply, NC 28462 |

### 3.15.6 Photos

Photo 1. Headwater wetland in front of auditorium

Photo 2. Stormwater pond surrounded by young pines

Photo 3. Channel downstream of stormwater pond

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## 3.16 PROJECT 16 SUPPLY INTERSECTION BMP

### 3.16.1 Location

The project site is located at the northwestern corner of the Stone Chimney Road and Southport-Supply Road (NC 211) intersection.

### 3.16.2 Project Description

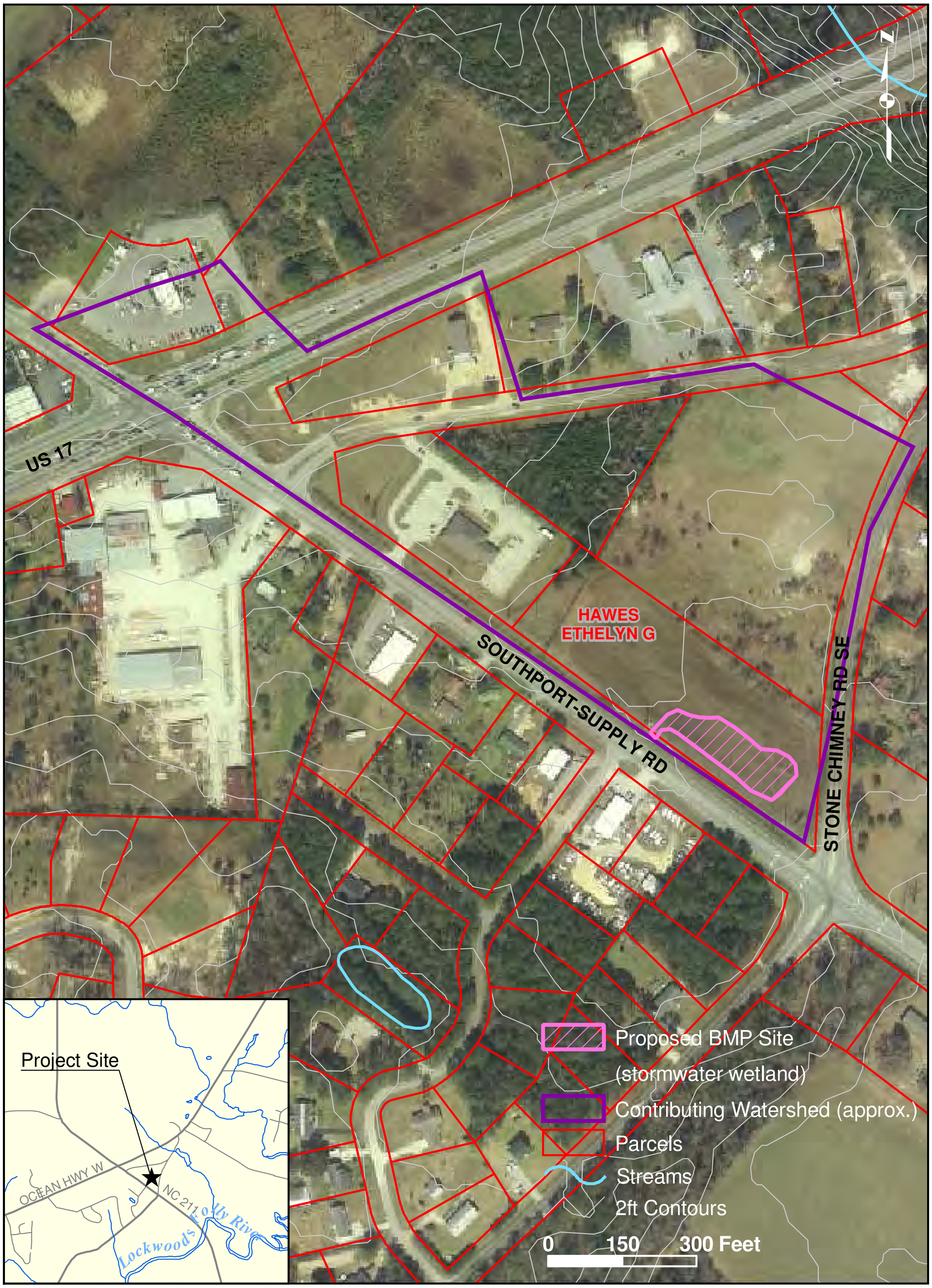
Stormwater from the Hardee's restaurant located at the intersection of US 17 and Southport-Supply Road (NC 211) flows under US 17 into a ditch that runs alongside Southport-Supply Road. This ditch then crosses under the intersection of Stone Chimney Road and Southport-Supply Road into a headwater wetland of an unnamed tributary of the Lockwoods Folly River. Stormwater could be diverted from the ditch into a stormwater wetland that would be constructed in the vacant lot at the corner of Stone Chimney Road and Southport-Supply Road. By constructing the wetland in this parcel, additional runoff from other buildings and roadways would be treated in the stormwater wetland before entering the headwater wetland.

### 3.16.3 Constraints

None

### 3.16.4 Cost Analysis

| Item | Estimated Cost |
|---|---|
| Construction Cost (stormwater wetland) | $ 18,600 |
| Approximate Area | 17,500 $ft^2$ |
| Estimated Cost/Square Foot | $1.06 |




Project 16. Supply Intersection BMP Retrofit

### 3.16.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 1680007608 | Hawes, Ethelyn G<br>171 Countryside Dr SW<br>Supply, NC 28462 |

### 3.16.6 Photos

Photo 1. Hardee's parking lot draining to Southport-Supply Road (NC 211)

## 3.17 PROJECT 17 BRUNSWICK COMMUNITY HOSPITAL BMPS

### 3.17.1 Location

The project site is located at the Brunswick Community Hospital on US 17 between Sellers Road and Stone Chimney Road.

### 3.17.2 Project Description

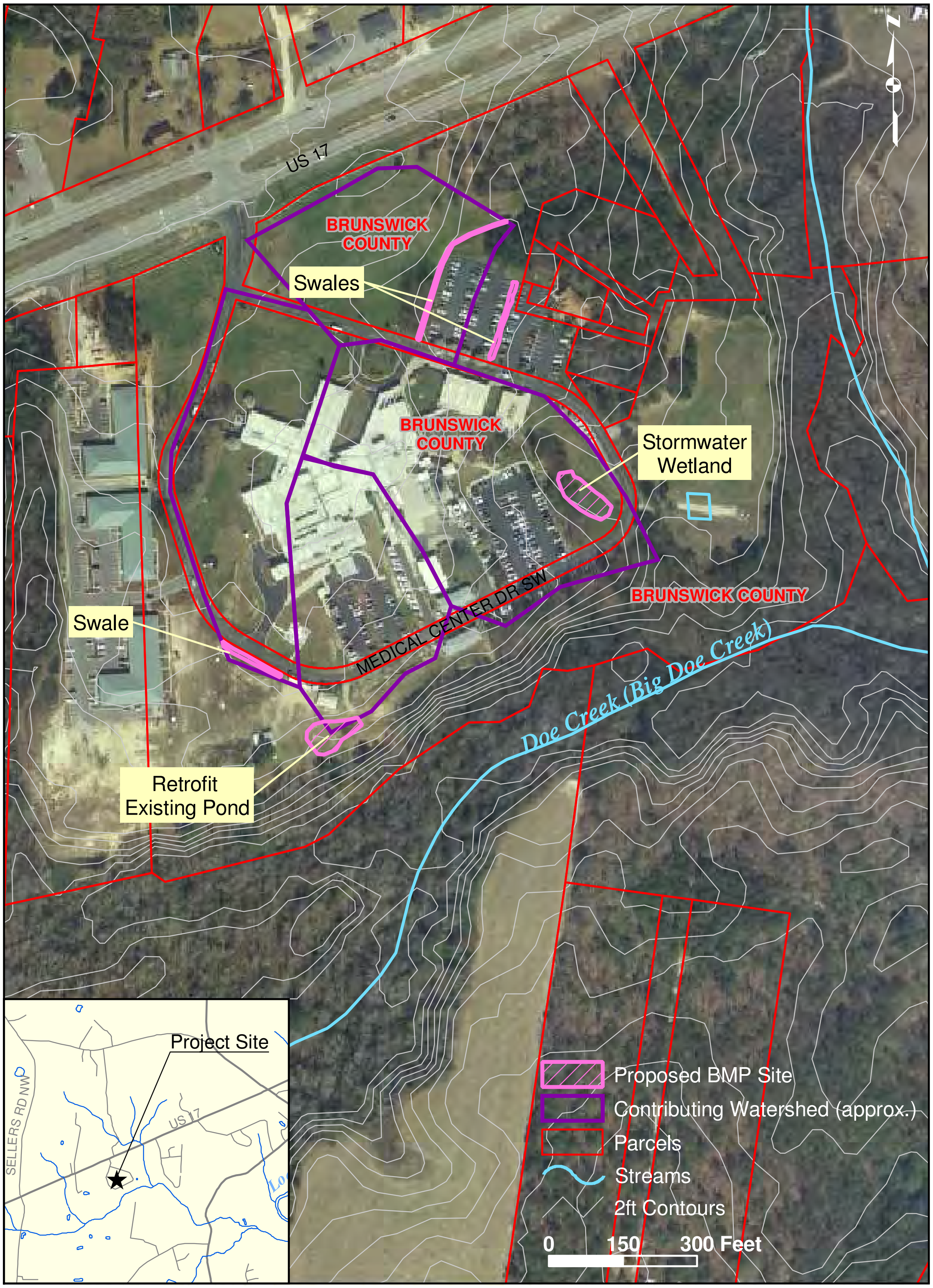
There are many opportunities to manage stormwater and improve existing BMPs at the hospital. The hospital sits on a ridge and drains to two watersheds. In addition, manmade ditches channel water around the perimeter of Medical Center Drive. Therefore, it is necessary to manage stormwater on all sides of the hospital. Currently there is a stormwater pond behind the hospital that holds runoff from half of the hospital property (Photo 1). This pond could be improved as the weir crest dam (forebay impoundment) is failing. Stormwater flowing to the pond comes from a number of sources and directions including an eroding ditch on the south side of the hospital. A water quality swale in place of the ditch would control stormwater as it moves toward the pond (Photo 2).

Much of the stormwater on site is discharged into a small ditch on the east side of the hospital which then flows under Medical Center Drive and discharges into Doe Creek (Big Doe Creek) (Photo 3). This channel may be an intermittent or ephemeral stream. A stormwater wetland could be constructed alongside of the channel to treat stormwater before it flows under Medical Center Drive.

A stormwater ditch in front of the hospital carries stormwater from the north side of the hospital as well as from the northern parking areas (Photo 4). A swale could be constructed here to treat runoff before it enters the unnamed tributary of Doe Creek.

### 3.17.3 Constraints

None.




Project 17. Brunswick Community Hospital BMP Retrofit

### 3.17.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---|
| Construction Cost (stormwater wetland) | $ 7,050 |
| Approximate Area | 12,400 $ft^2$ |
| Estimated Cost/Square Foot | $1.13 |
| | |
| Construction Cost swales (front) | $ 2,970 |
| Approximate Yield/Linear Feet | 330 ft |
| Estimated Cost/Square Foot | $9 |
| | |
| Construction Cost swale (back) | $1,350 |
| Approximate Yield/Linear Feet | 150 ft |
| Estimated Cost/Square Foot | $9 |

Cost for the detention pond retrofit cannot be estimated as an engineer's assessment is required to determine the necessary actions to repair it.

### 3.17.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 1680004301 | Brunswick County<br>c/o Finance Dept<br>PO Box 249<br>Bolivia, NC 28422 |

### 3.17.6 Photos

Photo 1. Existing stormwater pond with failing components

Photo 2. Eroding ditch with closely cut grass

Photo 3. Stormwater ditch on east side of hospital

Photo 4. Stormwater ditch on north side (front) of hospital

Photo 5. Culverts filling in the sediment

## 3.18 PROJECT 18 RIVER RUN PLANTATION BMPS

### 3.18.1 Location

The project site is located near the boat ramp off of Marina Drive in the River Run Plantation neighborhood. Access to the neighborhood is controlled by an electronic gate that requires a key code. Larry Lockwood is an officer of the homeowners association and has participated as an active member of the Lockwoods Folly Watershed Roundtable. His contact information can be found in the property owner section below. From Southport-Supply Road (NC 211) travel south on Sunset Harbor Road for approximately 4.5 miles and turn right on Folly Drive. After the gates, take the second right on Marina Drive. The project site is located on the south side of Marina Drive near the intersection with the driveway to the community boat ramp

### 3.18.2 Project Description

Currently runoff from Marina Drive enters a pipe near the road while a second pipe carries runoff from the adjacent neighborhood. The two pipes converge and discharge into the Lockwoods Folly River. The discharge is above water level in the boat ramp wall. A stormwater wetland could be constructed in the grassy area south of Marina Drive. The stormwater wetland would be sized to treat runoff from River Run and the adjacent neighborhood. Additional opportunities include installing a bioretention area or swale on the opposite side of the boat ramp driveway. This area receives less stormwater.

The River Run Property Owners Association (POA) owns the boat ramp and surrounding parcel and is interested in implementing stormwater BMPs.

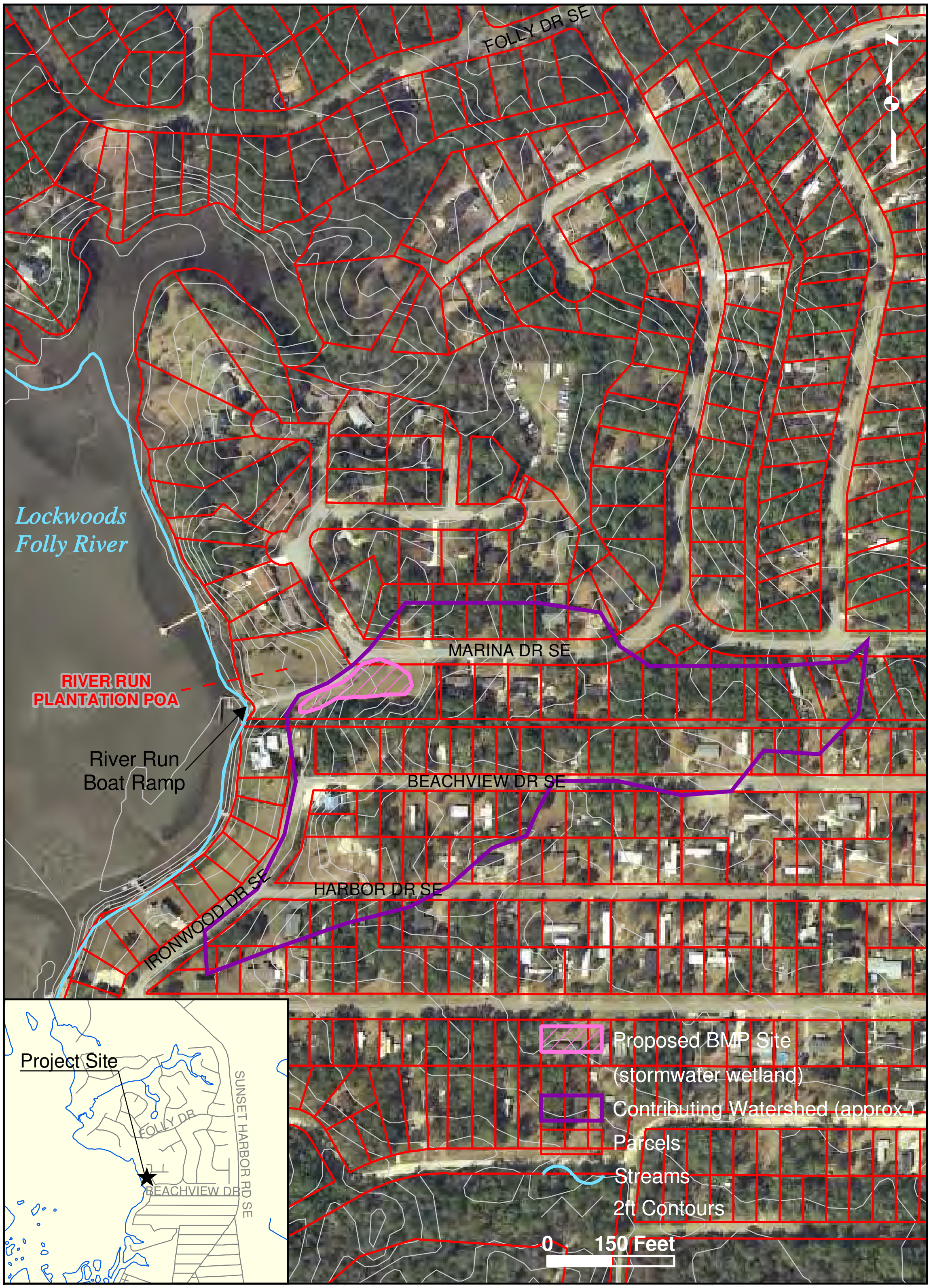
Other potential BMPs include construction of bioretention cells or simple depressions in the many traffic islands found throughout the neighborhood. A demonstration project could occur at the island located at the entrance to the neighborhood on Folly Drive.

### 3.18.3 Constraints

None

### 3.18.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---:|
| Construction Cost | $ 14,050 |
| Approximate Area | 12,400 $ft^2$ |
| Estimated Cost/Square Foot | $1.13 |




Project 18. River Run Boat Ramp BMP Retrofit

### 3.18.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 217MB02501 | River Run Plantation POA<br>828 Folly Dr. SE<br>Bolivia, NC 28422 |

River Run Plantation POA contact:
Larry Lockwood
910-842-8474
2869 Island Dr.
Bolivia, NC  28422

### 3.18.6 Photos

Photo 1. Ditch carries stormwater from houses and roadways

Photo 2. Runoff from this road would be intercepted by the stormwater wetland

## 3.19 PROJECT 19 HARBOR RIDGE BMP

### 3.19.1 Location

The project site is located in the Harbor Ridge neighborhood. To reach the site from Southport-Supply Road (NC 211) travel south on Sunset Harbor Road a little over a mile and turn right on to Harbor Ridge Drive.

### 3.19.2 Project Description

Stormwater in the neighborhood flows on both sides of Harbor Ridge Drive to a small cypress gum swamp that has been severely impacted. Most of the cypress trees are gone and the upper end of the wetland is filled with sediment. Swales constructed along the road could prevent additional sediment from entering the wetland. Swales would also slow the stormwater and help alleviate erosion.

### 3.19.3 Constraints

The swale could be constructed in the right-of-way on the east side of Harbor Ridge Drive. The right-of-way may not be wide enough on the west side of the road.

### 3.19.4 Cost Analysis

| Item | Estimated Cost |
|---|---|
| Construction Cost (stormwater wetland) | $ 16,740 |
| Approximate Yield/Linear Feet | 1860 ft |
| Estimated Cost/Linear Foot | $9 |

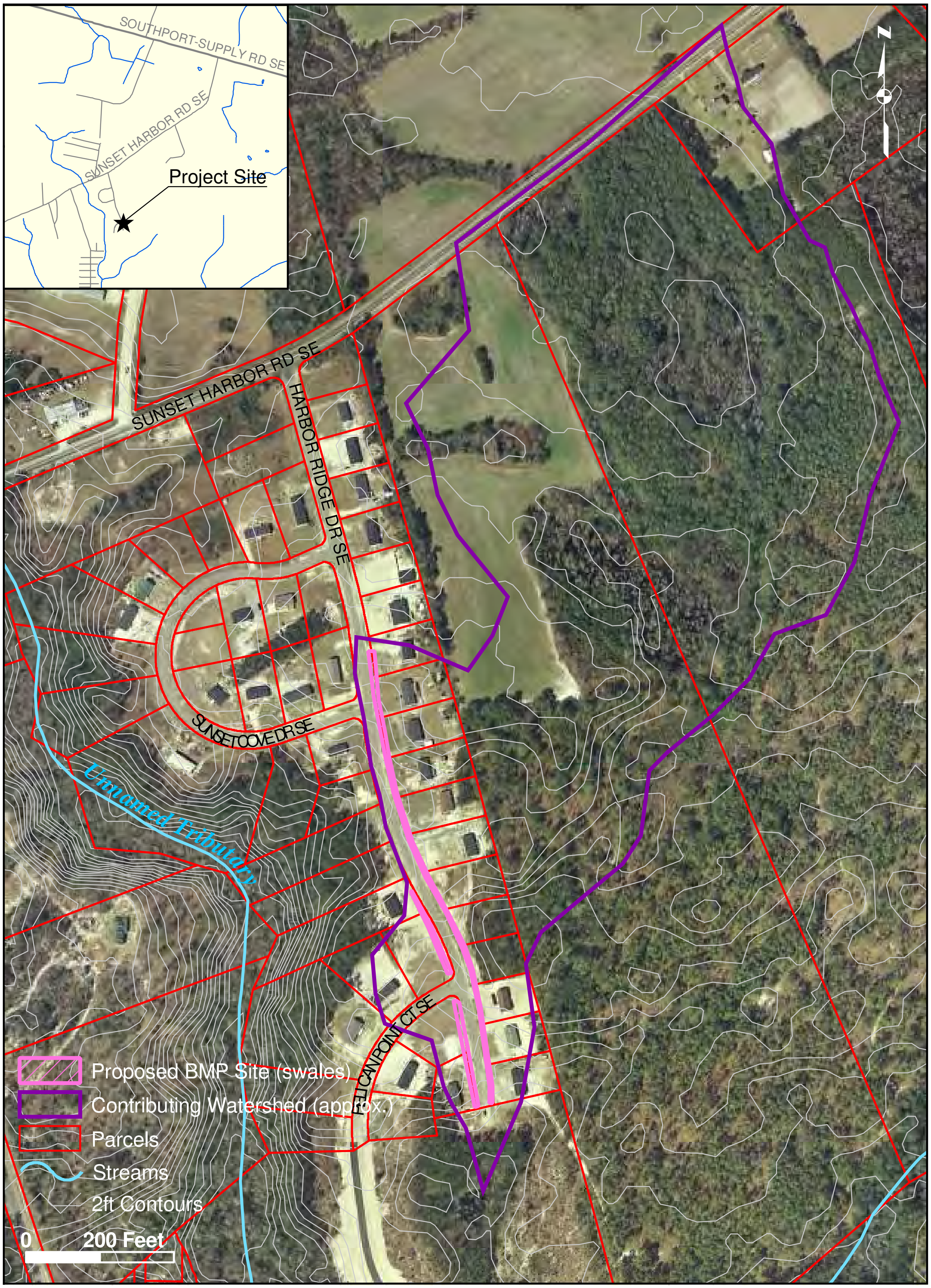
### 3.19.5 Property Owners – located in right-of-way

### 3.19.6 Photos

Photo 1. Stormwater carries sediment that is impacting this wetland



Stantec




Project 19. Harbor Ridge BMP Retrofit

## 3.20 PROJECT 20 SUPPLY ELEMENTARY SCHOOL BMPS

### 3.20.1 Location

The project site is located on the Supply Elementary School campus on Benton Road near the intersection with US 17.

### 3.20.2 Project Description

Stormwater from the school parking lots and buildings currently flows directly into two unnamed tributaries of Royal Oak Swamp. The parking lots and culverts are placed so that stormwater converges at two locations on the campus. Runoff from a new parking lot under construction in front of the school will also flow to one of these locations. Both locations have ample space for bioretention cells.

### 3.20.3 Constraints

None

### 3.20.4 Cost Analysis

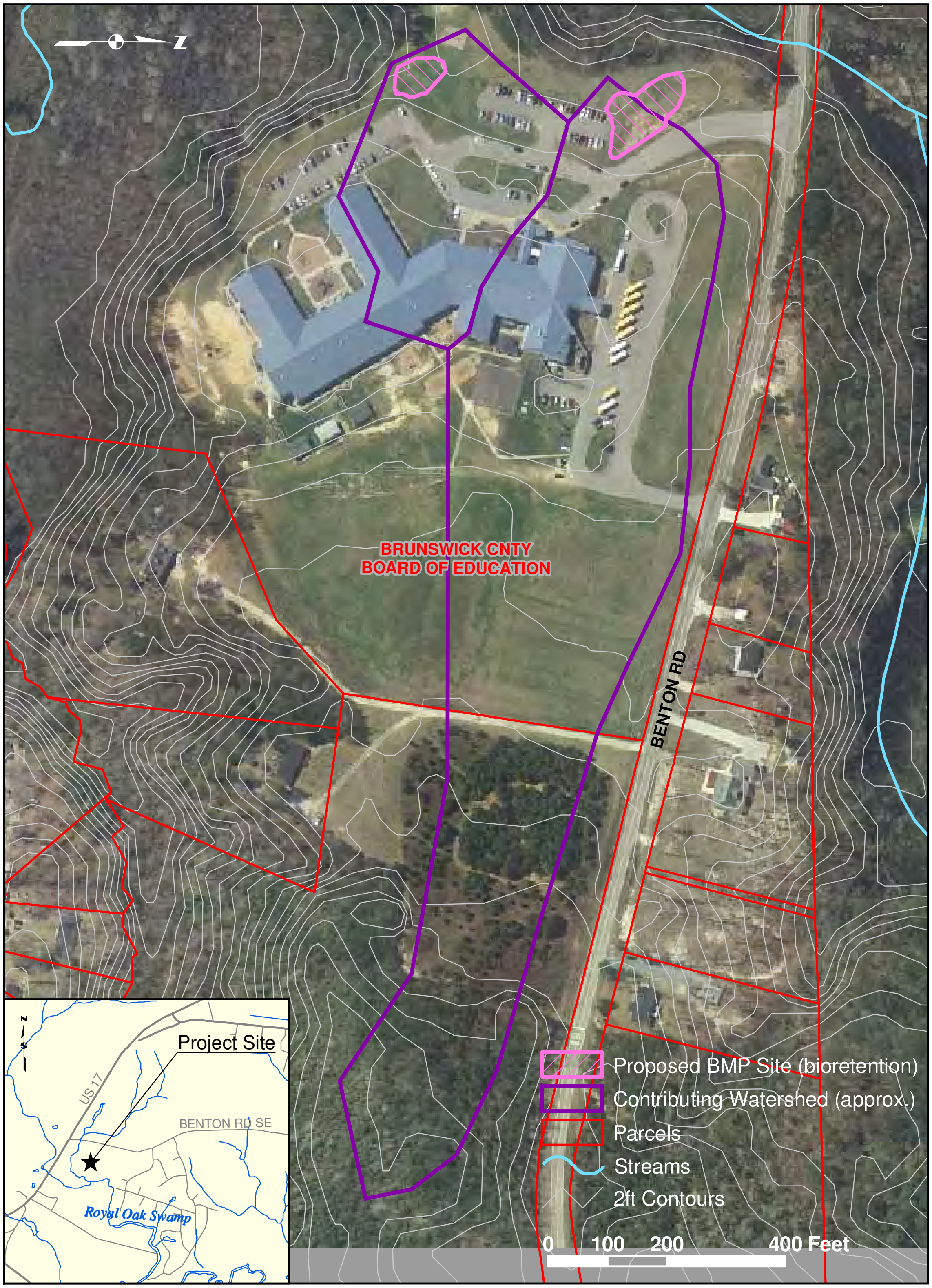
| **Item** | **Estimated Cost** |
|---|---:|
| Construction Cost (2 bioretention cells) | $ 155,000 |
| Approximate Area | 10,500 $ft^2$ |
| Estimated Cost/Square Foot | $10 |

### 3.20.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 1520005501 | Brunswick County Board of Education<br>35 Referendum Drive NE<br>Bolivia, NC 28422 |

### 3.20.6 Photos

Photo 1. Eroding channel due to stormwater runoff from school and parking lots.




Project 20. Supply Elementary School BMP Retrofit

## 3.21 PROJECT 21 ST. JAMES BMP

### 3.21.1 Location

The project site is in the Town of Saint James at the Members Club on Members Club Boulevard. From Southport-Supply Road travel south on St. James Drive for approximately 2.5 miles and turn right on Members Club Boulevard. Veer to the right at the fork in the road. The club is on the left hand side.

### 3.21.2 Project Description

Runoff from the parking lots and building at the Members Club flows through grates in the parking lots and discharges in a grassy area next to Members Club Boulevard. There is space in the grassy area to construct a stormwater wetland to treat the runoff.

### 3.21.3 Constraints

None

### 3.21.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---|
| Construction Cost (stormwater wetland) | $ 6,400 |
| Approximate Area | 3,800 $ft^2$ |
| Estimated Cost/Square Foot | $1.68 |

### 3.21.5 Property Owners

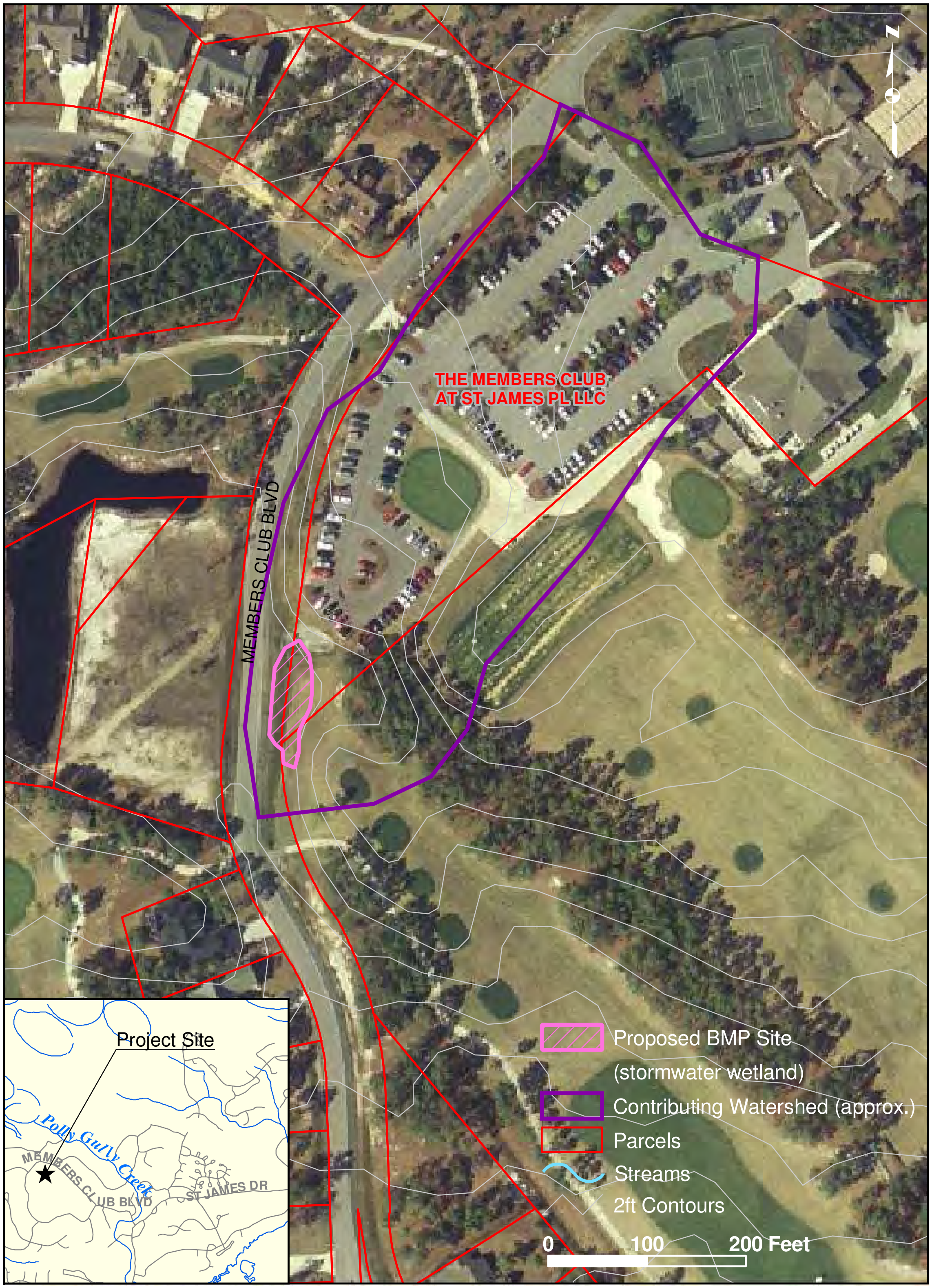
| Parcel Number | Property Owner |
|---|---|
| 21900011 | The Members Club at St James PL LLC<br>PO Box 10879<br>Southport, NC 28461 |

### 3.21.6 Photos

Photo 1. Stormwater outfall from clubhouse and parking lots



Stantec




Project 21. St. James Members Club BMP Retrofit

## 3.22 PROJECT 22 LOCKWOOD FOLLY COUNTRY CLUB BMP

### 3.22.1 Location

The Lockwoods Folly Country Club neighborhood is located on the Lockwoods Folly River south of Varnumtown. From Stone Chimney Road turn left on Clubhouse Drive. Proceed on Clubhouse Drive for approximately 1.5 miles until it ends, and turn left on Marina Drive. Marina Drive ends at Genoe's Point to the left and Genoe's Court to the right.

### 3.22.2 Project Description

Project 22A is located on Genoe's Court behind a small pond. The pond currently holds stormwater runoff from existing homes, roads, and driveways. It is evident that the pond cannot handle all of the runoff it receives, and it appears that the pond also lacks an outfall structure. Water flows out of the pond into a small ditch that empties directly into Lockwoods Folly River. Parcel A (see map blow) now contains two large recently constructed multifamily dwellings that cover most of the lot. The water table is close to the surface in this area making bioretention infeasible. A stormwater wetland could be built in place of the pond or between the the pond and river to catch pond overflow.

Project 22B is located along Genoe's Point. Roadside swales that currently carry stormwater have begun to erode creating shallow ditches. These ditches carry stormwater directly to small inlets of Lockwoods Folly River. Water quality swales would decrease stormwater flow and allow for an increase of infiltration in the sandy soils. This would decrease nutrients and fecal coliform input into the river.

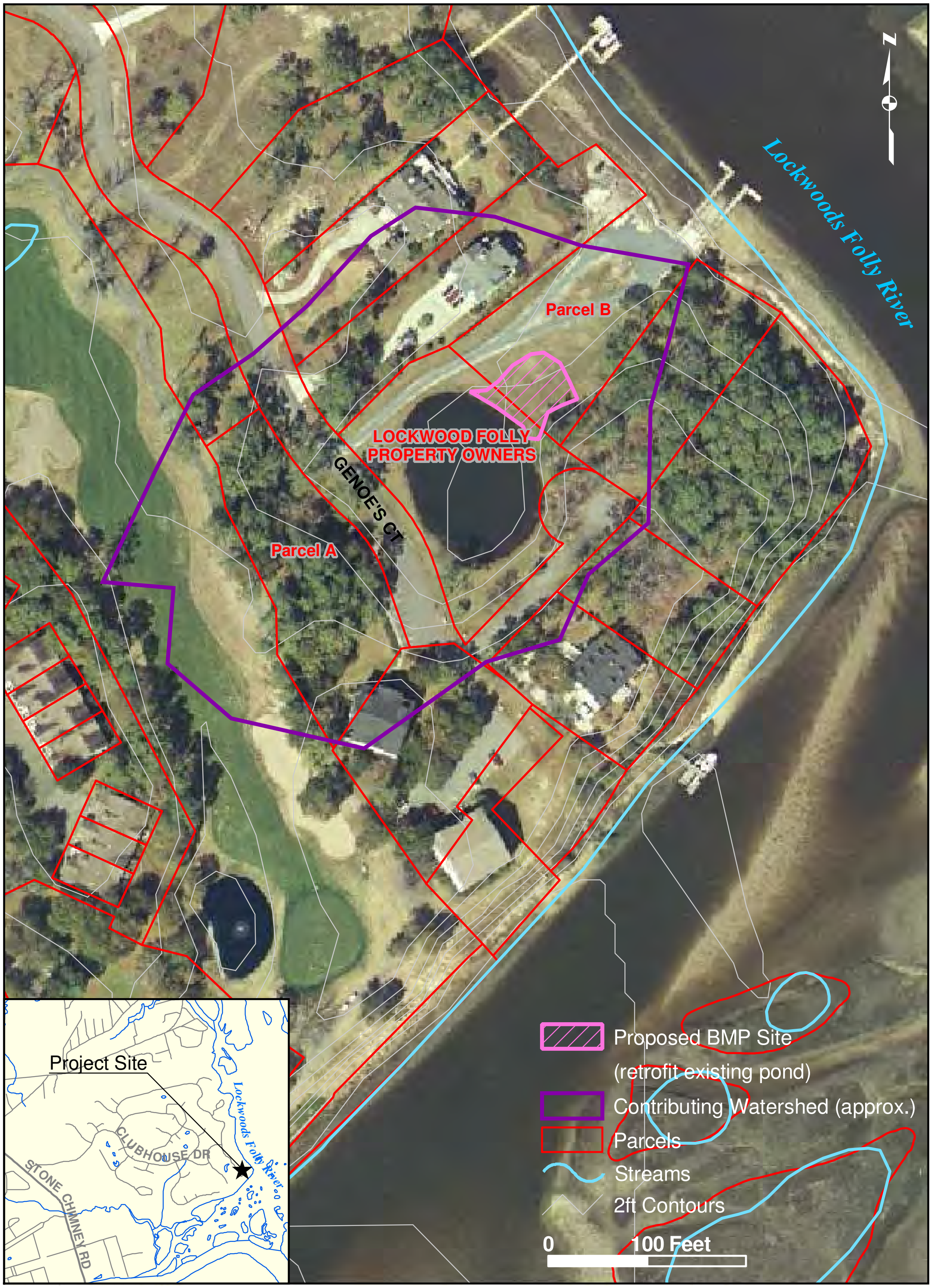
### 3.22.3 Constraints

None

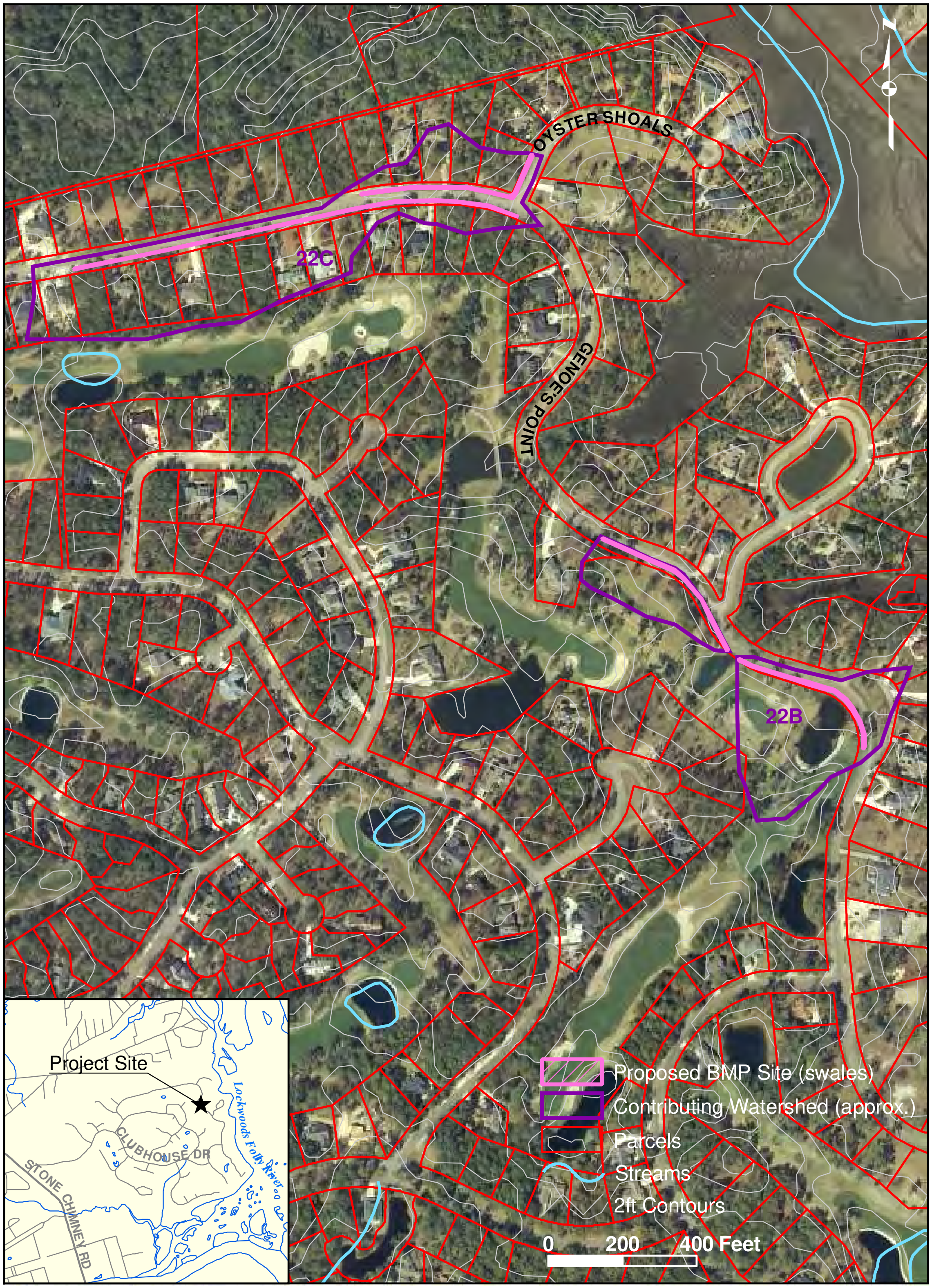
### 3.22.4 Cost Analysis

| Item | Estimated Cost |
|---|---|
| Construction Cost (swales) | $25,200 |
| Approximate Yield/Linear Feet | 2,800 ft |
| Estimated Cost/Linear Foot | $9 |

Cost for the detention pond/stormwater wetland retrofit cannot be estimated as an engineer's assessment is required to determine the necessary actions to expand and improve it.




Project 22A. Lockwoods Folly Country Club BMP Retrofit




Project 22B & 22C. Lockwoods Folly Country Club BMP Retrofit

### 3.22.5 Property Owners

Project 22A

| Parcel Number | Property Owner |
|---|---|
| 233BA170 | Lockwood Folly Property Owners<br>19 Clubhouse Dr SW<br>Supply, NC 28462 |

Project 22B

| Parcel Number | Property Owner |
|---|---|
| 233BA163 | Lockwood Folly Property Owners<br>19 Clubhouse Dr SW<br>Supply, NC 28462 |
| Right-of-Way | |

### 3.22.6 Photos

Photo 1. New construction in front of pond that was not designed to treat stormwater

Photo 2. Erosion along roadside due to stormwater flow

Photo 3. Ditch forming along roadside, discharges into LFR inlet

## 3.23 PROJECT 23 OAK ISLAND NORTHWEST BMPS

### 3.23.1 Location

The two project sites are located on the northwestern end of Oak Island between West Yacht Drive and the Intracoastal Waterway. One is located on NW 20th Street and the other is on NW 24th Street.

### 3.23.2 Project Description

Ditches line many of the roads in the northwestern portion of Oak Island. The ditches discharge directly into the Intracoastal Waterway. Swales could be constructed in the last block of each road in place of the ditch to treat the stormwater. The roadway in each of these blocks is unpaved and there is plenty of space to construct the swales. The two selected sites could serve as examples. Many of the other roads in this section of Oak Island have similar ditches although there were some roads without ditches.

### 3.23.3 Constraints

None

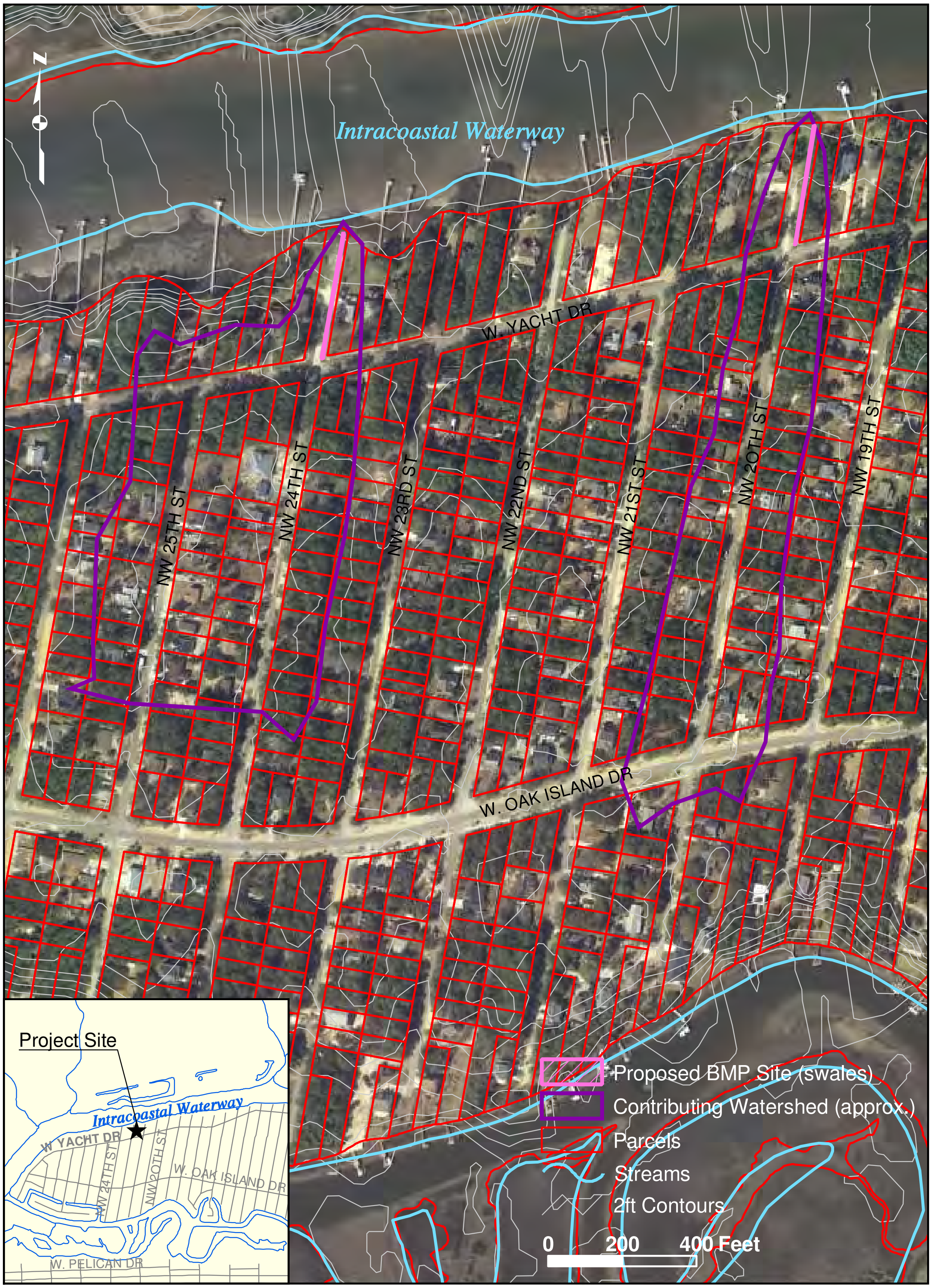
### 3.23.4 Cost Analysis

| Item | Estimated Cost |
|---|---|
| Construction Cost (swales) | $6,075 |
| Approximate Yield/Linear Feet | 675 ft |
| Estimated Cost/Linear Foot | $9 |

### 3.23.5 Property Owners -

### 3.23.6 Photos

Photo 1. Ditch discharges directly into Lockwoods Folly River




Project 23. Oak Island Northwest BMP Retrofit

## 3.24 PROJECT 24 OAK ISLAND RECREATION CENTER BMP

### 3.24.1 Location

The project site is located at the southern end of SE 30th Street on Oak Island next to the Oak Island Recreation Center.

### 3.24.2 Project Description

A stormwater wetland is recommended to treat runoff from the recreation center building and parking lot as well as from roads in the surrounding drainage area. The ideal location for the stormwater wetland would be on one of the parcels owned by Canal Associates, LLC. These parcels are currently undeveloped. If necessary, the stormwater wetland could be constructed behind the recreation center on land owned by the Town of Oak Island although it would have to be fit around an existing public trail and boardwalk.

### 3.24.3 Constraints

May require removal of some pavement.

### 3.24.4 Cost Analysis

| **Item** | **Estimated Cost** |
|---|---:|
| Construction Cost | $10,590 |
| Approximate Yield/Linear Feet | 8,500 ft |
| Estimated Cost/Linear Foot | $1.25 |

### 3.24.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 235NH016<br>235NH017<br>(also 235NH038 and 235NH039) | Canal Associates LLC<br>PO Box 10879<br>Southport, NC 28461 |

### 3.24.6 Photos

Photo 1. Town of Oak Island Recreation Center and parking area


Project 24. Oak Island Recreation Center BMP Retrofit

## 3.25 PROJECT 25 OAK ISLAND HOSPITAL BMP

### 3.25.1 Location

The project sites are located on the north and south sides of the J. Arthur Dosher Memorial Hospital located on the corner of E Oak Island Drive and NE 47th Street on Oak Island.

### 3.25.2 Project Description

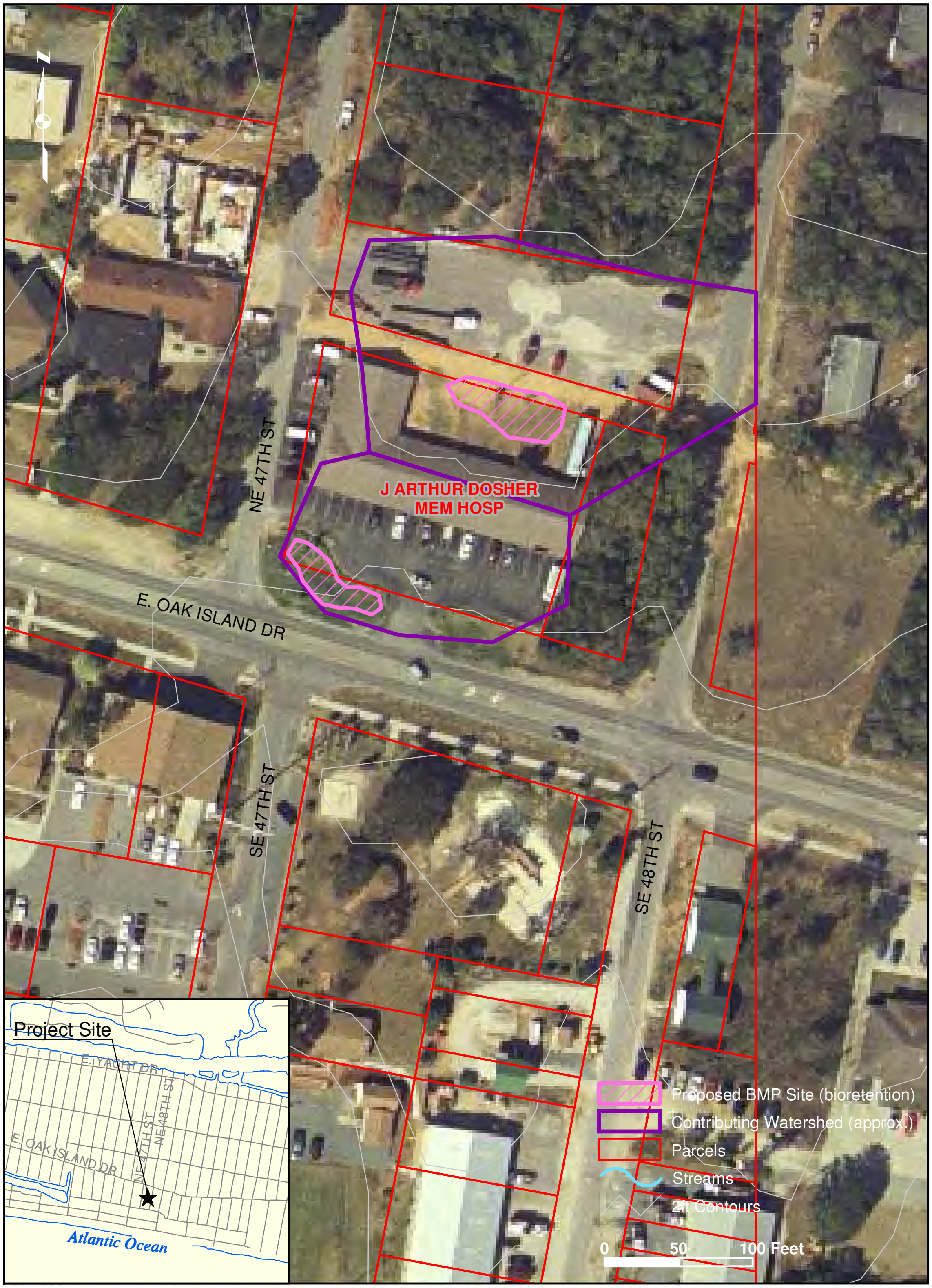
The project consists of two bioretention cells to treat runoff from the hospital building and parking lot. There are two grassy areas in front of the building that are located in the right-of-way. The bioretention cell could be constructed on each grassy area or on just one. Behind the hospital, a bioretention cell would treat runoff from the building and from the adjacent parking lot.

### 3.25.3 Constraints

None

### 3.25.4 Cost Analysis

| Item | Estimated Cost |
|---|---:|
| Construction Cost (2 bioretention cells) | $31,000 |
| Approximate Yield/Square Feet | 3,100 ft |
| Estimated Cost/Sqaure Foot | $10 |




Project 25. Oak Island Hospital BMP Retrofit

### 3.25.5 Property Owners

| Parcel Number | Property Owner |
|---|---|
| 235MK001 | J Arthur Dosher Mem Hosp<br>924 N. Howe St.<br>Southport, NC 28461 |

### 3.25.6 Photos

Photo 1. Parking area behind medical building

Photo 2. Grassy area in front of the medical building