ATTACHMENT A

A RESOLUTION ACCEPTING THE NORTH CAROLINA ECOSYSTEM ENHANCEMENT PROGRAM TARGETTING OF MANAGEMENT REPORT FOR THE MORGAN AND LITTLE CREEKS LOCAL WATERSHED PLANNING EFFORT

Resolution No. 87/2004-05

WHEREAS, the Carrboro Board of Aldermen seeks to partner with other local and state partners to assess opportunities for improving stormwater management and reducing export of nutrients and pollutants to Bolin and Morgan Creeks, as well as Jordan Lake, and

WHEREAS, the Town of Carrboro partnered with the North Carolina Ecosystem Enhancement Program (EEP; formerly the Wetlands Restoration Program) in a local watershed assessment and restoration project to assess the Carrboro watershed, select potential restoration projects, and follow up with implementation and monitoring of selected projects, and

WHEREAS, the NC EEP has completed the assessment project and submitted the "Targeting of Management" report to participants, and

WHEREAS, the NC EEP (formerly WRP) contract indicated in Section 2 item 3 that EEP agreed to "Implement one or more projects within the Town of Carrboro area based on feasibility studies, the NCWRP's need for projects, as well as compatibility with town planning priorities."

NOW, THEREFORE BE IT RESOLVED by the Carrboro Board of Aldermen that the Aldermen accept project reports, direct staff to prepare a letter to NC EEP acknowledging receipt of and expressing appreciation for the "Targeting of Management" report as well as direct staff to facilitate a priority list for implementation of best management practices and restoration projects for Board of Aldermen review and approval

This is the 8th day of February in the year 2005.

THIS DOCUMENT HAS BEEN EDITED TO CONTAIN INFORMATION RELEVANT TO CARRBORO ONLY

Morgan Creek
Local Watershed Plan
Targeting of Management Report
Draft

August 2004

Prepared for:
NORTH CAROLINA
ECOSYSTEM ENHANCEMENT PROGRAM

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1 Introduction

Tetra Tech, Inc. is conducting a local watershed planning (LWP) effort for Morgan Creek on behalf of the North Carolina Ecosystem Enhancement Program (NCEEP). In the initial phase of this LWP, all existing data and assessment information along with preliminary field reconnaissance data, were used to identify the primary threats, or stressors, to watershed functions within the study area. The conclusions of the initial phase are documented in the *Preliminary Findings Report* (Tetra Tech, 2004a), which also includes a detailed description of the study area and additional characterization information. The *Preliminary Findings Report* establishes the appropriate indicators necessary to measure conditions in the watershed in terms of the primary stressors, and describes the assessment tools and methods needed to further evaluate the indicators. The reader is urged to review the *Preliminary Findings Report* (PFR) prior to reading this document; a summary of the PFR is presented in Section 1.1 below.

The second phase of this local watershed planning effort produced a *Detailed Assessment Report* (Tetra Tech, 2004b) describing the assessments of each indicator and identifying those portions of the study area having the greatest existing functional losses and the greatest risk for future degradation of watershed functions. Areas with the greatest existing functional losses were targeted for stream and wetland restoration, retrofitting of best management practices (BMPs), and other management efforts to address those losses. Areas with the greatest risk of future degradation were targeted for development of the appropriate management and protection measures to prevent those losses. The most undisturbed portions of the study area with the highest levels of functional health were targeted for preservation. The reader is urged to review the *Detailed Assessment Report* (DAR) prior to reading this document; a summary of the DAR is presented in Section 1.2 below.

This *Targeting of Management Report* represents the final phase of this LWP effort, in which the management alternatives to address the targeted areas for restoration, protection, and preservation are identified and described in detail. To the extent possible, the report prioritizes recommended management measures for each of these three components based on factors such as feasibility and cost-effectiveness.

Key Terms

In the context of Local Watershed Planning the term **"stressor"** refers to forces within the watershed, usually resulting from human activities or alteration, which have the potential to degrade watershed functions. For instance, urban stormwater runoff is a common stressor with the potential to adversely impact aquatic habitat, water quality, and hydrologic functions within a watershed. Due to its diffuse nature, stormwater runoff cannot always be measured directly, but rather, is measured with indicators of its impacts. The term **"indicator"** is used to mean a quantifiable or subjectively rankable measure that provides a means of evaluating the health of watershed functions and that can be predicted in response to management options. Examples of indicators include water quality parameters (e.g., DO, temperature, nutrients, metals), percent imperviousness, percent disturbed buffer, sediment load, stream erosion/instability, and chlorophyll *a*. Linking management objectives to water quality and aquatic habitat impacts through the use of indicators provides decision-makers with meaningful information to support specific management decisions. That linkage is established through the use of assessment tools. The term **"assessment tool"** refers to the data collection, modeling and statistical analyses used to quantify the status of indicators and predict the outcome of management actions. In the course of watershed assessment, the level at which an indicator is said to show degradation of watershed functions is referred to as a **"targeting threshold."** When a given indicator exceeds the targeting threshold, it means that management action is necessary to address the appropriate stressor in order to restore the affected watershed functions. Often, the goal of management actions is to reduce or eliminate the impact of the stressor to a sufficient degree to lower the predicted indicator value to a level at or below the targeting threshold.

1.1 Summary of Preliminary Findings Report

The final PFR was submitted to NCEEP in January 2004. That document characterized existing watershed conditions based upon available information sources from previous assessment and characterization efforts within the study area. The report recommended indicators and assessment tools for evaluating watershed function to be used in the next phase of the planning process. For purposes of further discussion, a detailed map of the study area and its subwatersheds is presented in Figure 1-1.

Field reconnaissance efforts and assessments of existing data revealed a consistent pattern of watershed functional health across data types and data sources. The evidence consistently indicates that the primary watershed functions are fully or mostly intact in the rural headwater portions of both the Morgan and Bolin/Little Creek watersheds. However, the evidence also indicates a progressive decline in the health of these functions moving downstream into the urbanized portions of each watershed.

A number of factors contribute to this downstream decline in functional health including increases in imperviousness, disturbance of overall forest cover, riparian buffer disturbance and encroachment into floodplain areas. These changes in land use/land cover conditions from upstream to downstream have resulted in degradation of watershed functions that is evident in the decreasing taxonomic diversity of the benthic community data, and in the increased proportion of water samples that failed to meet DWQ water standards water quality criteria.

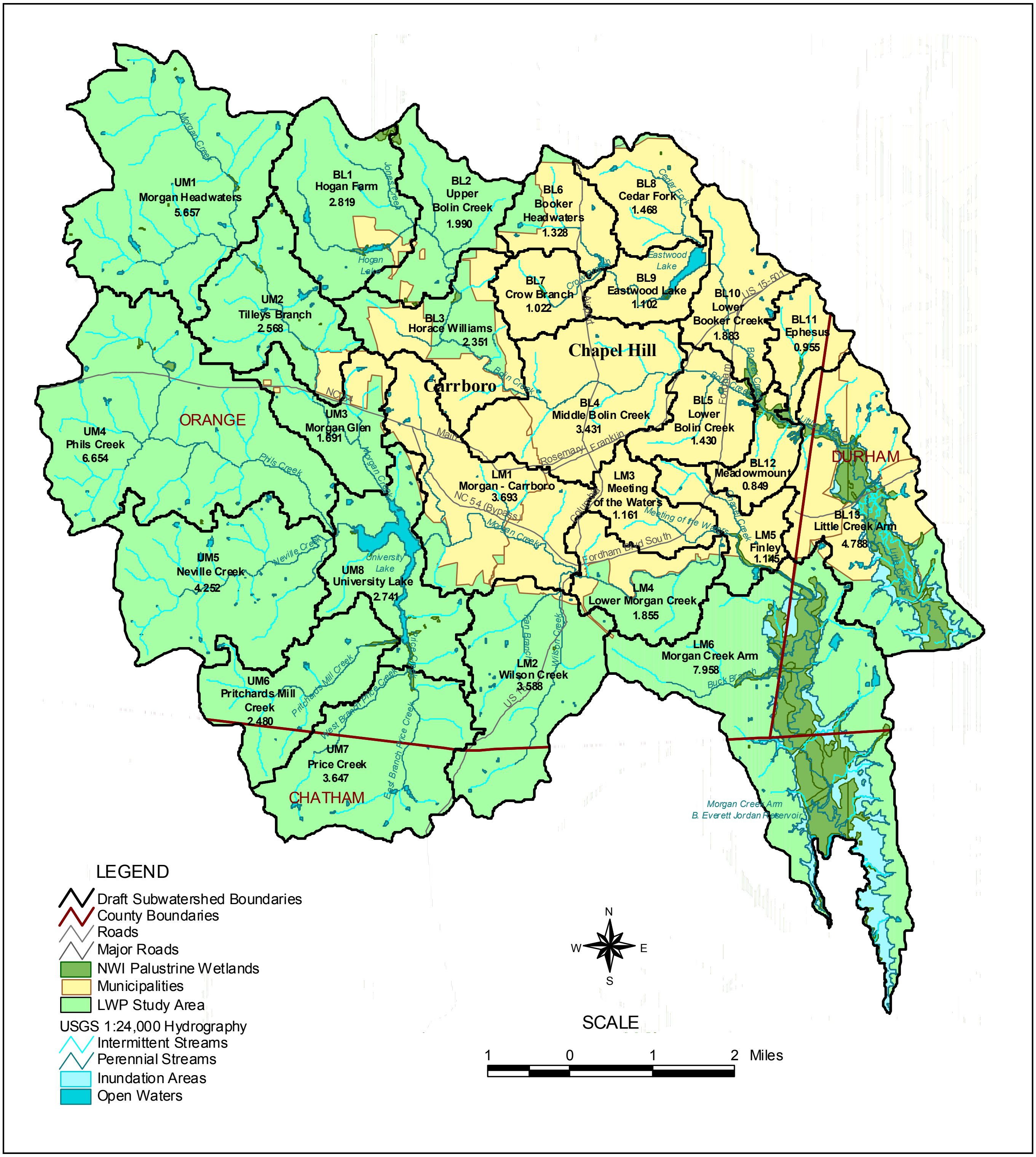

Figure 1-1. Local Watershed Plan Study Area and Delineated Subwatersheds

The distinction between rural upstream and urbanized downstream portions of the watersheds is also seen in channel geomorphic conditions as indicated by the visual stream assessments performed by Tetra Tech using the USDA (1998) Stream Visual Assessment Protocol (SVAP). With some exceptions, the SVAP stream morphology scores tend to be in the Good to Excellent range in the upstream segments, declining to Fair to Poor conditions in the downstream sections (refer to Sections 2.1 and 2.2 of the *Detailed Assessment Report*). Similarly, a greater proportion of the sites selected by the stakeholder team to reflect "Good" watershed conditions were located in headwater areas and a greater proportion of those deemed to reflect "Bad" conditions were located in the downstream sections of each watershed.

The upstream to downstream pattern of degradation illustrated in the PFR indicates that urbanization is the biggest overall threat to watershed functions. For this reason, the overall focus of the *Detailed Assessment* phase is quantifying impacts of urbanization on watershed functions where it has already occurred or is predicted to occur in the future. As urbanization occurs, threats to watershed functions can include: increased stormwater discharges directly to streams, in terms of both volume and velocity; increased overland flow of stormwater; increased pollutant loading in stormwater due to build-up and wash-off, illicit connections, and dumping into storm sewers; increased stream temperature due to lack of shading and heated stormwater runoff from ponds and impervious areas; reduced groundwater recharge and baseflow due to increased imperviousness; and decreased number and diversity of plants and animals due to the lack—or poor quality—of habitat.

Subsections 1.1.1 through 1.1.3 summarize the specific objectives for detailed assessment of the three distinct groups of subwatersheds (defined here as the USGS 14-digit hydrologic units) within the study area.

1.1.1 Upper Morgan Creek Subwatersheds (UM1 through UM6)

The PFR concluded that watershed functions are less threatened in the Upper Morgan Creek subwatersheds than in the other subwatersheds within this LWP study area. Due to development restrictions of a five-acre minimum lot size, imperviousness levels are relatively low, the majority of riparian buffers are intact, and nearly 60 percent of the watershed land area remains forested. Despite the overall rural and undisturbed nature of Upper Morgan Creek, some localized threats to watershed functions do exist. One or more dairy farming operations in the Morgan Creek headwaters (UM1) require implementation of appropriate BMPs to protect stream corridors. Future development across the entire area of the Upper Morgan Creek watershed has the potential to cause stream degradation. Despite the land use restriction holding new development to a five-acre minimum lot size, widespread low-density suburban development across the subwatershed will increase road infrastructure and convert forest land to buildings, driveways, and lawns, which could result in significant increases in stormwater runoff rates.

The PFR outlined the following objectives for Detailed Assessment:

- Quantify the range and extent of adverse impacts stemming from those localized stressors associated with agricultural activities in Upper Morgan Creek.
- Identify the restoration and management opportunities associated with those localized stressors in Upper Morgan Creek.
- Estimate the potential for stream degradation as a result of low-density suburban development on a watershed scale within the Upper Morgan Creek watershed and identify those areas most at risk.
- Identify those areas with the highest quality of aquatic and terrestrial habitat and prioritize them for preservation.

1.1.2 Lower Morgan Creek Subwatersheds (LM1 through LM6)

The health of Lower Morgan Creek varies significantly from subwatershed to subwatershed. University Lake and the storm flow control it provides has had a net beneficial effect on the mainstem of the creek resulting in relatively high benthic community ratings and good water quality at sites downstream of the lake.

In contrast, Meeting of the Waters (MOW) Creek drains a portion of the highly urbanized main campus of UNC-Chapel Hill resulting in high overall imperviousness within the subwatershed (LM3). Benthic community and water quality ratings in this subwatershed are among the lowest in the study area. The entire lengths of MOW Creek and Morgan Creek from the confluence with MOW downstream to Jordan Lake are listed as “impaired” on the NCDWQ 2002 303(d) List (2003) and the list attributes the impairment to urban runoff and storm sewers. The other tributaries of the Lower Morgan Creek watershed vary significantly in their condition depending on the level and location of development within them. Several tributaries including Wilson Creek are experiencing active stream erosion and received relatively low SVAP scores in their lower reaches due to development. However, the upper portions of these tributaries often are relatively undeveloped and preliminary reconnaissance efforts indicate healthy conditions.

Some of the quality wildlife habitat areas identified by a Triangle Land Conservancy (TLC) study (1999) are located in the Lower Morgan Creek watershed. However, in the intervening period since the TLC study, some of these quality habitat areas within the watershed have been lost to or significantly degraded by development.

The PFR outlined the following objectives for Detailed Assessment:

- Further quantify the impacts of urban stormwater runoff on MOW Creek and identify potential management and stormwater BMP retrofit opportunities to alleviate those impacts.
- Determine the need for stream restoration along MOW Creek and identify reaches where restoration would be feasible and beneficial.
- Identify those sections with the greatest existing levels of erosion and degradation and target those areas for restoration and management efforts to alleviate the losses of aquatic habitat and flood attenuation functions.
- Identify those segments where degradation has not yet occurred, but where future development is likely to result in damaging stormwater runoff and target those areas for the management efforts to prevent the associated functional losses.
- Identify those areas with the highest quality of aquatic and terrestrial habitat and prioritize them for preservation. (The highest priority will be given to those quality habitat areas at the greatest risk of being lost to development.)

1.1.3 Bolin/Little Creek Subwatersheds (BL1 through BL13)

The upstream to downstream pattern of increasing urbanization and degradation of watershed functions is most evident in the Bolin/Little Creek watershed. LWP subwatersheds BL1 through BL3 remain nearly or better than 50 percent forested with relatively low levels of riparian buffer disturbance. Imperviousness is also low in these headwater subwatersheds. Benthic community and water quality ratings are relatively good at the headwater stations on Bolin Creek. However, this portion of the LWP study area is the most threatened by future development. The risk of stream erosion and degradation occurring as a result of new development and increased stormwater runoff is heightened by the fact that soils in the upper Bolin Creek watershed have elevated K-Factors, similar to those in Morgan Creek headwaters, indicating a high potential for soil and stream bank erosion. K Factor is a relative measure of the propensity of soil particles to become dislodged when struck by water. As K Factors increase, susceptibility to erosion increases.

In the middle Bolin Creek subwatersheds, BL4 and BL5, urbanization increases and the stream receives stormwater runoff from much of downtown Chapel Hill. A gradual downstream decline of the conditions of various watershed indicators is evident. The riparian area is compromised by a sewer line easement and various encroachments. Benthic community ratings decrease from Fair at upstream stations above Airport Rd. (Waterside Dr., Estes Dr, and Village Rd.) to Poor at stations below Airport Rd. (Bollinwood Dr. and E. Franklin St.), and water quality declines relative to the headwater stations. Preliminary reconnaissance revealed active stream erosion occurring in segments along the Chapel Hill greenway from Airport Rd. to the Chapel Hill Community Center.

The Booker Creek watershed (LWP Subwatersheds BL6-BL10) is predominantly urban and suburban. Land cover analysis shows moderate to high levels of imperviousness, loss of the majority of the watershed's forest cover, and significant levels of disturbance of riparian buffers. All available benthic community data indicate that Booker Creek is in poor health throughout its length. Overall water quality ratings for Booker Creek stations indicate degradation relative to other stations. In terms of physical habitat, reconnaissance efforts have shown that the majority of Booker Creek appears to be stable with intact streambanks. Many areas of Booker Creek avoided becoming unstable by virtue of having substrates with high bedrock and large boulder content that provide grade control. High stormwater runoff volumes that have scoured out leaf packs and caused isolated areas of bank erosion resulted in some impairment of the biological community within this watershed (NCDWQ, 2003).

There are some indications of chronic toxicity issues on Crow Branch (subwatersheds BL7 and BL9) and Little Creek in the vicinity of Pinehurst Drive (NCDWQ, 2003). The assessment report notes that two UNC-CH hazardous waste landfills are located immediately adjacent to Crow Branch. However, no chemical pollutant monitoring was conducted in conjunction with the toxicity testing, so the specific pollutant(s) that may have caused the instream toxicity could not be identified with the available data. Benthic community monitoring for the NCDWQ assessment of the Little Creek watershed indicated "massive" deformities of *chironomid* larvae in the vicinity of Pinehurst Drive. The reported deformity rates and severity indicate that sediment or water column toxicity may be a problem in this vicinity, but sediment toxicity tests on sediment samples from this section of Little Creek were inconclusive.

Improvement of habitat conditions in Little Creek will require a comprehensive effort to address stream erosion and instability issues on a whole watershed scale. This comprehensive approach will need to include an effective stepwise strategy to restore morphological stability to streams within the Bolin/Little Creek watershed. This stability will only be achieved through a deliberately coordinated effort to mitigate the damaging storm flows entering the stream network while restoring the dimension, pattern, and profile that are appropriate for the new flow regime and associated sediment load. Measures such as stormwater retrofits and, where appropriate, construction/restoration of riparian wetlands are also likely to be integrated components of a successful restoration strategy for Bolin/Little Creek. The detailed assessment approach will be designed to identify the optimum locations for retrofits and other structural stormwater BMPs, and to compare potential implementation scenarios on the basis of benefit/cost ratios.

The PFR outlined the following objectives for Detailed Assessment:

- Further quantify the impacts of urban stormwater runoff on Bolin, Booker and Little Creeks and their tributaries and identify potential management and stormwater BMP retrofit opportunities to alleviate those impacts.
- Identify the stream reaches along Bolin, Booker and Little Creeks and their tributaries where erosion and instability have resulted in degradation of functions, and target those areas for management and restoration efforts (where restoration is deemed to be feasible and cost-effective) to alleviate that degradation and prevent any further loss of functions.

- Determine the need for stream restoration along Bolin, Booker and Little Creeks and their tributaries and identify reaches where restoration would be feasible and beneficial.
- Identify those segments of Bolin, Booker and Little Creeks and their tributaries where degradation has not yet occurred, but where future development is likely to result in damaging stormwater runoff and target those areas for the management efforts to prevent the associated functional losses.
- Develop recommendations for further monitoring and analysis to determine if sediment toxicity is a problem in Little Creek near Pinehurst Drive and identify sources if it is.
- Continue investigating potential sources of low dissolved oxygen (such as leaking sewer lines or organic loading from septic tanks).
- Continue evaluating any subsequently available chemical and biological data collected within the watershed to determine if conditions improve after recovery from the extended drought.
- Develop recommendations for further monitoring and analysis to identify sources of toxicity in Crow Branch and Booker Creek.

1.1.4 Threats for the Entire LWP Study Area

Nutrient concentrations have not been identified as a significant threat to the health of flowing streams within the study area. However, nutrient loads generated from the study area are of concern for the lakes receiving this flow, especially Jordan Lake and University Lake. Within these lakes, excess nutrient loads can lead to algal blooms that are unsightly, degrade recreational opportunities, alter biological uses, and present problems for treatment for use as potable water supplies.

Fecal coliform bacteria counts exceed the water quality criterion more frequently than any other parameter analyzed in study area. While these levels are of concern, fecal coliform bacteria and other pathogens can originate from a wide variety of sources including, but not limited to buildup and wash-off from impervious surfaces, failing septic tanks, leaking or failing sewer lines and pet wastes in runoff from suburban communities. Before further efforts can be undertaken to address fecal coliform bacteria (and other pathogens), The PFR recommended that an analysis be performed to identify the most likely sources within the study area.

The PFR outlined the following objectives for Detailed Assessment:

- Perform analysis to determine the most likely sources of fecal coliform and other pathogen loading to streams within the LWP study area.
- Develop a detailed nutrient loading and reservoir response model for University Lake under contract to OWASA; use these models to evaluate areas with the greatest potential to deliver nutrients to University Lake and target them for restoration and management efforts to reduce these loads.
- Identify the subwatersheds with the greatest potential to deliver nutrients to Jordan Lake and target them for restoration and management efforts to reduce those loads.

1.2 Summary of Detailed Assessment Report

The primary objective of the DAR was to evaluate magnitude and spatial pattern of functional stressors within the study area, so management strategies and BMPs could be targeted to the areas where they were most needed. Associated with this objective were three major assessment goals:

- To demonstrate linkage between stressors and indicators identified in the PFR.
- To identify targeting thresholds for specific indicators.

- To identify and rank subwatersheds for relative management priority where indicators exceed targeting thresholds.

The objectives for this Local Watershed Planning initiative are consistent with the primary stated goals of the North Carolina Ecosystem Enhancement Program (NCEEP), which are to:

- Protect and improve water and aquatic habitat quality by restoring wetland, stream, and riparian area functions and values which may have been, or may be, lost through historic, current, and future impacts.
- Achieve a net increase in riparian zone buffers and wetlands acreage, functions, and values in all of North Carolina's major river basins.
- Promote a comprehensive approach for the protection of natural resources.

The DAR summarized the assessment of the functional indicators set forth in the PFR. The assessment techniques for each indicator were described, thresholds for targeting of management were presented, and subwatersheds were prioritized for management, restoration or preservation. Indicators utilized in the Detailed Assessment included nutrients, impervious cover, buffer disturbance, channel bank stability indices, floodplain encroachment and measures of aquatic and terrestrial habitat quality. Targets were identified in the report where possible, and part of the overall local watershed planning process was to obtain information from, and work with stakeholders to establish appropriate indicators and targets. A summary of the key potential stressors to watershed functions, along with a listing of the assessment techniques used in the *Detailed Assessment* is presented in Table 1-1. The bulk of the DAR provides a description of the assessment tools and methods used to evaluate them, and presents the results for each indicator. Wherever possible, the results were presented in the context of the Local Watershed Plan (LWP) subwatersheds shown in Figure 1-1.

The DAR concludes with a comprehensive assessment of the results for all indicators that was achieved through the development and application of a numeric ranking system (Table 1-2). The ranking system generates two total scores for each LWP subwatershed on the basis of indicators applicable to that subwatershed. The first score, Existing Risk/Priority for Management combines the results for indicators of degradation of watershed functions under existing conditions as well as the indicators of terrestrial habitat quality/preservation potential. The intent behind combining these two separate groups of indicators is to maximize the watershed-scale benefits of restoration and management. The idea is that a subwatershed where both high quality terrestrial habitat and the need for stream restoration exists should be given high priority for restoration and preservation efforts because the actions would be mutually beneficial. The second score developed for each watershed, Future Risk/Priority for Prevention, reflects the incremental increase in risk for degradation predicted to occur as a result of the transition from existing land use conditions to the buildout scenario. Table 1-2 shows the varying levels of severity and numeric scores associated with each indicator.

It should also be noted that in the course of organizing and evaluating the array of indicators for the Detailed Assessment, it became very apparent that a clear distinction existed between LWP subwatersheds that are predominantly rural in nature and those that are predominantly urban. The distinction was apparent in the stressors found to be affecting watershed functions and the degree to which those functions were affected. In the rural subwatersheds existing degradation was found to be a function of existing or past agricultural practices and these areas tended to be at risk for degradation from future development, whereas in urban subwatersheds the impacts of existing development with loss of forest cover, increased imperviousness, and the associated increases in stormwater runoff and nonpoint source pollutant loads were found to drive the degradation of watershed functions. Based on professional judgment and the endorsement of stakeholders, the decision was made to compare urban and rural/developing subwatersheds separately for ranking and prioritization purposes, rather than comparing urban to rural. The split between urban and rural subwatersheds is illustrated in Figure 1-2.

Table 1-1. Summary of Indicators and Techniques Used for Detailed Assessment of Potential Stressors to Watershed Function

Watershed Function	Potential Stressor	Indicator	Scale	Assessment Technique
Hydrologic & Aquatic Habitat Functions	Multiple	Overall Stream Condition	Subwatershed/ Stream Reach*	NRCS-SVAP**
	Stream Erosion and Instability	Erosion and Instability Potential	Subwatershed/ Stream Reach*	SVAP** Morphology Critical Velocity
	Urban/Suburban Development	Imperviousness	Subwatershed*	GIS Analysis
	Riparian Buffer Disturbance	Riparian Buffer Condition	Subwatershed/ Stream Reach*	GIS Analysis
	Floodplain Alteration	Floodplain Encroachment	Subwatershed*	GIS Analysis
Water Quality & Water Supply Functions	Jordan Lake Eutrophication	Nutrient Loading Rates	Watershed	GWLF*** Derived Export Rates Fate & Transport Modeling (SPARROW)
	University Lake Eutrophication	Nutrient Loads Eutrophic Response	Watershed	GWLF*** Loading Model BATHTUB**** Response Model
	Fecal Coliform Loads	Water Quality Criteria Excursions	Subwatershed*	Statistical Analysis of Monitoring Data
Terrestrial Habitat Functions	Forest Habitat Contiguousness	Forest Cover Disturbance	Subwatershed*	GIS Analysis
	High Quality Habitat	Forest Age/ Habitat Composition	Subwatershed*	GIS Analysis of GAP Natural Heritage Inventory Local Habitat Studies
	Wetland Distribution	National Wetland Inventory (NWI)	Subwatershed*	GIS Analysis of NWI
	Species and Habitats of Special Concern	Natural Heritage Element Occurrences	Subwatershed*	GIS Analysis

*“Subwatershed” refers to smaller drainage areas within selected 14-digit hydrologic units delineated for the purposes of defining distinct management units within the context of Local Watershed Planning efforts, usually in the range of 1-10 square miles in area.

“Stream reach” scale refers to individual stream segments either upstream of, or between, significant tributaries, such that any given reach usually exhibits consistent channel size and characteristics. Using 1:24,000 scale hydrography to represent stream networks, reach lengths can vary significantly, but tend to be between 0.25 and 1.0 mile in length.

**Stream Visual Assessment Protocol (USDA, 1999)

***Generalized Watershed Loading Function (Haith et al, 1987)

****Walker BATHTUB Model (Walker, 1987)

Table 1-2. Scoring System Used to Rank Subwatersheds According to Status of Indicators

SCORE 1	**RISK LEVEL/PRIORITY POINTS**				
Existing Risk/Priority for Management	Low	Med	High	Very High	Extreme
Stream Stability (Rural Subs Only) *Score stems from modeling analysis*	0	1	2		
	Excellent	Good	Fair	Poor	
Stream Visual Assessment Protocol *Score based on SVAP Class*	0	1	2	3	
SVAP Morphology Assessment *Score based on SVAP Class*	0	1	2	3	
Riparian Buffer Disturbance *Low Risk = buffer disturbance less than 30%* *Medium Risk = buffer disturbance 30-40%* *High Risk = buffer disturbance 40-50%* *Very High = buffer disturbance greater than 50%*	0	1	2	3	
Imperviousness *High Risk = 10% impervious or more* *Very High Risk = 25% impervious or more*	0		2	4	
Nitrogen Loading Potential *Subwatersheds sorted and rated by quintile lbs/ac/yr*	0	1	2	3	4
Phosphorus Loading Potential *Subwatersheds sorted and rated by quintile lbs/ac/yr*	0	1	2	3	4
Floodplain Encroachment *Low Risk = 0-2% Encroachment* *Medium Risk = 2-4% Encroachment* *High Risk = 4-6% Encroachment* *Very High Risk = 6-8% Encroachment*	1	2	3	4	
Habitat Quality/Preservation Potential	*3 -7*	*8-11*	*12-17*	*18-22*	
Score stems from Habitat Assessment Scores	0	2	4	6	
SCORE 2	**RISK POINTS**				
Future Risk/Priority for Prevention	Low Risk	Med Risk	High Risk	Very High	Extreme
Stream Stability (Rural Subs Only) *Score stems from modeling analysis*	0	1	2		
Increase in Imperviousness *Low Risk = 0-5% increase in imperviousness* *Medium Risk = 6-10% increase in imperviousness* *High Risk = 11-15% increase in imperviousness* *Very High Risk = 16-20% increase in imperviousness* *Extreme Risk = 21-25% increase in imperviousness*	0	1	2	3	4
Increase in Phosphorus Load *Subwatersheds sorted and rated by quintile lbs/ac/yr*	0	1	2	3	4
Increase in Nitrogen Load *Subwatersheds sorted and rated by quintile lbs/ac/yr*	0	1	2	3	4

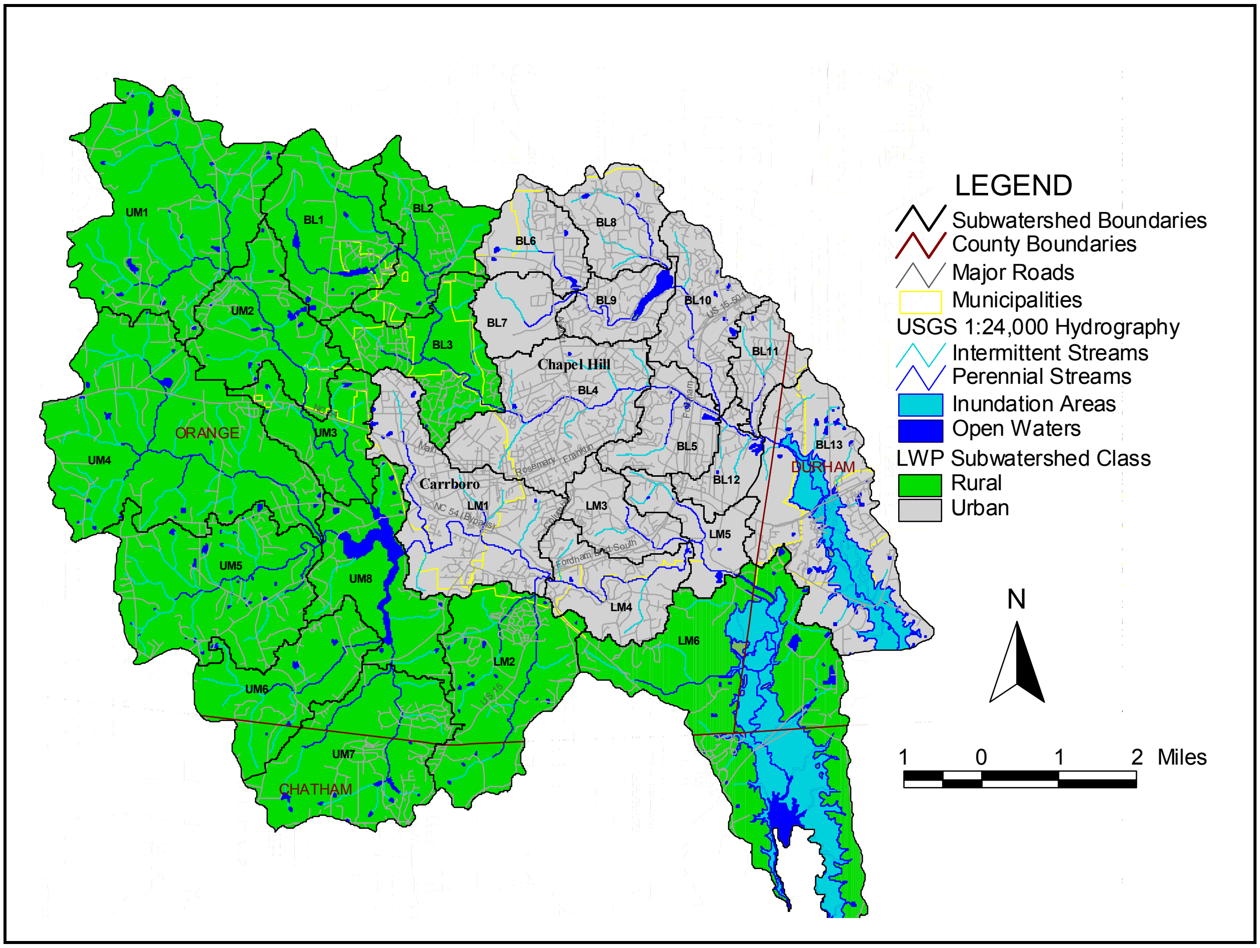

Figure 1-2. Urban vs. Rural and Developing LWP Subwatersheds

The combined scores for indicators showing the Existing Risk/Priority for Management are presented for rural and urban subwatersheds and illustrated spatially in Figure 1-3. When examining Figure 1-3, it is important to note that the subwatersheds are grouped by color according to their final scores, with rural subwatersheds spectrally grouped from pink to purple and urban subwatersheds spectrally grouped from beige to brown. In addition, each subwatershed is labeled with the final score and letters for each indicator that ranked high or very high risk/priority in that subwatershed. As a result, higher scoring subwatersheds are reflected in darker colors and the indicator letters provide insight into the potential stressors resulting in the rank/priority of those subwatersheds.

The combined scores for indicators showing the Future Risk/Priority for Prevention, based on the predictions of indicator conditions corresponding to the buildout land use scenario, are presented for rural and urban subwatersheds in Figure 1-4.

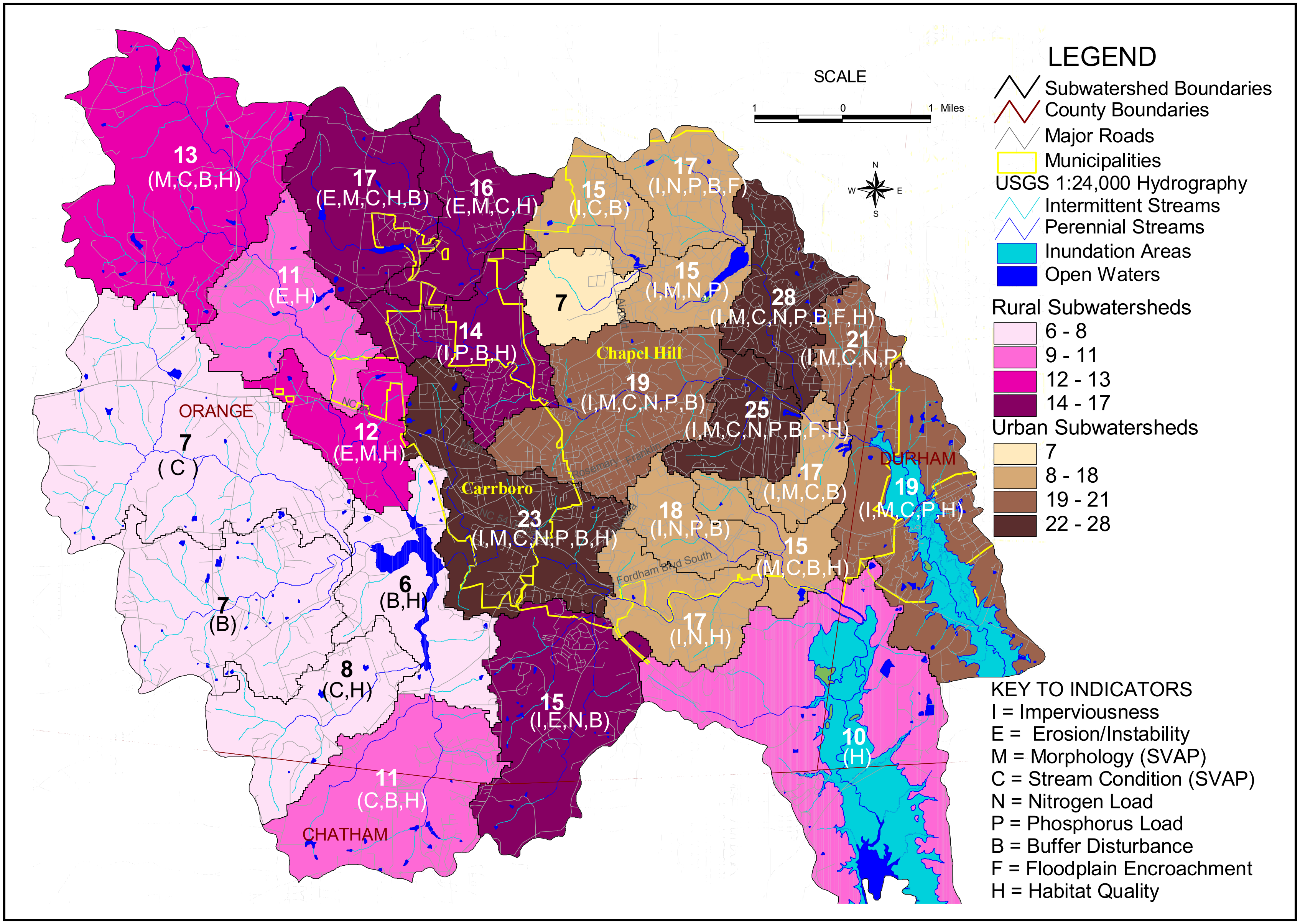

Figure 1-3. Score 1 – Existing Risk/Priority for Management for Rural and Urban LWP Subwatersheds

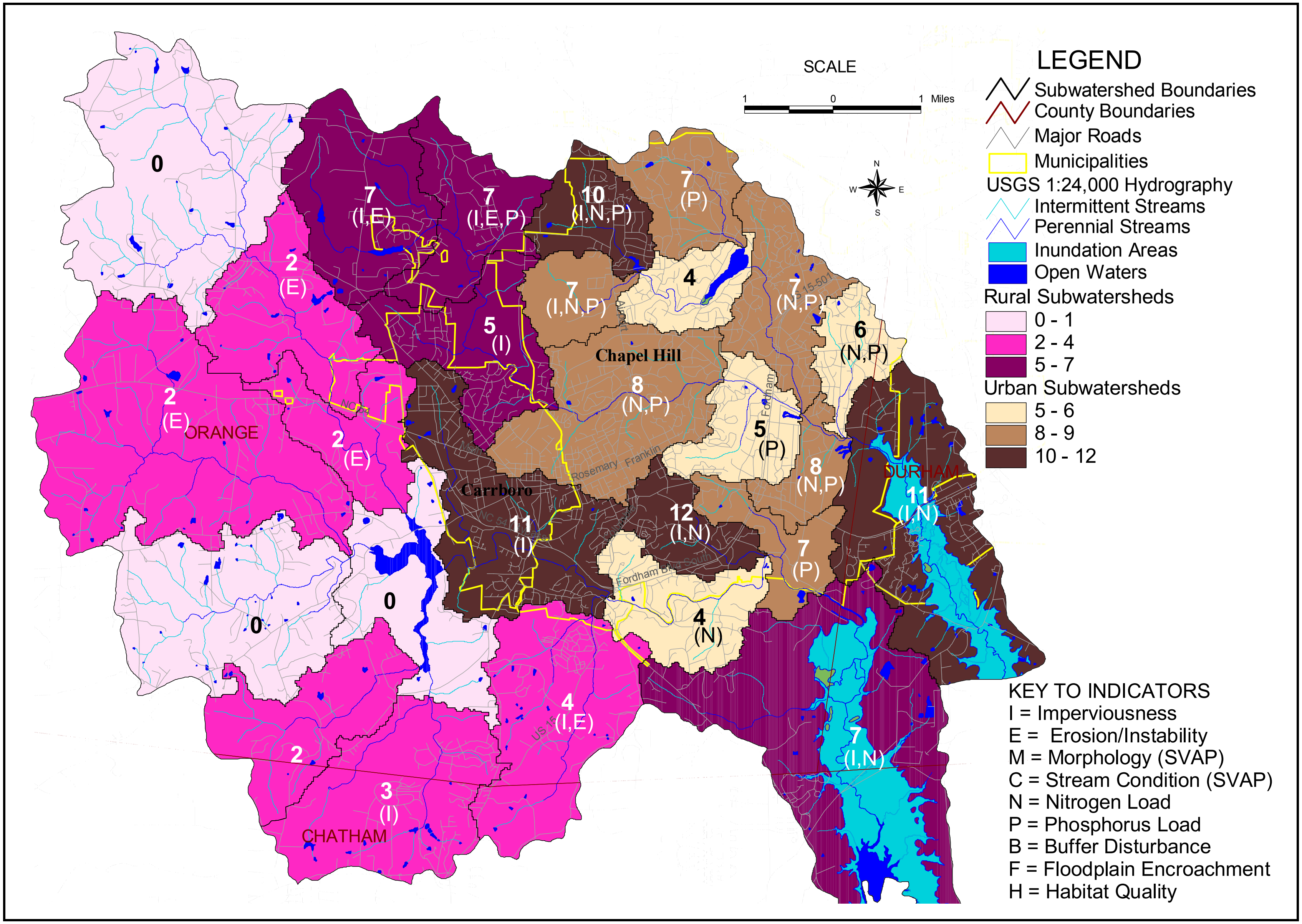

Figure 1-4. Score 2 – Future Risk/Priority for Prevention for Rural and Urban LWP Subwatersheds

The reader is encouraged to review Chapter 5 of the *Detailed Assessment Report* for the discussion of specific subwatershed scores. Based on the scores in each of the two ranking categories, groups of LWP subwatersheds were assigned priority *tiers* for further management efforts. The first tier of subwatersheds in which to focus further restoration, preservation and prevention efforts for the remainder of project resources in the local watershed planning study consists of the Bolin Creek subwatersheds BL1-BL5, lower Booker Creek (BL10), and the upper Morgan Creek subwatersheds UM1-UM3. The second tier of subwatersheds consists of the headwater portions of Booker Creek, subwatersheds BL6-BL9, the Little Creek subwatersheds BL11 and BL12, and the lower Morgan Creek subwatersheds LM1 and LM3-LM5, which include Meeting of the Waters and Chapel Creek. The two prioritized tiers of subwatersheds are illustrated in Figure 1-5.

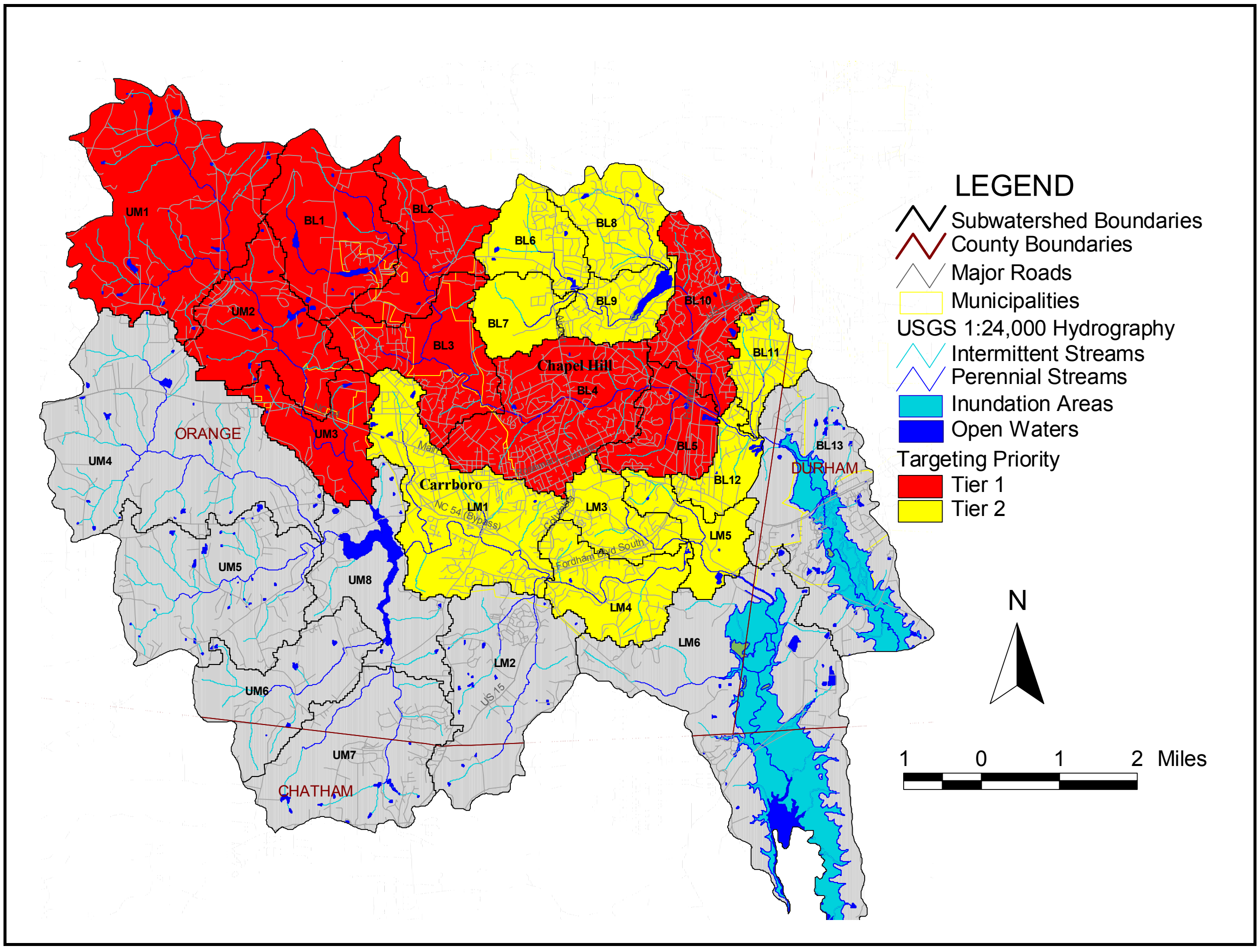

Figure 1-5. Recommended Tier 1 and Tier 2 Subwatersheds

The individual subwatershed scores in Figure 1-3 and Figure 1-4 do not indicate a great degree of overlap between high priority subwatersheds for efforts related to existing conditions and those with high priority for effort to prevent future degradation. However, the two tiers represent the intent to identify contiguous blocks of subwatersheds where the mutually enhancing benefits of restoration and protection measures can be realized.

1.3 ORGANIZATION OF THE TARGETING OF MANAGEMENT REPORT

This report details specific opportunities and/or management strategies to address three primary categories for targeting of management:

1) Measures to address existing degradation and restore watershed functions.
2) Measures to protect watershed functions from future degradation.
3) Preservation efforts to protect those areas where watershed functions exhibit the greatest existing value to overall watershed health.

The subsequent chapters of this *Targeting of Management Report* (TMR) reflect these three categories. The methods used to identify restoration retrofit sites and preservation areas, and the criteria used to prioritize them, are presented in the main body of the document. Maps and specific details pertaining to each site are presented in the associated appendices.

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2 Measures to Address Existing Degradation

2.1 Introduction and Background

The measures evaluated in this final phase of the local watershed planning effort to address existing degradation include BMP retrofitting to reduce the adverse impacts of stormwater runoff such as stream erosion, instability, and excess nutrient loading. Retrofitting opportunities have been evaluated in conjunction with opportunities to utilize natural channel design and bioengineering methods to restore aquatic habitat and hydrologic functions and reduce nutrient and other nonpoint source pollutant loads to stream channels within the Tier 1 subwatersheds: the Bolin Creek subwatersheds BL1-BL5, lower Booker Creek (BL10), and the upper Morgan Creek subwatersheds UM1-UM3 shown in Figure 1-5. The remaining project funding allowed for efforts to identify stream and wetland restoration opportunities and potential BMP retrofit sites to be extended into the Tier 2 priority subwatersheds, consisting of the headwater portions of Booker Creek, subwatersheds BL6-BL9, the Little Creek subwatersheds BL11 and BL12, and the lower Morgan Creek subwatersheds LM1 and LM3-LM5, which include Meeting of the Waters and Chapel Creek (refer to Figure 1-5).

The following sections detail the methods used to identify and screen restoration and retrofitting opportunities. The specific opportunities recommended for further consideration and investigation are described in detail in this section (Stream and Wetland Restoration Sites) and *Appendix A* (BMP Retrofit Sites). In addition the methods utilized to assess the feasibility and functional benefits of the identified restoration measures are described and high priority opportunities are outlined on the basis of these factors. Many of the opportunities cataloged in this report have been identified and evaluated in cooperation with the stormwater engineering and planning staffs of the towns of Carrboro and Chapel Hill.

2.2 Identification of Restoration Opportunities

2.2.1 Identification of Stream and Wetland Restoration Opportunities

Beginning with the Tier 1 subwatersheds identified in Figure 1-5, a comprehensive assessment of potential restoration sites was performed using detailed aerial photography and site investigations, and their restoration feasibility was evaluated onsite by an experienced stream restoration designer/practitioner. Upon completion in the Tier 1 subwatersheds, the restoration site assessment efforts continued in the Tier 2 subwatersheds. For each stream segment within the targeted subwatersheds in which restoration was deemed necessary and feasible, recommendations were developed reflecting the optimum restoration method and approach. The factors used to evaluate the feasibility of restoration for each stream segment are discussed below. The prioritization of restoration methods generally followed the priority levels set forth by Rosgen, which are illustrated in Figure 2-1 and summarized as follows (Rosgen, 1996):

Priority 1: Construct a new channel with an accessible floodplain at the stream's previous elevation adjacent to degraded and incised existing channel. Abandon and fill degraded channel.

Priority 2: Establish an accessible floodplain at the channel's existing elevation or higher, but not at original height.

Priority 3: Convert the stream (or reach) to a new stream type without an active floodplain but containing a flood prone area (typically involves construction of a step-pool stream type).

Priority 4: Stabilize the channel in place.

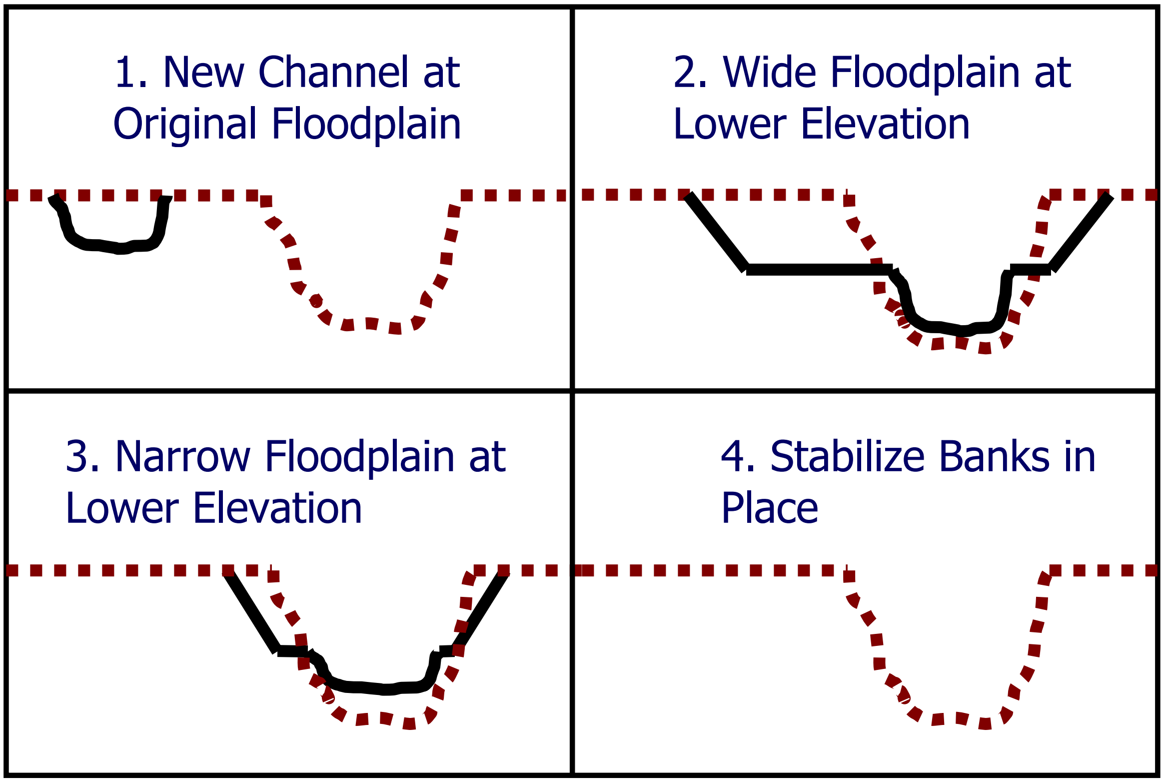

Figure 2-1. Four Priorities of Stream Restoration Methods (Rosgen, 1996)

Each of the methods outlined above has different advantages, disadvantages and constraints associated with it, and costs can vary significantly from method to method. For instance, Priority 1 restoration will not be feasible in many of the urbanized portions of the Bolin and Booker Creek watersheds because that approach requires significant available land area adjacent to the existing degraded channel. In most areas of Bolin and Booker Creek, water and sewer lines, roadways, and other infrastructure features are located immediately adjacent to stream channels, precluding establishment of the necessary stream meander associated with Priority 1 restoration. Also, urban land values are very high in this study area, and therefore the cost for acquisition of permanent conservation easements in such areas may be prohibitive. In most areas of the Bolin and Booker Creek watersheds, Priority 2 and Priority 3 restoration will be more appropriate, but these approaches often have higher costs than Priority 1 due to increased excavation and construction requirements. By contrast, in the more rural upper Morgan Creek watershed, the large areas of open agricultural land and absence of significant infrastructure constraints will allow for Priority 1 restoration methods. The lowest restoration costs per linear foot are likely to be achieved in this portion of the LWP study area.

It should be noted that Priority 4 restoration, which involves the use of riprap, gabions, or other stream hardening methods to fix an eroding channel in place, was not recommended for any portion of the sites identified. Priority 4 restorations only temporarily suspend the process of bank erosion and prevent the excess sediment transport downstream, but they do not contribute to restoration of the aquatic habitat functions of the stream channel.

While it is not possible to estimate exact cost without a detailed engineering analysis of restoration plans for a given reach, to the extent possible, the project team used *conceptual design* level costs to generate cost estimates for the recommended restoration approach at each site. It should be noted that the cost estimates are based on limited field reconnaissance; additional constraints and obstacles may be identified following a detailed survey of each site that could potentially increase the actual restoration cost. For instance, stream restoration projects will often significantly change flooding patterns along the restored stream segment. In locations where restoration projects are implemented in close proximity to buildings, roadways and other elements of the human infrastructure, detailed flood modeling studies are required to assess the change in flood hazard for those surrounding structures. The potential requirement for flood studies was not integrated into the cost estimates.

In addition, any observations of potential BMP retrofits that could be incorporated with existing site uses or integrated with potential stream restoration projects were noted.

Restoration Site Evaluation Methodology

The restoration site assessment was initiated by examining detailed aerial photography maps of the targeted LWP subwatersheds. Information detailed on the maps includes the following:

- Stream channel locations
- Parcel lines
- Infrastructure and utilities (roads, sanitary sewer lines and water lines)
- FEMA 100-year floodplains
- Hydric soil regions
- Wetlands included in the National Wetland Inventory

Potential restoration sites were systematically eliminated from the subset slated for onsite evaluation if they were less than 1,000 feet in length, encompassed an excessive number of property owners, or exhibited excessive utility or infrastructure constraints. Based on the onsite assessments, sites were eliminated from further consideration if numerous constraints (particularly impending development and utilities) were present, if large amounts of excavation would be required to create a flood plain bench, or if the site was characterized by short restoration segment lengths which, when combined with the other restrictions, would escalate costs. The sites identified with restoration potential after evaluation of remote sensed data and onsite evaluations are enumerated in Table 2-1 and shown on the map in Figure 2-2.

Innovative Restoration Site

Restoration Site 11, Morgan Creek at Old Mason Farm, is shown on Figure 2-2, but not listed in Table 2-1. The reason for this discrepancy is that this site is not reflective of a typical restoration project, and as such, does not lend itself well to description with the restoration characteristics presented in Table 2-1. This restoration project involves removal of a manmade berm to reconnect a segment of Morgan Creek with its historical floodplain. It should be noted that this restoration opportunity was not discovered by the LWP consulting team, but rather, was referred by NCEEP for inclusion in this report. By the time this document was written, a Memorandum of Agreement between the UNC Botanical Garden and NCEEP was already established allowing this restoration project to move forward. The project is described and mapped in greater detail with the other restoration project descriptions below.

Table 2-1. Key Characteristics of Potential Stream Restoration Sites in the Morgan Creek LWP Study Area

Site	Stream Name/Location	Estimated Stream Length	Potential Restoration Length	Observed Constraints	Recommended Restoration Priority	Estimated Restoration Cost/Linear Foot[1]	BMP Potential	Recommended for Restoration
1	UT* to Morgan Creek - Located on Maple View Farms and south of Dairyland Road	2,000	2,500	Mature bottomland forest.	Priority I and II	$160	Wetland creation at head of restored stream.	Yes
1a	Morgan Creek - Located on Maple View Farms and south of Dairyland Road	5,000	6,000	Mature bottomland forest, small existing flood plain.	Priority I and II	$180	Vernal Pools	Yes
2	Morgan Creek - Located on Lemola (Cheek Brothers) Dairy Farm and east of Dairyland Road	3,500	4,200	Upstream portion of segment is currently in use for cattle grazing; downstream portion occupied by mature bottomland hardwood forest.	Priority I and II	$130	Yes, Ag BMPs - cattle fencing and crossings to prevent access and upland watering structures.	Yes
3	Booker Creek - Located below Eastwood Lake and northwest and west of 15/501	4,000	4,500	Sanitary sewer, greenway trails and bridges, multiple property owners, mature bottomland hardwood forest, stormwater outfalls, other unknown infrastructure. Also will more than likely require Flood Study and LOMR.	Priority I, II and III	$300-350	Yes, flood plain detention ponds and retrofit existing BMP located behind strip mall off of East Franklin Street and west of 15/501.	Need additional information.

Site	Stream Name/Location	Estimated Stream Length	Potential Restoration Length	Observed Constraints	Recommended Restoration Priority	Estimated Restoration Cost/Linear Foot[1]	BMP Potential	Recommended for Restoration
4	UT* to Bolin Creek - East to Airport Road, south to Bolin Creek, west of Hillsborough Street	500	600	Sewer line, downstream end has very steep side slope and mature hardwood forest.	Priority I and II	$160	Yes, area dominated by kudzu could be used to treat stormwater from surrounding apartment complexes.	Yes
5	UT* to Bolin Creek - East of Hillsborough Road, south of Bolin Creek, near East Franklin Street	1,000	1,200	Apartment complex infrastructure, greenway, sewer line, mature bottomland and wetland areas located to east of concrete lined ditch.	Priority I	$125	Yes	Need additional information.
6	Little Creek - Located east of Pinehurst Drive	800	900 - 1000	Existing golf course and support infrastructure, may require flood study and LOMR.	Priority I	$180	Yes, retrofit existing irrigation ponds located to south of stream.	Yes
7	Bolin Creek - Located within Hogan Farms Subdivision 1,000 feet below Hogan Lake	3,300	4,000	Bottomland hardwood forest, gas line, sanitary sewer line, stormwater outfalls, may require flood study and LOMR. Control by neighborhood association and subdivision development continues.	Priority II possibly I	$160	Yes, treat stormwater discharges from subdivision.	Yes

Site	Stream Name/Location	Estimated Stream Length	Potential Restoration Length	Observed Constraints	Recommended Restoration Priority	Estimated Restoration Cost/Linear Foot[1]	BMP Potential	Recommended for Restoration
8	UT* to Morgan Creek - Located south of East Main Street and east of Greensboro Street and is partially piped	800	1,000	Channel is partially piped through site; overburden located above and adjacent to pipe.	Priority II	$160	Yes, retrofit existing sedimented pond located at outlet of piped creek and create BMP at bottom end of creek before it is once again piped under a parking lot and Greensboro Street.	Yes, off-set construction cost by locating contractor, municipality that needs excess dirt located above pipe.
9	UT* to Morgan Creek - Located east of NC 54 (Bypass) and south of Main Street	1,700	2,000	Channel is located parallel to sanitary sewer and apartment buildings located along west bank, Bottomland hardwood along east bank.	Priority II	$160	Yes, create BMP to treat stormwater generated by apartment complex and parking lots.	Yes, move creek to east away from apartment complex.
10	Chapel Creek - Located east of Fordham Blvd. and north of Mason Farm Rd.	1,100	1,300	Channel is located in abandoned Finley Golf Course fairway. Riparian vegetation was previously mowed, so no trees are present. Little or no infrastructure constraints in riparian corridor.	Priority 1	$110	Opportunity may exist to develop stormwater BMPs in headwater areas west of Fordham to treat runoff from UNC Campus.	Yes

*Unnamed Tributary

[1] While it is not possible to estimate exact cost without a detailed engineering analysis of restoration plans for a given reach, to the extent possible, the project team utilized *conceptual design* level costs to generate cost estimates for the recommended restoration approach at each site. It should be noted that the cost estimates are based on limited field reconnaissance; additional constraints and obstacles may be identified following a detailed survey of each site that could potentially increase the actual restoration cost. The cost estimates presented herein are not based on detailed engineering/design studies, but rather, are based on the professional judgment of stream restoration professionals with extensive experience in budgeting, designing and implementing restoration projects for a wide array of stream types and physical settings.

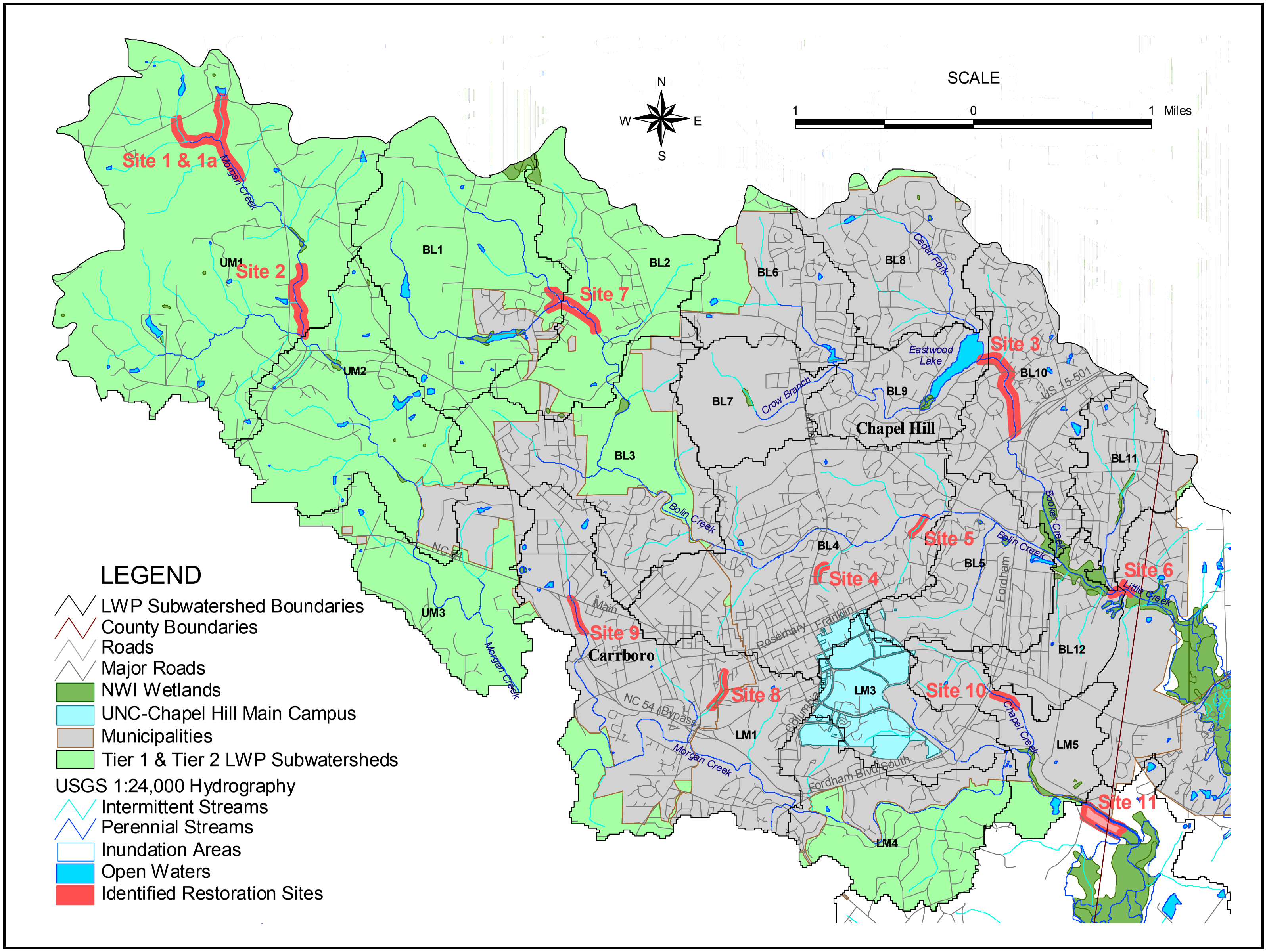

Figure 2-2. Potential Stream Restoration Sites in the Morgan Creek LWP Study Area

Observations from Onsite Assessments of Restoration Potential

The majority of the stream reaches selected and observed within the search area were in relatively similar physical condition. The streams were typically incised from historical physical modifications such as dredging, channelization, riparian and channel bank deforestation, or the effect of past and current land uses. The majority of the channel reaches observed were located in urbanized areas of Chapel Hill and Carrboro. Evidence observed in the field of channel dredging included remnant spoil piles, unnatural straightened alignments, and vertical confinement (i.e., incision, entrenchment). As a result of these channel modifications, channel bank angles were typically very steep (90 to 120 degrees) and bank sloughing, mass wasting and scour were common observations. Additional factors observed to contribute to channel incision included hydrologic modification such as stormwater inputs, flow constrictions (culverts, sewer line crossings located within the bankfull channel), and flood plain barriers (road beds). As a result of the degradation process the majority of the channels had scoured down to bedrock and sandstone.

The majority of the observed stream reaches are experiencing Class IV stage of the channel evolution (Rosgen, 1996). This stage describes the channel as degrading and widening in order to establish a new flood plain that will subsequently match its incised condition resulting in the abandonment of the original flood plain, which becomes a terrace. This condition also results in a tremendous amount of bank erosion and aquatic habitat loss due to the lack of bedform profile.

Restoration Sites Recommended for Further Consideration

Based on the evaluation process described in Section 2.2.1, the following sites, illustrated in the aerial photo maps in Figure 2-3 through Figure 2-14, are recommended for further efforts toward stream restoration in the Morgan Creek LWP study area:

Sites 1 & 1a – Morgan Creek at Maple View Farm (Figure 2-3)

The Maple View Farm is located within the headwaters of Morgan Creek approximately 1 mile east of Dodson's Crossroads and fronts Dairyland Road (SR 1177). Segments of Morgan Creek proper and a UT to Morgan Creek located south of Dairyland Road were evaluated for potential restoration during the field reconnaissance. These two streams were highly incised and the banks were exhibiting massive amounts of erosion despite the heavily wooded buffer. The majority of the banks are vertical or undercut and trees that are located immediately adjacent to the creek are systematically falling into the creek as a result of the active erosion undercutting their root structure. These channels will continue to degrade and widen until a new flood plain is created at a lower elevation. Neither channel exhibited evidence of over bank flooding (i.e., wrack lines, deposition, etc.) indicating severe entrenchment.

Although the riparian buffer is heavily forested, bank erosion will continue and trees will continue to fall until equilibrium is achieved naturally by the channel. In both cases, some deforestation will need to be conducted in order for a restoration design to be implemented. The main design objective should be raising the invert elevation so that the channel has access to the historic flood plain. Utilizing the existing alignment and/or re-routing the creek to limit tree removal could minimize construction disturbance. Transplantable material (i.e., native spicebush) located within the construction corridor should be protected and replanted within the restoration footprint.

Although restoration may result in some tree removal at the site, there are no infrastructure constraints within the riparian corridor, so Priority 1 restoration methods could be utilized to construct a new stream channels that would be connected to their floodplain. These reconnected stream segments would provide over 8000 linear feet of good to excellent quality aquatic habitat, whereas the current severely incised streams provide little or none. Priority 1 restoration at this site would also alleviate one of the largest sources of sediment deposition in the University Lake Watershed (refer to Section 2.4.1).

Site 2 – Lemola Dairy Farm (Figure 2-4)

The Lemola Dairy Farm (also known as the Cheek Brothers' Farm) is located within the headwaters of Morgan Creek approximately 1 mile downstream from Maple View Farm and also fronts Dairyland Road (SR 1177). Due to the inability to obtain access to the property, this restoration site was not evaluated in detail during field reconnaissance efforts. However, the stream segment is partially visible from Dairyland Road. The cattle grazing on the pastureland within the valley have full access to the stream and most of the native riparian vegetation has been removed. Even distant observations reveal that the banks are trampled and actively eroding, and the stream appears to be substantially incised. Field surveys of Morgan Creek performed for the Detailed Assessment phase of this LWP effort revealed that the erosion and instability induced by the riparian corridor degradation on the farm extends into the forested area downstream of this segment where banks have been observed to be excessively high and actively eroding.

In early August, Orange County closed on a conservation easement with the Lemola Dairy Farm to preserve in perpetuity 78 acres of land including active agricultural and natural areas of the property. In conjunction with the conservation easement, fencing has been installed to prevent the cattle from entering the stream. The Cheeks are to be commended for this effort. Now that the appropriate conservation measures are in place, restoration of the stream channel in this area could provide maximum benefits in terms of habitat improvement and sediment load reduction. However, in the absence of restoration efforts the past degradation of the stream channel will continue to manifest itself in the form of active stream erosion resulting in diminished habitat and substantial downstream sediment loads.

Restoration on the Lemola Dairy Farm and Maple View Farm tracts has the added benefit of being done in a subwatershed with numerous high priority preservation parcels (refer to Section 4). As a result, any preservation efforts occurring in the subwatershed will help protect the integrity of the stream restoration investment into the future by insuring the protection of riparian buffers and upland forest habitat. Conversely, the restoration projects would enhance the value of preservation efforts by improving the aquatic habitat within their confines.

Site 3 – Lower Booker Creek (Figure 2-5 and Figure 2-6)

This specific section of Booker Creek begins at the outlet of Eastwood Lake and continues to East Franklin Street. Once it approaches East Franklin Street it is confined within a box culvert which conveys the channel under the strip mall for a length of approximately 600 feet. Booker Creek then continues to the southeast under 15/501.

This stream becomes incised immediately below the dam where the channel type changes from a Rosgen B channel to an E/F channel type. The observed channel conditions are similar to those described for the Maple View Farm site; it is characterized by highly eroded vertical banks with minimal cover although located primarily within a forested riparian buffer. Residential neighborhoods, sewer utilities, a greenway trail, radio communication towers, and highway infrastructure surround the channel, and these site characteristics are likely to be the biggest limiting factors to the potential restoration design.

Despite substantial urban infrastructure constraints at this site, restoration would alleviate one of the largest sources of sediment in the Bolin/Booker Creek watershed because vertical, eroding stream banks 8-10 feet in height characterize the worst sections of this stream segment. Restoration would not only reduce the massive sediment load stemming from these banks; it would produce a much more aesthetically pleasing and accessible stream which would be of great public benefit along this highly used and visible greenway corridor.

Site 4 – Unnamed Tributary to Bolin Creek at Airport Road (Figure 2-7)

This tributary is located east of Airport Road and west of Hillsborough Street and is surrounded by apartment buildings.

The segment recommended for restoration is located immediately below a road crossing and an approximately 48-inch corrugated metal pipe. This area is almost completely inhabited by Kudzu. The channel is incised and it has scoured down to bedrock or in some places sandstone. The area contained with Kudzu could not only yield stream restoration but there appears to be enough room to implement a BMP to treat a portion of the stormwater runoff generated by the apartment buildings and Airport Road. The two efforts (stormwater treatment and stream restoration) could also be combined to maximize the benefits by integrating the treatment of floodwaters generated by overbank flooding and pretreatment of stormwater currently piped directly into the creek.

Restoration of this segment would generate approximately 600 linear feet of suitable aquatic habitat. This amount is below the 1000 linear feet threshold in NCEEP restoration guidelines, but the site also offers the opportunity to design and implement off-line stormwater BMPs in conjunction with the restoration effort that could store and treat the runoff from large impervious areas associated with the surrounding apartment complexes. Collectively the site offers an opportunity to reduce sediment loads from a highly erosive stream segment and significantly reduce nutrient loads from an urban area with high potential to deliver harmful nutrients to Jordan Lake (refer to Section 3.1 of the *Detailed Assessment Report*).

Site 5 - Unnamed Tributary to Bolin Creek near East Franklin Street (Figure 2-8)

This tributary is located east of Hillsborough Street, west of East Franklin Street and south of Bolin Creek, immediately adjacent to the apartment complex at the end of Elizabeth Street. This creek is also located immediately adjacent to a greenway trail.

This reach is not incised but rather is contained within a concrete lined ditch near its confluence with Bolin Creek and adjacent to the apartment complex. Immediately above the greenway trail it is completely enclosed within an undersized concrete pipe as evident by the scour observed immediately below the intake and around the greenway trail.

The restoration objective should be relocating the stream to a more natural setting within the adjacent wooded area. However, this objective may be limited since this wooded area also appears to possess wetlands.

Restoration of this site would generate 1200 linear feet of suitable aquatic habitat where there is currently little or none due to the existing concrete-lined channel. It would also alleviate the sediment loads resulting from the scour at the downstream culvert pipe outlet. Aesthetically, the restored stream would be a much greater asset to the surrounding residential property than the current concrete ditch.

Site 6 - Little Creek at Chapel Hill Country Club (Figure 2-9)

This creek is located within the Chapel Hill Country Club golf course approximately 4,000 feet east of Fordham Drive (Business 15/501). The channel is apparently aggrading, and the channel banks have been lined with rip-rap. Although beaver activity may be a contributing factor to the observed aggradation, it is more likely that the channel is over-wide and unable to hydrologically transport its current sediment load. It is also apparent that the rip-rap lined banks are beginning to erode as the rock appears to be sloughing off over time. This segment has no bank vegetation or trees and the plant community is limited to Bermuda grass. There are also two small intermittent tributaries to north and south of the main channel that are currently piped under the golf course.

Restoration objectives should include designing an appropriately sized channel so that the new channel has the capacity to transport its sediment load, and day lighting and constructing appropriate channels for the tributaries currently piped underground. Other objectives should include creating pattern, channel bed form, and restoring native vegetation to the banks for all three segments.

Restoration of this stream segment would produce approximately 1,000 linear feet of good aquatic habitat with vegetated stream buffers. The buffers would generate important riparian wildlife habitat and highly valuable pollutant removal capacity, which is of particular importance in the golf course setting where nutrient loading potential is high as a result of fertilizer applications necessary for turf management. In addition, day lighting of the small tributary streams would generate

linear feet of aquatic and riparian habitat.

Site 7 - Bolin Creek at Hogan Farms (Figure 2-10)

The tributary is located within the Hogan Farm subdivision, which is still undergoing phased expansion. The flood plain has not been infringed upon by the development except for a few road crossings and utility infrastructure and has apparently been preserved to accommodate Carrboro open space requirements. Although the floodplain contains a hardwood bottomland forest, the channel is highly incised and may also be entrenched. The channel is actively degrading in the attempt to create an active and accessible flood plain at a lower elevation, thereby indicating that the historic flood plain is now a terrace. Erosion will continue until equilibrium is attained.

Restoration objectives should include raising the invert elevation of the creek so that the flood plain is accessible during a 1.5- to 2-yr storm event if possible and dependent upon proof of not affecting the 100-year flood elevation or nearby structures. If a Priority I restoration is not feasible then a Priority II would be the next option, essentially excavation of a new flood plain that would be accessible to the restored creek channel.

Restoration of this segment would reconnect 3,000 – 4,000 feet of currently incised stream to a functioning floodplain. Given the headwater location of this segment a connected and functioning floodplain would provide valuable storage and energy dissipation functions that would protect downstream segments from excess scour and sediment loading. The restored segment would also generate quality aquatic habitat.

Site 8 - UT to Morgan Creek near South Greensboro Street (Figure 2-11)

This tributary is located south of Main Street and east of Greensboro Street within the town limits of Carrboro. Approximately 500 linear feet of the stream has been enclosed within a reinforced concrete pipe for no apparent benefit. The area immediately above the pipe is open lawn and it also includes a greenway easement held by the Town of Carrboro. Where stream exits the pipe, a vestigial granite dam exists, which is serving to hold the channel gradient upstream. Below the granite dam the creek becomes incised and constrained by steep side slopes and a sanitary sewer line.

Restoration objectives would include day lighting the segment of creek enclosed within the RCP, retrofitting the old pond behind the granite dam to perform as a BMP to treat stormwater runoff; and restoring the longitudinal profile and possible pattern to the channel below the dam.

Restoration of this site would generate approximately 1,000 linear feet of suitable aquatic habitat where there is currently none due to the existing underground pipe. Aesthetically, the restored stream would be a much greater asset to the surrounding residential property than the current buried channel that is topped by a rip-rap lined drainage ditch. The potential for the integrated stormwater BMP behind the old dam also offers the opportunity to store and treat some runoff from the high-density residential development adjacent to the stream, which would in reduction of nutrient and sediment loads.

Site 9 - Toms Creek at Main Street (Figure 2-12)

The creek is located east of NC 54 Bypass and located south of Main Street immediately adjacent to a sanitary sewer line and a series of apartment buildings to the west of the channel. A wooded undeveloped parcel of property is located to the east of the stream. The tributary is incised and the banks are as high as 8 feet along some sections and highly eroded. The section just above Poplar Street is beginning to develop pattern and create a flood plain at a lower elevation.

Restoration objectives would be to shift the stream channel to the east within the wooded parcel away from the sewer line and apartment buildings, which would enable the appropriate channel pattern, slope, and dimension to be designed along with the space to provide an accessible flood plain.

Restoration of this site would generate approximately 2,000 linear feet of suitable aquatic habitat where there is currently little or none due to the severely incised condition of the existing channel. The restoration would also generate 2,000 feet of functioning riparian buffer on the west side of the stream that would provide riparian habitat and important pollutant removal capacity by treating the runoff from the adjacent apartment complexes. The potential to integrate offline stormwater BMPs to store and treat runoff from the apartments also exists in conjunction with this restoration. Aesthetically, the restored stream would be a much greater asset to the surrounding residential property than the current incised and channelized ditch.

Site 10 - Chapel Creek at Finley Golf Course (Figure 2-13)

The creek is located east of Fordham Boulevard and north of Mason Farm Road behind the Highland Woods community. It is readily apparent that the immediate riparian corridor for the creek is in an abandoned fairway for Finley Golf Course. Past removal of the riparian vegetation to accommodate the fairway and increased stormwater runoff from development of the UNC campus upstream of Fordham Blvd. have destabilized the stream and active erosion is ongoing, as is evidenced by golf cart bridges collapsing into the stream. The stream is significantly incised and entrenched relative to appropriate channel dimensions, and mass wasting of stream banks is apparent in several locations.

Given that no infrastructure constraints exist in the riparian corridor at this site, Priority I restoration methods could be utilized to construct a new channel that would alleviate stream erosion, improve aquatic habitat, and reconnect the stream to an accessible floodplain.

Efforts are already under way to obtain the agreements between NCEEP and UNC necessary to affect restoration at this site.

Site 11 - Morgan Creek at Old Mason Farm (Figure 2-14)

This section of Morgan Creek is located immediately southeast of Finley Golf Course at the end of Finley Golf Course Road, and the Orange County-Durham County line bisects the stream segment in question. In this area the southern edge of Morgan Creek (right bank, facing downstream) is bounded by a 6-10 foot manmade berm that is likely to be a remnant spoil pile from past channelization of this segment of the creek. Morgan Creek is somewhat incised in this section and the berm prevents it from accessing a large area of historical floodplain land to the south. Fields associated with the NC Botanical Garden currently occupy the floodplain area in question. Some active stream bank erosion is evident on the bank adjacent to the berm.

The restoration objective at this site would consist of removal of the berm so that Morgan Creek could access the substantial floodplain area (approximately 20-30 acres) along its southern border during bank-full flow events, along with revegetation of the restored floodplain area. There are no infrastructure constraints at this site that would prevent pursuit of this objective.

Restoring floodplain functions to this segment of Morgan Creek will ultimately result in creation of a substantial area of bottomland hardwood forest that will provide approximately 20-30 acres high quality riparian and wetland habitat. The wetting and drying of the restored floodplain will also result in increased nutrient removal relative to the existing incised channel. The reduction of nutrient loads in Morgan Creek is of particular value in this area immediately upstream of the Morgan creek arm of Jordan Lake, where excess eutrophication has been documented on numerous occasions.

A Memorandum of Agreement has already been established between NCEEP and UNC to allow this project to go forward. The university and the Botanical garden should be commended for their efforts to facilitate this innovation watershed restoration project.

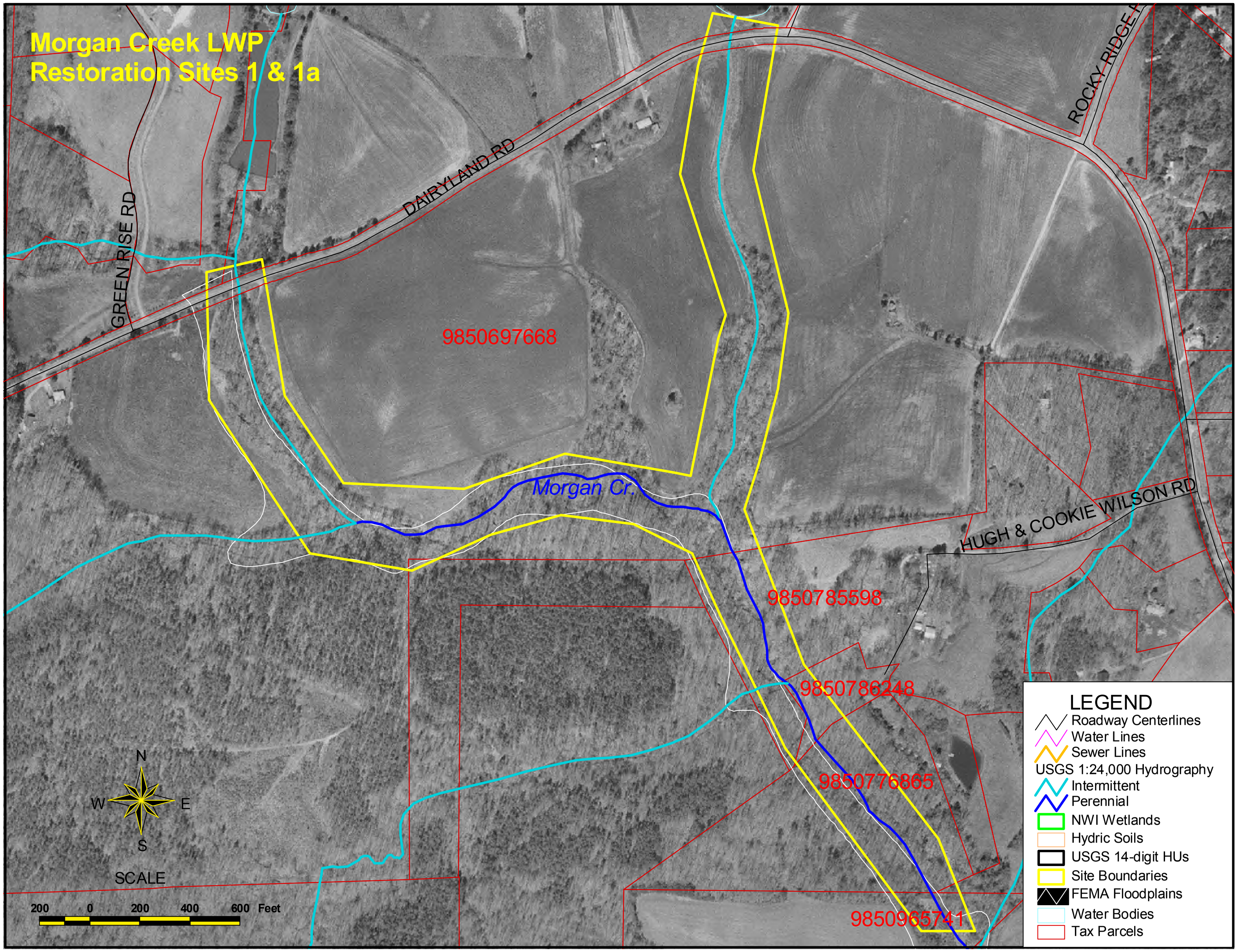

Figure 2-3. Morgan Creek at Maple View Dairy Farm

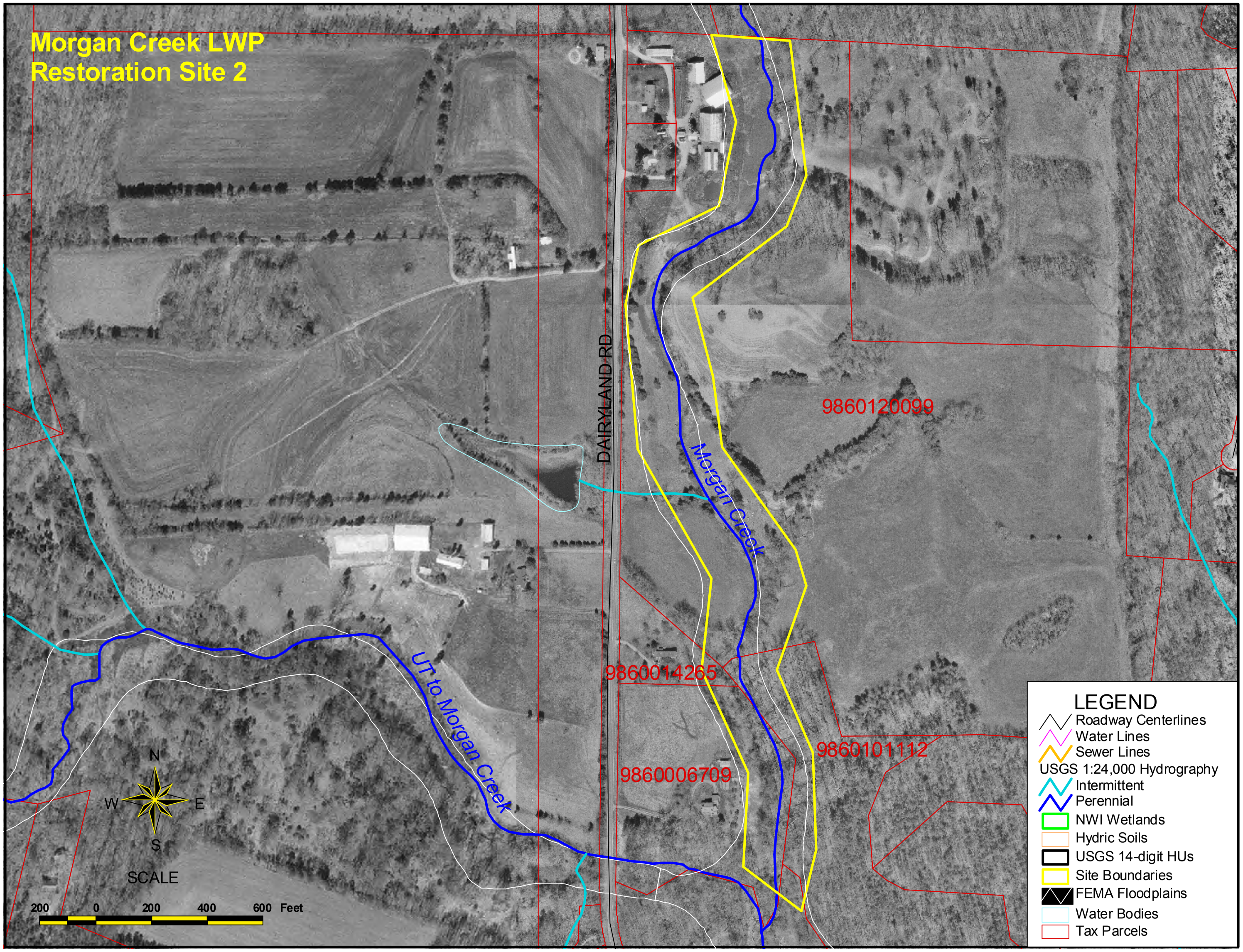

Figure 2-4. Morgan Creek at Lemola Dairy Farm

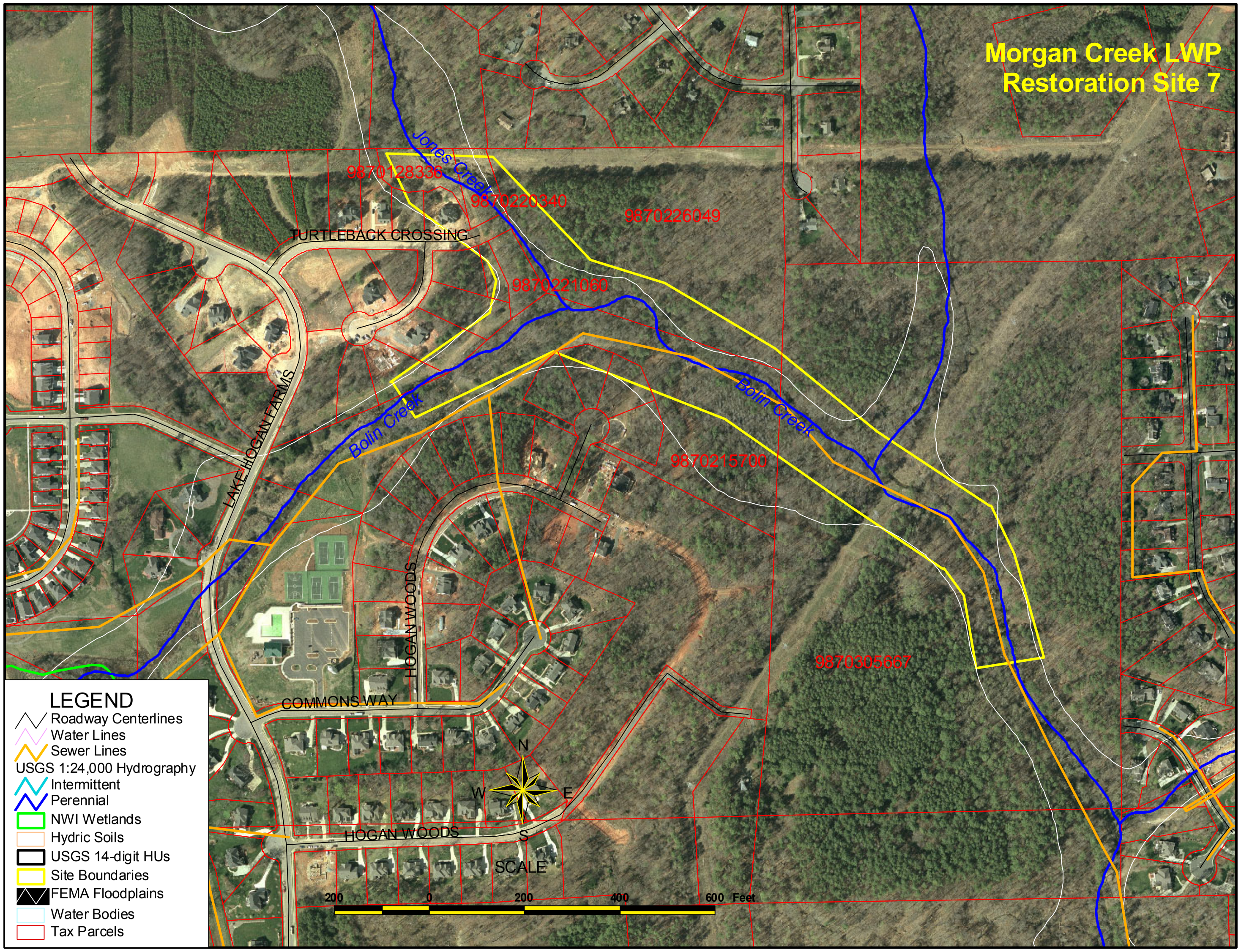

Figure 2-10. Bolin Creek at Hogan Farms Subdivision

Figure 2-11. **Unnamed Tributary to Morgan Creek near South Greensboro Street**

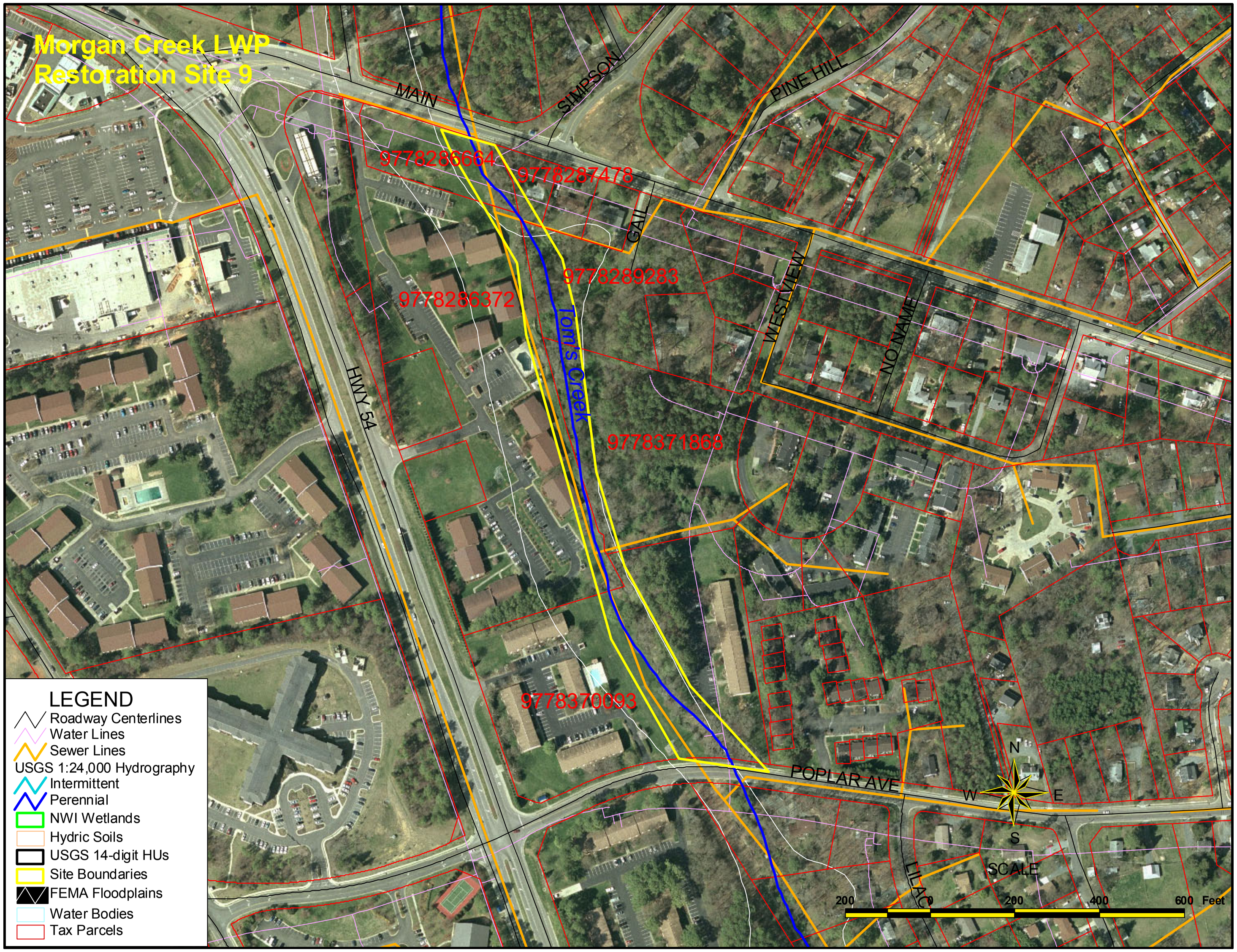

Figure 2-12. Toms Creek at Main Street

2.2.2 Identification of Stormwater BMP Opportunities

Within the Tier 1 and Tier 2 Priority subwatersheds, a comprehensive search was conducted to identify suitable locations for stormwater BMPs such as wet detention facilities (stormwater ponds), constructed stormwater wetlands, and bioretention cells (rain gardens). For reasons discussed below, the effort was not made to identify all potential bioretention retrofit sites. Rather, when suitable bioretention retrofit sites were found during the course of field investigations for this project, they were characterized and have been presented in this document as good examples of opportunities to implement this type of stormwater BMP.

It should also be noted that the search for suitable stormwater BMP sites was not conducted in Upper Morgan Creek subwatershed (UM1-UM3). This portion of the University Lake watershed was excluded from the effort to identify appropriate retrofit sites because the watershed nutrient loading and eutrophic response modeling analysis performed for the University Lake Baseline Analysis Memo (Tetra Tech, 2003) concluded that the very low density restriction on new development within the watershed (five-acre minimum lot size) was sufficient to protect the lake from excessive nutrient loads and the associated algal blooms. In addition, the stream stability modeling analysis performed for this study (refer to Section 2.2.2 of the *Detailed Assessment Report*) indicated that the low density zoning of the University Lake watershed provided sufficient protection against stream erosion and instability.

BMP Site Selection Criteria

The following set of *criteria* was used to evaluate the feasibility of a potential site for a stormwater BMP.

- The site must be located in a subwatershed identified as Tier I or Tier II in the *Detailed Assessment Report*.
- The Town of Chapel Hill, Town of Carrboro, or other local government/institution must own the parcel(s) of property on which a BMP is proposed. If this criterion cannot be met, sites situated on private land cannot impact more than two landowners.
- The site must not impound urban runoff above water or sanitary sewer infrastructure in order to prevent excess infiltration into water and sewer lines and ensure adequate access for maintenance.
- The site cannot be located in an existing perennial stream channel.

In addition to these selection criteria, a set of *guidelines* was also considered when evaluating the suitability of a potential BMP site.

- Proposed BMP sites will ideally be located in headwaters of the subwatershed.
- The ratio of the surface area of the proposed BMP to the surface area of the contributing watershed should be no less than 2 percent to adequately address water quality concerns, in particular, the trapping efficiency for total suspended solids (NCDENR, 1999).
- The natural topography of the site should accommodate the proposed stormwater BMP with minimal excavation and hauling requirements.
- Proposed BMP sites should be situated to minimize impacts on established forested areas.

A violation in any of the selection *criteria* would eliminate a potential site from further consideration. Selection *guidelines* that cannot be satisfied only reduce the suitability of a potential site.

Stormwater BMPs Considered

The factors that degrade watershed functions in the Tier I and Tier II subwatersheds of the study area are peak storm flows associated with increasing amounts of imperviousness, excess sedimentation, and excess nutrient loading. Stormwater BMPs that address these factors include stormwater wetlands, pocket wetlands, wet detention ponds, and bioretention. Each of these practices is ideally suited to address a range of contributing watershed areas. Stormwater wetlands are ideal for managing contributing drainage areas between 5 and 75 acres, while pocket wetlands are better suited to contributing drainage areas between 5 and 10 acres. Wet detention ponds require a minimum drainage area of 25 acres. Bioretention facilities are targeted at watersheds no larger than 5 acres, with a preferred drainage area of 0.5 – 2 acres. The contributing drainage area guidelines were assembled from multiple data sources (Hunt, 2002; ARC, 2001; NCDENR, 1999). On the basis of these guidelines, stormwater wetlands and wet detention ponds are more appropriate as regional facilities whereas bioretention is better suited to an individual site. Bioretention facilities are typically designed to "disconnect" a contributing impervious surface, such as a roof or parking area, from the stormwater system, usually by incorporation into a previously developed site. Due to the site-specific requirements for bioretention facilities and their small scale nature, this type of stormwater BMP was not actively pursued during this stage of identifying potential BMP locations in the Morgan Creek watershed. Identification of all potential bioretention retrofit opportunities within the targeted Tier I and Tier II subwatersheds would be an undertaking beyond the resources available for this local watershed planning project. However, a few potential bioretention sites were discovered in the course of BMP site investigations and are described in this section. The Town of Chapel Hill has already implemented bioretention facilities to treat runoff from parking lots at University Mall (refer to Figure 3.1) and numerous bioretention facilities and other LID components have been implemented on the UNC main campus (refer to Section 3.4.3). It is recommended that the Towns of Chapel Hill and Carrboro, as well as UNC-Chapel Hill, continue to pursue the implementation of additional bioretention facilities in their future stormwater management plans.

In order to compare the suitability of stormwater wetlands, wet detention ponds, and bioretention for a proposed site, the parameters in Table 2-2 were considered. The total suspended solids (TSS) removal efficiency is an indicator of how much sediment a particular practice will remove. The removal efficiencies listed in Table 2-3 are derived from data collected in North Carolina (Hunt, 2002). Stormwater wetlands and wet detention ponds remove approximately the same amounts of suspended solids; bioretention removes nearly a third more suspended sediment as compared to either of these BMPs. The fecal coliform removal efficiency is derived from data published in the *Georgia Stormwater Management Manual* (ARC, 2001), which shows that stormwater wetlands and wet detention ponds perform similarly while no data are available for bioretention. The fecal coliform removal rates assume neither stormwater wetlands nor wet detention ponds support a resident waterfowl population. The total nitrogen and total phosphorous removal efficiencies are provided from various research conducted in North Carolina (NCDWQ, 2003: Hunt, 2002; Hunt, 2003). The contributing drainage area guidelines were assembled from multiple data sources (Hunt, 2002; ARC, 2001; NCDENR, 1999). The land required is simply an estimate of the footprint required for a typical facility, without consideration for the size of the contributing drainage area. Capital cost estimates are approximate values for a given practice implemented in North Carolina (Hunt, 2002) and reflect actual construction and maintenance costs, but do not reflect the costs of engineering design or of land acquisition. The maintenance burden is an indicator of the relative amount of annual maintenance required. Aquatic habitat is a relative estimate of how much additional aquatic habitat is added to a watershed when a particular BMP is installed.

Table 2-2. Practice Specific Parameters for Stormwater BMPs

Parameter	Stormwater Wetlands	Wet Detention Pond	Bioretention
TSS Removal (%)	61	65	87
Fecal Coliform Removal (%)	70	70	No Data
TN Removal (%)	40	25	40
TP Removal (%)	35	40	35
Contributing Drainage Area (acres)	5 - 75	> 25	0.5 - 5
Land Required	High	Medium	Low
Capital Cost (per ft2)	$1.50 + $0.35/plant	$2 - $4	$4 - $6
Maintenance Burden	Medium	Low	Medium
Aquatic Habitat	High	Medium	Low

Potential Stormwater BMP Sites and Recommended Practices

Using the selection criteria and guidelines presented above, 24 potential stormwater BMP retrofit sites were identified (illustrated on the map in Figure 2-15 along with contributing drainage areas, and summarized briefly in Table 2-3). Appendix A provides a 2-page detailed summary for each site, including an aerial photograph illustrating the proposed location of a BMP as well as the contributing watershed, a general list of pros and cons for each site, and a capital cost estimate for each BMP.

The summary information presented in Table 2-3 includes a recommended BMP practice for each site identified. Given that each BMP practice under consideration has a certain range in the size of the contributing drainage area for which it is feasible and/or economically practicable, the size of the drainage area being treated at each site was the primary factor in determining the recommended practice for that site. While there is considerable overlap in the size of a suitable drainage area for a wet detention pond and that of a stormwater wetland, stormwater wetlands are recommended over wet ponds for all sites in which both would be appropriate. This preference is due to the fact that, due to lesser excavation requirements, stormwater wetlands are cheaper to construct (Hunt, 2003). In addition, once vegetated, they have higher aesthetic value than traditional ponds. Since constructed wetlands, with lower allowable average depths, require more land area to achieve the same storage capacity as a wet pond, wet ponds are recommended when available land is limited.

It should be noted that the cost estimates provided in Table 2-3 are purely conceptual level estimates, meaning that they are based on a regression analysis of construction costs for similar practices in North Carolina (Wossink and Hunt, 2003). The estimates do not include factors for engineering and design work, nor do they include any approximation of the costs associated with land acquisition. Therefore, these estimates are intended merely to provide potential implementers with relative cost figures for use in considering various options.

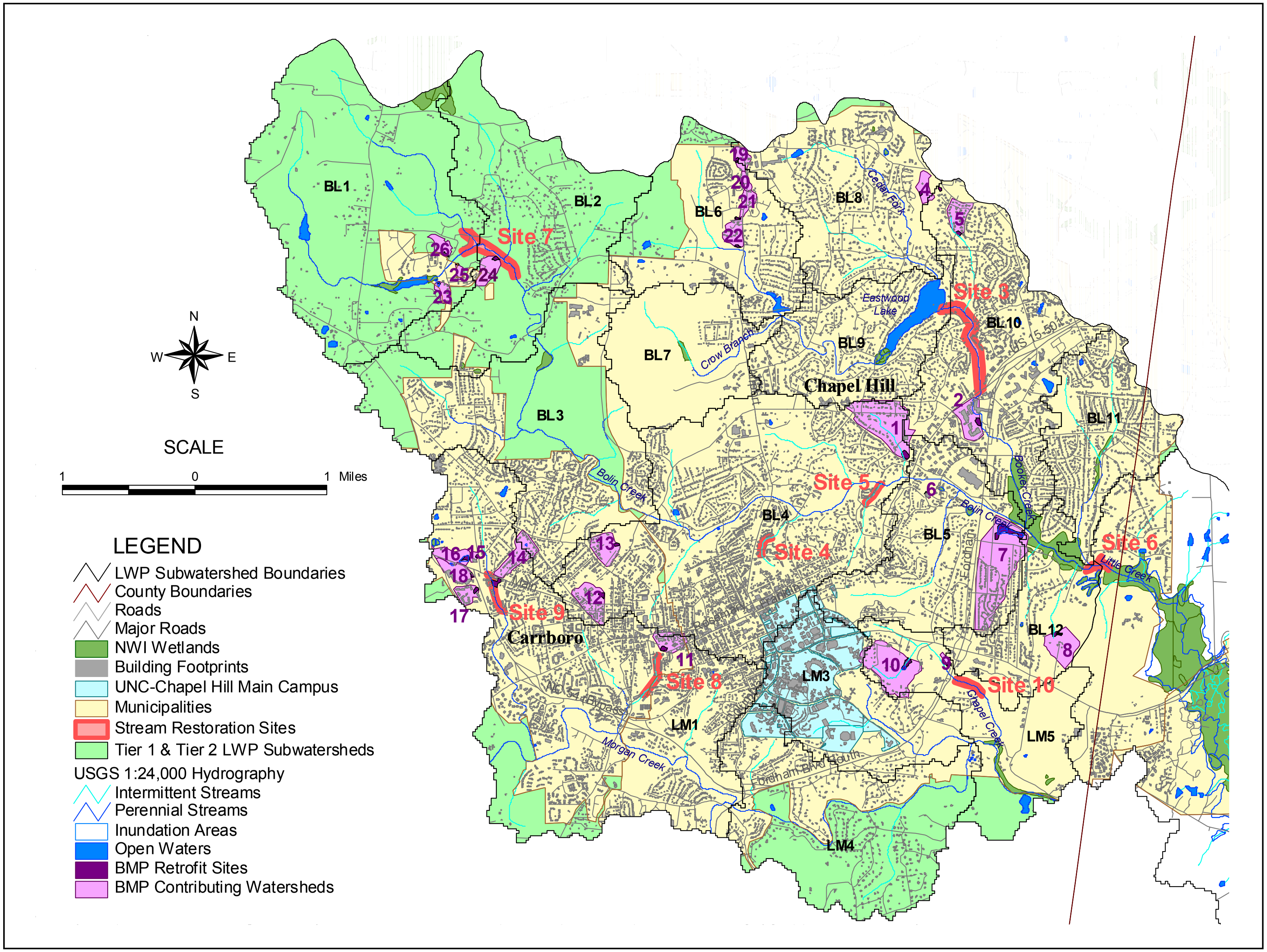

Figure 2-15. Potential BMP Sites and Contributing Watersheds within the Tier 1 and Tier 2 Priority Subwatersheds

Table 2-3. Key Characteristics of Recommended Stormwater BMPs

Site Num	Location	LWP Sub	Site (acres)	Contributing Watershed (acres)	Watershed Landuse	Watershed Impervious	Recommended Practice	Estimated BMP Size (acres)	Estimated Const. Cost	Estimated Maint. Cost (20 yr-PV*)	Total Annualized Cost**
1	Chapel Hill Library	BL4	1.590	81.628	Residential	Moderate	Stormwater Wetland	1.63	$32,435	$3,758	$1,810
2	Eastgate Shopping Center	BL10	1.130	28.766	Parking/Roofs	Very High	Stormwater Wetland	0.86	$19,579	$3,204	$1,139
4	Cedar Falls Park	BL8	0.353	12.447	Ball Fields	Low	Pocket Wetland	0.25	$13,053	$2,819	$794
5	Weaver Dairy Retrofit	BL8	0.699	21.333	Residential	Moderate	Retrofit Existing Pond	NA	NA	NA	NA
6	Chapel Hill Comm. Center	BL5	0.095	0.569	Rooftop	Very High	Bioretention	0.040	$5,502	$1,343	$342
7	Rainbow Soccer Field	BL5	6.151	129.047	Res/Ball Fields	Low	Retrofit Existing Pond	NA	NA	NA	NA
8	Meadowmont Pool	BL12	0.981	31.534	Residential	High	Stormwater Wetland	0.79	$20,469	$3,249	$1,186
9	Chapel Ck. Bioretention	LM5	0.305	1.996	Parking	Very High	Bioretention	0.140	$21,555	$1,625	$1,159
10	UNC CH Tennis Courts	LM5	2.015	72.219	Residential	Low	Stormwater Wetland	1.44	$30,568	$3,689	$1,713
11	Carrboro Tracks	LM1	0.795	20.106	Urban	Very High	Wet Detention	0.40	$104,503	$8,781	$5,664
12	Carrboro Elementary Sch.	BL4	0.756	30.890	Institutional	Moderate	Stormwater Wetland	0.62	$20,266	$3,239	$1,175
13	Carrboro Park	BL4	0.526	24.365	Courts/Fields	Moderate	Stormwater Wetland	0.49	$18,067	$3,124	$1,060
14	Toms Creek @ Main St.	LM1	1.776	29.023	Residential	Moderate	Stormwater Wetland	0.58	$19,663	$3,208	$1,144
15	Carrboro USPS	LM1	0.263	2.800	Parking/Roofs	High	Bioretention	0.084	$31,152	$1,711	$1,643
16	Adjacent Carrboro USPS	LM1	0.859	16.629	Road/Res	Low	Stormwater Wetland	0.33	$15,017	$2,946	$898
17	Tarheel Manor Apts	LM1	0.601	12.471	Parking/Apts	High	Stormwater Wetland	0.37	$13,065	$2,819	$794
18	Food Lion Parking Lot	LM1	0.389	16.763	Parking/Roofs	Very High	Wet Detention	0.34	$92,483	$8,362	$5,042
19	Airport Road Retrofit #1	BL6	0.429	9.890	Road/Res	Moderate	Pocket Wetland	0.20	$11,678	$2,721	$720
20	Airport Road Retrofit #2	BL6	0.138	5.136	Road/Res	Moderate	Pocket Wetland	0.10	$8,504	$2,462	$548
21	Airport Road Retrofit #3	BL6	0.264	10.403	Road/Res	Moderate	Pocket Wetland	0.21	$11,967	$2,742	$735
22	Airport Road Retrofit #4	BL6	0.359	16.775	Road/Res	Moderate	Stormwater Wetland	0.34	$15,081	$2,950	$902
23	Hogan Farms D/S Lake	BL1	0.202	9.191	Residential	Moderate	Pocket Wetland	0.18	$11,271	$2,691	$698
24	Hogan Farms Power Lines	BL2	0.641	17.560	Residential	Moderate	Stormwater Wetland	0.35	$15,418	$2,971	$919
25	Hogan Farms Old Silo	BL1	0.168	3.212	Residential	Moderate	Bioretention	0.10	$36,170	$1,747	$1,896
26	Hogan Farms Main Road	BL1	0.424	10.746	Residential	Moderate	Pocket Wetland	0.21	$12,157	$2,756	$746

*Maintenance costs are presented as 20-year estimates at present values based on a 10% annual discount rate.

** Total Annualized Costs reflect the sum of initial construction costs and 20-year present value maintenance costs divided by 20.

Source of information to derive cost estimates: Wossink and Hunt, 2003.

2.3 RELATIVE FEASIBILITY OF RESTORATION OPPORTUNITIES

On the basis of basic site characteristics and other logistical concerns, some restoration projects and BMPs are easier to implement than others. For instance, for a project on public land where interagency or intergovernmental agreements for use of the site can be arranged, implementation is easier than on privately owned land where land acquisition can be an issue. The topography of a site is a major factor affecting the feasibility of implementing BMPs and stream restoration projects, because it dictates the amount of earthwork (excavation) that will be required. The existing vegetative cover of a potential site can also affect feasibility of implementation. Wooded sites require greater effort for clearing and grubbing than sites with few or no trees, and the removal of trees – especially mature hardwoods – can induce public resistance to a proposed restoration or retrofitting project. Finally, sites without spatial constraints due to the presence of roadways, sewer or water lines, and other infrastructure are obviously easier for implementation.

In the interest of having a means to compare the relative feasibility of the stream restoration projects and BMP retrofit opportunities under consideration here, a simple scoring approach was developed for comparison. The feasibility scores for both stream restoration and BMP opportunities were based on the four primary factors discussed above: 1) land ownership, 2) site vegetative cover, 3) infrastructure constraints, and 4) the level of earthwork required. The scoring categories and the points assigned for each are outlined in Table 2-4.

Table 2-4. Restoration Opportunity Feasibility Scoring

Feasibility Factor	Point Score
Land Ownership	
Public	3
Private or mixed public/private with few landowners	2
Private with several landowners	1
Site Cover	
Grassed (few or no trees)	3
Mixed	2
Wooded	1
Infrastructure Constraints	
None	3
Minimal	2
Numerous	1
Earthwork Requirements	
Low	3
Medium	2
High	1

Higher scores indicate a greater overall degree of feasibility for any proposed project. The feasibility scoring approach was applied separately to stream restoration projects and to potential BMP opportunities, and the respective results are shown in Table 2-5 and Table 2-6. In each table, sites are sorted in order of feasibility score, from highest to lowest.

Table 2-5. Feasibility Scores for Potential Stream Restoration Projects

Site Num	Stream Name/Location	Est. Stream Length	Est. Rest. Length	Owners		Infrastructure		Site Cover		Earthwork Req		FEASIBILITY
					Pts		Pts		Pts		Pts	SCORE
10	Chapel Creek at Finley Golf Course	1,100	1,300	Public-Few	3	None	3	Open	3	Low	3	**12**
2	Morgan Creek at Lemola Dairy Farm	3,500	4,200	Private-Few	2	None	3	Open	3	Low	3	**11**
1& 1a	Morgan Creek at Maple View Farms	7,000	8,500	Private-Few	2	None	3	Wooded	1	Low	3	**9**
6	Little Creek at Chapel Hill Country Club	800	900 - 1000	Private-Few	2	Minimal	2	Open	3	Med	2	**9**
8	UT to Morgan Creek near S. Greensboro St.	800	1,000	Private-Few	2	Few	1.5	Open	3	Med	2	**8.5**
5	UT to Bolin Creek near E. Franklin St.	1,000	1,200	Mixed-Few	2	Numerous	1	Mixed	2	Low	3	**8**
4	UT to Bolin Creek at Airport Rd.	500	600	Private-Few	2	Numerous	1	Mixed	2	Med	2	**7**
7	Bolin Creek at Hogan Farms	3,300	4,000	Private-Numerous	1	Minimal	2	Wooded	1	Med	2	**6**
9	Toms Creek at Main St.	1,700	2,000	Private-Numerous	1	Numerous	1	Mixed	2	Med/High	1.5	**5.5**
3	Lower Booker Creek	4,000	4,500	Mixed-Numerous	1	Numerous	1	Wooded	1	High	1	**4**

Table 2-6. Feasibility Scores for Potential BMP Projects

Site Num	Stream Name/Location	Site (ac)	Wshed (ac)	Owners		Infrastructure		Site Cover		Earthwork Req		FEASIBILITY SCORE
					Pts		Pts		Pts		Pts	
9	Chapel Ck. Bioretention	0.31	2.00	1 Public (UNC)	3	None	3	Grass	3	Low	3	**12**
19	Airport Road Retrofit #1	0.43	9.89	1 Public (NCDOT)	3	None	3	Grass	3	Low	3	**12**
20	Airport Road Retrofit #2	0.14	5.14	1 Public (NCDOT)	3	None	3	Grass	3	Low	3	**12**
21	Airport Road Retrofit #3	0.26	10.40	1 Public (NCDOT)	3	None	3	Grass	3	Low	3	**12**
22	Airport Road Retrofit #4	0.36	16.78	1 Public (NCDOT)	3	None	3	Grass	3	Low	3	**12**
10	UNC CH Tennis Courts	2.02	72.22	1 Public (UNC)	3	None	3	Grass	3	Medium	2	**11**
13	Carrboro Park	0.53	24.37	1 Public (Carrboro)	3	Sewer <20'	2	Grass	3	High	3	**11**
5	Weaver Dairy Retrofit	0.70	21.33	1 Public (TOCH)	3	None	3	Wooded	1	Low	3	**10**
6	Chapel Hill Comm. Center	0.10	0.57	1 Public (TOCH)	3	None	3	Grass	3	High	1	**10**
7	Rainbow Soccer Field	6.15	129.05	1 Public (UNC)	3	None	3	Pond	3	High	1	**10**
16	Adjacent Carrboro USPS	0.86	16.63	1 Private	2	None	3	Grass	3	Medium	2	**10**
18	Food Lion Parking Lot	0.39	16.76	1 Private	2	None	3	Grass	3	Medium	2	**10**
23	Hogan Farms D/S Lake	0.20	9.19	1 Private (Hogan Farms)	2	None	3	Grass	3	Medium	2	**10**
25	Hogan Farms Old Silo	0.17	3.21	1 Private (Hogan Farms)	2	None	3	Grass	3	Medium	2	**10**
11	Carrboro Tracks	0.80	20.11	1 Public (Carrboro)	3	Water <25'	2	Wooded	1	Low	3	**9**
15	Carrboro USPS	0.26	2.80	2 Mixed (USPS & Private)	1	None	3	Grass	3	Medium	2	**9**
17	Tarheel Manor Apts	0.60	12.47	1 Private	2	None	3	Mixed	2	Medium	2	**9**
2	Eastgate Shopping Center	1.13	28.77	2 Private	1	Sewer <20'	2	Mixed	2	Low	3	**8**
4	Cedar Falls Park	0.35	12.45	1 Public (TOCH)	3	None	3	Wooded	1	High	1	**8**
8	Meadowmont Pool	0.98	31.53	1 Private (Meadowmont)	2	None	3	Wooded	1	Medium	2	**8**
12	Carrboro Elementary Sch.	0.76	30.89	1 Public (CH/Carr. PSS)	3	W&S <20'	1	Wooded	1	High	3	**8**
24	Hogan Farms Power Lines	0.64	17.56	2 Mixed (Hogan & UNC)	1	None	3	Wooded	1	Low	3	**8**
26	Hogan Farms Main Road	0.42	10.75	1 Private (Hogan Farms)	2	None	3	Wooded	1	Medium	2	**8**
1	Chapel Hill Library	1.59	81.63	1 Public (TOCH)	3	Water <20'	2	Wooded	2	High	1	**8**
14	Toms Creek @ Main St.	1.78	29.02	1 Private	2	Sewer <20'	2	Wooded	1	Medium	2	**7**

2.4 POTENTIAL STRESSOR REDUCTIONS AND COST-EFFECTIVENESS OF RESTORATION OPPORTUNITIES

In this section the methods used to quantify the degree of stressor reduction achieved by each of the recommended restoration projects are presented along with their cost-effectiveness.

In terms of achieving reductions in stressors to watershed functions, stream restoration projects and stormwater BMPs have some benefits in common, but they are largely targeted at different stressors. The use of natural channel design principles for stream restoration is primarily intended to reduce stream instability and erosion, which results in the reduction of instream sediment loads and the improvement of hydrologic and aquatic habitat functions. Studies have shown that stream restoration projects can also achieve significant reductions of nutrients and other pollutant loads relative to the previously degraded status of the restored stream segment, but the potential for such reductions is far more difficult to quantify than their sediment load reduction potential. Conversely, the level of nutrient and pollutant load reduction achieved by various stormwater BMPs is fairly well documented, while the means necessary to approximate their benefit in terms of reduction of peak storm flow and the resulting stream erosion would require detailed hydrologic and hydraulic modeling that is beyond the scope and resources of this project. For these reasons, in the following sections, the stressor load reduction potential and cost-effectiveness of identified stream restoration projects is measured primarily in terms of the reduction of sediment loads, while BMP projects are evaluated primarily on the basis of their potential for nutrient load reduction.

2.4.1 Potential Stressor Reductions and Cost-effectiveness of Identified Stream Restoration Projects

As discussed above, the most practical way to approximate potential stressor reductions of the candidate stream restoration projects is to estimate the reduction in sediment loading that could result from each project. Relative cost-effectiveness is approximated by using the estimates of potential sediment load reduction in conjunction with the conceptual design-level cost estimates presented in Table 2-1. Given that the restoration of floodplain function along Morgan Creek at Old Mason Farm (Restoration Site 11) is atypical of the stream restoration projects considered in this study, it was not included in this analysis of stressor reduction and cost effectiveness. In addition, no cost estimate could be generated for the Mason Farm site without detailed design information, and the data necessary to estimate erosion rates for the stream segment were unavailable.

Estimates of existing sediment loads from channel erosion were made using a semi-quantitative methodology utilizing Stream Visual Assessment Protocol (SVAP) evaluations of channel condition at numerous locations and using SVAP ratings to assign stream reaches to bank erosion hazard categories analogous to that produced by the Bank Erosion Hazard Index (BEHI) introduced by Rosgen (2001). These erosion hazard categories were derived from three components of the SVAP scoring system including the channel condition, hydrologic alteration, and bank stability scores. Channel condition scores indicate the degree of channel down cutting or excessive lateral cutting. Hydrologic alteration scores indicate the degree of access the stream has to its flood plain, and the degree of channel incision. Together the two previous scores indicate the degree to which flow is confined to stream channels as opposed to being able to dissipate erosive energy by accessing the flood plain. The bank stability score is an indicator of the height and pervasiveness of unprotected and actively eroding bank surfaces. These three scores were summed and divided by 3 for a total of 10 possible points and a conversion factor was used to translate this score to the 50-point scale used in BEHI. Table 2-7 presents the category assignment criteria.

Table 2-7. Assignment Criteria for Erosion Risk Categories

SVAP Score	Index (Scaled to 50 pts)	Erosion Risk Category
7-10	0-20	Low
5-6	21-30	Moderate
3-4	31-40	High – Very High
1-2	41-50	Extreme

A statistical model was developed to relate SVAP variables at assessment locations to reach scale and watershed scale variables including erodibility of riparian soils, depth to bed rock, buffer condition (intactness), and watershed runoff potential. This model was used to assign erosion risk categories to stream reaches where no SVAP assessments occurred.

Annual bank erosion rates (tons) were estimated using erosion risk categories, bank heights, and stream bank erosion rates. Actual rates of stream bank erosion were not available for this investigation and had to be estimated. Erosion rates from studies in Colorado (Rosgen, 2001) and North Carolina (Harmon and Jessup, 1999, Jessup, 2003) were used to estimate stream bank erosion rates for various erosion hazard categories.

In the Colorado study (Rosgen, 2001), erosion rates were measured and correlated with Near Bank Shear Stress (NBS) and BEHI. Six categories are used to represent BEHI and six categories are also used to represent NBS, potentially yielding 36 different erosion rates depending on the conditions observed in the stream. Preliminary regional curves in relating bank erosion rates to BEHI scores are being developed in western North Carolina (Harmon et al, 1999 from Rosgen, 2001). Jessup (2003) has continued to collect data for these regional curves. These preliminary regional erosion rates compare favorably to similar curves developed in Colorado and Wyoming (Rosgen, 2001). NBS measurements were not collected in this study effort; so median erosion rates for each BEHI category were used for erosion rate estimates. Rosgen (2001) measured bank erosion rates in Colorado and Wyoming and found stream reaches with extreme BEHI ratings had erosion rates that ranged from 0.43 to 3.2 ft/yr with median rates of 1.7 and 1.5 ft/yr at the Colorado and Wyoming Stations respectively. Jessup (2003) found bank erosion rates in the mountains and piedmont of North Carolina ranged from 2.8 to over 11 ft/yr on stream reaches with extreme BEHI ratings. The erosion rates used in this study are presented in Table 2-8. Because the goal of this analysis was to estimate relative erosion rates for targeting purposes, conservative erosion rates were selected. The conversion of SVAP morphology assessment variables to BEHI values was aggregated and erosion rates were not selected for the full range of BEHI values because the aggregated conversion would not support the resolution of the full range.

Typical reach stream bank heights were estimated through direct field measurements and interpolation using stream order. Bank heights were multiplied by stream segment length to yield total bank area. Total bank area was multiplied by the bank average erosion rate (ft/yr) for each appropriate erosion category. The resulting volume estimate was converted to a mass estimate of annual bank erosion (tons) using bulk density of 1.2 tons per cubic yard.

Table 2-8. Annual Stream Bank Erosion Rates (ft/yr) Associated with Various Erosion Risk Categories and Assuming Moderate Near Bank Shear Stress

BEHI Category	Observed Rates ft/yr			Selected Rates for this Study
	Colorado[1]	Wyoming[1]	North Carolina[2]	
Very Low	—	—	—	—
Low	0.09	0.13	—	0.06
Moderate	0.25	0.45	0.15	0.2
High	—	—	0.14	—
Very High	—	—	1.11	—
High-Very High	0.38	0.87	—	0.5
Extreme	1.7	1.5	2.49	1.0

[1] From Rosgen, 2001, [2]From Jessup, 2003

Reductions in bank erosion due to stream restoration were estimated by assuming stream channels in restored areas return to stable conditions with low bank erosion risk. Stream channels with low risk of bank erosion have lateral erosion rates of approximately 0.06 ft/yr (Table 2-8). Stressor reduction (or restoration benefit) is simply the difference (or delta) between current erosion rates and future erosion rates. This delta is then multiplied by average bank height (feet), stream length (feet), and a bulk density factor to convert volume into mass (tons). Table 2-9 presents estimates of current and post-restoration production of sediment from bank erosion for stream segments targeted for restoration. It should be noted that estimates of sediment load reduction were not appropriate for Site 5 (UT to Bolin Creek near East Franklin Street) and Site 8 (UT to Morgan Creek at South Greensboro Street) due to the fact that the stream segment in Site 5 currently flows through a concrete lined channel and the stream segment in Site 8 is currently piped underground. In their present status, neither stream segment is a direct source of sediment.

Table 2-9. Current and Post-Restoration Estimates of Total Annual Sediment Load (tons) from Bank Erosion at Potential Stream Restoration Sites

Site Num	Bank Height (ft)	Stream Length (ft)	Current Erosion (tons/year)	Post Restoration Erosion (tons/year)	Benefit (tons/year reduced)
1 & 1a	5.0	7122.4	1555.0	93.3	1461.7
2	5.0	3604.3	421.8	47.2	374.5
3	5.0	4608.1	796.0	36.4	759.6
4	3.5	940.2	143.7	8.6	135.0
5	—	—	—	—	—
6	3.0	1118.0	73.2	8.8	64.4
7	3.5	3797.2	285.8	34.9	250.9
8	—	—	—	—	—
9	4.0	1653.6	144.4	17.4	127.0
10	3.5	1237.2	94.5	11.4	83.2

Evaluation of the results in Table 2-10 shows that in terms of bulk sediment load reduction, restoration of the rural segments of Morgan Creek in the headwater areas upstream of University Lake will yield some of the greatest benefits. It should also be noted that, while the restoration of Booker Creek below Eastwood Lake rates lowest in terms of feasibility, it would produce the second largest benefit in sediment load reduction, largely due to the high erosion state of that stream segment. The estimates of sediment load reduction presented in Table 2-10 were combined with the cost estimates presented in Table 2-1 to generate approximations of cost-effectiveness for the stream restoration projects under consideration. The results are expressed in terms of dollars per ton of sediment reduced in Table 2-10 and the results are sorted from the most cost-effective (cheapest per ton reduced) to the least cost-effective.

Table 2-10. Sediment Load Reduction Cost-effectiveness for Potential Stream Restoration Sites

Site Num	Stream Name/Location	Stream Length	Rest. Length	Cost/ Foot	Total Cost	Sediment Reduction (tons/yr)	Cost/Ton (initial)	Cost/Ton per Year (20 yrs)
4	UT to Bolin Cr. at Airport Rd.	500	600	$160	$96,000	135.0	$711	$36
1&1a	Morgan Cr. at Maple View Farms	7,000	8,500	$170	$1,445,000	1461.7	$989	$49
2	Morgan Cr. at Lemola Dairy Farm	3,500	4,200	$130	$546,000	374.5	$1,458	$73
10	Chapel Cr. at Finley Golf Course	1,100	1,300	$110	$143,000	83.2	$1,719	$86
3	Lower Booker Cr.	4,000	4,500	$325	$1,462,500	759.6	$1,925	$96
9	Toms Cr. at Main St.	1,700	2,000	$160	$320,000	127.0	$2,520	$126
7	Bolin Cr. at Hogan Farms	3,300	4,000	$160	$640,000	250.9	$2,551	$128
6	Little Cr. at Chapel Hill Country Club	800	950	$180	$171,000	64.4	$2,655	$133
5	UT to Bolin Creek near E. Franklin St.	1,000	1,200	$125	$150,000	—	—	—
8	UT to Morgan Cr. near S. Greensboro St.	800	1,000	$160	$160,000	—	—	—

Evaluation of the cost-effectiveness results shows that restoration of the small UT to Bolin Creek near Airport Road (Site 4) would produce the most cost-effective sediment load reductions of any of the sites under consideration at $35 per ton over 20 years. However, in terms of the bulk load reduced, it generates one of the smallest reductions. Just as with bulk load reduction and cost-effectiveness, restoration of the upper segments of Morgan Creek (Site 1 & 1a and Site 2) would result in two of the most cost-effective sediment load reductions. Due to its low cost per linear foot the sediment reduction achieved by restoration of Chapel Creek (Site 10), while small, is fairly cost-effective. It should be noted that, despite the infrastructure constraints and high restoration cost associated with Lower Booker Creek (Site 3), it remains relatively cost-effective in comparison due to the shear size of the sediment load it is contributing in its currently degraded state.

2.4.2 Potential Stressor Reductions and Cost-effectiveness of Identified BMP Retrofit Opportunities

As previously discussed, the magnitude of potential stressor reductions for the identified stormwater BMP opportunities under consideration was analyzed in terms of potential nutrient removal capacity. The analysis was performed by generating estimates of the total nitrogen and total phosphorus loads to each BMP and applying research-based levels of nutrient reduction for each of the recommended BMP practices to those loads. Nutrient loads to BMPs were generated by delineating the contributing watersheds for each practice and applying the loading rates from the nutrient load modeling analysis developed for the Detailed Assessment (refer to Section 3 of Appendix A in the *Detailed Assessment*

Report) for the specific land uses in those watersheds. Once nutrient loads and appropriate reductions were calculated for each BMP, the annualized cost estimates presented in Table 2-3 were applied to develop relative estimates of cost-effectiveness. The results of this analysis are presented in Table 2-11. In Table 2-11, the Treated Area column shows the size of the contributing watershed for each stormwater BMP, and the Total Annualized Cost figures were taken directly from the cost analysis described in Section 2.2.2 and presented in Table 2-3. The TP and TN Load amounts presented in table 2-11 are the specific loads to each BMP as derived from the nutrient load modeling analysis developed for the Detailed Assessment (refer to Section 3 of Appendix A in the *Detailed Assessment*), and the BMP nutrient reduction rates are taken directly from Wossink and Hunt (2003). Cost-effectiveness results are expressed in cost per pound of nutrient removed and results are sorted from most to least cost-effective.

While nutrient load and reduction estimates could be generated for the two BMPs that consist of retrofitting existing ponds at Rainbow Soccer Fields (Site 7) and Weaver Dairy (Site 5), generating cost estimates for these two BMPs would require detailed engineering analyses, so cost-effectiveness numbers are not presented for these two facilities. However, given that excavation requirements, and hence costs, for retrofitting existing ponds are relatively low compared to constructing new facilities, these two options would likely prove to be highly cost-effective.

Not surprisingly, the results in Table 2-11 indicate that the constructed stormwater wetlands with moderately to highly impervious watersheds were found to be the most cost-effective. Overall, the results indicate that constructed stormwater wetlands are generally more cost-effective BMPs in this study. However, Wossink and Hunt (2003) have shown that bioretention can be cost-effective on small residential and commercial watersheds in the North Carolina Piedmont. Due to the collective scale of this local watershed planning effort, the BMP site search was biased toward larger watersheds than will typically allow for effective implementation of bioretention facilities. However, adequate land area is not always available for larger stormwater BMPs (ponds and wetlands), so diffuse application of bioretention is often a valuable alternative and necessary to reduce nonpoint source pollutant loads.

Table 2-11. Results of BMP Nutrient Load Reduction and Cost-effectiveness Analysis

Site Num	Location	Recommended Practivce	Treated Area (acres)	Total Annualized Cost (20 yr)	TN Load (lbs/yr)	TP Load (lbs/yr)	TN Reduction (percent)	TP Reduction (percent)	TN Reduction (lbs/yr)	TP Reduction (lbs/yr)	TN cost/lb (20 yr)	TP cost/lb (20 yr)
2	Eastgate Shopping Center	Stormwater Wetland	28.77	$1,139	711.5	108.4	22.0%	32.5%	156.5	35.2	$7	$32
8	Meadowmont Pool	Stormwater Wetland	31.53	$1,186	541.7	85.0	22.0%	32.5%	119.2	27.6	$10	$43
10	UNC CH Tennis Courts	Stormwater Wetland	72.22	$1,713	697.0	115.4	22.0%	32.5%	153.3	37.5	$11	$46
17	Tarhell Manor Apts	Stormwater Wetland	12.47	$794	310.6	47.4	22.0%	32.5%	68.3	15.4	$12	$52
1	Chapel Hill Library	Stormwater Wetland	81.63	$1,810	672.0	117.4	22.0%	32.5%	147.8	38.1	$12	$47
12	Carrboro Elementary Sch.	Stormwater Wetland	30.89	$1,175	422.4	67.6	22.0%	32.5%	92.9	22.0	$13	$54
14	Toms Creek @ Main St.	Stormwater Wetland	29.02	$1,144	329.1	54.2	22.0%	32.5%	72.4	17.6	$16	$65
13	Carrboro Park	Stormwater Wetland	24.37	$1,060	304.0	48.8	22.0%	32.5%	66.9	15.9	$16	$67
24	Hogan Farms Power Lines	Stormwater Wetland	17.56	$919	160.7	27.2	22.0%	32.5%	35.3	8.9	$26	$104
22	Airport Road Retrofit #4	Stormwater Wetland	16.78	$902	148.6	25.8	22.0%	32.5%	32.7	8.4	$28	$108
23	Hogan Farms D/S Lake	Pocket Wetland	9.19	$698	96.0	15.9	22.0%	32.5%	21.1	5.2	$33	$135
4	Cedar Falls Park	Pocket Wetland	12.45	$794	99.7	17.1	22.0%	32.5%	21.9	5.6	$36	$143
26	Hogan Farms Main Drag	Pocket Wetland	10.75	$746	93.0	15.7	22.0%	32.5%	20.5	5.1	$36	$147
19	Airport Road Retrofit #1	Pocket Wetland	9.89	$720	86.3	14.2	22.0%	32.5%	19.0	4.6	$38	$156
21	Airport Road Retrofit #3	Pocket Wetland	10.40	$735	80.9	13.8	22.0%	32.5%	17.8	4.5	$41	$164
11	Carrboro Tracks	Wet Detention	20.11	$5,664	432.1	66.6	28.0%	46.0%	121.0	30.6	$47	$185
16	Adjacent Carrboro USPS	Stormwater Wetland	16.63	$898	79.7	16.4	22.0%	32.5%	17.5	5.3	$51	$168
6	Chapel Hill Comm. Center	Bioretention	0.57	$342	14.1	2.1	45.0%	71.0%	6.3	1.5	$54	$225
18	Food Lion Parking Lot	Wet Detention	16.76	$5,042	417.4	63.7	22.0%	32.5%	91.8	20.7	$55	$244
20	Airport Road Retrofit #2	Pocket Wetland	5.14	$548	34.1	6.3	22.0%	32.5%	7.5	2.0	$73	$268
9	Chapel Ck. Bioretention	Bioretention	2.00	$1,159	34.5	5.5	45.0%	71.0%	15.5	3.9	$75	$299
25	Hogan Farms Old Silo	Bioretention	3.21	$1,896	49.9	7.9	45.0%	71.0%	22.5	5.6	$84	$338
15	Carrboro USPS	Bioretention	2.80	$1,643	42.2	6.7	45.0%	71.0%	19.0	4.7	$86	$346
5	Weaver Dairy Retrofit	Retrofit Existing Pond	21.33	NA	248.3	41.1	28.0%	46.0%	69.5	18.9	NA	NA
7	Rainbow Soccer Field	Retrofit Existing Pond	129.05	NA	1485.9	244.3	28.0%	46.0%	416.1	112.4	NA	NA

2.5 WATERSHED-SCALE FUNCTIONAL BENEFITS OF RESTORATION OPPORTUNITIES

In the previous section, potential stressor reduction and cost-effectiveness were evaluated on the basis of sediment load reduction for stream restoration projects and nutrient load reduction for stormwater BMPs. While these benefits are readily quantified for the two groups of restoration options, they do not take into account the fact that stream restoration projects achieve nutrient reductions and that stormwater BMPs achieve sediment load reductions through peak storm flow reduction and subsequently reduced stream erosion. For these reasons a simple scoring system was applied to gage the more comprehensive range of watershed-scale functional benefits for the various restoration opportunities. While the overall scoring approach was the same for restoration projects and BMPs, the parameters in the scores varied slightly between them. The respective scoring method and results for each are presented in the sections below.

2.5.1 Functional Benefits of Stream Restoration Projects

Each potential stream restoration project was assigned benefit points on the basis of the scoring parameter and categories outlined in Table 2-12. The first parameter in the Benefit Score is based on the projected cost-effectiveness regarding sediment load reduction. For this parameter the sites were divided into a top, middle and lower third on the basis of the cost-effectiveness estimates presented in Table 2-9 and given three, two, or one Benefit Points, respectively. In order to prioritize restoration projects in subwatersheds where they are most needed, the subwatershed risk scores for overall stream degradation, as indicated by onsite SVAP assessments, were taken directly from the subwatershed rankings in Table 5.2 of the *Detailed Assessment Report* and assigned as Benefit Points. In other words, a stream restoration project located in an LWP subwatershed with a high level of morphological and aquatic habitat degradation would be presumed to have a greater benefit and would receive a higher score. Similarly, the Exerted TN and TP Load risk scores for each subwatershed, which reflect the loads they are predicted to deliver to Jordan Lake, were also taken from the Detailed Assessment Report, giving greater estimation of benefit to those restoration projects located in subwatersheds delivering large nutrient loads to the lake. Finally, a parameter was included in the Benefit Score to give additional points to restoration projects located in subwatersheds with stormwater BMPs or high priority preservation areas to reflect the potential for mutual benefits of various restoration and management efforts.

Given that the restoration of floodplain function along Morgan Creek at Old Mason Farm (Restoration Site 11) is atypical of the stream restoration projects considered in this study, and that the initial phases of implementation are already under way on this project, it was not included in this analysis of functional benefits.

Table 2-12. Restoration Benefit Scoring

Benefit Factor	Point Score
Cost-effectiveness for Sediment Load Reduction	
Top third of projects	3
Middle third of projects	2
Lower third	1
Levels of Stream Degradation in Subwatershed	
SVAP Risk Score taken directly from Table 5.2 of *Detailed Assessment Report* (possible range: 0-3 points)	
Subwatershed Potential to Deliver Nutrients to Jordan lake	
Average of Exerted TP and TN Load Risk Scores taken directly from Table 5.2 of *Detailed Assessment Report* (possible range: 0-4 points)	
Project Sited in Conjunction with Stormwater BMPs or High Priority Preservation Areas	
Immediate Conjunction	2
Some Potential for Interaction	1
Not Sited in Conjunction	0

The resulting Restoration Site Benefit Scores and the individual parameters from which they are derived are presented in Table 2-13. The columns under the heading "Sed Reduction" in Table 2-13 represent the dollar cost per ton per year for sediment reduction by each restoration site, as described in Section 2.4.1 and presented in Table 2-10 and the benefit points assigned to each restoration project according to Table 2-12 for their sediment reduction cost effectiveness. The columns in Table 2-13 under the heading "LWP Subwatershed" represent the risk scores taken directly from Table 5.2 of *Detailed Assessment Report* for the overall stream condition (reflected b SVAP ratings) and nutrient loading potential (to Jordan Lake) of the subwatershed where the restoration project is located. The benefit point scores for these subwatershed parameters are directly equal to the risk scores taken from the Detailed Assessment to reflect greater benefit for restoration projects located in high-risk LWP subwatersheds for these two parameters. The columns labeled "Conjunction" reflect whether or not a stream restoration site is located in a subwatershed in conjunction with stormwater BMPs such that the two types of restoration efforts could provide mutual and additive benefits.

Results in Table 2-13 are sorted from highest to lowest scores, and a second adjusted benefit score is presented that does not include the LWP subwatershed parameter that reflects nutrient delivery to Jordan Lake. The second Benefit Score is present to provide a fairer comparison of the collective benefits of the restoration projects upstream of University Lake (Sites 1&1a and 2). Due to the nutrient trapping function of University Lake, the potential nutrient delivery to Jordan Lake from these subwatersheds is very low. However, the University Lake Baseline Analysis Memo (Tetra Tech, 2003) has indicated that, while the low density development restrictions in the watershed go a long way toward prevention of excess eutrophication in University Lake, water quality benefits could be realized through preservation efforts, buffer re-establishment and other restoration projects.

Since cost-effectiveness estimates could not be generated for Sites 5 and 8 for reasons discussed in Section 2.4.1, they were arbitrarily assigned 2 Benefit Points in the cost-effectiveness category for comparative purposes.

Table 2-13. Watershed Functional Benefit Scores for Identified Stream Restoration Projects

Site Num	Stream Name/Location	Cost Per Foot	Total Cost	Sed Reduction (cost/ton/yr)	Sed Reduction Pts	LWP Subwatershed SVAP	Pts	Nutrient	Pts	Conjunction	Pts	BENEFIT SCORE	BENEFIT SCORE*
8	UT to Morgan Cr. near S. Greensboro St.	$160	$160,000	NA	2	LM1	2	LM1	3.5	BMP	2	**9.5**	**6**
3	Lower Booker Cr.	$325	$1,462,500	$96	3	BL10	2.5	BL10	2.5	BMP	1	**9**	**6.5**
4	UT to Bolin Cr. at Airport Rd.	$160	$96,000	$84	3	BL4	2	BL4	4	No	0	**9**	**5**
10	Chapel Cr. at Finley Golf Course	$110	$143,000	$101	3	LM5	2.5	LM5	1	BMP	2	**8.5**	**7.5**
6	Little Cr. at Chapel Hill Country Club	$180	$171,000	$99	3	BL12/13	3	BL12/13	2.5	No	0	**8.5**	**6**
9	Toms Cr. at Main St.	$160	$320,000	$250	1	LM1	2	LM1	3.5	BMP	2	**8.5**	**5**
5	UT to Bolin Cr. near E. Franklin St.	$125	$150,000	NA	2	BL4	2	BL4	4	No	0	**8**	**4**
1	Morgan Cr. at Maple View Farms	$170	$1,445,000	$103	3	UM1	2	UM1	0	Pres	2	**7**	**7**
2	Morgan Cr. at Lemola Dairy Farm	$130	$546,000	$89	3	UM1	2	UM1	0	Pres	2	**7**	**7**
7	Bolin Cr. at Hogan Farms	$160	$640,000	$169	1	BL1/2	2.5	BL1/2	1.5	BMP	2	**7**	**5.5**

*Score without LWP Subwatershed Parameter reflecting nutrient delivery to Jordan Lake

2.5.2 Functional Benefits of Stormwater BMPs

Each potential stormwater BMP project was assigned benefit points on the basis of the scoring parameter and categories outlined in Table 2-14. The first parameter in the Benefit Score is based on the projected cost-effectiveness regarding nutrient load reduction. Just as with the benefit scoring approach for stream restoration projects, prospective BMPs were divided into a top, middle and lower third on the basis of the cost-effectiveness estimates presented in Table 2-9 and given three, two, or one Benefit Points, respectively. In order to prioritize BMPs in subwatersheds where they are most needed, the subwatershed risk scores for morphological stream degradation, as indicated by onsite SVAP morphology assessments, were taken directly from the subwatershed rankings in Table 5.2 of the *Detailed Assessment Report* and assigned as Benefit Points. The intent is that a stormwater BMP located in an LWP subwatershed with a high level of stream erosion and instability would be presumed to have a greater benefit and hence would receive a higher score. Exerted TN and TP Load risk scores for each subwatershed, were also used in the Benefit Score for BMPs, giving a greater estimation of benefit to those retrofit opportunities located in subwatersheds delivering large nutrient loads to the lake. In addition, the parameter in the Benefit Score giving additional points to BMPs located in subwatersheds with stream restoration projects was included in the BMP ratings to reflect the potential for mutual benefits of various restoration and management efforts.

Table 2-14. BMP Benefit Scoring

Benefit Factor	Point Score
Cost-effectiveness for Nutrient Load Reduction	
Top third of projects	3
Middle third of projects	2
Lower third	1
Levels of Stream Erosion and Morphological Degradation in Subwatershed	
SVAP Morphology Risk Score taken directly from Table 5.2 of *Detailed Assessment Report* (possible range: 0-3 points)	
Subwatershed Potential to Deliver Nutrients to Jordan lake	
Average of Exerted TP and TN Load Risk Scores taken directly from Table 5.2 of *Detailed Assessment Report* (possible range: 0-4 points)	
Project Sited in Conjunction with Stream Restoration Projects	
Immediate Conjunction	2
Some Potential for Interaction	1
Not Sited in Conjunction	0

The resulting BMP Benefit Scores and the individual parameters from which they are derived are presented in Table 2-15. The columns under the heading "Nitrogen Reduction" in Table 2-15 represent the dollar cost per pound per year for nitrogen reduction by each recommended BMP, as described in Section 2.4.2 and presented in Table 2-11 and the benefit points assigned to each BMP project according to Table 2-14 for their nitrogen reduction cost effectiveness. Nitrogen reduction was somewhat arbitrarily utilized as the ranking parameter, rather than phosphorus reduction, but BMP cost effectiveness values for phosphorus reduction follow patterns identical to those for nitrogen. The columns in Table 2-15 under the heading "LWP Subwatershed" represent the risk scores taken directly from Table 5.2 of *Detailed Assessment Report* for the nutrient loading potential (to Jordan Lake) and the morphological stream condition (reflected b SVAP morphology ratings) of the subwatershed where the BMP and its contributing watershed are located. The benefit point scores for these subwatershed parameters are directly equal to the risk scores taken from the Detailed Assessment to reflect greater benefit for BMPs located in high-risk LWP subwatersheds for these two parameters. The columns labeled "Conjunction" reflect whether or not a BMP is located in a subwatershed in conjunction with a stream restoration site such that the two types of restoration efforts could provide mutual and additive benefits.

Results in Table 2-15 are sorted from highest to lowest scores. The scores indicate the stormwater BMP opportunities in the Toms Creek watershed and in the downtown portion of Carrboro (Subwatershed LM1) are projected to provide the greatest overall benefit, followed closely by those in Middle Bolin Creek (BL4) and the Meadowmont subwatershed in lower Bolin Creek (BL12). It should be noted that the Airport Road Retrofit series of BMPs, while having some of the highest Feasibility Scores, produce the least benefit on a watershed scale. The lower benefit of these BMPs is largely a result of their location upstream of Eastwood Lake, where the nutrient trapping function of the lake prevents significant delivery of nutrients to Jordan Lake from these Booker Creek headwater subwatersheds. In addition, the onsite SVAP morphology assessment indicated nothing but good to excellent stream conditions in this area (refer to Section 2.2.1 of the *Detailed Assessment Report*).

Table 2-15. Watershed Functional Benefit Scores for Identified BMP Retrofit Opportunities

Site			Recommended	Annualized	TN Reduction		LWP Subwatershed				Conjunction		BENEFIT
Num	Location	Stream/Catchment	Practice	Cost	(cost/lb/yr)	Pts	Nutrient	Pts	Morph	Pts		Pts	SCORE
14	Toms Creek @ Main St.	Toms Creek	Stormwater Wetland	$1,144	$16	3	LM1	3.5	LM1	3	Yes	2	**11.5**
17	Tarheel Manor Apts	Toms Creek	Stormwater Wetland	$794	$12	3	LM1	3.5	LM1	3	Yes	2	**11.5**
2	Eastgate Shopping Center	Booker Creek	Stormwater Wetland	$1,139	$7	3	BL10	4	BL10	3	Yes	1	**11**
11	Carrboro Tracks	UT to Morgan Creek	Wet Detention	$5,664	$47	2	LM1	3.5	LM1	3	Yes	2	**10.5**
15	Carrboro USPS	Toms Creek	Bioretention	$1,643	$86	1	LM1	3.5	LM1	3	Yes	2	**9.5**
16	Adjacent Carrboro USPS	Toms Creek	Stormwater Wetland	$898	$51	1	LM1	3.5	LM1	3	Yes	2	**9.5**
18	Food Lion Parking Lot	Toms Creek	Wet Detention	$5,042	$55	1	LM1	3.5	LM1	3	Yes	2	**9.5**
1	Chapel Hill Library	UT to Bolin Creek	Stormwater Wetland	$1,810	$12	3	BL4	4	BL4	2	No	0	**9**
12	Carrboro Elementary Sch.	UT to Bolin Creek	Stormwater Wetland	$1,175	$13	3	BL4	4	BL4	2	No	0	**9**
13	Carrboro Park	UT to Bolin Creek	Stormwater Wetland	$1,060	$16	3	BL4	4	BL4	2	No	0	**9**
8	Meadowmont Pool	UT to Little Creek	Stormwater Wetland	$1,186	$10	3	BL12	3	BL12	3	Near	0	**9**
10	UNC CH Tennis Courts	Chapel Creek	Stormwater Wetland	$1,713	$11	3	LM5	1	LM5	2.5	Yes	2	**8.5**
24	Hogan Farms Power Lines	Upper Bolin Creek	Stormwater Wetland	$919	$26	2	BL2	1.5	BL2	3	Yes	2	**8.5**
7	Rainbow Soccer Field	Little Creek	Retrofit Existing Pond	NA	NA	2	BL5	4	BL5	2	No	0	**8**
23	Hogan Farms D/S Lake	Upper Bolin Creek	Pocket Wetland	$698	$33	2	BL1	1	BL1	3	Yes	2	**8**
26	Hogan Farms Main Road	Upper Bolin Creek	Pocket Wetland	$746	$36	2	BL1	1	BL1	3	Yes	2	**8**
6	Chapel Hill Comm. Center	Lower Bolin Creek	Bioretention	$342	$54	1	BL5	4	BL5	2	No	0	**7**
25	Hogan Farms Old Silo	Upper Bolin Creek	Bioretention	$1,896	$84	1	BL1	1	BL1	3	Yes	2	**7**
9	Chapel Ck. Bioretention	Chapel Creek	Bioretention	$1,159	$75	1	LM5	1	LM5	2.5	Yes	2	**6.5**
4	Cedar Falls Park	Cedar Fork	Pocket Wetland	$794	$36	2	BL8	3	BL8	0.5	No	0	**5.5**
5	Weaver Dairy Retrofit	UT to Booker Creek	Retrofit Existing Pond	NA	NA	2	BL8	3	BL8	0.5	No	0	**5.5**
19	Airport Road Retrofit #1	Upper Booker Creek	Pocket Wetland	$720	$38	2	BL6	2	BL6	1	No	0	**5**
21	Airport Road Retrofit #3	Upper Booker Creek	Pocket Wetland	$735	$41	2	BL6	2	BL6	1	No	0	**5**
22	Airport Road Retrofit #4	Upper Booker Creek	Stormwater Wetland	$902	$28	2	BL6	2	BL6	1	No	0	**5**
20	Airport Road Retrofit #2	Upper Booker Creek	Pocket Wetland	$548	$73	1	BL6	2	BL6	1	No	0	**4**

2.6 PRIORITIES FOR IMPLEMENTATION

The scores presented in the previous sections are not offered as definitive measures of the value of the various restoration and BMP projects identified in this report, but rather are intended to serve as a guide for prospective implementers for use in establishing priorities. The indications of feasibility and benefit presented here may be overridden by factors such as the interests of local jurisdictions, landowner willingness to participate, or linkages to unrelated projects such as site developments or roadway improvements.

Implementation priorities can be established by working to strike an optimum balance between feasibility of implementation and functional benefits of the recommended restoration projects. Striking this balance can be challenging, however, because many of the potential projects thought to be the most feasible, or easy, to implement are also projected to provide the least benefits (e.g., Airport Road BMP Retrofits), while those projects that provide the greatest benefit are hardest to implement (e.g., Lower Booker Creek stream restoration project). Projects that should be given higher or lower priority for implementation are identified in the sections that follow.

2.6.1 Projects Recommended for High Priority Implementation

It is recommended that the following projects be given high priority for implementation. The order in which they are presented here is not intended to reflect priorities within this list. Rather, this list is offered as a group that should be given higher priority within the context of priorities determined between NCEEP and local jurisdictions.

- **Stream Restoration and BMPs in the Toms Creek Watershed (Subwatershed UM1)**

  The BMP opportunities within the watershed (Toms Creek at Main Street, Tarheel Manor Apts., two at the Carrboro USPS, and the Food Lion parking lot) all rated among the highest in terms of Benefit Scores, and while not necessarily among the easiest in terms of feasibility, they do not suffer excessive constraints as projects in an urban setting go. The Benefit Score for Toms Creek stream restoration falls among the middle third and in terms of feasibility it ranks as one of the most difficult, but if implemented in conjunction with one or more of the BMP opportunities identified in this small watershed it offers the opportunity to make a substantial improvement in the functions of this small urban watershed.

- **Restoration of Stream Segments in Upper Morgan Creek (Subwatershed UM1)**

  The stream restoration projects identified at the Maple View and Lemola Dairy Farms offer two opportunities that are among the easiest to implement, provided landowner participation can be successfully negotiated, and they both offer large and highly cost-effective benefits in terms of sediment load reduction and aquatic habitat improvement. As discussed in Section 2.5.1, they do not provide significant tangible benefit regarding reduction of nutrient loads to Jordan Lake, but these sites are of great value to University Lake in that respect, and their location provides watershed scale opportunity to realize mutual benefits between stream restoration and preservation of high quality riparian and terrestrial habitats (refer to Section 4).

- **Stream Restoration and BMPs in the Chapel Creek Watershed (Subwatershed LM5)**

  The restoration of Chapel Creek is rated as the most feasible to implement and the project is among the top tier in terms of projected benefits. It is also highly cost-effective in terms of sediment load reduction. The appropriate agreements are in place between UNC and NCEEP to bring about stream restoration at this site. If the BMP opportunities identified in the headwaters of this watershed can be implemented in conjunction with this restoration, it offers another small watershed where substantial improvement in watershed functions could be realized. The potential stormwater wetland BMP at the UNC Tennis Courts (Site 10) is not rated particularly high in terms of Benefit Score, but it does offer the opportunity for one of the most cost-effective sites in terms of nutrient load reduction (refer to Table 2-10). This BMP would also provide critical peak flow reduction to protect the integrity of the restoration site.

- **Restoration of Lower Booker Creek and Stormwater BMP at Eastgate Mall**

  As previously noted, while restoration of Booker Creek below Eastwood Lake may prove to be a large and challenging undertaking, it would provide one of the greatest overall benefits to watershed functions. The stormwater BMP site just downstream behind Eastgate Mall has a very similar low feasibility/high benefit profile. However, implementation of these projects together could make significant progress toward alleviating the impairment of lower Booker Creek.

- **Restoration of UT to Morgan Creek Near South Greensboro Street and Stormwater BMP at Carrboro Tracks**

  Sediment load cost-effectiveness could not be approximated for this stream restoration project because the stream segment is currently buried in an underground conveyance. Day-lighting the stream would provide obvious benefits to a full range of watershed functions, and the wet detention BMP site at the Carrboro Tracks (Site 11) offers an opportunity to capture and treat runoff from a substantial portion of the urbanized downtown section of Carrboro.

- **Restoration of Floodplain Functions along Morgan Creek at Mason Farm**

  While this project may not be directly comparable to the other stream restoration projects considered in this study, it is likely to provide significant functional benefit for a relatively low cost. Since the project involves removal of a berm disconnecting Morgan Creek from a historical floodplain area, it will not require construction of a new channel, and the excavation requirements, and hence cost, for the project should be lower than those associated with conventional stream restoration projects. The nutrient reduction potential of the restored floodplain area is of high functional value in this area immediately upstream of Jordan Lake. A field study is planned for implementation in conjunction with this project to evaluate the level of nutrient removal resulting from the restored floodplain.

- **Stand-Alone Stormwater BMP Projects**

  Several of the potential BMPs identified in this report, while not necessarily associated with a particular stream restoration project, are projected to offer significant watershed benefits based on their strategic locations and are highly cost-effective in terms of reducing nutrient loads. They are the sites at Chapel Hill Library (Site 1), Meadowmont Pool (Site 8) and Carrboro Elementary School (Site 12). In addition, while cost estimates could not be developed for the retrofits of existing ponds at Weaver Dairy and Rainbow Soccer Fields, given that they would have only minimal excavation requirements, it is likely that they will prove to be highly cost-effective sources of nutrient load reduction, and they are both located in watersheds with high to very high potential to deliver nutrients to Jordan Lake.

2.6.2 Projects Recommended as Low Priority for Implementation

It is recommended that the following projects be given low priority for implementation due to limited watershed benefits, logistical concerns, or other reasons as discussed.

- **BMP Retrofits at Airport Road**

  Retrofitting the existing sediment basins along North Airport Road should be given low priority because the resulting stormwater wetlands would provide only limited nutrient load reduction benefit due to their location in the Bolin/Little Creek watershed (refer to Section 2.5.2). However, if detailed source identification investigations in the future show that nonpoint source pollutant loads from the vicinity of the upper Booker Creek watershed are contributing to the impairment of Booker Creek, the local jurisdictions may wish to consider implementing them at a later date. As the level of development increases in this portion of the Booker Creek watershed, the localized benefit of these facilities will also increase.

- **Stream Restoration and BMPs in the Hogan Farms Vicinity (Subwatersheds BL1 and BL2)**

  The stream restoration of Bolin Creek in this area and the potential BMP projects identified all fell in the lower half or at the bottom of the list in terms of the Benefit Scores, and they tend toward the lower half of the Feasibility Scores as well. In addition, implementing a stream restoration project in the Hogan Farms subdivision may be premature at this juncture, due to the fact that significant amounts of additional development are projected in the next phases of the community (currently under construction). Stream restoration and BMP implementation may be more prudent after the whole development is complete and its full imperviousness realized.

  While it is recommended that stream restoration and BMP implementation in the Hogan Farms area be given lower priority among the project opportunities identified in this report, the future phases of Hogan Farms and other subdivision developments planned for this upper Bolin Creek portion of the LWP study area, such as Winmore, offer ideal opportunities for implementation of low impact design measures in conjunction with restoration projects. Appropriate low impact design features and the means to facilitate their implementation are discussed in the following section.

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3 Measures to Prevent Future Degradation

In the *Detailed Assessment Report* the analysis of subwatershed risk levels indicated that there was considerable overlap between subwatersheds at risk for degradation of watershed functions under existing conditions and those at risk for degradation in the future. Given that the sources of degradation identified in this local watershed planning effort are all nonpoint sources in nature, the core effort in determining the measures recommended to prevent future degradation involved a review of the measures utilized by each of the jurisdictions affecting the Tier 1 and Tier 2 priority subwatersheds to control, manage, and prevent the adverse impacts of stormwater. The core elements of stormwater management programs for Chapel Hill, Carrboro and Orange County were reviewed and compared to elements of the most progressive programs currently in existence throughout the southeast region and across the country. Key elements of the local jurisdictions' development ordinances were also reviewed to determine the degree to which they allowed, or even facilitated, low impact design (LID) development, and the LID elements were also compared to those of "ideal" ordinances in practice in other communities. Based on the review and comparison, potential gaps were identified in the stormwater management and LID frameworks of the local jurisdictions. The following section presents the results of the review and recommendations to fill those potential gaps.

3.1 Background Information

According to the Detailed Assessment, key findings of future watershed conditions are:

1) Urbanization is the biggest overall threat to watershed functions. Many of the threats to watershed functions are heightened after construction of developments is completed, called "post-construction" impacts: increased stormwater discharges directly to streams, in terms of volume and velocity; increased overland flow of stormwater; increased pollutant loading in stormwater due to build-up and wash-off; increased stream temperature due to lack of shading and heated stormwater runoff from ponds and impervious areas; reduced groundwater recharge and baseflow; and decreased number and diversity of plants and animals due to the lack—or poor quality—of habitat.
2) Increased imperviousness, increased phosphorus and nitrogen load, and stream stability comprise the key indicators for identifying areas of high risk for future degradation and prioritizing watersheds for protection.

A number of site features contribute to post-construction stormwater impacts: level of imperviousness; types of vegetation or land cover on the site; types of soils and their infiltration capacity; the removal of vegetation on streambanks; and the increased total volume and velocity of stormwater leaving the site compared to preconstruction conditions. The factors that affect the severity of erosion, stream bank/channel instability, and pollutant loading are: rainfall frequency and intensity; slopes; soil structure and type; vegetation; and the stormwater management control practices used. Most of these factors reflect site design or development policy considerations. As the land is converted from farms and forest to developed areas, use of more protective ordinances and performance standards as well as more effective site design with LID techniques will be needed to protect good quality streams and help mitigate existing impairment in the watersheds.

Why should local governments care about future sedimentation and erosion, and upland sediment and nutrient delivery in these watersheds?

Loss of watershed functions means loss of things people in the community care about and value: Increased sedimentation and erosion and upland sediment delivery mean increased loss of fishing habitat; loss of the beauty of the streams and stream corridors through people's land; increased flooding problems;

loss of water supply storage capacity in the reservoirs due to sediment buildup; and increased eutrophication of water supply lakes such as University Lake and Jordan Lake.

New federal and state regulations: Federal and state Phase II NPDES Stormwater Regulations cover post-construction impacts from development in medium-sized communities. Under Senate Bill 1210, ratified July 12, 2004, municipalities located in whole or in part within an urbanized area as designated by the 1990 or 2000 census are required to submit a Phase II NPDES permit application for stormwater management. Unincorporated areas surrounding federally designated Phase II communities must meet stormwater management requirements if the development is: 1) in an area that is considered an "urbanized area" under the federal 1990 or 2000 census; or 2) is located within the potential extraterritorial jurisdiction (ETJ) of a Phase II community; or 3) if the combination of the area covered by Phase II municipalities, potential extraterritorial jurisdiction, and urbanized areas totals at least 85 percent of the entire area of the county.

Note: Under the State of North Carolina's Temporary Stormwater Management Rule, adopted by the NC Environmental Management Commission October 10, 2002, municipalities greater than 10,000 population, or having a density of at least 1,000 per sq.mi. and counties with a population greater than 45,000, were automatically designated as Phase II communities. Pursuant to this Temporary Rule, the towns of Carrboro and Chapel Hill and Orange County were designated Phase II communities.

Designated Phase II communities were required to submit their NPDES applications for compliance with the Phase II Stormwater Regulations in March 2003. Municipalities have two years to adopt and begin implementation of a post-construction ordinance (from the date of application approval). Unincorporated areas must comply with the post-construction stormwater requirements by July 1, 2006. (Note: Control and treatment of post-construction runoff is only one of six minimum control measures under the Phase II Permit. All Phase II minimum control measures must be fully implemented by 2008.) Large communities, such as Raleigh and Durham, have already been required to implement extensive stormwater management programs under Phase I of the USEPA NPDES Stormwater Program.

Local governments may petition the North Carolina Environmental Management Commission for a water quality protection program offset. The commission will review the effectiveness of any existing water quality protection programs that may offset the need to obtain a Phase II NPDES permit for stormwater, including the water quality of receiving waters and whether the water supports its intended uses. This water quality protection program offset could provide an incentive for local governments to enact strong local programs to protect and restore watershed functions.

Pending Total Maximum Daily Load (TMDLs): The North Carolina Department of Environment and Natural Resources (DENR) has established a nitrogen TMDL in the Neuse River Basin which is being implemented by local governments. DENR is currently developing phosphorus and nitrogen TMDLs for the Upper New Hope Creek arm of Jordan Lake, including the Morgan Creek Local Watershed Plan (LWP) study area. While the exact TMDL is still undecided, all parties have agreed that, at minimum, the total nonpoint source loading should be capped at existing levels. Whether this load target or a more stringent load target is adopted, the TMDL will clearly require additional controls on new development and redevelopment.

The purpose of this section of the report is to assist local governments in decreasing impacts of post-construction runoff from future development and redevelopment through:

- Sharing information about progressive stormwater management ordinances and programs that strongly encourage (or even require) LID.
- Sharing information about potential minimum stormwater management requirements (i.e., Phase II NPDES Stormwater).

- Identifying gaps and opportunities in local stormwater management (in light of progressive and potential new minimum standards), based on a review of jurisdictions' existing regulations.
- Recommending high priority actions for local governments to consider in strengthening their stormwater management and site-design related ordinances.

This section has three sub-parts. The first is a discussion of the elements of progressive stormwater ordinances addressing post-construction runoff and an evaluation of existing local ordinances for the three main LWP local governments: Carrboro, Chapel Hill, and Orange County. The second part is a discussion of the elements of effective site design to better reduce and manage stormwater, including a summary of a survey/evaluation of three LWP governments regarding their site design practices. Sub-part three recommends high priority actions for strengthening ordinances to address post-construction impacts. With this information, local governments can build upon existing stormwater management efforts to address stressors threatening future degradation of the Morgan Creek Watershed.

It is important to note that one source of sediment is land disturbance *during* construction. While Orange County faces the same challenge with its sedimentation and erosion control (S&EC) program as other local governments, i.e., lack of resources for adequate enforcement, the county has very strong sedimentation and erosion control policies, regulations, and procedures which it administers for all three LWP jurisdictions. In fact, the county's S&EC program is recognized as a state and national leader. Therefore, this TMR section focuses on review of regulations related to *post-construction* stormwater runoff.

3.2 Elements of Progressive Stormwater Ordinances Addressing Post-construction Runoff

Until recently, typical, conventional stormwater management consisted of performance standards requiring treatment of the runoff from the first inch of rainfall (and/or 85 percent removal of TSS) and peak flow control for the 2-yr and 10-yr, 24-hr storm event. These standards could be met with onsite or offsite water quality ponds and dry detention ponds.

In the last decade, state and local governments observed that these performance standards and BMPs were inadequate to address the multiple impacts from stormwater runoff. At the same time, governments began to take a watershed approach to assessing existing and future potential stormwater impacts from development. These watershed assessments included multiple, new parameters to address pollution runoff, such as nutrients, metals, and fecal coliform. Importantly, stormwater volume became a primary parameter of concern because of its impact on downstream habitat.

Some state and local governments have recently adopted stormwater management goals and objectives that address these multiple quality and volume impacts, have set strong performance standards associated with these objectives, and have begun to require onsite management of stormwater. Analysis in some case study areas shows that conventional BMPs alone cannot meet these new performance standards. In urban and suburban areas, particularly, multiple LID techniques (i.e., a treatment and retention train) will be needed to meet the requirements. The ordinances adopted either require use of Low Impact Development (LID) design techniques or retention of stormwater onsite (e.g., Huntersville and Portland, respectively), or encourage the use of LID (e.g., Chapel Hill, Upper Neuse River Basin Association, and Rockdale County, GA). Whether encouraging or requiring LID, all of these jurisdictions provide some level of LID education or assistance, including but not limited to a design manual. After local ordinances are debated and adopted, it is clear that the objectives adopted and performance criteria required for new development greatly influence the extent to which better site design and LID techniques will be used.

Sections 3.2.1 and 3.2.2 provide case studies for consideration in Morgan Creek from progressive stormwater ordinances.

3.2.1 Development of Stormwater Management Goals and Objectives

In the case study areas, often draft goals and objectives were used to help develop stormwater management criteria and craft "scenarios" to test in watershed modeling and/or pilot-project development. Local advisory groups or boards were used to help draft the preliminary goals and objectives.

Clearly, different communities have different goal and objective statements depending on local circumstances and requirements. For example, some communities may only wish to meet Phase II requirements, while others may set higher goals than state minimum requirements due to local concerns, such as drinking water supply or habitat protection. Following are examples of goals and objectives statements from several of the case study communities. Generally, they are ordered from basic level to higher level of protection.

Example Goals Statements

Example 1 (modified from Town of Chapel Hill's Land Use Management Ordinance)

"The purpose of this section is to establish minimum stormwater management requirements and controls to protect and safeguard the general health, safety, and welfare of the public residing in watersheds within this jurisdiction. This ordinance seeks to meet that purpose through the following objectives:"

Example 2 (modified from the Town of Huntersville Water Quality Ordinance)

"The purpose of this regulation is to establish stormwater management requirements and controls to prevent surface water quality degradation to the extent practicable in the streams and lakes within the Town Limits and Extraterritorial Jurisdiction of Huntersville and to protect and safeguard the general health, safety, and welfare of Huntersville's residents. This regulation seeks to meet this purpose by fulfilling the following objectives:"

Example 3 (modified from the City of Portland's Stormwater Management Ordinance)

"The purpose of this Stormwater Management Ordinance is to provide for the effective management of stormwater and drainage and to maintain and improve water quality in the watercourses and waterbodies within and leaving the City. This ordinance seeks to meet that purpose through the following policies and standards:"

Example Objectives Statements

Example 1– Meeting New and Existing Requirements (preliminary considerations for Mecklenburg County)

"Achieve compliance with Phase II NPDES stormwater permit requirements for post-construction pollution control for new development (Note: City of Charlotte would cite Phase I and Phase II requirements);

a) Reduce stormwater peak runoff rates and volumes from new development, wherever possible, through stormwater controls to mitigate stream bank and channel erosion and flooding impacts;

b) Where surface waters have been listed as impaired due to urban runoff or storm sewers (on the NC 303(d) list of impaired waterbodies), support local efforts to address existing impairment through actions to mitigate additional impairment caused by new development;

c) (For Mint Hill and other affected jurisdictions) Address guidelines to mitigate the cumulative and secondary impacts on aquatic and terrestrial wildlife resources and water quality specified by the N.C. Wildlife Resources Commission and U.S. Fish and Wildlife Service for the Goose Creek and Yadkin River Watershed."

Example 2 – (adapted from Town of Huntersville Water Quality Ordinance and from Town of Chapel Hill Land Use Management Ordinance)

a) "Minimize increases in storm water runoff from development or redevelopment in order to reduce flooding, siltation and streambank erosion, and maintain the integrity of stream channels;

b) Minimize increases in nonpoint source pollution caused by stormwater runoff from development or redevelopment that would otherwise degrade local water quality;

c) Minimize the total volume of surface water runoff that flows from any specific site during and following development in order to replicate pre-development hydrology to the maximum extent practicable;

d) Reduce stormwater runoff rates and volumes, soil erosion and nonpoint source pollution, to the extent practicable, through stormwater management controls (BMPs) and ensure that these management controls are properly maintained and pose no threat to public health or safety; and

e) Meet the requirements of the National Pollution Discharge Elimination System (NPDES) Storm Water Permit and other requirements as established by the Clean Water Act."

Example 3 – Policies and Standards (adapted from City Code, City of Portland, Oregon)

The City of Portland code lists policies rather than objectives.

a) "Stormwater shall be managed as close as is practicable to development sites, and stormwater management shall avoid a net negative impact on nearby streams, wetlands, groundwater, and other waterbodies. All local, state, and federal permit requirements related to implementation of stormwater management facilities must be met by the owner/operator prior to facility use. Surface water discharges from onsite facilities shall be conveyed via an approved drainage facility.

b) The quality of stormwater leaving the site after development shall be equal to or better than the quality of stormwater leaving the site before development, as much as is practicable.

c) The quantity of stormwater leaving the site after development shall be equal to or less than the quantity of stormwater leaving the site before development, as much as is practicable."

As shown in the above examples, the goal or purpose statement is very general. The objectives provide more detail on what implementation of the ordinance is intended to accomplish. The objectives can be regulatory based (e.g., meet Phase II requirements), resource based (e.g., minimize increases in nonpoint source pollution), or both. Importantly, the goals and objectives set the stage for selecting appropriate performance standards and criteria, and for encouraging LID techniques.

3.2.2 Performance Criteria Encouraging LID Techniques

The examples below reflect key elements of progressive stormwater programs' approaches to using performance criteria to encourage LID:

Example 1 - Huntersville's Performance Standards

a) "All stormwater treatment systems used to meet these performance criteria shall be designed to achieve average annual 85 percent Total Suspended Solids (TSS) removal for the developed area of a site. Areas designated as open space that are not developed do not require stormwater treatment. All sites must employ LID practices to control and treat runoff from the first inch of rainfall.

b) LID practices or a combination of LID practices and conventional stormwater management practices shall be used to control and treat the increase in stormwater runoff volume associated with post-construction conditions as compared with pre-construction (existing) conditions for the

2-yr frequency, 24-hr duration storm event in the Rural and Transitional Zoning Districts. All other zoning districts shall meet this standard for the 1-yr frequency, 24-hr duration event.

c) Where any stormwater BMP employs the use of a temporary water quality storage pool as a part of the treatment system, the drawdown time shall be a minimum of 48 hours and a maximum of 120 hours.

d) Peak stormwater runoff rates shall be controlled for all development above 12 percent imperviousness (for the 2-yr, 24-hr and the 10-yr, 24-hr storm events). The emergency overflow and outlet works shall be capable of safely passing a discharge with a minimum recurrence frequency of 50 years.

e) No one BMP shall receive runoff from an area greater than 5 acres."

The town also has Open Space performance standards (see Table 3-1). It is important to note that in revising its development ordinance, Huntersville tested using significant open space requirements (35 percent or 40 percent) as its primary stormwater management technique for its rural residential and traditional neighborhood zones, but found that development on the remaining 60 percent of the tract generated significantly more stormwater volume and pollutant loading compared to the predevelopment conditions. Therefore Huntersville adopted open space standards that work in tandem with the stormwater performance standards.

Table 3-1. Open Space and Density Requirements for Huntersville's Rural Residential and Traditional Neighborhood-Rural Zoning Districts

Amount of Open Space Provided	Density Permitted
0% unless tract is within a proposed greenway in which case the greenway shall be designated as open space	0.33 units per Adjusted Tract Acreage
25% - 29.9% Open Space	0.4 units per Adjusted Tract Acreage
30% - 34.9% Open Space	0.6 units per Adjusted Tract Acreage
35% - 39.9% Open Space	0.8 units per Adjusted Tract Acreage
40% - 44.9% Open Space	1.0 unit per Adjusted Tract Acreage
45%+ Open Space	1.2 units per Adjusted Tract Acreage

Note that the performance standards required by the Town of Chapel Hill are similar to the Huntersville standards, with the following exceptions: Chapel Hill requires volume control for the 2-yr, 24-hr storm event throughout its jurisdiction. The stormwater runoff rate is controlled for the 1-, 2-, and 25-year, 24-hour storm event (rather than the 2- and 10-year storm events). The Town of Chapel Hill encourages rather than requires LID to meet its performance standards. The University of North Carolina took the lead in developing and adopting these performance standards for new development on its Central Campus. The Town, in development and discussion of its Land Use Management Ordinance, adopted the University's standards, providing for a unified stormwater management approach throughout its jurisdiction. **Based on Tetra Tech's review of stormwater performance standards in other communities, no community in the country has stronger standards than the Town of Chapel Hill.**

Each of the programs described above stipulates certain activities or types of development that are exempt from the guidelines and regulations described above. Those regulatory exemptions are as follows:

Town of Huntersville: Any new development, redevelopment or expansions that include the creation or addition of less than 5,000 sq.ft. of new imperviousness.

Town of Chapel Hill: Single family and two family developments and redevelopments that do not disturb more than 5,000 sq.ft. of land area, provided they are not part of a larger common development plan, are exempted.

Example 2 - Upper Neuse River Basin, NC and Rockdale County, GA

As a part of implementation of its nitrogen TMDL and development of a watershed management plan to protect drinking water supplies and stream habitat, the Upper Neuse River Basin Association developed and endorsed the performance standards listed in Table 3-2. The onsite targets presented in Table 3-2 reflect the performance standards that developments were required to meet for each of the parameters listed. Use of LID is encouraged to meet the performance standards.

Table 3-2. Upper Neuse River Basin Performance Standards

Land Use	Onsite Target (lb/ac/yr)
Nitrogen	
Rural/Conservation Area	3.78
Urban Area	3.6 to 10 (maximum) (TMDL)
Phosphorus	
Rural/Conservation Area	0.54
Urban Area	1.08
Stream Buffers	
Rural/Conservation Area	100 feet (min)
Urban Area	50 feet (TMDL) (min)
Enhanced Peak Flow Control	
All Areas	For new developments with greater than or equal to 10% total impervious cover

Rockdale County, GA has adopted a similar approach to performance standards. Based on its watershed study, the county established performance standards for new development:

- Urban Area - 56 percent removal TP, 78 percent removal TSS, 57 percent removal Copper. These standards must be met by new developments in the City of Conyers (existing municipal jurisdiction and planned, long-term sewer service area);
- Suburban/Rural Area - 52 percent removal TP, 72 percent removal TSS, 51 percent removal Copper. These standards must be met by new developments in the county jurisdiction, excluding the drinking water supply watershed and urban area; and
- Rural Residential (Water Supply Watershed) Area – 1 unit /3 acres.

Rockdale County encourages LID in meeting these standards.

Each of the programs described above stipulates certain activities or types of development that are exempt from the guidelines and regulations described above. Those regulatory exemptions are as follows:

Rockdale County, GA: any development or redevelopment less than 7 percent imperviousness is exempted from enhanced volume control. Otherwise, GA Phase II stormwater control thresholds apply.

Upper Neuse: enhanced volume control not recommended for developments less than 10 percent imperviousness.

Example 3 - Portland, OR

"The quality of stormwater leaving the site after development shall be equal to or better than the quality of stormwater leaving the site before development, as much as is practicable, based on the following criteria:

a) Water quality control facilities required for development shall be designed, installed and maintained in accordance with the Stormwater Management Manual, which is based on achieving at least 70 percent removal of the Total Suspended Solids from the flow entering the facility for the design storm specified in the Stormwater Management Manual.

b) Land use activities of particular concern as pollution sources shall be required to implement additional pollution controls, including, but not limited to, those management practices specified in the Stormwater Management Manual.

c) Development in a watershed that drains to streams with established Total Maximum Daily Load limitations, as provided under the Federal Clean Water Act, Oregon Law, Administrative Rules, and other legal mechanisms shall assure that water quality control facilities meet the requirements for pollutants of concern, as stated in the Stormwater Management Manual."

d) Note: additional criteria follow related to implementing these criteria on site or on an offsite facility. Otherwise, there is an option for payment in lieu.

"The quantity of stormwater leaving the site after development shall be equal to or less than the quantity of stormwater leaving the site before development, as much as is practicable, based on the following criteria:

a) Development shall mitigate all project impervious surfaces through retention and onsite infiltration to the maximum extent practicable. Where onsite retention is not possible, development shall detain stormwater through a combination of provisions that prevent an increased rate of flow leaving the site during a range of storm frequencies as specified in the Stormwater Management Manual.

b) The Director may exempt areas of the City from the requirement a. above if flow control is not needed or desirable and if stormwater is discharged to a large waterbody directly through a private outfall or if stormwater is discharged to a waterbody directly through a separated public storm sewer having adequate capacity to convey the additional flow.

c) Any development that contributes discharge to a tributary to the Willamette River shall design facilities such that the rate of flow discharging from water quantity control facilities for up to the two-year storm does not lengthen the period of time the channel sustains erosion-causing flows, as determined by the Bureau. (Note: This criterion is required due to evidence of excessive stream bank erosion and channel erosion in most tributary streams in Portland.)

d) Facilities shall be designed to safely convey the less frequent, higher flows through or around facilities without damage.

Note: additional criteria follow related to implementing these criteria on site or on an offsite facility. Otherwise, there is an option for payment in lieu.

<u>Regulatory Exemptions:</u>

Developments less than 15,000 sq.ft. are exempted from detention (devices with orifices); development less than 500 sq.ft. is exempted from retention."

3.3 PENDING STATE MINIMUM REQUIREMENTS

DENR has designated Carrboro, Chapel Hill, and Orange County as a Phase II NPDES community. Designated Phase II communities were required to submit their NPDES applications for compliance with the Phase II Stormwater Regulations in March 2003. Municipalities have two years to adopt and begin implementation of a post-construction ordinance (from the date of application approval). Unincorporated areas must comply with the post-construction stormwater requirements by July 1, 2006. The local ordinance and stormwater management program must meet and implement the state's minimum performance standards. Chapel Hill and Carrboro have submitted their applications. No application has been filed by Orange County, which is contesting its Phase II designation.

SB 1210 requires that individual NPDES stormwater permittees at least meet the Interim Stormwater Management Rule. Those developments covered under a General Phase II Stormwater Permit can not be asked to meet requirements more stringent than the Interim Rule. Therefore, the Interim Rule provides insight into the performance standards the state will likely require for new development:

Total Suspended Solids (TSS) Treatment (all new development > 15 percent impervious)

–85 percent average annual removal

Volume Control (all new development one acre or more and greater than 24 percent impervious)

–Control and treat increased stormwater volume (post development) from 1-yr, 24-hr storm

Regulatory Exemptions:

TSS Treatment: development less than or equal to 15 percent imperviousness is exempted
Volume control: development less than or equal to 24 percent imperviousness is exempted

In comparing the regulatory performance standards for the state's pending Phase II requirements to the performance standards from the progressive ordinances (i.e. those that encourage or require LID techniques), with few exceptions, the progressive standards are more protective (i.e., stricter standards for both treatment and volume control). Also, the progressive ordinances apply the requirements to most new development and allow fewer exemptions than the pending state requirements. For example, the Town of Huntersville exempts any new development, redevelopment or expansions that include the creation or addition of less than 5,000 sq.ft. of new imperviousness. The Town of Chapel Hill exempts single family and two family developments and redevelopments that do not disturb more than 5,000 sq.ft. of land area. The Upper Neuse River Basin Association recommends exempting developments that are less than 10 percent impervious from peak flow control requirements, while Rockdale County exempts developments that are less than 7 percent impervious. Under the pending Phase II requirements, development less than or equal to 15 percent imperviousness is exempted from TSS Treatment, while development less than or equal to 24 percent imperviousness is exempted from volume control.

Based on studies (Center for Watershed Protection, 2000) of the relationship between the extent of watershed imperviousness and habitat and water quality impairment, degradation can be expected within watersheds with more than 10 percent imperviousness. Depending on the natural characteristics of the watershed, this threshold may be somewhat lower or higher. Therefore, if local governments adopt stormwater management ordinances pursuant to the state's Phase II requirements, a significant number of developments will likely be exempted from stormwater volume control that can cause downstream degradation. Tetra Tech would recommend that the LWP local governments either adopt standards similar to the progressive communities, or if adopting the Phase II NPDES standards, use a minimum threshold of 10 percent imperviousness for application of the stormwater treatment and volume control requirements. As noted previously, if a local government requests to be covered by the NPDES Phase II General Permit, developments cannot be required to meet standards more stringent than those outlined above (i.e., the Phase II Temporary Rule requirements). Therefore, Tetra Tech would recommend that local governments in the LWP study area apply for individual permits from DWQ to enable them to retain or adopt more protective regulations.

3.3.1 Evaluation of Three LWP Stormwater Ordinances

Tetra Tech reviewed portions of Carrboro's, Chapel Hill's, and Orange County's stormwater management ordinances, or development ordinance sections devoted to stormwater management. Where available, Tetra Tech also reviewed their Phase II stormwater permit applications outlining the intent to revise or upgrade ordinances to meet new Phase II requirements. Tetra Tech then compared the existing ordinances to elements of a strong/progressive stormwater program (clear goals and objectives, strong performance standards, and buffer requirements) and to Phase II requirements. Each local program's strengths, gaps and opportunities are described in the following sections. These three local governments represent the main jurisdictions in the Morgan LWP study area.

Carrboro

The Town of Carrboro staff forwarded relevant portions of the Carrboro Land Use Ordinance as well as the town's NPDES Phase II permit application to Tetra Tech for evaluation. Section 15-263 (Stormwater Management) provides a general policy and standard related to property damage stipulating that all developments shall be constructed and maintained so that they do not cause storm-related damage to upstream or downstream properties. The ordinance further states:

> *Compliance with this standard shall be determined in reference to storm events up to the 100-year storm for upstream properties and up to the 25-year storm for the downstream properties. To achieve this objective, the potential impact on surface water quantity and quality from all proposed developments requiring special use or conditional use permits shall be identified and evaluated.*

The storm events referenced above are traditionally associated with evaluations to mitigate flooding and property damage associated with flooding. Missing from the ordinance are clear goals, objectives, and performance standards related to stream channel and stream bank stability and water quality. On an administrative level, the town staff and contract engineer evaluate the adequacy of the developer's stormwater impact statement using a treatment performance standard of 85 percent removal of TSS and peak discharge matching for pre- and post-development conditions for the 2-, 5-, 10-, and 25-year storm events. The town, using the impact statement, also checks on potential impacts from the 100-yr storm. The town believes that having a general goal and putting the burden on the developer to show the impact, allows for working and negotiating with developers on a project-by-project basis (per conversation with Mr. Henry Wells, Town of Carrboro Contract Engineer). The impact statement is required only for developments needing a special use or conditional use permit; all individual single family and two family residences are exempted (regardless of impervious level or land disturbance).

At this time, the town does not have a total volume control/treatment requirement (e.g., control and treat increased stormwater volume (post-development) from 1-yr, 24-hr storm or the 2-yr, 24-hr storm event), which can be a more stringent standard than controlling for the peak discharge. Most progressive ordinances and the Phase II requirements have total volume control performance standards.

The Town of Carrboro has strong stream buffer requirements (Sections 15-264 through 15-269), and open space requirements (Section 15-198). Creek and tributary buffers are 50 ft from the edge of the floodplain plus a distance of 4 x slope x 100. Intermittent stream buffers are 50 ft from steam centerline (unless in University Lake watershed, which is 100 ft from centerline). In the Bolin Creek watershed, buffer requirements are even stronger: 100 ft from centerline for creeks; 60 ft for intermittent streams; 30 ft for minor intermittent streams. The town has a 40 percent open space requirement for new development (the stream buffers can help meet this open space requirement).

The peak discharge and TSS performance standards, along with the buffer and open space requirements, form the core of the town's post-construction stormwater management program; these are also the standards/requirements that the town intends to use to meet Phase II requirements. As noted in the Town of Huntersville example, Huntersville explored using a strong open space requirement (30 to 40 percent) and buffer rules along with the state's minimum water supply protection rules (treatment of runoff from the first inch of rainfall for development greater than 24 percent impervious). When the Town of Huntersville tested how adequate this approach was in mitigating development impacts, it found that significant degradation could still occur. Based on that analysis, Huntersville strengthened its stormwater ordinance performance standards.

Note: In the University Lake drinking water supply watershed, the town has strong impervious surface limits for residential development (4 percent impervious cap). Commercial development is allowed up to 24 percent imperviousness, but must retain the first inch of rainfall.

In comparing the town's existing regulations to the Phase II Interim Rule, it appears that the existing rules at least partially meet the interim regulations (control and treat the difference in volume between the pre- and post-development conditions for the 1-yr, 24-hr storm event). Additional analysis is needed to determine the adequacy of the town's stormwater management and open space regulations in meeting the Phase II Interim Rule. Also, to meet the state's minimum Phase II NPDES stormwater requirements, the town will need to add provisions to its stormwater ordinances and program for inspecting and monitoring BMPs to ensure they are performing as intended.

<u>Opportunities for Strengthening the Town's Stormwater Ordinance</u>

When the Town adopts its Phase II stormwater ordinance, it has the opportunity to clarify, formalize, and strengthen its stormwater management regulations. Key areas to focus on include:

- Develop and adopt a clear goal statement for the town's stormwater management program, and include it in the stormwater ordinance.
- Develop and adopt clear objectives related to natural resource protection, and include these in the stormwater ordinance.
- Based on goals and objectives, evaluate the effectiveness of existing regulations, Phase II requirements, or stronger standards in meeting the town's goals.
- Enhance performance standards, particularly for stormwater volume control. If adopting Phase II minimum requirements, use stronger "thresholds" of applicability: instead of 24 percent imperviousness, use at minimum 10 percent imperviousness as the threshold for treatment and volume control. Consider adopting even stronger performance standards than minimum Phase II requirements, using the progressive community examples as models. Apply the standards to all new developments and redevelopment, not only to special use and conditional use permits.
- Add provisions for inspecting and monitoring the BMPs to ensure they are working properly.

Chapel Hill

In 2003, the Town of Chapel Hill adopted a new stormwater ordinance. The ordinance has very clear goals, objectives, and performance standards. The threshold of applicability is strong, allowing few development exemptions. The town's ordinance is a model for other communities. It clearly meets the Phase II Interim Rules.

Chapel Hill has strong stream buffer requirements through its Resource Conservation District Ordinance. New development is required to preserve a 150-ft stream buffer (each side of the stream).

Redevelopment or development in the Downtown or Community Commercial Districts may find it difficult at times to meet these performance standards onsite. The town may wish to develop a mechanism for partial offsite mitigation.

Opportunities for Strengthening the Town's Stormwater Ordinance:

- For the Downtown or Community Commercial Districts, some projects may find it very difficult to meet the performance standard on-site. In order to not penalize the developer or create an incentive for a variance to the stormwater performance standard, the town could create a mechanism for partial offsite mitigation (i.e., the developer would have to provide for some onsite stormwater management, but provide the rest offsite). High priority watersheds could be targeted for preservation or restoration efforts. At minimum, the state's phase II requirements must be met in these areas.

Orange County

Most of Orange County's jurisdiction in the Morgan Creek LWP is in the University Lake Watershed. The county's University Lake (drinking) water supply protection overlay zone requires a maximum density of 1 unit per 5 acres and 6 percent impervious cap on development. Modeling during the Detailed Assessment showed that these drinking water supply protection standards also met other habitat and water quality objectives. The county also has strong buffer requirements: 50-ft minimum measured from the 100-year floodplain.

Opportunities for Strengthening the County's Stormwater Ordinance:

- As noted above, for the University Lake Watershed (Upper Morgan Creek), the county's existing performance standards are sufficiently strong to meet multiple objectives including but not limited to drinking water supply protection. In a Phase II Stormwater Ordinance or other amendments to the existing development ordinance, the county should broaden the scope of its stormwater management authority, and formally adopt other habitat and water quality goals and objectives.
- Although not a high priority area, the Lower Morgan Creek 6 area near Jordan Lake faces continued development pressure. The rural buffer regulations (1 unit per 2 acres) should, at minimum, be coupled with the state's Phase II stormwater management requirements, or stormwater management performance standards that provide additional protection in this area. Protection of this are could also be improved if similar measures were adopted for the Chatham County portion of this subwatershed.

As noted previously, DENR is currently developing a phosphorus and nitrogen TMDL for the Upper New Hope Creek arm of Jordan Lake, including the LWP study area. While the exact TMDL is still undecided, all parties have agreed that, at minimum, the total nonpoint source loading should be capped at existing levels. Whether this load target or a more stringent load target is adopted, the TMDL will clearly require additional controls on new development and redevelopment. The final TMDL will determine the extent to which local governments must go beyond their existing regulations and Phase II requirements in reducing phosphorus and nitrogen loads from new development.

Table 3 summarizes opportunities for strengthening the local stormwater ordinances.

Table 3-3. Opportunities for Strengthening Stormwater Ordinances

Jurisdiction	Meeting Elements of Progressive Stormwater Management Programs				Meeting Pending State Requirements	
	Clear Goals and Objectives	**Strong Performance Standards**	**Applicability and Exemptions**	**Stream Buffers**	**Phase II Stormwater Rules**	**Nutrient TMDL**
Carrboro	○	◐	◐	●	◐	*
Chapel Hill	●	●	●	●	●	*
Orange Co.	○	●	●	●	●	*

○ BigGap/Opportunity

◐ Moderate Gap/Opportunity

● Meets Element/Requirement

* TMDL requirements still pending at the time of report production.

3.4 ELEMENTS OF EFFECTIVE SITE DESIGN

A strong stormwater ordinance is only half of the equation for effective stormwater management. A local government also needs to have a development ordinance that allows – or even encourages – effective site design for reducing and managing stormwater. This section describes the concepts and elements of LID, summarizes a survey of LWP communities regarding LID practices, and recommends ways to strengthen existing regulations.

3.4.1 What is Effective Site Design?

Tetra Tech recommends that local governments encourage developers to follow low-impact stormwater design principles for high-density and rural, low-density areas. The fundamental concepts of LID design are:

- Using hydrology as the integrating framework for site design.
- Preserving (and creating) a multifunctional landscape.
- Focusing on micromanagement of stormwater.
- Controlling stormwater at the source.
- Using simple, nonstructural methods where possible.

LID design, although it is called innovative, actually combines time-proven site design methods for minimizing stormwater runoff in a way that enhances water quality protection and the aesthetics of the site. The approach offers a wide range of techniques, which can vary depending on the site and its planned use. These techniques include:

- Minimizing disturbance to conserve forested or natural areas onsite.
- Designing and using smaller parking lots and parking stalls and shared parking agreements.
- Managing and treating stormwater through the use of conditioned planting soil beds and planting materials (e.g., bioretention cells and wetlands) (Figure 3-1).

- Designing narrower streets integrated with open drainage (e.g., grass swales) (Figure 3-2).
- Using conservation design with clustered buildings and preserved open space.
- Disconnecting impervious surfaces and associated runoff (e.g., rooftop runoff) from stormwater sewer system (Figure 3-3).
- Preserving riparian buffers.

Through minimized impervious area and maximized retention of the rainwater onsite, the designer can closely replicate pre-development runoff conditions. If it is a highly impervious area, other stormwater storage and detention facilities may be needed such as dry wells, ponds, and inlet devices, to help lower the peak volume discharge to pre-development conditions.

Figure 3-1. Bioretention Cell at University Mall

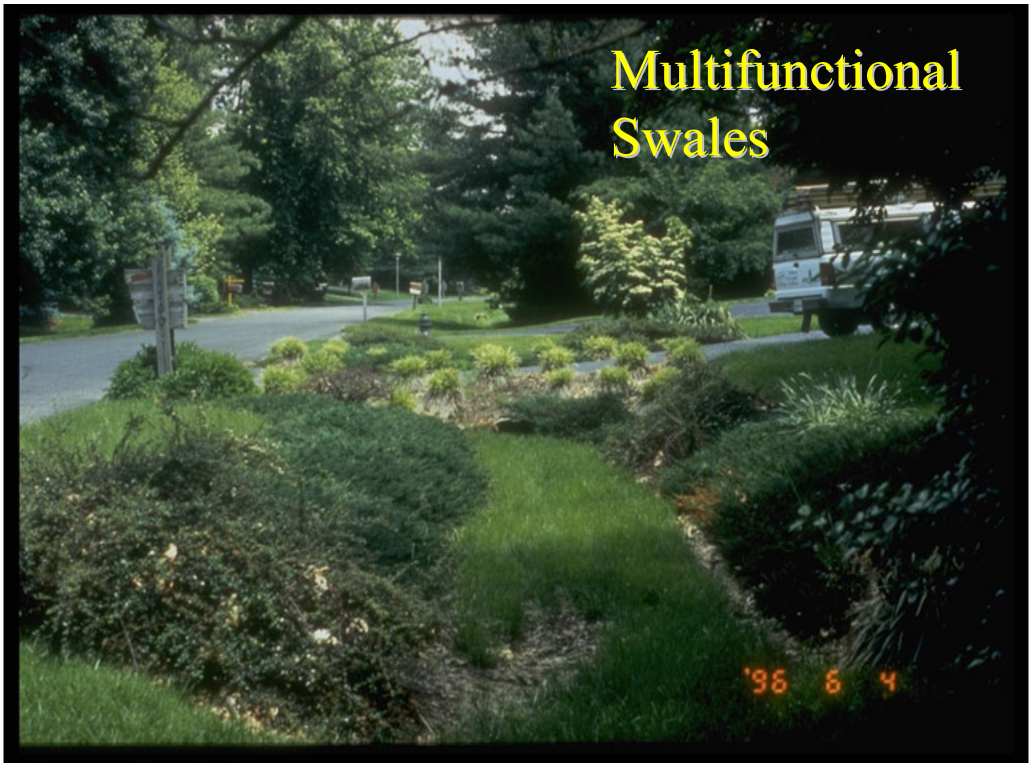

Figure 3-2. Dry Swale

Figure 3-3. Dry Well

Low-Impact Site Design

Local governments and developers practicing LID design over the last decade have developed some tools and methods for doing so. They have provided useful guidelines for low-impact site design, which include the following steps:

1) Identify applicable zoning, land use, subdivision, and other local regulations.
2) Define development envelope and protected areas (reduce limits of clearing and grading; use site fingerprinting).
3) Use drainage/hydrology as a design element.
4) Reduce/minimize total impervious area.
5) Develop integrated preliminary site plan.
6) Minimize directly connected impervious areas.
7) Modify/increase drainage flow paths.
8) Compare pre- and post-development hydrology (using hydrologic analysis).
9) Complete site plan.

Based on local governments' experience, USEPA, the Center for Watershed Protection, and others have developed a number of "how to" LID design documents. In taking the first step toward LID, i.e., identifying applicable zoning and land use regulations, the Center for Watershed Protection developed Better Site Design: A Handbook for Changing Development Rules in Your Community (1998). The Guide includes a Code and Ordinance Worksheet, which is a tool for reviewing the standards, ordinances, and codes that shape how development occurs in a community and how the local rules compare to the principles of better site design. In addition, the USEPA has produced a series of documents on LID. The first in the series is *Low-Impact Development Design Strategies, An Integrated Approach* (1999). This and other LID manuals are at: http://www.epa.gov/owow/nps/urban.html.

Evaluating Management Practices

The selection of good stormwater management practices depends on the type and intensity of land use and the conditions onsite such as soils and slopes. For the purposes of helping evaluate the effectiveness of BMPs in suburban and urban settings, Tetra Tech grouped similar types of development land uses that Triangle counties and municipalities are experiencing today. For each grouping, we recommend best management practices to consider incorporating into site designs. Appendix B, Attachment A provides tables for helping evaluate effective and appropriate BMPs for urban and suburban developments.

One feature of LID is spreading stormwater management techniques, both landscape and engineered, throughout the site to manage stormwater at its source and, wherever possible, linking stormwater BMPs onsite to create a "treatment train." Recent studies have shown that these LID techniques can significantly reduce stormwater volume, sediment, nutrient, and metals loading compared to conventional stormwater management. Depending on the site design and land uses, LID can also decrease the costs of infrastructure and best management practices.

3.4.2 Summary of Local Governments LID Design Survey

As a part of this project, the Cape Fear River Assembly worked with the staff from Carrboro, Chapel Hill, and Orange County to administer the *Better Site Design Handbook*'s Code and Ordinance Worksheet. The worksheet has a scoring/point system which helps evaluate how well local practices meet better site design principles. The scoring ranges include:

Score	Evaluation
90-100:	Community has above average provisions that promote the protection of streams and lakes.
80-89:	Local development rules are good, but could use minor adjustments or revisions in some areas.
70-79:	Opportunities exist to improve development rules. Consider creating a site planning roundtable.
60-69:	Development rules are likely inadequate to protect aquatic resources. A site planning roundtable would be very useful.
Less than 60:	Development rules are definitely not environmentally friendly. Serious reform is needed.

Staff from each community's planning department reviewed their respective ordinances and completed the worksheet, including the assigned scoring. Cape Fear River Assembly staff noted that the Morgan Creek LWP jurisdictions scored higher than any other jurisdictions surveyed in the Cape Fear Basin. The Town of Carrboro scored 81, indicating good rules, minor adjustments needed. The Town of Chapel Hill scored 71, indicating that opportunities still exist to improve development rules. Since many of the points related to urban issues, the overall point system was not applicable to Orange County's ordinance. The county had an average score on design issues related to rural development in the Cape Fear Basin, indicating opportunities for improvement.

The worksheet exercise helped staff identify areas of the development ordinance that could be strengthened. In addition, Tetra Tech talked with staff to discern what the ordinances allow versus what the town encourages and discourages "on the ground." Based on the survey and follow-up conversations, below is a summary of key opportunities that offer the most potential for strengthening habitat and water quality protection.

All Jurisdictions (Carrboro, Chapel Hill, Orange County):

- Encourage pervious pavement material for residential applications for ultra-urban infill or redevelopment (e.g., downtown Carrboro or Chapel Hill) and for nonresidential developments that have a minimum of 50 parking stalls. Recently, Tetra Tech has worked with Bill Hunt of NCSU and Bradley Bennett of DWQ's stormwater program to develop more detailed guidance on the use of pervious pavement materials in piedmont North Carolina. Appendix B, Attachment B provides more details in design, maintenance, and installation (see Section 3.4.3 for descriptions of UNC park and ride lots using pervious pavement).
- Develop and adopt a maximum parking requirement.
- Require at least 30 percent of parking spaces at large commercial lots to have smaller dimensions for compact cars.
- Encourage use of 4-ft wide sidewalks, where sidewalks are built.
- Reduce residential setback and frontage requirements (front setbacks for ½ acre lot –20 ft or less; rear setbacks for ½ acre lot –25 ft or less; side setbacks for ½ acre lot –8 ft or less. (For the county, this would be appropriate for "cluster design" residential development.)

Carrboro only:

- Encourage water quality swales in place of curb and gutter (where there is low to moderate slope). (Note: The town does allow swales, but according to staff, does not encourage them. In some areas where swales have been used, two problems have occurred: swales were used in steeply sloped areas and now are eroding and were built so deep as to pose a safety problem for children. Also, citizens do not want to maintain (or mow) the swales. The first two problems can be handled with proper design; the latter could be addressed through town maintenance).

- Provide incentives for parking garages rather than parking lots (especially in town center).

Chapel Hill only:

- Encourage water quality swales in place of curb and gutter (where there is low to moderate slope).
- Reduce the minimum right-of-way width for a residential street to less than 45 ft.
- Develop and adopt street standards that promote efficient street layout and reduce overall street length.
- Reduce minimum radius allowed for a cul-de-sac to 35 ft or less and allow alternative turnarounds such as hammerheads.
- Slope sidewalks to yards.
- Reduce minimum driveway width (9 ft or less for single lane and 18 ft or less for double lane).
- If forest or specimen trees are present at a residential development, require that some of the stand be preserved.

Orange County:

- Reduce the minimum right-of-way width for a residential street to less than 45 ft.
- Develop and adopt street standards that promote efficient street layout and reduce overall street length.
- Allow sidewalks on one side of residential streets instead of requiring them on both sides.
- Slope sidewalks to yards.
- Require that at least some part of the stream buffer be maintained in native vegetation. (Note: the county's regulations for the Cape Fear Basin require that existing vegetation be maintained or replaced with new vegetation that will provide similar drainage characteristics. This wording does not require that property owners plant or maintain the buffers with native vegetation.)
- Develop and adopt ordinance provisions that limit clearing and grading and encourage the preservation of natural vegetation at residential development sites.
- If forest or specimen trees are present in a residential development, require that some of the stand be preserved.
- Provide flexibility to meet stormwater management or conservation restrictions (density compensation, transfer of development rights, offsite mitigation). Target high priority watersheds for offsite mitigation.
- Do not allow stormwater to be directly discharged into a jurisdictional wetland without pretreatment. (At this time, Orange County does not allow such discharges in the Neuse Basin, but does allow them in the Cape Fear Basin.)

Tetra Tech recommends making the ordinance revisions highlighted above, either through a holistic "roundtable process" described in the *Better Site Design Handbook*, or incrementally through text amendments. However, as noted in conversations with staff, many LID elements are currently allowed in the local ordinances, but are not encouraged and in some cases discouraged. Therefore, Tetra Tech recommends that each jurisdiction work interdepartmentally—with the Planning, Engineering and Public Works Departments—to resolve issues and remove barriers which are currently blocking use of the above LID practices. Once these internal issues have been resolved, and ordinances revised as needed, Tetra Tech recommends that local jurisdictions meet with development applicants early in the process to educate them about LID techniques and to discuss their potential use in the project. Use of a "checklist" in this process can proactively encourage LID. Appendix B, Attachment C provides an example checklist for local governments to consider.

3.4.3 Example Developments Using LID Techniques

Several planned developments recently approved in Chapel Hill and Carrboro are incorporating LID principles and techniques. Below is a highlight of a few of these developments, including their size, types of land uses, performance standards met, and stormwater management techniques used.

Winmore

Winmore is a 66-acre tract of land off of Homestead Road, north of downtown Carrboro. Located in the "transition zone" planned for future urban development, a large portion of the acreage was farmland in recent decades and is now second-growth forest. It is a hilly area with a lowland around Bolin Creek rising 67 feet to the peak of a hill on which Winmore village will sit. The land use is "village mixed use," which is planned to include a village green surrounded by townhouses and live-work units (small retail shops on street, living areas above) and approximately 100 townhouses and 100 single family lots on a street and alley grid that follows traditional neighborhood street patterns. Additionally, there will be two 24-unit apartment buildings, which combined with Habit for Humanity single family houses, will constitute the 15 percent residential that meet Town of Carrboro affordability guidelines.

Green site planning and building principles is an important concept for Winmore (per Glenn Parks, Architect with Phil Szostak and Associates, developer of Winmore). Areas outside the flood plain of Bolin Creek where natural wetlands exist or could be built to catch run-off have been identified. Forty-two percent of the tract will be preserved in open space.

The stormwater design for Winmore follows Town of Carrboro design standards. According to Mr. Parks, Winmore will employ both hard and soft wastewater management techniques. A "hard" technique involves directing rainwater to street drains connected to pipes which deliver the water to a concrete box called a "hydro-dynamic separator." A hydro-dynamic separator is an underground area that stores water for a period of time to allow accumulated solids to settle before water is further transported to a creek. Each box removes at least 85 percent of solids before water is released.

Of the "soft techniques," Szostak and Associates investigated a "linear infiltration system," use of grass swales, and constructed wetlands. Poor soil permeability precluded the use of the linear infiltration system. Grass swales are employed through the open space along the entrance parkway. Of constructed wetland types, Winmore will employ the *free water surface constructed wetland* consisting of a shallow pool planted with emergent vegetation (vegetation which is rooted in the sediment but with leaves at or above the water surface.)

There are four types of *free water surface constructed wetlands*:

- Shallow marsh
- Extended Detention
- Pond/Wetland System
- Pocket Wetland

Winmore will use the pond/wetland and pocket wetland types. There will be one major pond/wetland feature. It has two cells: a wet pond and a shallow marsh. The wet pond traps sediments and reduces runoff velocities prior to entry into the wetland. At this time, the developers of Winmore are also assessing the feasibility of converting required erosion control sediment traps into pocket wetlands.

The "hard" and "soft" management techniques are designed to complement each other, so that pollutant removal can meet and exceed town standards. Additionally, the "soft" techniques are seen as aesthetic site amenities as well as reminders of the interdependence of urban activities, urban wildlife, and water quality.

University of North Carolina Central Campus Stormwater Management Plan

The University of North Carolina in Chapel Hill has completed a stormwater management plan for its planned development over the next eight years on Central Campus. The campus, comprising approximately 740 acres, includes five subwatersheds. Changes from existing to projected landscape and impervious cover were evaluated for each subwatershed, including resultant changes in stormwater runoff volume for the 2-year, 24-hour storm event. Structural and non-structural measures were evaluated to meet the university's and the town's strong performance standards (control and treat the increase in stormwater runoff volume associated with post-construction conditions as compared with pre-construction (existing) conditions for the 2-yr frequency, 24-hr duration storm event, etc.). Based on that assessment, the plan proposed structural and non-structural systems, including their locations on campus, sizes and related costs.

The following *structural systems* were proposed in the Draft Plan:

- Convert existing lawn area to rain gardens 9.91 acres
- Convert impervious surface to rain gardens 1.53 acre
- Convert existing planted areas to rain gardens 6.06 acres
- Plant street trees in a continuous trench 1.64 acres
- Pervious paving systems with infiltration/storage 1.93 acres
- Green roof plazas over buildings and parking areas 2.69 acres
- Surface pond and wetlands for treatment and storage .53 acres
- Retrofit parking islands to receive stormwater runoff .19 acres
    - Infiltration trench
    - Bio-swale

The above structural controls comprise over 22 acres of the campus. However, most of these acres designed for stormwater control are integrated into the landscape or building design (rather than dead space dedicated only to stormwater management), and help meet other goals such as those related to open space, aesthetic design, and conservation).

The following non-structural measures were recommended:

- Street sweeping and vacuum removal
- Reduction in chemical and salt application

- Land cover type conversion
  - Restore managed woodland to forest 16.42 acres
  - Convert existing lawn to planted areas 23.42 acres
  - Convert lawn to old field meadow 6.32 acres
  - Convert rough grass to old field meadow 1.87 acres
  - Convert rough grass to planted area 1.61 acres
  - Convert impervious area to planted area 9.84 acres
  - Convert impervious area to old field meadow 0.42 acres

Street sweeping and reductions in chemical/salt application are recommended to reduce the amount of pollutants that enter the storm sewer system (and the streams). The land cover conversions are land management strategies intended to optimize infiltration and storage of stormwater, thus reducing stormwater runoff.

The university has begun to implement the stormwater management plan through several BMP case studies or pilot projects. Carmichael Field, intramural field #3, is a water storage and irrigation system. A subsurface stormwater storage system comprised of a large stone bed drains a 5-acre area and provides storage for more than 550,000 gallons of water and rescue opportunities for irrigation. Stormwater from existing stormwater piping is redirected into two Vortechs solids separator units, enabling solids to separate out before entering the storage area.

The Friday Center Park and Ride Lot is a stormwater storage parking area, and is the largest pervious pavement parking lot in North Carolina. The parking lot is designed for the 100-yr storm. Underground is a stepped bed system with cells to mitigate stormwater volume and peak flow control, such that post-development (paved) total site runoff is less than predevelopment (wooded) total site runoff. The Estes Drive Park and Ride Lot is also a pervious parking area, using pervious asphalt. Both of these lots are being monitored for water quality and volume control.

Currently, the university is designing a vegetated roof for the new Rams Head Plaza Parking Garage. This will be a three-story parking facility with a two-story campus recreation building and student dining facility. Plaza level planting beds will be capable of absorbing the first flush of runoff from the impervious surfaces, which will include walkways and the recreation and dining building roofs. The roof leaders from the dining and recreation buildings will be directly connected to perforated pipes below the finished grade of the plaza to help supply water to the turf and plantings. Cisterns that collect runoff from the rooftops will supply the irrigation system on the plaza, which will be augmented by the university's water supply. Stormwater storage will also occur in a layer of Rainstore cisterns that will lie below the plaza's pavers.

Pacifica

Pacifica is an eight-acre housing development recently approved in Carrboro. With 46 homes clustered on 4.5 acres, 30 percent of the tract is undisturbed open space, while 13 percent is managed open space (playing field, bioretention areas, community garden, etc.). For stormwater runoff that is generated from the developed area, Pacifica uses treatment train approaches across the site. A primary objective of these approaches is to treat the stormwater as close to its point of origin as possible. According to Joanna Massey of Carrboro Collaborative, the goals of the proposed Pacifica project's treatment train approach to stormwater management are to have aesthetic and effective solutions to:

- Capturing stormwater.
- Providing opportunities for treating stormwater.

- Reducing the use of potable water for non-potable uses.
- Providing opportunities to maintain pre-development surface, groundwater, and evapotranspiration components of the site's hydrologic budget.
- Meeting the Town of Carrboro's and the State of North Carolina's requirements for water quality.

Pacifica is using the following LID techniques in its treatment trains:

- Vegetated Swales
- Filter and Buffer Strips
- Bioretention Areas
- Irrigation Pond
- Level Spreaders
- Pervious Pavement (pervious concrete in parking spaces and some sidewalks, pervious patios on houses, etc.).

It is also using a stormwater storage cistern in the development's "common house."

Developers of Pacifica anticipate that the design of the stormwater management system will exceed the Town of Carrboro's requirements for stormwater quality and volume control as well as address removal of other significant pollutants such as nitrogen and phosphorus.

3.5 Summary and Recommended High Priority Actions

3.5.1 Summary of Stormwater Management Ordinances and Site Design Practices

The Town of Chapel Hill and UNC are leaders in the region and the country in their stormwater management ordinances and performance standards for new development, clearly meeting the state's Phase II stormwater management requirements. Orange County also has very strong performance standards for the majority of its jurisdiction in the Morgan Creek LWP study area—the University Lake watershed. The water supply protection regulations for this watershed clearly meet the Phase II stormwater requirements. However, the county's Lower Morgan Creek 6 area near Jordan Lake faces continued development pressure. The rural buffer regulations (1 unit per 2 acres) alone will not mitigate post-construction impacts to the streams and lake. The Town of Carrboro's stormwater management policies at least partially meet the state's Phase II requirements; however, additional volume control for habitat protection may be needed to meet the regulations. Clearly, in order to meet the elements of truly progressive stormwater programs, Carrboro will need to strengthen and clarify its ordinance provision regarding stormwater goals and objectives, performance standards, and applicability/exemptions.

The three jurisdictions are leaders in the Cape Fear River Basin regarding development ordinance provisions that allow for effective site design for stormwater management. In a survey of local ordinances in the basin, the Town of Carrboro achieved the highest score of any local government surveyed. The town's score indicated minor adjustments are needed to the development ordinance. The survey of Chapel Hill's and Orange County's ordinances revealed more opportunities to improve the development regulations. Some developments in the Morgan Creek LWP study area are already using state-of-the-art and science stormwater management and site design practices.

3.5.2 High Priority Actions

All Jurisdictions

- As noted previously, if a local government requests to be covered by the NPDES Phase II General Permit, developments cannot be required to meet standards more stringent than those outlined above (i.e., the Phase II Temporary Rule requirements). Therefore, Tetra Tech would recommend that local governments in the LWP study area apply for an individual permit to enable them to retain or adopt more protective regulations.
- Tetra Tech recommends making the development ordinances' revisions highlighted in this section related to effective site design. The process for such revisions could be either through a holistic "roundtable process" described in the *Better Site Design Handbook*, or incrementally through text amendments. However, as noted in conversations with staff, many LID elements are currently allowed in the local ordinances, but are not encouraged and in some cases discouraged. Therefore, Tetra Tech recommends that each jurisdiction work interdepartmentally—with the Planning, Engineering and Public Works Departments—to resolve issues and remove barriers which are currently blocking use of the above LID practices. Once these internal issues have been resolved, and ordinances revised as need, Tetra Tech recommends that local jurisdictions meet with development applicants early in development process to educate them about LID techniques and to discuss their potential use in the project. Use of a "checklist" in this process can proactively encourage LID. Appendix B, Attachment C provides an example checklist for local governments to consider.

Carrboro

When the town adopts its Phase II stormwater ordinance, it has the opportunity to clarify, formalize, and strengthen it stormwater management regulations. Key areas to focus on include

- Develop and adopt a clear goal statement for the town's stormwater management program, and include it in the stormwater ordinance.
- Develop and adopt clear objectives related to natural resource protection, and include these in the stormwater ordinance.
- Based on goals and objectives, evaluate the effectiveness of existing regulations, Phase II requirements, or stronger standards in meeting the town's goals.
- Enhance performance standards, particularly for stormwater volume control. If adopting Phase II minimum requirements, use stronger "thresholds" of applicability: instead of 24 percent imperviousness, use at minimum 10 percent imperviousness as the threshold for treatment and volume control. Consider adopting even stronger performance standards than minimum Phase II requirements, using the progressive community examples as models. Apply the standards to all new developments and redevelopment, not only to special use and conditional use permits.
- Add provisions for inspecting and monitoring the BMPs to ensure they are working properly.

Orange County

- In Orange County's Lower Morgan Creek 6 area near Jordan Lake, the rural buffer regulations (1 unit per 2 acres) should, at minimum, be coupled with the state's Phase II stormwater management requirements, or more progressive stormwater management performance standards to provide additional protection in this area.

Chapel Hill

- For the Downtown or Community Commercial Districts, some projects may find it very difficult to meet the performance standard onsite. In order to not penalize the developer or create an incentive for a variance to the stormwater performance standard, the town could create a mechanism for partial offsite mitigation (i.e., the developer would have to provide for some onsite stormwater management, but provide the rest offsite). High priority watersheds could be targeted for preservation or restoration efforts. At minimum, the state's phase II requirements must be met in those areas designated for ultra-urban development.

With these actions, Carrboro, Chapel Hill, and Orange County can build upon existing stormwater management efforts to address the stressors threatening future degradation of the Morgan Creek Watershed, and can continue to provide leadership in water quality protection.

4 Targeting of Preservation Opportunities

While the other chapters of this document have focused on measures to address existing degradation of watershed functions and the risk of future degradation, this chapter focuses on targeting high resource value areas of the Morgan and Bolin/Little Creek watersheds for preservation where watershed functions are healthy and fully intact (or at least relatively unimpaired). Obviously, it is important to identify areas where aquatic habitat, water quality, hydrology and other such watershed functions have been degraded or lost, and determine the management and restoration measures necessary to recover those functions. It is equally important to identify those portions of the watershed that have very high quality habitat, or very pristine water quality, or have flood storage capacity that is integral to the well-being of downstream segments.

Section 4 of the Detailed Assessment Report (DAR) describes the indicators utilized to identify the pristine, high quality habitat areas of the Morgan and Bolin/Little Creek watersheds. In brief, the key indicators used to identify high priority subwatersheds for preservation efforts in the DAR were:

1) Percent forest cover in each subwatershed.
2) Percent high priority habitats defined by the NC Gap Analysis Project (GAP) (NCGAP, 2003) vegetation species alliances within the riparian corridor of each subwatershed.
3) Percent National Wetlands Inventory (NWI) (USFWS, 1994) wetlands in the floodplain or riparian buffer of each subwatershed.
4) Presence of valuable habitat and rare species as defined by the Significant Natural Heritage Areas (SNHAs) delineated by the NC Natural Heritage Program.
5) Presence of valuable habitat and rare species as defined by the Natural Heritage Element Occurrences enumerated by the NC Natural Heritage Program.
6) Presence of valuable habitat as defined by the Triangle Land Conservancy Prime Forest Assessment (TLC, 1999).

A GIS analysis was performed during the detailed assessment to determine the proportion of each subwatershed containing the key preservation potential indicators listed above. Based on their content of each indicator, subwatersheds were broken into quartiles and assigned point scores by quartile (4 points for the top quartile, 3 points for the next lowest quartile, etc.). Bonus points were also added to the scores for subwatersheds with identified high value preservation targets, such as Significant Natural Heritage Areas. The combined scores for all indicators were used to determine those subwatersheds with the greatest preservation potential. The scoring system is described in detail in Section 4 of the DAR, and the results are illustrated below in Figure 4-1. Based on the assessment of high priority subwatersheds from the DAR, and the subwatersheds identified within the Tier 1 and Tier 2 high priority subwatersheds where the greatest preservation opportunities exist, the parcel level analysis presented here was focused in the three headwater LWP subwatersheds of Morgan Creek (UM1-UM3) and Bolin Creek (BL1-BL3).

In addition to the authority to affect stream and wetland restoration for mitigation purposes, within its programmatic mission NCEEP has the authority to direct some funding to the preservation of riparian corridors (possibly extending to some upland areas) that exhibit high quality habitat and/or high watershed functional value in terms of the contribution to hydrology or water quality. To effectively target the available preservation funding efficiently within the high priority subwatersheds, a GIS analysis was performed to evaluate the preservation value of individual tax parcels within those subwatersheds.

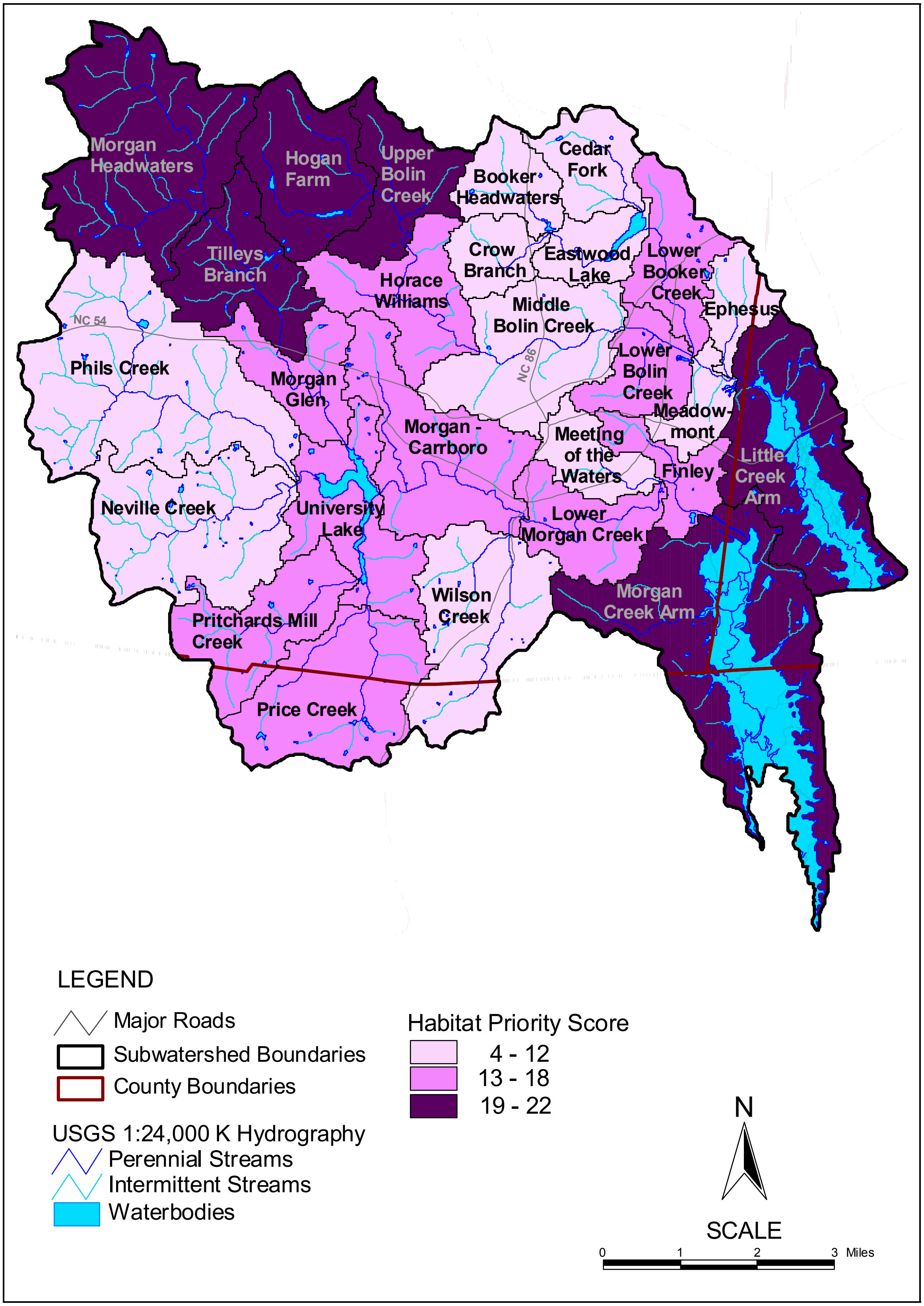

Figure 4-1. Preservation Potential Scores for the Morgan Creek LWP Study Area

4.1 METHODS USED FOR PARCEL-LEVEL PRESERVATION ANALYSIS

Within the six high priority subwatersheds for preservation, the GIS analysis focused on parcels that intersect the conservation zone according to NCEEP's Preservation Guidelines, defined as being within the 100-year floodplain or within 300 feet of streams. Of the 412 parcels intersecting the conservation zone, 211 parcels were not prioritized because the conservation zone was too small (<0.53 acres) to accurately tabulate forest area. For the 201 parcels that were analyzed, the areas within the conservation zone for each parcel of total land area, total forest, high priority forest, and NWI wetlands were quantified.

The vegetation land cover data from the NC-GAP analysis project was used to determine the percent of forest and high priority habitat. The NC-GAP Analysis Project developed the vegetation data by extracting forested areas from the 1992-1993 National Land Cover Data (NLCD). Then, aerial videos of the forested areas were recorded across the state. The NC-GAP staff visited selected sites that corresponded to the aerial footage and identified the common species at those sites. Using the species data as well as NWI and NRCS soils data, they developed decision rules to classify the satellite imagery (NC Gap Analysis Project, 2003). Percent forest was determined by tabulating the area of deciduous, evergreen, mixed, and woody wetlands (excluding shrublands) in the NC-GAP vegetation data.

To determine the high priority habitats, representatives of wildlife habitat and natural resource agencies advised NCEEP and Tetra Tech on the prioritization of the GAP vegetation data. Agencies and organizations represented in this effort included the NC Wildlife Resources Commission, the NC Natural Heritage Program, the NC Gap Analysis Project, the US Fish and Wildlife Service, and the Triangle Land Conservancy (TLC). The vegetation species alliances given the highest priority by the advising resource professionals included dry mesic oak and hardwood forests, oak bottomland forest, all bottomland hardwood and swamp forest, submerged aquatic vegetation, and emergent wetland vegetation.

The parcels were prioritized by their quartile distribution of the four land cover metrics according to the scoring system in Table 4-1. Scores from 1 to 4 were awarded, and the highest quartile received the highest score for each land cover. Two bonus points were awarded to parcels that intersected with TLC prime forests. If the designated conservation zone on a parcel directly intersected with an SNHA two bonus points were awarded, and if the conservation zone of the parcel was within a reasonable proximity to an SNHA, one bonus point was awarded. "Reasonable proximity" was determined by GIS analysis and best professional judgment. It was not necessary to give separate scores for Natural Heritage Element Occurrences (NHEOs) because each NHEO occurred within one of the SNHAs. The total score represents the sum of the four land cover scores and the additional habitat points.

Table 4-1. Scoring System for Preservation Potential

Criteria	Score
Highest Quartile (Total area, % subwatershed forested, % high priority habitat, NWI wetlands in conservation zone)	4
Second Highest Quartile (Total area, % subwatershed forested, % high priority habitat, NWI wetlands in conservation zone)	3
Second Lowest Quartile (Total area, % subwatershed forested, % high priority habitat, NWI wetlands in conservation zone)	2
Bottom Quartile (Total area, % subwatershed forested, % high priority habitat, NWI wetlands in conservation zone)	1
Conservation zone intersects with one or more TLC Prime Forest Tracts	2
Conservation zone intersects with one or more Significant Natural Heritage Areas	2
Parcel is near one or more Significant Natural Heritage Areas	1

4.2 Results of the Parcel-Level Preservation Analysis

The results of the parcel-level analysis of preservation potential are presented on two maps in Figure 4-2 and Figure 4-4. The numbers shown on the parcels in Figure 4-2 through Figure 4-4 are ID numbers that correspond to a database of land ownership information for targeted preservation parcels provided to NCEEP and TLC staffs for this project. The individual parcel scores are presented in Table 4-2 with results sorted from highest to lowest score.

For the 200 parcels evaluated the scores ranged from the minimum possible score of 4 points to the maximum possible score of 18 points, but only one parcel received a score of 18. Low scoring parcels tend to be small, disturbed parcels or forested parcels with negligible stream buffer area, while high scoring parcels generally have contiguously forested riparian corridors with significant deciduous forest and wetland content. Only 27 of the 200 parcels received scores in the top range (14-18 points) and these parcels could be viewed as the largest and most important preservation targets for protection of riparian habitat and watershed functions within the targeted subwatershed. By targeting preservation efforts toward the high-value parcels identified in this analysis, NCEEP can use the preservation funding applied to this LWP study area in the most efficient manner.

On the basis of this analysis, one of the highest scoring and perhaps the most significant parcel in terms of habitat and natural heritage features is the Horace Williams tract owned by UNC and planned for development of the Carolina North campus expansion (shown as Parcel 160 in the lower right quadrant of Figure 4-3). The Horace Williams tract represents the largest contiguous area of undisturbed forest cover in the entire Bolin Creek watershed. The distribution of Forest Cover and GAP habitats identified as high priority by resource agencies (refer to Section 4.1) is shown in Figure 4-5. Note the prevalence of GAP priority habitats along the riparian corridor and in the western portion of the Horace Williams tract.

In addition to large areas of high quality forest habitat, along Bolin Creek in the middle of the Horace William tract, there is currently a substantial active beaver impoundment. While beavers and their hydro-modifications are often viewed as a nuisance, it should be noted that this particular beaver pond is serving an important hydrologic function in of upper Bolin Creek. By detaining and dampening the peak storm flows and settling out sediment from the developed areas upstream, this pond is protecting this very valuable and healthy section of Bolin Creek from erosion and degradation that would likely occur in its absence. If a means can be found to prevent damage to or inundation of the OWASA sewer line near the pond, it is recommended that the impoundment be left in place as long as the beaver see fit to maintain it.

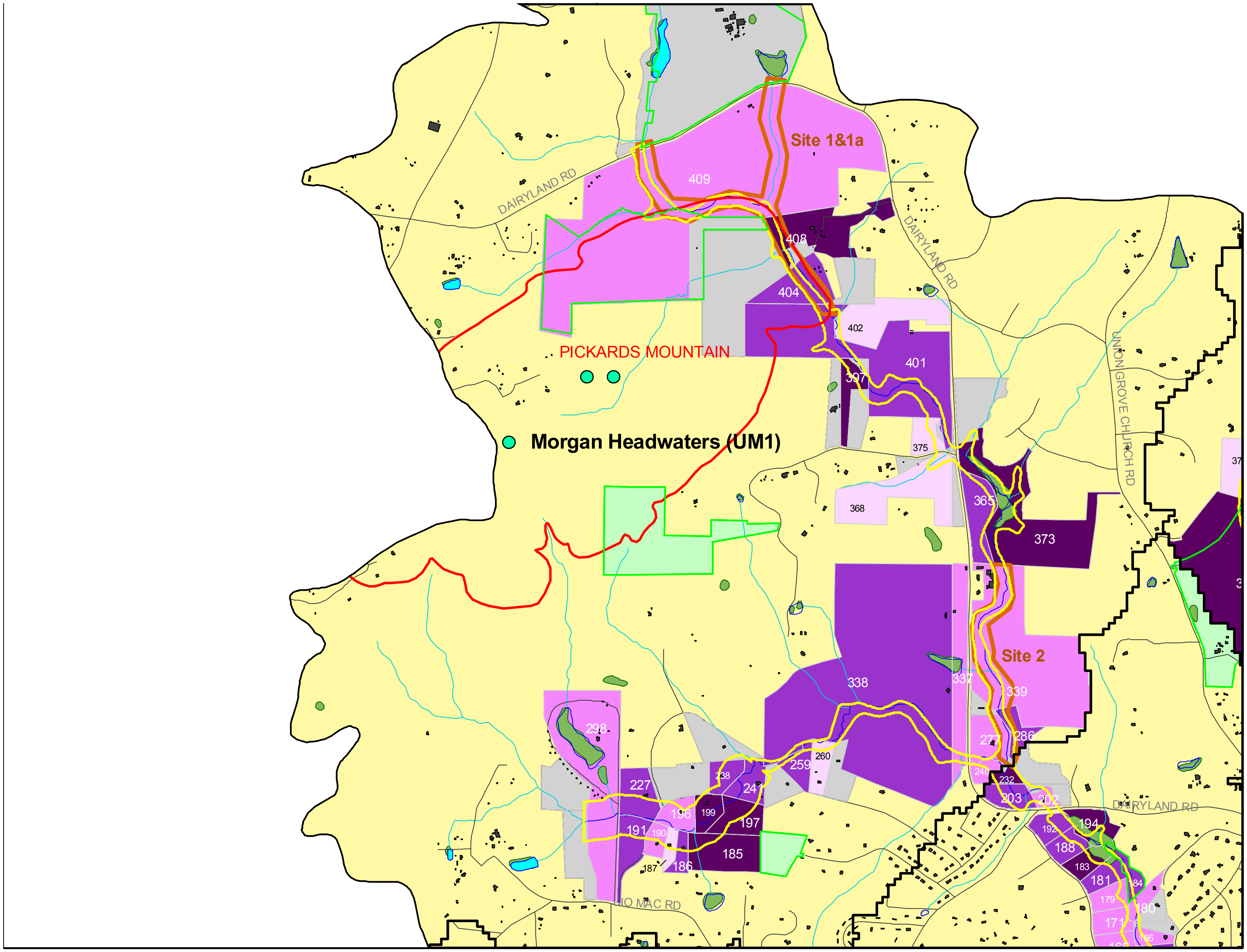

Figure 4-2. Parcel-Level Analysis of Preservation Potential – Subwatershed UM1

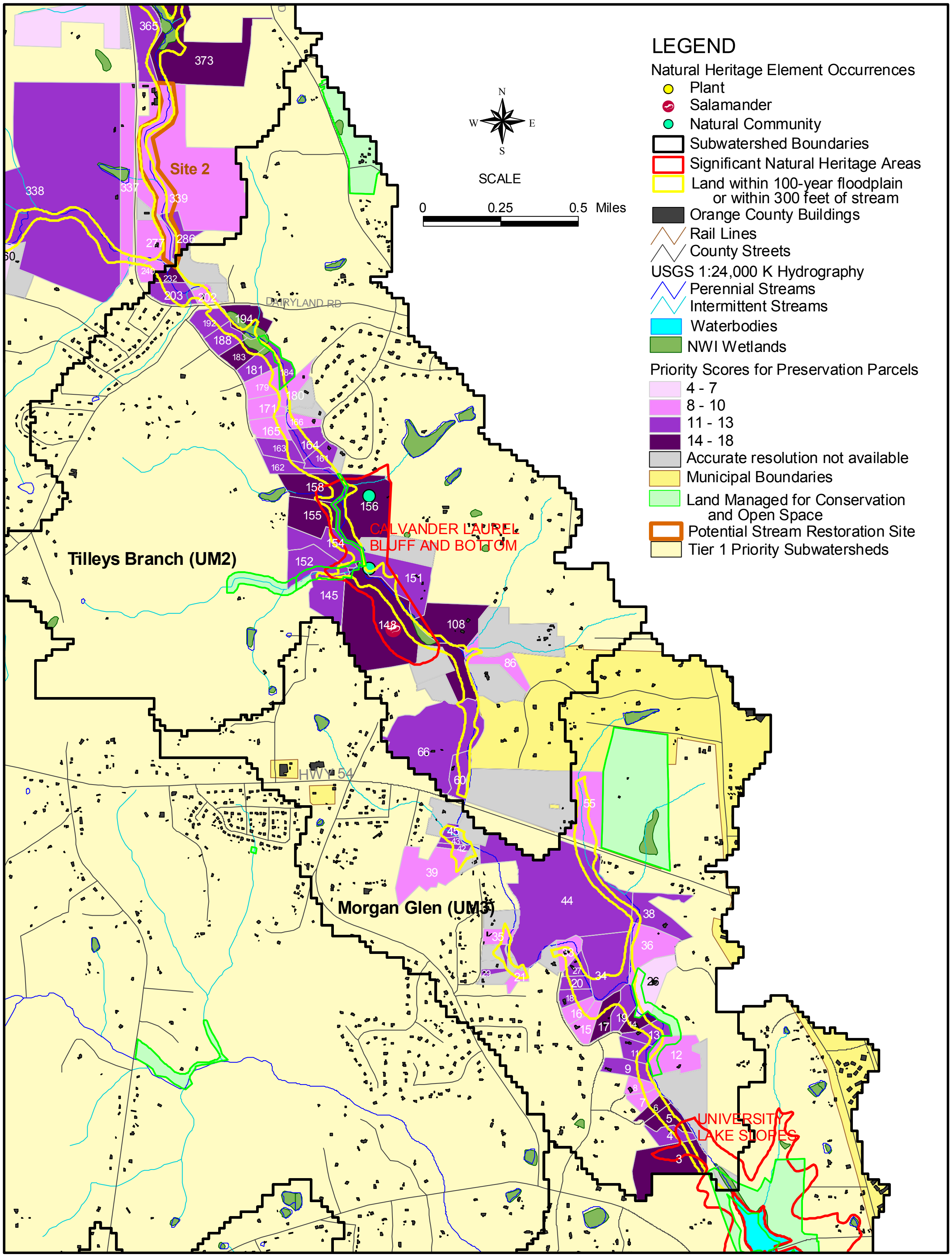

Figure 4-3. Parcel-Level Analysis of Preservation Potential – Subwatersheds UM2 – UM3

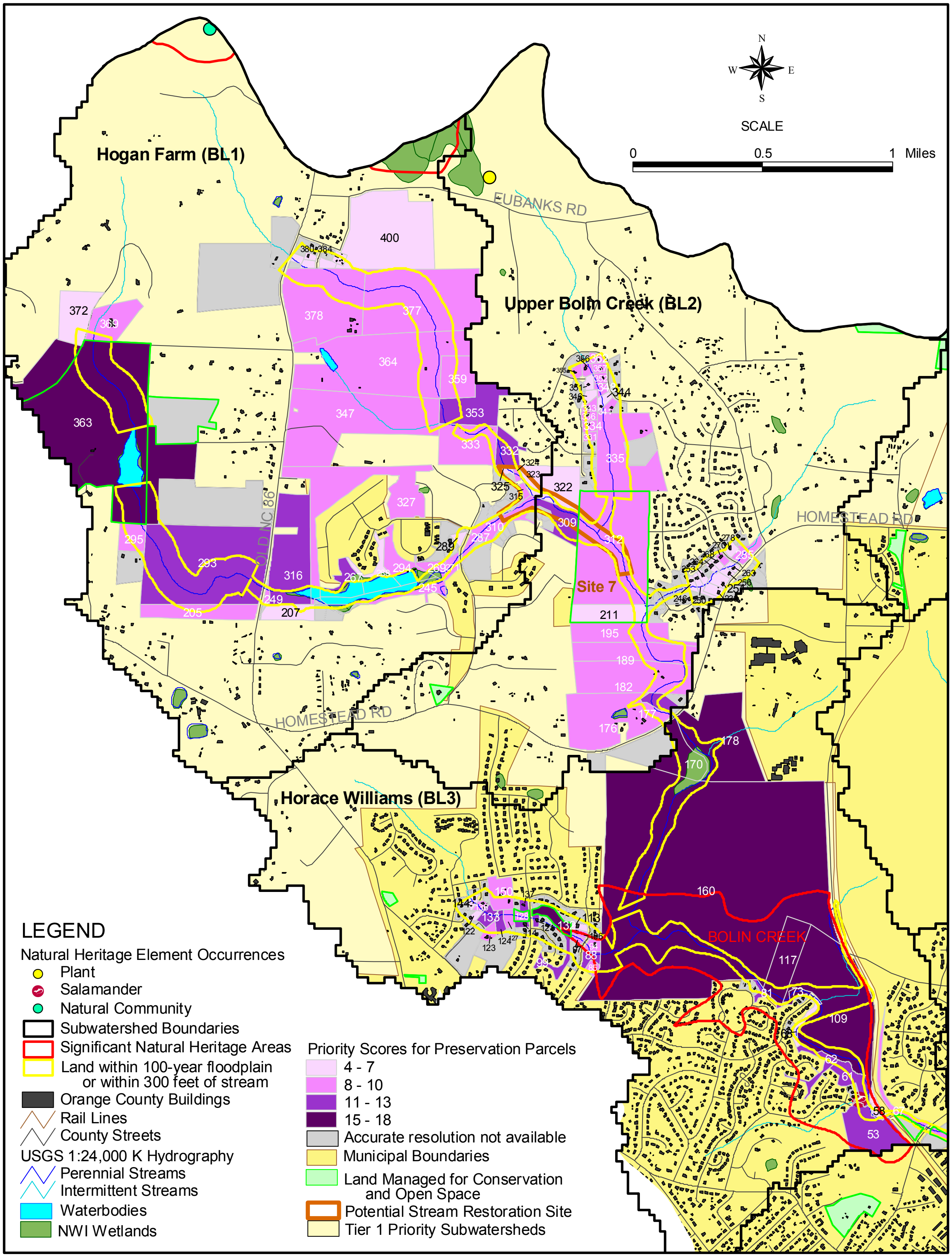

Figure 4-4. Parcel-Level Analysis of Preservation Potential – Subwatersheds BL1 – BL3

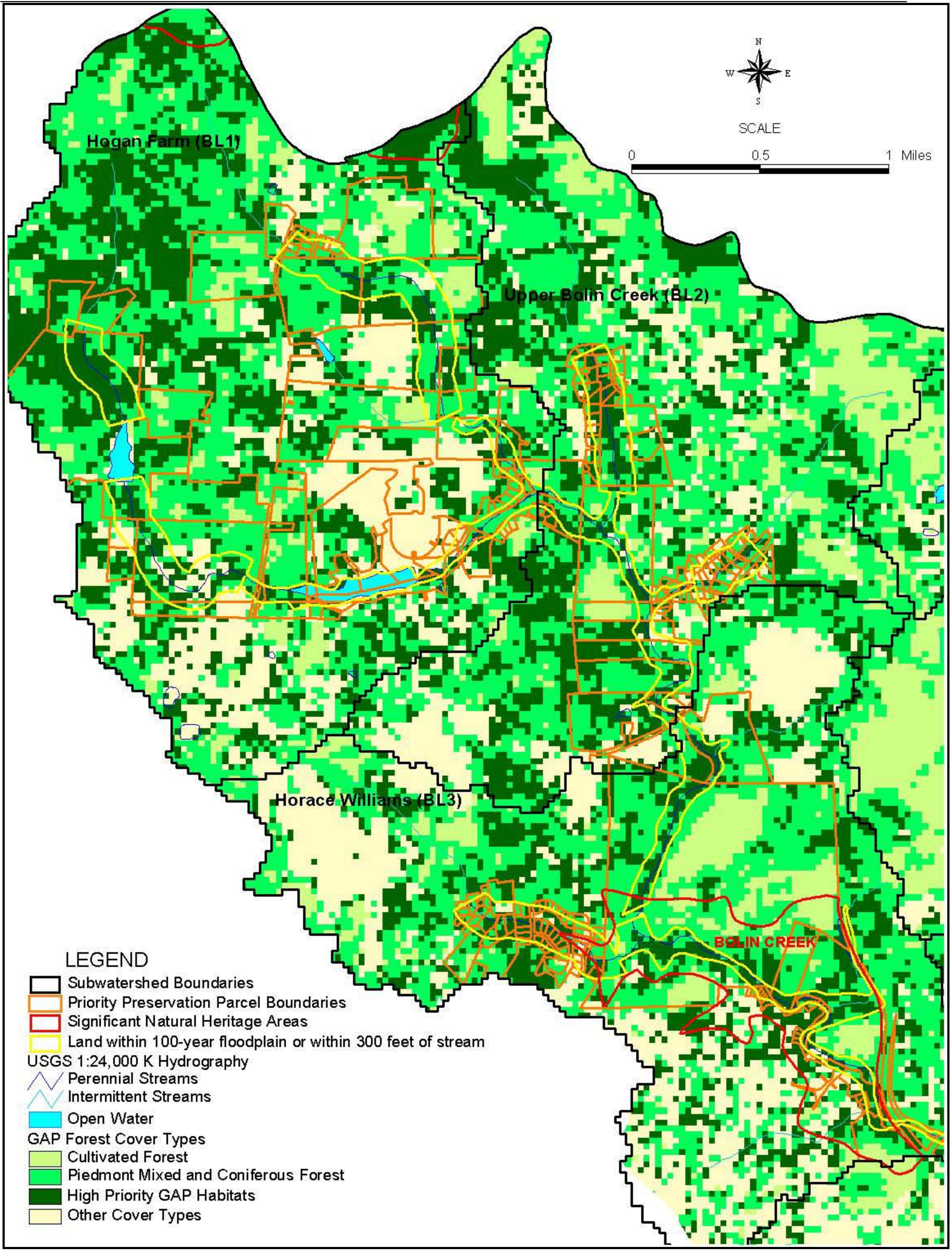

Figure 4-5. Distribution of High Quality Habitats – Subwatersheds BL1 - BL3

Table 4-2. Individual Parcel Scores from Analysis of Preservation Potential

Parcel Number	Acres in Conservation Zone	% Forest Cover in Subwatershed	% Top Priority Habitat in Conservation Zone	% NWI Wetlands in Conservation Zone	Total Land Area in Conservation Zone	TLC Prime Forest Tracts Within Conservation Zone	SNHA Within or Near Conservation Zone	Total Score
170	7.19	4	4	4	4	2		18
156	3.25	4	4	1	4	2	2	17
183	1.72	4	4	4	3	2		17
194	1.47	4	4	4	3	2		17
108	0.91	3	4	3	2	2	2	16
148	13.81	3	3	2	4	2	2	16
160	39.78	4	3	1	4	2	2	16
373	12.06	3	4	3	4	2		16
5	1.98	4	3	1	3	2	2	15
73	0.96	4	4	1	2	2	2	15
155	1.08	4	4	1	2	2	2	15
158	3.17	3	3	1	4	2	2	15
178	5.46	3	4	2	4	2		15
197	4.59	4	4	1	4	2		15
3	1.57	4	2	1	3	2	2	14
6	1.25	4	4	1	2	2	1	14
14	1.62	4	4	1	3	2		14
17	1.59	4	4	1	3	2		14
109	15.85	2	3	1	4	2	2	14
117	1.94	2	4	1	3	2	2	14
132	2.85	1	4	1	4	2	2	14
185	2.17	4	4	1	3	2		14
199	4.79	3	4	1	4	2		14
232	2.04	4	4	1	3	2		14
363	33.04	4	3	1	4	2		14
397	2.04	4	4	1	3	2		14
408	2.75	4	4	1	3		2	14
9	1.26	4	3	1	3	2		13
19	2.62	4	3	1	3	2		13
27	1.48	4	3	1	3	2		13
34	6.18	4	2	1	4	2		13
61	2.97	2	4	1	4		2	13
88	1.58	3	4	1	3		2	13

Parcel Number	Acres in Conservation Zone	% Forest Cover in Subwatershed	% Top Priority Habitat in Conservation Zone	% NWI Wetlands in Conservation Zone	Total Land Area in Conservation Zone	TLC Prime Forest Tracts Within Conservation Zone	SNHA Within or Near Conservation Zone	Total Score
121	0.56	4	4	1	1	2	1	13
133	1.67	4	3	1	3	2		13
154	2.95	2	2	1	4	2	2	13
162	1.59	3	3	1	3	2	1	13
163	1.55	4	3	1	3	2		13
241	6.16	3	3	1	4	2		13
259	0.95	4	4	1	2	2		13
401	13.39	1	3	1	4	2	2	13
20	1.77	4	2	1	3	2		12
44	5.39	2	3	1	4	2		12
53	1.21	4	3	1	2		2	12
60	2.75	2	4	1	3	2		12
62	0.79	4	4	1	1		2	12
66	4.46	2	3	1	4	2		12
99	0.54	2	4	1	1	2	2	12
114	0.58	4	4	1	1	2		12
137	0.63	4	4	1	1	2		12
157	1.95	2	2	1	3	2	2	12
161	2.26	4	1	1	3	2	1	12
164	2.82	4	2	1	3	2		12
181	1.36	3	1	3	3	2		12
184	1.01	4	4	2	2			12
188	1.40	2	4	1	3	2		12
191	3.26	4	1	1	4	2		12
203	3.36	3	4	1	4			12
227	4.40	4	1	1	4	2		12
286	1.26	4	2	1	3	2		12
316	4.11	4	2	2	4			12
332	2.63	4	4	1	3			12
4	1.16	1	3	1	2	2	2	11
11	1.16	2	4	1	2	2		11
13	1.73	4	1	1	3	2		11
18	1.35	3	2	1	3	2		11
29	0.66	4	3	1	1	2		11

Parcel Number	Acres in Conservation Zone	% Forest Cover in Subwatershed	% Top Priority Habitat in Conservation Zone	% NWI Wetlands in Conservation Zone	Total Land Area in Conservation Zone	TLC Prime Forest Tracts Within Conservation Zone	SNHA Within or Near Conservation Zone	Total Score
38	0.63	4	3	1	1	2		11
42	0.65	4	3	1	1	2		11
43	0.68	3	4	1	1	2		11
45	1.03	4	2	1	2	2		11
81	0.68	3	4	1	1		2	11
124	1.23	4	2	1	2	2		11
145	0.76	4	1	1	1	2	2	11
151	1.77	1	2	1	3	2	2	11
152	0.59	4	1	1	1	2	2	11
177	1.48	4	3	1	3			11
186	1.14	4	2	1	2	2		11
192	1.70	2	3	1	3	2		11
238	3.46	2	2	1	4	2		11
267	2.94	1	2	4	4			11
293	33.89	1	3	1	4	2		11
309	5.45	4	2	1	4			11
338	11.87	1	3	1	4	2		11
353	3.22	4	2	1	4			11
365	2.50	3	2	1	3	2		11
404	2.24	2	3	1	3		2	11
7	0.92	1	4	1	2	2		10
8	0.89	1	4	1	2	2		10
35	0.78	2	4	1	1	2		10
39	1.30	2	2	1	3	2		10
55	5.54	4	1	1	4			10
67	1.09	4	2	1	2		1	10
86	0.70	1	4	1	1	2	1	10
94	1.15	3	2	1	2		2	10
128	1.06	4	3	1	2			10
150	2.03	1	3	1	3	2		10
165	1.29	2	2	1	3	2		10
180	0.99	4	1	1	2	2		10
182	6.30	2	3	1	4			10
190	1.79	3	1	1	3	2		10

Parcel Number	Acres in Conservation Zone	% Forest Cover in Subwatershed	% Top Priority Habitat in Conservation Zone	% NWI Wetlands in Conservation Zone	Total Land Area in Conservation Zone	TLC Prime Forest Tracts Within Conservation Zone	SNHA Within or Near Conservation Zone	Total Score
196	4.70	2	1	1	4	2		10
202	1.45	1	3	1	3	2		10
205	1.47	1	3	1	3	2		10
240	1.27	4	2	1	3			10
245	5.14	1	2	3	4			10
277	3.63	1	2	1	4	2		10
298	7.06	2	1	1	4	2		10
310	5.20	4	1	1	4			10
312	14.99	2	3	1	4			10
331	0.59	4	4	1	1			10
335	15.39	2	3	1	4			10
336	0.73	4	4	1	1			10
337	0.70	4	4	1	1			10
347	2.99	3	2	1	4			10
352	0.90	3	4	1	2			10
356	0.92	3	4	1	2			10
359	4.25	1	4	1	4			10
364	11.78	3	2	1	4			10
377	23.03	2	3	1	4			10
409	11.84	1	2	1	4		2	10
15	1.16	3	1	1	2	2		9
21	0.65	4	1	1	1	2		9
36	1.71	1	2	1	3	2		9
48	1.22	2	3	1	2		1	9
127	1.19	1	3	1	2	2		9
136	0.76	4	3	1	1			9
171	0.70	2	3	1	1	2		9
179	1.15	2	2	1	2	2		9
189	5.84	2	2	1	4			9
249	0.59	4	3	1	1			9
269	1.27	1	2	3	3			9
271	1.10	4	2	1	2			9
295	3.00	1	1	1	4	2		9
324	0.57	4	3	1	1			9

Parcel Number	Acres in Conservation Zone	% Forest Cover in Subwatershed	% Top Priority Habitat in Conservation Zone	% NWI Wetlands in Conservation Zone	Total Land Area in Conservation Zone	TLC Prime Forest Tracts Within Conservation Zone	SNHA Within or Near Conservation Zone	Total Score
334	0.81	2	4	1	2			9
339	11.11	1	3	1	4			9
341	1.00	4	2	1	2			9
343	0.86	2	4	1	2			9
348	0.94	2	4	1	2			9
355	0.80	4	3	1	1			9
362	0.69	3	4	1	1			9
378	12.57	2	2	1	4			9
12	0.81	4	2	1	1			8
16	1.05	2	1	1	2	2		8
33	1.24	2	1	1	2	2		8
85	0.76	1	3	1	1		2	8
97	0.61	1	1	1	1	2	2	8
106	0.71	1	1	1	1	2	2	8
123	0.69	1	3	1	1	2		8
166	0.97	2	1	1	2	2		8
176	2.22	2	2	1	3			8
195	2.95	1	2	1	4			8
270	0.67	3	3	1	1			8
285	1.46	2	2	1	3			8
287	1.62	2	2	1	3			8
294	2.23	1	2	2	3			8
315	0.67	3	3	1	1			8
327	0.86	1	1	4	2			8
333	3.56	1	2	1	4			8
357	0.92	3	2	1	2			8
369	1.12	2	1	1	2	2		8
26	0.75	2	3	1	1			7
68	0.85	1	1	1	2		2	7
113	0.71	1	1	1	1	2	1	7
144	0.71	2	3	1	1			7
187	1.22	1	1	1	2	2		7
211	1.55	2	1	1	3			7
239	1.18	2	2	1	2			7

Parcel Number	Acres in Conservation Zone	% Forest Cover in Subwatershed	% Top Priority Habitat in Conservation Zone	% NWI Wetlands in Conservation Zone	Total Land Area in Conservation Zone	TLC Prime Forest Tracts Within Conservation Zone	SNHA Within or Near Conservation Zone	Total Score
251	1.54	2	1	1	3			7
288	3.03	1	1	1	4			7
322	0.81	2	2	1	2			7
344	1.10	2	2	1	2			7
346	0.91	3	1	1	2			7
351	0.91	3	1	1	2			7
372	0.93	1	1	1	2	2		7
375	1.52	1	2	1	3			7
380	0.79	4	1	1	1			7
382	0.62	4	1	1	1			7
400	0.66	4	1	1	1			7
58	0.69	1	1	1	1		2	6
207	0.67	1	3	1	1			6
250	1.14	1	2	1	2			6
260	0.99	1	2	1	2			6
263	0.68	3	1	1	1			6
268	0.59	1	3	1	1			6
278	0.84	2	1	1	2			6
325	0.92	1	2	1	2			6
368	1.16	2	1	1	2			6
381	0.99	2	1	1	2			6
246	0.82	1	1	1	2			5
264	0.55	2	1	1	1			5
383	0.54	2	1	1	1			5
402	0.64	1	1	1	1		1	5
122	0.65	1	1	1	1			4
253	0.69	1	1	1	1			4
256	0.68	1	1	1	1			4
289	0.66	1	1	1	1			4
323	0.63	1	1	1	1			4
384	0.63	1	1	1	1			4

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Appendix A. Identified BMP Opportunities

THIS DOCUMENT HAS BEEN EDITED TO CONTAIN INFORMATION RELEVANT TO CARRBORO ONLY

SITE NUMBER: 11

Site Location: Carrboro Tracks

Contributing Watershed: 20.106 acres

Watershed Land Use: Urban

Watershed Imperviousness: Very High

Site for Proposed Practice: .795 acres

LWP Subwatershed: LM1

Pros:	Cons:
• Carrboro already owns property • Treats highly impervious urban contributing watershed • Good site access for construction and maintenance purposes • Potential for public education component in conjunction with planned greenway • BMP will work in conjunction with stream restoration project to increase overall functional benefit. • High nutrient load reduction potential • High rating for Watershed Functional Benefit • Headwater location	• Some infrastructure constraints • Site is wooded • Earthwork requirements may be significant

Recommended Practice: Wet Detention

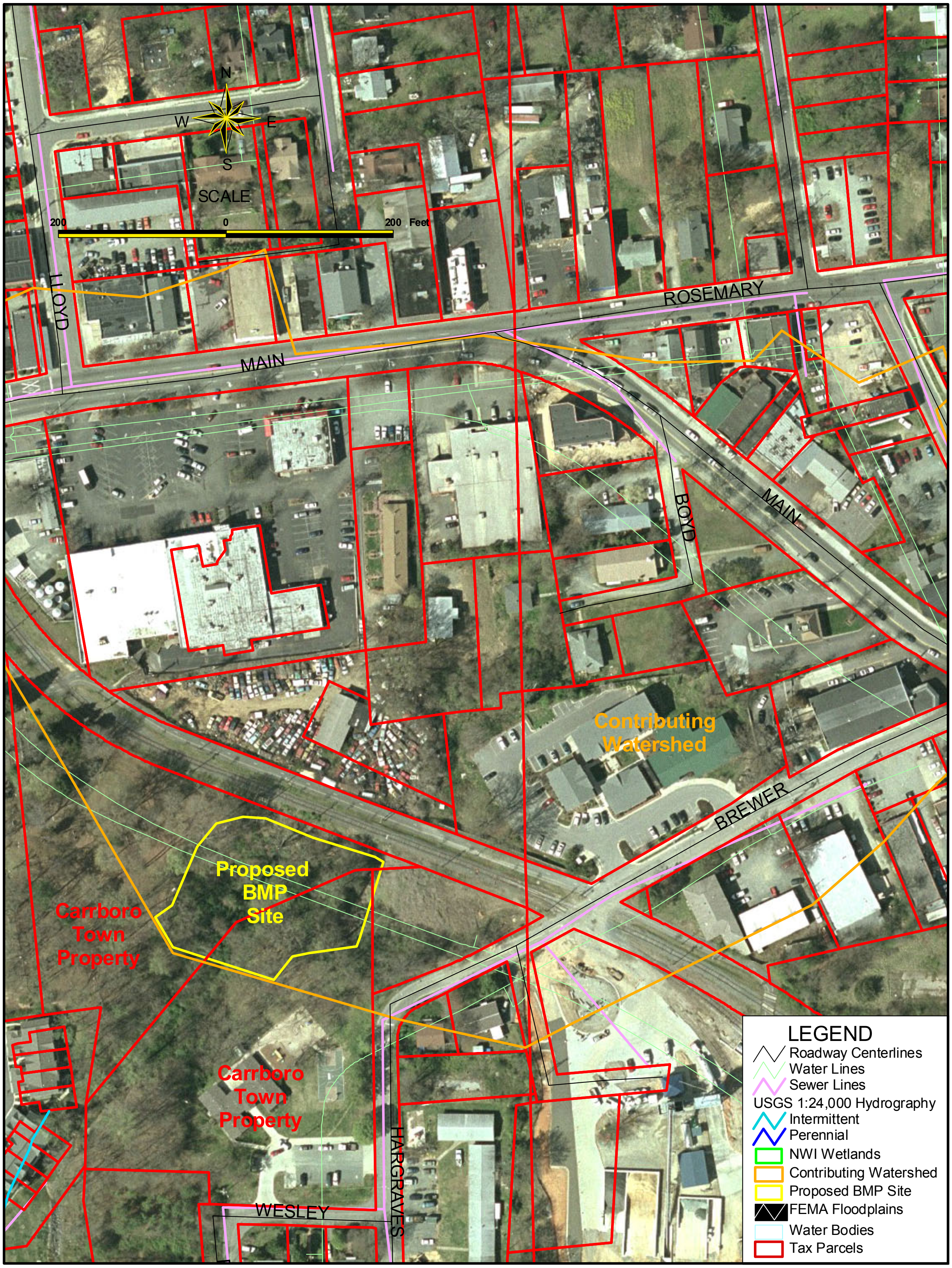
Recommended Size of Practice: 0.40 acres

Estimated Construction Cost: $104,503

Estimated 20-Year Maintenance: $8,781

Comments: Two land parcels owned by the Town of Carrboro are located between the northern end of the Roberson Place subdivision and the railroad tracks. The small headwater tributary that runs through these parcels drains a highly urbanized portion of downtown Carrboro. As the Town owns these parcels, no land acquisition costs would be incurred to implement a stormwater BMP at this site. The location is ideal for a BMP because the contributing drainage area is highly impervious, restoration of the receiving stream reach is proposed, and both sites could be incorporated into a planned greenway to increase public awareness and education. The proposed site is wooded and may require considerable earthwork to create an embankment at the downstream end of the natural depression. Due to the limited surface area of the site, a wet extended detention pond is better suited to the site than a stormwater wetland. Despite the constraints presented by this site, the ability to disconnect a significant portion of impervious surfaces and simultaneously provide an upstream control for the proposed stream restoration project warrants serious consideration.

Map of Site 11 at Carrboro Tracks:



SITE NUMBER: 12

Site Location: Carrboro Elementary School

Contributing Watershed: 30.890 acres

Watershed Land Use: Institutional/Residential

Watershed Imperviousness: Moderate

Site for Proposed Practice: 0.756 acres

LWP Subwatershed: BL4

Pros:	Cons:
• Publicly owned property • Treats moderately impervious institutional and residential contributing watershed • Good site access for construction and maintenance purposes • Strong potential for education component in conjunction with school and greenway • High nutrient load reduction cost-effectiveness • Headwater location	• Some infrastructure constraints • Site is wooded

Recommended Practice: Stormwater Wetland

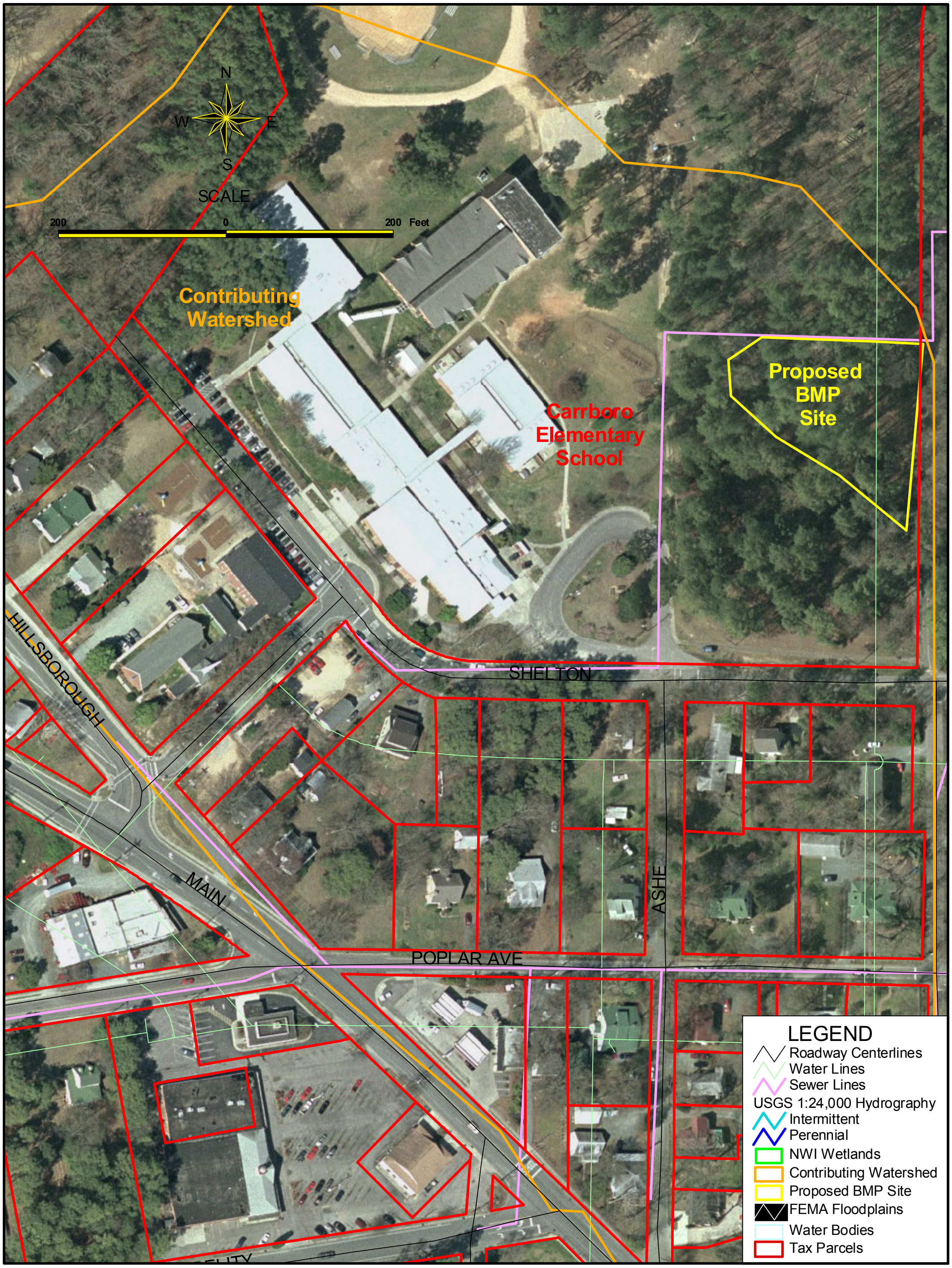
Recommended Size of Practice: 0.62 acres

Estimated Construction Cost: $20,266

Estimated 20-Year Maintenance: $3,239

Comments: A stormwater wetland is proposed in the headwaters of a Tier I watershed in which the Carrboro Elementary School is located. The contributing drainage area to this site consists of the school and the surrounding single-family residences. The location at the school affords the unique opportunity of both addressing stormwater runoff issues and of educating the public about the benefits of stormwater BMPs. Additionally, the site is located along a greenway trail through Carrboro that will further enhance public exposure. The Chapel Hill-Carrboro school system owns the property on which the site is proposed, which will likely prevent the need for land aquisition. The site is highly accessible for construction and maintenance purposes. Potential impediments to the implementation of this site include a sanitary sewer line that runs along the northern border of the facility, as well as the clearing and grading of the site for a stormwater wetland.

Map of Site 12 at Carrboro Elementary School:



SITE NUMBER: 13

Site Location: Carrboro Park

Contributing Watershed: 24.365 acres

Watershed Land Use: Courts/Fields/Residential

Watershed Imperviousness: Moderate

Site for Proposed Practice: 0.526 acres

LWP Subwatershed: BL4

Pros:	Cons:
• Carrboro already owns property • Good site access for construction and maintenance purposes • Treats moderately impervious residential contributing watershed • Strong potential for public education component in conjunction with Park • Minimal earthwork required • Fairly high cost-effectiveness for nutrient load reduction • Entirely cleared site • Headwater location	• Potential infrastructure constraint • Implementation may require relocation of some playground equipment and park facilities

Recommended Practice: Stormwater Wetland

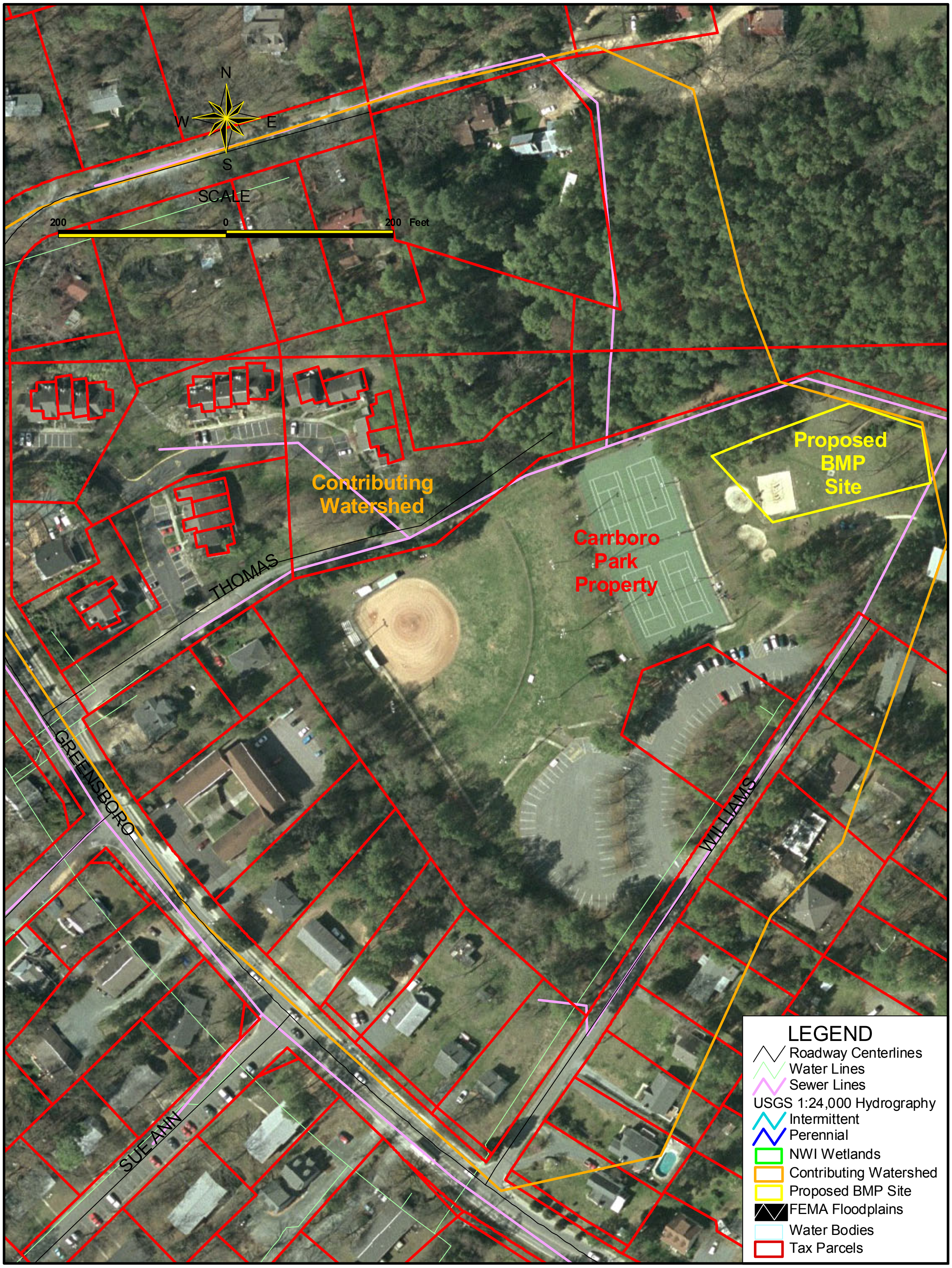
Recommended Size of Practice: 0.49 acres

Estimated Construction Cost: $18,067

Estimated 20-Year Maintenance: $3,124

Comments: In order to control and treat headwater runoff in a Tier I watershed, a stormwater wetland is proposed in the northeastern corner of Wilson Park. This site would address runoff from the single and multi family residences around the park as well as the parking lots and courts associated with the park. Construction at this site is highly feasible as the existing cover is only grass, the Town of Carrboro owns the park property, site access is available, and expected earthwork is minimal. A sanitary sewer line runs along the north side of the site, but it does not appear that it would affect implementation of the BMP. However, it should be noted that implementation of this BMP may require relocation of some playground equipment in the Park. By incorporating the wetland into a town park, a strong potential for public education could be realized.

Map of Site 13 at Carrboro Park:



SITE NUMBER: 14

Site Location: Toms Creek at Main Street

Contributing Watershed: 29.023 acres

Watershed Land Use: Residential

Watershed Imperviousness: Moderate

Site for Proposed Practice: 1.776 acres

LWP Subwatershed: LM1

Pros:	Cons:
• Treats large moderately impervious residential area • BMP will work in conjunction with Toms Creek stream restoration project to increase overall functional benefit. • Good site access for construction and maintenance purposes • High nutrient load reduction cost-effectiveness • Rated highest among BMPs evaluated for Watershed Functional Benefit • Headwater location	• Privately owned property • Substantial earthwork required due to site topography • Some infrastructure constraints • Partially wooded site

Recommended Practice: Stormwater Wetland

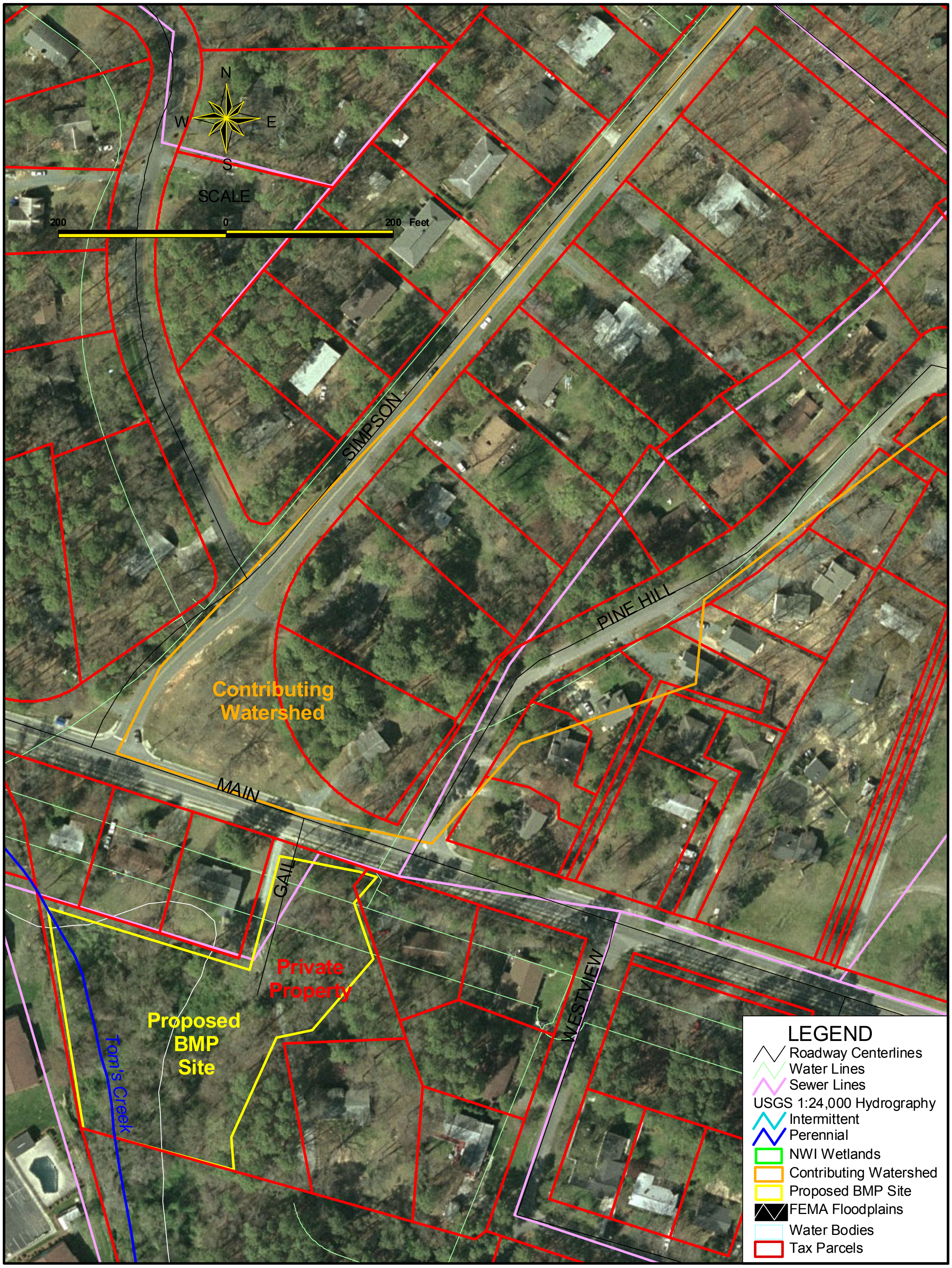
Recommended Size of Practice: 0.58 acres

Estimated Construction Cost: $19,663

Estimated 20-Year Maintenance: $3,208

Comments: Toms Creek, a tributary to lower Morgan Creek, is categorized as a Tier II watershed due to the relative health of Morgan Creek. However, Toms Creek and its drainage are highly impaired making it more similar to other Tier I watersheds. In order to disconnect some of the imperviousness in this watershed, a stormwater wetland is proposed just south of the Main Street crossing of the creek. The potential site is located on one private parcel, with wooded cover, and a sanitary sewer line along one side of the site. The site may require considerable earthwork to adjust the existing topography to suit a stormwater wetland. Despite these difficulties with the site, it should be seriously considered due to benefits it affords. The site is located in the headwaters of the watershed, access is available, and most importantly, the hydrologic and water quality influence of the BMP would benefit a proposed stream restoration project on Toms Creek.

Map of Site 14 at Toms Creek at Main Street:



SITE NUMBER: 15

Site Location: Carrboro USPS

Contributing Watershed: 2.800 acres

Watershed Land Use: Parking/Roofs

Watershed Imperviousness: High

Site for Proposed Practice: 0.263 acres

LWP Subwatershed: LM1

Pros:	Cons:
• Good site access for construction and maintenance purposes • No infrastructure constraints • Practice would capture and treat runoff from highly impervious contributing watershed • BMP will work in conjunction with Toms Creek stream restoration project to increase overall functional benefit. • Minimal earthwork required. • High rating for Watershed Function Benefits (highest among bioretention facilities evaluated) • Almost entirely cleared site • Headwater location	• Property ownership split between US Government and private party – may require complicated agreements and/or acquisition • Low cost-effectiveness and low nutrient load reduction potential.

Recommended Practice: Bioretention

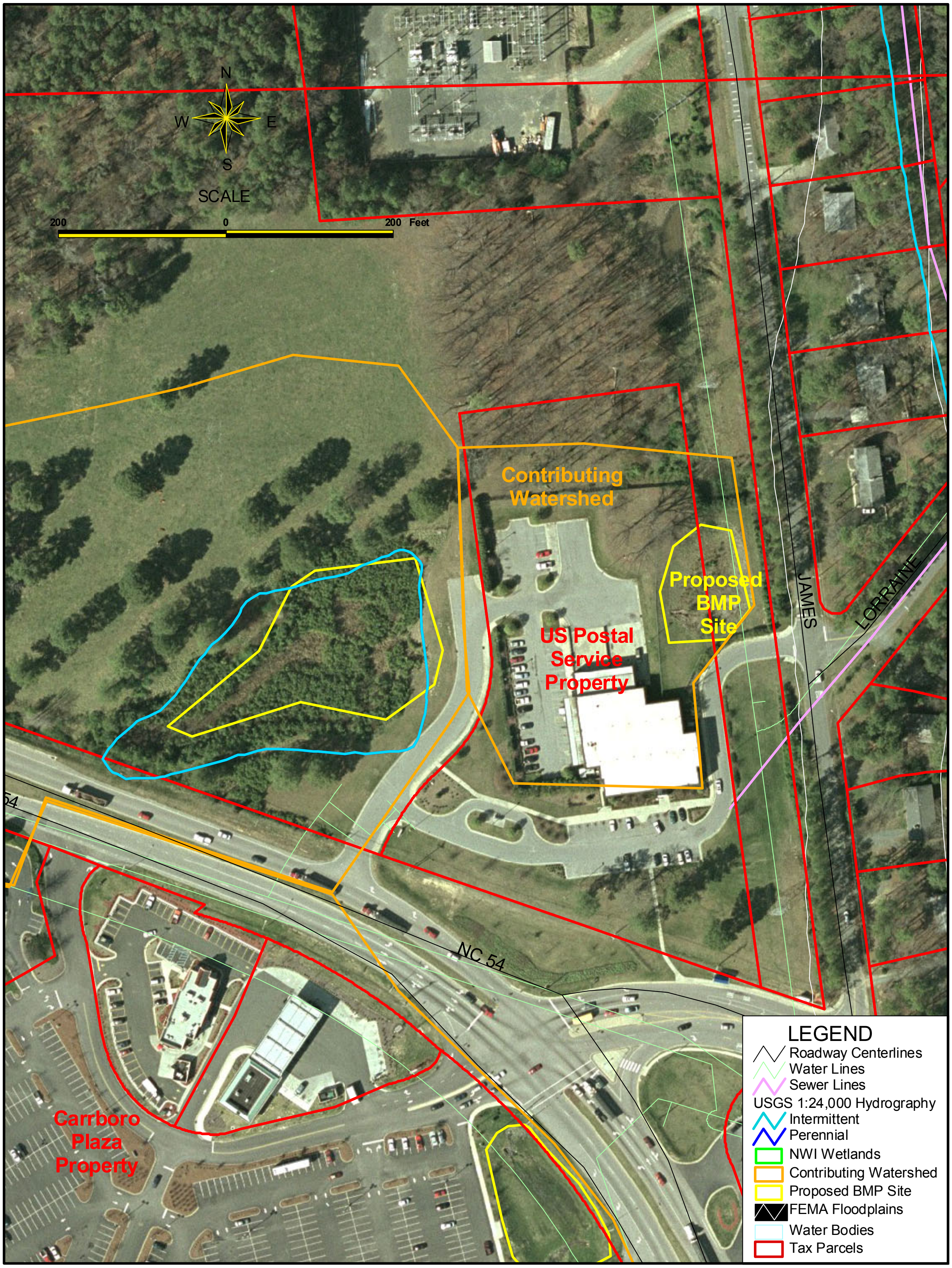
Recommended Size of Practice: 0.084 acres

Estimated Construction Cost: $31,152

Estimated 20-Year Maintenance: $1,711

Comments: The USPS office in Carrboro is located north of Main Street in the headwaters of the Toms Creek watershed. The rooftop and parking areas at the office drain to an onsite dry detention basin that could be retrofit as a bioretention facility to enhance the water quality entering Toms Creek. The proposed site spans two land parcels – one privately owned; the other owned by the USPS. However, acquisition of land may be the only challenge with this site. Infrastructure presents no apparent constraints, access is available, minimal clearing and earthwork are anticipated, and the site is located in the headwaters of the watershed such that it benefits a proposed stream restoration project on Toms Creek.

Map of Site 15 at Carrboro USPS:



SITE NUMBER: 16

Site Location: Adjacent Carrboro USPS

Contributing Watershed: 16.629 acres

Watershed Land Use: Road/Residential

Watershed Imperviousness: Low

Site for Proposed Practice: 0.859 acres

LWP Subwatershed: LM1

Pros:	Cons:
• Good site access for construction and maintenance purposes • No infrastructure constraints • Practice would capture and treat runoff from highly impervious contributing watershed • BMP will work in conjunction with Toms Creek stream restoration project to increase overall functional benefit. • Minimal earthwork required. • Entirely cleared site • Headwater location	• Property ownership split between US Government and private party – may require complicated agreements and/or acquisition • Low cost-effectiveness and low nutrient load reduction potential. • BMP would capture runoff from large undeveloped area

Recommended Practice: Stormwater Wetland

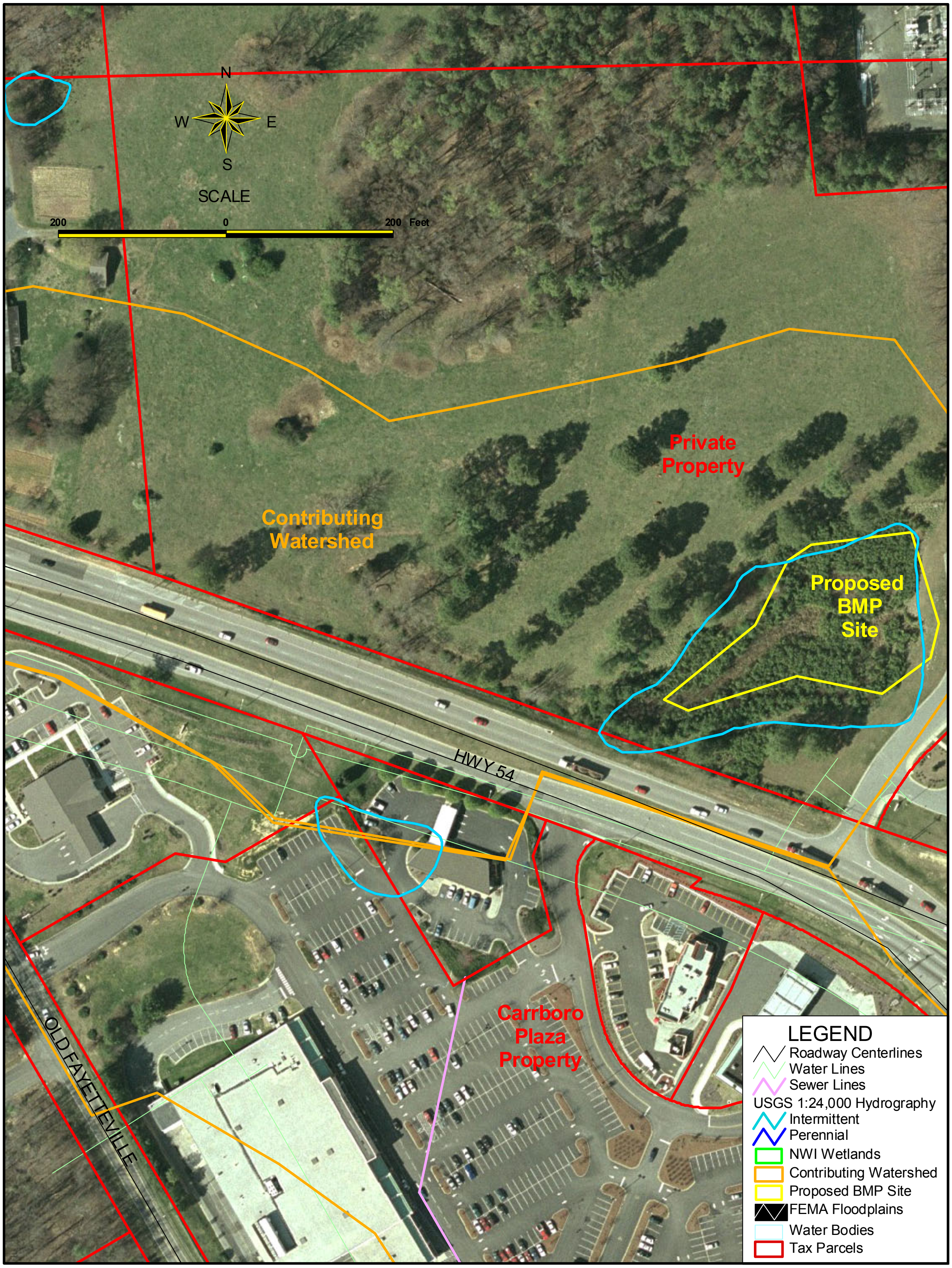
Recommended Size of Practice: 0.33 acres

Estimated Construction Cost: $15,017

Estimated 20-Year Maintenance: $2,946

Comments: Stormwater runoff from a section of North Carolina Highway 54 drains to a dry detention basin located immediately west of the Carrboro USPS. A stormwater wetland is proposed as a retrofit for this detention basin to improve the water quality and reduce the peak flows of the runoff entering Toms Creek. The existing basin is located on a privately owned parcel, which may require costs for land acquisition. However, the no infrastructure constraints are obvious, access is readily available, the existing land cover is grass, benefits would be provided to the proposed stream restoration on Toms Creek, the site is located in the Toms Creek headwaters, and earthwork is expected to be minimal due to the existing basin topography.

Map of Site 16 at Adjacent Carrboro USPS:



SITE NUMBER: 17

Site Location: Tarheel Manor Apartments

Contributing Watershed: 12.471 acres

Watershed Land Use: Parking/Apartments

Watershed Imperviousness: High

Site for Proposed Practice: 0.601 acres

LWP Subwatershed: LM1

Pros:	Cons:
• Good site access for construction and maintenance purposes • No infrastructure constraints • Practice would capture and treat runoff from highly impervious contributing watershed • BMP will work in conjunction with Toms Creek stream restoration project to increase overall functional benefit. • Headwater location • High nutrient load reduction cost-effectiveness • Second highest rating for Watershed Function Benefits (among BMPs evaluated) • Minimal earthwork required	• Property privately owned – may require acquisition • Partially wooded site

Recommended Practice: Stormwater Wetland

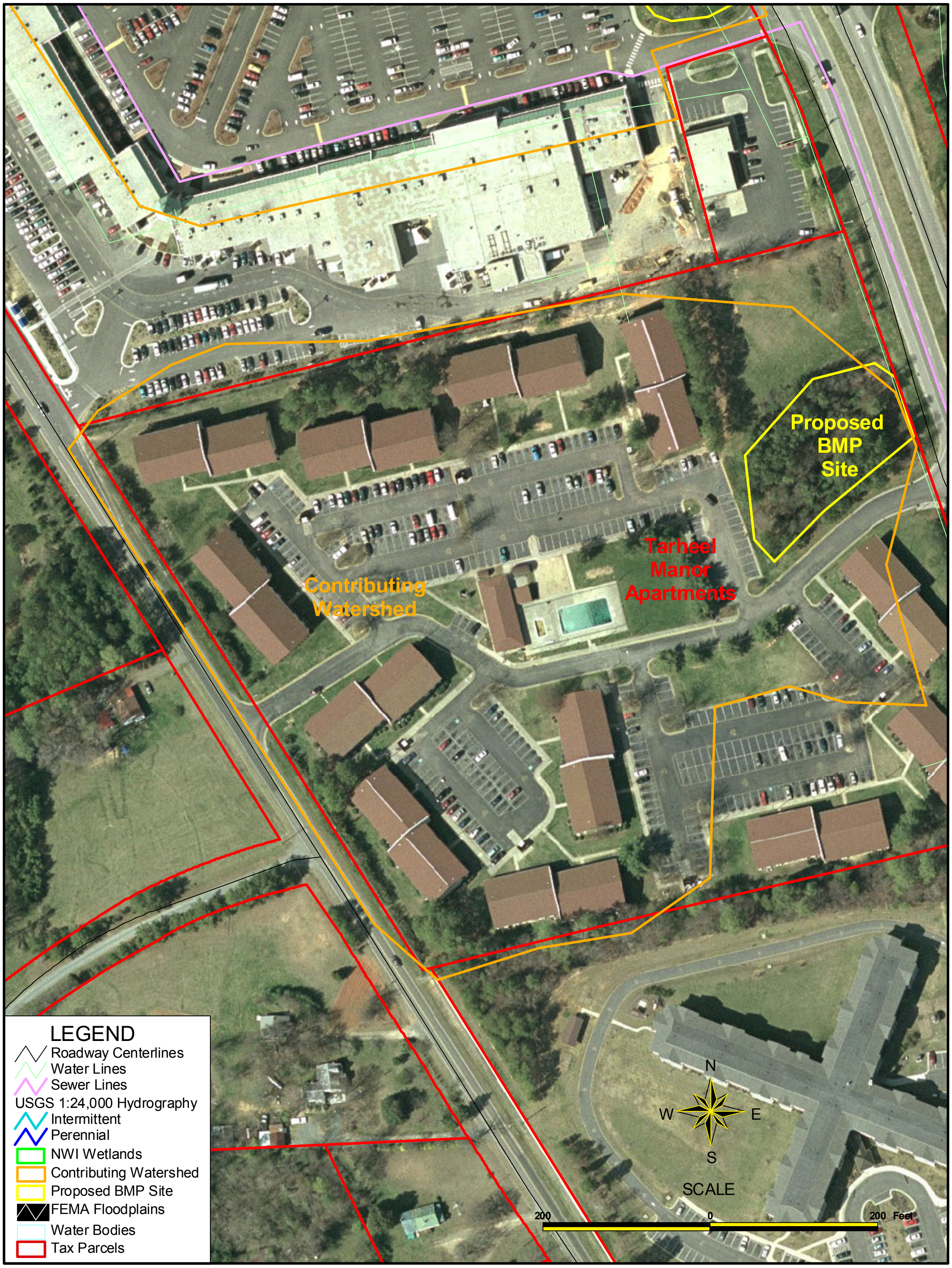
Recommended Size of Practice: 0.37 acres

Estimated Construction Cost: $13,065

Estimated 20-Year Maintenance: $2,819

Comments: A stormwater wetland is proposed as a retrofit of an old, poorly maintained detention basin that receives runoff from the Tarheel Manor apartment complex. The current topography appears to have once been a detention basin, however, some trees and underbrush now cover the site. Due to the high levels of imperviousness associated with the apartment buildings and the parking lots, a stormwater wetland would provide substantial water quality benefits to the runoff entering Toms Creek, while concurrently controlling the volume leaving the site. Nearly all of the impervious surface at the apartment complex could be disconnected from Toms Creek. The proposed site is located on property owned by the Tarheel Manor Association, but it is expected that the land would be donated if an easement has not already been granted. The existing basin will likely need to be expanded, so some earthwork is anticipated. Infrastructure does not appear to present any constraints, access is available, the site would benefit the proposed restoration of Toms Creek, and the site is located in the headwaters.

Map of Site 17 at Tarheel Manor Apartments:



SITE NUMBER: 18

Site Location: Food Lion Parking Lot

Contributing Watershed: 16.763 acres

Watershed Land Use: Parking/Roofs

Watershed Imperviousness: Very High

Site for Proposed Practice: 0.389 acres

LWP Subwatershed: LM1

Pros:	Cons:
• Good site access for construction and maintenance purposes • No infrastructure constraints • Practice would capture and treat runoff from highly impervious contributing watershed • BMP will work in conjunction with Toms Creek stream restoration project to increase overall functional benefit. • Headwater location • High rating for Watershed Function Benefits (among BMPs evaluated) • Entirely Cleared Site • Minimal earthwork required	• Property privately owned – may require acquisition • Highest estimated construction cost of all BMPs considered (see Comments below)

Recommended Practice: Wet Detention

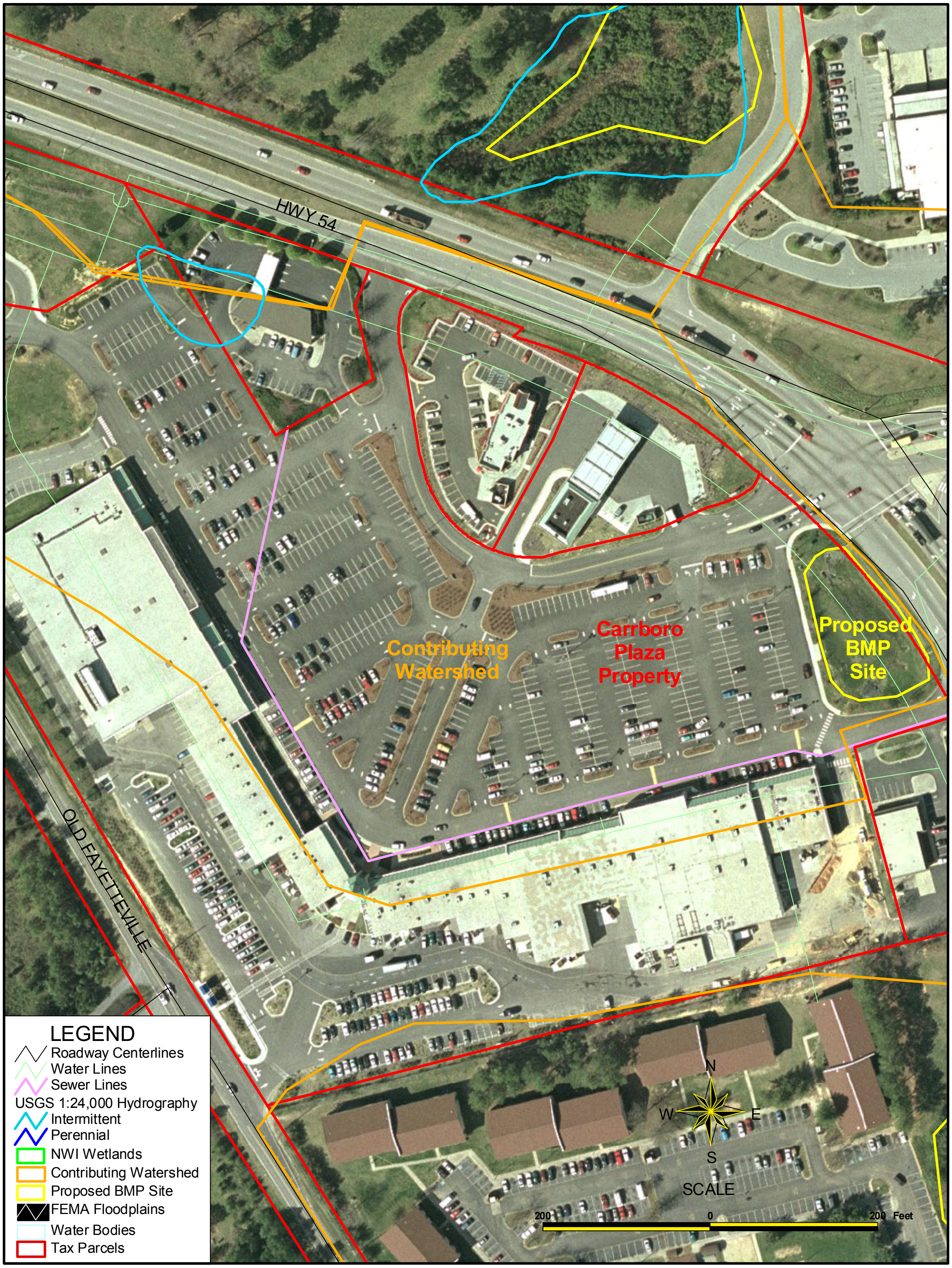
Recommended Size of Practice: 0.34 acres

Estimated Construction Cost: $92,483

Estimated 20-Year Maintenance: $8,362

Comments: A retrofit of a natural depression with an extended wet detention pond is proposed for a site located between the Carrboro Plaza parking lot and Fordham Drive. Currently, a few stormwater outfalls enter this grassed depression and flows exit through a culvert under Fordham Drive. This site could be retrofit such that the depression will be expanded and an outlet structure installed to provide control and treatment of stormwater runoff before it enters Toms Creek. The site is located on property privately held by the owners of the shopping plaza, but it could be donated to minimize land acquisition costs. Earthwork requirements are unclear as the extent of the contributing drainage area is unknown, but substantial earthwork is not anticipated. The site does not appear to be constrained by infrastructure, access is available, the existing cover is grass, and the headwater site would provide benefits to a proposed restoration of Toms Creek. Note that the estimated cost presented above was calculated by a standardized cost model that does not account for the existing level of excavation already present at this site, so actual construction coats are likely to be lower.

Map of Site 18 at Food Lion Parking Lot:



SITE NUMBER: 23

Site Location: Hogan Farms D/S Lake

Contributing Watershed: 9.191 acres

Watershed Land Use: Residential

Watershed Imperviousness: Moderate

Site for Proposed Practice: 0.202 acres

LWP Subwatershed: BL1

Pros:	Cons:
• Treats moderately impervious residential contributing watershed • Good site access for construction and maintenance purposes • No infrastructure constraints • Headwater location • Almost entirely cleared site • Minimal earthwork required • BMP will work in conjunction with upper Bolin Creek stream restoration project to increase overall functional benefit.	• Site is privately owned – land acquisition may be required • Limited nutrient load reduction capacity

Recommended Practice: Pocket Wetland

Recommended Size of Practice: 0.18 acres

Estimated Construction Cost: $11,271

Estimated 20-Year Maintenance: $2,691

Comments: The topography of a detention basin (potentially constructed for sedimentation and erosion control during the preliminary development of the community) is evident in the Lake Hogan Farms Community between Lake Hogan Farms Road and Lake Manor Road. A pocket wetland is proposed to control and treat stormwater runoff from the relatively small contributing drainage area predominantly consisting of residences and roadways. The community is located in a Tier I watershed and the proposed site is located on land owned by the homeowners association. The retrofit proposed for this site is ideal because there are no apparent infrastructure constraints, minimal clearing and earthwork would be required, access to the site for construction and maintenance purposes is available, and the site is located in the headwaters where it can beneficially impact a proposed stream restoration project. As an individual site, the potential education benefits are not considerable; however, in conjunction with the other three proposed BMPs in the community along with the proposed stream restoration project, the comprehensive benefits of a watershed-based approach to stormwater management could be highly educational.

Map of Site 23 at Hogan Farms D/S Lake:

SITE NUMBER: 24

Site Location: Hogan Farms Power Lines

Contributing Watershed: 17.560 acres

Watershed Land Use: Residential

Watershed Imperviousness: Moderate

Site for Proposed Practice: 0.641 acres

LWP Subwatershed: BL2

Pros:	Cons:
• Treats moderately impervious residential contributing watershed • Good site access for construction and maintenance purposes • No infrastructure constraints • Headwater location • Minimal earthwork required • BMP will work in conjunction with upper Bolin Creek stream restoration project to increase overall functional benefit.	• Property ownership split between UNC and Hogan Farms – may require complicated agreements and/or acquisition • Limited nutrient load reduction capacity • Wooded Site

Recommended Practice: Stormwater Wetland

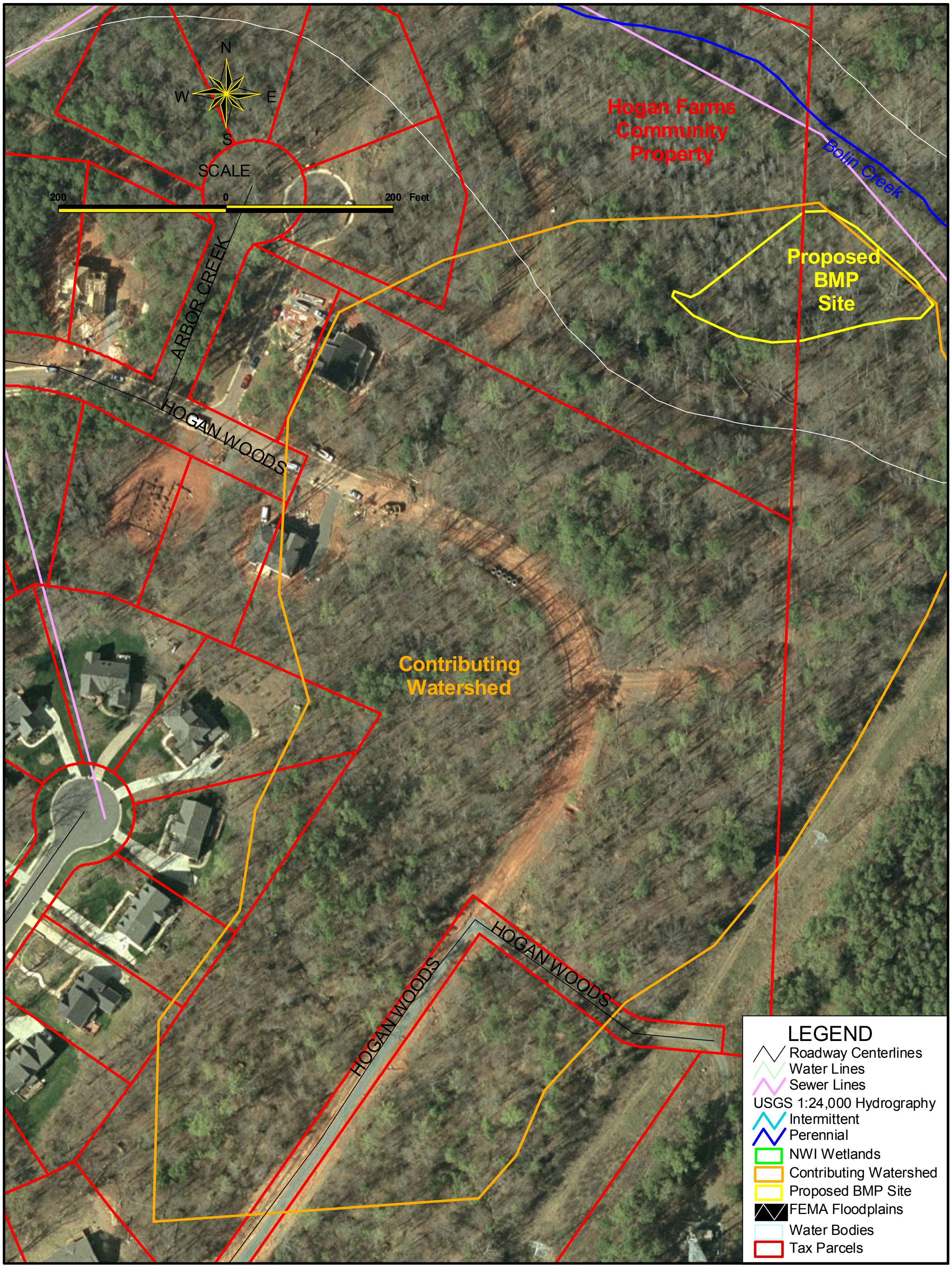
Recommended Size of Practice: 0.35 acres

Estimated Construction Cost: $15,418

Estimated 20-Year Maintenance: $2,971

Comments: A stormwater wetland is proposed to control and treat stormwater runoff from the eastern section of the Hogan Farms Community. The construction of a wetland at this site faces some challenges, but it presents the only feasible site for treating runoff from this section of the development. The site is located across two parcels, one owned by the Hogan Farms homeowners association and one by the University of North Carolina. Acquisition of the land from UNC increases the likelihood of increasing costs, unless UNC donates the property. Land clearing efforts will be high as the site is currently wooded. The site is located on the 100-year floodplain of Bolin Creek; however, as an excavated stormwater wetland is not expected to increase base flood elevations, this should present only minor concerns. The benefits of the site include no conflicts with existing infrastructure, available site access, linkage to a proposed stream restoration project, and low potential earthwork requirements. As an individual site, the potential education benefits are not considerable; however, in conjunction with the other three proposed BMPs in the community along with the proposed stream restoration project, the comprehensive benefits of a watershed-based approach to stormwater management could be highly educational.

Map of Site 24 at Hogan Farms Power Lines:



SITE NUMBER: 25

Site Location: Hogan Farms Old Silo

Contributing Watershed: 3.212 acres

Watershed Land Use: Residential

Watershed Imperviousness: Moderate

Site for Proposed Practice: 0.168 acres

LWP Subwatershed: BL1

Pros:	**Cons:**
• Treats moderately impervious residential contributing watershed • Good site access for construction and maintenance purposes • No infrastructure constraints • Headwater location • Almost entirely cleared site • Minimal earthwork required • BMP will work in conjunction with upper Bolin Creek stream restoration project to increase overall functional benefit.	• Site is privately owned – land acquisition may be required • Limited nutrient load reduction capacity and cost-effectiveness.

Recommended Practice: Bioretention

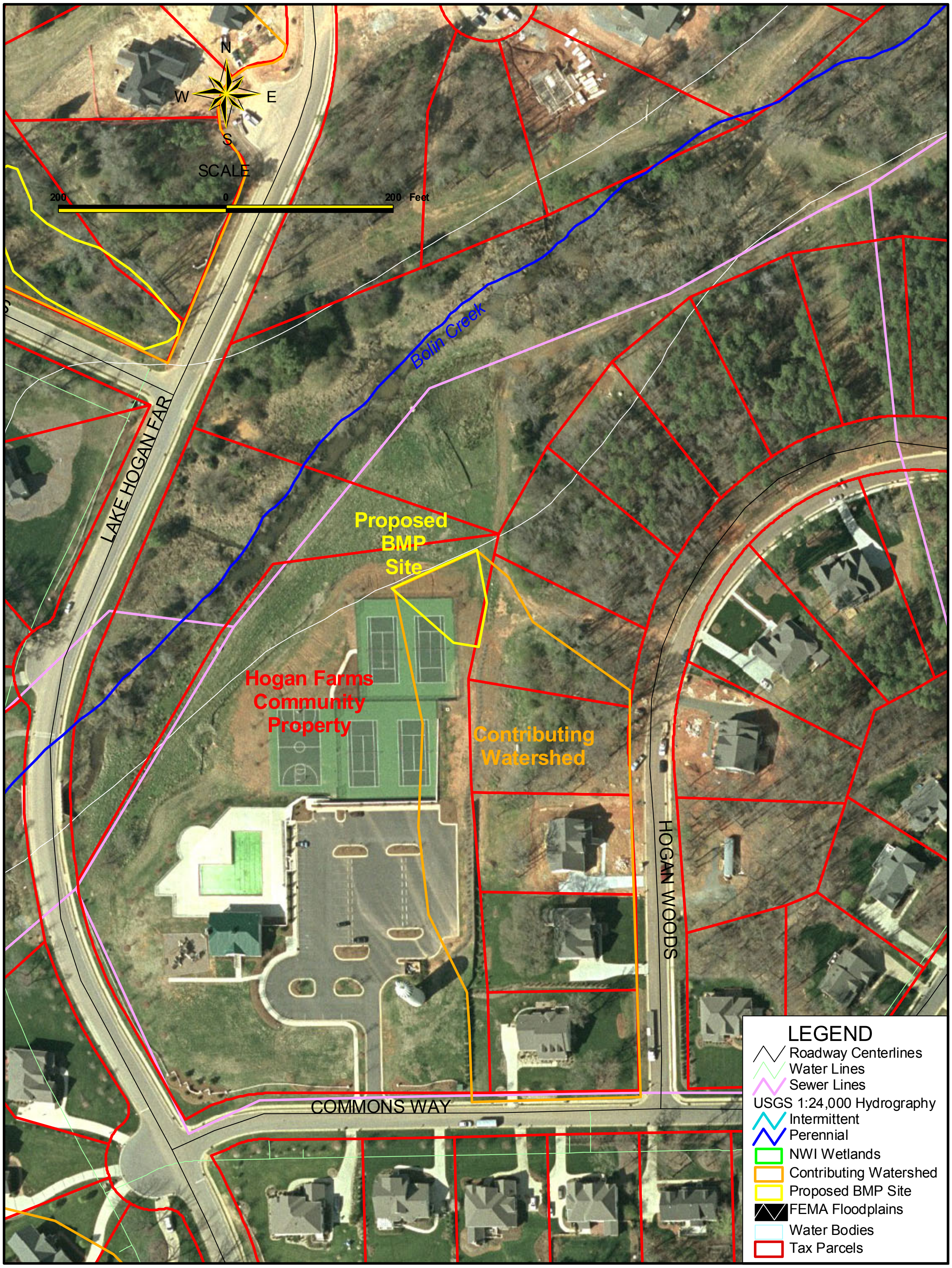
Recommended Size of Practice: 0.10 acres

Estimated Construction Cost: $36,170

Estimated 20-Year Maintenance: $1,747

Comments: In order to treat stormwater runoff from the tennis courts and parking lots associated with the playground, pool, and tennis facilities, a bioretention facility is proposed. This facility is a prime example of a site level control that would be located in the heart of the Hogan Farms Community. The location of the site on property owned by the homeowners association potentially eliminates costs associated with land acquisition. The bioretention site is located in the headwaters of a Tier I watershed that would provide immediate downstream benefits to a proposed stream restoration project. Minimal earthwork is anticipated and the site does not appear to be impacted by any existing infrastructure. As an individual site, the potential education benefits are not considerable; however, in conjunction with the other three proposed BMPs in the community along with the proposed stream restoration project, the comprehensive benefits of a watershed-based approach to stormwater management could be highly educational.

Map of Site 25 at Hogan Farms Old Silo:



SITE NUMBER: 26

Site Location: Hogan Farms Main Road

Contributing Watershed: 10.746 acres

Watershed Land Use: Residential

Watershed Imperviousness: Moderate

Site for Proposed Practice: 0.424 acres

LWP Subwatershed: BL1

Pros:	Cons:
• Treats moderately impervious residential contributing watershed • Good site access for construction and maintenance purposes • Headwater location • BMP will work in conjunction with upper Bolin Creek stream restoration project to increase overall functional benefit.	• Site is privately owned – land acquisition may be required • Limited nutrient load reduction capacity • Wooded site • Potential infrastructure constraints

Recommended Practice: Pocket Wetland

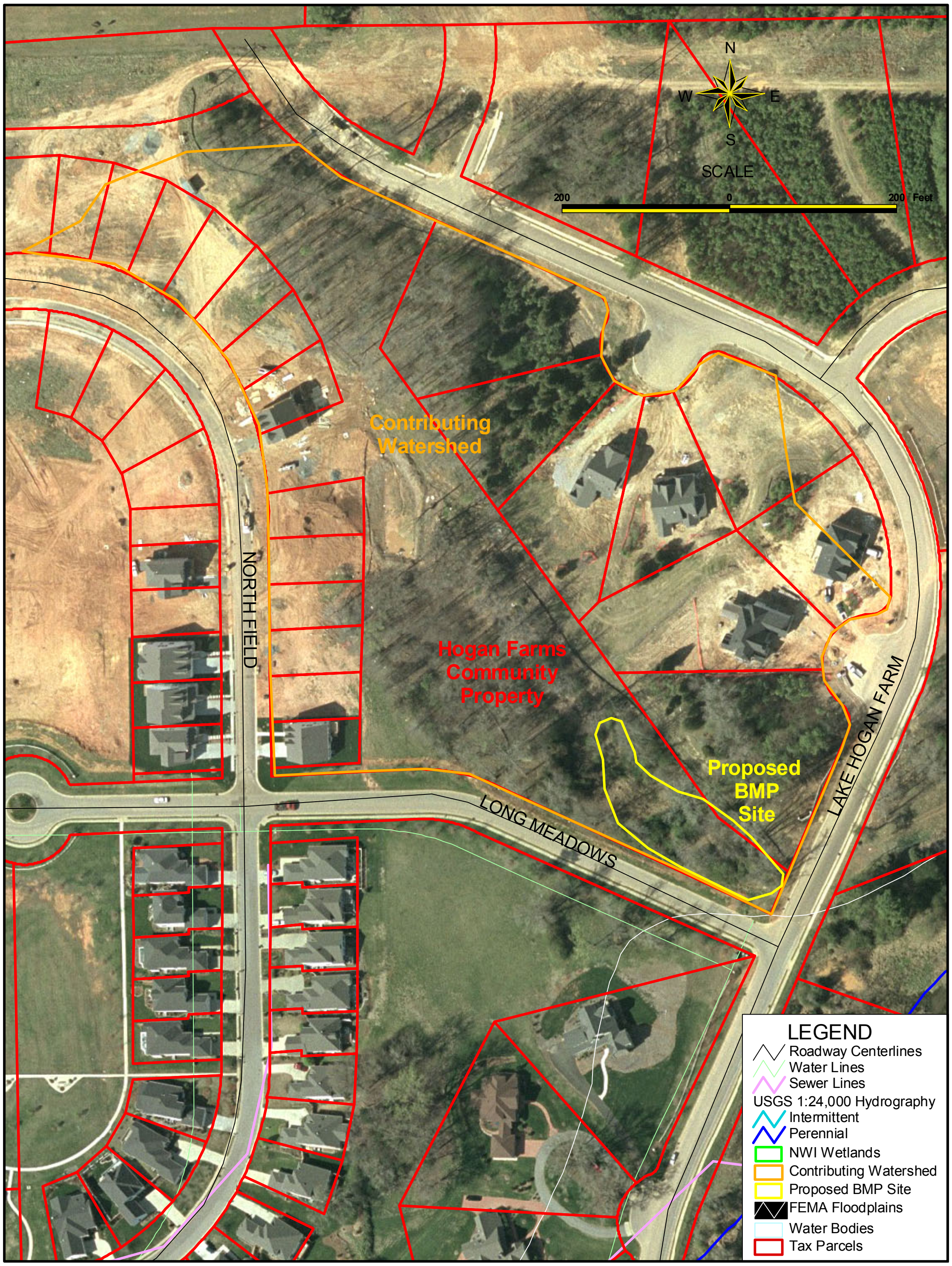
Recommended Size of Practice: 0.21 acres

Estimated Construction Cost: $12,157

Estimated 20-Year Maintenance: $2,756

Comments: A pocket wetland could be situated to treat stormwater runoff originating from the higher density development located to the northeast of Lake Hogan in the Hogan Farms Community. The proposed site is located at the intersection of Lake Hogan Farms Road and Long Meadows Road on property currently owned by the homeowners association. The primary difficulties with the site are its wooded cover and its proximity to Long Meadows Road, neither of which considerably reduces the feasibility of the site. If the roadway is located too close to the site, it would likely result in additional earthwork rather than removal of the site from consideration. Otherwise, no potential infrastructure constraints are apparent. The site is located in the headwaters of a Tier I watershed, access is available, and a proposed stream restoration project on Bolin Creek would benefit from the control and treatment afforded by this site. As an individual site, the potential education benefits are not considerable; however, in conjunction with the other three proposed BMPs in the community along with the proposed stream restoration project, the comprehensive benefits of a watershed-based approach to stormwater management could be highly educational.

Map of Site 26 at Hogan Farms Main Road:



Appendix B. Attachments for Section 3

A. Evaluating Best Management Practices

B. Permeable Pavement Guidance

C. Checklist: Opportunities for Low-Impact Development Design Techniques

Attachment A

Evaluating Management Practices

The selection of good stormwater management practices depends on the type and intensity of land use, and the conditions onsite such as soils and slopes. For the purposes of helping evaluate the effectiveness of best management practices, Tetra Tech grouped similar types of development intensities and/or land uses that counties and municipalities are experiencing today. For each grouping, best management practices to consider incorporating into site designs are recommended.

Table 1. Development/Land Use Groupings for BMP Mitigation Evaluation

Residential Development Description	Max % Imperv.
Low-Density Residential	20
Rural Residential w/Business	30
Medium-Density Residential	30

Urban Residential Development Description	Max % Imperv.
High-Density Residential Garden	45
Mixed Density Residential	60
High-Density Residential Mid-Rise	60

Commercial/Institutional Description	Max % Imperv.
Office & Institutional	70
Office & Industrial	90
Commercial Low Intensity	70
Commercial	80

Ultra-urban Description	Max % Imperv.
High Intensity Mixed Use	95

Mixed Use Description	Max % Imperv.
Mixed Use	70

The first and best step in stormwater management design is to use techniques that reduce impervious area. Then begin screening for appropriate retention and detention BMPs. In the tables below, Tetra Tech has listed some LID BMP choices for pollutant and flow reduction for each of the development categories above. Tetra Tech conducted a literature search of flow reduction and pollution removal (TSS, TP, and TN) efficiencies for each BMP. While study results varied, the efficiencies reported below represent a conservative estimate of BMP performance. Note that these tables are not exhaustive, but simply provide a screening tool to begin BMP evaluation and selection.

Table 2. BMP Choices for Pollutant and/or Flow Reduction by Development Group

Residential Development

BMP Choices for Pollutant and/or Flow Reduction	Pollution Removal TSS	TP	TN	Flow Reduction Notes
Bioretention	87%[4,5]	35%[7]	40%[7]	Medium reduction potential - some detention storage
Veg. Filter Strips w/ Level Spreader	57%[2,3]	20%[7]	20%[7]	Medium reduction potential - some detention storage
Grass Swales (Open Channels)	68%[1]	29%[1]	30%[12]	Low reduction potential
Water Quality Swales	76%[6]	31%[6]	35%[6]	Medium reduction potential - some detention storage
Permeable Pavers	No removal[12]			Low reduction potential - many opportunities for use
Stormwater Wetlands	61%[8]	35%[7]	40%[7]	High reduction potential - very land intensive
Pocket Wetlands	53%[12]	28%[12]	35%[12]	Medium reduction potential - some detention storage
Wet Ponds	65%[8]	40%[7]	25%[7]	High reduction potential - somewhat land intensive
Detention Basin (no permanent pool)	47%[1]	19%[1]	25%[1]	High reduction potential

Urban Residential Development

BMP Choices for Pollutant and/or Flow Reduction	Pollution Removal TSS	TP	TN	Flow Reduction Notes
Bioretention	87%[4,5]	35%[7]	40%[7]	Medium reduction potential - some detention storage
Veg. Filter Strips w/ Level Spreader	57%[2,3]	20%[7]	20%[7]	Medium reduction potential - some detention storage
Grass Swales (Open Channels)	68%[1]	29%[1]	30%[12]	Low reduction potential
Water Quality Swales	76%[6]	31%[6]	35%[6]	Medium reduction potential - some detention storage
Permeable Pavers	No removal[12]			Low reduction potential - many opportunities for use
Stormwater Wetlands	61%[8]	35%[7]	40%[7]	High reduction potential - very land intensive
Pocket Wetlands	53%[12]	28%[12]	35%[12]	Medium reduction potential - some detention storage
Wet Ponds	65%[8]	40%[7]	25%[7]	High reduction potential - somewhat land intensive
Detention Basin (no permanent pool)	47%[1]	19%[1]	25%[1]	High reduction potential

Commercial/Institutional

BMP Choices for Pollutant and/or Flow Reduction	Pollution Removal TSS	TP	TN	Flow Reduction Notes
Bioretention	87%[4,5]	35%[7]	40%[7]	Medium reduction potential - some detention storage
Sand Filters (Delaware design)	87%[1]	45%[7]	35%[7]	Medium reduction potential - some detention storage
Inlet/Manhole Devices	63%[9,10,11]	41%[9,10,11]	19%[11]	Medium reduction potential - some detention storage
Green Roofs	0%[6]	0%[6]	10%[12]	Medium/High reduction potential - stores first 1/2 inch of rainfall, attenuates flow after that. No additional land cost.
Veg. Filter Strips w/ Level Spreader	57%[2,3]	20%[7]	20%[7]	Low/Medium reduction potential - some infiltration and peak flow reduction
Grass Swales (Open Channels)	68%[1]	29%[1]	30%[12]	Low reduction potential
Water Quality Swales	76%[6]	31%[6]	35%[6]	Medium reduction potential - some detention storage
Permeable Pavers	No removal[12]			Low reduction potential - many opportunities for use
Underground Parking Lot Storage	No removal[12]			High reduction potential - no additional land costs
Stormwater Wetlands	61%[8]	35%[7]	40%[7]	High reduction potential - very land intensive
Pocket Wetlands	53%[12]	28%[12]	35%[12]	Medium reduction potential - some detention storage
Wet Ponds	65%[8]	40%[7]	25%[7]	High reduction potential - somewhat land intensive
Detention Basin (no permanent pool)	47%[1]	19%[1]	25%[1]	High reduction potential

Ultra-urban

BMP Choices for Pollutant and/or Flow Reduction	Pollution Removal TSS	TP	TN	Flow Reduction Notes
Bioretention	87%[4,5]	35%[7]	40%[7]	Medium reduction potential - some detention storage
Sand Filters (Delaware design)	87%[1]	45%[7]	35%[7]	Medium reduction potential - some detention storage
Inlet/Manhole Devices	63%[9,10,11]	41%[9,10,11]	19%[11]	Medium reduction potential - some detention storage
Green Roofs	0%[6]	0%[6]	10%[12]	Medium/High reduction potential - stores first 1/2 inch of rainfall, attenuates flow after that. No additional land cost
Permeable Pavers	No removal[12]			Low reduction potential - limited opportunities for use
Underground Parking Lot Storage	No removal[12]			High reduction potential - no additional land costs
Detention Basin (no permanent pool)	47%[1]	19%[1]	25%[1]	High reduction potential

Notes:

[1]Winer, R. 2000. National Pollutant Removal Performance Database for Stormwater Treatment Practices, 2nd Edition. Center for Watershed Protection. Ellicott City, MD.

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[4]Davis, A.P. "Bioretention – Studies Completed by the University of Maryland" http://www.ence.umd.edu/~apdavis/Biodata.htm. Updated: August 27, 2002.

[5]Low Impact Development Center. "Watershed Benefits of Bioretention Techniques." http://www.lid-stormwater.net/bioretention/bio_benefits.htm. Accessed: December 13, 2002.

[6]Best Professional Judgment.

[7]NCDWQ. 2003. Tar-Pamlico River Basin: Model Stormwater Program for Nutrient Control.

[8]Hunt, William F. 2002. Stormwater BMP Cost-Effectiveness Relationships for North Carolina. Conf paper for Watershed 2002.

[9]Clausen, J.C., P. Belanger, S. Board, M. Dietz, R. Phillips, and R. Sonstrom. 2002. Final Report – Stormwater Treatment Devices Section 319 Project – Project #99-07. Dept of Natural Resources Management and Engineering. University of Connecticut. Report submitted to Connecticut Dept. of Environmental Protection.

[10]Yu, S.L., X. Zhang, A.Earles, and M. Sievers. Field Testing of Ultra-urban BMPs. Available at http://www.people.virginia.edu/~engstorm/pdf/ASCE99BMP.pdf .

[11]Yu, S.L., M.D. Stopinski, and J.X. Zhen. Field Monitoring and Evaluation of Stormwater Ultra-Urban BMPs. Available at http://www.people.virginia.edu/~engstorm/pdf/ultraBMP.pdf .

[12]Hunt, W.F., 2003. Personal Communication - Stormwater Wetland and Bio-retention Design Workshop. Caldwell County Library, Lenoir, North Carolina. April 15, 2003.

Attachment B

Permeable Pavement Guidance

Design

- Location:
    - Residential applications for ultra-urban infill or redevelopment only (e.g., downtown Durham or Raleigh).
    - All other parking applications have a minimum of 50 parking stalls. Recommend conventional pavement for entrance and access, especially if the parking area receives heavy vehicle traffic (i.e., more daily uses than two times the number of stalls).
- Block paver specifics:
    - Must have a base of washed 57 stone (or similar washed gravel).
        - Generally, 6 inches base for residential applications.
        - Generally, 10 - 12 inches base for commercial applications.
        - Depth can vary. There is some design variation depending on the block paver system, and site/substrate (sandy soils require less depth). However, the minimum depth must support its designed vehicle traffic for the anticipated life of the parking area (flexible pavement design from AASHTO should be followed.)
        - Minimum depth may also be guided by capture volume goals (such as 1- or 2-year storm events).
    - Additional layer of chocker stone or sand (with filter fabric) on top of base. Configuration depends on block paver system.
- Permeable asphalt/concrete specifics:
    - Must have a base of washed 57 stone (or similar washed gravel).
        - Minimum depth 6 inches base needed to avoid freeze/thaw issues; otherwise runoff will pond inside pavement matrix, freeze, and cause it to crumble.
        - Minimum depth also influenced by site/substrate and capture volume goals.
- All systems (both block pavers and permeable asphalt/concrete):
    - Installation should take place as late as possible in the construction process. Site must be as stable as possible.
    - Must have a simple slow drainage system, assuming construction in soils tighter than sandy loam. Suggested design is 4-inch corrugated pipe. The pipe selection and design should be geared for a minimum drawdown time of stored water (e.g.,2 days). Use of this design requires a base layer minimum depth of 6 inches.
    - Base layer depth capture volume:
        - 6 inches will completely capture at least 2.0 inches of runoff.
        - 12 inches will completely capture 2-year 24-hour storm event. Parking lots with a drop in elevation of 6 or more inches must have internal berms to slow runoff

rates. A suggested guideline is one berm for each 6 inches drop in elevation. The berms could be composed of any number of materials, such as poured concrete or hard plastic. The internal berms must be sufficiently strong to handle vehicular traffic and weight.

- Suggested design element to improve infiltration:
  - Allow for 2 inches stone base below drainage system. Water will pond in this layer and slowly infiltrate into underlying soil. Use of this design element increases the minimum base layer to 8 inches.

Maintenance

- Require the use of a pressure wash vacuum sweeper two times annually. Standard street sweepers are not sufficient to remove particles.
- Exception – block pavers with sand need only to have their surface scarified, which can be performed with a standard street sweeper. Must be performed two times annually.

Testing

- Testing shall be performed shortly after installation to ensure proper design and construction. It is critical that testing take place quickly; if the pavement was constructed improperly, the property owner is more likely to have recourse to force the contractor to reconstruct or remedy the pavement.
- Testing shall be performed with a double-ring infiltrometer.
- Testing shall be performed in at least three locations at or near the entrance. If any of those tests show potential problems, additional testing should be performed at parking area edges.
- The average infiltration rate must be at least 10 in/hr for the permeable pavement installation to pass the test.

Attachment C

Checklist: Opportunities for Low-Impact Development Design Techniques*

Clearing and Grading

- Is disturbance of vegetated areas and riparian areas minimized?
- Do the building envelopes avoid sensitive environmental areas such as riparian areas, wetlands, high infiltration soils, steep slopes, etc.?
- Is total site disturbance minimized?

Minimizing Impervious or Built Upon Area

Streets

- If this is a residential development, are the street pavement widths between 18 to 22 feet?
- Does the design promote the most efficient street layout to reduce overall street length?
- If there are cul-de-sacs, is the radius 35 feet or less?
- If there are cul-de-sacs, is there a landscaped island or bioretention island?
- Are grass swales or bioretention swales used instead of curb and gutter where slopes allow?

Parking/Driveways/Sidewalks

- If this is an office building, is the parking ratio 3.0 spaces per 1000 sq.ft. of gross floor area or less?
- If this is a commercial center, is the parking ratio 2 to 4.5 spaces per 1,000 sq.ft. of gross floor area or less?
- Is a mass transit stop provided or nearby (if applicable)?
- Does the proposed development take advantage of opportunities for shared parking?
- Is the minimum stall width for a standard parking space 9 feet or less?
- Do the parking medians (if required) have bioretention cells where feasible?
- Are driveways 9 feet or less in width?
- Are shared driveways used?
- Is on-street parking considered and imperviousness minimized (no on-street or single-side parking where allowed)?
- Are sidewalks (if required) designed to the narrowest allowable width?
- Are sidewalks on one side of street only?

Clustering Development

- To encourage clustering and open space design, are setbacks minimized (e.g., for residential lots that are ½ acre or less in size is the front set back 20 feet or less, the rear setback 25 feet or less, and the side setback 8 feet or less)?
- Does the design focus development on areas of lesser slopes and farther from watercourses?

Preserving Sensitive Areas

Wetlands

- Are existing wetlands preserved?
- Will the site design minimize hydrologic alteration to existing wetlands?

Steep Slopes

- Is building footprint concentrated on slopes 10 percent or less?
- Is disturbance minimized on slopes 15 percent to 25 percent and revegetation proposed where disturbance occurs?
- Are areas with 25 percent or greater slope preserved?

Soils

- Do the building footprints avoid highly erodible soils (Roanoke Silt Loam, Cartecay and Chewacla soils, Cecil Sandy Loam, Cecil-Urban Land Complex, Gwinnett Sandy Loam, Hiwassee Sandy Loam, and Madison Sandy Loam)?
- Do the building footprints avoid soils with high permeability (e.g., Hydrologic Soil Group A and B)?

Stream Buffer

- Is a 50 to 75 foot stream buffer provided?
- Will the stream buffer remain in a natural state?

Managing Stormwater

- Are efforts made to retain/infiltrate stormwater onsite (through bioretention, natural areas, and swale infiltration)?
- Are stormwater management practices designed and sized correctly to provide sufficient storage volume?
- Are outfalls stabilized to reduce erosion?
- Has a BMP maintenance plan been submitted?

Managing Open Space

- Is open space available for preservation?
- Will the preserved open space be managed in a natural condition?
- Will there be a Homeowners Association or other association that can effectively manage the open space?

** Adapted from Low-Impact Development Design Strategies, Prince George's County MD. 1999; Better Site Design: A Handbook for Changing Development Rules in Your Community, Center for Watershed Protection, 1998; State of North Carolina Model Ordinance for Water Supply Watershed Protection.*

ATTACHMENT C

STATE OF NORTH CAROLINA
THE TOWN OF CARRBORO

MEMORANDUM OF UNDERSTANDING

THIS MEMORANDUM OF UNDERSTANDING, made this the 8 day of April, 2002, by and between the the NORTH CAROLINA DEPARTMENT OF ENVIRONMENT AND NATURAL RESOURCES, DIVISION OF WATER QUALITY, WETLANDS RESTORATION PROGRAM (NCWRP) and the TOWN OF CARRBORO.

SECTION 1 - Background

The mission of the NC Wetlands Restoration Program (NCWRP) is to restore, enhance, and preserve wetlands, streams, and riparian buffer areas throughout North Carolina's 17 major river basins with the overall goal of improving water quality. The NCWRP is interested in restoring and protecting the wetlands, creeks, streams and unnamed tributaries within the New Hope Creek Drainage area (which includes the Town of Carrboro). These waterbodies are experiencing impacts from increased development including loss of buffers, channelized streams, flooding and degraded water quality.

As part of this restoration effort, the NCWRP is interested in working with the Town of Carrboro to actively initiate Local Watershed Planning within watersheds that include the Town of Carrboro. The overall goal of Local Watershed Planning is to identify projects which can improve water quality, floodwater retention and aquatic habitat. This initiative will involve local government and resource professionals as well as some other local stakeholders. Local Watershed Planning works to identify locally owned sites for wetland, stream, and riparian buffer restoration. In addition to wetland, stream and buffer projects, other innovative techniques to reduce pollution such as stormwater best management practices and stormwater control retrofits may be identified. The Local Watershed Planning process for these local watersheds within the Upper Cape Fear River Basin is planned to begin this spring 2002.

SECTION 2 - Scope of Work

The NCWRP agrees to:

1. Work with the Town of Carrboro (Town) to initiate a Local Watershed Planning Process within watersheds which encompass portions of Towns of Carrboro and Chapel Hill as well as additional portions of Orange County.

2. Assist the Town with evaluating buffers, impervious surfaces, and other related matters to improve non-structural protections.

3. Develop a Watershed Restoration Plan in conjunction with Carrboro and other jurisdictions in the study area.

4. For any restoration projects identified, and approved by the Town, provide an environmental contractor to conduct a feasibility study of potential projects to improve water quality in the Town of Carrboro area.

C-2

3. Implement one or more projects within the Town of Carrboro area based on feasibility studies, the NCWRP's need for projects, as well as compatibility with town planning priorities.

4. Monitor and manage implemented projects for a period of five years.

5. Provide the Town with all data and analysis and other work products from the project, written records of the planning process, and reports during the monitoring phase (in electronic format at minimum).

The Town of Carrboro agrees to:

1. Allow the NCWRP to coordinate its efforts through one main Town representative. This representative appointed by the Town will serve as the Town of Carrboro's point of contact on all NCWRP project and Local Watershed Planning efforts.

2. Hear and receive the recommendations developed through the Local Watershed Planning process.

3. Participate in the development, review, and implementation strategy for the plan.

4. Provide the NCWRP with previously collected data, mapping, utility information, trail plans, and other pertinent information as may be reasonably required and which is readily available to the Town at little or no cost to the Town.

5. Allow the NCWRP to implement one or more projects within the Town of Carrboro at such location or locations as may be satisfactory to the Town and the NCWRP provided that the projects do not conflict with town plans.

SECTION 3 - Cooperation and Termination

This Memorandum of Understanding is an agreement in principle and good faith concerning the work described above. Both the NCWRP and the Town of Carrboro acknowledge that it is their desire to facilitate the process set forth in this agreement by open communication and cooperation. If either party wishes to withdraw from this agreement, either party may do so by giving written notification to the other party. Amendment of this Memorandum of Understanding requires written approval by both parties.

[signature] Date 12 Apr 02

Gregory J. Thorpe, Ph.D.
Acting Director - Division of Water Quality

____________________ Date________

Michael R. Nelson, Mayor
Town of Carrboro