BOLIN CREEK WATERSHED RESTORATION PLAN

NOVEMBER 1, 2012

PREFACE

The intention of this plan is to support those who reside or work in or near Bolin Creek, or have a responsibility or an ethic to be a steward of Bolin Creek, to take concrete actions to improve the condition of Bolin Creek. What exactly does that mean? First, the focus is on the creek and the aquatic organisms that live in the creek. The creek obviously does not exist in a vacuum, so caring for the land, plants, animals, and yes, people, in the watershed cannot be dismissed or disconnected from care for the creek. However, care for the land, terrestrial plants, animals, and people and care for the water do have distinct differences. For example, invasive plants eradication may be desirable for a variety of non-creek oriented reasons, but these pioneer plants may in fact be filling, at least temporarily, a restorative niche from an aquatic perspective in the watershed by stabilizing stream banks, working and protecting the soil and helping mitigate hydrologic disruptions. Similarly, meeting human needs for recreational enjoyment and municipal infrastructure are clearly valued, but what is the proper balance when these values compromise aquatic health through hydrologic modification, increased erosion and sedimentation, habitat disruption, and pollutant delivery? Ultimately, the success of this plan and its beneficial ongoing evolution will be a function of finding ways to integrate the plan with all of the other interests in the community and watershed for health and wellbeing. As Wendell Berry wisely observed:

> *Because a community is, by definition, placed, its success cannot be divided from the success of its place, its soil, forests, grasslands, plants and animals, water, light, and air. The two economies, the natural and the human, support each other; each is the other's hope of a durable and livable life.*

So what's wrong with Bolin Creek? Why do we need to fix it? How will this plan remain fresh and helpful and not be something lost in the immensity of cyberspace or gather dust on a shelf? This plan is the Bolin Creek Watershed Restoration Team's attempt to shed light on these questions. At the same time, this plan can be viewed as as much an inquiry for the reader as questions to be answered herein. One core concept is suggested. If this plan is to be of value, it will be because it is seen not as a mandate from government or a pontification from experts, but as an invitation to collective collaboration. If there is a second foundational idea, it is that there really is not a compromise or partial solution. The watershed behaves as a whole; its integrity and health therefore relies on holistic, comprehensive, synergistic, and integrated strategies, programs, projects, and actions. Readers are invited to determine what patch of the restoration quilt that they can offer.

ACKNOWLEDGEMENTS

This plan represents the first drafting of a comprehensive watershed restoration plan for Bolin Creek. The primary authors of this version of the plan have been staff from Chapel Hill's Stormwater Management program and Carrboro's Planning Department. The work, however, could not have been completed without previous and supportive efforts of many individuals and organizations too numerous to mention. Particularly noteworthy are previous State sponsored studies completed in 2003 and 2004 and summarized in this plan. This plan is seen as a next step in an ongoing process initiated through those reports.

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CHAPTER 1: INTRODUCTION

1.1 OVERVIEW

Watershed restoration presents a variety of special challenges. One challenge is that restoration requires changes (e.g., repairs, retrofits) to the existing condition rather than an effort pursued originally when a site is developed. Restoration therefore is typically contingent on voluntary cooperation. It is usually more difficult and expensive to retrofit a site relative to inclusion in the original planning, design, and development. Additionally, funding and financing of retrofits can be difficult, without a strong rationale for profitability on the private side, and limited capacity on the public side. It is also more difficult to achieve broad commitment without compelling incentives (carrots), penalties (sticks), and/or a paradigmatic shift. Ultimately, ecological or watershed restoration requires a heightened collective understanding of the harm occurring, valuing of improvement, commitment to reduce the harm, and the ability to follow through with responsible action. In this regard, restoration is fundamentally different than conservation or preservation, which attempt to maintain and protect an ecosystem from harmful future impacts. Obviously, restoration efforts that are ignorant of the need for protection from future impacts are a recipe for failure. Optimally, restoration is also framed in a way that enhances other community values such as enjoyment of place, cultural identity, prosperity, and other measures of human health and well-being.

Recognizing this context for restoration, this Watershed Restoration Plan has also been shaped by several practical influences. The first is EPA's nine key elements of watershed restoration planning that are prerequisites for receiving federal funding for watershed restoration. Specifically, this plan is a required deliverable that must address these elements under an EPA grant being administered by the Town of Chapel Hill, in collaboration with members of the Bolin Creek Watershed Restoration Team. The second influence is a series of studies within the past decade that have lent insight into the condition of the watershed and improvement opportunities. In addition, the approach is geographically oriented around smaller subwatersheds. These sources of guidance and structure are briefly discussed below and more fully developed in the remainder of the plan.

1.2 BACKGROUND

Bolin Creek is one of the major streams draining southern Orange County, as it drains 12 square miles in carving a path through the heart of Carrboro and Chapel Hill (Figure 1). Bolin Creek's headwaters rise to the west of NC Old 86, just north of Carrboro. Moving downstream, the watershed transitions from rural to suburban to urban. Bolin Creek is a major tributary to Little Creek, eventually flowing to Jordan Lake.

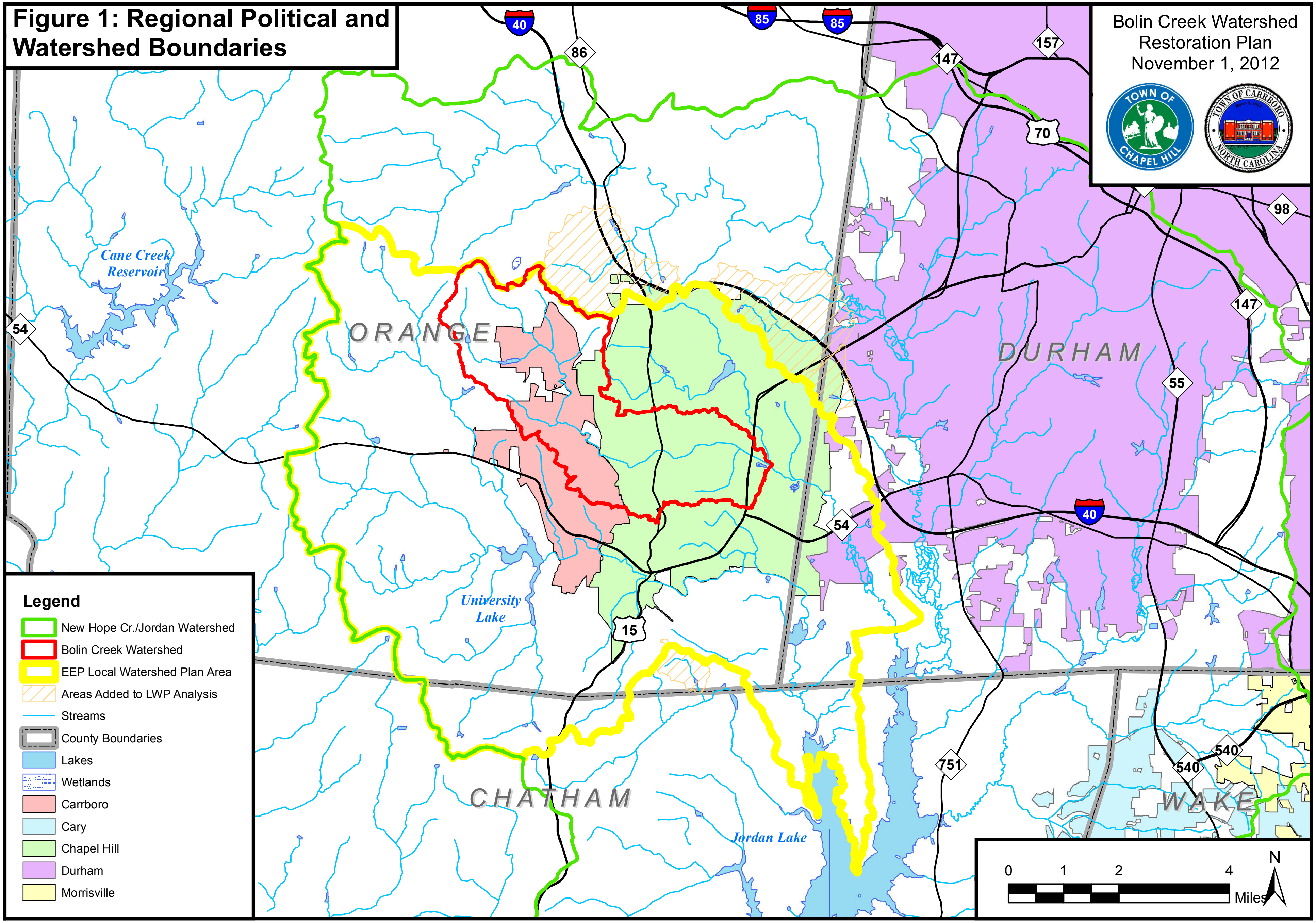


Figure 1: Regional Political and Watershed Boundaries

The local community has a fond relationship with the creek, and at the same time, a growing body of evidence over the past several decades has documented that the aquatic life of Bolin Creek and its tributaries is threatened and impaired from the human activity occurring within its watershed. The details of the harm that has occurred are discussed to a limited degree in this plan, and more thoroughly in studies referenced herein. The causes of the impairment are both simple—land disturbance and development—and complex: alterations in hydrology, erosion and sedimentation, introduction of toxic contaminants and other pollutants, and habitat disruption. The bottom line is that the concern is also an opportunity for restoring the creek to a healthier status.

Staff from the Carrboro Planning Department, Chapel Hill Stormwater Management Division, the North Carolina Department of Environment and Natural Resources (DENR), and the US Environmental Protection Agency (EPA) began meeting in April 2006. Together these organizations formed the Bolin Creek Watershed Restoration Team (BCWRT) to participate in EPA's Watershed Restoration Program in restoring and enhancing Bolin Creek and its tributaries, and invited other local staff to participate.

In 2008, the Towns received a 319 grant that included several restoration elements, including small stream restorations, installation of stormwater retrofits, and the creation of a Watershed Restoration Plan in the mold of EPA's 9-element watershed plans. This was undertaken with the understanding that future grant funding was largely contingent on a coordinated, targeted, well-supported approach to restoring Bolin Creek Watershed, as would be presented in the Plan.

1.3 EPA'S NINE ELEMENTS OF WATERSHED RESTORATION PLANNING

EPA requires that watershed plans address "nine elements" in developing a restoration plan that is funded using 319 funds. 319 refers to the section of the Clean Water Act that allows EPA to fund nonpoint source activities such as technical and financial assistance, education, training, technology transfer, demonstration projects, and monitoring to assess the success of specific nonpoint source implementation projects. These nine elements include:

1. An information/education component to enhance public understanding of the project and increase public participation. (Chapter 4)
2. A monitoring component to evaluate the effectiveness of the implementation efforts over time measured against the criteria. (Chapter 6)
3. An identification of the causes (stressors) and sources or groups of similar sources that need to be controlled to achieve pollutant load reductions estimated in the watershed. (Chapter 3, Appendix 3)
4. An estimate of the improvements associated with the chosen management measures. (Chapter 5)
5. A description of the measures that will need to be implemented to achieve load reductions as well as to achieve other watershed goals identified in the watershed based plan.(Chapter 4, Chapter 5, Appendix 4, Appendix 5)
6. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made towards attaining water quality standards. (Chapter 6)
7. An estimate of the amount of technical and financial assistance needed, associated costs and or sources, and authorities that will be relied upon, to implement the plan. (Chapter 6)

8. A schedule for implementing the NPS management measures identified in this plan that is reasonably expeditious. (Chapter 6)
9. A description of interim, measurable milestones to track progress in achieving restoration goals. (Chapter 6)

The location in this Watershed Restoration Plan where these elements can be found is listed in parentheses after every element.

1.4 RELATIONSHIP TO REGULATORY EFFORTS

The initiative has initially focused on hydrologic modification and habitat degradation by addressing some of the primary causes of these stressors including streambank and streambed erosion, disconnection from stream floodplains, sedimentation, scour, thin/absent/bypassed forested riparian buffers, the "flashy" nature of urban streams, very low base flow, and the effects of stream crossings. One note is that water quality issues related to toxins and nutrients have not thus far been a focus of this initiative, as toxic concerns are being addressed primarily through the Towns' respective Illicit Discharge Detection and Elimination programs as part of their municipal stormwater permits and nutrients are being addressed primarily through the implementation of the Jordan Lake rules. However, through development of the Plan it has become apparent that addressing pollutants will be important to recovering Bolin Creek's natural functions, but will also be easily combined with other restoration efforts.

1.5 WATERSHED RESTORATION GOALS

The Bolin Creek Watershed Restoration Team has developed the following goals to guide the development and implementation of this plan.

ECOLOGICAL GOALS

- Restore aquatic and riparian habitat in the watershed—in areas where impacts have occurred, implement projects that will provide measurable improvement to habitat in the stream and riparian system.
- Improve water quality in the watershed—implement management strategies that will improve water quality in Bolin Creek so it can support its designated use.
- Reduce nutrients reaching streams and Jordan Lake. Jordan Lake is a critical resource to the region for both drinking water supply and recreation.
- Protect lands critical for habitat and water quality by protecting riparian buffers, floodplains, wetlands, and steep slopes.
- Improve the ability of vegetated buffers to serve as water quality filters by establishing diffuse flow and correcting situations with concentrated flow that bypasses the buffer.

SOCIAL GOALS

- Improve natural conditions for people living in the watershed. Identify and pursue opportunities to improve human use of managed natural areas and trails. Improve aesthetics, and reduce impacts from erosion and flooding where these objectives align with the protection of water quality and habitat functions.

- Foster community stewardship of the watershed. Educate and involve the local community in the ongoing implementation of the plan, and long-term stewardship of the watershed.
- Enhance education and outreach by increasing capacity and establishing a program that engages the community. Implement a program in all public schools.
- Encourage restoration through financial and social incentives. Create a defined community response and participation system. Actively promote incentive programs to reach the community. Increase the sharing of responsibility for restoration efforts between more centralized government agencies to more distributed public, private, nonprofit, and grass roots organizations and individuals. Maximize collaborative opportunities and partnerships.

IMPLEMENTATION GOALS

- Monitor plan implementation progress on a schedule that allows identification and funding of new projects as appropriate for capital improvements programs, annual budgets, and other funding opportunities.
- Identify and prioritize restoration opportunities that have the greatest opportunity of resulting in demonstrable improvements in aquatic health. Prioritize opportunities based on effectiveness, feasibility, and cost.

1.6 PLAN FRAMEWORK/STRUCTURE

The plan is divided into the following components:

This Introduction that presents the overview, purpose and scope, vision, and guiding principles of this plan (Chapter 1).

A characterization of the natural and cultural features of Bolin Creek (Chapter 2)

An analysis and summary of findings about the watershed health, stresses, and causes and sources of impairment (Chapter 3).

Watershed stewardship recommendations that are seen as a cornerstone of restoration progress. (Chapter 4).

Methods for stormwater retrofits, buffer restoration, and stream repair, as well as protection from future impacts (Chapter 5).

Implementation recommendations that identify steps, responsible parties and roles, schedules and milestones, funding and technical assistance needs, monitoring, and plan evaluation (Chapter 6).

Appendices on local environmental policies and programs, local environmental agencies and organizations, stressor sources, source alternative behaviors, selected management practices, and details of a watershed restoration projects database.

CHAPTER 2: WATERSHED CHARACTERIZATION

2.1 NATURAL ENVIRONMENT

POLITICAL AND WATERSHED BOUNDARIES

Bolin Creek is a fourth order stream draining an area of about 7800 acres, or approximately 12 square miles. It starts in unincorporated parts of Orange County, NC and flows mostly southeast into first the Town of Carrboro and then into the Town of Chapel Hill. When it reaches the confluence with Booker Creek in Chapel Hill the combined streams become known as Little Creek.

Little Creek is one of the many streams included in the drainage area known as the "Upper New Hope Arm" of Jordan Lake, which also includes Morgan Creek, New Hope Creek, Northeast Creek, and Third Fork Creek. The Bolin Creek Watershed is shown in Figure 1 (in previous chapter) in relation to the drainage area for the Upper New Hope Arm of Jordan Lake, and the combined drainage areas for Little Creek and Morgan Creek. This watershed plan is an adjunct to the Local Watershed Plan developed by the Ecosystem Enhancement Program in 2006 for the Morgan and Little Creek Watersheds.

Figure 2 divides the watershed into 9 subwatersheds for purposes of analysis and cartography. These subwatersheds are the "management units" of this plan. Each subwatershed has been considered separately to facilitate specific management strategy recommendations. This approach allows efforts to be pursued in individual subwatersheds over time in order to concentrate hydrological, morphological, and biological improvements. These subwatersheds are subsets of the Ecosystem Enhancement Program's prior watershed plan for this area, the Morgan and Little Creek Watersheds Local Watershed Plan. This allows for easier comparison of the two plans. Names for the Bolin Creek Subwatersheds are thus based on the names given to the EEP Local Watershed Plan subwatersheds.

Named tributaries of Bolin Creek on USGS maps include Jones Creek, Buckhorn Branch, Jolly Branch, and Tanbark Branch. Locally, several other tributary names have been found on old UNC maps, neighborhood plats and deeds, including Dry Gulch, Mill Race, Tanyard Branch, Cole Springs Branch, and Battle Branch.

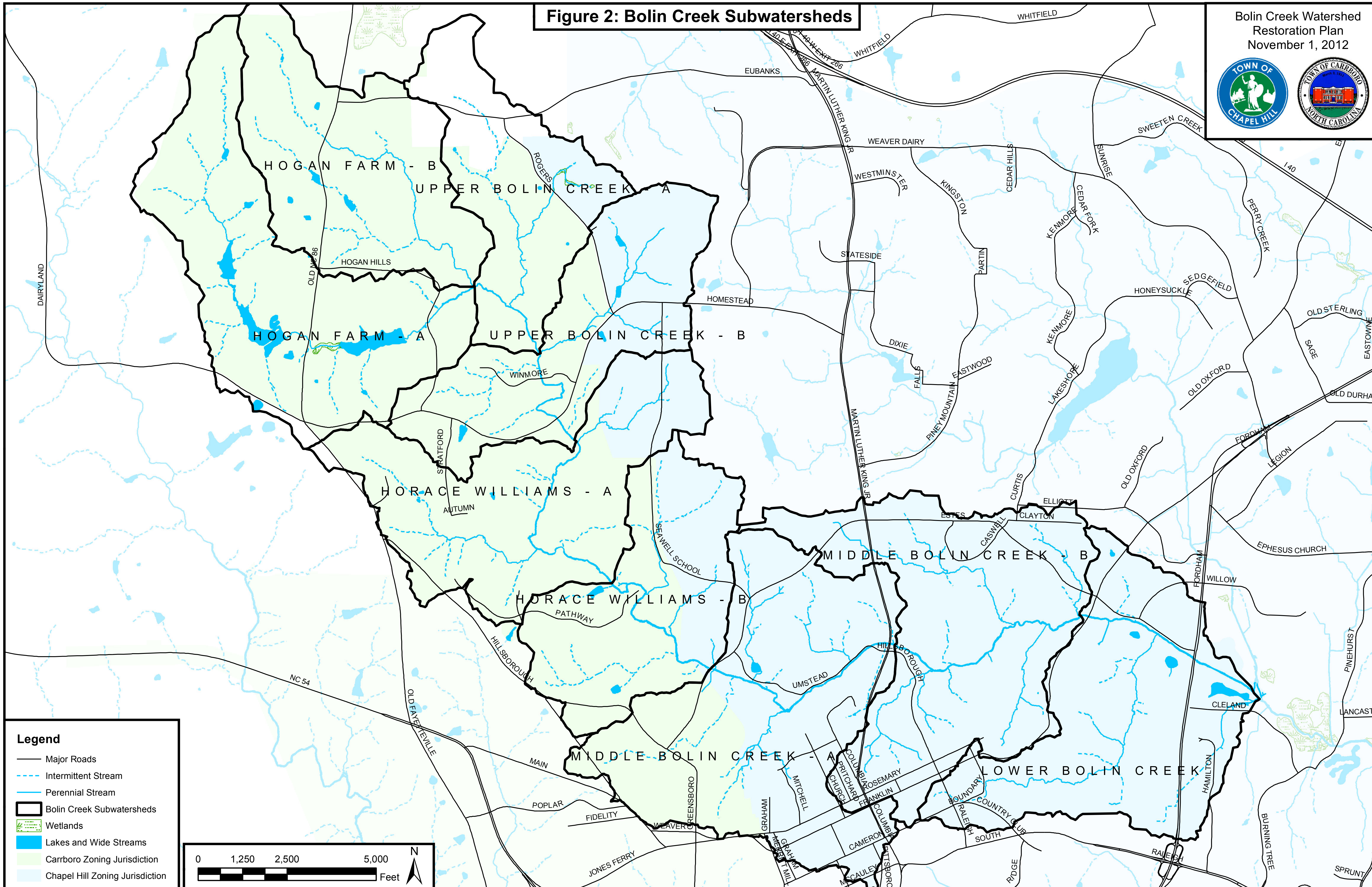


Figure 2: Bolin Creek Subwatersheds

GEOLOGY, TOPOGRAPHY, HYDROLOGY, AND SOILS

The Bolin Creek Watershed is located in the Carolina Terrane (formally known as the Carolina Slate Belt) and the Durham Triassic Basin. The different geological characteristics between upper and lower Bolin Creek affect the speed at which the water flows and the shape of the river's floodplain. Further upstream, the watershed is characterized by faster moving water and relatively narrow, V-shaped river valleys and floodplains. Locally, slightly larger floodplain deposits may be present upstream of very resistant layers of rock. These resistant layers form a local base level that temporarily slows the river, allowing sediment to be deposited, and prevents the river upstream of the base level from eroding and deepening its valley. Where Bolin Creek flows into the sedimentary rocks in the Triassic lowland, the creek flows through a much broader valley. The sedimentary rocks over which it flows are soft and easily eroded. The creek is able to flow across a much wider valley and develop a wide floodplain. Figure 3 shows the geology of the area, with the approximate boundary between the Carolina Terrane (Carolina Slate Belt) and Triassic Basin.

The watershed's general topography is rolling plains, with a few areas of steeper gradients. Bolin Creek's headwaters are at about 600 feet above sea level near Old NC 86. The lowest point, at the confluence with Little Creek is about 250 feet above sea level. Figure 4 gives a color representation of the elevation differences and changes in the Bolin Creek Watershed and surrounding area.

The watershed's upland soils (in the Carolina Slate Belt) are generally fairly well drained loams and clays, derived from metamorphosed granite, metamorphosed volcanic ash and lava, and metamorphosed gabbro and diorite. These soils have supported agricultural uses historically. Bottomlands soils are often more poorly drained. Soils in the Triassic Basin tend to be heavy clays developed from underlying conglomerate, sandstone, siltstone, and mudstone. Bolin Creek and its tributaries have varying degrees of exposed bedrock substrate. Where the stream channel does not sit on solid bedrock, incision can occur as the added energy of urban runoff cuts out a deeper, and eventually wider, channel. Many of the soils in the watershed erode easily, exacerbating the phenomenon of channel enlargement and erosion and sedimentation. Lower reaches of Bolin Creek, and urban stream channels more generally, provide lower quality aquatic habitat because of the instability of the channels along with other factors such as reduced tree canopy and instream woody debris. Figure 5 shows areas of higher erosion risk due to steep slopes and erodible soils.

Bolin Creek's hydrology is affected by several small impoundments near the headwaters. Bolin Creek has limited existing wetlands due to topography, geology, and historical land use. Small farmpond impoundments at the upper ends of headwater streams are common across the Piedmont, including Bolin Creek.

Portions of region with greater topographic relief were favorable locations historically for water-driven mills, and the remains of mill dams, mill races, and the fine sediment that filled up the pool behind them can still be found along Bolin Creek and other larger creeks in the area. These areas of "legacy" fine sediment are often out of geomorphic equilibrium with the rest of the stream system, and thus can be areas subject to significant stream downcutting and bank erosion.

Most wetlands in the Bolin Creek Watershed are floodplain wetlands, and are largely found in the lower portions of the watershed after the stream has entered the Triassic Basin geologic zone. The Carolina Slate Belt is an area that tends to have water tables that drop significantly during dry periods; hence, the creeks can easily dry up. Groundwater resource users in this area rely on finding areas of fractured rock in the otherwise fairly impermeable metamorphic rocks.

Groundwater contaminants typically preferentially follow small faults and fractures in this area, rather than spreading out fairly evenly downgradient of a contamination source as you would expect in more water-permeable rocks.

Soil characteristics are particularly important when designing stormwater management treatment for developed areas, and can limit the ability to adequately treat stormwater, especially for higher-intensity land uses. Area soils have varying capability to absorb and transmit rainwater down into the ground. This ability to transmit water through soil is grouped into four Soil Hydrologic Groups, with Group A being most transmissible and Group D the least. Our area has none of the soils that most readily transmit runoff through them (Group A), and comparatively large areas of Group D. Depth to bedrock or other restrictive layer also limits how far soil water can travel downwards. The shallowest depth to the water table, usually occurring in the wintertime, also limits the distance available for filtration of rainwater through the soil. Figure 6 shows the distribution of soil hydrologic groups, depth to the water table, and depth to a restrictive layer. This distribution of soil properties contributes to the difficulty in finding feasible locations for stormwater treatment structures, including locating sites for watershed restoration projects.

CLIMATE AND PRECIPITATION

The local climate is warm-humid temperate, with very mild seasonal variation in rainfall patterns (peaks in the late winter and again in mid-summer coincident with tropical storm systems). This area is subject to occasional severe to exceptional droughts, with the most recent drought of 2008 being the drought of record for the area. Droughts in particular have long-lasting effects on stream organisms, and may result in suppression of stream biodiversity for years until organisms recolonize.

The El Nino / Southern Oscillation climate pattern of the Pacific Ocean has noticeable effects on wintertime precipitation and temperature patterns. The late-winter precipitation peak is a good opportunity for groundwater recharge, as fewer plants will be pulling water from the soil at that time of year. Thus, any changes to El Nino patterns will have effects on wintertime groundwater recharge.

Precipitation patterns tend towards intense short storms rather than milder long storms, especially during the warmer season. Precipitation frequency estimates (recurrence intervals of 1 year or more) are shown on Table 1. To understand this table, “Duration” is the length of time of a rainfall event of a given intensity, and “recurrence interval” is the average amount of time between storms of this duration and amount of rainfall. For example, a short, 5-minute rainstorm totaling 0.41 inches of rain happens on average once a year. However, it does not mean that one of each of the different duration storms listed for a 1-year return interval is what happens on average. Frequencies are calculated for longer-duration storms to be inclusive of shorter-duration based on statistical analysis of complete storms and portions of storms. So an average 24 hour storm totaling 2.96 inches (one that happens once per year) is likely to have within it a 5 minute time period where 0.41 inches falls, a 10 minute period where 0.66 inches falls, or a 15 minute period where 0.82 inches falls, and so forth.

Figure 3: Bolin Creek Watershed Geology

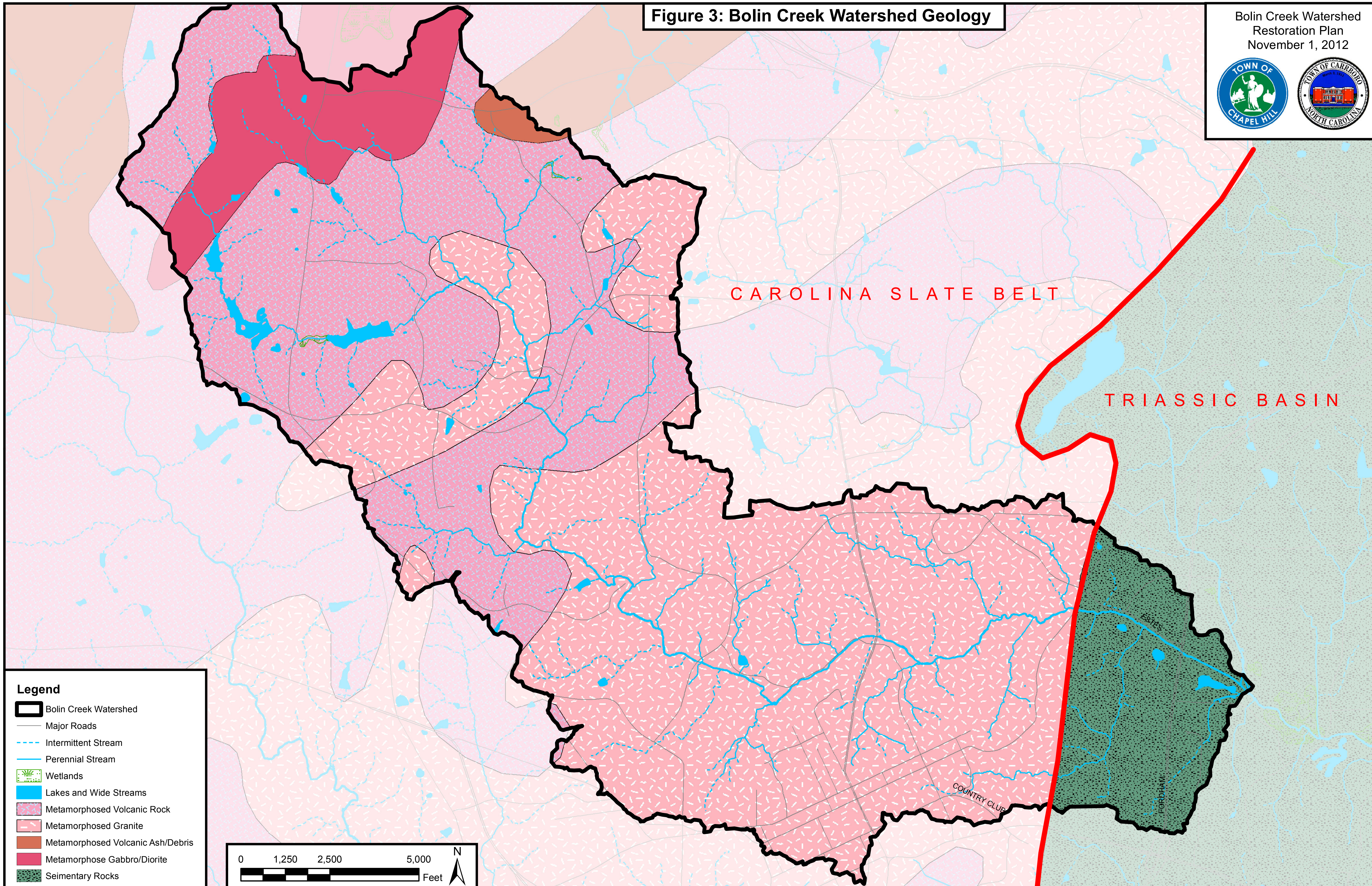
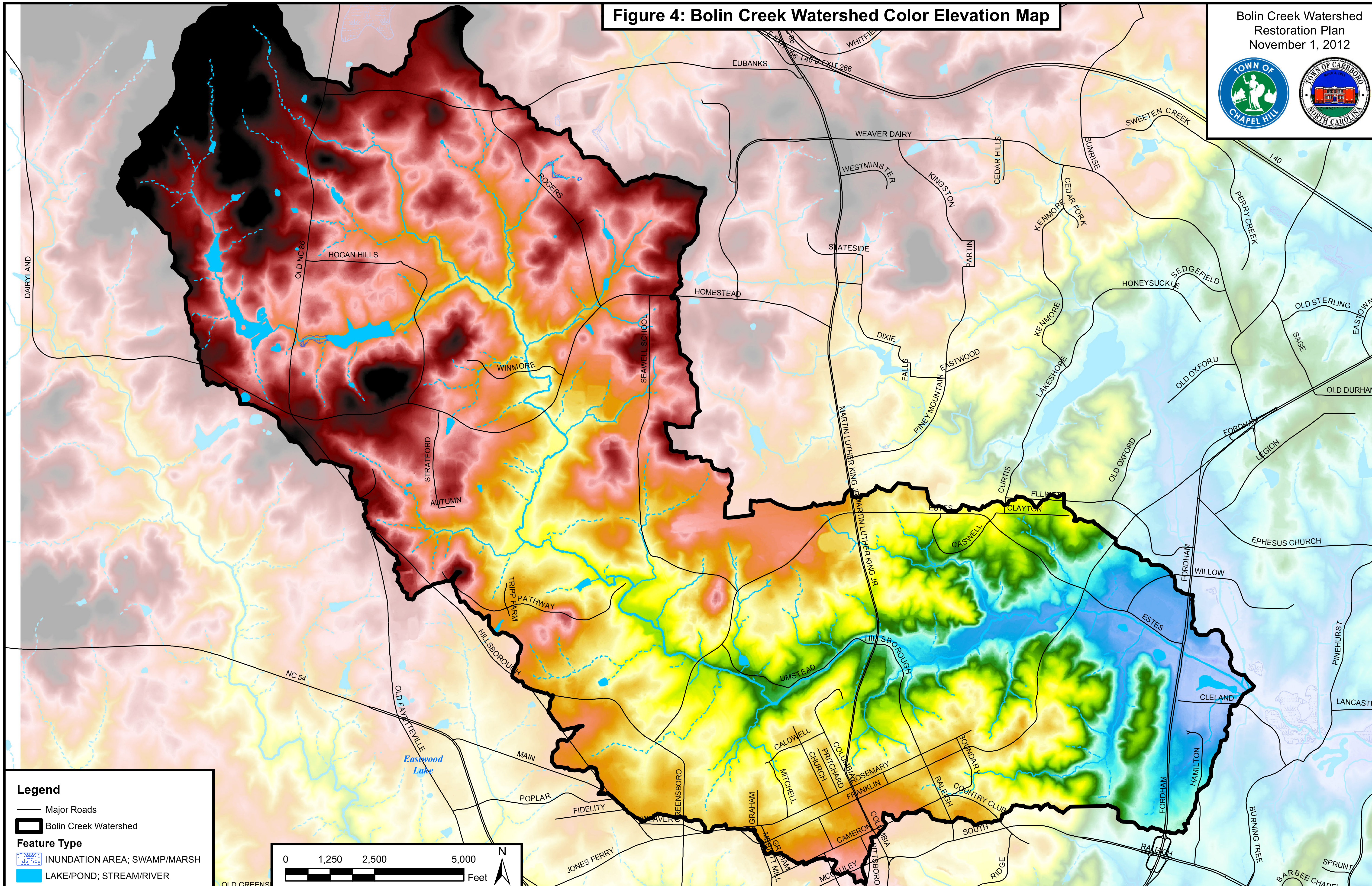


Figure 4: Bolin Creek Watershed Color Elevation Map

Bolin Creek Watershed
Restoration Plan
November 1, 2012



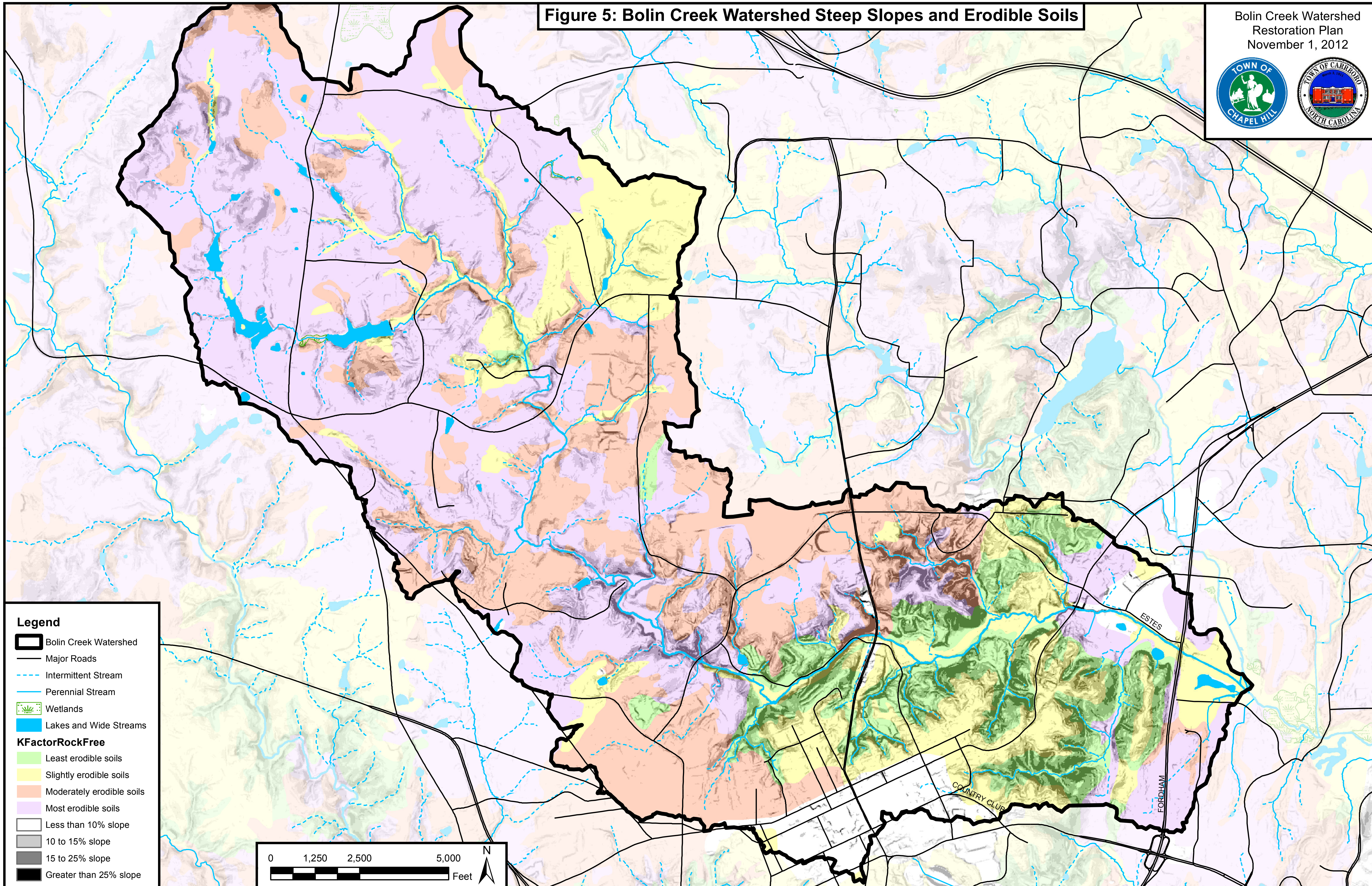


Figure 5: Bolin Creek Watershed Steep Slopes and Erodible Soils
Bolin Creek Watershed
Restoration Plan
November 1, 2012
TOWN OF CHAPEL HILL
TOWN OF CARRBORO NORTH CAROLINA
Legend
Bolin Creek Watershed
Major Roads
Intermittent Stream
Perennial Stream
Wetlands
Lakes and Wide Streams
KFactorRockFree
Least erodible soils
Slightly erodible soils
Moderately erodible soils
Most erodible soils
Less than 10% slope
10 to 15% slope
15 to 25% slope
Greater than 25% slope
0
1,250
2,500
5,000
Feet
N
ESTES
COUNTRY CLUB
FORDHAM

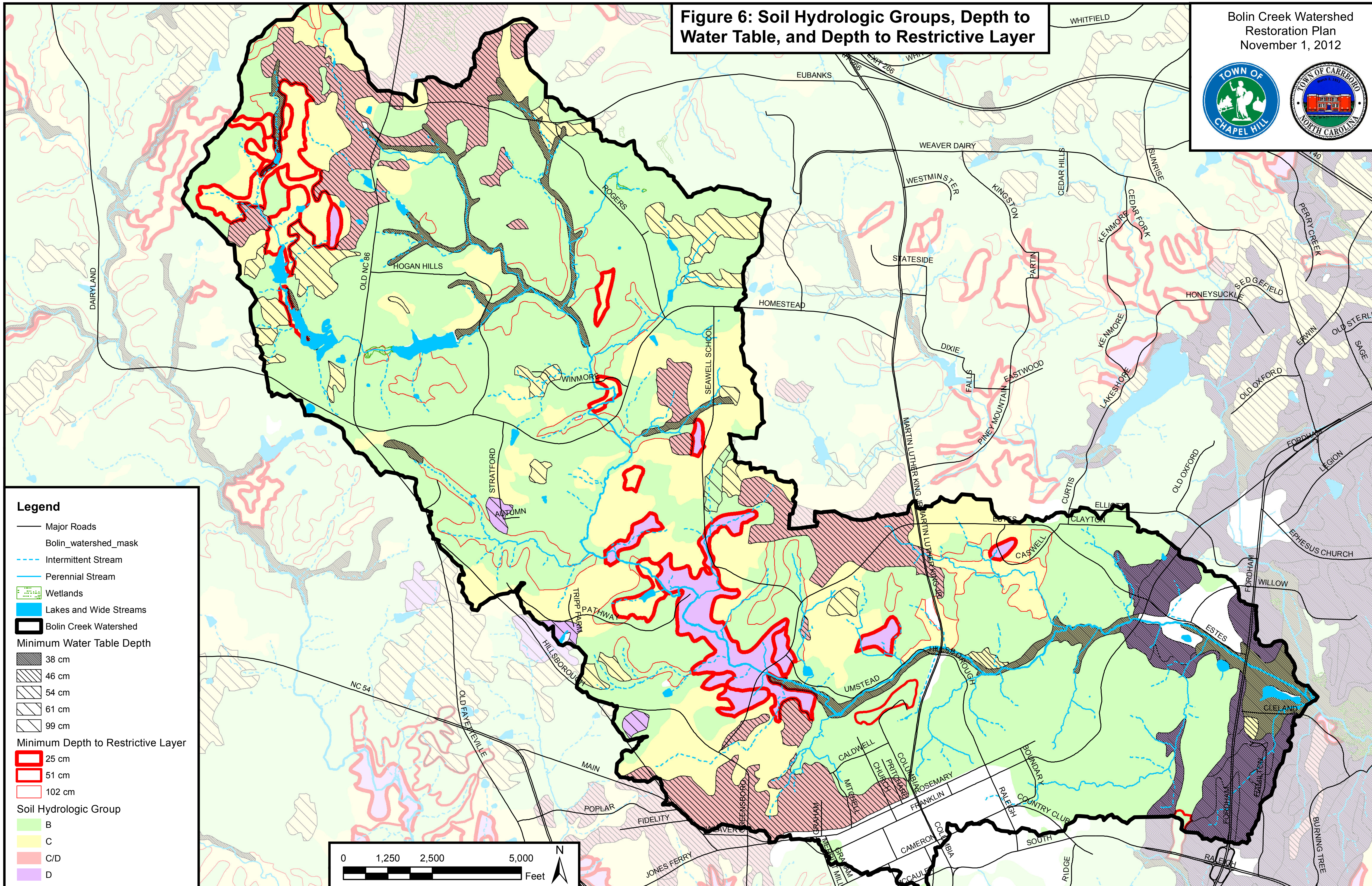


Figure 6: Soil Hydrologic Groups, Depth to Water Table, and Depth to Restrictive Layer

These precipitation frequencies and intensities are used in the engineering modeling and design of stormwater conveyances and treatment systems to make sure they can handle the volumes and intensities of rainfall. The particular values used are based on the return frequencies specified in stormwater management ordinances. For instance, on new development projects Chapel Hill requires capture and slow release of rainfall from the 24-hour duration storms that occur on average once every year, every 2 years, and every 25 years.

Table 1: Precipitation frequency estimates (inches) for Chapel Hill NOAA site (ID 31-1667)[1]

	Average recurrence interval (years)									
Duration	*1*	*2*	*5*	*10*	*25*	*50*	*100*	*200*	*500*	*1000*
5-min	0.41	0.48	0.56	0.61	0.68	0.72	0.76	0.79	0.82	0.85
10-min	0.66	0.77	0.89	0.98	1.08	1.14	1.2	1.25	1.3	1.34
15-min	0.82	0.97	1.13	1.25	1.36	1.45	1.52	1.57	1.64	1.68
30-min	1.12	1.34	1.6	1.8	2.02	2.18	2.33	2.45	2.6	2.72
60-min	1.4	1.69	2.06	2.35	2.69	2.95	3.2	3.44	3.73	3.96
2-hr	1.68	2.02	2.49	2.87	3.33	3.7	4.05	4.4	4.86	5.23
3-hr	1.79	2.16	2.66	3.08	3.61	4.04	4.46	4.89	5.46	5.93
6-hr	2.15	2.59	3.2	3.71	4.37	4.92	5.47	6.03	6.8	7.44
12-hr	2.54	3.06	3.8	4.44	5.28	5.99	6.71	7.47	8.53	9.43
24-hr	2.96	3.58	4.47	5.17	6.11	6.86	7.62	8.41	9.5	10.35
2-day	3.46	4.17	5.17	5.95	6.99	7.81	8.64	9.49	10.66	11.58
3-day	3.67	4.41	5.44	6.25	7.33	8.19	9.07	9.96	11.2	12.17
4-day	3.87	4.64	5.71	6.54	7.68	8.57	9.49	10.44	11.73	12.76
7-day	4.44	5.3	6.44	7.34	8.57	9.54	10.53	11.56	12.96	14.06
10-day	5.05	6	7.21	8.15	9.42	10.43	11.44	12.47	13.87	14.97
20-day	6.76	7.97	9.41	10.56	12.11	13.34	14.57	15.83	17.55	18.89
30-day	8.39	9.88	11.47	12.72	14.36	15.62	16.87	18.12	19.8	21.09
45-day	10.69	12.52	14.32	15.72	17.55	18.95	20.31	21.67	23.46	24.83
60-day	12.84	14.97	16.89	18.37	20.28	21.72	23.11	24.46	26.21	27.53

[1] Precipitation frequency (PF) estimates in this table are based on frequency analysis of partial duration series (PDS).Please refer to NOAA Atlas 14 document for more information.

NATURAL COMMUNITIES

The Bolin Creek Watershed lies predominantly in the Carolina Slate Belt Ecoregion, with the lower section in the Triassic Basin Ecoregion. The overarching Freshwater Ecoregion is the Appalachian Piedmont. In the eastern US, the shape and function of natural streams are dictated by the plant communities they flow through. The "forest makes the stream", so to speak, because of the different ways plant species affect drainage patterns, stream channel stability, instream habitat structure, and material at the base of the food chain. Natural plant communities in this area include various mixes of softwood (pine) and hardwood tree species, shrub and brush species, with small areas of remnant, isolated prairie. Forest fires are not known to be important to forest community composition in this area, as compared to forests in eastern North Carolina.

The Natural Heritage Program has mapped out the plant community types for North Carolina (shown in Figure 7), and published maps of Significant Natural Heritage Areas. The National Wetlands Inventory has mapped wetland areas. Significant Natural Heritage Areas and wetlands are shown in Figure 8.

Forests in the watershed harbor a great many terrestrial and aquatic animal species common and uncommon in the eastern US, including forest mammals such as beaver, muskrat, white-tailed deer, skunk, a large variety of bird species, and a few amphibians, reptiles, and freshwater fish. Orange County has a fairly dense population of white-tailed deer, largely from abundant food sources and lack of predation. Coyotes have been observed in the County and the Towns, and it is expected they may put some predation pressure on deer populations.

Forests and streams in the watershed provide important ecosystem services and functions, including groundwater recharge, filtering pollutants from runoff, nutrient processing and cycling, clean air, beneficial soil organisms, temperature moderation, food and habitat for pollinator species, food and habitat for wildlife and wildflowers, and educational and recreational opportunities. These areas, in addition to urban trees and dense landscaped areas, provide shade for buildings and pedestrians, a softening of the urban environment, increased property values, lower rates of crime, and improved mental and physical well-being for residents.

Different types of natural areas differ in sensitivity to disturbance and ecological resilience. Steep slopes and erodible soils are more sensitive areas at risk of erosion and degradation, which can lead to changes in plant community and soil function, as well as the export of fine sediment that can negatively impact stream health. (Figure 5 above shows a map of steep slopes and erodible soils.) Riparian areas and natural floodplains are subject to different amounts of flood inundation. Many important biogeochemical processes take place in riparian zones and depend on normal processes of flooding and draining, requiring "connection" of streams to their floodplains or riparian zones. These processes can be interrupted by severe stream channel erosion or intentional modifications to stream channels, which prevents high-flowing water from reaching the riparian zone. Small streams in particular serve as important refuge and colonization sources for stream organisms, particularly streams fed by reliable groundwater. These colonization sources may be critical for maintaining a healthy biological community in larger streams such as Bolin Creek that experience severe scouring flows, "flashy" peaks in flow, and very low dry weather flows, all of which can dislodge or be inhospitable to aquatic organisms.

Healthy, contiguous forests with high plant biodiversity and structure (tall trees, mid-story, understory, and groundcover) are more resistant to damage from windstorms and ice storms, and fend off invasive plant species more successfully than forests with uniform structure, low biodiversity, or multiple interruptions and openings in the canopy. Small streams in particular are dependent on a continuous forest buffer for maintaining channel stability, riparian biogeochemical processes, runoff filtration and infiltration, shade and temperature modulation, habitat features, and material for the food web. Invasive plants, especially vines and other species that reduce tree cover along the stream, change the physical and biological characteristics of the streams flowing through those areas.

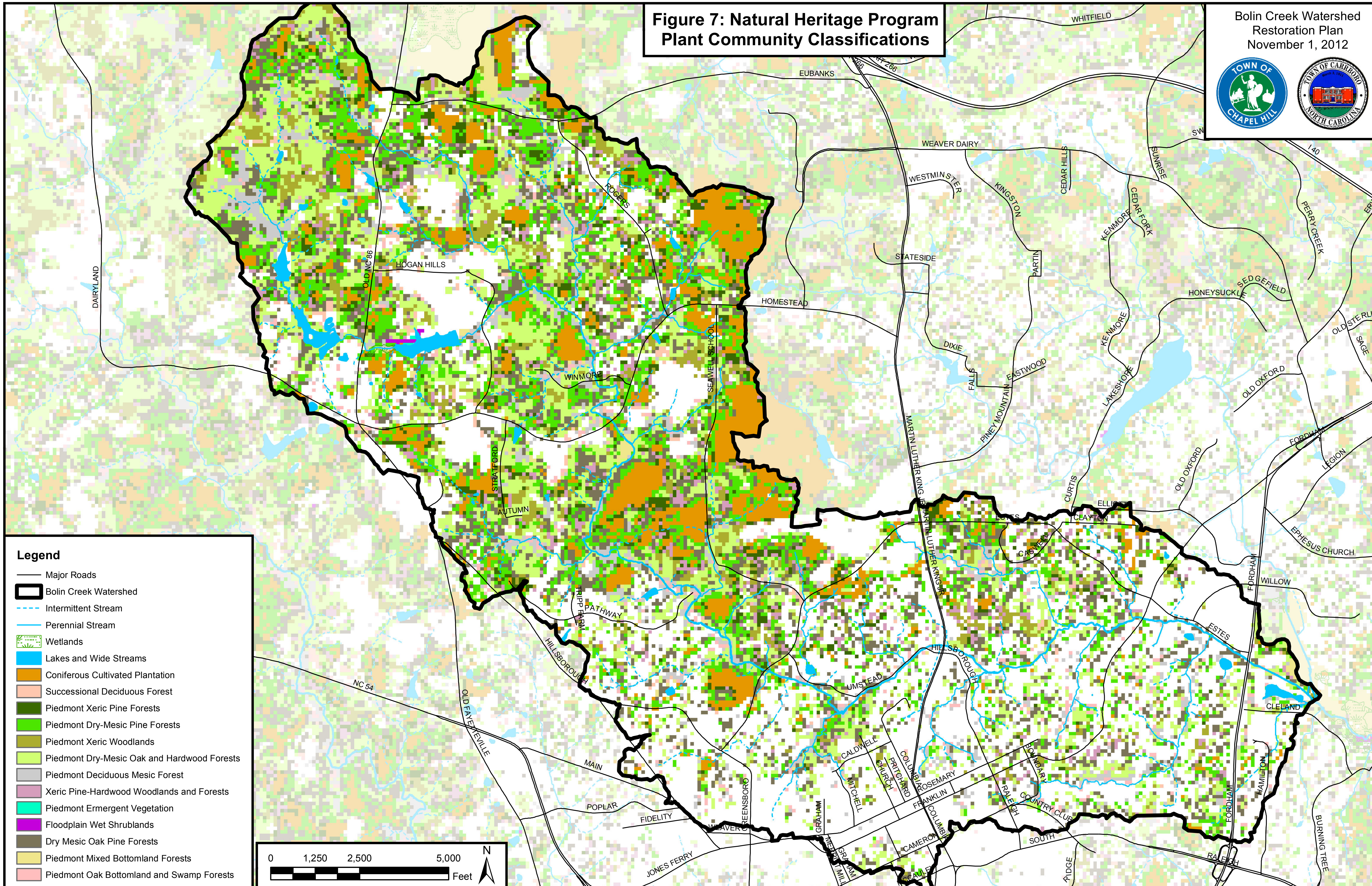
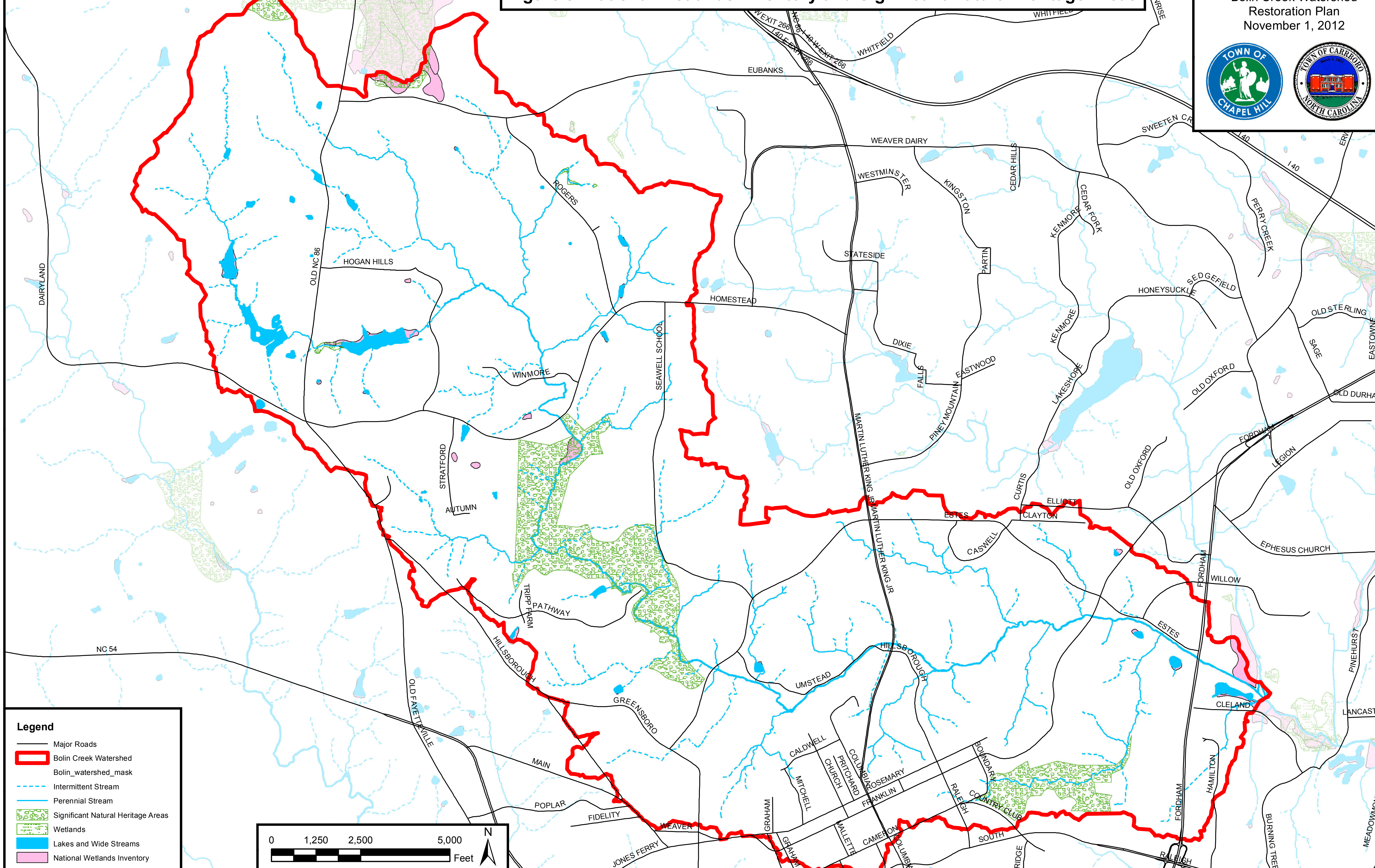


Figure 7: Natural Heritage Program
Plant Community Classifications
Bolin Creek Watershed
Restoration Plan
November 1, 2012
TOWN OF CHAPEL HILL
TOWN OF CARRBORO NORTH CAROLINA
Legend
Major Roads
Bolin Creek Watershed
Intermittent Stream
Perennial Stream
Wetlands
Lakes and Wide Streams
Coniferous Cultivated Plantation
Successional Deciduous Forest
Piedmont Xeric Pine Forests
Piedmont Dry-Mesic Pine Forests
Piedmont Xeric Woodlands
Piedmont Dry-Mesic Oak and Hardwood Forests
Piedmont Deciduous Mesic Forest
Xeric Pine-Hardwood Woodlands and Forests
Piedmont Ermergent Vegetation
Floodplain Wet Shrublands
Dry Mesic Oak Pine Forests
Piedmont Mixed Bottomland Forests
Piedmont Oak Bottomland and Swamp Forests
0
1,250
2,500
5,000
Feet
N
WHITFIELD
EUBANKS
NC 86
WEAVER DAIRY
WESTMINSTER
KINGSTON
CEDAR HILLS
SUNRISE
CEDAR FORK
KENMORE
PERRY CREEK
ERWIN
I 40
ROGERS
STATESIDE
PARTIN
HOGAN HILLS
OLD NC 86
DAIRYLAND
HOMESTEAD
SEAWELL SCHOOL
HONEYSUCKLE
SEDGEFIELD
OLD STERLING
SAGE
DIXIE
FALLS
EASTWOOD
WINMORE
LAKESHORE
OLD OXFORD
PINEY MOUNTAIN
MARTIN LUTHER KING JR
FORDHAM
LEGION
STRATFORD
AUTUMN
CURTIS
ELLIOTT
CLAYTON
ESTES
CASWELL
EPHESUS CHURCH
WILLOW
TRIPP FARM
PATHWAY
HILLSBOROUGH
NC 54
UMSTEAD
CLELAND
OLD FAYETTEVILLE
MAIN
CALDWELL
CHURCH
PRITCHARD
COLUMBIA
ROSEMARY
BOUNDARY
HAMILTON
MITCHELL
FRANKLIN
RALEIGH
COUNTRY CLUB
POPLAR
FIDELITY
WEAVER
GREENSBORO
GRAHAM
CAMERON
SOUTH
RIDGE
BURNING TREE
JONES FERRY
MERRITT MILL
CAMERON

Figure 8: National Wetlands Inventory and Significant Natural Heritage Areas



2.2 BUILT ENVIRONMENT

LAND USE HISTORY

Prior to European colonization, the Bolin Creek Watershed contained primarily hardwood forest habitat. As the eastern US was settled by European colonists, the land experienced considerable changes. Widespread clear-cutting for farming not only removed large areas of forest, but destabilized the soils, leading to considerable erosion. Sediment from this erosion wound up deposited in floodplains across the eastern US. Where there was enough local land relief, dams were built for running mills, interrupting the natural flow of streams and rivers, and trapping some of that sediment behind the dams. These developments led to significant changes in stream and valley morphology, building up floodplains with sediments high in nutrients derived from eroded fertile topsoil.

More recently, land uses have changed, with a considerable decrease in agriculture and enlargement of urban and suburban area. Increased impervious surface increases the total volume and velocity of runoff, leading to more scouring of stream channels and subsequent erosion down into the floodplain. Increased runoff also leads to the creation of more small stream channels, and more opportunities for direct access of pollutants to stream channels without prior filtration. Increased impervious surface also leads to less groundwater recharge, with subsequent reductions in the amount of water available to streams during dry weather. With less groundwater recharge, once-perennially-flowing streams start to dry out during hot or dry weather, leading to changes in stream ecological conditions.

With removal or neglect of old mill dams, remnant areas of "legacy sediments" remain out of geomorphic equilibrium with the stream. As a result, many streams have cut down sharply through their floodplains, even further or to a greater extent than may be explained by changes in runoff volume or velocity from impervious surfaces. Where floodplains were built up by deposition from excess erosion during colonial times, or deposition behind dams, these soils store large amounts of nutrients that can now be released as the stream cuts down and the floodplain erodes away. As a result, area streams may be carrying large nutrient loads partly because of land use changes centuries ago.

CURRENT LAND USE AND LAND COVER

Current land use is a mix of different urban and suburban intensities, rural residential and undeveloped land, with a pattern of increasing land use intensity as you move from the headwaters to the confluence of Bolin Creek with Booker Creek. This shift in intensity across the watershed can be seen in the 2006 national land use classifications (Figure 9) and current locations of impervious surfaces (Figure 10). Land use intensity is a well-known stressor to freshwater ecosystems. The amounts of different landuse classifications and impervious surfaces in each subwatershed are analyzed in the following chapter on Watershed Impairment . These analyses provide different ways of looking at the same stressor and understanding its relationship to aquatic health.

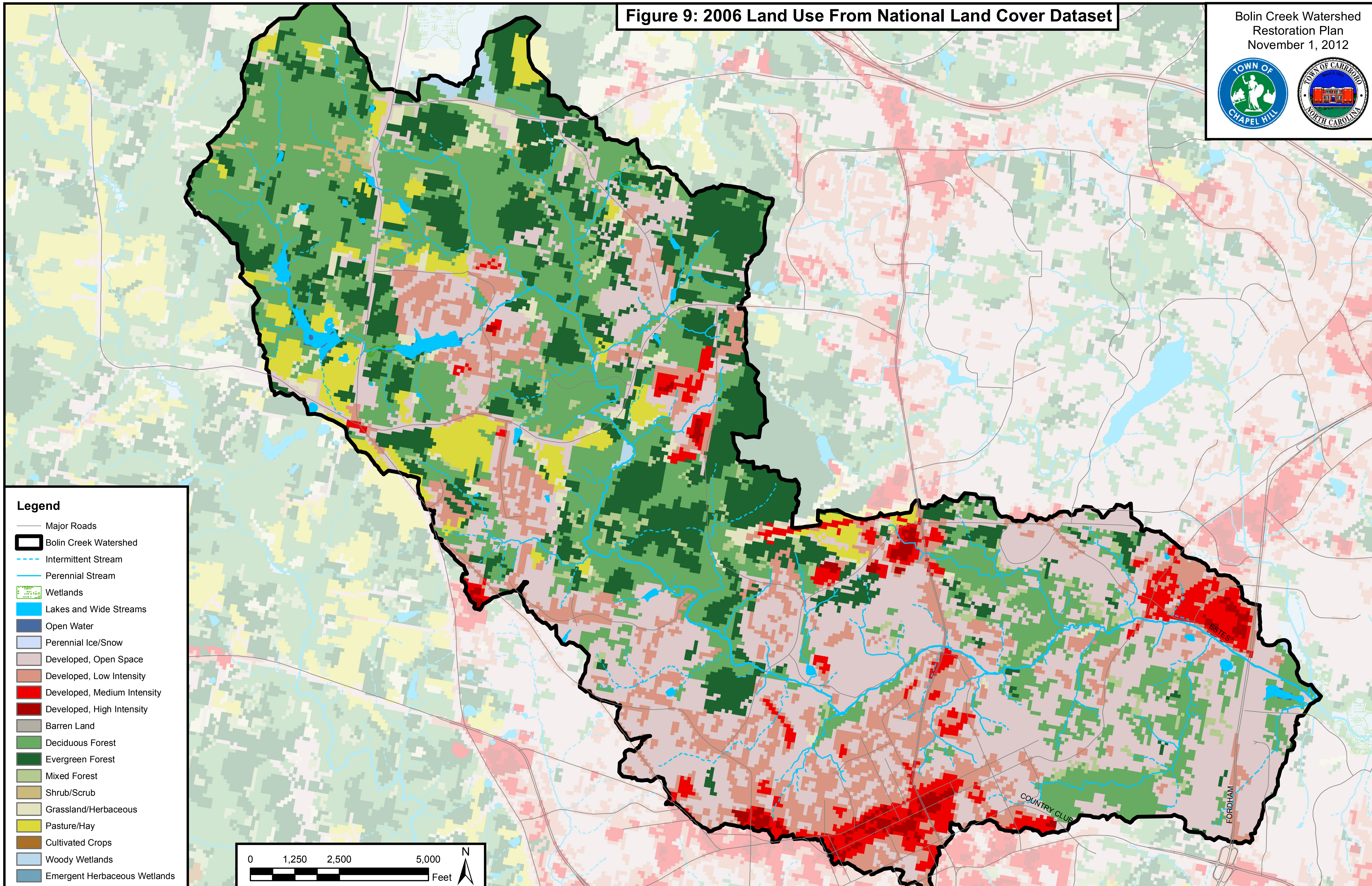


Figure 9: 2006 Land Use From National Land Cover Dataset
Bolin Creek Watershed
Restoration Plan
November 1, 2012
TOWN OF CHAPEL HILL
TOWN OF CARRBORO NORTH CAROLINA
Legend
Major Roads
Bolin Creek Watershed
Intermittent Stream
Perennial Stream
Wetlands
Lakes and Wide Streams
Open Water
Perennial Ice/Snow
Developed, Open Space
Developed, Low Intensity
Developed, Medium Intensity
Developed, High Intensity
Barren Land
Deciduous Forest
Evergreen Forest
Mixed Forest
Shrub/Scrub
Grassland/Herbaceous
Pasture/Hay
Cultivated Crops
Woody Wetlands
Emergent Herbaceous Wetlands
0 1,250 2,500 5,000
Feet
N
ESTES
COUNTRY CLUB
FORDHAM

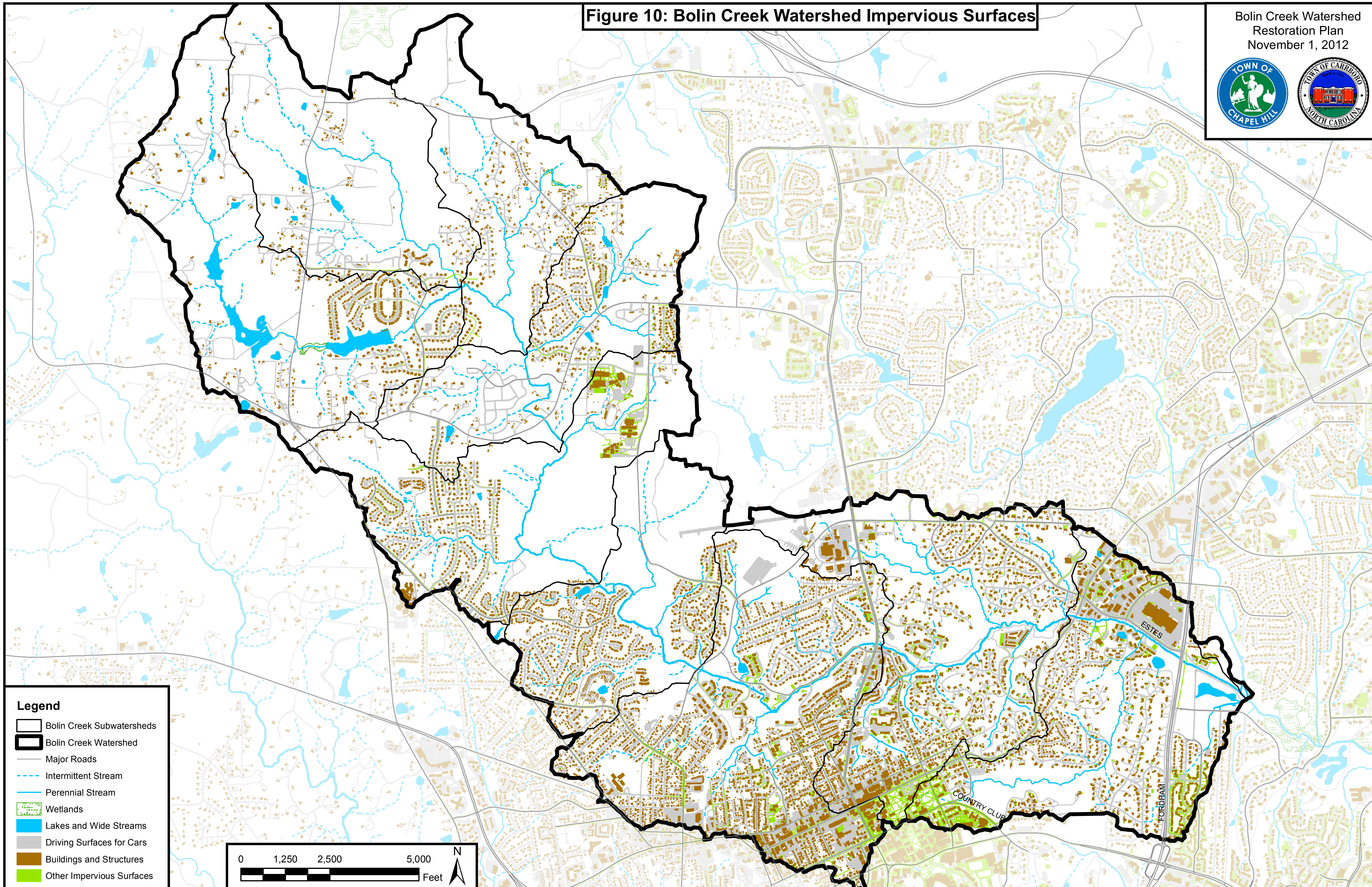


Figure 10: Bolin Creek Watershed Impervious Surfaces

SUBDIVISIONS AND NEIGHBORHOODS

We have observed that different subdivisions and neighborhoods have different drainage characteristics, not necessarily based on natural characteristics such as soil type or slope of the land. Differences in density of housing or intensity of land use, such as more impervious surfaces, change the amount of runoff leaving an area. Similarly, different subdivisions were developed with subtle differences in runoff management that can make a big difference in runoff impacts. In particular, the use of roof drains rather than downspout splashblocks reduces the available area and distance for runoff to infiltrate into the soil before reaching a stream. In some neighborhoods, roof drains are run all the way to property boundaries, nearby stormdrain pipes or structures, or even directly to streams.

Some neighborhoods have curb and gutter along streets, concentrating street runoff into impermeable stormwater pipes, where it is discharged all at a single outlet point. In contrast, other neighborhoods have roadside ditches which concentrate runoff less than curb and gutter, and provide area (the ditches themselves) where some runoff can infiltrate the soil.

The process of development compacts the soil, and usually removes the top layers of soil, affecting runoff infiltration for years. After several decades and protection from heavy use (like parking), the soil may develop better permeability. This process of improved infiltration is accelerated if trees and shrubs are planted. Thus, both the age of the development and the vegetation planted after houses are built further alters the drainage characteristics of a neighborhood.

Neighborhoods also differ in demographics, with different mixes of renters and owners, long-term vs. short-term residents (such as students), ethnicities and cultures, education and income levels. All of which lead to different attitudes towards acceptable landscaping, runoff management, use of fertilizers and pesticides, available resources, and valuing of the natural environment. Part of a long-term watershed management program should therefore attempt to characterize neighborhoods and subdivisions by these differences, as different communication and environmental management strategies will be required for different combinations of factors. Subdivisions and neighborhoods have been mapped out by Subwatershed, as shown on Figures 11 through 19. Appendix 9 is a lookup table that allows you to find the name based on the ID number on the maps.

Broadly speaking, Hogan Farm, Horace Williams and Upper Bolin Creek subwatersheds support moderate to high incomes, owner-occupied residential neighborhoods with a low crime rate. The Middle Bolin Creek subwatershed has eclectic neighborhoods and business districts, including the Northside Community and Downtown Chapel Hill which is composed of mostly rental property and downtown businesses and churches. On the east end of downtown Chapel Hill lays the Historic District, with long-term residency, high incomes, and large lots. Sororities, fraternities and student rentals are also woven into the neighborhood. The Lower Bolin Creek Watershed has high economic diversity with a mix of low-income rental property and higher-income owner-occupied homes. Lower Bolin Creek's residential sections along South Estes Drive include affordable apartments, condominiums, wide roads, and public housing in addition to shopping and business centers and University Mall, most lying within the regulatory floodplain.

Figure 11: Subdivisions and Neighborhoods in Hogan Farm A Subwatershed (BL1A)

Bolin Creek Watershed Restoration Plan
November 1, 2012

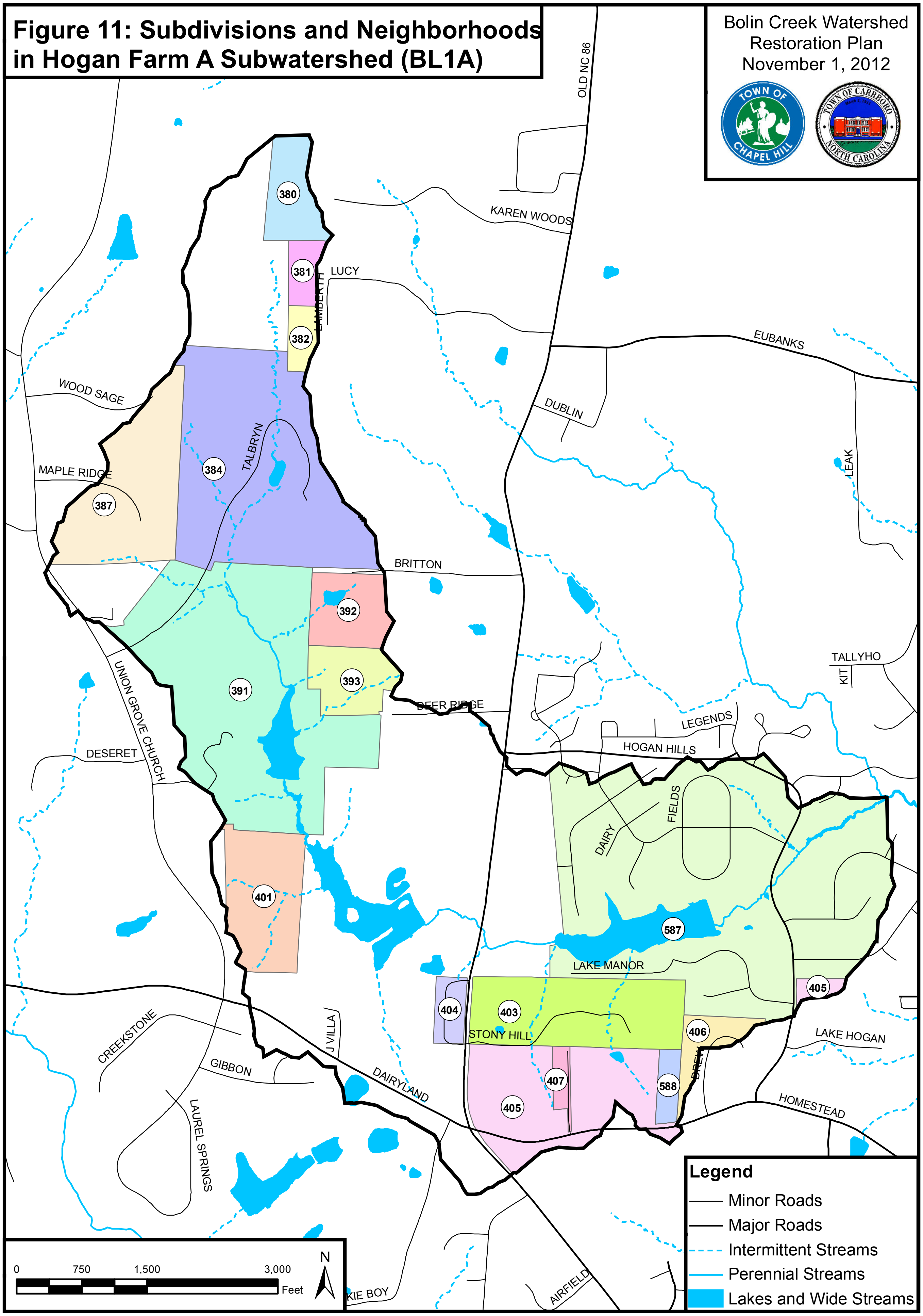


Figure 12: Subdivisions and Neighborhoods in Hogan Farm B Subwatershed (BL1B)

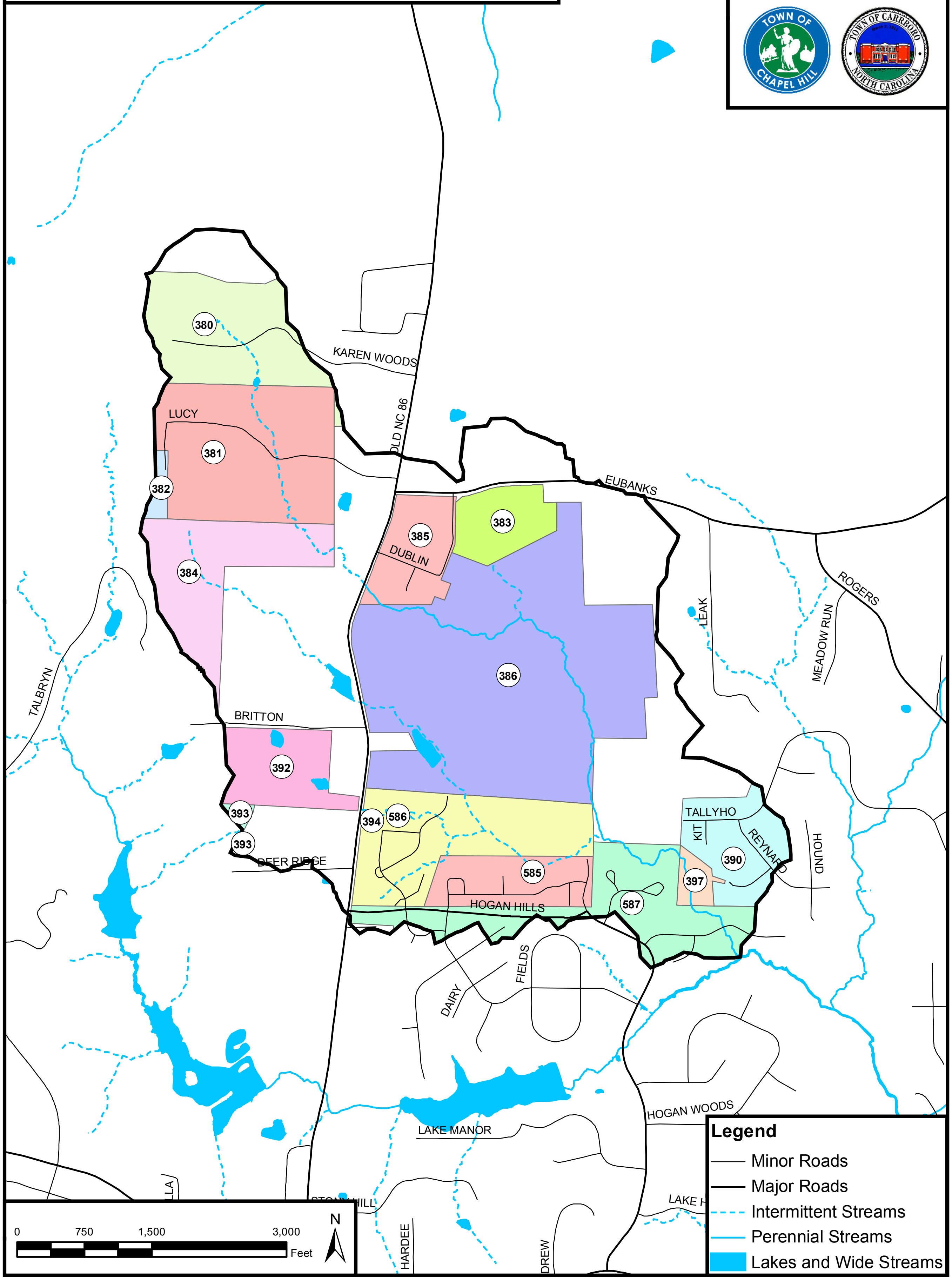


Figure 13: Subdivisions and Neighborhoods in Upper Bolin Creek A Subwatershed (BL2A)

Bolin Creek Watershed Restoration Plan
November 1, 2012

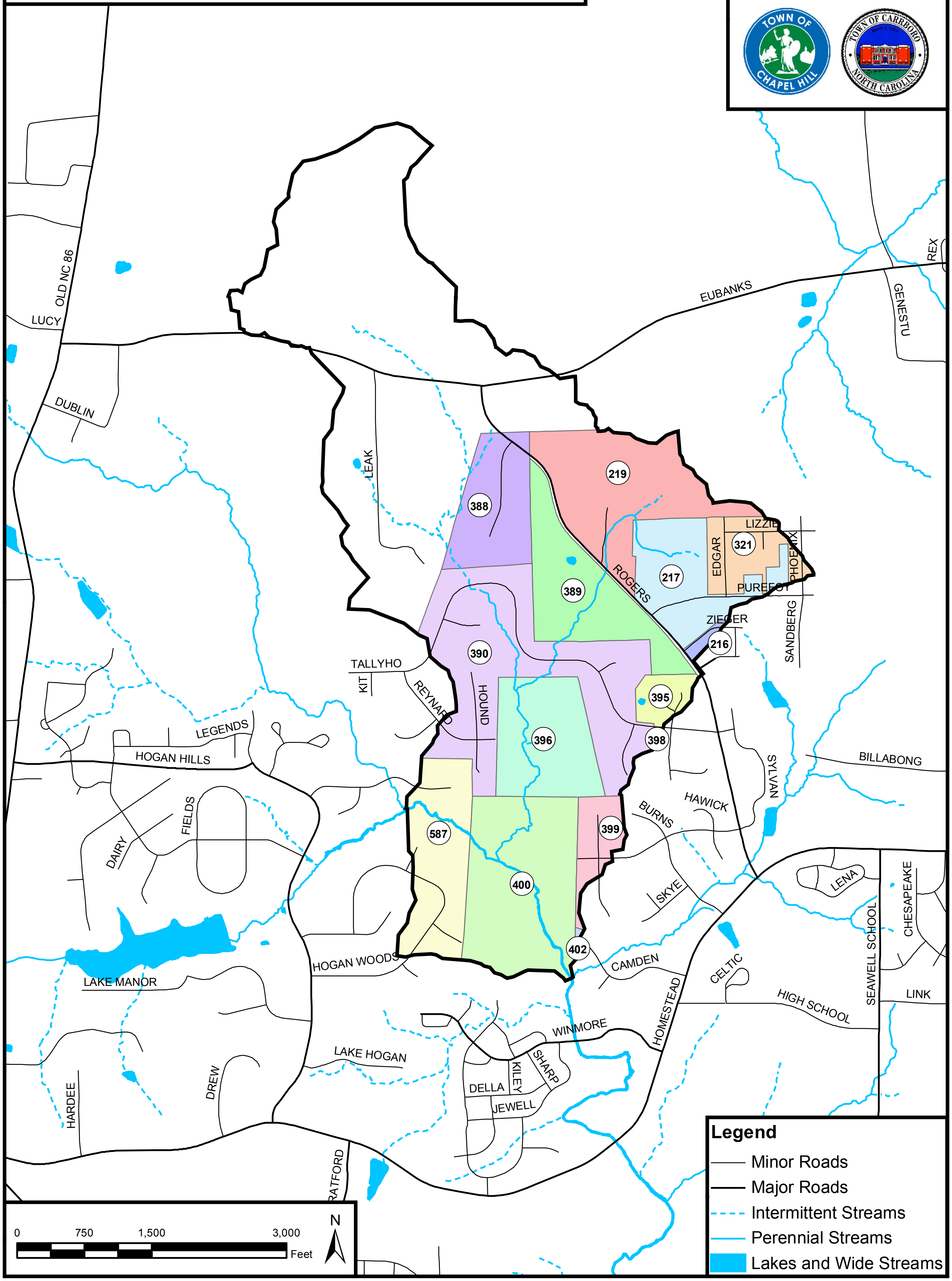


Figure 14: Subdivisions and Neighborhoods in Upper Bolin Creek B Subwatershed (BL2B)

Bolin Creek Watershed Restoration Plan
November 1, 2012

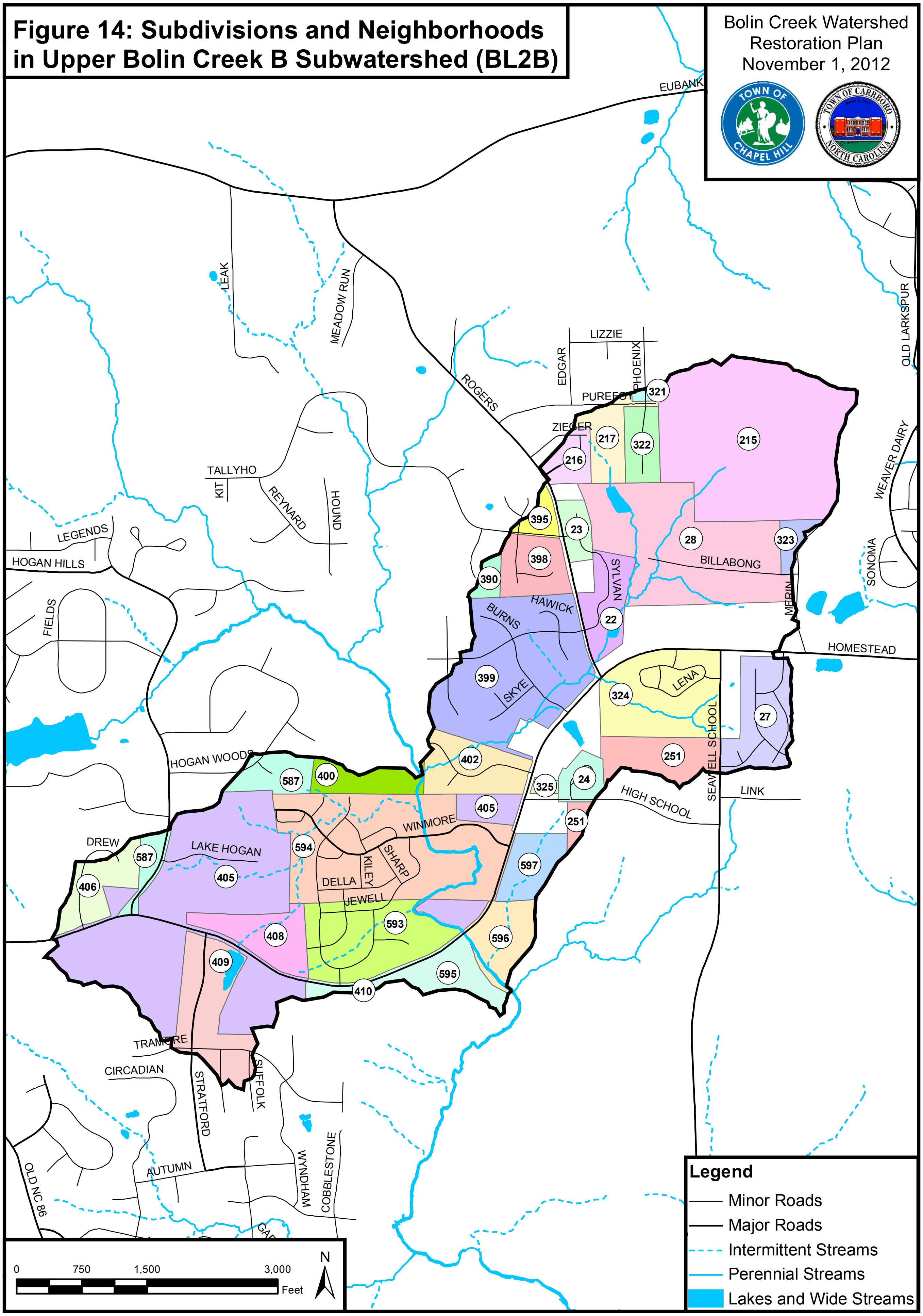
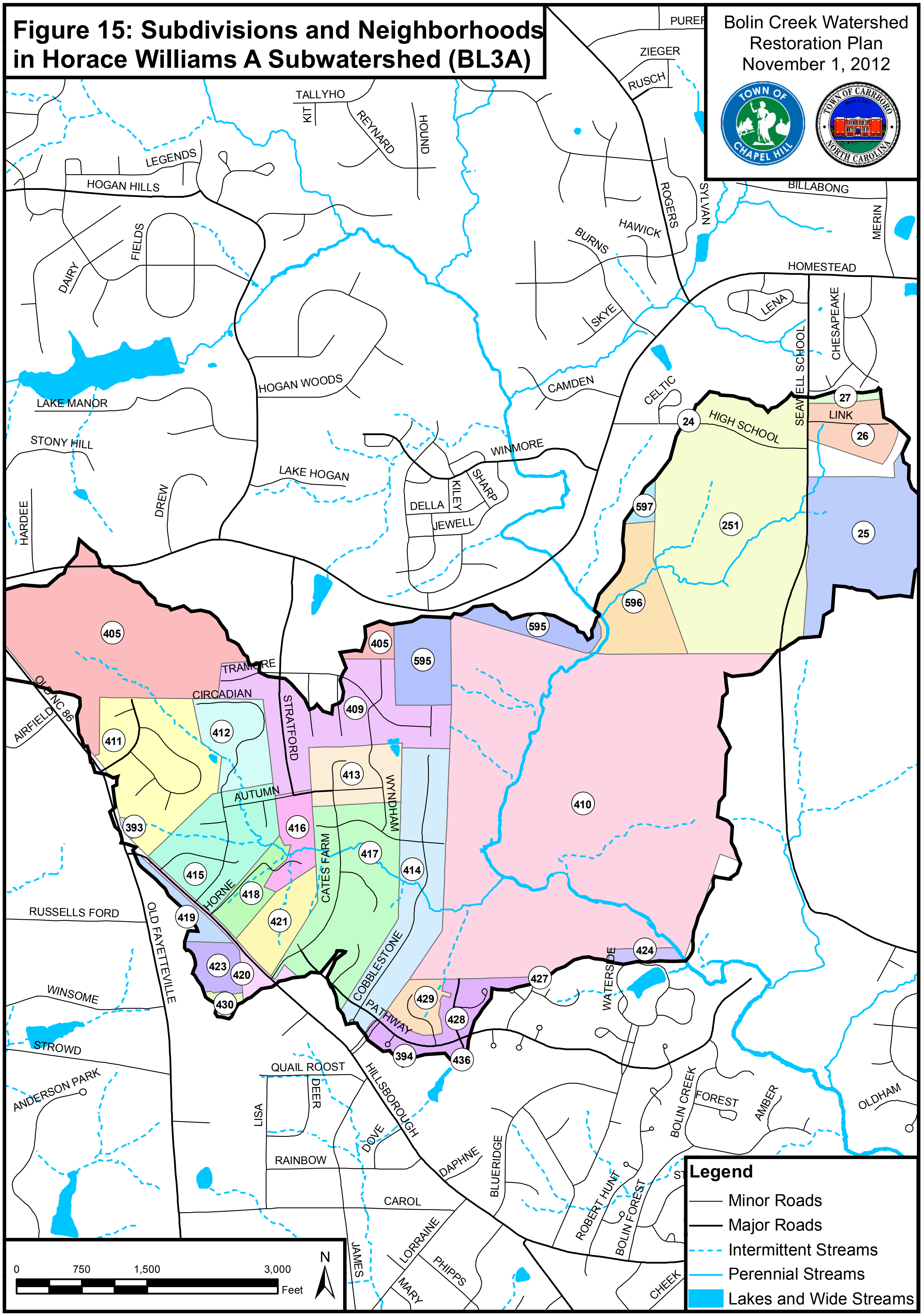


Figure 15: Subdivisions and Neighborhoods in Horace Williams A Subwatershed (BL3A)



Bolin Creek Watershed Restoration Plan
November 1, 2012

Figure 16: Subdivisions and Neighborhoods in Horace Williams B Subwatershed (BL3B)

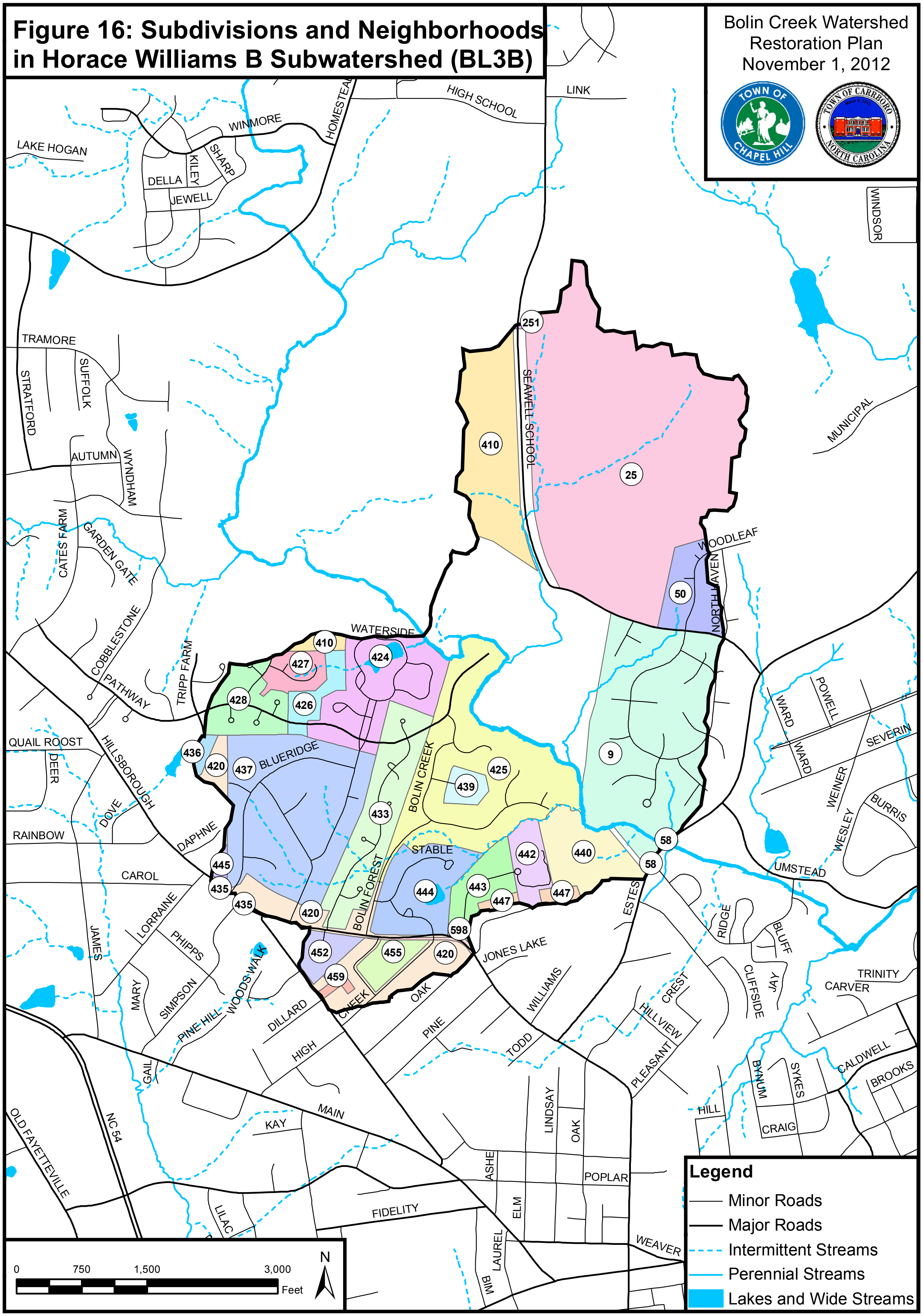


Figure 17: Subdivisions and Neighborhoods in Middle Bolin Creek A Subwatershed (BL4A)

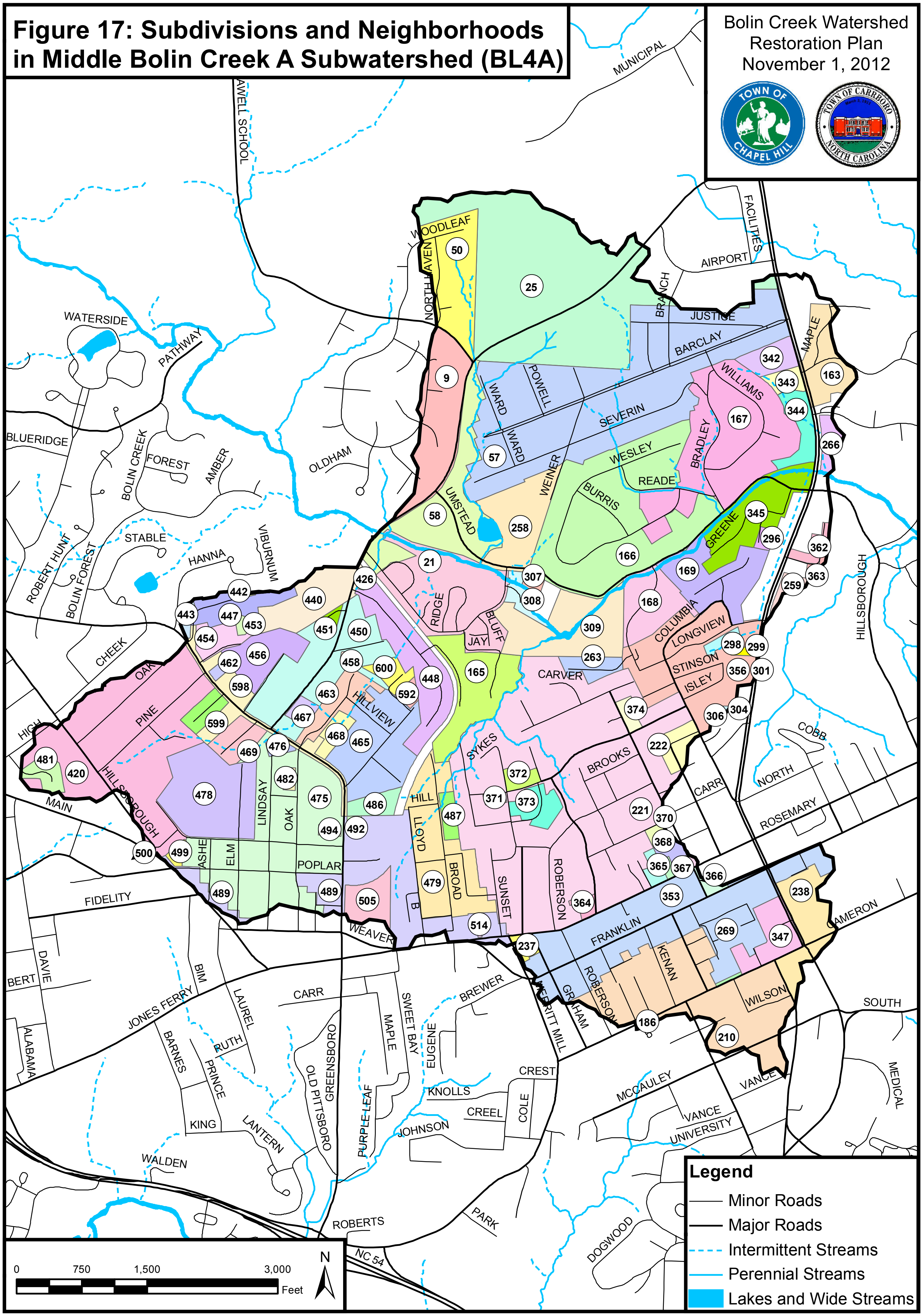


Figure 18: Subdivisions and Neighborhoods in Middle Bolin Creek B Subwatershed (BL4B)

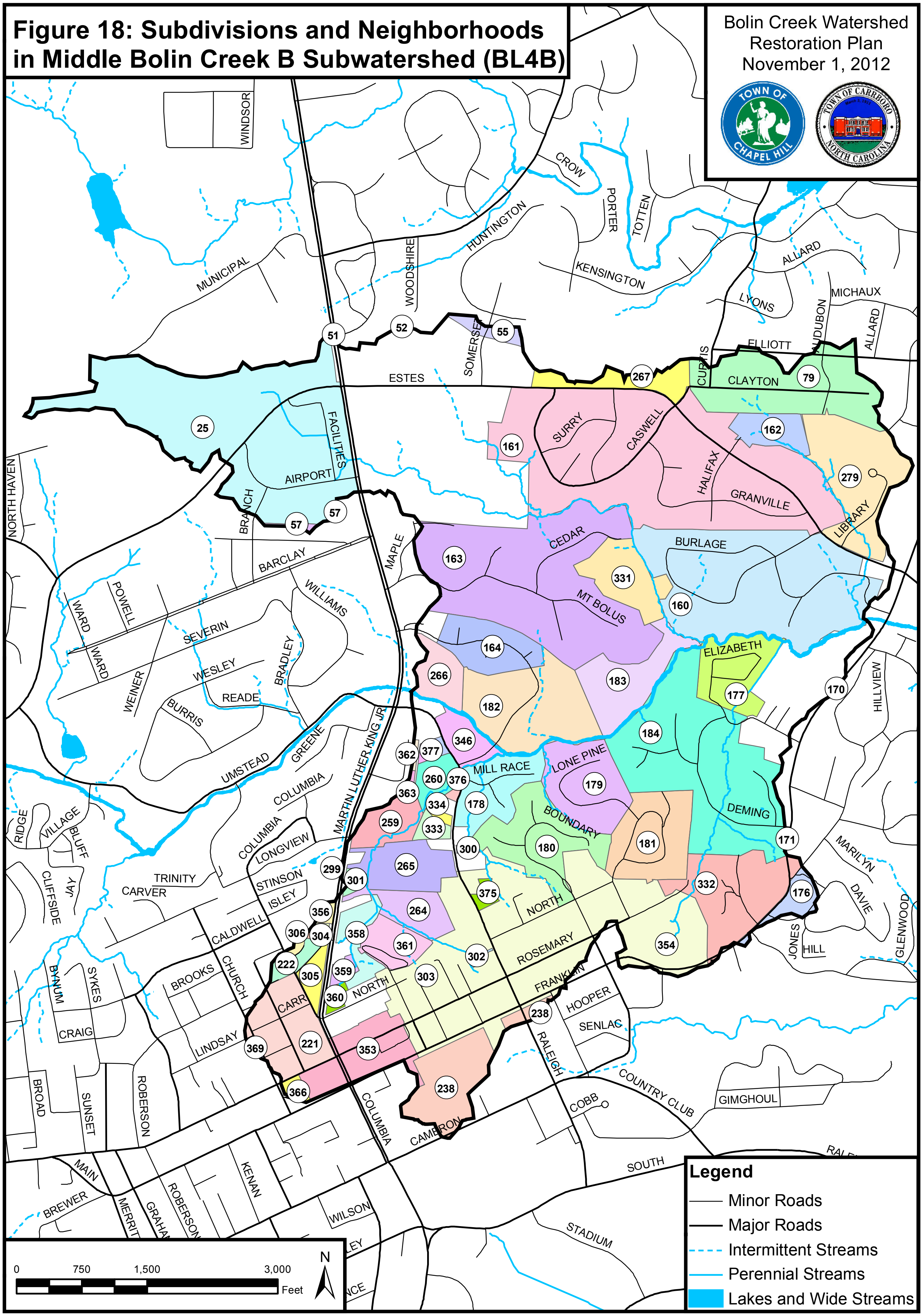
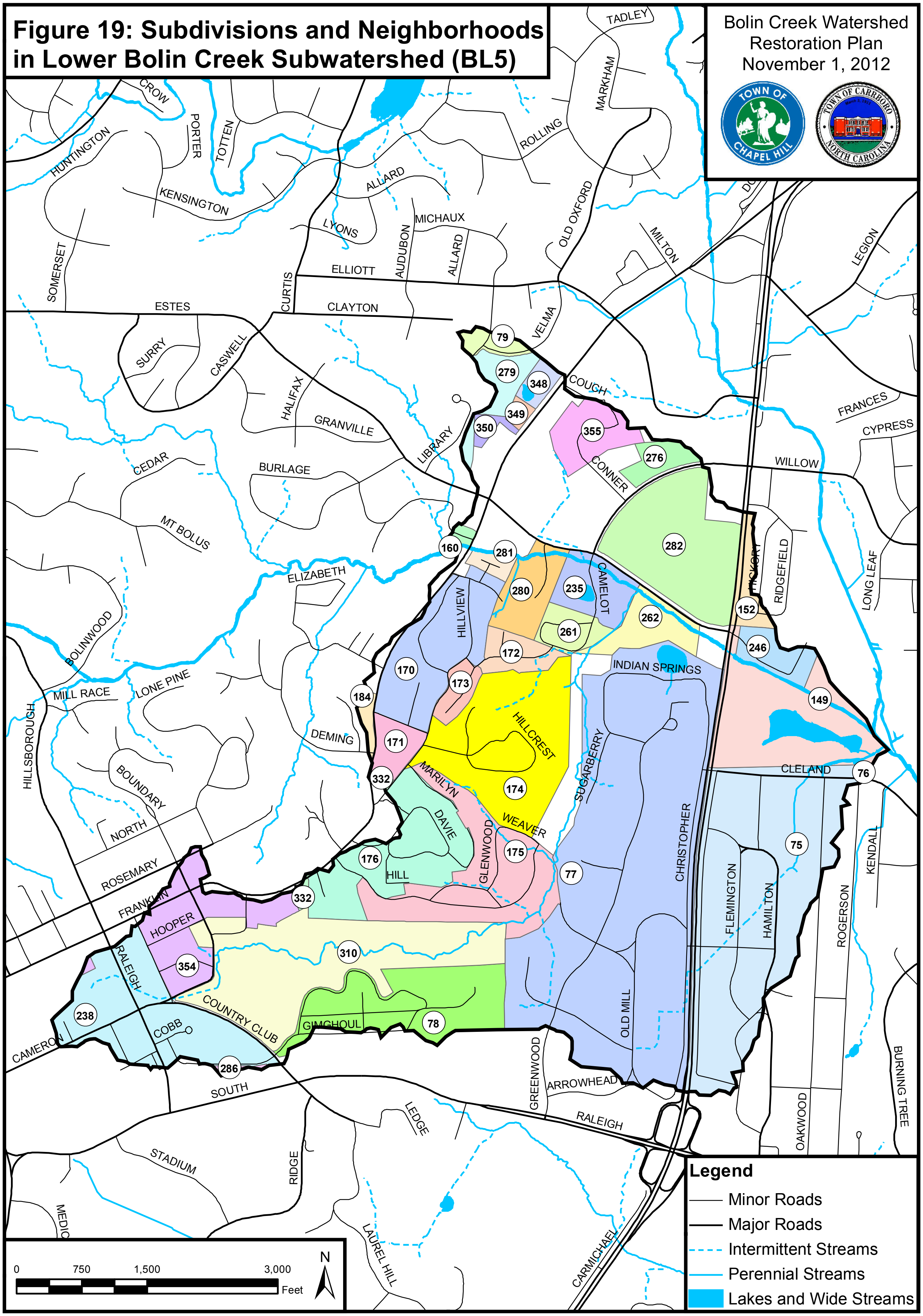


Figure 19: Subdivisions and Neighborhoods in Lower Bolin Creek Subwatershed (BL5)



POPULATION DEMOGRAPHICS

Together, Chapel Hill and Carrboro have an estimated 8,433 households in the Bolin Creek Watershed. A little over half of the Bolin Creek Watershed residents rent property and are more likely to be students and/or short-term residents: rentals are primarily located in the Middle Bolin Creek sub-basin. According to the results of a 2006 Chapel Hill Community Based Survey to measure residents' perceptions, knowledge and interest in stormwater issues, the only factor that correlated with a lack of knowledge regarding stormwater management and creek health in Chapel Hill was the amount of time lived in Chapel Hill being less than five years. Residents who rent may to a certain extent also correlate with a lack of adoption of the town as a lasting home and therefore may have a lesser interest in community action and participation. Rental property owners may also have a lesser probability of having a "willingness to pay" for property improvements to benefit water quality. Expenses for maintenance of special landscaping or stormwater BMPs would not likely be a high priority. Yard care, if any, may not go beyond routine grass cutting as property owners want to maximize their income on rental property. They also may not have responsible tenants to care for the property. Table 2 shows demographic factors within each of the five sub-watersheds. Figure 20 shows the percent of residents who have moved in the past year.

Outreach in Middle Bolin Creek Watershed must target transient populations such as students and property managers and must be repeated periodically and consistently in order to have much effect. In the late 1990's, during a recycling survey of the Northside community in Middle Bolin Creek subwatershed Eagle Scouts conducted a house to house, in-person survey to address low recycling participation and what could be done to increase the number and quality of recycling bin set outs. It was found that residents were motivated by "wanting to help." After the survey, set outs were tallied and participation increased by 35% over several months. Data is not available for longer term participation. The success of "neighbor to neighbor" or in-person outreach is supported by annual visits of UNC, Town and Recycling representatives who visit rental housing communities in August, soon after the fall semester move-in, to educate new residents about being good neighbors by showing courtesy to others and by following local rules and regulations about occupancy, parking, alcohol, noise, and trash. This outreach has improved compliance rates, showing that *direct communication* with residents motivates them to become involved in their community.

According to the April 2010-April 2011 total of 911 calls for service, Lower and Middle Bolin Creek sub-watersheds had almost triple the number of calls as any other watershed. The nature of calls to 911 varied considerably and included those for medical or accident assistance, or to report fires, robberies, assaults, suspicious behaviors, and noise among other things. In all, calls coming from the Middle Bolin Creek watershed comprised 37.6% of total calls going to Chapel Hill and Carrboro police. In contrast, the Upper Bolin Creek Watershed had the lowest number of police calls. This correlates directly with median household incomes and home values (see Table 2), but also reflects Chapel Hill's major business district and nightlife, which comprises a large portion of Middle Bolin Creek.

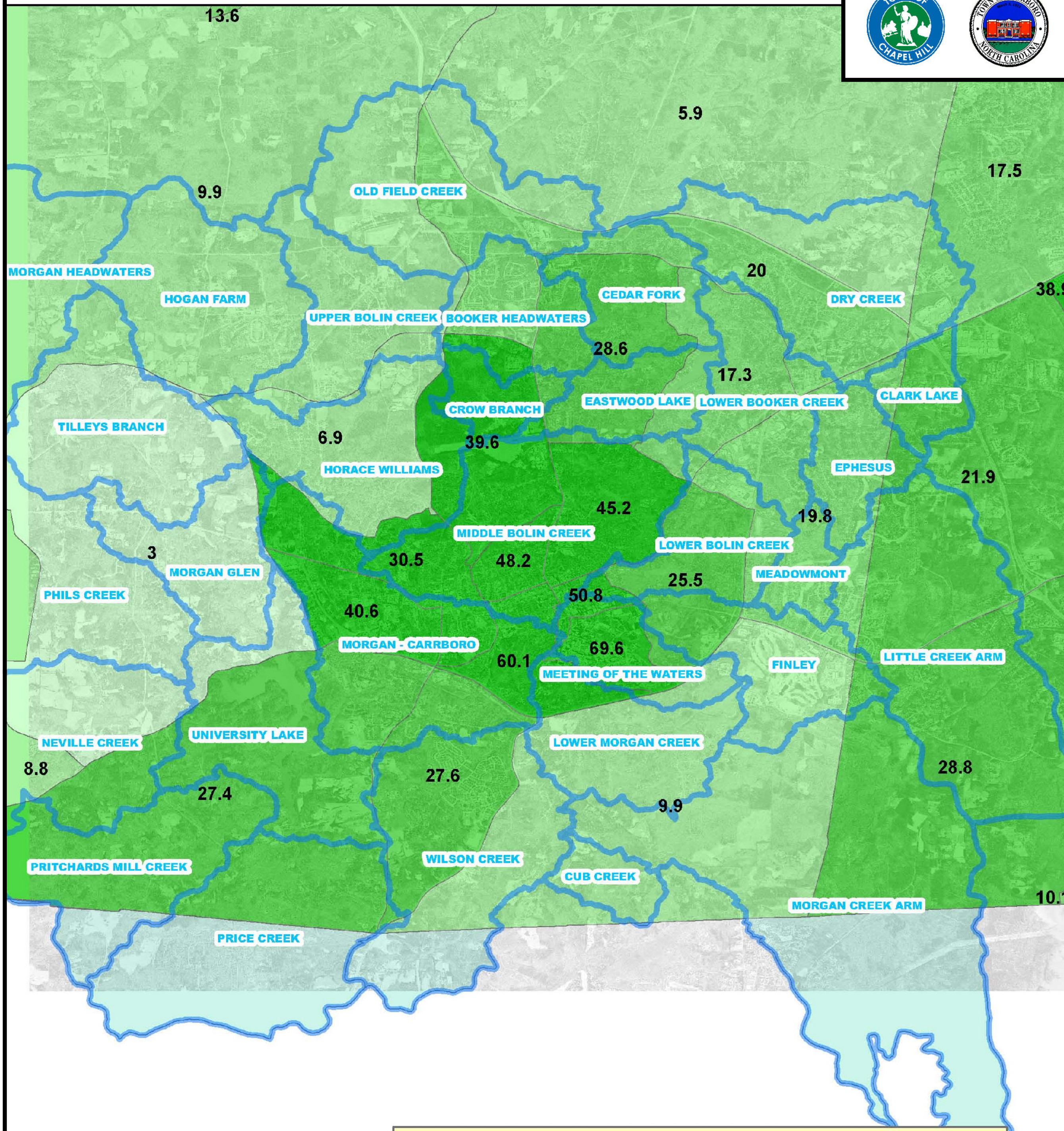
Crime statistics are significant. One reason some property owners do not want to maintain high vegetation, especially along creeks, is the fear of (potential) criminals (and snakes unrelated to crime) being able to hide. Call-for-assistance statistics also support perceptions that downtown has safety issues. This is especially true for restaurant and bar employees in the downtown area who have outdoor duties such as disposing of trash and grease after closing at night.

Table 2: Demographics of Subwatersheds Within Bolin Creek Watershed						
	Subwatersheds within Bolin Creek Watershed					
Demographic Factor	**Hogan Farm**	**Horace Williams**	**Upper Bolin Creek**	**Middle Bolin Creek**	**Lower Bolin Creek**	**Total Bolin Creek Watershed**
Sum of Home Units	635	1208	461	4945	1184	8433
Number / % All Rentals in SubWatershed	82 / 1.9%	119 / 2.7%	29 / 0.7%	3393 / 78%	730 / 16.8%	4353 rentals / 51.6% HH
Median HH Income	$133,323	$65,417	$122,722	$34,624	$44,257	$80,068
Median Home Value (Owner Occupied Units)	$400,100	$314,958	$392,186	$273,253	$458,636	$367,827
911 Calls for Service (Police/Fire/Medical, Traffic Accidents or Vehicle Problems) April 2010 - April 2011	57	385	60	11,121	2,687	14,310
% Caucasian Residents: Distribution* within subwatershed / % within subwatershed	8.6% /74.8%	15.4% / 79.1%	6.2% / 68.3%	53.3% /71.8%	16.4% /74.4%	73.30%
% of African American Residents: Distribution* within subwatershed / % within subwatershed	3.4% /3.3%	3.8% / 2.3%	4.7% / 5.9%	70% / 10.9%	18.1% /9.4%	8.40%
% Hispanic Latino: Distribution* within subwatershed / % within subwatershed	8.3% / 8.2%	17.6% / 10.3%	11.1% / 14%	49.0% /7.5%	14.0% / 7.2%	8.40%
% Asian: Distribution* within subwatershed / %within subwatershed	13.7% / 8.2%	13.6% / 6.3%	10.6% / 10.5%	45.9% /5.6%	16.1% /6.6%	6.60%
Notable: % Total Impervious Surface Including Roads, Parking, Roofs, Sidewalks, Pavement, Pools	6.20%	8.40%	12.70%	30.60%	21.80%	16.40%

Demographic data condensed from 2010 US Census Data, Town of Chapel Hill Planning Department

*Distribution is number of residents of certain race in subwatershed, divided by total number of residents of same race in the Bolin Creek Watershed. Race demographic within Bolin Creek Watershed (last column) is total number of residents of certain race divided by total number of residents in Bolin Creek Watershed.

Figure 20



Percent

(lightest)	3.000000 - 5.000000
	5.000001 - 10.000000
	10.000001 - 20.000000
	20.000001 - 30.000000
(darkest)	30.000001 - 100.000000

Percent of Residents who moved in the past year

Source: American Community Survey 2010

Note: These percentages are derived from survey responses sent to a small sample of the population within each Census Tract. The margin of error can vary for each area.

WATER USES AND CLASSIFICATIONS

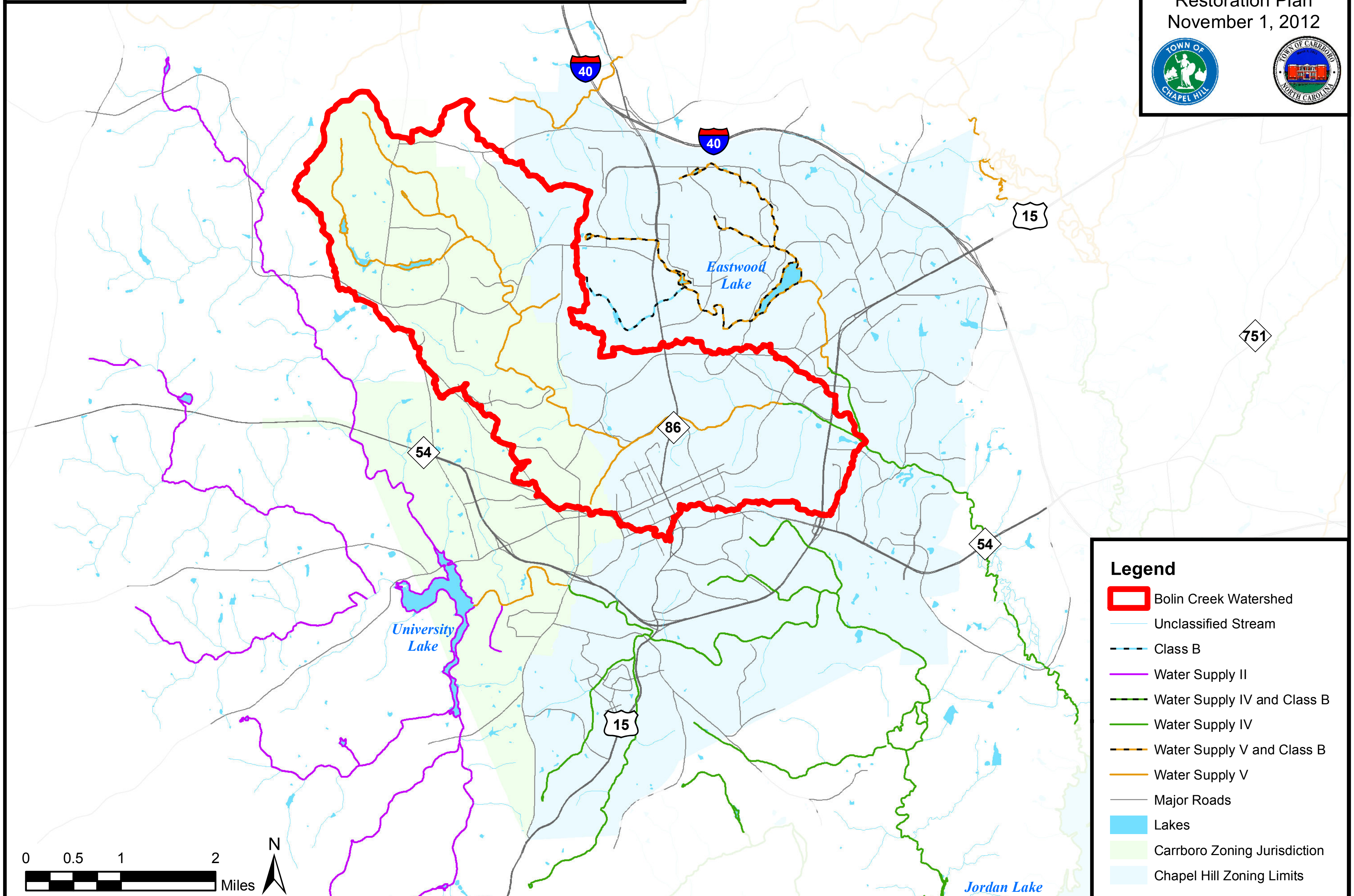
Streams and lakes in our area are classified for particular uses, or ecological functions, by the State in order to set a standard against which we can rate their functioning. Streams, lakes, ponds, and reservoirs ("waters") can have designated uses ranging from "fishable/swimmable" to water supplies with various amounts of protection. Waters may have multiple classifications based on being nutrient sensitive, high quality, or having other characteristics. All waters must at least meet the standards for Class C, also known as "fishable/swimmable". The descriptions of surface water classifications can be found in Table 3. The highest classification assigned for local waterbodies is shown on Figure 21. Note that all waters in our area are at a minimum designated for Class C uses and all are determined to be Nutrient Sensitive Waters. All Water Supply II waters are also designated High Quality Waters.

Table 3: Surface Water Classifications for Local Waterbodies

DWQ Primary Classifications	Description
Class C ("fishable / swimmable", "aquatic life")	Waters protected for secondary recreation (wading, boating, and other incidental human body contact), fishing, wildlife, fish and aquatic life propagation and survival, agriculture, and other uses suitable for Class C. No restrictions on watershed development or types of discharges.
Class B ("primary contact")	Waters used for primary recreation (swimming, diving, water skiing and similar) and other uses suitable for Class C. There are no restrictions on watershed development or types of discharges.
WS-II ("Water Supply II")	Waters used as sources of potable water where a WS-I classification is not feasible. These waters are generally in predominantly undeveloped watersheds and only general permits for discharges are allowed. All WS-II are High Quality Waters by definition.
WS-IV ("Water Supply IV")	Waters used as sources of potable water where WS-I, WS-II, or WS-III classification is not feasible. These waters are generally in moderately to highly developed watersheds or Protected Areas, and involve no categorical restrictions on discharges.
WS-V ("Water Supply V")	Waters protected as water supplies which are generally upstream of and draining to Class WS-IV waters or waters used by industry to supply their employees with drinking water or as waters formerly used as water supply. These waters have no categorical restrictions on watershed development or wastewater discharges.
DWQ Secondary Classifications	**Description**
Nutrient Sensitive Waters (NSW)	Waters needing additional nutrient management due to their being subject to excessive growth of microscopic or macroscopic vegetation.
High Quality Waters (HQW)	Classification to protect waters with quality higher than state water quality standards. WS-II waters are High Quality Waters by definition. There are associated wastewater treatment and development controls enforced by DWQ.

From NC DENR webpage: Guide to Freshwater Classifications Chart. See this document for more details on requirements for watershed protection, critical areas, and other restrictions and requirements for specific land uses.

Figure 21: Stream and Waterbody Use Classifications



ZONING AND LAND USE RESTRICTIONS

Local jurisdictions in the watershed manage land use and development primarily through zoning and additional land use restrictions for particular situations. Zoning requirements encompass everything from land use or type of activity, compatible land uses, land use intensity, building requirements, dimensional standards, buffers between land uses, appearance, multi-modal traffic and access needs, effects on adjacent existing development, in addition to various public health and environmental protections. With regard to environmental protection, the most important aspects of zoning are the type or mix of land use activities (such as residential, commercial, industrial, institutional) and the density or intensity of use. Current zoning requirements for the zoning jurisdictions of the Towns of Carrboro and Chapel Hill are shown in Figure 22. Because of the large variety of zoning district types, and the small distinctions between types in Chapel Hill compared to Carrboro, zoning districts have been generalized to some degree.

While some aspects of environmental protection are included in general zoning requirements, specific areas or sensitive environmental conditions may have additional "overlay" zoning districts or other kind of land use restrictions that are not zoning or overlay districts. These additional land use restrictions, including stream buffers, regulatory floodplains, and water-supply watershed protection areas are shown in Figure 23. Additionally, while not explicitly mapped, steep slopes of over 10% inclination have specific building requirements. These areas must be indicated on individual development applications, but areas where steep slopes are most likely to be found (overlaid with erodible soils) are shown above in Figure 5.

As lands have been developed under this ordinance over the past several decades, areas have been set aside in both public and private open space. Public ownership of land provides some restriction on development opportunities or practices, usually through intensive public or stakeholder involvement in the planning process. These public entities include federal, state, and local governments, the local school system, and the University of North Carolina. There are also a few areas specifically protected by conservation easements which restrict development in perpetuity. Large conservation easements have been placed on the Lloyd-Andrews farmstead and the Adams Tract. The Carolina North development agreement includes a large amount of land set aside for conservation in the Bolin Creek watershed. Government-owned properties are shown in Figure 24.

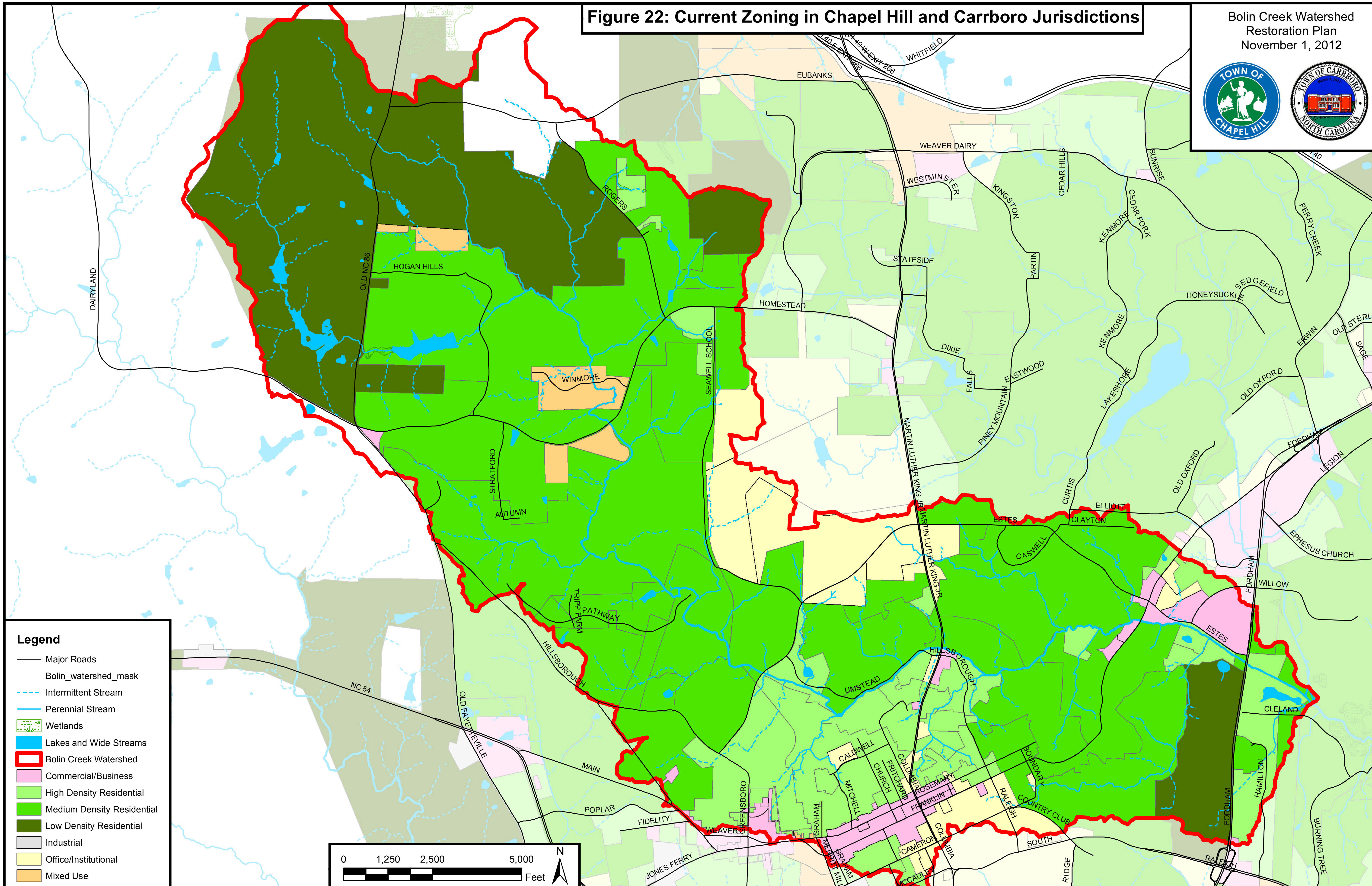


Figure 22: Current Zoning in Chapel Hill and Carrboro Jurisdictions

Figure 23: Regulatory Floodplains, Stream Buffers, and Watershed Protection District

Bolin Creek Watershed
Restoration Plan
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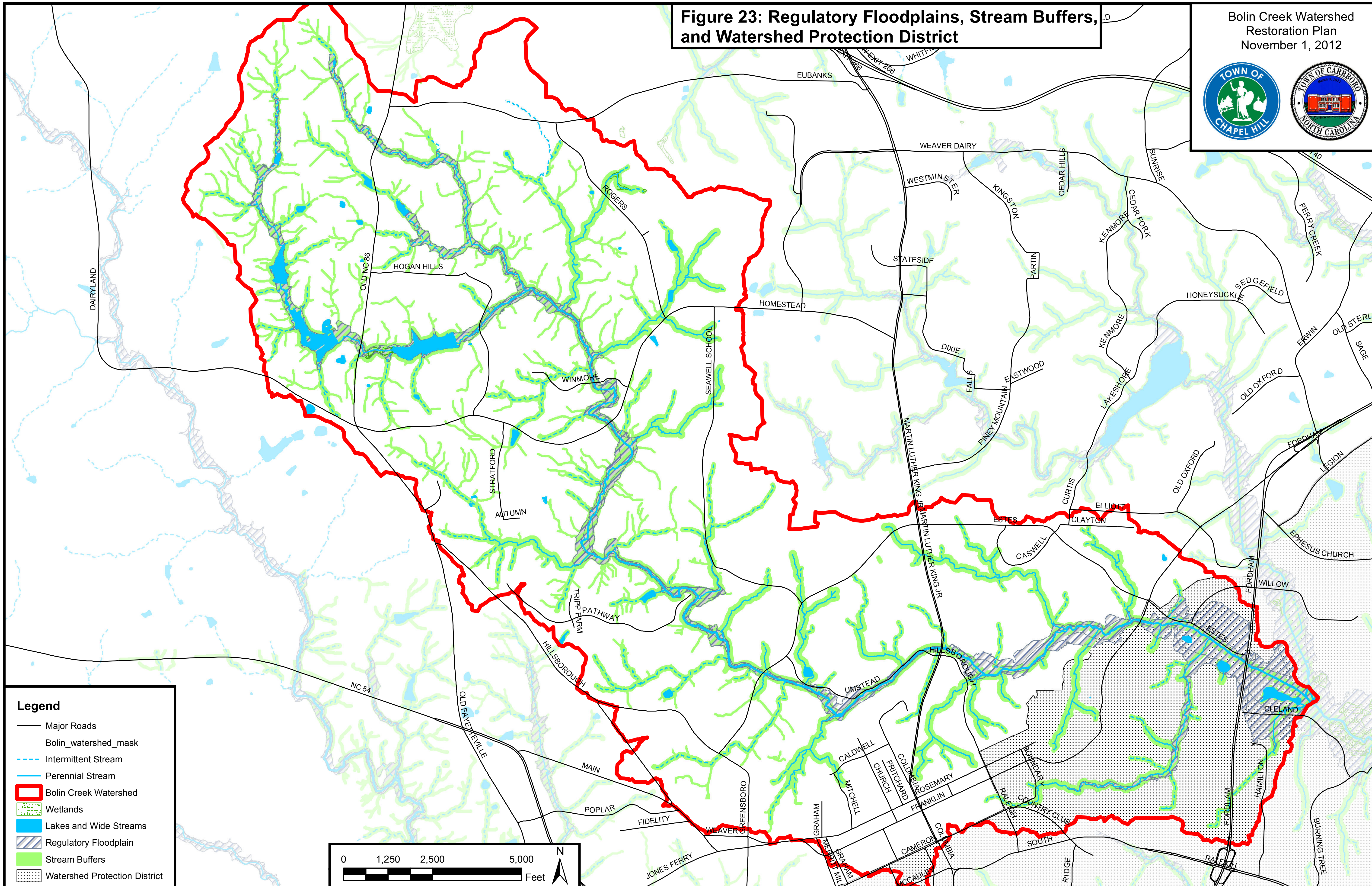
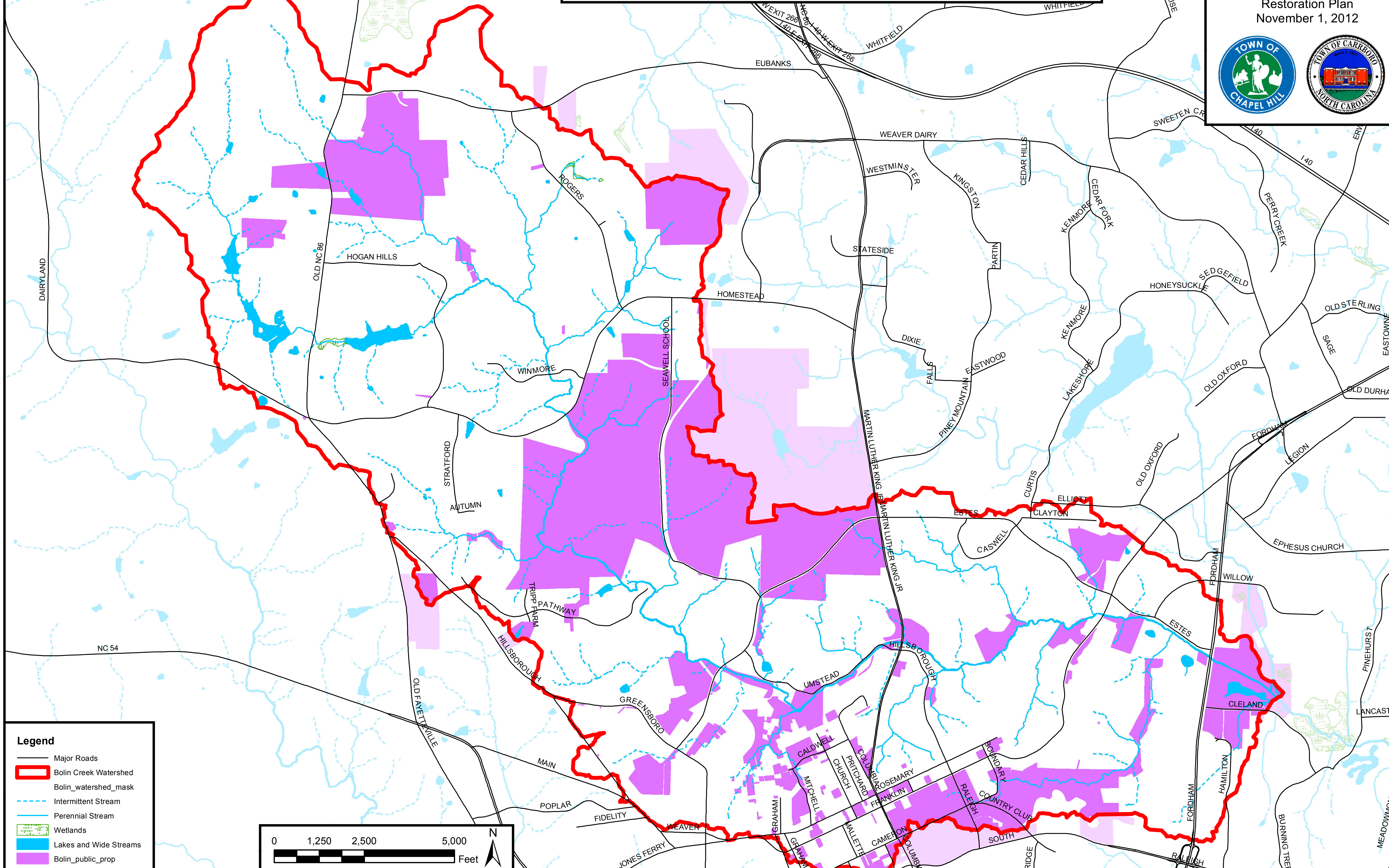


Figure 24: Publicly-Owned Properties in Bolin Creek Watershed



ENVIRONMENTAL REGULATIONS AND PROGRAMS

Much water resource protection in North Carolina is ultimately based on the federal-level Clean Water Act, with some contribution by requirements of the Safe Drinking Water Act and Resource Conservation and Recovery Act, among others. These regulations have led to state-level requirements regarding streams, stream buffers, wetlands, sewage treatment, septic systems, industrial dischargers, land use intensity, building requirements, stormwater management, underground storage tanks, pollution prevention, illegal discharging and dumping, erosion and sedimentation control, groundwater pollution, nutrient management, drinking water wells, reservoirs, dams, and water supply protection and management. Some of these requirements are enforced by the state, but for the most part enforcement is delegated to local jurisdictions, which create local ordinances that meet state requirements yet are customized in a way to meet local needs and capabilities.

State agencies and local governing bodies in the watershed address these requirements through a variety of ordinances, guidelines and manuals, education and outreach, inspection and enforcement, development plan review, zoning and overlay districts, comprehensive and targeted plans, and cooperative programs with citizens and other agencies. Appendix 1 describes the variety of local environmental policies, programs, ordinances, and plans currently in place.

A number of steps have been put in place in recent years to protect creeks from the impacts of development in federal, state, and local government laws, ordinances, and programs. EPA oversees municipal stormwater permits, with administration by States, and ultimate responsibility residing with local governments. In addition to administering the stormwater permits, the NCDWQ also provides regulatory oversight for the Jordan Lake rules which were adopted in 2009. Regulations under federal and state efforts focus on 1) minimizing impacts from construction, and primarily erosion and sediment control, and 2) minimizing impacts after construction due to altered hydrology and water quality. The term coined for the latter category is “post construction” impacts; these regulations focus on designing stormwater controls and insuring adequate operation and maintenance of stormwater management devices. Key components of construction and post construction regulations are shown in Table 4. While new development in the Bolin Creek Watershed is affected by new rules that became fully effective in 2012 to address nutrients in runoff being delivered to Jordan Lakes, and federal regulations, ultimately, a project must comply with either Carrboro’s or Chapel Hill’s ordinance. Both Chapel Hill and Carrboro’s stormwater permits have been through one 5 year cycle; permits for a second cycle were recently reissued by the North Carolina Division of Water Quality. Chapel Hill and Carrboro have delegated authority for erosion control at development sites to Orange County.

In total, the regulations discussed focus on requirements that currently manage erosion and sedimentation on developing sites through approved erosion control management techniques, control peak flow, matching post-development stormwater peak flow rates to pre-development rates, and minimize water quality impacts through removal of total suspended solids. The Jordan rules also, beginning in 2012, limit nitrogen and phosphorus runoff from development sites.

Table 4: Selected Post Construction Stormwater Regulatory Performance Standards for Development

Regulatory Focus	Carrboro Performance Standard	Chapel Hill Performance Standard	Jordan Rules Performance Standard	NPDES Permit

Applicability	5,000 square feet of disturbance	5,000 square feet of disturbance (except 1 and 2 family homes)	½ acre (commercial) of disturbance; 1 acre (residential) of disturbance	1 acre of disturbance
Flood Protection	Control flow rate from 1,2,5,10,25 year recurrence, 24 hour design storms; no increase in 1% flood elevation	Control flow rate from 1,2,25 year recurrence, 24 hour design storms	Treat flow rate from 1 year recurrence, 24 hour design storm	NA
Stormwater volume	Control annual volume increase based on curve number	Control volume from 2-year recurrence, 24-hour design storm event	NA	NA
Water Quality	85% TSS removal; 1 inch rain event	85% TSS removal; 1 inch rain event	2.2 #/ac/yr nitrogen; 0.82 #/ac/yr phosphorus; 1 inch rain event	NA
Other	NA	NA	NA	Provisions for: adequate BMPS, plan review, operation and maintenance, inspection, enforcement, education, recordkeeping

LOCAL DEPARTMENTS, AGENCIES, AND ORGANIZATIONS

These environmental protection and management programs and efforts are implemented by a variety of local government departments and agencies in the watershed. Their efforts are frequently supplemented and augmented by local non-profit organizations. Appendix 2 details the various departments, agencies, and organizations that have a responsibility for, capacity to help with, or interest in participating in environmental management. These organizations form the beginning of a list of stakeholders for Bolin Creek. How they currently interact with water resources is described in the appendix.

CHAPTER 3: WATERSHED ANALYSIS

3.1 WATERSHED STUDIES AND ASSESSMENTS

DWQ STREAM AND WATERBODY RATINGS

Streams and waterbodies are monitored by the North Carolina Division of Water Qulaity (DWQ) in order to determine whether they are meeting their designated uses. Designated uses are described in the previous chapter, Watershed Characterization.

DWQ uses stream organisms as a primary indicator of condition. As noted in the previous chapter,one of the Class C designated use of streams and waterbodies in this region is the propagation and survival of fish and aquatic life. Different macroinvertebrate species in our area have different tolerances of poor water quality conditions, and these differences have been ranked for use in calculating the Index of Biotic Integrity for a given stream. Ratings for ecological communities range from Excellent, Good, Good-Fair to Fair, Fair-Poor, and Poor. When a stream's ecological community is rated Fair, Fair-Poor, or Poor, the stream is considered not to be meeting the requirements for aquatic life. Where it has been determined that a stream or waterbody cannot fulfill one or more designated uses, based on its classification, then it is considered "Impaired". Impaired streams and waterbodies that do not have management plans created for them are published every two years on the state's 303(d) List of Impaired Waterbodies. The most recent State ratings of streams and waterbodies in our area are shown on Figure 25.

AQUATIC HEALTH

The Division of Water Quality has conducted several rounds of targeted macroinvertebrate collection to better track changes going on in the area. Studies of local aquatic health were produced in 1993, 1998, and 2003 (this last collection as part of the Watershed Assessment Restoration Project described below).

DWQ has recognized that the aquatic health of Bolin Creek is impaired, and exhibits a progressive decline in watershed functional health from upstream to downstream. Such issues have been analyzed in their periodic Basinwide Water Quality Plan for the Cape Fear River Basin, which includes several monitoring stations along Bolin Creek. Table 5 has a summary of biological ratings for DWQ monitoring stations along Bolin Creek.

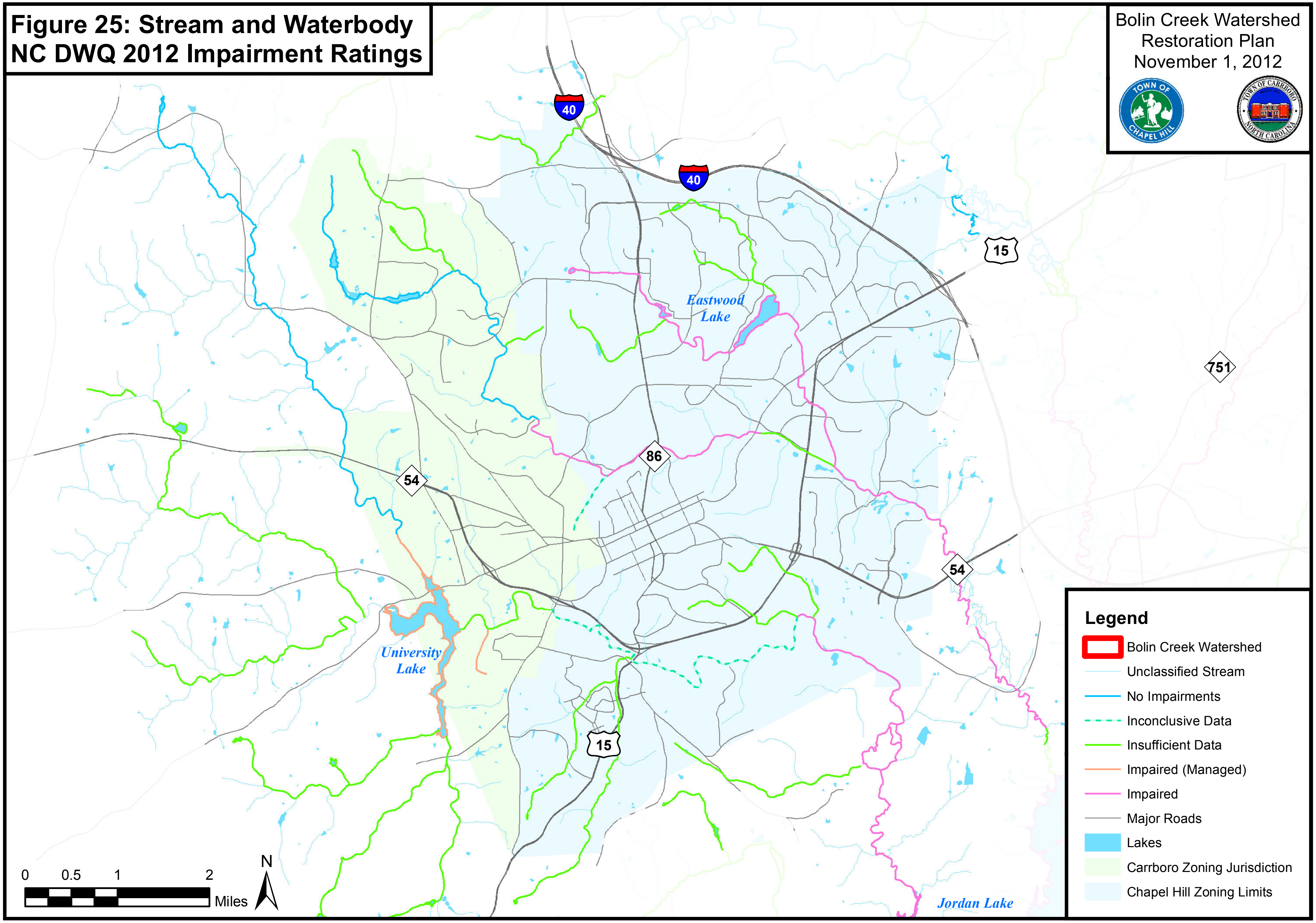


Figure 25: Stream and Waterbody
NC DWQ 2012 Impairment Ratings
Bolin Creek Watershed
Restoration Plan
November 1, 2012
40
15
Eastwood Lake
751
86
54
University Lake
15
Jordan Lake
0 0.5 1 2
Miles
N
Legend
Bolin Creek Watershed
Unclassified Stream
No Impairments
Inconclusive Data
Insufficient Data
Impaired (Managed)
Impaired
Major Roads
Lakes
Carrboro Zoning Jurisdiction
Chapel Hill Zoning Limits

Table 5: DWQ Biological Ratings for Stations Along Bolin Creek			
Site Name	Site ID	Date	Bioclassification
Bolin Creek at SR1777 (Homestead Rd.)	(BB330)	7/10/2001	**Good-Fair**
		2/27/2001	**Not Rated**
		4/6/2000	**Good**
		3/11/1998	**Good**
		4/1/1993	**Good**
Bolin Creek 400m upstream of Estes Dr.	(BB506)	7/9/2009	**Fair**
Bolin Creek at Village Drive	(BB449)	3/14/2002	**Fair**
		7/10/2001	**Fair**
		2/27/2001	**Poor**
		2/26/1998	**Good**
		4/1/1993	**Good-Fair**
Bolin Creek at Bolinwood Drive	(BB62)	3/14/2002	**Poor**
		3/1/2001	**Poor**
Bolin Creek at East Franklin Street	(BB71)	7/10/2001	**Poor**
		3/1/2001	**Poor**
		3/11/1998	**Fair**
		2/2/1998	**Poor**
		2/10/1993	**Fair**
		4/29/1986	**Good-Fair**

The Towns of Carrboro and Chapel Hill have been conducting annual monitoring of local benthic macroinvertebrate populations in support of DWQ's less-frequent assessments. Macroinvertebrates and their habitat are collected and characterized using the same methods as the state, ensuring comparability of data. These efforts have demonstrated that droughts have long-lasting effects on stream community composition, and may mask the specific effects of other water quality problems. However, it also indicates that low base flow (dry weather flow) is in itself a problem for the stream community and a stressor that should be considered and addressed.

Benthic monitoring suggests specific likely stressors for particular streams, including low dissolved oxygen, stormwater runoff (toxics), nearby or upstream construction activity, sedimentation, scouring and erosion, filamentous algae, very low base flows (near intermittent), poor riparian buffer zones, and illicit discharges. The fine scale of sampling allows Town staff to look for smaller or intermittent sources that may not be easily detected through more general monitoring methods.

In 2011 and 2012 the Towns conducted fairly extensive, coordinated macroinvertebrate monitoring. Figures 26 and 27 show the results of these monitoring efforts.

WATER CHEMISTRY

In 1994 the Town of Chapel Hill initiated monthly low-flow stream water chemistry monitoring in coordination with the Town of Carrboro. Thirteen sites in the area were sampled until 2008, shown in Figure 28. Constituents included nutrients, total suspended solids and total dissolved solids, fecal coliforms, lead, copper, and zinc. Limited physical stream condition components, commonly called field parameters which include temperature, pH, dissolved oxygen, and conductivity, were also collected as part of this effort.

An analysis for status and trends in water quality conditions showed no clear trend for any constituent except for expected seasonal variations in temperature and dissolved oxygen. No clear pattern of exceedance of state standards was apparent from the available data, either. Some constituents show occasional spikes in concentration that we were unable to explain by season, location, or other available information about the area. Other constituents simply had a broad scatter of values with no discernible pattern over several years. It is uncertain whether we were monitoring the constituents that were most responsible for an impaired aquatic community at any one location. The constituents analyzed are known to change in response to increasing urban development, but they may not be the most important ones.

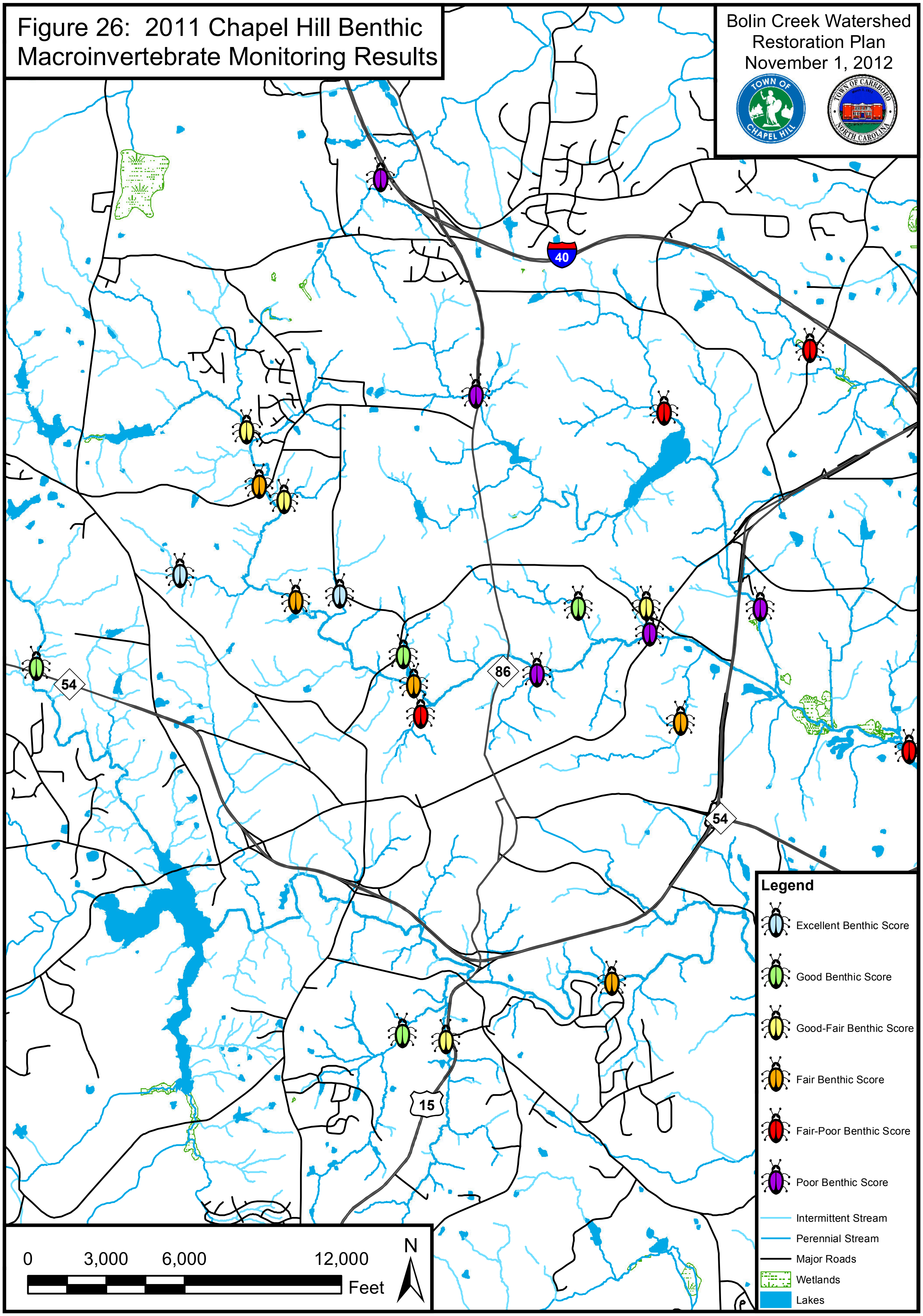


Figure 26: 2011 Chapel Hill Benthic Macroinvertebrate Monitoring Results
Bolin Creek Watershed
Restoration Plan
November 1, 2012
TOWN OF CHAPEL HILL
TOWN OF CARRBORO NORTH CAROLINA
40
54
86
54
15
Legend
Excellent Benthic Score
Good Benthic Score
Good-Fair Benthic Score
Fair Benthic Score
Fair-Poor Benthic Score
Poor Benthic Score
Intermittent Stream
Perennial Stream
Major Roads
Wetlands
Lakes
0
3,000
6,000
12,000
Feet
N

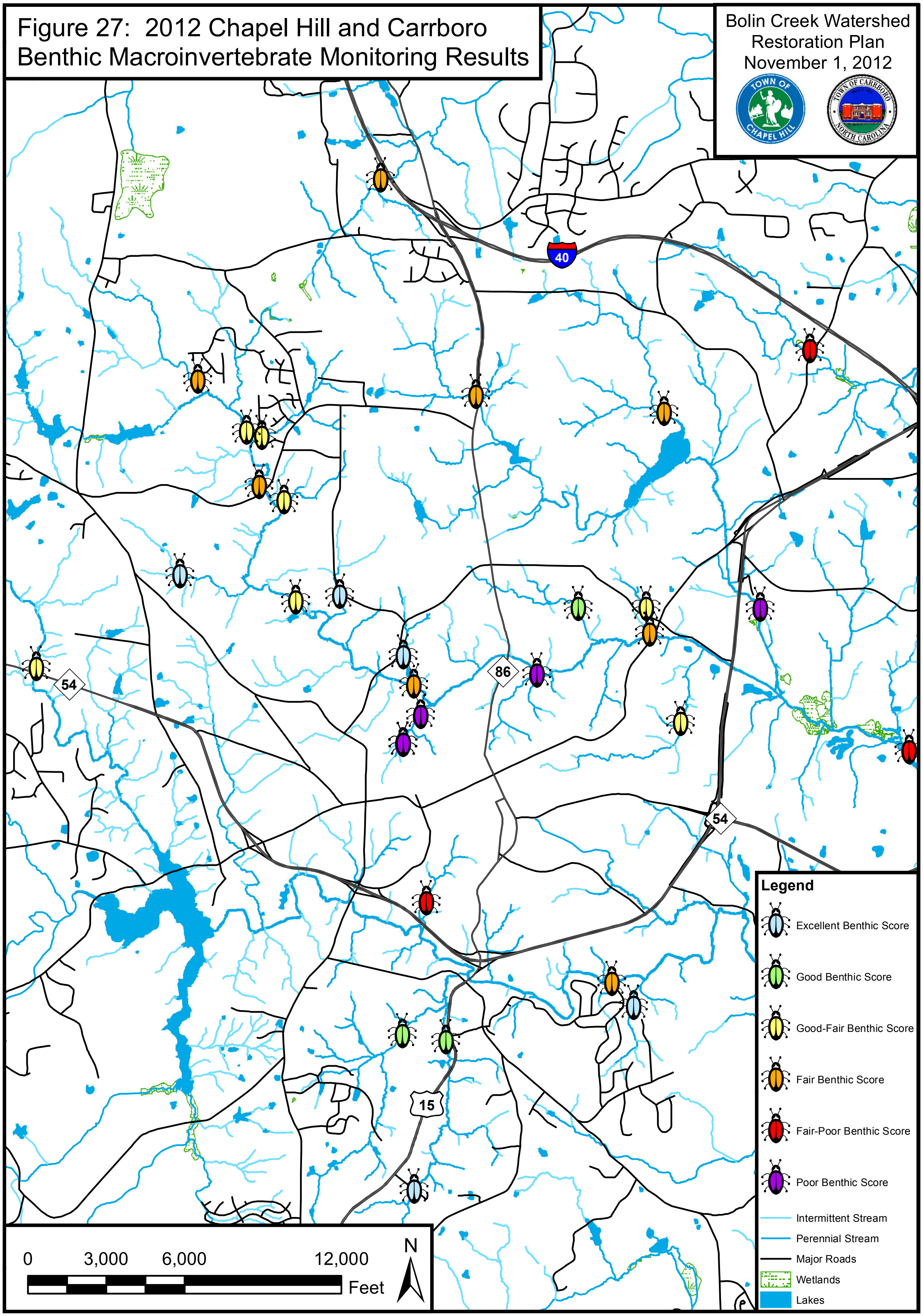


Figure 27: 2012 Chapel Hill and Carrboro Benthic Macroinvertebrate Monitoring Results

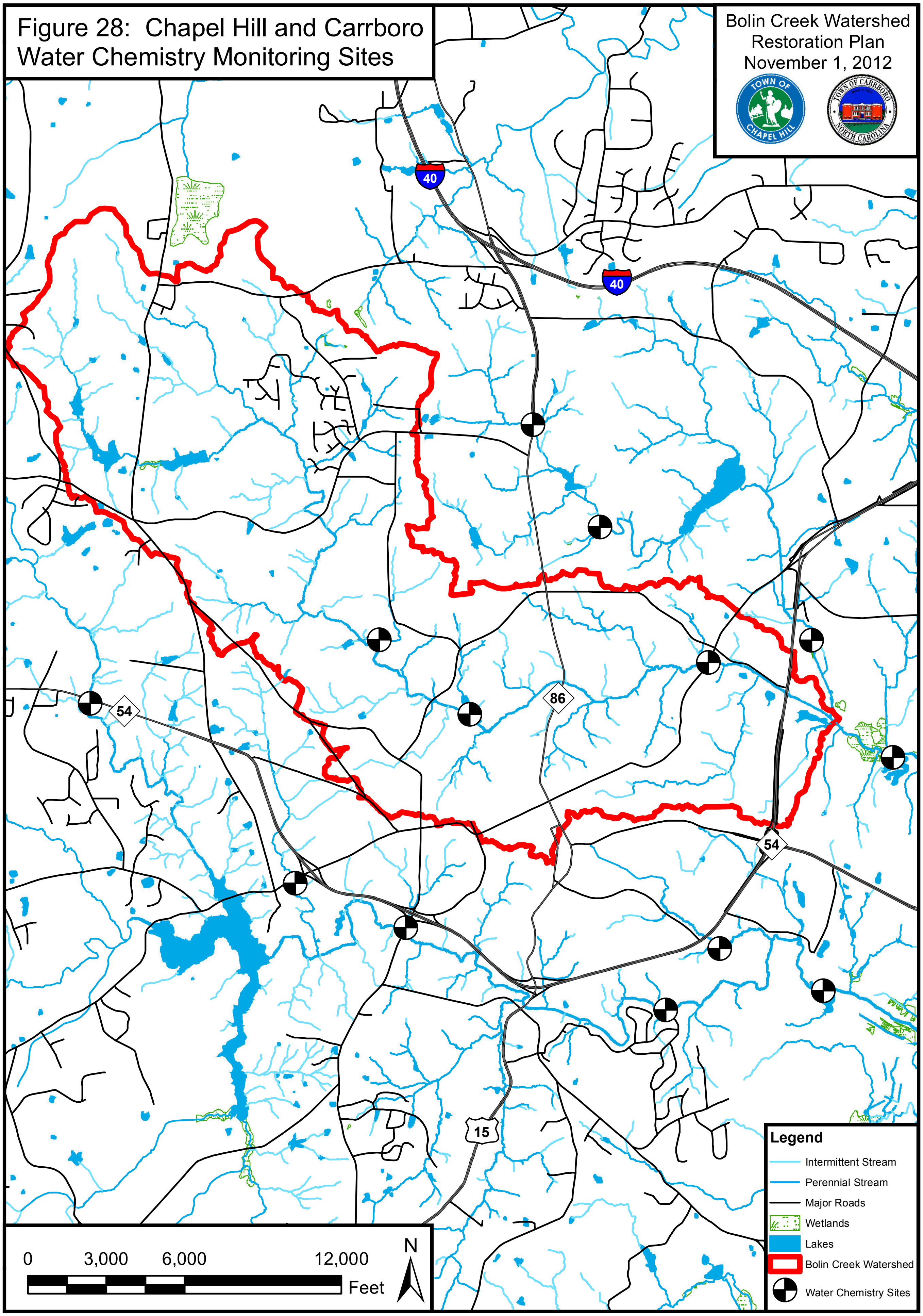


Figure 28: Chapel Hill and Carrboro Water Chemistry Monitoring Sites

WATERSHED ASSESSMENT AND RESTORATION PROJECT

The Watershed Assessment and Restoration Project (WARP) was a two-year project funded by the Clean Water Management Trust Fund. This was a study of the Little Creek Watershed, which includes Bolin Creek, conducted from 2001 to 2003. Results were published in 2003 in "Assessment Report: Biological Impairment in the Little Creek Watershed Cape Fear River Basin."

The goal of the project was to provide the foundation for future water quality restoration by (1) identifying the most likely causes of biological impairment (such as degraded habitat or specific pollutants), (2) identifying major watershed activities and sources of pollution associated with those causes (such as stormwater runoff from particular areas, stream bank erosion, or changes in watershed hydrology), and (3) outlining a watershed strategy that recommends restoration activities and best management practices which address these problems and improve the biological condition of the impaired streams.

Research focused on the collection of three types of data: (1) biological community data, (2) physical and chemical water quality data, and (3) stream quality data. Biological assessments were accomplished through the monitoring of aquatic macroinvertebrates (stream insects, clams, worms, etc.). Physical and chemical water quality data such as dissolved oxygen, nutrients, and pesticides were collected throughout the watershed at regular intervals and stream habitat data, such as stream bottom type, stream bank stability and riparian vegetation character were collected during stream walks and biological community monitoring.

The study found that Bolin Creek's condition has deteriorated from Good quality in 1986, and that this impairment has worked slowly upstream. More broadly, the study found that aquatic organisms in Little Creek and its tributaries are heavily impacted by multiple stressors associated with the high levels of development in the watershed. The relative contribution of these stressors could not generally be clearly differentiated as noted in the findings below:

1. Habitat degradation manifested as sedimentation and a lack of organic microhabitat (leaf packs, sticks, root mats and other natural organic material) can be considered a cause of impairment in creeks in the Triassic Basin, with transitional quality upstream from that. But it is likely not a primary limiting factor.

2. Excessive stream bed and bank scouring occurs due to the increased storm runoff volumes and velocities associated with the high levels of development in much of the watershed. This contributes to impairment of the macroinvertebrate community both by degrading habitat (through the flushing of organic material and contribution to stream bank erosion) and by dislodging organisms.

3. The removal of riparian vegetation and past channel modification also contributes to habitat degradation.

4. Toxicity is a likely contributor to impairment in much of the watershed, especially at the lower end of the study area and in Crow Branch. The specific pollutants responsible for this toxicity cannot be identified from the available data and may be variable.

5. Sources of toxic pollutants in the lower part of the study area include runoff from the developed portions of the watershed and inputs from specific events (e.g., spills and

underground storage tank leaks). For Crow Branch the two inactive UNC hazardous waste sites are the most plausible source of the problem.

6. The causes of impairment in the portion of Bolin Creek between Airport Road and Waterside Drive are less clear than in the downstream section of Bolin Creek. In-stream habitat is adequate. Some effects of toxicity and scour are likely, although these impacts appear less pronounced than in lower Bolin Creek, and likely decline significantly at the upstream end of this section.

7. Low flow conditions during the summer of 2002, and resultant low dissolved oxygen (DO) levels, were extremely stressful to biota. While low DO concentrations occur periodically in more typical years, biological community data provide little evidence that these conditions, though a concern, are normally severe enough to be considered a cause of impairment. Ongoing DO impacts appear most likely in lower Booker Creek and in Little Creek.

8. The underlying Carolina Slate Belt geology in the drainage of upper Booker Creek and its tributaries supplies little baseflow during the summer, limiting biological potential in this portion of the watershed.

9. The lack of summer outflows from Eastwood Lake contributes to impairment in lower Booker Creek by exacerbating summer low flow conditions associated with the underlying geology and the urban nature of the drainage area. The dam also limits downstream macroinvertebrate recolonization.

10. Future development is likely to result in further habitat degradation if post-construction stormwater volumes are not effectively controlled.

The study recommended several actions addressing specific causes of impairment:

1. Implement feasible and cost-effective stormwater retrofit projects to mitigate the hydrologic effects of existing development (increased stormwater volumes and increased frequency and duration of erosive and scouring flows). The most densely developed areas should be given priority for the evaluation of retrofit opportunities.

2. Develop and implement a strategy to address toxic inputs, including a variety of source reduction and stormwater treatment methods.

3. Undertake remediation at the two UNC hazardous waste disposal sites to address toxicity in Crow Branch.

4. Implement stream channel restoration activities in the lower portion of the study area, in conjunction with stormwater retrofit BMPs, in order to improve aquatic habitat.

5. Encourage cooperation between OWASA and the Towns of Chapel Hill and Carrboro to improve the condition of riparian vegetation along sanitary sewer rights of way and greenways, limit future riparian disturbance, and encourage property owners to reestablish native woody riparian vegetation and limit future disturbance.

6. Prevent further channel erosion and habitat degradation with effective post-construction stormwater management for all new development in the study area. For best results,

stormwater management should include active promotion of infiltration practices, low impact development (LID) practices and other approaches to limit stormwater volume, criteria to address geomorphically relevant flows, and required application for all but the lowest density development.

7. Implement activities to address organic loading including the identification and elimination of illicit discharges; education of homeowners, commercial applicators, and others regarding proper fertilizer use; street sweeping; catch basin clean-out practices; and the installation of additional Best Management Practicies (BMPs) targeting biochemical oxygen demand (BOD) and nutrient removal at appropriate sites.

8. Improve efforts by OWASA to prevent sewer overflows and address leaking sewer lines, critical to reducing nutrient inputs and potential ammonia toxicity from these sources.

9. Explore the technical, economic and regulatory feasibility of implementing minimum releases from Eastwood Lake should be explored.

10. Enforce sediment and erosion control regulations to prevent additional sediment inputs from construction activities. Increasing attention to the phasing of construction activities and to the rapid establishment of stabilizing vegetation is also important.

The Bolin Creek Watershed Restoration Plan is heavily based upon the work done in this effort. The WARP study was a primary starting point for the Earth Tech study described below, and for further efforts to get a more detailed and nuanced understanding of stressors and sources in the Bolin Creek Watershed. Many of the recommendations in this study have been implemented, partly as the Towns meet NPDES Phase 2 requirements, and partly in the implementation of Chapel Hill's Stormwater Management Program.

ECOSYSTEM ENHANCEMENT PROGRAM'S LOCAL WATERSHED PLAN

In 2004 a planning initiative was undertaken by the Ecosystem Enhancement Program (EEP, then Wetlands Restoration Program) for the identification and implementation of water quality improvement projects in the Little and Morgan Creek Watersheds. Identified projects could be used to offset impacts to streams by North Carolina Department of Transportation projects, and other projects that may acquire mitigation credits through EEP. The project collected a large amount of information regarding geomorphology, land use/land cover, riparian condition, and habitat in the Morgan Creek and Little Creek watersheds.

The Preliminary Findings Report recommended key indicators of overall watershed integrity, and recommended assessment tools necessary to evaluate responses of key indicators to proposed management strategies. It also identified a set of goals and objectives, potential strategies, and data gaps and outlined a data collection plan. It provided a description of physical features, an assessment of (then) current ecological condition, identified primary threats to watershed function, delineated objectives for detailed assessment, and recommended indicators and assessment tools and data needs.

The Detailed Assessment Report provided a more in-depth assessment of hydrology and aquatic habitat functions. The project evaluated stream erosion and instability, impervious cover, riparian buffers, floodplain encroachment, delivery of nutrients to Jordan Lake, University Lake eutrophication, and potential sources of fecal coliforms. The project also assessed terrestrial habitat functions and preservation potential. All of this was combined into subwatershed rankings of Existing Risk, Priority for Management and Future Risk, and Priority for Prevention, and an overall ranking and recommendation for targeting management was made. Next steps were summarized as identification and prioritization of restoration opportunities, opportunities to prevent future degradation, and prioritization of preservation efforts.

The Targeting of Management Report summarized the findings and analysis, and presented strategies and priorities for restoration, prevention of degradation, and preservation efforts. Many potential restoration projects were identified through GIS analysis methods and ranked by a variety of metrics to meet EEP goals (such as a minimum project size/area), minimize costs and impediments, and maximize potential improvement. In subsequent years, staff from the Towns have evaluated many of these potential projects in the field and found them less feasible than proposed, beyond the capabilities of the Towns to implement, or not able to address the kinds of degradation as described in the WARP study. This disconnect between the recommendations of the WARP study and the EEP Local Watershed Plan recommendations led the two Towns to investigate stressors and sources at a much finer scale, with the hope that smaller, more feasible projects could be identified. This effort led to the Earth Tech Geomorphic Study described below.

In addition to the WARP study described above, the present Watershed Restoration Plan is also heavily based upon the work done in this effort, and much of the more detailed stressor analysis and project identification in the restoration plan is a refinement of the information presented and projects proposed in the Local Watershed Plan.

EARTH TECH GEOMORPHIC STUDY

Previous studies indicated problems with high, scouring stormwater flows, lack of adequate instream habitat, severe bank and streambed erosion – all indicators of a stream network that is unstable and still responding to changes in its hydrology that have occurred since the Colonial era.

In 2007 the Towns of Carrboro and Chapel Hill worked with Earth Tech and other partners to do a watershed-wide study of geomorphic conditions of streams, to identify and rank the locations most contributing to poor conditions, and to propose projects to correct these problems. This information could point to problems with excess stormwater, erosion, sedimentation, and other instability of the stream channel.

The purpose of this study was to more systematically identify areas of geomorphic instability across the entire Bolin Creek Watershed and try to rank them by their severity. This study also proposed and ranked 32 projects to stabilize the stream, reduce effects from high, scouring flows, or otherwise improve physical conditions.

Professionals from Earth Tech and members of the Bolin Creek Watershed Assessment Team walked along all perennial and intermittent streams in the Bolin Creek watershed and many ephemeral streams. They identified areas of geomorphic instability (areas prone to erosion or sediment build-up due to changes in flow patterns), described and compared individual stream lengths, documenting with channel measurements and photos where needed. These data were used to compare and rank the different geomorphic problems observed in the watershed. Corrective projects were proposed and costs estimated so that these could be ranked as well.

Multiple indications of deteriorating stream condition and multiple types of problems were observed at many locations along the streams. The particular sources of instability observed included stream channelization (straightening/ditching), culverts and channel crossings, utility impacts (sewer lines along streams, other utilities crossing), bank erosion and collapse, direct discharges to the channel, railroad impacts, recreation impacts, and stormwater runoff.

Several of the projects described in the Earth Tech report were taken on in the two Towns' 319 Nonpoint Source Grant projects, augmented and expanded upon as the details of individual sites became better understood. The overall effect of these increasingly targeted and smaller-scale studies has been to emphasize the broad distribution of water quality stressors and sources in the watershed and the importance of understanding their unique characteristics when proposing solutions.

3.2 STRESSORS, FUNCTIONS, AND SOURCES

WATERSHED STRESSORS AND "URBAN STREAM SYNDROME"

Studies in our area have recognized the kind of ecological impairment that is common to other urban areas, and have found a wide variety of stressors and sources, making direct targeting of problems challenging. Stressors in urban areas include changes in streamflow, groundwater recharge, runoff and stormwater, stream channel form and characteristics, the aquatic and riparian ecological community and structure, and water and sediment chemistry. This combination of a predictable set of stressors, none individually necessarily resulting in a a demonstrable disturbance, but in the aggregate resulting in considerable ecological impairment is known as "urban stream syndrome".

Appendix 3 profiles the variety of stressors common in urban areas and their known and suspected effects on water quality. Teasing apart the causes of water quality changes can be essentially impossible in urban areas where you can't isolate stressors one at a time for testing effects. The degree to which these relationships are understood is thus noted in the table.

All of these stressors are present in urban environments to some degree. The degree to which individual stressors plays a role in Bolin Creek's water quality, and in the streams in the Chapel Hill and Carrboro area in general, is similarly difficult to determine because of their intertwined and interdependent nature.

It is the cumulative and collective effect of these stressors spread out across an urban area that creates what is called the "urban stream syndrome". It is an ecosystem-wide response to chronic and widespread chemical, physical, and biological changes due to both traditional and modern patterns of development and human behaviors. No one stressor or event is enough to create the kinds of changes seen. Rather, it is a proverbial "death by a thousand cuts" – innumerable seemingly inconsequential actions that over time have added up to a huge effect.

HOW STRESSORS AFFECT FUNCTIONS

Streams, and their ecosystem functions, can be impaired in a variety of ways. "Impairment" in this sense is broader than the state's use rating described above. Stream and watershed functions are usually broken down into hydrologic (the amount of water through the system), geomorphic (the shape of the land and stream channels), physico-chemical (water chemistry and conditions), and ecological (the organisms and their habitats). The interdependent nature of these functions means that changes to one will necessarily result in changes to the others.

This also means that watershed restoration efforts need to carefully examine the multiple aspects and causes of impairment to try to identify those changes to the watershed that are "controlling", or otherwise can inhibit rehabilitation or restoration if not addressed. For instance, a stream restoration project may be undertaken on a stream segment, improving the geomorphology, habitat, and riparian condition of the segment. If the stream channel was purposefully modified by people, but the hydrology of the system is not significantly changed from the undeveloped state, then the stream restoration is likely to be successful. But if the impaired geomorphology and habitat are a consequence of changes to the hydrology of the system, then that changed hydrology is likely to destabilize and possibly destroy the restored stream segment.

Figure 29 gives a generalized picture of the interrelatedness of watershed functions, and how stressors and their sources can affect multiple watershed functions.

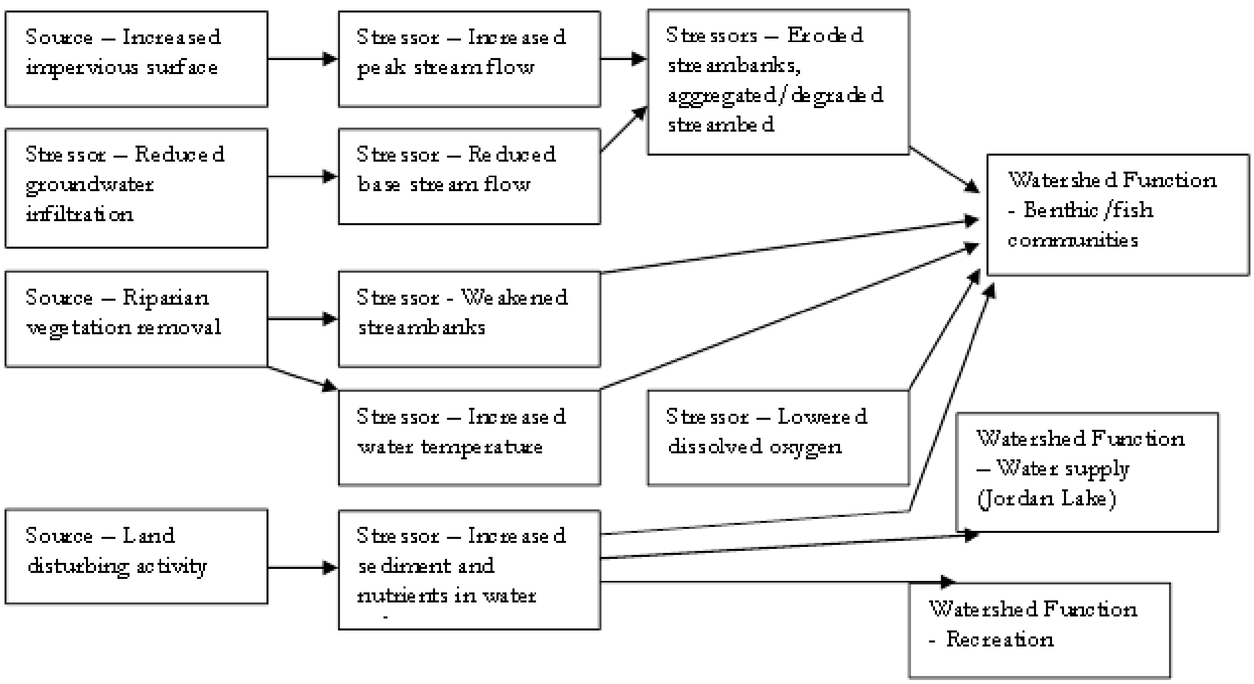


Figure 29: How Stressors and Sources Impact Watershed Functions

Hydrologic functions of streams can be impaired by large amounts of impervious surface with or without stormwater management; direct connection of stormwater systems to streams; soil compaction; and reduced infiltration (groundwater recharge). In turn, stream geomorphic functions are indirectly impaired by these changes in hydrology, leading to changes in channel shape and dimensions. Geomorphic functions are also directly impaired by deliberate modifications such as piping, culverts, straightening, and hardening of the banks. Riparian clearing can also indirectly impair geomorphic function through changes in bank and channel stability.

Chemical functions are directly impaired through pollutant sources, but indirectly through changes in hydrology, geomorphology, and ecology. These changes modify how easily chemicals stay dissolved in the water; what other compounds may be present to change the chemistry; biochemical action of organisms; and when and how much water is available. Ecological functions are indirectly impaired through all these kinds of changes, and directly through riparian forest clearing, deliberate removal of habitats (like large woody debris), competing or invasive organisms, and changes in available food sources.

INDICATORS AND ANALYSIS OF STRESS

While bioclassification based on the macroinvertebrate community is commonly-used to evaluate whether a stream or its functions are impaired, exactly how the system is being stressed and what the source is requires more detailed investigation. A variety of methods for evaluating stressors targeted to different stream functions were described and used in the preparation of EEP's Local Watershed Plan, and their summary is adapted directly here in Table 6. These methods were well suited to a broader-scale analysis of stressors and likely sources.

Local experience has shown that further, more detailed investigation at a much smaller scale may be needed to understand how or why a stream is not functioning well. These indicators of stress are described in the following section of the Plan.

Table 6: EEP Local Watershed Plan Indicators of Stress and Techniques for Assessment

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 Analysisof 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

3.3 SUBWATERSHED ASSESSMENT OF STRESSORS AND SOURCES

LANDUSE STRESSOR ANALYSIS

Urban development and other land uses are known to be a broad, but poorly-understood, stressor to freshwater ecosystems, but in the case of Bolin Creek they do appear to correlate well with measures of aquatic health. Land use and land cover are generally described in the Watershed Characterization chapter, with maps of 2006 land use classifications shown on Figure 9, and 2012 impervious surfaces shown on Figure 10.

To better understand the variation of land use intensity across the watershed, both the 2006 land use classification data and the 2012 impervious surface data have been broken up into subwatersheds. To create these subwatersheds for analysis, we have started with the subwatersheds developed in the EEP Local Watershed Plan. However, we found some of these subwatersheds to be larger than desired, combining disparate areas, and not allowing sufficient detailed examination. Thus we split 4 of the 5 Local Watershed Plan subwatersheds each into two, for a total of 9 Bolin Creek Subwatersheds. Figure 2 in the previous chapter shows the new delineated subwatershed boundaries.

Land use classification by subwatershed is shown in Table 7. Developed land uses in particular are implicated in the decline of aquatic communities, so the percent of all developed land uses includes "Developed, Open Space" because it encompasses heavily-managed open areas such as parks and athletic fields. These usescombined by subwatershed are shown in Figure 30. Subwatershed abbreviations are as follows:

- BL1 A & B – Hogan Farm Subwatersheds A & B
- BL2 A & B - Upper Bolin Creek Subwatersheds A & B
- BL3 A & B – Horace Williams Subwatersheds A & B
- BL4 A & B – Middle Bolin Creek Subwatersheds A & B
- BL5 - Lower Bolin Creek Subwatershed

Table 7: 2006 Land Use Classifications - Percent in Total Watershed and in Each Subwatershed

Land Use	All Bolin (%)	BL1A %	BL1B %	BL2A %	BL2B %	BL3A %	BL3B %	BL4A %	BL4B %	BL5 %
Open Water	0.44	2.89	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.49
Developed, Open Space	29.88	15.53	7.74	12.81	21.77	17.66	33.49	48.25	44.82	50.45
Developed, Low Intensity	12.07	7.64	2.32	2.33	8.13	12.20	12.05	27.71	14.83	11.80
Developed, Medium Intensity	3.86	0.63	0.23	0.00	0.54	3.40	0.76	9.43	6.04	8.89
Developed, High Intensity	0.95	0.11	0.00	0.00	0.00	0.93	0.00	3.16	1.68	1.19
Deciduous Forest	28.15	41.67	52.20	37.28	30.79	28.28	24.73	4.03	22.54	23.62
Evergreen Forest	15.29	14.94	19.45	32.62	27.15	24.15	25.29	5.36	5.09	0.58
Mixed Forest	2.59	2.80	3.83	3.52	2.82	3.25	1.83	0.90	2.58	2.69
Shrub/Scrub	0.45	0.72	2.72	0.42	0.57	0.00	0.00	0.00	0.00	0.00
Grassland/Herbaceous	1.97	3.82	4.09	4.97	1.65	1.99	1.86	0.47	0.45	0.17
Pasture/Hay	3.95	9.25	6.41	3.48	6.39	7.72	0.00	0.70	1.98	0.00
Woody Wetlands	0.40	0.00	1.01	2.56	0.19	0.43	0.00	0.00	0.00	0.12

Impervious surfaces have been divided into rooftops, driving surfaces for cars, and other surfaces (such as sidewalks) because studies have shown them to have different contaminant runoff characteristics. Results of the analysis are shown in Table 8. A substantial empirical basis exists for relating increased impervious surfaces and land use intensity to declines in aquatic communities. The percent totals of all impervious surfaces in each subwatershed are shown in Figure 31. Rooftop runoff will reflect materials that are deposited from the atmosphere, as well as roofing materials dissolved partially by rainwater. Driving surfaces show much more dust and materials related to operation of automobiles, including heavy metal particles from brake pads and other wear-and-tear, oil and gasoline, and combustion products. This is in addition to dust from the pavement itself, from gravel and sand applied for traction, and deicers applied to melt ice and snow. Other surfaces reflect materials used in landscaping, such as pesticides and fertilizers. Driving surfaces tend to generate much more polluted runoff, and stormwater management retrofits should be targeted to areas with much higher total amounts, or disproportionately higher amounts of driving surfaces.

Table 8: Percent Impervious Surface by Type and Subwatershed										
Impervious surface type	**whole watershed %**	**BL1A %**	**BL1B %**	**BL2A %**	**BL2B %**	**BL3A %**	**BL3B %**	**BL4A %**	**BL4B %**	**BL5 %**
Driving surfaces	10.13	4.78	3.37	3.75	7.51	6.70	8.50	22.82	14.93	13.40
Rooftops	5.27	2.56	1.05	1.89	2.90	4.18	5.28	12.60	7.83	6.34
Other impervious	0.96	0.14	0.06	0.07	0.28	0.69	0.32	2.16	1.73	2.06
Total impervious	**16.36**	**7.48**	**4.48**	**5.71**	**10.69**	**11.57**	**14.09**	**37.58**	**24.49**	**21.80**

RIPARIAN BUFFER DEFORESTATION ANALYSIS

In order to examine the degree to which stream buffers are impacted by development and deforestation, a series of buffers were created in GIS for intermittent and perennial streams: 5 foot buffers to approximate vegetation directly on the banks, 30 foot buffers to represent Zone 1 Jordan buffers, 50 foot buffers to represent both zones of Jordan buffers, and 100 foot buffers to represent the recommended buffer width for protecting stream biological community health[1]. The 100 foot buffer is a width based on research showing that greater buffer widths may be needed for protective functions that filter out sediment, pesticides and herbicides, nutrients, and other toxins, and may be strongly implicated in a higher quality biological community. A layer representing the 100-year regulatory floodplain was also used.

To approximate the minimum area that has been cleared of forest, a GIS layer of "cleared zones" was created. 15 foot buffers were placed on OWASA sanitary sewer lines (OWASA easements are 30 feet wide), power and natural gas easements were digitized from aerial photos, and a 5 foot buffer was placed around all impervious surfaces to approximate the minimum area that would be cleared for these structures and surfaces.

The buffer layers were overlaid with the "cleared zones" layer to approximate the minimum area in different buffer widths that could be covered by forest. This is a minimum because we do not have information on other areas that are cleared of forest as there would be with a utility easement. In particular, cleared area within the 5 foot buffer means that the listed percentage of area can never be converted back to forest, which approximates the amount of bank area that is at greater risk of erosion. Where this area is cleared it can be inferred that the streambank lacks the stabilization and channel shading that trees and shrubs provide. Because continuity of buffers is important for their functioning, the amount of cleared area in each buffer zone also represents the minimum amount of discontinuous buffer area. These minimum "unforestable" areas are important for determining the maximum amount of improvement that can be expected for riparian zones and their streams in a subwatershed.

[1] Note that Carrboro's buffers for perennial streams are 50' for Zone 1 and an additional 50' for Zone 2

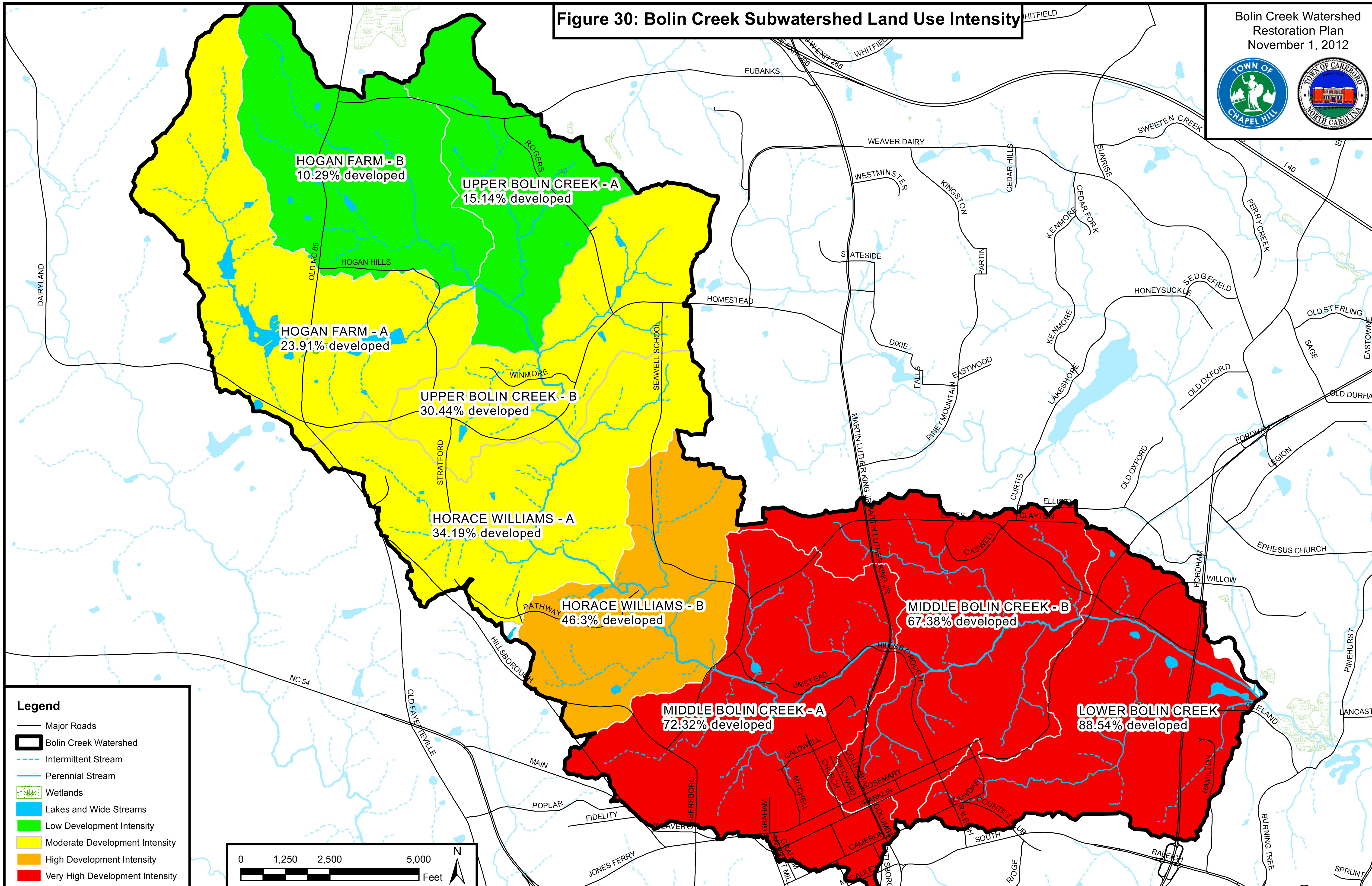


Figure 30: Bolin Creek Subwatershed Land Use Intensity

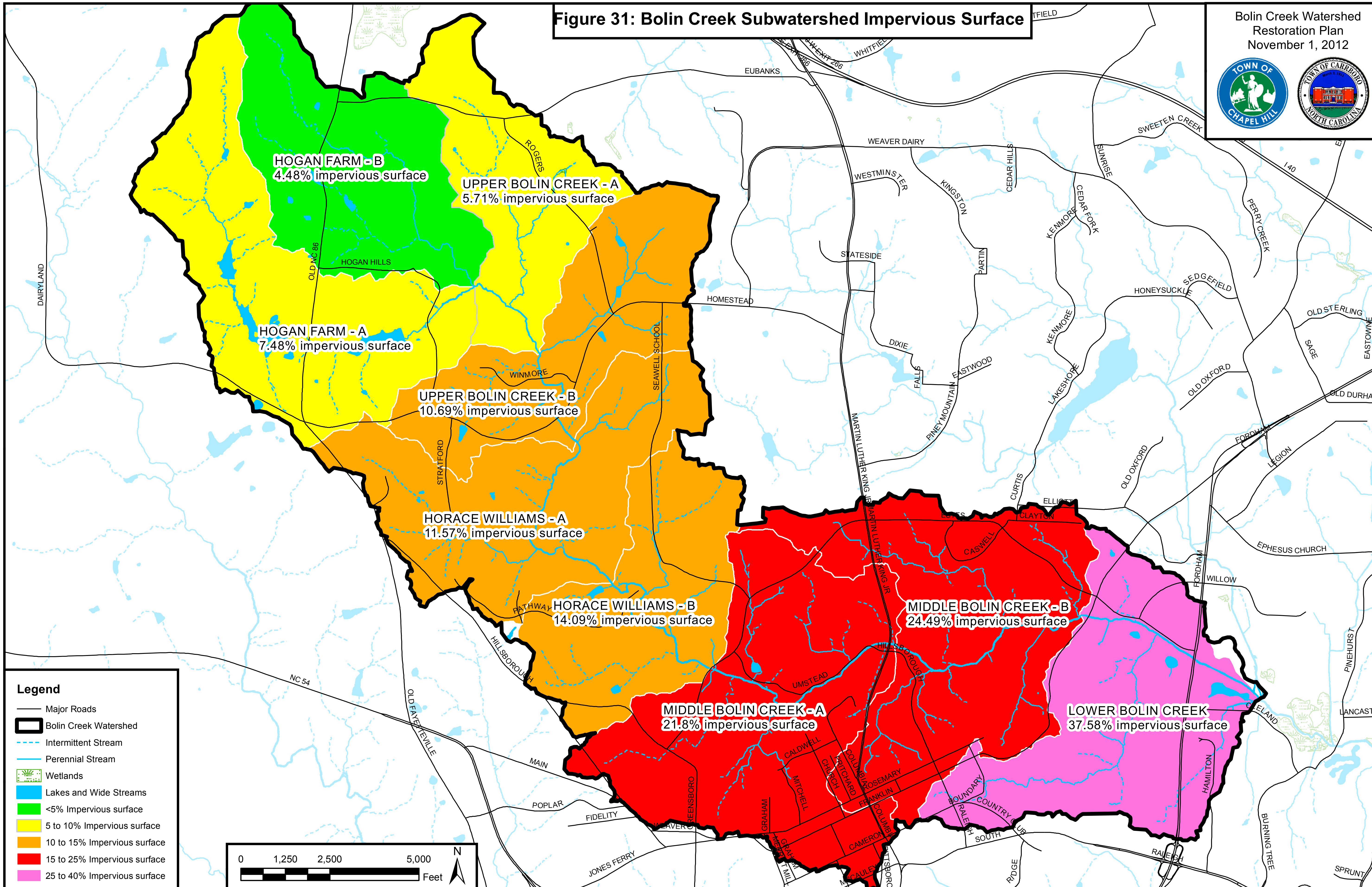


Figure 31: Bolin Creek Subwatershed Impervious Surface

Table 9 presents the minimum amount of deforestation in each subwatershed, andbroken out by the buffer widths. The amount of impact in the subwatershed, as well in the various buffer widths mimics the increase in land use intensity shown in earlier stressor analyses. The one stand out is the much larger amount of regulatory floodplain impact in the most downstream subwatershed, BL5. This subwatershed is all within the Triassic Basin and has very large areas of regulatory floodplain due to the low relief.

Table 9: Minimum Deforested Area in Whole Subwatershed and in Different Buffer Zones

	Minimum Deforested - % of Area					
Subwatershed ID	**Whole subwatershed**	**Within 5ft stream buffer**	**Within 30ft stream buffer**	**Within 50ft stream buffer**	**Within 100ft stream buffer**	**Within regulatory floodplain**
BL1A	13.75	2.43	4.04	5.55	7.45	9.03
BL1B	10.21	4.76	7.01	7.32	8.88	5.98
BL2A	14.72	3.79	6.23	8.60	10.71	2.21
BL2B	18.81	6.15	11.34	13.37	13.24	3.01
BL3A	19.59	4.53	10.81	12.88	12.64	4.46
BL3B	23.74	9.31	18.03	19.51	19.89	3.70
BL4A	44.61	9.03	21.32	26.23	29.23	2.49
BL4B	36.85	9.35	14.88	17.48	21.77	6.38
BL5	40.05	9.10	19.44	24.23	27.77	20.09

TARGETED STRESSOR ANALYSIS

While this plan is not attempting to evaluate risk more completely than was done for the EEP Local Watershed Plan, we now have the information and further study to present a more detailed and smaller-scale understanding of identifiable stressors, sources, and causes. The Local Watershed Plan analysis indicated that there is a comparatively low risk of worsening conditions unless development continued with insufficient stormwater management, and no attempts were made to reduce toxic discharges. However, without addressing existing stressors, conditions should not be expected to get any better.

Even without direct observation of an impairment of watershed function, we are able to identify areas that are under higher stress just by the amount and kind of stressors that are in the vicinity. Given the difficulty of catching intermittent chemical stressors “in the act”, this is a sound way to address toxic stressors. In general, it can be assumed that a greater density of stressors in a subwatershed or portion of a subwatershed at the very least indicates an area that should receive greater investigation of stream condition and more frequent monitoring of potential pollutant sources.

For purposes of visual presentation, we have divided stressors into more direct, potential pollutant sources and stressors (Figures 32 through 40) and indirect, riparian and stream channel stressors (Figures 41 through 49).

Since the creation of the EEP Local Watershed Plan, the Towns have acquired much more detailed and specific information about the locations and types of stressors in the Bolin Creek Watershed. Part of the project that led to the creation of this watershed restoration plan also included a database of clearly identified problem areas (identifiably impaired areas) and potential restoration or rehabilitation projects. This database of problems and projects, and how they are prioritized and follow up on, will be described in more detail in the Management and Restoration Measures chapter.

POTENTIAL POLLUTANT SOURCES

Potential pollutant sources include a variety of commercial sources such as dry cleaners, restaurants and food establishments, pet care, automotive service, salons, commercial dumpsters, and facilities with a Resource Conservation and Recovery Act permit. Staff experience has shown that these are likely to be potential illicit discharge sources, and a higher density of these sources may be reasonably expected to have greater impact than isolated sources. With sufficient outreach and education these establishments have an excellent likelihood of reducing their impacts. And because people tend to look to each other for an indication of reasonable and proper behavior, where there is a concentration of these establishments attention and education can have a broad impact.

Stormwater outfalls have also been identified as potential pollutant sources merely because they are the point at which concentrated runoff from impervious surfaces across the watershed are discharged to the stream. In the absence of overland flow and filtration, or treatment within a stormwater management structure, pollutants can travel easily to these points, and this is where their chemical effects will be most strongly felt by the biological community.

The North Carolina Department of Environment and Natural Resources (DENR) has tracked underground storage tanks, including incidents of leakage as well as which ones are no longer in service, have been removed, or have had soil or groundwater remediation. DENR has also tracked historic dry cleaning facilities known to have groundwater contamination. The Towns keep track of official and unofficial trash dumps and landfills, which can also lead to groundwater contamination. While neither Town may have the resources to remediate these groundwater impacts, it is helpful to know where they are when trying to understand poor stream conditions or functions at a given location. This information is also useful when prioritizing problems and projects.

Points where Orange Water and Sewer Authority's (OWASA) sanitary sewers cross streams are potential weak points where overflows, line leaks, or line breaks are likely to occur and have the greatest impact on a stream. Aerial crossings are at the highest risk, but these cannot be positively identified from the available data. Private lateral sewer line crossings of streams also cannot be identified from the available data. Being smaller (or generally unmapped entirely) they are easier to miss, but being private they are less likely to have regular maintenance.

Lastly, properties with septic systems are potential locations for failures in sewage treatment and thus potential pollution sources. The database of septic systems itself is incomplete or infrequently updated, making positive identification difficult. Current regulatory requirements may not place sufficient emphasis on proper care, maintenance, and eventual replacement of these systems. Property owners of more limited means may wind up missing maintenance needed for proper septic system functioning. Even with properly maintained sites, nutrient reduction is not an objective of proper septic system functioning, so greater densities of septic systems present areas of greater nutrient discharge than areas served by sanitary sewer.

RIPARIAN AND STREAM CHANNEL STRESSORS

Riparian and stream channel stressors overlap to some degree with potential pollutant sources. Stormwater outfalls, in addition to being direct conduits for polluted stormwater, are also conduits for concentrated flow, regardless of any contamination. These points of concentrated flow exert considerable stress on the receiving stream channel and can lead to channel instability that propagates both upstream and downstream. A more detailed analysis of stormwater networks would delineate individual networks and their watersheds to identify those that have higher proportions of impervious surface and, as part of that, where more of the impervious surfaces are driving surfaces for cars. These surfaces have been shown to accumulate a much greater amount of contaminants than rooftops or surfaces only for non-motorized vehicles and pedestrians.

OWASA sanitary sewer crossings also pose a stress to riparian zones and stream channels. These are points where only shallow-rooting grasses are allowed to grow on the banks, and thus these areas do not have the same resistance to shear stresses that other parts of the streambank may have. These are also points where maintenance vehicles cross the stream, putting further erosive stress and soil compaction stress on the streambank, and potential erosion and destabilization of the streambed. In some locations, OWASA has attempted to mitigate these erosive stresses by stabilizing with riprap. As it is commonly installed, the riprap ford acts as a short dam, an instream structure that instigates channel instability upstream and downstream. Proper ford construction is essential to maintaining the natural, stable, and self-reinforcing structure of the stream channel, and clear guidelines for how to do this are difficult to find. It can be expected that where this is a higher density of crossings, there are more opportunities for instability and changes to channel geomorphology and function.

Deliberate channel modifications are a clear stressor on geomorphic and ecological function. Such modifications include simple straightening, also known as ditching or channelizing; lining with loose artificial material such as riprap, which may or may not also include some straightening; or full hardening using concrete or mortared or stabilized stone or brick, which almost invariably also includes straightening. These channels have simplified, if not completely absent, aquatic habitats and are generally devoid of much life. Where only straightening has occurred, some small reestablishment of instream habitats may occur over time. But the process of redevelopment of natural meanders requires considerable streambank erosion, which produces large quantities of inhospitable fine sediments. Thus, where the banks can resist erosive shear stresses less fine sediment will cover the small habitat areas that may form, but resistant banks also mean they can tolerate larger shear stresses that can scour away instream habitats. In general, straightened and modified reaches are difficult places for organisms to live in.

Dams and historic mill sites are other kinds of deliberate channel modifications. For the most part, the only existing dams are in the highest portions of the watershed. They do still exert an effect on the channels upstream and downstream of the dam location, and some of these have been positively identified as areas of impairment and poor function. But abandoned, nearly obliterated historic mill sites, and small abandoned farm pond sites, are also scattered across the area. These locations exert a geomorphic effect long after they are gone. Built during colonial times, they would have trapped the large amounts of sediment eroded from uplands as they were cleared for agriculture en masse. After the dams are gone, the sediment remains as an unstable terrace that the stream will cut down into. It goes without saying that when the stream cuts into these sediments, huge amounts of sediment are released back into the stream system with all the negative effects that large amounts of fine sediment have on geomorphology, chemistry, and ecology. Even at the site of erosion, the stream becomes cut off from natural floodplain processes. It is important to be aware of the locations of these dams, since restoration strategies for “legacy sediments” are very different from restoration strategies trying to mitigate against increases in stormwater volume and velocity.

Stream culverts are a much smaller deliberate channel modification, except where this means extensive piping of the stream itself. Only one area of extensive stream piping is positively known based on maps from the time of the establishment of the University in the late 1700s – the historic upper reaches of Tanyard Branch in downtown Chapel Hill. But smaller culverts for streets, driveways, and other crossings are abundant and scattered throughout the watershed. As with fords, these structures can theoretically be designed to maintain natural, stable, and self-reinforcing geomorphic structure that allows natural processes such as organism migration and transport of bed sediments and large woody debris. But these designs are generally not used, being considered “over-engineered” because they pass much more water than is considered necessary for sufficient function of the road or stream crossing. Similarly to raised stream fords, and similar blockages, they create backwater zones upstream and scour zones downstream, both of which can propagate in their respective directions due to the changes in hydraulics these new channel shapes exert. In turn, these channel changes result in different water conditions (especially dissolved oxygen, temperature, depth, and velocity), and changes in ecological conditions. This doesn’t include the simple blockage to movement that culverts present for many organisms, particularly if they attempt to go upstream. The cumulative effect of many culverts is to concentrate mobile organisms downstream, preventing them from establishing populations in potentially lower-scour, protected areas higher up in the watershed where they can act as colonization sources for scoured downstream segments.

Lastly, as part of an analysis of forest clearing in the watershed referenced above, as well as forest clearing in different stream buffer zones, these maps present the minimum areas cleared for utility easements or impervious surfaces within 50 feet of an intermittent or perennial stream. This includes only areas that will always remain cleared because of the presence of the utility easement or impervious surface. It excludes areas that could have forest but are currently cleared, since these areas cannot currently be detected with available information. As such, this represents the minimum impact of riparian forest clearing, not the actual impact. Studies have shown that uninterrupted riparian canopy is essential for stream protection. The more interruptions there are in the canopy, the lower the quality of riparian forest that does still remain. Furthermore, these open areas serve as conduits for invasive plant species that can take down even more of the forest, reducing available riparian forest cover.

Figure 32: Potential Pollution Sources in Hogan Farm A Subwatershed (BL1A)

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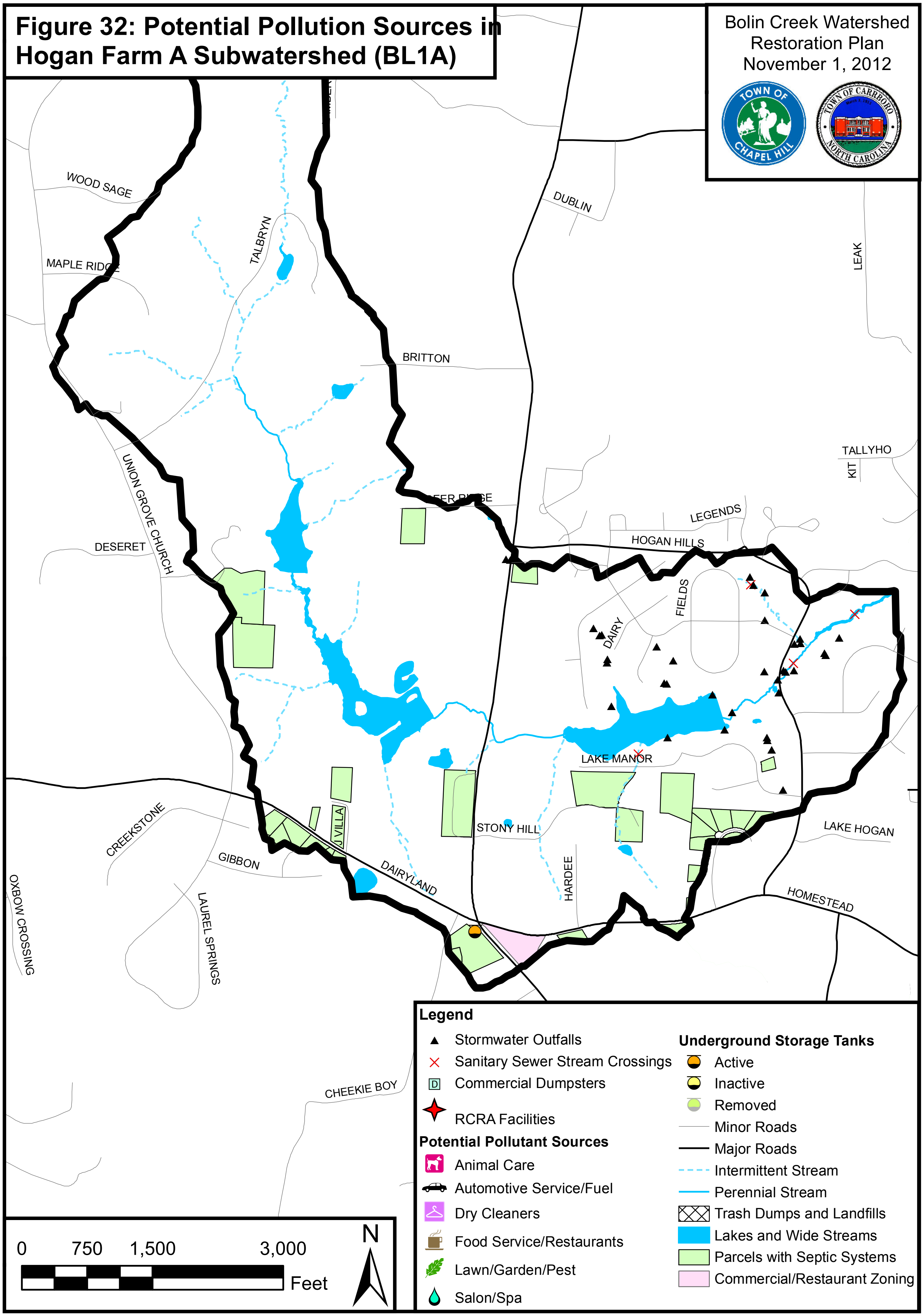

Figure 33: Potential Pollution Sources in Hogan Farm B Subwatershed (BL1B)

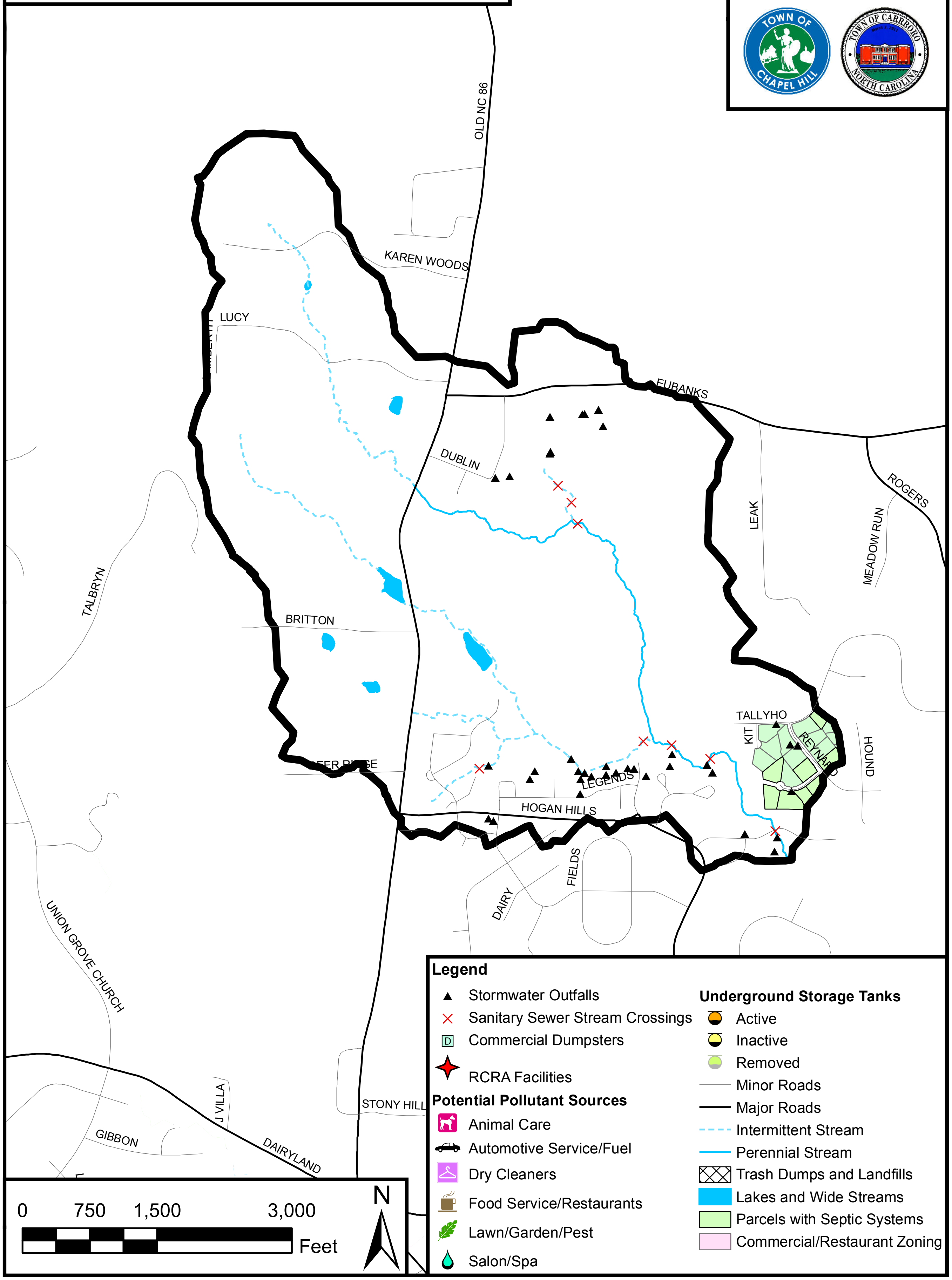

Figure 34: Potential Pollution Sources in Upper Bolin Creek A Subwatershed (BL2A)

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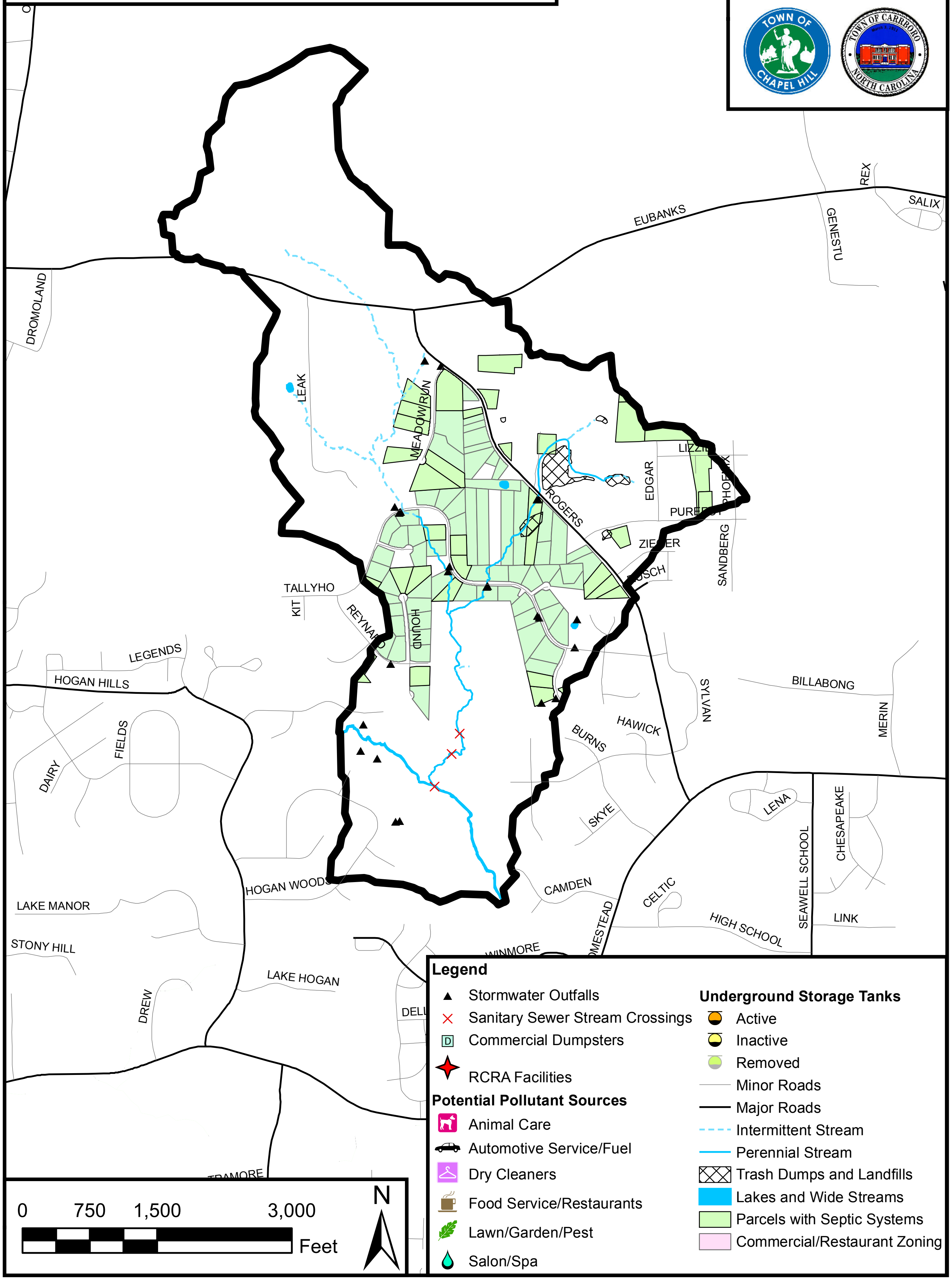

Figure 35: Potential Pollution Sources in Upper Bolin Creek B Subwatershed (BL2B)

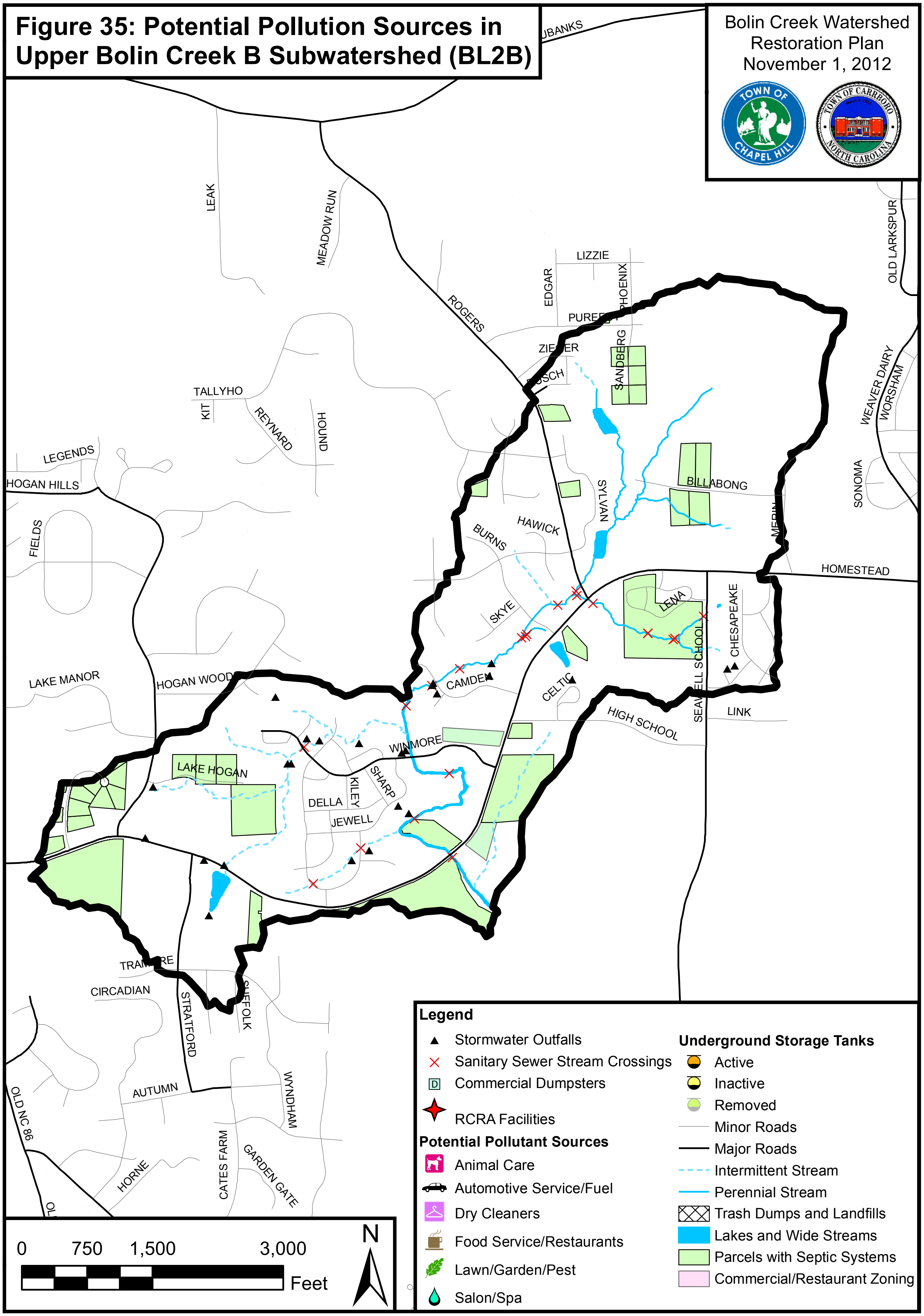

Figure 36: Potential Pollution Sources in Horace Williams A Subwatershed (BL3A)

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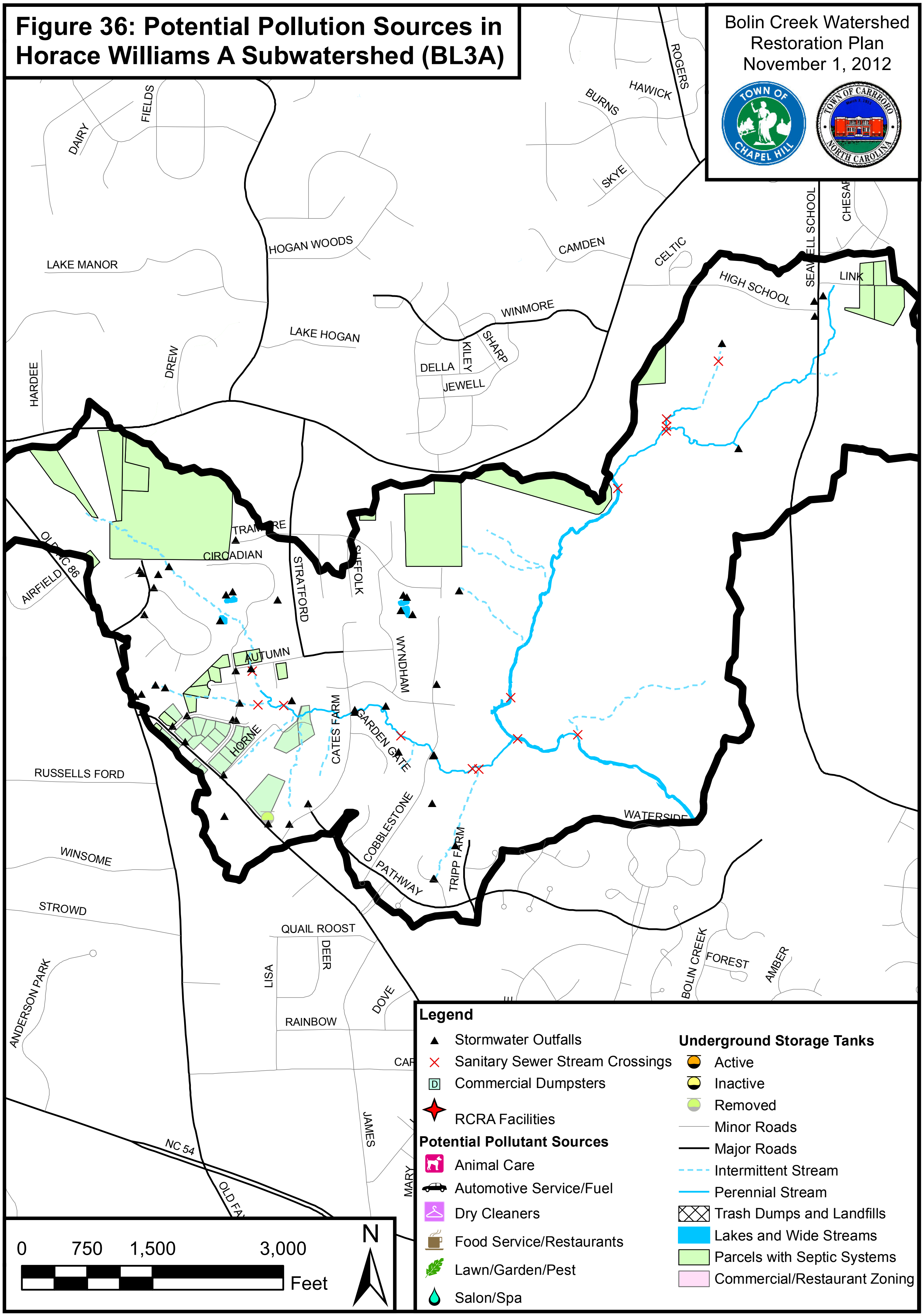

Figure 37: Potential Pollution Sources in Horace Williams B Subwatershed (BL3B)

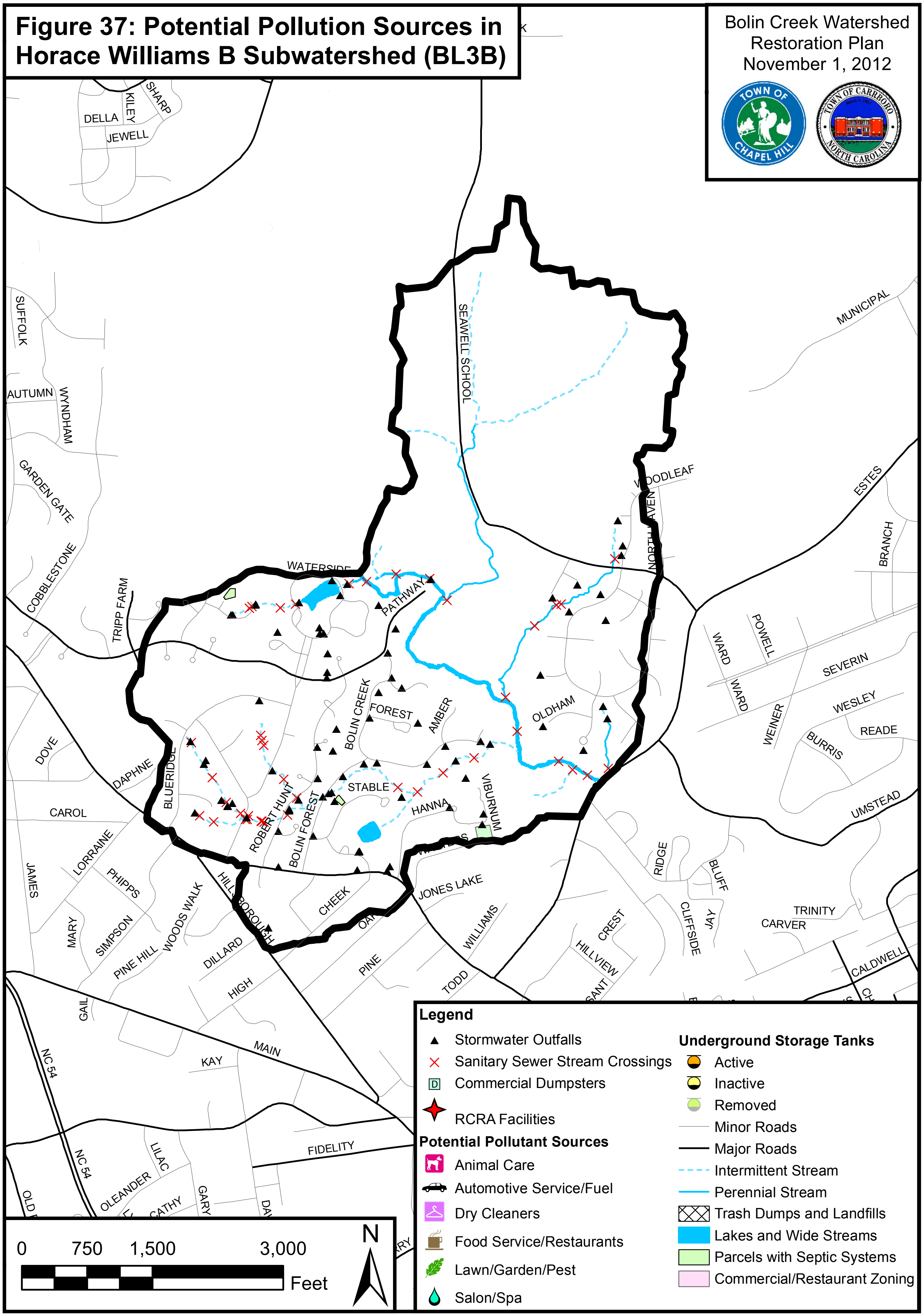

Figure 38: Potential Pollution Sources in Middle Bolin Creek A Subwatershed (BL4A)

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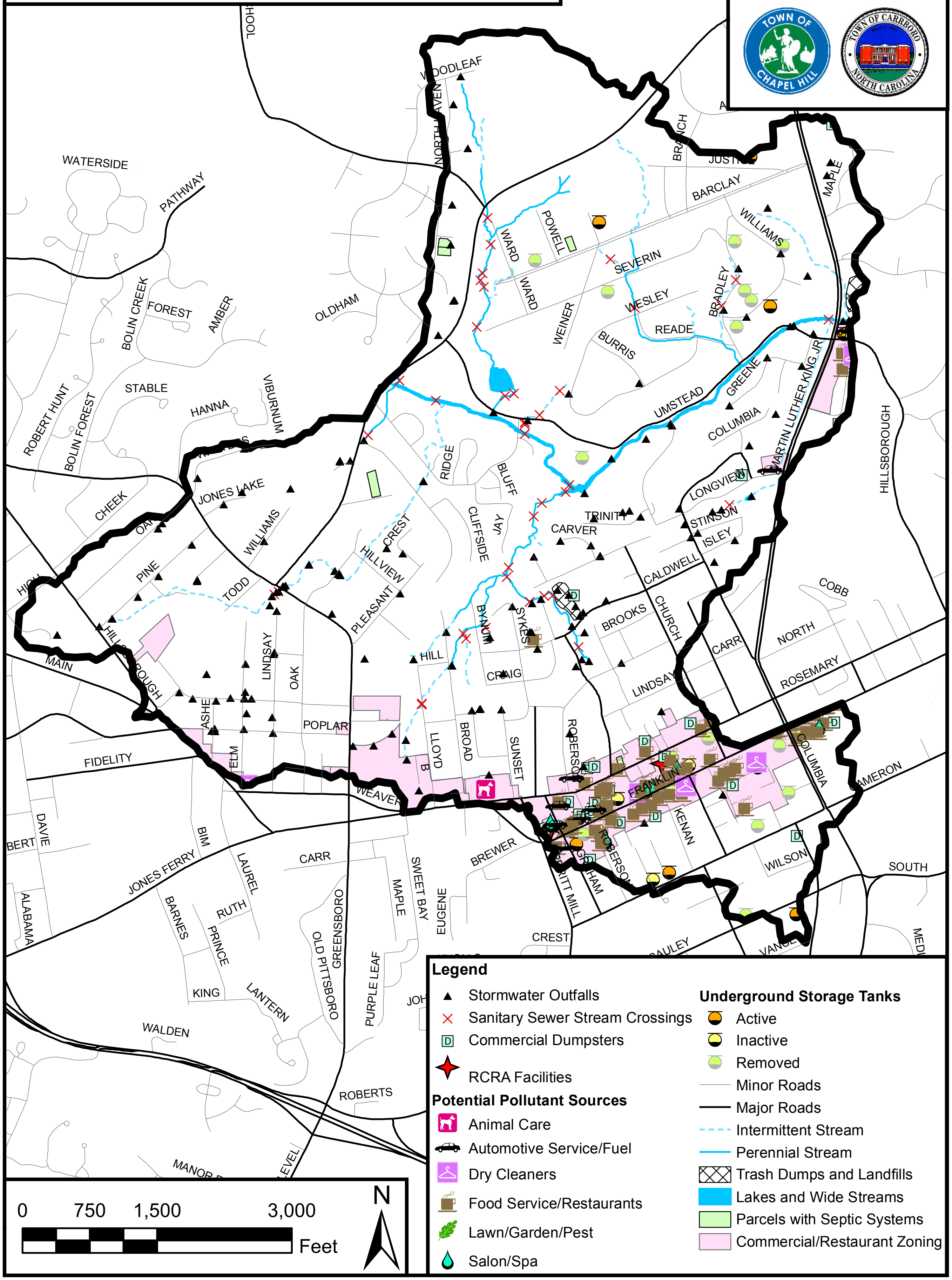

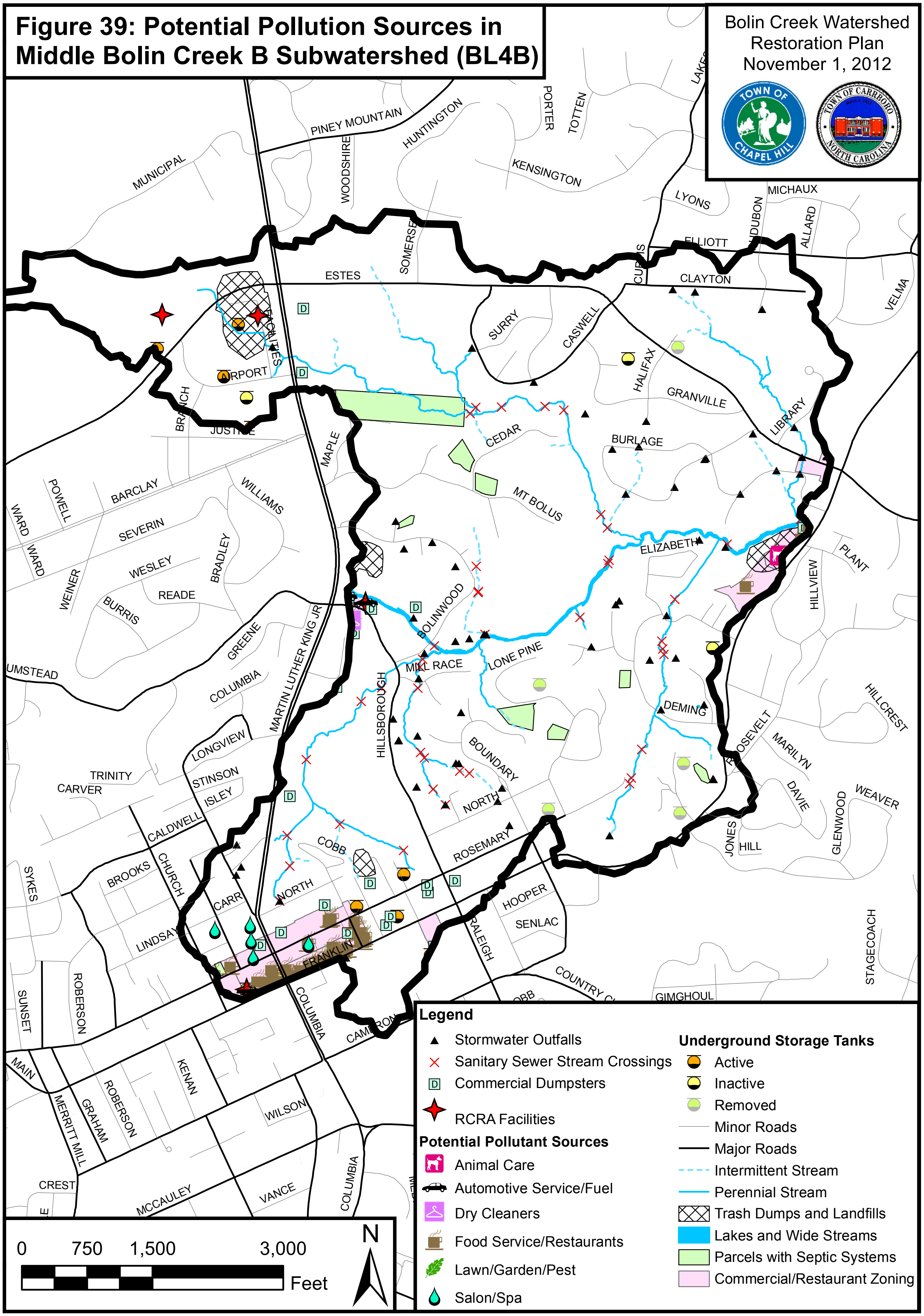

Figure 39: Potential Pollution Sources in Middle Bolin Creek B Subwatershed (BL4B)

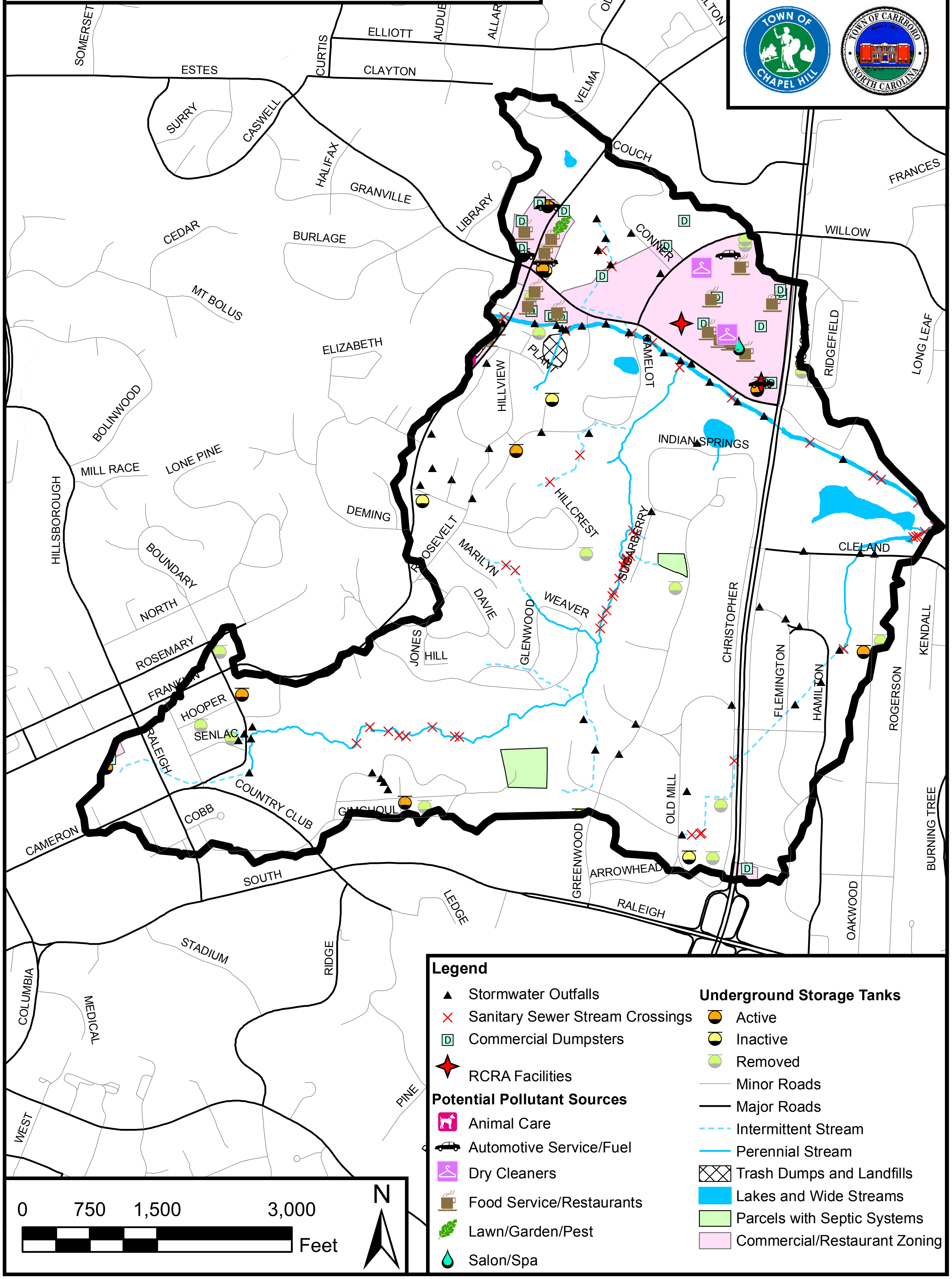

Figure 40: Potential Pollution Sources in Lower Bolin Creek Subwatershed (BL5)

Figure 41: Riparian and Stream Channel Stressors in Hogan Farm A Subwatershed (BL1A)

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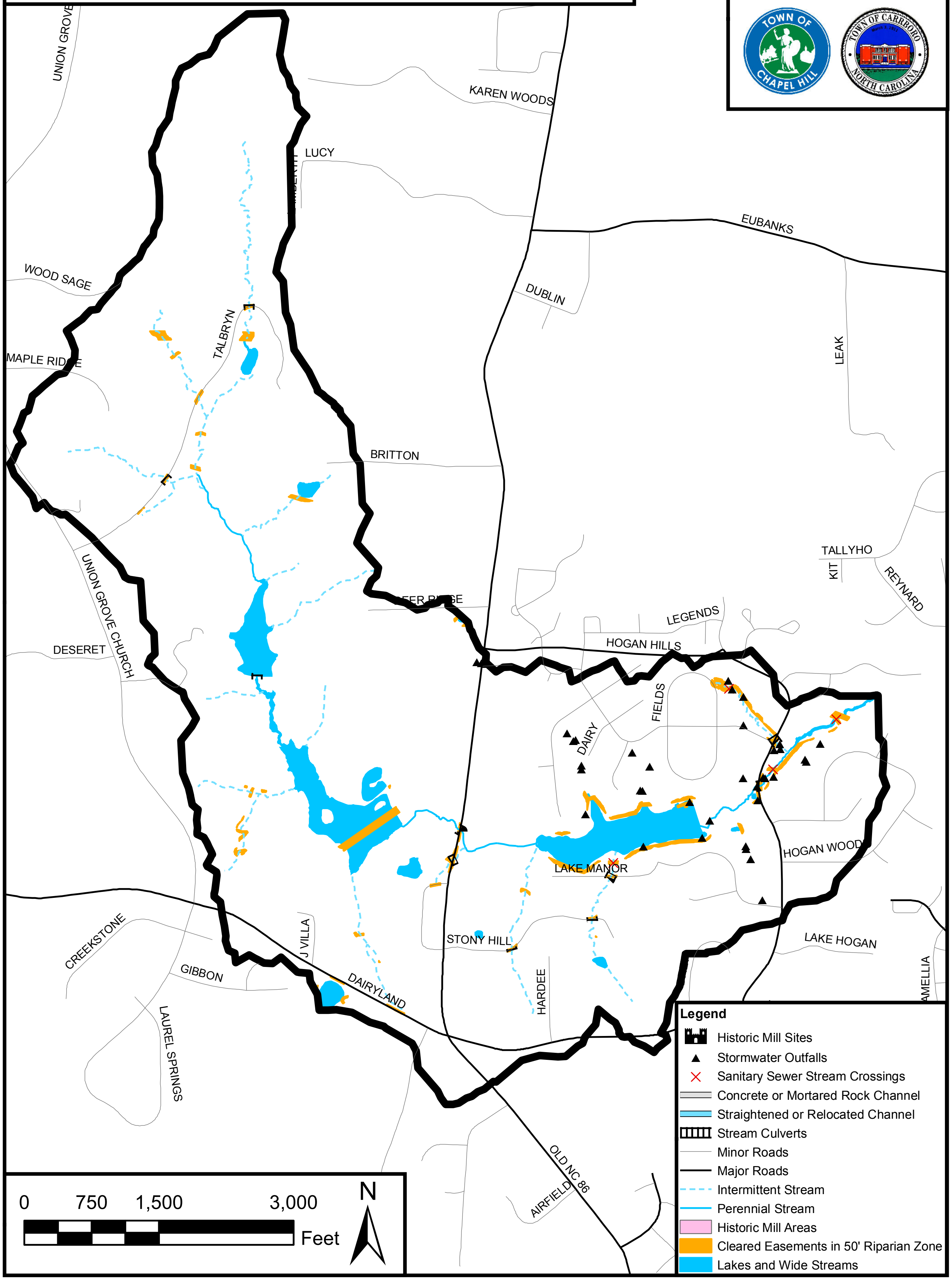

Figure 42: Riparian and Stream Channel Stressors in Hogan Farm B Subwatershed (BL1B)

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November 1, 2012

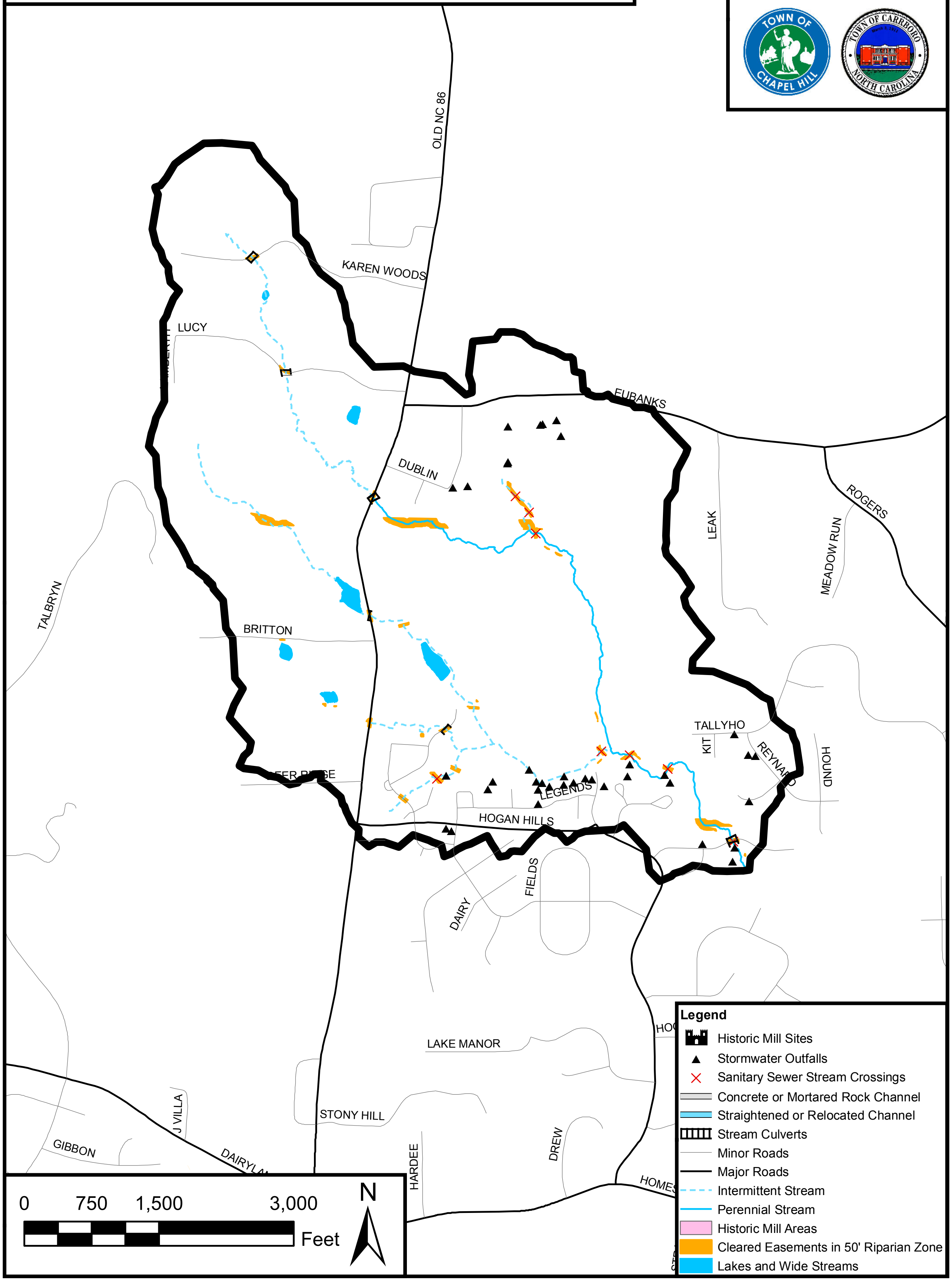

Figure 43: Riparian and Stream Channel Stressors in Upper Bolin Creek A Subwatershed (BL2A)

Bolin Creek Watershed Restoration Plan
November 1, 2012

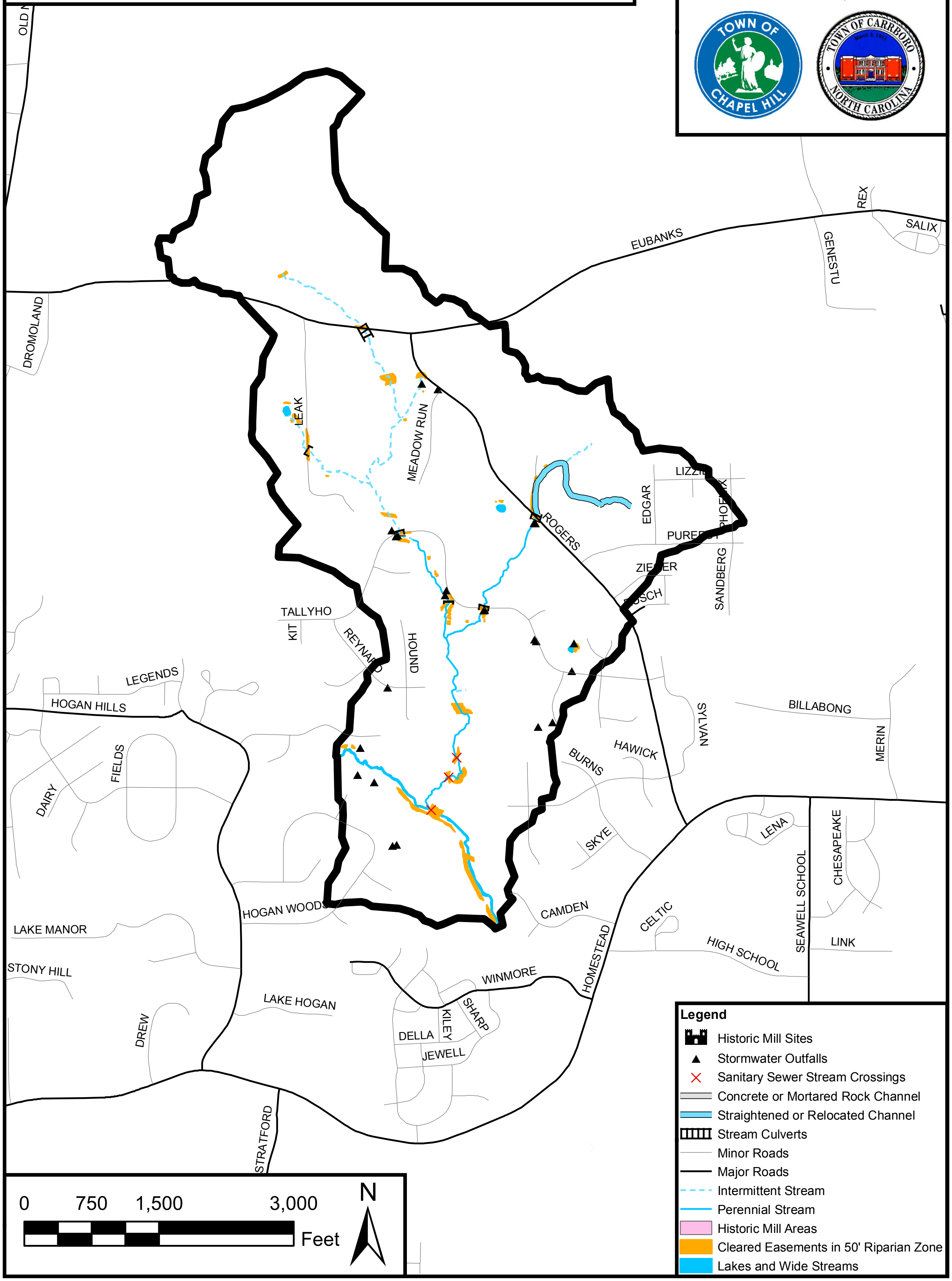

Figure 44: Riparian and Stream Channel Stressors in Upper Bolin Creek B Subwatershed (BL2B)

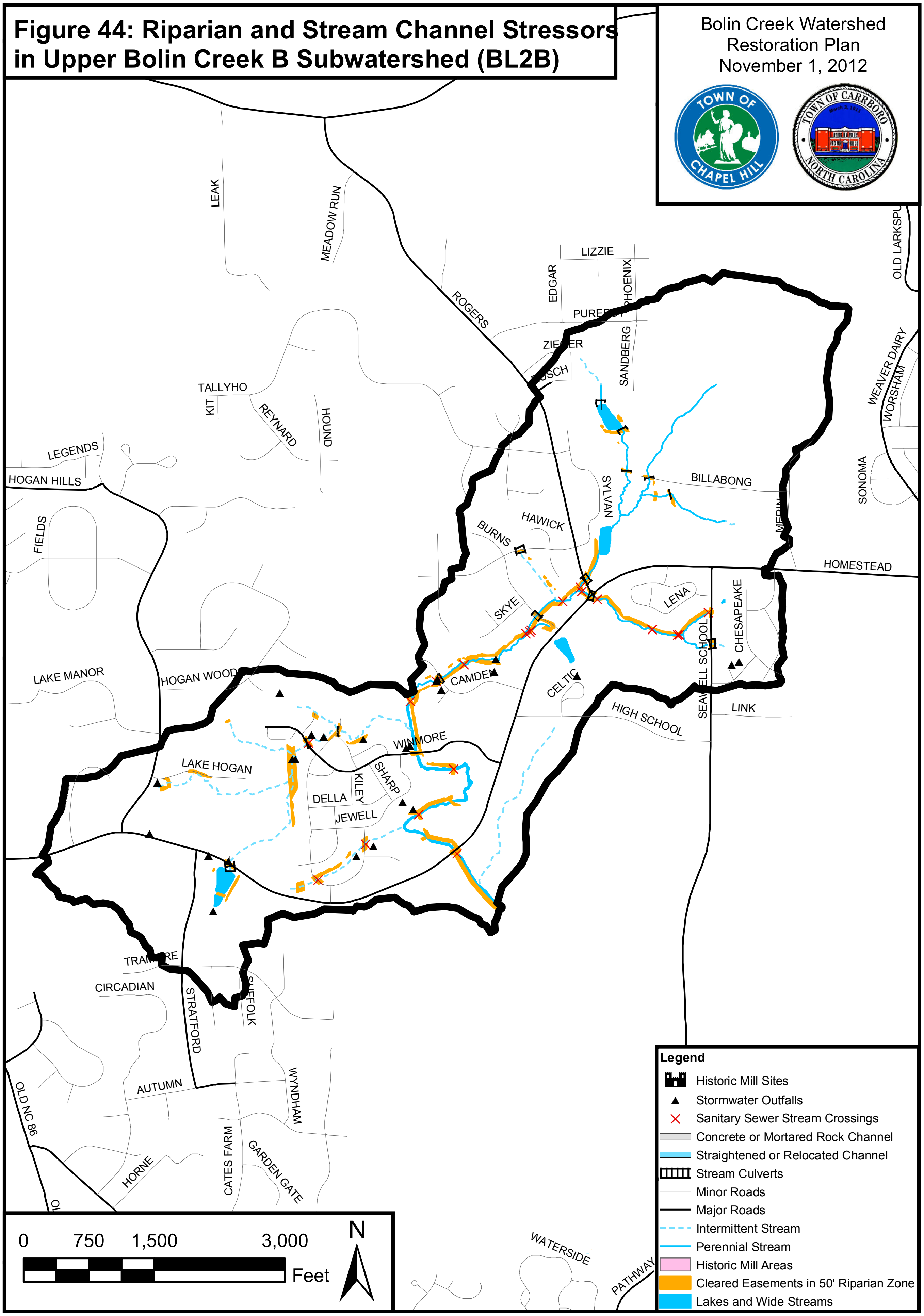

Figure 45: Riparian and Stream Channel Stressors in Horace Williams A Subwatershed (BL3A)

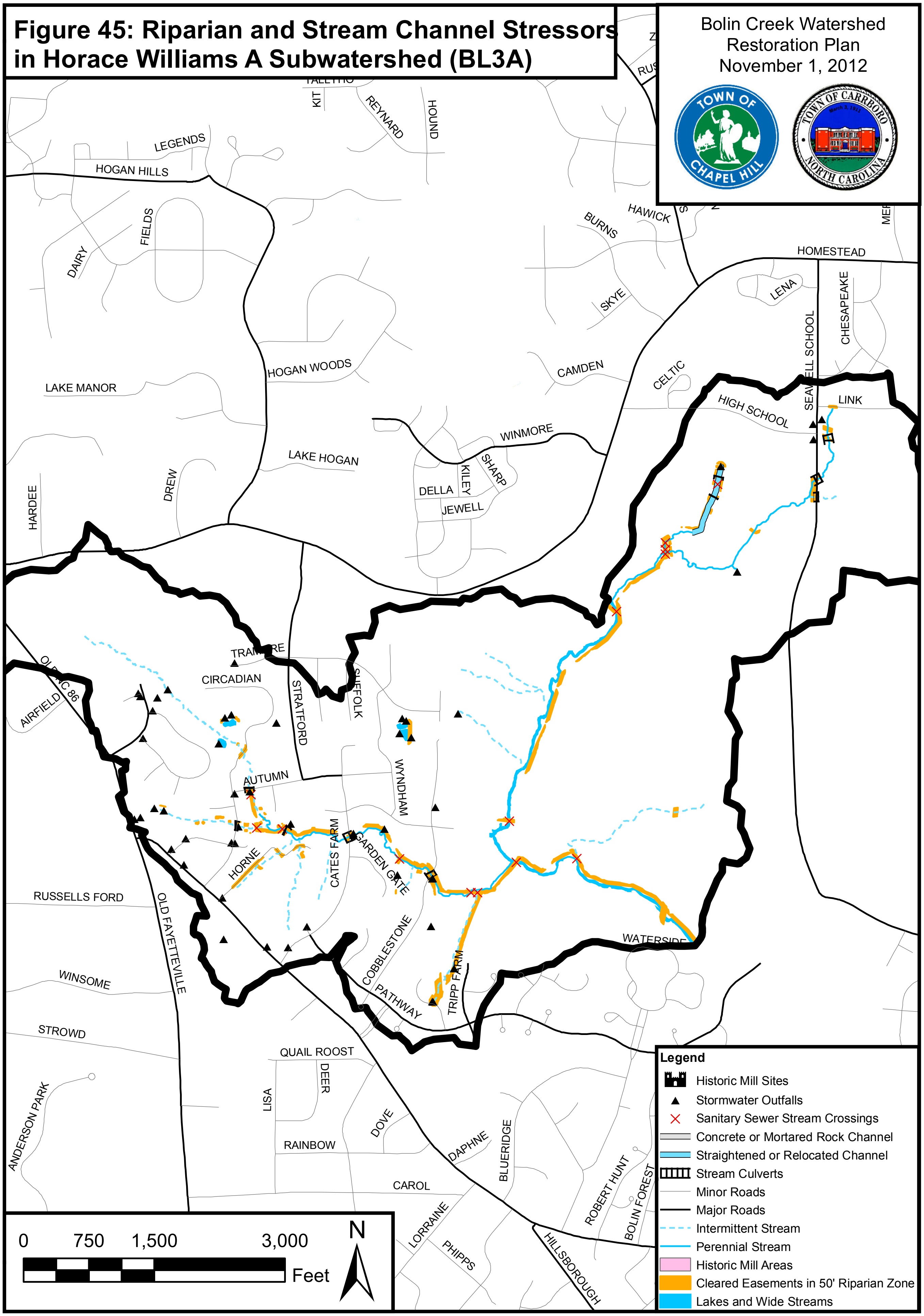

Figure 46: Riparian and Stream Channel Stressors in Horace Williams B Subwatershed (BL3B)

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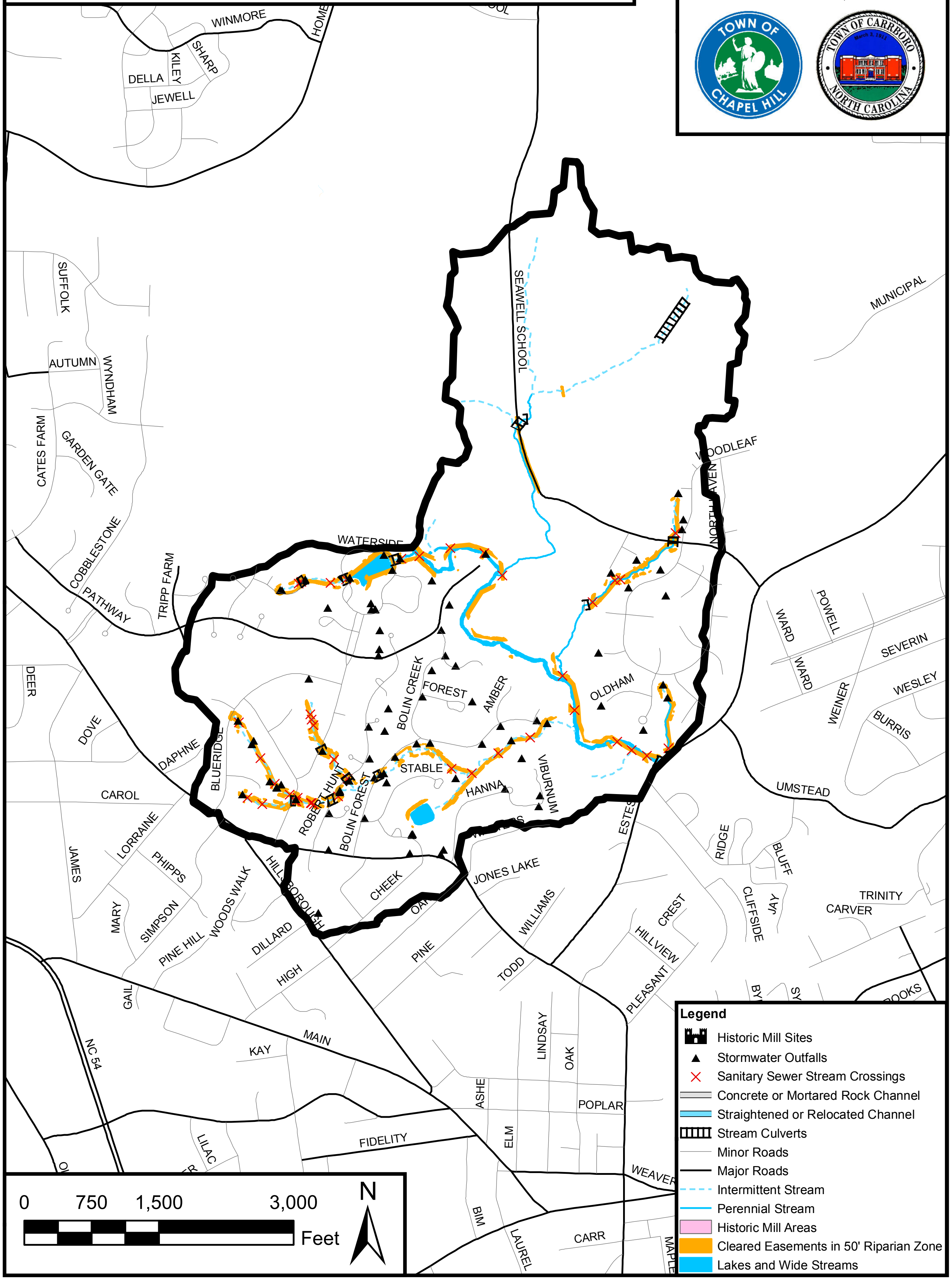

Figure 47: Riparian and Stream Channel Stressors in Middle Bolin Creek A Subwatershed (BL4A)

Bolin Creek Watershed
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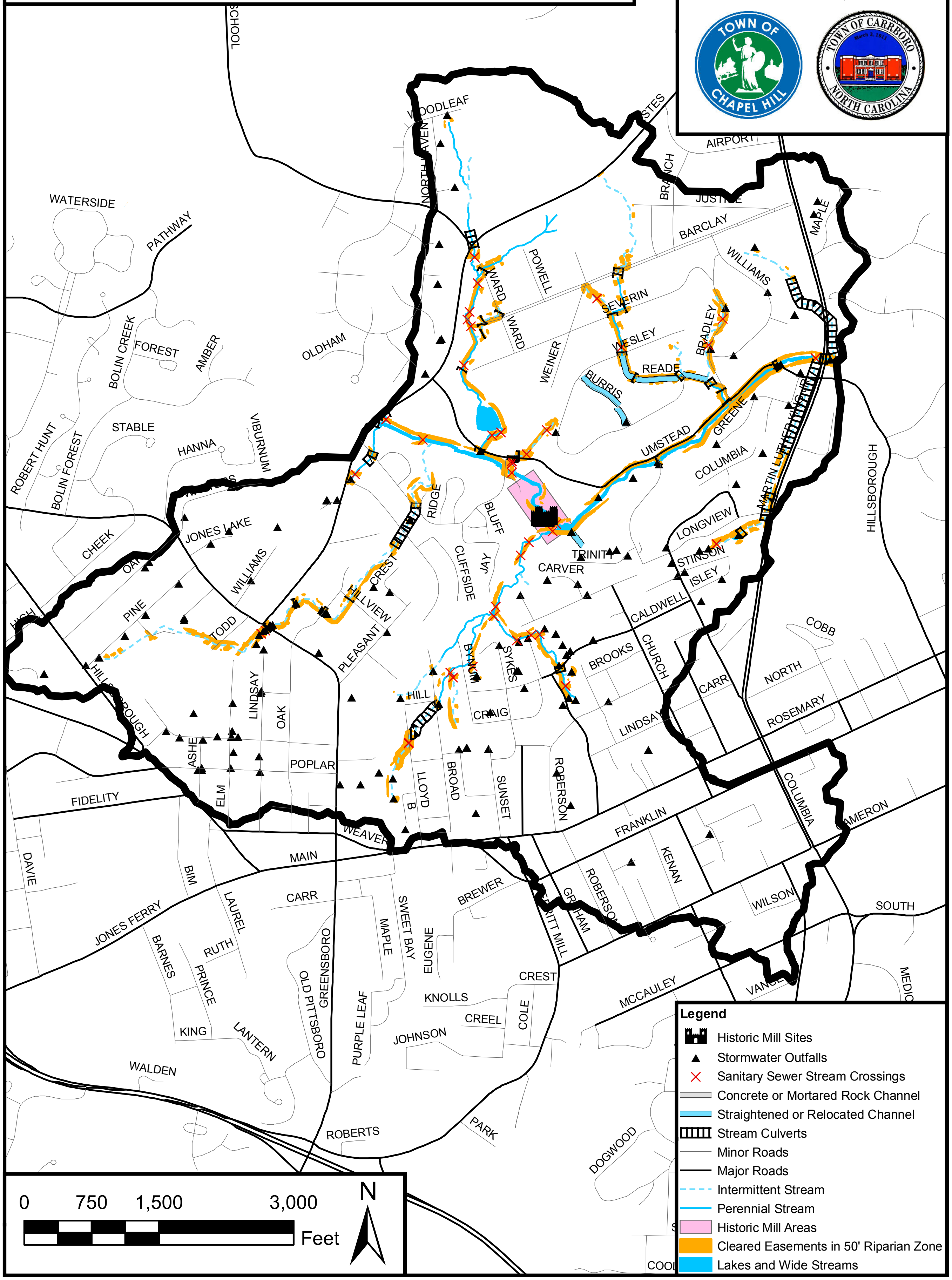


Figure 48: Riparian and Stream Channel Stressors in Middle Bolin Creek B Subwatershed (BL4B)

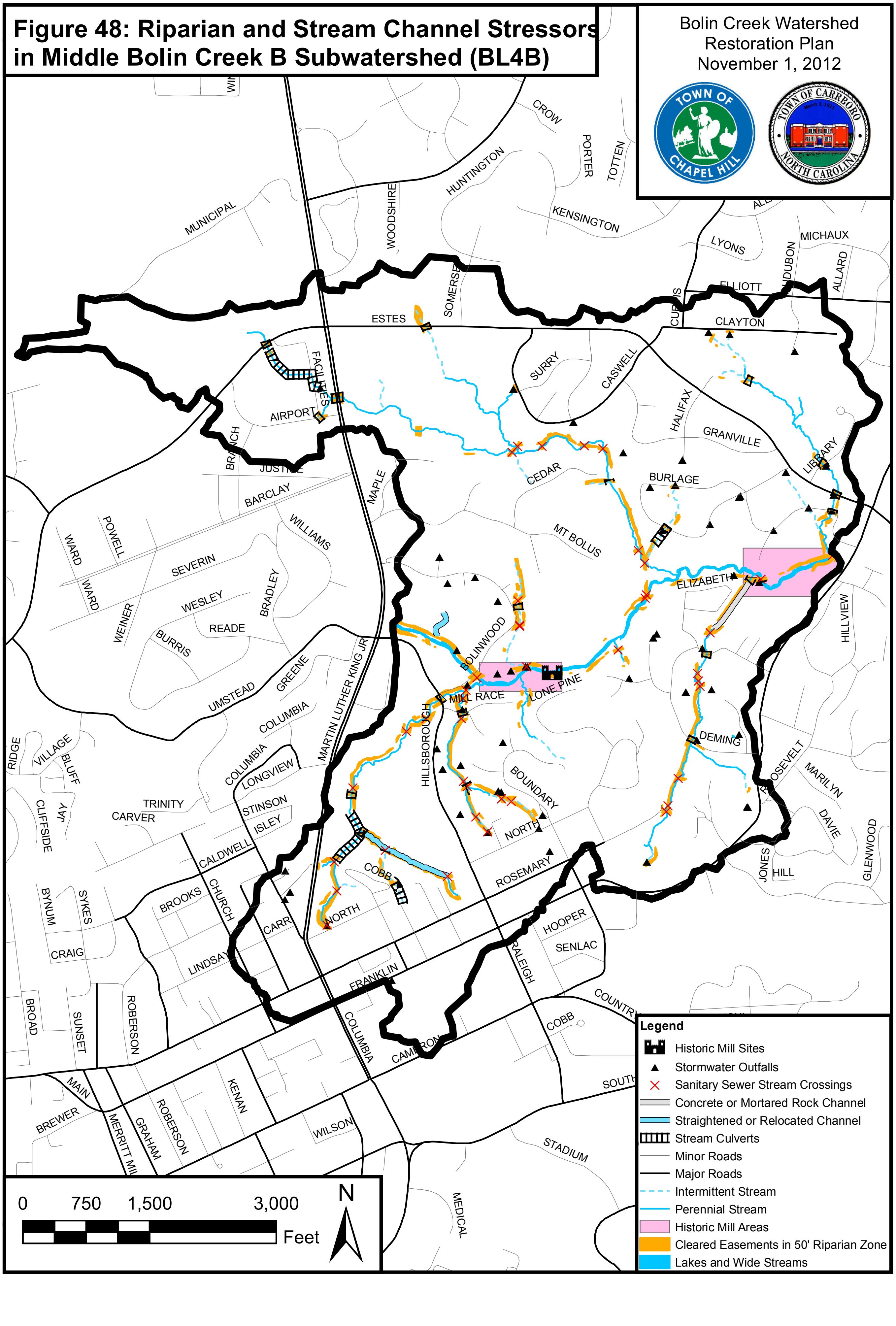
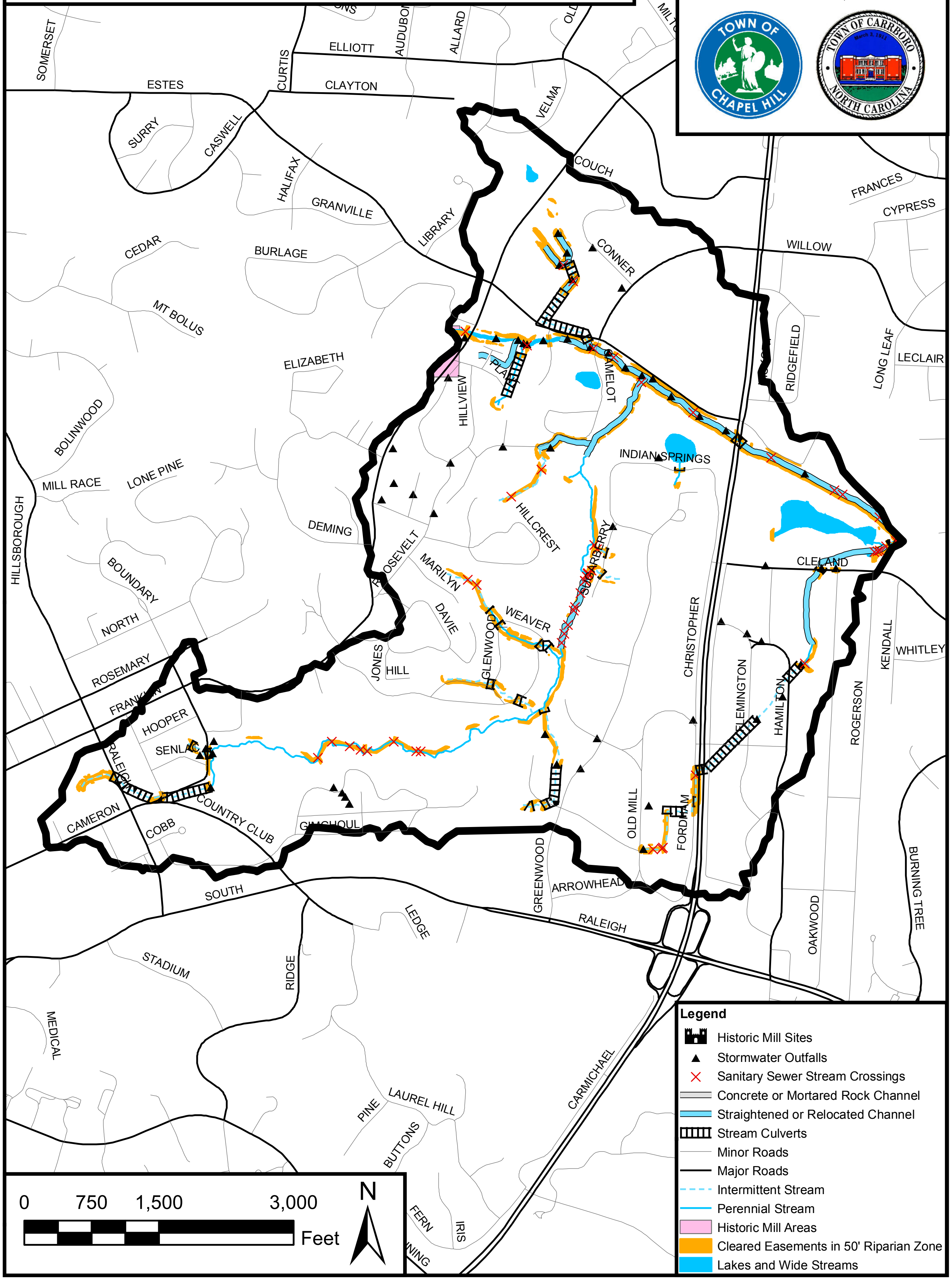


Figure 49: Riparian and Stream Channel Stressors in Lower Bolin Creek Subwatershed (BL5)

Bolin Creek Watershed Restoration Plan
November 1, 2012



CHAPTER 4: WATERSHED STEWARDSHIP

4.1 OVERVIEW

We seek to build the community's capacity for communication, networking, coordination, mutual leveraging of resources, and leadership that is required for successful long-term watershed restoration. Bolin Creek and its tributaries need a diverse group of stewards filling multiple restoration niches. As discussed in previous chapters, land use patterns and the distributed nature of watershed stressors indicate that progress towards the goals of this plan requires a comprehensive and collaborative approach that achieves a very high degree of private landowner awareness and adoption of improvements that reduce impacts of runoff on streams and aquatic life.

The general level of awareness of watershed challenges and opportunities must be raised; however, a high level of awareness will not, on its own, improve water quality and aquatic habitat. The watershed's residents and businesses need to not only understand, but be committed to modify both their properties and their behavior to support community wide goals to protect Bolin Creek and its tributaries. A goal of this plan is to help expand awareness and collaboration on behalf of the watershed as a home in need of repair. The aquatic life in the creeks is a strong indicator of the health of the larger community; it is both an ambitious aspiration and a potential source of civic pride and identity for a community to be an urban area that has figured out how to support healthy creeks.

4.2 OUTREACH, EDUCATION, AND PUBLIC PARTICIPATION STRATEGIES

PURPOSE OF AN OUTREACH PLAN

The purpose of an outreach and education plan is to identify and prioritize problems that need solving; to know which audiences are interested in, contributing to, or affected by each problem; to educate and enable community individuals and groups to follow practices to remove Bolin Creek from the 303(d) list; and finally to inspire community members to become watershed advocates to help teach and/or motivate others to live in ways that protect our waterways, and to work diligently and creatively to provide necessary resources for implementation and completion of important projects. In order to think and plan holistically and strategically, the rules of social marketing can lay a foundation and path as found in Philip Kotler and Nancy R. Lee's Third Edition Social Marketing: Influencing Behaviors for Good (2008 Sage Publications, Inc.) and Doug McKenzie Mohr's Third Edition Fostering Sustainable Behavior: An Introduction to Community-Based Social Marketing (2011 New Society Publishers).

OUTREACH STRATEGIES AND CAMPAIGNS

Using social marketing for separate campaigns and outreach will require a blend of different approaches and strategies. We know that person-to-person outreach results in the highest participation rates, yet person-to-person is very time intensive. One of the best models for community residential participation is the block leader program, often used by recycling programs and national parks' campgrounds host programs to provide a leader to those living or staying in a neighborhood. Block leaders are educated peers, who can remind their neighbors about acceptable and unacceptable behaviors and practices, can provide newsletter articles to their HOAs or hand out written information when necessary, conduct meetings, and set out reminder signs for events. In the stormwater management outreach arena, the Adopt-A-Drain or Adopt-A-Stream programs would work well in involving leaders and their neighbors. A volunteer coordinator, most likely within each Town, would be necessary to set up and maintain a block leader program, due to the time requirements for doing a thorough job.

In considering campaign/outreach projects, Philip Kotler and Nancy Lee (Third Edition Social Marketing: Influencing Behaviors for Good (2008 Sage Publications, Inc.) page 98) suggest use of several criteria in choosing from an initial list of options:

> *Behavioral Change Potential:* Is there a clear behavior that can be promoted to address the issue?
> *Market Supply:* Is this issue already being addressed adequately in this way by other organizations and campaigns?
>
> *Organizational Match:* Is this a good match for the sponsoring organization? Is it consistent with its mission and culture? Can its infrastructure support promoting and accommodating the behavior change? Does it have staff expertise to develop and manage the effort?
>
> *Funding Sources and Appeal:* Which approach has the greatest funding potential?
>
> *Impact:* Which approach has the greatest potential to contribute to the issue?

After reviewing each of the above questions, the Towns and/or other leaders of outreach campaigns may then assess organizations' internal strengths and weaknesses, and list factors and forces from inside and outside of the campaign leader's organization to determine what factors may need to be addressed in order to have a successful campaign. For better collaboration, we propose setting up a local work team called FLOW (Friends and Leaders of Watersheds) to meet on a bimonthly schedule. Through this team, collaborative efforts can be planned and initiated, tasks delegated to avoid duplication or confusion, committees created for special events or projects, resources shared, promotion of projects or programs coordinated, and clear and open communication optimized.

General education, awareness building and group development will continue to take place through current programs, symposia, festivals, Earth Action Day events, and public involvement opportunities.

COMMUNITY BASED SOCIAL MARKETING

Community based social marketing (CBSM) is an attractive and effective alternative to outreach based on information-intensive campaigns, attitude-behavior or economic self-interest perspectives. Its effectiveness is due to its pragmatic approach that involves carefully selecting the behavior to be promoted; identifying the barriers and benefits associated with the selected behavior; designing a strategy to address these barriers and benefits; piloting the strategy with a small segment of a community; and evaluating the impact of the program once it has been implemented broadly. The following considerations are all part of a social marketing approach to issues and campaigns, and summarizes the approach as described in Doug McKenzie Mohr's Third Edition Fostering Sustainable Behavior: An Introduction to Community-Based Social Marketing (2011 New Society Publishers):

1. SELECTING BEHAVIORS: Watershed restoration presents a wide array of both landscape changes and human behaviors that may be promoted. For example, a goal of promoting rain gardens might be achieved by involving community members in the building of a demonstration rain garden. Similarly, there are numerous behaviors that could be encouraged related to fertilizer use, rainwater harvesting, erosion control, car washing, and tree planting. The first step of community-based social marketing is to determine which specific practices and behaviors should be chosen to be promoted, determine the impact this change would make, and the probability that this change would happen. Choose behavior to target - calculate impact – determine probability – consider visibility of action for ongoing evaluation - then prioritize for outreach impact and success.

2. IDENTIFYING BARRIERS AND BENEFITS: If any form of sustainable behavior is to be widely adopted, *barriers* that impede people from engaging in the activity must first be identified along with identifying *motivators* for them to take the desired action. But barriers that prevent an unwanted behavior also need to be identified. You want to keep those! Approaches to identifying these barriers and benefits can include literature reviews, observations, focus groups, surveys, meetings, and other means of information gathering. Barriers identified may be "internal" to individuals such as lack of knowledge regarding how to carry out an activity, or "external" as in structural changes that need to be made in order for the behavior to be more convenient. Social science has found that that the barriers that prevent individuals from engaging in one form of sustainable behavior (e.g., installing a rain garden) likely have little in common with the barriers that keep them from engaging in other desired behavior (e.g., adopting a stream reach). Further, this research demonstrates that even within a class of sustainable activities, very different barriers emerge as being important. Since the barriers that prevent individuals from engaging in sustainable behavior are activity-specific, the barrier-benefit approach develops a strategy only after a particular activity's barriers and benefits have been identified. Once the barriers and benefits have been identified, a strategy to remove the barriers and enhance the benefits is developed. One proven element of adoptability of a new behavior is convenience. Make a behavior easy and convenient and the probability of it happening skyrockets.

3. DEVELOPING STRATEGIES: Social scientists have identified a variety of effective "tools" that span the gamut from gaining commitments from an individual that they will try a new specific activity to developing community norms that encourage people to behave more sustainably. The techniques that are used can be carried out both at the community level and also involve direct personal contact. Personal contact is encouraged because social science research indicates that we are most likely to change our behavior in response to direct appeals from others.

4. COMMITMENT: Baby steps work to increase commitment. Have someone agree to a small project, gain trust with its results, then ask them to participate in a larger project. Ask people to sign pledges to do something or to change a behavior after sharing with them the reasons you need their participation. Offer follow up and/or coaching to make sure a project is on task. Send out a letter from a respected community member asking people to participate in a survey before sending out the survey. Send free "tools" to help implement the behavior, such as a storm drain protector or

free plants for a rain garden, upon commitments to use them. But remember, commitment must be voluntary or the commitment will not last.

5. BUILDING COMMUNITY SUPPORT: Norms, peer pressure, modeling behavior. One case study in downtown Chapel Hill comes from the Chapel Hill Downtown Partnership's grant with Keep America Beautiful to install cigarette urns on Franklin Street. In the past cigarette butts littered the street from east to west. At one count, scheduled with a weekly halt in maintenance to better calculate need for the grant, over 6,000 butts were found in landscaping, gutters, rights of way and on the sidewalks. After installation of cigarette urns in several strategic locations, the change was slow, but caught on as smokers observed other smokers using the urns to dispose of their butts. The urns now in place are filling up and the Chapel Hill Downtown Partnership hopes to expand the program. Getting people to pick up after their dogs is the same type of issue: with greenway signs requesting this behavior and modeling by dog walkers, those who may not have picked up earlier are more likely to adopt the behavior.

6. SOCIAL DIFFUSION: Social networking, influence with friends and family, block leader influence, public and personal recognition of models for the behavior, using the grapevine to distribute an invitation to join in a desired behavior, making the desired behavior very visible and able to be participated in by others – all are very effective means of speeding up and gaining both commitment and long lasting results. Chapel Hill Stormwater Management's rain barrel sale and H_2Oh! Fair during the drought of 2008 attracted more than 700 people, mostly by word of mouth. Can you spell flash mob?? Social media can play a very large role in this element of marketing.

7. CREATING PROMPTS: How many of you have reusable grocery bags but leave them in the car when you go in to shop? You get the picture. People forget, get sidetracked, don't think straight sometimes. Prompts, or reminders to behave in a certain way, are helpful. Wouldn't it be nice if we could place squawkers on all storm drains to go off when someone approaches with a polluting substance? We can't do that, but we can adhere storm drain labels or paint storm drain hoods a caution yellow. We can place the pollution hotline number on the labels so an observer can call to report dumping. We can place stickers on painters' or concrete workers' truck windows to remind them to protect our storm drains and creeks. Doug McKenzie-Mohr cites a case that by simply beautifying a litter receptacle increased its use by 100% in one study and by 61% in another study.

8. COMMUNICATION: How can we use communication to persuade others to adopt a desired behavior? Grab attention with information that is the opposite of boring, but personalized and clear, using comparisons that people can relate to, especially in the use of measurements or volumes. The use of humor, art, music can help a message or it can hurt, depending on the audience and how the message is framed and crafted.

9. INCENTIVES: The "what's in it for me?" question often arises, especially if a government is asking citizens to participate in a new program. Let them know, be consistent with incentives, and update participants with results of their participation. Create incentives like having clean water to drink and swim in, saving money, reducing the amount of work needed to maintain a yard, earning a beautiful yard ornament, or gaining recognition by being part of a project.

10. CONVENIENCE: Basically, is the desired behavior going to make the participants' lives harder or easier? Will the participation in a project require large amounts of time or money? Will the behavior be sustainable in the long term? Is what we are asking going to have more benefits than costs?

11. TESTING A STRATEGY: Before piloting a project or a campaign, the strategy should be tested with a focus group from the pilot test area. The focus group participants will be able to find the flaws or suggest tweaks that would be more effective for their community. They may also possibly become the leaders within the community, as they have formed some ownership and commitment to the outreach by participating in the focus group.

12. PILOTING: Prior to implementing a community-based strategy, it is a good idea to pilot the strategy in a small portion of a community. Conducting a pilot allows a program to be refined to improve effectiveness and cost-effectiveness in other areas. Finally, conducting a pilot can produce evaluative results and be a crucial step in demonstrating to supporters/funders the worthiness of implementing a program on a broader scale.

13. BROAD·SCALE IMPLEMENTATION AND EVALUATION: The final step of community-based social marketing involves broad implementation and ongoing evaluation. In conducting an evaluation, community-based social marketers emphasize the direct measurement of behavior change over less direct measures such as self-reports or increases in awareness. The information gleaned from evaluation can be used to refine the marketing strategy further as well as provide evidence that a project should receive further funding.

4.3 LEADERSHIP AND COLLABORATION

The Bolin Creek Watershed has three local government jurisdictions - The Towns of Carrboro and Chapel Hill, and Orange County; and a State landholder - the University of North Carolina at Chapel Hill. The public non-profit Orange Water and Sewer Authority (OWASA) is an important stakeholder in the Bolin Creek watershed as well. Each holds its own NPDES permit, with the exception of the County which does not have a separate stormdrain system. Collaborative efforts include erosion control issues, illicit discharge detection and elimination, watershed outreach and education, planning and/or funding for projects sharing the common mission of improving the health of Bolin Creek and protecting Jordan Lake under the Jordan Lake Rules. In addition, Friends of Bolin Creek, Orange County Soil & Water Conservation District, the Haw River Assembly, UNC's Institute for the Environment, teachers and students from the local school system, and other individuals and groups interested in stream restoration and protection lend huge amounts of energy to governmental programs as well as to implementing projects and workshops on their own. Having such active groups allows exponential outreach that just one entity could not attain on its own.

COLLABORATION STRATEGIES

Top Down P's (Typical government strategy):

Policies, practices, programs, projects, payments

Bottom Up E's (Typical grassroots strategy):

Education, encouragement, engagement, empowerment, enthusiasm

How do we simultaneously build from the bottom up ("the E's" mentioned above) and top down ("the P's")? The common thread and the secret ingredient that holds these approaches together is *community*. A united community is primed to help restore Bolin Creek, while a struggling, divided, distracted, or disinterested community creates many barriers to progress. Often in plans like this one, recommendations are presented as policies, practices, programs, and projects led by local governments. This approach is typically task oriented, formally structured, and linear from the top down, and is often slow and methodical. Those using this approach plan carefully, but can also underestimate grassroots expertise, energy, and enthusiasm, and can find themselves being left behind as others charge ahead.

The BCWRT is dedicated to making public involvement and participation a community process. Therefore, plans for implementation will rely on consensus building and collaboration among the many stakeholders. The key is in:

- consensus building among stakeholders already actively involved with caring for and repairing Bolin Creek;
- inviting participation from those not yet committed to a team approach;
- building leaders' and volunteers' skills and knowledge;
- identifying and delegating tasks and projects clearly and appropriately to ensure that legal requirements and regulations are met and that skills and tools are matched to delegated tasks;
- and having clear communication and interchange between stakeholders throughout the process.

STAKEHOLDERS AND ROLES

Laying the foundation of partnership requires up-front work to understand watershed stakeholders and change agents' interests, facilitate information-sharing and visioning, build trust, and experience successes together. The Bolin Creek Watershed, possibly more so than any other in Chapel Hill and Carrboro, has a plethora of residents and visitors who deeply appreciate the creek and enjoy its recreational aspects for walking, biking, running and playing; its natural habitat for the study and teaching of flora and fauna; and its opportunities to become involved with its care. Citizen groups such as The Friends of Bolin Creek and Save Bolin Creek, along with the Towns' Parks and Recreation, Stormwater Management and Planning Departments, have over the years, brought attention to the beauty of the creek itself as well as to issues that affect its health. Differing opinions among the groups, especially about Carrboro's proposed greenways and bicycle paths, have led to discord, yet all parties agree that working collaboratively to ensure the best management for Bolin Creek is the most important goal.

This watershed teems with leaders. By bringing active citizens and agencies together to work towards important goals and objectives, confusion, errant messages and overlap can be avoided, while providing the needed talents, knowledge, people and energy to fulfill goals and objectives.

Actual and potential outreach partners are listed in Table 10, with asterisks for level of involvement. It identifies who is currently involved as well as potential others who have an interest in the watershed.

Those involved in local stormwater education and outreach are already working together to establish a collaborative Chapel Hill-Carrboro network called FLOW (Friends and Leaders of Our Watersheds) to enable integrated planning and discussions. Those involved with one subwatershed are often involved with another creek association, and lessons learned in the Bolin Creek watershed can be applied in others. Friends of Bolin Creek, the Towns of Chapel Hill and Carrboro, UNC's Institute for the Environment, Chapel Hill High School, Morgan Creek Valley Alliance, and Orange County Soil & Water District have formed a base to which other stakeholders will be added. Group members bring expertise, knowledge, and contributions of time to fulfilling goals and objectives. In addition, potential for funding is also increased as a number of agencies working together can draw from different sources and combine funds for larger, more expensive restoration projects.

Delegating tasks and having specific duties and training for volunteers, with their different strengths, perspectives, associates and audiences, will increase outreach more quickly to improve our waterways. Therein also lies the challenge of maintaining consistent messages, communicating important issue and project updates, providing training, and organizing several community efforts at once.

Table 10: Actual and Potential Outreach Partners as of June 2012

Activity * ** * (Less ---> More)**	
***	Friends of Bolin Creek
***	Morgan Creek Valley Alliance
***	OWASA
***	UNC-Institute for the Environment
***	Chapel Hill - Carrboro City Schools
***	Chapel Hill Downtown Partnership (representing downtown businesses)
***	NCSU- Stream Restoration Program and NC Cooperative Extension
**	Orange County Cooperative Extension Service
***	Orange County Soil & Water Conservation District
***	Orange County Animal Control/Shelter
***	Triangle J COG: Clean Water Education Partnership & Jordan Lake Groups
***	Orange County Environmental Health, Solid Waste Departments
*	Real Estate Agents
**	Town and County Elected Officials
***	UNC Stormwater Management & EHS
**	UNC Office of Sustainability
***	Town of Carrboro working jointly with Town of Chapel Hill (Stormwater)
*	Sierra Club Orange Chatham Group
*	New Hope Audubon Society
*	NC Forest Service
***	NC Botanical Garden
***	Haw River Assembly
***	NC Division of Water Quality
*	NC Office of Public Affairs & Environmental Education
***	NC Big Sweep
*	UNC Environmental Clubs and Groups
***	Boy Scout Troops
*	Girl Scout Troops
*	Churches
*	University Mall and Other Businesses

**	Town of Chapel Hill Grounds/Landscaping
**	Town of Chapel Hill Parks & Recreation - Greenways, Events, Activities
	UNC Carolina North Forest (UNC Division of Facilities Services)

UNIVERSITIES AND ACADEMIC INSTITUTIONS

The BCWRT partnerships are strong with UNC-Chapel Hill and NC State University. Both universities are a constant source for research and have provided exceptional technical assistance, funding and staffing to enhance and expand our local watershed programs, especially through NCSU's Stream Restoration Program and Cooperative Extension (including Watershed Education for Communities and Officials), and through UNC's Institute for the Environment and Office of Environment, Health and Safety. In addition to NCSU's partnership on stream restoration, both universities have contributed to education and support of outreach programs, such as conducting a local rain garden workshop, providing science curriculum assistance and science teacher training, helping to organize watershed advocates, and partnering to develop and produce a water pollution prevention training program for food service establishments. UNC-Chapel Hill stormwater engineers and outreach staff often work with Town stormwater staff in projects and outreach programs, and UNC is represented on Chapel Hill's Stormwater Management Utility Advisory Board. The NC Botanical Garden Foundation, umbrella organization for the Morgan Creek Valley Alliance, also supports work by Bolin Creek advocates, providing space and staff support and leadership for educational watershed programs, such as Friends of Bolin Creek's cosponsored "Can We Heal Our Waterways?" Symposium in February 2011.

LOCAL SCHOOL SYSTEM

Schools present special opportunities since they not only are centers of education but also have schoolyards with real restoration opportunities that can serve as focal points for both youth and adult education and outreach, while producing significant environmental improvements. The main challenges with working with schools are time demands on teachers and limited funds. Parents, teachers, school clubs, administration, PTA, and the CHCCS Foundation are all invited to help identify ways that these barriers can be overcome and education and outreach efforts can be pursued at schools. The Chapel Hill-Carrboro Schools District is currently in the process of assessing architectural integrity of buildings and stormwater problems on the campuses of older schools. This architectural study will help to support the working relationships currently fostered between the school system and those agencies currently working with Chapel Hill High School on stormwater management projects and the Water Sustainability Initiative.

The Town of Carrboro and Friends of Bolin Creek worked with McDougle Middle School in Carrboro through a 319-grant to promote stormwater education and clean water by installing a bioretention cell and cistern on the school campus. Recent collaborative work at Chapel Hill High School under the "Water Sustainability Initiative" (Addendum X) has built teamwork among 12 various agencies and organizations to promote hands on learning by students, stormwater drainage improvements and demonstration projects, and water quality improvement projects. Funding has been requested by the Green Tigers Environmental Club, Friends of Bolin Creek, CHHS Science Teacher Rob Greenberg, and Orange County Soil & Water Conservation District. In-kind funding has been provided by Friends of Bolin Creek, the Redwoods (Insurance) Group, NC Cooperative

Extension, the NC Stream Restoration Program (NCSU), and the Town of Chapel Hill Stormwater Management Division.

In a recent PRISM (Promoting Innovation in Science and Mathematics) grant from Burroughs Wellcome to Chapel Hill High School (CHHS) teacher Rob Greenberg, funding was given for contracting with Shodor, a Durham based national resource for computational science education to develop a model of water flow through the CHHS campus. This company has specific experience in developing stormwater models for high school classrooms and specializes in working with teachers on developing individualized computational projects. Professional development for CHHS teachers will allow teachers to project how specific improvements would decrease stormwater volumes. In addition to technical assistance, CHHS would receive guidance in the integration of modeling and simulation tools into the high school curriculum, consistent with state and national standards.

A matching grant from Strowd Roses, Inc. was awarded to Friends of Bolin Creek to further water quality and hydrology studies by students attending CHHS and the Carolina Center for Educational Excellence.

PRIVATE PROPERTY OWNERS

Stormwater retrofit and stream restoration projects typically require substantial technical and often legal/regulatory input and permitting, not to mention financial outlays and land area. There are limited opportunities for engineered restoration and stormwater retrofit projects since much of the watershed is owned by private property owners and built upon to some degree. Most of the needs for restoration will require the involvement, or at least permission to enter, from private landowners. Working with landowners to gain their trust and instill the importance of repairing our watershed to motivate them to participate in restoration efforts is an art as well as a science. Finding the right approach is critical before planning gets too far along. Project design and property owner commitment is a chicken or the egg quandary: receive commitment from homeowners first or design and plan the project first to present to homeowners? How can a property owner commit to an unknown process and outcome? It is best to involve landowners at the outset, before a grant proposal is even undertaken. This will require many hours spent following up with and visiting one-on-one with those who do not accept invitations to initial meetings.

Optimally, many smaller landscape enhancements, along with the larger projects that are feasible, will be pursued. "Soft" restoration through watershed friendly norms and behavior will require attention to the rich mix of cultural practices, social interactions, economic status, and human feelings that influence individuals, groups, and organizations. The fundamental goals are for stewardship efforts to educate, encourage, and empower the community to pursue watershed restoration goals such as reducing the rate and volume of runoff, recharging groundwater by capturing and infiltrating stormwater, and preventing illicit discharges into creeks and storm drains. Campaigns such as Seattle's 12,000 rain gardens or Kansas City's 10,000 rain gardens are models for the country. Working together with stakeholders, Chapel Hill and Carrboro can also design effective campaigns for each of the above goals.

WATERSHED SITUATION ASSESSMENT AND RECOMMENDATIONS

Recent research highlights that "the design of transparent and open social learning processes is a key requirement of sustainable water management regimes. Effort has to be devoted to building trust and social capital for problem solving and collaborative governance. An increase in, and maintenance of, the flexibility and adaptive capacity of water management regimes should be a primary management goal. Entrenched perceptions and beliefs block innovation and change. Space has to be provided for creative and out-of-the-box thinking and experiments. " (Pahl & Wost)

As part of the Bolin Creek Watershed Restoration 319 grant, NCSU Cooperative Extension's Watershed Education for Communities and Officials (WECO) was contracted in 2010 to conduct a non-biased situation assessment of stakeholders in the Bolin Creek watershed to help identify:

- the key stakeholder voices that must be engaged for any successful public participation;
- the main stakeholder concerns, issues, and interests;
- the specific opportunities where public input can help to shape decisions about the issues;
- any issues or constraints that may affect public participation;
- successes achieved so far that can be built upon.

WECO conducted interviews and a focus group with 41 stakeholders. The report's recommendations include:

1. Create a multi-organizational Bolin Creek initiative group that can receive training on building collaborative and consensus decision-making skills in order to agree upon common goals and objectives, and divide into productive workgroups.
2. Design an online network for sharing ideas and discussions, preferably managed by a neutral party.
3. Examine how to more holistically plan and manage water resources across departments and jurisdictions. (Local governments and OWASA)
4. Increase community outreach and engagement on UNC's Carolina North Forest Stewardship Plan.
5. Investigate how to raise revenue dedicated to water quality protection and restoration. Continue to work together to address the landfill and groundwater contamination issues in the Rogers-Eubanks community. (Note: Orange County will close the Eubanks Road landfill on July 1, 2013.)
6. Convene a facilitated search for common understanding about ways to connect pedestrian and cyclist routes while also protecting and improving Bolin Creek's riparian corridor.

IDENTIFYING AND PRIORITIZING PROBLEMS

After putting together a collaborative team, we must identify and prioritize problems that need solving; to know which audiences are interested in, contributing to, or affected by each problem; and to set forth a plan for collaboration of stakeholders to identify and work towards goals and objectives in an efficient and friendly manner, with clear communication and task division, ending with measurable results. The ultimate goal is to remove Bolin Creek from the 303(d) list.

Appendix 4 identifies stressors and their sources that impair our waters, and targets who can make the changes to eliminate the stressors and what practices are recommended to avoid or fix the problems. Appendix 5 (Outreach Methods) lists perceived barriers and benefits to fixing the problem and suggests outreach methods and tools that can be used. The barriers and benefits are taken from experience with field calls and talking with citizens; however, others may exist that can be identified through focus groups or surveys once a topic is selected for a targeted outreach campaign.

RECOMMENDATIONS FOR COLLABORATION

Where do we go from here? Stakeholders have a significant number of issues in need of response.

Convene a multi-organizational initiative group whose members will make a long term commit to working on outreach and education in the Bolin Creek watershed. One suggestion is to hold a series of at least three or four intensive facilitated workshops at the beginning:

1) to build team skills, and come to an understanding of outreach strengths and weaknesses with each partner; to understand what various group members can or cannot bring into the group as a whole;
2) provide training on consensus decision-making in order to agree upon common goals and objectives;
3) discuss current work in the watershed and evaluate for efficiency and effectiveness; what needs are still lacking in order to meet current goals, and which programs should be dropped or modified, if any;
4) choose and prioritize projects and campaigns for the Bolin Creek watershed based on the model of social marketing; and
5) divide into productive workgroups, each with clear leadership, for tackling the top priorities.

4.4 OUTREACH STRATEGIES FOR DIFFERENT AUDIENCES

Educating both adults and children about proper watershed restoration practices and water quality protection is critical for creating a watershed restoration-friendly community. The most effective outreach program will address both the "how-to" of watershed restoration practices and the engagement of the community. Information can be distributed through brochures, newsletters, newspapers, bumper stickers, other print media, and electronic delivery such as social media, posting on the web, and distribution lists. However, while *information delivery* can present a message, it is not a sufficient and effective means of encouraging watershed stewardship. Local events and initiatives such as person-to-person contact, festivals, summer camps, neighborhood campaigns, workshops, public projects, and Stream Steward Programs are examples of ways to engage the community in restoration efforts that are much more holistic – and effective - than information delivery. Items such as bumper stickers and social media may transfer information, but also be used to give a sense of belonging to an active group with a mission, which may motivate people to go beyond what they read, and *act* to help Bolin Creek.

Education also needs to reach a variety of audiences, such as homeowners, schools, businesses, and municipal staff in engaging ways. Efforts need to be made to reach out in ways that recognize diversity in age, ethnicity, and other socioeconomic factors to encourage watershed restoration.

DIRECT COMMUNICATION WITH RESIDENTS

Outreach in the Middle Bolin Creek watershed must target transient populations such as students and property managers and must be repeated periodically and consistently in order to have much effect. In the late 1990's, during a recycling survey of the Northside community in Middle Bolin Creek sub-basin, Eagle Scouts conducted a house to house, in-person survey to address low recycling participation and what could be done to increase the number and quality of recycling bin set outs. It was found that residents were motivated by "wanting to help." After the survey, recycling set outs were tallied and participation increased by 35% over several months. The success of "neighbor to neighbor" or in-person outreach is supported by annual visits of UNC, Town and Recycling representatives who visit rental housing communities in August, soon after the fall semester move-in, to educate new residents about being good neighbors by showing courtesy to others and by following local rules and regulations about occupancy, parking, alcohol, noise, and trash. This outreach has improved compliance rates, showing that *direct communication* with residents motivates them to become involved in their community.

MIDDLE CLASS TO AFFLUENT NEIGHBORHOODS

For middle class to affluent neighborhoods, where many services are likely to be contracted out, outreach should include landscapers and service providers as well as residents. According to the 2006 Community Based Survey conducted by Jewell Engineering and the Town of Chapel Hill Stormwater Management Division, approximately 50% of homeowners had their lawns cared for by contractors. In addition, with busy schedules and older age, a good percentage of households most likely have a housekeeper or maid service, and may use mobile services such as carpet cleaners, dog grooming, car washing, and pressure washing. All of these services have been found to occasionally and illegally discharge wash water into the storm drain systems. Most instances have been attributed to the individual not knowing that storm drains lead directly to creeks with no treatment, or to ignorance about proper wash water disposal.

ENGLISH AS A SECOND LANGUAGE COMMUNITIES

The Hispanic or Latino population comprises 8.4% of the total Bolin Creek watershed. Anecdotally, Hispanic and Latino families use English as a second language to varying degrees. It is often the children who are most proficient in English. Therefore, it is important to reach school aged children in this population so that they can educate their families, or to provide programs in Spanish for adults.

During focus groups conducted for developing a pollution prevention training program for food service establishments, UNC-Institute for the Environment and the Town of Chapel Hill found that Hispanic and Latino workers want to do the right thing and to be part of their communities. The largest motivating factor was to keep their families healthy and safe. Correlating clean streams with a clean and safe Jordan Lake, where many families fish and swim, is an important outreach strategy.

El Centro Hispano, Cliff's Meat Market, and various Mexican restaurants and Tiendas would be good locations to talk with customers and employees, and to distribute printed information about proper household hazardous wastes and storm drain protection. Visiting with families whose children are in the dual language program through Chapel Hill-Carrboro City Schools or meeting with day workers who assemble in Carrboro each day are other potential outreach opportunities. Finding a Spanish-speaking ambassador for clean water would be optimal.

Only 6.6% of the Bolin Creek Watershed population is Asian, with the larger distribution of the population in the Upper Bolin Creek subwatershed. Little has been done in Chapel Hill or Carrboro to design outreach materials or programs for this population that may include different dialects such as Mandarin and Karen. The Chinese School at Chapel Hill and UNC Chinese House students would be possible sources of assistance for translation and outreach.

RENTERS

According to the results of a 2006 Chapel Hill Community Based Survey to measure residents' perceptions, knowledge and interest in stormwater issues, the only factor that correlated with a lack of knowledge was having lived in Chapel Hill less than five years. Short-term residents who rent may also correlate with lower incomes. Rental property owners may have a lesser probability of having a "willingness to pay" for property improvements to benefit water quality. Expenses for maintenance of special landscaping or stormwater BMPs would not likely be a high priority. Yard care, if any, may not go beyond routine grass cutting as property owners want to maximize their income on rental property. They also may not have responsible tenants to care for the property. Outreach to landlords and property managers as well as residents is necessary. Incentives for watershed protection would be a motivating factor, such as free or heavily subsidized rain gardens, decreasing impervious surface to reduce stormwater fees, or subsidizing plants for landscaping.

MULTI-FAMILY UNITS (APARTMENTS AND CONDOMINIUMS)

Many residents in Chapel Hill and Carrboro are students, as apartments are located close to campus and on the bus routes. Much work can be done with residents of multi-family units, especially in educating about proper fats, oils, and grease (FOGs) disposal. At least 50% of sewer overflows contaminating Bolin Creek have come from grease clogs, and drains blocked with grease in apartment complexes are not unusual. OWASA has information about FOGs disposal, Orange County Solid Waste-Recycling accepts used cooking oil at the household hazardous waste collection, but other than information, little has been done to promote proper disposal. Triangle J Council of Governments' Clean Water Education Partnership is now planning to print grease can lids so that our communities can distribute these "tools" to get the message to residents about proper disposal and cleaner creeks.

Car wash areas, improper landscaping and waste disposal (i.e., dumping in the woods or drains behind complexes), and dog waste disposal are other potential sources of pollution into Bolin Creek from apartment complexes. Conducting walk arounds with apartment and condominium managers is recommended to discuss opportunities to prevent water pollution. Special storm drain labels could also be designed for placing on parking lot storm drains. Bus placards could be designed to reach students with stormwater messages.

FRATERNITIES AND SORORITIES

Most if not all of the UNC fraternity and sorority houses are in the Bolin Creek watershed. Parties and rush activities can contribute trash, sand and other debris that can block storm drains or be washed into Bolin Creek. Outreach staff will continue to educate students that storm drains lead directly to the creek and need to be protected. Entertaining stories, ads and PSAs can be run in the Daily Tar Heel, on WXYC Radio, and through the Office of Fraternity and Sorority Life.

LOCAL GOVERNMENT AND AGENCY INTERNAL EDUCATION

'Internal' education refers to the training of staff who are involved in the operation and maintenance of public lands (e.g., parks) and infrastructure (e.g., streets, sidewalks, utility lines) to become more aware of how their practices affect our waterways, and to help in implementing more watershed friendly protocol and practices. In addition to relevant Town and utility staff, elected and appointed government representatives should also be included in training sessions whenever possible. This training should cover all aspects of watershed restoration, including planning, design, development review, construction, and maintenance. This type of 'inreach' can be in the form of brown bag lunches, certification programs, workshops, and establishment of working groups. Even simple meetings to go over the Watershed Restoration Plan and communicate its strategies and objectives can be useful. Watershed restoration planning and design issues are complex, and state-of-the-art research and guidelines continue to evolve. Therefore, training sessions need to be updated and repeated on a regular basis.

PUBLIC HOUSING

Ten of the 13 public housing properties (www.townofchapelhill.org/index.aspx?page=211) are located within the Bolin Creek watershed with 250 of 336 units, or 74.4% of all public housing units. The Town of Chapel Hill's Housing Department operates and maintains each property. Some of the properties have resident representatives who lead programs and serve on the Public Housing Board. Stormwater outreach programs have been given for after school programs, resident meetings and participation in NC Big Sweep litter cleanups. Further work needs to be done by both the Housing Department and Stormwater Management in both educating about and enforcing proper waste disposal, especially as described under multi-family outreach.

SAFETY ISSUES

Crime statistics are significant. One reason some property owners do not want to maintain healthy riparian buffers, is the fear of (potential) criminals (and snakes unrelated to crime) being able to hide. Safety issues may also contribute to late night dumping by restaurant and bar employees in the downtown area who have to go into alleys to dispose of trash and grease after closing at night. The downtown business district continues to have significant issues with improper disposal of trash.

BUSINESSES

Outreach to employees, especially those in the landscaping, cleaning, construction, painting and restaurant businesses, is important, as we have answered many calls reporting improper disposal of waste in these professions. A guide to proper business waste disposal insert is included in each business license that is sent out to address part of the issue. Work with staff from the solid waste divisions and recycling is also ongoing and education-oriented.

Bilingual pollution prevention education is available to food service establishments through the Chapel Hill Stormwater Management Division or UNC's Institute for the Environment. We have seen improvement with several restaurants after they were cited for violations and took the training. In two cases, major plumbing work was done to avoid wash water running into storm drains. Some have stopped outdoor washing of compactors and mats. Others relocated and resized grease/oil collection containers which solved problems of sharing a site, and reduced spills on pavement and into the storm drains. Some restaurants are even training their neighboring businesses about proper wash water disposal. Workshops have been conducted and will continue to take place for local food service establishments. Inspections by Stormwater Management or the Orange County Environmental Health Department can find violations for which the training is given to the manager. Citizen reports of problems are also a cause for visiting a food service establishment.

Point of sales information/education could be implemented for painting contractors who too often dump painting wash water down storm drains or clean out their equipment directly in creeks. We have written newspaper articles, advised those who have been in violation, and worked with OWASA to come to an agreement about proper disposal. The Orange County Solid Waste Management Recycling Division also encourages proper disposal of paint and has a household hazardous waste collection that also includes a business disposal program.

We have explored outreach to concrete workers under a Wallace Genetics Foundation grant with UNC-Institute for the Environment, but abandoned that aspect of our proposal when UNC was unable to find workers for interviews, focus groups or surveys. Fear and mistrust prevented workers from wanting to talk about their practices of concrete wash outs. This is an area that should be revisited, as concrete trucks still occasionally use storm drains for wash out. However, working with the concrete company representatives and the plants where concrete is loaded is advised. Ideally, the employee taking the order for concrete would ensure that a proper wash out area was provided at the site. However, with batches being distributed to different locations, this may not be possible. "Prompts" or window stickers for concrete trucks with a clean water message and an emergency number to call if the delivery site has no wash out area would be ideal. The emergency number could go to a service that could bring a portable filter or pool.

For DIYers we could work with home and garden stores to include proper washout information along with bags of concrete and rentals of concrete mixers. A suggestion also was made by an engineering inspector that clean water messages and environmental protection be included in required OSHA tailgate talks with construction workers. Steps have been taken to investigate creation of storm drain protection waddles (filter socks) with a message to distribute to restaurants and other businesses that may need storm drain protection.

RECREATION

The Town of Chapel Hill's Community Center Park and 1970's unlined, but now covered, landfill are located between Bolin Creek and Battle Branch. This is the most used park in Chapel Hill and draws many families with young children, day campers in summer, and swimmers who use the pool. The Center has a beautiful rose garden and gazebo, a learning garden and a compost demonstration area. Chapel Hill Stormwater Management is currently discussing possible educational demonstrations with Parks and Recreation, Orange County Solid Waste and a local artist. The paved Bolin Creek greenway stretches from the Community Center west to Umstead Park. Several repetitively flooded single family homes on Dickerson Court, just north of the Center, were removed with a FEMA grant around 2001. A demonstration bioretention cell has been constructed in this area with a 319-grant.

The Chapel Hill Public Library straddles the Middle and Lower Bolin Creek boundaries. This large property is under construction with reopening expected in 2013. The library is a major gathering spot for families and individuals, and boasts the largest circulation of public library books in the state. With its property, trails, and significant visitation, it has high potential for hosting watershed education programs, films and exhibits and providing outdoor education.

It will be essential for Stormwater to work with Chapel Hill Parks and Recreation and the Greenways Commission regarding riparian buffer protection as the Bolin Creek greenway expands.

CHAPTER 5: MANAGEMENT AND RESTORATION MEASURES

5.1 OVERVIEW

Impairment in the Bolin Creek Watershed has been determined based on the poor condition of aquatic organism communities. As noted in the previous chapter, aquatic organism communities in urban settings are affected by a wide variety of stressors contributed by sources in a diffuse, distributed, "non-point-source" way. One of the goals of watershed restoration planning is to estimate the amounts of stressors contributing to impairment and the amount by which these stressors need to be reduced to restore ecological function. However, when stressors are as broad and difficult to measure as they are in cases of "urban stream syndrome," it is difficult to say exactly how much of any one stressor is to blame for impairment or how much any one stressor needs to be reduced to restore ecological function. This means it is at a minimum not practical and more pointedly and likely not possible to select or prescribe management measures based on the specific amount they control or reduce a specific stressor.

Therefore, the approach this plan takes is to look at urban stressors and sources, and the management measures needed to address them, in more general terms. We have identified broad categories of hydrologic impairment, geomorphic impairment, water chemistry impairment, and biological impairment. Further, we have identified stressors and characterized the ways they impair streams and waterbodies, as shown in Appendix 3. We understand that addressing the complex and interrelated stressor combination presented by "urban stream syndrome" will require a broad approach that addresses the multiple levels of stream ecosystem functions all at once.

Restoration of Bolin Creek's ecological functions will require a multi-pronged approach to counter the multiple stressors common to urban settings. This is because of the wide variety of sources. Appendix 4 presents management measures in terms of countering specific sources. Appendix 5 profiles specific methods used to address the various stressors identified in Appendix 3 and analyzed in the Watershed Analysis chapter. This chapter will review the aspects of stream ecosystem functions we have determined need to be addressed in order to effect changes in physical, chemical, and biological conditions to allow the biological community to improve.

Lastly, the portions and functions of the watershed that are still functioning well need to be protected to maintain that function. But simply making all of these few remaining areas off-limits to new development is not viewed favorably by the owners of these properties. Therefore, this chapter also reviews techniques to protect ecological functions, as well as methods to develop a property in a way that minimizes negative effects on ecological functions.

5.2 MANAGEMENT APPROACH BY LEVEL OF ECOSYSTEM FUNCTION

HYDROLOGIC FUNCTIONS – ADDRESSING "FLASHY" FLOWS AND LOW BASE FLOW

A large proportion of the developed areas in the Bolin Creek watershed have no structures or methods to control stormwater rate or volume. Increasingly "flashy" stream flows following rainfall are a hydrologic symptom of changes in the watershed that in turn lead to changes in stream geomorphology. High velocity flows put considerable stress on stream banks and stream beds, causing erosion and changes in the shape of the channel. Erosion can undermine riparian trees, remove all kinds of habitats, and generate large amounts of sediment that is carried downstream to be deposited in another stream segment. Heavy deposits of fine sediment in turn fill in and obliterate stream habitats, change the shape of the channel, and smother organisms and their food sources.

With regard to other direct ecological effects, "flashy" flows reduce the nutrient processing capabilities of streams by reducing the time that leaf litter stays in one place. When leaf litter stays and decomposes for a long time in one location, fungi have time to colonize the material, animals have time to graze on the colonizing fungi, and thus the nutrients in the leaves cycle slowly through the stream food chain.

Reducing erosive, "flashy" flow is best dealt with by controlling stormwater runoff, particularly its rate (discharge, or volume in a given amount of time) and its total volume. This is done through the use of structures or grading of land that slows down or retains runoff. These methods can be fully engineered structures such as wet ponds or simpler methods that increase surface roughness and topographic depressions to slow the movement of runoff to streams. However, engineered structures usually require regular maintenance for their continued proper functioning. This and other retrofitting challenges are addressed more directly later in this chapter.

In contrast to "flashy" storm flows, low base flows (stream flow in between storms) are a different kind of hydrologic symptom of change in the watershed. Low base flows have not been definitively linked to increased impervious surface, or to any one particular cause. However, as described in Appendix 3, there are a variety of identified watershed and land use changes that can have baseflow effects. Increasing soil infiltration of rainfall, and eventual groundwater recharge, throughout the watershed holds the potential to improve base flows in the most straightforward way. Fortunately, increased groundwater recharge does not have to take place in the context of formal, engineered stormwater management, making it highly accessible to the average property owner. Furthermore, once begun, it requires little maintenance beyond ensuring the general health of the vegetation and soil in the area.

The simplest way to increase soil infiltration is correct soil compaction (via soil restoration), and where present, remove impervious surfaces. Without rebuilding the soil it takes many years (or even decades) for natural processes to improve permeability, depending on how heavily compacted the soil is. Rebuilding, or restoring, the soil usually involves deep plowing to break up compacted layers and the addition of organic material to encourage the growth and activity of soil organisms, including healthy plant roots. In areas where soil has been compacted, an 18 inch plow is used to break up deep soil layers. In places where the forest leaf litter or topsoil has been removed, the soil is amended in place by adding compost and rototilling it in. This can be achieved using a pre-approved amendment rate of 2.5 inches or through a custom amendment rate calculated specifically for the site. For soil that is too rocky, compacted, or poorly drained to amend effectively, a topsoil mix with 8% to 13% soil organic matter can be imported and placed on the surface. For all these sites, soil inoculants add critical microorganisms back into the soil. Microorganisms digest the organic materials, producing compounds that "glue" the soil together into larger blocks. Even earthworms are available for amending soils. Larger organisms burrow through the soil, and plants push roots through, opening up tunnels of many sizes. The blocks and the tunnels vastly increase the ability of the soil to absorb rainfall.

Even where plants are currently growing, such as lawns, the soil may not be as healthy as it was prior to development. The development process usually involves the removal of topsoil down to a clayey, rocky subsoil in order to smooth the surface for building ("grading"). Heavy equipment compacts the entire area during grading and construction. Topsoil may, or may not, be laid back down after construction is complete; it is not required in practice or regulation. Plants, even grass, growing on this material often struggle to survive since the soil cannot absorb very much rainfall. It can take decades for the soil to loosen by weathering and plant and soil organism action, and that requires that a healthy soil ecosystem be allowed to develop. Removal of organic matter and use of herbicides and pesticides can very effectively prevent the reestablishment of a healthy soil community. Forests can very effectively restore soil condition given time. Grass lawns have a poorer record in this regard, mostly because of the intense management, and potential compaction involved during management, and shallow root zone.. Reforestation of available area not covered by rooftops, pavement, or gravel is generally considered to be a highly effective method to slow and absorb runoff, providing benefits for both groundwater recharge and control of stormwater runoff.

GEOMORPHIC FUNCTIONS – ADDRESSING STREAM INSTABILITY

As noted in the Watershed Impairment chapter, "flashy" storm flows can lead directly to changes in a stream's shape (geomorphology), which can in turn cascade to further changes in shape and effects on water chemistry and ecological conditions. But other direct stream impacts can also destabilize stream channels, as noted in the stressors table (Appendix 3). Beyond repairing geomorphic changes when hydrologic problems are addressed, management methods also include repairing direct or deliberate changes to the stream channel from straightening, armoring, and stream crossings such as culverts and fords.

Direct rebuilding of natural geomorphology is not advised in the absence of moderation of flashy hydrology. Thus stream restoration projects that have a stream channel reshaping component should not be undertaken without accompanying stormwater volume and velocity control upstream of the restoration area. Direct rebuilding of natural geomorphology has also been found to be highly disruptive of any existing biological community in the restoration zone, as should be expected when the entire streambed and banks are moved around with heavy equipment. Furthermore, in these cases it has been found that it can take several years for the biological community to return merely to the pre-construction state. Therefore, the best geomorphic rebuilding tools in stream restoration use a "light touch", attempting to disturb as little of the stream channel bed as possible, focusing more on reduction of erosive water energy at high flows through reconnection with the floodplain and reduction of bank erosion through bank reshaping and stabilization. The idea behind the "light touch" is to reduce the most stressful physical impacts and restore stabilizing natural features such as woody bank vegetation to start a natural process of reestablishment of geomorphic features. However, in some cases rebuilding of pool-riffle pattern and reestablishing hyporheic flow (flow under the surface of the stream bed) may be necessary where the geomorphic structure has been greatly simplified and natural processes cannot be easily "jump-started". Therefore, the need for rebuilding of natural shapes and features is one that should be individually addressed for each stream segment.

WATER CHEMISTRY FUNCTIONS – ADDRESSING POLLUTANTS AND CONTAMINANTS

Low water flow conditions and lack of geomorphic complexity can lead to changes in water chemistry, notably dissolved oxygen, and high flows can transport huge amounts of sediment that are stressful to aquatic organisms. However, in urban areas direct pollutant and contaminant sources are abundant, and may be significant enough that the biological community cannot recover even if the hydrology and geomorphology are restored.

The most direct methods of addressing water chemistry problems are the identification and correction of direct discharge sources, most of which are likely to be illicit or unpermitted, and the treatment of runoff that has washed over paved surfaces, carrying numerous contaminants. For direct discharges, it may be difficult to identify the contaminants involved and their source location, but the prevention of discharge is a fairly direct and inexpensive process (unless an extensive legal process is required for enforcement). In comparison, the latter sources typically require stormwater treatment structures (BMPs) to use natural processes of settling, filtration, adsorption, absorption, chemical reactions, and biological metabolism to reduce or convert contaminants to less toxic or disruptive forms. This requires engineering to design them, area for them to be located, and construction effort and materials to install them.

Another significant source of pollutants may be soil water (interflow) or ground water that has been contaminated through dumping of liquids or solids, or leakage from storage areas. However, such contamination requires much more expensive remediation methods, usually involving excavation of contaminated soil or landfill, and pumping and treatment of contaminated groundwater.

ECOLOGICAL FUNCTIONS – ADDRESSING POOR INSTREAM HABITAT AND CLEARED RIPARIAN ZONES

Ecological conditions are ultimately the combination of the aforementioned aspects of stream ecosystems: the hydrology, geomorphology, and water chemistry, and the effects of these factors on organisms. Poor hydrologic, geomorphic, and water chemistry conditions have considerable effects on stream communities. But stream communities may be affected in very directly biological or ecological ways, such as: removal of the riparian forest that disrupts physical conditions in addition to the carbon sources available at the base of the food chain; introduction of invasive aquatic species that disrupt predator-prey relationships or interspecies competition; introduction of invasive terrestrial plant species that take down riparian forest or contribute leaf matter that has different nutrient qualities; and other changes in interactions between plants, fungi, and animals of the stream and the forest.

Stream restoration is rarely carried out through direct restoration of ecological functions, with the exception of riparian reforestation and invasive species eradication. Oftentimes, these methods are used as part of the "light touch" in restoring geomorphic condition, through restoration of the stabilizing functions of the riparian forest.

PRIORITIZATION OF MANAGEMENT MEASURES

As described in the previous chapter, the hydrologic, geomorphic, water chemistry, and biological functions of stream ecosystems are highly interdependent. Disruption of one function will cascade through the other functions, making it difficult to decide where to start restoring stream ecosystem functions. However, we can generally view stream ecosystem functions as a kind of pyramid, where functions above are more affected by those below, but there is less effect in the opposite direction. In terms of direction of effect, for the most part hydrologic conditions dominate all other stream ecosystem functions, geomorphic conditions mostly dictate water chemistry and biological conditions, and so forth. It should be understood these "directions of effect" are not absolute, but used more to identify the aspects of the system that are least affected by the others.

Studies have identified that watershed-wide hydrologic changes underlie a great deal of the impairment of Bolin Creek. As noted in the previous chapter, hydrologic function is impaired in two major ways: in the reduction of base flow and the increase in "flashy" flows. Based on the idea that the other stream ecosystems functions cannot begin to return to a "healthy" state without at least partial improvement of hydrologic function, it would make sense to make management measures that improve hydrologic function a greater priority in implementation. Indeed, many studies have shown that restoring a stream's hydrologic condition leads to the geomorphic, water chemistry, and biological functions restoring themselves through natural processes. This is only the case where more direct stressors to these other functions, such as direct pollution sources, riparian clearing, changes in the food web, or direct modifications to the stream channel are not present. Where these stressors are present, as is common in urban settings, management approaches must improve all of these functions to some degree.

5.3 RETROFITTING AND RESTORATION CHALLENGES

Approaches to controlling stormwater in existing development areas (also known as "retrofitting") range from large regional facilities treating stormwater from a large number of properties, to lot-level stormwater management structures. Retrofitting at any scale suffers from particular challenges that don't exist for new developments. Successful retrofitting requires several things:

1. Space available for the structure and access for maintenance
2. Permission from the owner of the space, or acquisition of the space
3. Funding for engineering design and initial construction
4. Regular maintenance and a funding source for maintenance and repairs
5. An entity responsible for maintenance and repairs
6. A way to guarantee or enforce maintenance and repairs after construction

Regional- and neighborhood-scale stormwater management is for the most part what is used in those areas developed after stormwater management ordinances were enacted. This method requires that stormwater structures are installed at the time of development, when land can be set aside. They provide a mechanism to ensure there is a dedicated location for the structure, that maintenance will be performed (through a bond or other means), and that funds are collected to cover maintenance costs (usually through a property owners association that is responsible for maintenance). Neighborhood-scale stormwater management may be regional for particularly large developments, although the trend currently is to have smaller structures distributed throughout a development. Regional-scale stormwater retrofits are most likely to treat runoff from many different developments. These will also have the benefits of a dedicated location and easement, and usually have funding for regular maintenance. On the other hand, acquisition of property or even stormwater easements after development is considerably more difficult and may be a significant limiting factor.

On the other hand, lot-level stormwater management has the benefit of a fully-distributed approach to stormwater management. Treating runoff as close to the source as possible has been found to be the most effective when installed and maintained properly. Distributed stormwater management mimics natural runoff processes. Increased groundwater recharge is best achieved in a highly distributed manner as well, and is supported by distributed stormwater management.

Lot-level stormwater management addresses the issue of space and responsible entity. There is a single property owner, so these requirements are rather simple. However, in the absence of significantly increased inspection capacity, there is no clear way to guarantee regular maintenance, or even that the structure will be left in place. Property owners generally view their property as under their complete control, and our culture reinforces this view. Even sympathetic or cooperative property owners may not fully grasp the required maintenance and funds required. Property owners associations may be able to enforce maintenance through neighborhood covenants, or at least that the structure stays in place and isn't removed. But there is no mechanism to add such responsibilities to existing associations and covenants.

Successful restoration will involve more than projects and programs. The long-term success of the restoration will also depend on how maintenance is approached. A program for maintenance of stormwater practices in neighborhoods developed in the past decade or so has been set up under NPDES stormwater permits. However, the Bolin Creek Watershed Restoration Team recognizes that a broader maintenance mechanism is needed to fully support watershed restoration efforts. Towards that goal, a request response system is recommended in which anyone can report maintenance needs that can then be provided to the most appropriate entities.

Types of maintenance required include:

- Regular inspection of stormwater devices
- Repair of stormwater devices
- Trash and debris removal
- Vegetation maintenance, including native species establishment, invasive species control, creating vegetated areas that promote infiltration and interception
- Recreational trail and utility corridor maintenance to reduce erosion

Volunteers may assist the BCWRT in maintenance. Maintenance programs can be further developed with local civic groups, scouts, schools, and. Adopt-a-trail programs can be developed to address trail maintenance.

A challenge that Carrboro and Chapel Hill staff (along with most local governments) are currently facing is the development of programs and capacity to inspect and maintain the increasing number of stormwater practices installed as required as lands develop. This applies to restoration and retrofit projects as well as those installed as part of development. Carrboro has committed to a goal of inspecting every private, permitted practice as part of the Town's recently issued NPDES stormwater permit. Chapel Hill has a stormwater utility that provides the support to perform inspections of private BMPs. Both Towns rely on private maintenance of systems, but neither Town has been able to either perform inspections or to reach out to landowners to educate them about their maintenance responsibilities. But for retrofits and restoration projects carried out by the Towns, who is responsible for maintenance and repairs becomes much less straightforward.

5.4 ESTIMATION OF IMPROVEMENT

Given the many types of stressors that impair ecological function, the incremental changes required to improve ecological function in the watershed, and the slow response of biological systems to such changes, it can be difficult to estimate how much improvement any given project will provide, even to estimate how long it would take to see such improvement. There is insufficient literature regarding the results of watershed-scale restoration efforts, especially how the stream biological community responds and how quickly, to be able to predict changes in Bolin Creek relative to any particular management method.

However, we can rate conceptualized projects (projects with enough specificity to be able to calculate treatment areas and estimated efficiency) well enough to compare projects of similar kinds, particularly those that have a well-established rating system for management of flow rate, volume, total suspended solids, nitrogen, phosphorus, fecal coliform, etc. At the present time, this method of rating benefits is largely confined to formally-engineered stormwater control structures, although there is better understanding about the effects of various ecosystem restoration methods and erosion control and soil protection methods. Where possible, calculations will be run to determine the hydrologic and chemical changes an engineered structure could be expected to provide and recorded in the "projects" part of the geodatabase.

In particular, we can describe the hydrologic and geomorphic improvements an engineered project is expected to provide by projected changes in streambank or streambed erosion based on estimates of changes in shear stress. The most commonly used method for estimating streambank erosion is the Bank Erosion Hazard Index (BEHI) combined with an estimate of Near-Bank Stress (NBS). NBS can be estimated from the kind of hydrologic modeling that is used to estimate pre- and post-construction runoff rate and volume.

We can describe the chemical improvements an engineered project is expected to provide for particular constituents that have crediting systems set up for them, such as total suspended solids, nitrogen compounds, and phosphorus compounds. In particular, the Jordan Lake Nutrient Accounting Tool would be most useful for these estimates. There are published removal efficiencies for other constituents that can be referenced if needed.

Estimating chemical source reduction (such as from detecting and eliminating illicit discharges) relies on being able to get a good estimate of the source discharge constituents, concentrations, and total volumes. This kind of information is usually more difficult to get than even detecting the discharge in the first place.

To our benefit, to meet the needs of Jordan Lake nutrient management, the State is creating a more extensive crediting policy for nutrient management measures, including methods for rating new ideas and technologies. These methods can be incorporated to rate projects as the methods are developed.

It is likely that addressing the hydrologic and chemical problems of the most heavily-developed (and incidentally, oldest) tributaries, Tanyard Branch, Mill Race Branch, and Tanbark Branch would address a significant proportion of the problems in the lower Bolin Creek watershed. These tributaries have consistently scored Poor on measures of macroinvertebrate community integrity, and are likely to comprise a significant proportion of stressor sources in the lower Bolin Creek watershed.

5.5 WATERSHED RESTORATION PROJECTS DATABASE

As part of this planning effort, a geographically-referenced database (a geodatabase) has been created as a centralized way to store information about known stressors (or "problems") and potential water quality improvement projects as a way to help coordinate the multiple organizations that would implement such projects and collect all in one place the many projects that have been recommended or suggested.

"Problems" and their locations have been collected from many sources, including past plans (such as the EEP Local Watershed Plan and the "WARP study"), stream walks, and information from citizens. "Projects" have been collected from even more sources, but include most of the past studies that were summarized in the previous chapter. For completeness even projects that have been rejected as "infeasible" have been recorded in this dataset to prevent futurestaff from having to investigate projects that have already been investigated but results not recorded anywhere. All these projects, and others that have been conceived in the intervening time, have been collected into this one geodatabase. Attributes and documentation for the projects portion of the geodatabase are described in Appendix 8.

For the time being, this geodatabase is used only by the Towns of Carrboro and Chapel Hill, and it is expected that the geodatabase will be split and the Towns will maintain information relevant to their jurisdictions independently of each other. The Towns will apply their own prioritization schemes to their own set of "problems" and "projects" as they are developed. Where these methods of prioritization have been formalized they are presented in the Implementation, Monitoring, and Plan Revision chapter.

5.6 PROTECTION FROM FUTURE IMPACTS

Efforts to restore the aquatic health of Bolin Creek need to also insure that planned new development and redevelopment do not result in new stresses to the creek and its tributaries. Benthic monitoring sponsored by Carrboro in the upper watershed has indicated potential signs of more recent stress, and highlights the need for vigilance in planning for new development in the watershed. The discussion focuses on strategies for better management of erosion and stormwater on development sites to minimize impacts from construction and increased post-development stormwater volume and protection of critical lands and their watershed functions.

CONSTRUCTION PRACTICES

This chapter has described how development can impair soil function through compaction, removal of topsoil, and other kinds of degradation. Ideally, soil functions on a site will be preserved simply by leaving areas undisturbed: no removal of forest cover, no tracking heavy equipment across an area, and no grading or removal of topsoil. However, without completely limiting all development, some soils are going to be disturbed. Fortunately, the same methods that can be used to restore a poorly-functioning soil are even easier to use before an area has been seeded or planted with vegetation.

Other opportunities exist for improvements in protection during the construction phase of projects. One opportunity is to increase the frequency of inspections of construction sites. This could be pursued either via additional staff capacity and/or additional volunteer efforts. The Friends of Bolin Creek have led efforts to train volunteers via the statewide Muddy Water Watch program. Another consideration is that there are ongoing policy investigations at both the federal level and at the state level to adopt new erosion control legislation that would significantly increase the scope of regulations to not only address installation and maintenance of management measures, but require performance standards for turbidity leaving a site as well.

LOW IMPACT DEVELOPMENT

Prevention of further channel erosion and habitat degradation will require effective post-construction stormwater management for all new development in the watershed. Current (and proposed) development regulations for stormwater management have focused on two primary environmental concerns: flood management in the form of peak flow and total volume, and water quality in the form of total suspended solids (TSS) and nutrient concentrations and loads leaving a site. However, even with the best available stormwater management approach, the total volume and peak rate of flow from a developed site can not completely mimic the natural flow volume and peak rate from an undeveloped state. The explicit goal of Low Impact Development (LID) is to maintain a site's hydrology as close as possible to that undeveloped state.

Low Impact Development techniques combined with engineered storm water management practices can be used to achieve volume control that exceeds current regulatory requirements and provides additional protection. The goal of LID is to develop site design techniques, strategies, BMPs, and criteria to store, infiltrate, evaporate, retain, and detain runoff on the site to replicate pre-development runoff characteristics and mimic the natural and unique hydrology of the site thereby minimizing hydrologic alterations relative to pre-development conditions. With LID, storm water is managed in small, source control landscape features rather than in large structures located at the downstream extent of drainage areas. However, ponds may be required in addition to LID practices to create a "treatment train" designed to satisfy volume control performance criteria. Through LID, hydrologic functions such as infiltration, peak and volume of discharges, and ground water recharge can be maintained with the use of reduced impervious surfaces, functional grading, open channel sections, disconnection and utilization of runoff, and the use of landscaped bioretention/filtration areas. The net result will be to mimic the site's natural hydrologic functions or water balance between runoff, infiltration, storage, ground water recharge, and evapotranspiration. With the LID approach, receiving waters experience little change in the volume, frequency, or quality of runoff or in the base flows fed by ground water.

There is a wide array of impact reduction and site design techniques that allow the site designer to create storm water control mechanisms that function in a similar manner to natural control mechanisms (see Table 11). In technical terms, LID provides an added layer of protection by both increasing the time of concentration (T_c) and decreasing the runoff curve number (CN). Time of concentration is defined as the time required for runoff to flow from the most remote point of a drainage area to the outlet or downstream most point in a drainage area. The runoff curve number is an empirical parameter developed by the USDA Natural Resources Conservation Service and used in hydrology for predicting direct runoff and infiltration. It is widely used and is an efficient method for determining the approximate amount of direct runoff from a rainfall event in a particular area, based on based on the area's hydrologic soil group, land use and cover, treatment and hydrologic condition.

An example of a specific LID performance standard is that no one BMP shall receive runoff from an area greater than, for example, five (5) acres. LID can be a challenging standard to meet, and one that is most frequently implemented for lower-density development. The Pacifica development in Carrboro presents an example of a successful extremely thoroughly studied higher density LID project. In many cases, the LID approach will allow developers to save money by reducing infrastructure costs.

Table 11: Low Impact Design Techniques

Low Impact Design Goals	Flatten slope	Increase flow path	Increase sheet flow	Increase roughness	Minimize disturbance	Flatten slopes on swales	Infiltration swales	Vegetative filter strips	Constricted Pipes	Disconnected impervious areas	Reduce curb and gutter	Rain barrels	Rooftop storage	Bioretention	Revegetation	Vegetation preservation
Increase Infiltration					X		X	X		X	X			X	X	X
Increase Time of concentration	X	X	X	X		X		X	X	X	X	X	X	X	X	X
Retention							X	X				X	X	X	X	X
Detention						X			X			X	X			

CRITICAL LAND PROTECTION

The upper part of the watershed contains currently undeveloped or minimally developed lands with the most likelihood of future development, whereas the middle and lower watershed will see little new development but some redevelopment in the coming years. This low-density and rural land is almost exclusively all in Carrboro's Northern Transition Area. As new development level increases, will there be sufficient regulatory methods to ensure that stream runoff and associated pollutants and stresses will not increase and cause further impact on the already stressed stream channels and biota?

High conservation value lands for a variety of ecological services have been identified in the past in multiple studies, including the EEP Local Watershed Plan, a study of land conservation for terrestrial wildlife ("Landscape for Wildlife in Orange County"), and a conservation study and newly adopted conservation requirements for Carolina North, 900+ acres of largely undeveloped university property in the middle of the two Towns. The North Carolina Wildlife Commission has also developed a "Green Growth Toolbox", with specific recommendations presented to Orange County governmental staff, that provides conservation oriented recommendations for "greener" developments. Education and outreach to all stakeholders and ongoing consideration of approaches to better protect critical lands is a necessary component of watershed management efforts.

RECOMMENDATIONS FOR PROTECTION

The following steps are recommended to further extend watershed protection for developing and redeveloping lands.

Local governments can encourage and require where possible that stormwater management for new development use "Low-Impact Development" techniques. LID practices or a combination of LID and conventional storm water management practices can be used to control and treat the increase in storm water runoff volume associated with postconstruction conditions as compared with preconstruction (existing) conditions. This may be achieved by hydrologic abstraction, recycling and/or reuse, extended detention or other accepted management practices that increase the time of concentration and decrease runoff curve numbers, and address geomorphically relevant flows. One specific step that Carrboro can take is to add a provision like Chapel Hill's in its Land Use Ordinance for stormwater volume control. A regulatory step that both local governments can take is to encourage LID by limiting the area that any one BMP can treat. Local governments can increase their capacity for inspection and enforcement of relevant local regulations, including erosion control, stormwater management, buffer protection and integrity, and other relevant ordinance provisions. Local governments can also review and amend ordinance provisions that provide additional steps to increase infiltration and interception through soil, vegetation, and runoff management and additional protection of watershed critical areas. Carrboro can specifically review and update its Land Use Ordinance for open space protection to include approaches to insure that required open space is composed of substantial areas that provide ecological services. As is, significant areas of open space can include recreational playfields, utility easements, and other areas that provide minimal ecological services, including maintenance of hydrologic functions.

IMPLEMENTATION, MONITORING, AND PLAN REVISION

6.1 OVERVIEW

Previous chapters focused on public stewardship and general descriptions of available management and restoration measures. This chapter lays out concrete steps for the two Towns to undertake for turning the vision of restoring the aquatic health of Bolin Creek into a reality.

As the first step in implementation, the Towns of Chapel Hill and Carrboro are being asked to adopt this Plan. Through adoption of this document as the official plan, the community is better able to shape decisions so that they fit with the goals of this plan. Adoption of this plan also will help shape future development and redevelopment so that the resulting built form achieves the goals and vision of this plan. Importantly, adoption is key to securing funding from state and federal agencies in support of implementing the recommendations of this plan.

The implementation process listed below encompasses a mixture of both broad and specific early strategies that are recommended for stewardship, retrofits and restoration projects, funding, responsible parties and roles, and a time frame. Following these implementation steps will provide structure to the entire effort, avoid pitfalls experienced in earlier retrofit efforts, and should help ensure that watershed restoration is progressing on track. These details will make it easier to identify problem areas and update this plan.

Watershed Restoration has already begun in the form of public outreach, involvement, and actions individuals can take as described in the Watershed Stewardship chapter. The Stewardship effort is an essential part of implementation, since understanding and support from the public will be essential to more capital-intensive implementation.However, as recommended in prior studies, stormwater retrofits and stream restorations targeted directly in the most intensely-developed parts of the two towns will be necessary to the restoration of Bolin Creek's biological health.

6.2 CARRBORO RESTORATION PRIORITIES AND IMPLEMENTATION

In Carrboro, the most heavily-developed, and oldest, part of Town in the Bolin Creek watershed drains to Tanbark Branch and an adjacent unnamed tributary (which has been named Shetley Branch) as part of developing this plan. Biological sampling associated with a recent restoration project at Baldwin Park shows that Tanbark Branch has Poor biological integrity. This part of the watershed within Carrboro: is at highest risk for illicit discharges and sites of groundwater contamination; has stream impacted by piping, channelization, or other direct and indirect modifications; has minimal stormwater controls and extensively-cleared riparian zones; and demonstrates compromised geomorphic conditions. In association with the more intensive development, these tributaries in Carrboro have the highest degree of impairment, and are "exporting" some of their problems downstream to Bolin Creek in the form of flashy flows, heavy sediment loads, high stormwater temperatures, and chemical pollution.

Similar studies as have been done on Tanyard Branch and Mill Race have not been completed for these tributaries. Carrboro staff have therefore not had the opportunity to determine the best strategy for moving forward with implementation, beyond these observations:

1) There is a stream daylighting/restoration opportunity at the headwaters of Tanbark Branch that warrants further study
2) The Town has already committed in its Capital Improvements Program to complete a significant stormwater/restoration project adjacent to Carrboro Elementary School at the headwaters of Shetley Branch
3) Prioritizing these watersheds for municipally led efforts would compliment efforts in Chapel Hill described above and result in the highest likelihood of improvements to Bolin Creek.

Carrboro also is home to the headwaters of Bolin Creek, the section of the watershed facing the most development pressure. It is critical for Carrboro to protect the headwaters from new impacts as this area continues to develop. By the nature of land use patterns in Carrboro, it is also essential that watershed restoration efforts have a strong distributed, residential focus with broad participation.

6.3 CHAPEL HILL RESTORATION PRIORITIES AND IMPLEMENTATION

In Chapel Hill, the most heavily-developed, and oldest, parts of Town drain to Tanyard Branch and Mill Race. Biological sampling in 2011 and 2012 shows that both of these tributaries show Poor biological integrity. Based on staff experience, both tributaries are exposed to illicit discharges and sites of groundwater contamination; have considerable lengths of stream impacted by piping, channelization, or other direct and indirect modifications; have no stormwater controls installed throughout the drainage area; have extensively-cleared riparian zones; and demonstrate some of the worst geomorphic conditions. Quite simply, of all the Bolin Creek tributaries in Chapel Hill, these have by far the worst conditions. There is no doubt these two tributaries are "exporting" some of their problems downstream to Bolin Creek in the form of flashy flows, heavy sediment loads, high stormwater temperatures, and considerable chemical pollution.

One watershed restoration approach would be to install stormwater structures where we find willing property owners. While this approach acclimates residents and property owners to modern methods of lot-level stormwater management, it's quite likely these volunteers will not be located in the two watersheds most in need of stormwater retrofit of existing development. Furthermore, Chapel Hill's staff have experienced the difficulty of trying to site a small stormwater management project that was targeted to address a specific problem. Town staff spent considerable time and effort in outreach to gain property owner support for a project that was not expected to improve conditions in Bolin Creek significantly. This is an inefficient use of staff time and resources.

Studies by NCSU staff have shown that in more densely-developed areas, there is a level at which there are greatly diminishing returns for installing stormwater structures to treat nutrients, such as for Jordan Lake retrofit projects. It has been found that the greatest stormwater treatment efficiency (cost for developed area treated) in these areas is provided by regional stormwater treatment facilities that treat a few hundred acres, rather than on widely distributed retrofits each treating only a few acres.

Therefore, to maximize the amount of stormwater improvement for the amount of staff time spent developing project concepts and gaining property owner cooperation, the Town has chosen to focus its efforts on regional stormwater retrofitting of these two tributary watersheds. As a Stormwater Alternatives Analysis for Tanyard Branch has shown, additional distributed stormwater management would still be necessary in lower density portions of the watershed in order to adequately protect the stream from excessive erosion. But these projects can be pursued as part of the public-oriented Watershed Stewardship. In contrast, the complex process to install the required capital-intensive, regional stormwater management in these two tributary watersheds is laid out as a series of implementation steps and milestones as described in Appendix 7.

Implementation would start with detailed stream walk assessments to evaluate stream condition and to look for the small but significant sources of impairment that we suspect we are likely to find, along with other monitoring to get a "baseline" condition. Since we suspect that the primary stressors in these two watersheds are hydrologic changes (specifically, greater flashiness), poor geomorphic condition, poor riparian condition, and considerably-polluted urban runoff, it is likely that some sort of stormwater retention will be necessary to get the situation under control and allow for restoration of the streams where possible along their lengths. Our alternatives analysis for Tanyard Branch has already demonstrated that some amount of stormwater retention in a wet pond is necessary to allow downstream restoration projects to be protected from "blowout". Such a wet pond would also provide much-needed chemical treatment of stormwater runoff. We expect this is likely for Mill Race because it shares similar land uses, densities, ages of development, and geophysical characteristics.

After initial hydrologic monitoring is started, Town engineers can identify alternative management methods that would provide the needed amount of stormwater control to compare and contrast with each other. Working with this information, we will attempt to find multiple acceptable locations on each tributary for a wet retention pond and for alternative management methods for comparison. From there, cost estimates would include the cost for design, construction, and maintenance of the stormwater structures plus costs for land or easement acquisition (including legal and property assessor fees). We would also need to determine whether any utilities would need to be moved, costs for acquiring new utility easements, and costs for any permitting or additional studies that would need to be done.

Because we would be installing these structures with the expressed purpose of conducting successful, stable restoration projects downstream, and incidentally using these restoration areas as mitigation for the portions of perennial stream we would impact with construction of the wet ponds, identification of the potential restoration zone would need to be done with the assistance of the US Army Corps of Engineers. Ideally, we would identify the areas most in need of restoration and estimate the amount of functional uplift we could attain. Depending on adjacent land uses, we may need to come up with alternative restoration scenarios with different amounts of uplift and different project costs. Ideally, we would identify a sufficient segment of stream with adequate uplift potential to meet the mitigation needs for the wet pond impacts. From this point we would do cost estimations similar to those conducted for the stormwater management alternatives upstream of the restoration sites.

Given changing political attitudes of the general public and Town leaders, we feel an explicit monetary cost-benefit analysis is needed to gain the needed support for implementation. These estimates above would form the core of the *costs* of implementing watershed restorations. We would begin to calculate the *benefits* by evaluating the amount of Jordan Lake nutrient retrofit credits we could expect to get. Given we would be treating moderately large areas, with high land use intensities, using reasonably-high efficiency stormwater treatment, the amount of awardable credits could be a significant proportion of the total retrofit burden the Town carries. To get an idea of the value of these credits, we would need to identify other potential retrofits around Town to determine how much it would cost to get a comparable number of retrofit credits in other parts of Town. This will admittedly require cost estimation for a considerable number of stormwater structures, as no other parts of Town have the same land use intensity and are therefore less likely to be able to provide the same amount of credits for the area treated. The difference in costs between downtown treatment and other parts of Town would be in ease of land or easement acquisition and cost of installation.

The second part of calculating benefits would require assistance from NC DWQ. Since it is very likely properly treating these two watersheds could pull sections or all of Bolin Creek off of the Impaired Waters list, we need to know what the monetary value is of doing that. This may be estimated by any fees or charges the Town may face if it does not ever restore the stream sufficiently to remove it from the Impaired Waters list. There are alternative ways of estimating the value of improving the stream's health based on various environmental economics methods of valuing natural resources, and we would request assistance from the Division of Water Quality to get these estimates.

We expect that this is the minimum amount of information that would be required to present to the Town Council, Town Manager, property owners, and general public to win support of this fairly complex pair of restoration projects. We also expect that we will need to do presentations of information gathered at every step. This may be facilitated by holding presentations in cooperation with Friends of Bolin Creek as part of a special symposium or event.

6.4 FINANCIAL AND TECHNICAL ASSISTANCE NEEDED

A premise of this plan is that the commitment is in place to secure the funding necessary to immediately begin the short-term phase work, and start working on a funding strategy that will allow the community to incrementally complete many of the recommendations over a 5-10 year period. Recommendations are most likely to be undertaken effectively if a reliable long-term source of funding is available. Possible sources include grants, stormwater utility fees, or other local government financing mechanisms. The Town of Chapel Hill has developed a stormwater utility that includes program elements to address water quality and quantity through a comprehensive stormwater and floodplain management program. The Town of Carrboro should pursue the development of a long-term funding strategy. Ideally, the Towns should have a budget line item in annual and capital improvement budgets for restoration efforts in order to implement the top priority recommendations. It is also recommended that each Town establish a Bolin Creek restoration fund and use it to pursue municipal projects. Meanwhile, Town staff will continue to pursue state/federal funding support through grants.

Chapel Hill has staff certified for doing civil engineering studies and designs, staff certified/experienced in: environmental outreach and education; project management and planning; mapping and GPS/GIS; surveying;, and environmental assessment and monitoring of many kinds. Their skills cover engineering concept designs, calculation of Jordan nutrient credits, identification of potential retrofit sites, broad public outreach and involvement, and various data collection, monitoring methods, and tasks. Provided these staff are still available during the implementation period, technical assistance is only likely to be required at the points of formal engineering design, assessment/valuation of property or easements, acquisition of property or easements, formal alternatives analysis (for Mill Race only), macroinvertebrate identification, laboratory sample analysis, ecosystem services valuation, and construction of stormwater retrofits, stream restorations, and utility moves. Some technical assistance in the form of review, addressing fine details, or "second opinions" may be needed at many points along the implementation process. We believe NCSU's Water Quality Group/Bio & Ag Engineering staff, NC Cooperative Extension, and NC DWQ staff can provide the needed expertise and advice in these cases.

For Chapel Hill, the greater restriction on progress will be the cost of implementation. As Appendix 7 makes clear, even an estimate of costs for a full combination BMP retrofit and stream restoration and associated maintenance are not currently known. However, the Alternatives Analysis for installing a stormwater wet pond at the head of Tanyard Branch estimated approximately $510,000 in capital costs alone to install an "undersized" pond. The most efficient combination of stormwater management that still adequately protected downstream restoration included this pond in addition to extensive retrofits on UNC property and residential areas with capital costs totaling more than $4 million. But these values may be seen as a lower bound on costs for stormwater management in Tanyard Branch, and thus indicates the magnitude of costs Chapel Hill may face in implementation.

Carrboro does not currently have a stormwater utility and by association, the breadth and depth of staff skills and experience as in Chapel Hill. Currently, the Environmental Planner has extensive watershed management experience, but this position is able to dedicate limited time to restoration efforts. Carrboro works with a contract engineering firm, however, this firm to date has not been tasked with supporting watershed restoration efforts. Carrboro therefore has greater technical assistance and capacity building needs than in Chapel Hill to include, but not necessarily be limited to, civil engineering studies and designs, environmental outreach and education, mapping and GPS/GIS, surveying, and environmental assessment and monitoring of many kinds, (macroinvertebrate identification, field and laboratory sample analysis), ecosystem services valuation, and construction of stormwater retrofits, stream restorations, and utility moves. Carrboro also faces a significant hurdle with the cost of implementation, amplified by the absence of a revenue stream through a stormwater utility. The cost that Carrboro may face has not been quantified in this plan, but given the analysis done for Tanyard Branch, estimated costs for Jordan Lake compliance, and experience in other jurisdictions, it is clear that the costs will be significant and will require extensive technical and policy study to estimate and review.

Implementation also includes the extensive public outreach and involvement described in the Watershed Stewardship chapter. Extensive time will be required to produce outreach materials and organize and run events, and it is uncertain whether either Town will have much staff time to devote to this. Outreach materials for Chapel Hill's current 319 grant have run close to $2000, for just a small set of projects. More complex projects will require much more extensive outreach.

The costs of monitoring general watershed conditions and in support of preparing and installing restoration designs can be more easily estimated. The USGS stream gage on Bolin Creek costs $15,000 annually for maintenance (as quoted by USGS). Macroinvertebrate monitoring in both the two Towns combined runs at about $15,000 annually as well (summarized by 2012 collection costs for the entire area, for Bolin only these costs are closer to $8,000). Planned water chemistry monitoring at fairly high frequencies, but at a limited number of sites, may run from $8,000 to $15,000 depending on the number of constituents analyzed. This estimate is based on the cost of water chemistry monitoring conducted from 1994 to 2009, which had a similar number of annual samples collected less frequently at many more sites. Fortunately, Chapel Hill has equipment to conduct continuous water level and temperature monitoring at two small stream sites, using the

ISCO stormwater samplers that were acquired as part of the current 319 grant. (Carrboro does not have similarequipment). Other data collection will use minimal equipment or supplies, and rely primarily on staff time and experience. It may be assumed that combined annual monitoring costs (limited to Bolin Creek watershed) will run between $32,000 and $40,000 annually for the two Towns combined.

6.5 RESPONSIBLE PARTIES, STAKEHOLDERS, AND ROLES

An important goal of this plan is clarity in assignment of responsibility for different aspects of the implementation. The implementation steps described above are specific to the two Towns, and they will have primary responsibility for pursuing these projects because of their complex, capital-intensive nature. But these are just a portion of what will be required to restore Bolin Creek's biological health.

Our streams suffer from a cumulative "death by a thousand cuts" – from many seemingly harmless actions that add up to a large harmful effect. Environmental laws in the past 40 years have dramatically reduced the "big sources" – the singular and intense disruptions of ecosystem function that once happened with great media attention. However, these environmental protection efforts have only slowed the worsening of degradation when it comes to urban stream stressors, not reverse it. Furthermore, our system of laws, being focused on big actions that have demonstrably bad effects, cannot deal adequately with common actions that have infinitesimally small, but still negative, environmental effects. It is difficult to demonstrate to anyone that any particular small action is part of a pattern that causes a significant problem.

Given the distributed, non-point-source nature of impairment in the Bolin Creek Watershed, restoration measures must necessarily be distributed to some degree. The Watershed Stewardship chapter describes many actions individual property owners can take to contribute to watershed restoration. However, small, individual actions that aim to repair the damage from millions of other individual actions may not give a person much gratification, or the feeling that their actions matter. Small, singular projects may appear to have negligible improvement on downstream areas. While individual actions may seem like they make no difference, the difference is evident when many people take such actions. The difference *starts* when individuals demonstrate to others alternative attitudes and behaviors, sharing these with many others. Therefore, it is important for individuals to understand they are very much part of the solution, no matter how small their actions may seem. One of our most important management measures is continual outreach to the public to emphasize that their small contributions are in fact very valuable. Our message must be "Every little bit counts!"

Whether the projects are complex capital improvement projects spearheaded by the Towns, or individual, lot-level, volunteer efforts, the success in pursuing measurable goals at any scale will be in large part a factor of the degree to which private residential landowners can understand and participate and cooperate in the implementation of the plan. This is because most of each Town is in residential development, and areas owned by institutional, commercial, and governmental entities are much smaller (with the exception of UNC's Carolina North property). Institutional and commercial sectors also need to be active and important as the plan is pursued; however, the reality of land use within Bolin Creek lends credence to the idea that ultimately the fate of Bolin Creek is most intimately tied with behaviors and values of the homeowners who reside in the watershed. It is the intent of this plan to support all watershed residents, but especially homeowners, in practices that help restore Bolin Creek and its tributaries.

Many other restoration projects may be implemented by a variety of stakeholders, such as those listed in Appendix 2, with more extensive source types and actions listed in Appendix 4. The Situation Assessment conducted by WECO, as described in the Watershed Stewardship chapter, highlights the great number of stakeholders and their interests. With so many actors, it will be easy for projects to conflict or be lacking in cooperation or coordination. One of the primary recommendations from the Situation Assessment was the creation of a Watershed Restoration Coordinator to bring together the many stakeholders and their interests in a neutral setting, to help coordinate their actions, and maintain a focused implementation of the Watershed Restoration Plan.

An important implementation objective is to insure that watershed planning is integrated with other planning efforts in the community including long-range and current land use planning, economic development planning, and environmental planning. An additional objective is to create the necessary administration capability to oversee the implementation of this plan and the proper maintenance of the restoration practices that are developed. Since Bolin Creek crosses a joint planning and two municipal boundaries, it is important to coordinate efforts to develop a restoration program and projects across administrative boundaries. We believe a Watershed Restoration Coordinator would be in the best position to achieve these objectives.

Because of their intense interest in the restoration of Bolin Creek, and watershed orientation, one possibility is for the two Towns to hire a consultant to act as a Watershed Restoration coordinator, or for the Friends of Bolin Creek to work with the Bolin Creek Watershed Restoration Team and others to create and fund this position. This person would handle the day-to-day implementation of recommended outreach activities described within this plan. Other responsibilities could include working with the BCWRT to periodically update this plan, serving on local advisory boards. This position could initially be part time in nature but may become full time as dictated by workload. The Coordinator could lead efforts to apply for funding, oversee planning, mapping, and design and development of homeowner/neighborhood/business scale projects and programs. The Coordinator should assist the BCWRT with programming, public outreach, and policy development. This new position is necessary given the existing responsibilities of the Towns' staff and the additional responsibilities that would come with implementing this Plan, as well as the other duties as described above. The Coordinator should report to the Bolin Creek Watershed Restoration Team on a regular basis.

6.6 PLAN EVALUATION AND REVISION

This Restoration Plan should be updated periodically and completely updated within the next 5-10 years. Annual reports of restoration activities, including and especially public outreach and involvement activities, and progress along the implementation steps should be attached as an addendum to the existing Plan. It will be the responsibility of the Bolin Creek Watershed Restoration Team in cooperation with interested stakeholders, or the Watershed Restoration Coordinator if that position is funded, to evaluate and monitor the implementation of this Plan. The BCWRT should use the evaluation and review process to evolve and adapt as needed. Land use, transportation, development, the economy, and the overall landscape will continue to change as

Bolin Creek changes. Also, new opportunities or input from an on-going monitoring and evaluation process may emerge, leading to the need to adapt and update the recommendations of this Plan.

Implementation progress can be compared for Chapel Hill against their proposed implementation steps and milestones as shown in Appendix 7. As a formal way to ensure plan evaluation, several "decision points" are noted in Chapel Hill's implementation steps. These are points at which the management approach and implementation steps should be evaluated carefully. If the presented management approach or implementation steps need extensive modification, are infeasible, or are inadequate to address the problem of Bolin Creek impairment, these are the points at which a new management approach or implementation steps would be determined. In this event, the Watershed Restoration Plan would experience a major revision. Small adjustments do not require a revision of the Watershed Restoration Plan, although an addendum should be added with a revised series of steps or milestones as appropriate.

6.7 MONITORING AND EVALUATION OF RESULTS OF PLAN IMPLEMENTATION

Macroinvertebrate monitoring has been used to rate Bolin Creek as impaired, and the Towns have conducted additional macroinvertebrate monitoring on the Bolin Creek main stem and its tributaries to try to better understand the sources of impairment as well as to gauge the highest priority tributaries for restoration efforts. Because the sources of impairment are multifold, we believe continuing annual macroinvertebrate monitoring on Bolin Creek and its tributaries using NC DWQ methods is the best way to evaluate progress towards the overall goal of getting Bolin Creek off of the list of impaired waterbodies. Since our management measures and implementation are being targeted towards specific tributaries, macroinvertebrate monitoring on other tributaries will tell us whether we are maintaining water quality standards or whether we have unaccounted-for stressors and sources in these tributary subwatersheds. Should we have negative changes in these tributaries, this will be an indication we need to revisit management measures, our priorities, and implementation.

Since stressor types and sources are so broad and variable in this watershed, we don't believe monitoring other aspects of stream condition will be useful to evaluating progress towards the goal of restoring Bolin Creek's biological health. However, other monitoring will allow us to watch for progress or any other changes to some degree, as well as identify finer-scale stressors and sources for targeted projects. Experience has shown us that sources can be very concentrated indeed, and easy to miss with larger GIS-based or watershed-scale assessments. In cooperation with the Ecosystem Enhancement Program and the US Geological Survey, a real-time stream discharge gage has been installed on Bolin Creek at Village Drive. This position was chosen as the closest practical gaging site to the Towns' mutual boundary, and a good point for monitoring water chemistry. Real-time monitoring (i.e. every 15 minutes) will help us understand Bolin Creek's hydrograph and response to storms, and allow us to detect whether any projects in Carrboro are having a noticeable effect on Bolin Creek's hydrograph.

The Town of Chapel Hill expects to do more targeted assessment and analysis of conditions in the Tanyard Branch and Mill Race tributary subwatersheds as these two tributaries have the highest priority for restoration projects, but also have the most complex combinations of stressors and sources. As shown in Appendix 7, we expect to conduct more detailed stream walks including assessment of habitat condition, culvert condition and fish barriers, geomorphic condition and stability, riparian condition, locations of major and minor stormwater contributions, and potentially water chemistry monitoring. While this monitoring is intended for the purpose of fully understanding the magnitude and type of stressors in each subwatershed, and designing appropriately to mitigate their effects, it can also be used to evaluate how well full implementation addresses the impairments of these two streams. Such monitoring would need to continue several years past the conclusion of construction to truly evaluate stable post-restoration conditions.

Monitoring results will be used to evaluate stability of conditions in the watershed as a whole, as well as to be vigilant for potential new stressor sources developing. Monitoring may lead to actions such as illicit discharge enforcement, emergency small capital improvements projects, low-tech stream stabilization or enhancement (such as live stake planting), and targeted public involvement and neighborhood projects. These activities should be reported as an annual addendum to the Plan, rather than a Plan revision. Should monitoring indicate a tributary other than Mill Race or Tanyard Branch is experiencing dramatic worsening, this would be a reason to consider a Watershed Restoration Plan revision. Other reasons for plan revision are described in the section above.

APPENDIX 1: EXISTING LOCAL ENVIRONMENTAL POLICIES, PROGRAMS, ORDINANCES, AND PLANS

Appendix 1: Existing Local Agency Policies, Programs, Activities, and Ordinances

Policy or Program	**Jurisdiction**	**Effectiveness for Restoration and Rationale**	**Description**
Town of Chapel Hill 2000 Comprehensive Plan	Chapel Hill	**Low** - Sets general community goals for new development and growth management. May help prevent or reduce impacts to streams from new development.	The Plan spells out goals to minimize disturbance of natural areas, infiltrate stormwater on-site, enhance erosion and sedimentation cotrol standards, and create a Stormwater Utility.
Chapel Hill 2020	Chapel Hill	**Medium** - states community values with regards to new development, growth management, environmental protection, transportation, accessibility, etc. Does have an explicit section on stormwater management and possible stream improvement projects	Includes a significant section on protection of natural resources, particularly calls out protection and improvement of streams and waterbodies, and management of stormwater
Carrboro Vision 2020		**Low** - states community values with regards to new development, growth management, environmental protection, transportation, accessibility, etc.	Includes statements on environmental protection, including protection and improvement of streams and waterbodies and stormwater management
Town Stormwater Management Program, Utility and Advisory Board	Chapel Hill	**High** - program in Chapel Hill that implements watershed restoration projects	The stormwater management program provides a majority of the Town stormwater management programs and Laud Use Management Ordinance administration for stormwater management, Resource Conservation District, National Flood Insurance Program, NPDES Phase 2 permit, and other stormwater and waterbody management. A Master Plan will be developed to include a comprehensive and holistic approach.
Chapel Hill NPDES Phase 2 permit	Chapel Hill	**High** - program involves detection and elimination of illicit discharges which are known to be a contributor to Bolin Creek impairment	Includes programs for public education/outreach/involvement, illicit discharge detection and elimination, post-construction stormwater management requirements, sediment and erosion control requirements, Town operations spill prevention and cleanup practices ("Good Housekeeping")
Carrboro NPDES Phase 2 permit	Carrboro	**High** - program involves detection and elimination of illicit discharges which are known to be a contributor to Bolin Creek impairment	Includes programs for public education/outreach/involvement, illicit discharge detection and elimination, post-construction stormwater management requirements, sediment and erosion control requirements, Town operations spill prevention and cleanup practices ("Good Housekeeping")
Resource Conservation District (RCD)	Chapel Hill	**Medium** - protects existing stream buffers	The RCD is established as a district that overlays other zoning districts established in Article 3.6.3 of the Land Use Management Ordinance and is primarily intended to reduce flood damage and maintain riparian buffers.
University of North Carolina at Chapel Hill Stormwater Management Master Plan	UNC	**High** - program at UNC that implements watershed restoration projects	Individual zoning districts set varying standards for individual tracts of land owned by the University. However, the University has committed itself to responsible stormwater management.
Capital Improvements Drainage and Open Space Bond Projects	Chapel Hill	**Medium -** many stormwater retrofits would be rated, ranked, and funded through this program	The CIP identifies capital needs and identifies funding sources for capital projects.
Tree Protection	Chapel Hill	**Medium** - reduces degradation due to new development	The Town recognizes trees are a contributing element of economic and environmental value and provide a mechanism to control flooding and places strict regulations on tree removal at construction sites. Abundance of trees in Town contributes to debris removal after ice or wind storms.

Appendix 1: Existing Local Agency Policies, Programs, Activities, and Ordinances			
Policy or Program	**Jurisdiction**	**Effectiveness for Restoration and Rationale**	**Description**
Zoning Districts, Uses, and Dimensional Standards	Chapel Hill	**Medium** - reduces degradation due to new development	The zoning district section recognizes the RCD and WPD (see below) as overlay districts. Land use intensity restrictions are established for each zone in Article 3.5.
Watershed Protection District (WPD)	Chapel Hill	**Medium** - puts limits on new development intensity in the Jordan Lake critical area	The WPD is established as a district that overlays other zoning districts established in Article 3.6. The WPD is primarily intended to preserve water quality, pursuant to North Carolina General Statues, Chapter 143, Article 21.
Zoning Districts, Uses, Dimensional Standards, Stormwater	Carrboro	**Medium** - reduces degradation due to new development	Land use intensity restrictions are established for each zone. Stormwater management and other requirements are components of the manual that serve to mitigate natural and manmade hazards.
Design Manual and Standard Details	Chapel Hill	**Medium** - reduces degradation due to new development	Design manual and standard details provide guidelines for overall design performance and safety. Stormwater management and other requirements are components of the manual that serve to mitigate natural and manmade hazards.
Hazard Mitigation Grant Assistance Program/ Flood Mitigation Assistance Program	US Government	**Low** - Grant source for potential property acquisition along streams, must be to remove structures from floodplain	The Town has received a Flood Mitigation Assistance grant to remove three houses from the Bolin Creek floodway.
Flood Damage Prevention Ordinance	Chapel Hill	**Low -** prevents further development in the floodplain and any changes to existing structures must protect from flooding	Restricts or prohibits uses which are dangerous to health, safety, and property due to water or erosion or flood heights or velocities. Requires that uses vulnerable to floods to be protected against flood construction at the initial time of construction. Controls the alteration of natural floodplains, stream channels, and natural protective barriers, which are involved in the accommodation of Flood waters. Controls filling, grading, dredging, and other development which may increase erosion or flood damage. Prevents or regulates the construction of obstructions which will unnaturally divert flood waters or which may increase flood hazards to other lands.
Soil Erosion and Sedimentation Control	Chapel Hill	**Medium** - prevents or reduces degradation to streams during construction activities	This ordinance has the purpose of regulating the clearing, grading, excavating, filling, and manipulation of the earth and the moving and storing of waters in order to: control and prevent accelerated soil erosion and sedimentation, prevent the pollution of water, prevent damage to property, maintain the balance of nature, prevent the obstruction of natural and artificial drainageways, and inhibit flooding and reduce the undermining of roads and other transportation features.
Steep slopes building restrictions	Chapel Hill	**Medium** - prevents or reduces degradation to streams as a result of new development siting/conditions and methods used in steep areas	The purpose of this section is to minimize the grading and site disturbance of steep slopes by restricting impervious surfaces and land disturbance in such areas, and by requiring special construction techniques in steeply sloped area in order to: Protect water bodies (streams and lakes) and wetlands from the effects of erosion on water quality and water body integrity, Protect the plant and animal habitat of steep slopes from the effects of land disturbance, and Preserve the natural beauty and economic value of the town's wooded hillsides.
Open Space and Greenways Programs	Chapel Hill	**Medium** - may provide locations for some retrofit demonstration projects	The Town's Open Space and Greenways Programs target tracts of open lands for acquisition to maintain the property as open space and to install a paved greenways system for alternative pedestrian and bike transportation away from streets.

Appendix 1: Existing Local Agency Policies, Programs, Activities, and Ordinances

Policy or Program	Jurisdiction	Effectiveness for Restoration and Rationale	Description
Stormwater Structures Inventory	Chapel Hill	**High -** important to implementation of illicit discharge and detection program, important to identifying promising stormwater management retrofit locations	The developing Storm Sewer Inventory, which includes inlet and outlet locations, elevations and conditions and network of sewers, should be properly managed through a Geographic Information Systems (GIS) format.
Stormwater Maintenance database	Chapel Hill	**High** - database with a ranking system to quickly and effectively prioritize capital improvements and drainage assistance projects, method for ranking restoration projects	The Town currently has a "Stormwater Maintenance Program" database underway that lists stormwater/flood problem areas in Chapel Hill. Further planning, modeling and ranking needs to be performed.
Bolin Creek Problems and Projects Geodatabase	Carrboro and Chapel Hill	**High** - database of identified water quality problems and proposed solutions, proposed retrofits for managing stormwater in existing development, method to rank problems and projects, helps with coordination between jurisdictions, preserves important information in the midst of staff turnover	Database of identified/known stream condition problems in the two jurisdictions, proposed stormwater retrofit projects to address identified problems or to reduce nutrient export
Jordan Riparian Buffer Protection	Chapel Hill	**Medium** - protects existing riparian buffers	Stream buffer protection ordinance that is more restrictive than RCD, requires reforestation in the event of avoidable impacts, or mitigation in the event of unavoidable impacts
Jordan "new development rule"	Chapel Hill	**Medium -** prevents or reduces additional degradation from new development by controlling nutrients	New development stormwater management requirements that include specific reductions in nitrogen and phosphorus loading resulting from development
Jordan "existing development retrofit" requirements	Chapel Hill	**High -** program that requires installation of stormwater structures to treat nutrients in runoff in existing development areas	Stormwater retrofitting requirements that set targets for stormwater retrofit installation in areas of existing development for the purposes of reducing nitrogen and phosphorus export from existing development, particularly where no stormwater management methods currently are in use
Streetscape	Chapel Hill	**Medium -** may provide locations for some retrofit demonstration projects in Downtown area	Downtown street beautification project that seeks to improve connectivity along downtown streets in a way that is attractive and consistent, includes street tree planting
Jordan Riparian Buffer Protection	Carrboro	**Medium** - protects existing riparian buffers	Stream buffer protection ordinance that is more restrictive than State rules, including wider buffers and protection of ephemeral streams
Jordan "new development rule"	Carrboro	**Medium -** prevents or reduces additional degradation from new development by controlling nutrients	New development stormwater management requirements that include specific reductions in nitrogen and phosphorus loading resulting from development
Jordan "existing development retrofit" requirements	Carrboro	**High -** program that requires installation of stormwater structures to treat nutrients in runoff in existing development areas	Stormwater retrofitting requirements that set targets for stormwater retrofit installation in areas of existing development for the purposes of reducing nitrogen and phosphorus export from existing development, particularly where no stormwater management methods currently are in use

APPENDIX 2: LOCAL ENVIRONMENTAL MANAGEMENT GOVERNMENTAL DEPARTMENTS, AGENCIES, AND ORGANIZATIONS

Appendix 2: Local Environmental Management Departments, Agencies, and Organizations				
Department, Agency, or Organization	**Affiliation, Jurisdiction, or private NGO**	**Delegated Water Resources Activities**	**Other Activities Affecting Water Resources**	**Possible Water Resource Activities**
Town Manager	Town of Chapel Hill	Designated Floodplain Manager	decisions regarding other divisions that have an impact on stormwater, stream health, or Stormwater Management Div activities	place importance on all divisions contributing to stormwater and stream health improvement; provide leadership and strongly encourage cooperation between divisions
Planning Department - Current Development	Town of Chapel Hill	enforces environmental regulations in the Land Use Management Ordinance (on "front end" during development application phase); guides Town in implementation of 2020 Comprehensive Plan (has a strong water resources component)		continue good cooperation on riparian protection and stormwater management regulations, advise SWM of potential development activities and potential opportunities for retrofits done in concert with new/redevelopment
Housing	Town of Chapel Hill	maintenance of storm drains on their property	maintenance of Town housing facilities including trash collection	cooperate with SWM to educate residents on proper grease and trash disposal, keep properties free of trash, identify and handle repeat littering offenders
Public Works - Traffic Division	Town of Chapel Hill		main contact with NCDOT, including bridge/culvert inspections and related NCDOT road maintenance	assist with traffic management when stormwater retrofit or stream restoration projects affect traffic on streets
Public Works - Stormwater Management Division	Town of Chapel Hill	responsible for implementing the Town's NPDES Phase 2 permit; implementing Jordan rules for riparian buffer protection, nutrient reduction from new and existing development; compliance with NFIP floodplain regulations; Town-wide drainage system maintenance and repairs; drainage assistance for property owners; stream and waterbody monitoring and assessment, etc.		
Public Works - Inspections Division	Town of Chapel Hill	code enforcement including sediment and erosion control, building codes, some stormwater management	enforcement actions for illicit discharge, riparian impacts, etc.	

Appendix 2: Local Environmental Management Departments, Agencies, and Organizations				
Department, Agency, or Organization	**Affiliation, Jurisdiction, or private NGO**	**Delegated Water Resources Activities**	**Other Activities Affecting Water Resources**	**Possible Water Resource Activities**
Public Works - Engineering Division	Town of Chapel Hill	Stormwater Engineering Division reports to Engineering Division; reviews development plans for tree protection ordinance; provides construction inspector who can also review construction of stormwater infrastructure	installs and modifies drainage infrastructure in response to citizen complaints; responds to citizen concerns regarding drainage problems, stormwater regulations, etc.; implements Streetscape	coordinate with Stormwater Management on drainage problems and complaints (direct them to Stormwater rather than try to address them within Eng Div); install (otherwise not required) stormwater management devices where space is available in Streetscape projects
Public Works - Facilities Management	Town of Chapel Hill		drainage repairs/installation at Town facilities	coordinate with Stormwater Management on drainage methods that improve stormwater and stream health; coordinate with SWM on retrofit projects on Town property
Public Works - Administration	Town of Chapel Hill	Illicit discharge and other citations/fees are issued by the Public Works director; directs spill prevention and cleanup practices/training at Town Operations Center	directs drainage complaint problems to various divisions, not always involving Stormwater Management	direct all drainage complaints to SWM, or notify them of complaint and encourage SWM to weigh in on solutions; delegate illicit discharge enforcement more clearly to Stormwater Management Div; place emphasis on staff training in spill prevention and cleanup, providing adequate equipment
Information Technology	Town of Chapel Hill	GIS services, Cityworks support		
Public Works - Streets & Construction	Town of Chapel Hill		some drainage system maintenance and construction related to street construction and maintenance, erosion control and stormdrain protection at streets construction sites	coordinate with Stormwater Management on edge-of-street stormwater retrofits, help identify locations where this might be most suitable/feasible; create coordinated Capital Improvements Project list that can address streets and stormwater issues
Fire	Town of Chapel Hill		Respond to Illicit Discharge/Spill calls - containment and cleanup of toxic substances; wash fire trucks	preventing illicit discharges; coordinate with Stormwater Management on capturing vehicle wash-water and properly disposing or treating it
Police	Town of Chapel Hill		Respond to Illicit Discharge/Spill/Dumping/Littering calls (fill out police reports for these)	

Appendix 2: Local Environmental Management Departments, Agencies, and Organizations				
Department, Agency, or Organization	**Affiliation, Jurisdiction, or private NGO**	**Delegated Water Resources Activities**	**Other Activities Affecting Water Resources**	**Possible Water Resource Activities**
Public Works - Solid Waste / Fleet	Town of Chapel Hill		solid waste management, leaf and yardwaste collection, compactor management downtown	more aggressively manage collective grease pits and trash compactors downtown to prevent illicit discharges into stormdrain system, cooperate with SWM to address areas of persistent littering, dumping, or pressure washing; change leaf collection strategy to reduce leaves in stormdrains
Parks & Recreation - Administration	Town of Chapel Hill		guides and implements Greenways Plan, other recreation uses potentially in riparian zone or floodplain; greenways projects installed in riparian zones may include stream "restoration" not reviewed by SWM	cooperate with SWM on siting and installation of stormwater retrofits and stream restoration projects, siting and installation of greenways paths, siting and installation of other footpaths and stream crossings; become familiar with environmental regulations, how recreation impacts streams
Parks & Recreation - Landscaping Services & Park Maintenance	Town of Chapel Hill		maintains landscaping on rights-of-way, greenways, other Town properties	cooperate with SWM on alternative vegetation species and management methods in riparian zones, identification and eradication of invasive plant species (anywhere in Town); cooperate with SWM on rehab of existing Town BMPs, installation and maintenance of existing BMPs and new stormwater retrofits and stream restoration projects
Parks & Recreation - Festivals and Community Celebrations	Town of Chapel Hill		organizes Town-wide events suitable for environmental issues outreach and education	
Economic Development	Town of Chapel Hill		coordination of development schemes that can include stream impacts, floodplain impacts, stormwater management requirements	become familiar with existing environmental protection regulations and cooperate with appropriate Town divisions on development implementation that adequately protects the environment

Appendix 2: Local Environmental Management Departments, Agencies, and Organizations				
Department, Agency, or Organization	**Affiliation, Jurisdiction, or private NGO**	**Delegated Water Resources Activities**	**Other Activities Affecting Water Resources**	**Possible Water Resource Activities**
Sustainability Office	Town of Chapel Hill	sustainability initiatives related to drinking water conservation	implements Town initiatives related to various environmental resources management and sustainability efforts	place importance on all divisions contributing to stormwater and stream health improvement; provide leadership and strongly encourage cooperation between divisions; hold regular meetings between various divisions that affect environmental resources to come up with coordinated policies, practices, and programs
Planning Department	Town of Carrboro	enforces environmental regulations in the Land Use Ordinance; guides Town in implementation of comprehensive plans; lead for implementing the Town's NPDES Phase 2 permit; implementing Jordan rules for riparian buffer protection, nutrient reduction from new and existing development; compliance with NFIP floodplain regulations; supports stream and waterbody monitoring and assessment	guides and implements Greenways Plan, and other uses potentially in riparian zone or floodplain; greenways projects installed in riparian zones may include stream "restoration"	continue enforcing riparian protection and stormwater management regulations; identify potential opportunities for retrofits done in concert with new/redevelopment
Economic and Community Development	Town of Carrboro		coordination of development plans that can include stream impacts, floodplain impacts, stormwater management requirements	become familiar with existing environmental protection regulations and cooperate with appropriate Town divisions on development implementation that adequately protects the environment
Recreation and Parks	Town of Carrboro			cooperate on siting and installation of stormwater retrofits and stream restoration projects, siting and installation of greenways paths, siting and installation of other footpaths and stream crossings; become familiar with environmental regulations, how recreation impacts streams
Public Works	Town of Carrboro		drainage construction and maintenance related to street construction and maintenance	drainage methods that improve stormwater and stream health; coordinate on retrofit projects on Town property

Appendix 2: Local Environmental Management Departments, Agencies, and Organizations				
Department, Agency, or Organization	**Affiliation, Jurisdiction, or private NGO**	**Delegated Water Resources Activities**	**Other Activities Affecting Water Resources**	**Possible Water Resource Activities**
Environment, Agriculture, and Parks & Recreation	Orange County		natural resources inventory, land trusts	
Health Department	Orange County	restaurant inspection program	promotes Town's training program, calls to collaborate on problem dumping or discharge	
Cooperative Extension	Orange County		Waterwise workshops, education and outreach, Master Gardeners	
Planning & Inspections	Orange County	Erosion control for Chapel Hill and		
Solid Waste	Orange County	household hazardous waste collection, landfill administration	composting education, household hazardous waste outreach, cooperates with CH Stormwater Div	
Orange Water & Sewer Authority	Public Utility	provision of drinking water in service area; provision of sanitary sewer collection and treatment infrastructure in service area	maintenance and replacement of sanitary sewer infrastructure has direct effect on streams because of proximity, educates public about proper disposal of fats/oils/grease, prescription take-back program	cooperate with Towns on moving infrastructure away from streambanks and out of riparian zones when possible; cooperate with Towns on retrofitting stream crossings to reduce impacts to stream geomorphology
Time-Warner Cable	Public Utility		trimming/clearing vegetation in easements, use of herbicides	coordinating with Towns on alternative vegetation management methods that reduce impacts to streams, minimize herbicides, clean up after clearing
Duke Energy	Public Utility		trimming/clearing vegetation in easements, use of herbicides	coordinating with Towns on alternative vegetation management methods that reduce impacts to streams, minimize herbicides, clean up after clearing
Bell South	Public Utility		trimming/clearing vegetation in easements, use of herbicides	coordinating with Towns on alternative vegetation management methods that reduce impacts to streams, minimize herbicides, clean up after clearing

Appendix 2: Local Environmental Management Departments, Agencies, and Organizations				
Department, Agency, or Organization	**Affiliation, Jurisdiction, or private NGO**	**Delegated Water Resources Activities**	**Other Activities Affecting Water Resources**	**Possible Water Resource Activities**
PSNC Energy	Public Utility		trimming/clearing vegetation in easements, use of herbicides	coordinating with Towns on alternative vegetation management methods that reduce impacts to streams, minimize herbicides, clean up after clearing
UNC - Institute for the Environment	State Government - UNC	grants to promote watershed education and support, grant with WECO to assess needs of volunteers working on watershed issues	main partner with local government and agencies in watershed education	
UNC - School of Government	State Government - UNC	provide training and clarification of water resources regulations, stormwater utility funding		
UNC - School of Public Health	State Government - UNC	studies local drinking water and water treatment issues (such as septic failure rates)		
Botanical Garden	State Government - UNC		Botanical Garden Foundation supports Morgan Creek Valley Alliance	
UNC Sustainability Office	State Government - UNC		listserve used for announcements of environmental activities and advice	
NCSU - Bio & Ag Eng	State Government - NCSU	conduct research on stormwater management methods, erosion and sediment control methods, stream restoration methods; provide guidance to design and implement such projects		
NCSU - Water Quality Group	State Government - NCSU	conduct research on stormwater management methods, erosion and sediment control methods, stream restoration methods; provide guidance to design and implement such projects		

Appendix 2: Local Environmental Management Departments, Agencies, and Organizations				
Department, Agency, or Organization	**Affiliation, Jurisdiction, or private NGO**	**Delegated Water Resources Activities**	**Other Activities Affecting Water Resources**	**Possible Water Resource Activities**
NC Emergency Management	State Government	provides and updates FEMA floodplain maps	works with local jurisdictions to create/update hazard mitigation plans which may have a stream restoration component/aspect	
NCDA - Soil and Water Conservation	State Government	provides education and outreach to professionals and general public on stormwater management, stream restoration, gardening/reforestation, soil improvement, etc. (local: Orange County Soil and Water Conservation District)	can provide match funds for grants depending on local watershed activity	can assist with analyzing stormwater and stream problems, can assist with proposing retrofit or restorative projects, can assist in identifying and applying for grants, can implement projects
NC Cooperative Extension	State Government	provides education and outreach to professionals and general public on stormwater management, stream restoration, gardening/reforestation, soil improvement, etc.		can assist with analyzing stormwater and stream problems, can assist with proposing retrofit or restorative projects, can assist in identifying and applying for grants, can implement projects
NC Wildlife Resources Commission	State Government	biological monitoring	workshops, fishing licenses	education through fishing licenses
DENR - Div Water Quality	State Government	creates and enforces statewide water quality laws (including Jordan Rules), conducts stream water quality monitoring, produces assessment reports and watershed plans, provides guidance on restoration activities and grant sources, operates 319 grant program; funds research into water quality improvement methods		
DENR - Div Water Resources	State Government	creates and enforces statewide water resources laws related to drinking water, water wells, instream flow, etc.; funds research into same		
DENR - Div Land Quality	State Government	creates erosion and sediment control standards for the state, local jurisdictions must meet these standards	funds/conducts research on erosion and sediment control alternatives and improvements	

Appendix 2: Local Environmental Management Departments, Agencies, and Organizations				
Department, Agency, or Organization	**Affiliation, Jurisdiction, or private NGO**	**Delegated Water Resources Activities**	**Other Activities Affecting Water Resources**	**Possible Water Resource Activities**
DENR - Ecosystem Enhancement Program	State Government	conducts or facilitates stream mitigation projects for NCDOT	can provide match funds for grants depending on local watershed activity	
NC Department of Transportation	State Government	installs stream crossings for roads, pays mitigation costs when impacts are unavoidable, stormdrain maintenance on DOT roads	retrofit and restoration activities to meet Jordan existing development rules, DOT litter cleanups and high way beautification efforts	cooperate with Towns on installation of stormwater retrofits along NCDOT streets; cooperate with Towns on median and right-of-way vegetation management; state needs improve training and oversight of contractors to ensure adequate erosion and sediment control
Clean Water Management Trust Fund	State Government	provides grants for retrofit and stream restoration projects		
DENR - Div Waste Management	State Government	maintains underground storage tank registry; conducts Superfund dry cleaner cleanups and groundwater testing	recycling/household hazardous waste, pollution prevention pays program	advise Towns of data collection taking place in area for use in planning and assessment
Natural Heritage Program	State Government	identifies valuable and rare natural communities in need of protection	administers some conservation easements	
US Geological Survey	Federal Government	installation and operation of streamgaging program, collection of streamflow and water quality data, scientific studies and reports	maps for Jordan Lake rules	cooperation with Towns on installation of additional streamgages
EPA	Federal Government	ultimately enforce Clean Water Act provisions, including wetlands protection, toxic substances, NPDES, etc.	education resources and grants	assist Towns with identifying and applying for appropriate grants for retrofit or restoration projects
US Army Corps of Engineers	Federal Government	maintain and revise FEMA floodplain maps		assist Towns with permit process for retrofit or restoration projects that take place in the regulatory floodplain
Friends of Bolin Creek	Environmental Non-Profit Organization		public outreach and education; watershed stakeholder group	applying for grants, leading watershed restoration projects; stream and lake cleanups
Haw River Association	Environmental Non-Profit Organization		public outreach and education; watershed stakeholder group	applying for grants, leading watershed restoration projects; stream and lake cleanups
Upper Cape Fear River Basin Association	Environmental Non-Profit Organization		public outreach and education; watershed stakeholder group	applying for grants, leading watershed restoration projects; stream and lake cleanups

Appendix 2: Local Environmental Management Departments, Agencies, and Organizations				
Department, Agency, or Organization	**Affiliation, Jurisdiction, or private NGO**	**Delegated Water Resources Activities**	**Other Activities Affecting Water Resources**	**Possible Water Resource Activities**
Sierra Club	Environmental Non-Profit Organization		public outreach and education; environmental resources stakeholder group	applying for grants, leading watershed restoration projects; stream and lake cleanups
Ducks Unlimited	Environmental Non-Profit Organization		public outreach and education; environmental resources stakeholder group	applying for grants, leading watershed restoration projects; stream and lake cleanups
National Wildlife Federation	Environmental Non-Profit Organization		public outreach and education; environmental resources stakeholder group	applying for grants, leading watershed restoration projects; stream and lake cleanups
Triangle Land Conservancy	Environmental Non-Profit Organization		public outreach and education; environmental resources stakeholder group	applying for grants, leading watershed restoration projects; stream and lake cleanups
Nature Conservancy	Environmental Non-Profit Organization		public outreach and education; environmental resources stakeholder group	applying for grants, leading watershed restoration projects; stream and lake cleanups
NC Water Resources Association	Professional Organization		professional water resources association	education/outreach to their members on stream science, techniques to minimize impact, restoration techniques
NC Association of Environmental Professionals	Professional Organization		professional environmental management association	education/outreach to their members on stream science, techniques to minimize impact, restoration techniques
NC Chapter of the American Public Works Association	Professional Organization		professional water resources association	education/outreach to their members on stream science, techniques to minimize impact, restoration techniques
NC chapter of the American Society of Civil Engineers	Professional Organization		professional civil engineering association	education/outreach to their members on stream science, techniques to minimize impact, restoration techniques
NC chapter of the US Green Building Council	Professional Organization		professional LID/green development association	education/outreach to their members on stream science, techniques to minimize impact, restoration techniques
Triangle J Council of Governments	multi-jurisdictional organization	multi-jurisdictional cooperative organization for addressing a variety of local government issues; host meetings for Jordan Rules, water quality monitoring, etc.	regional education and outreach programs	

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Department, Agency, or Organization	**Affiliation, Jurisdiction, or private NGO**	**Delegated Water Resources Activities**	**Other Activities Affecting Water Resources**	**Possible Water Resource Activities**
Clean Water Education Partnership	multi-jurisdictional organization	multi-jurisdictional cooperative program for environmental outreach		
Chapel Hill Carrboro Chamber of Commerce	non-profit organization			
Chapel Hill Carrboro City Schools	local grade school system		education and public participation	possible locations for stormwater retrofit and stream restoration demonstrations
Boy Scouts of America	non-profit organization		environmental badges/activities, eagle scout projects, participation in watershed events and projects	
Chapel Hill Downtown Partnership	non-profit organization		Mission for a Clean Downtown - leads cigarette butt cleanup campaigns, hires street maintenance workers, promotes clean water messages	
UNC - Engineers Without Borders	Student Organization		environmental education and outreach to students and community; works closely with Rogers-Eubanks neighborhood association on drinking water and sanitation issues	source of volunteers for stream cleanups, etc.
Students United for a Responsible Global Environment	Student Organization		environmental education and outreach to students and community	source of volunteers for stream cleanups, etc.
Carolina Environmental Student Alliance	Student Organization		environmental education and outreach to students and community	source of volunteers for stream cleanups, etc.
Student Environmental Action Coalition	Student Organization		environmental education and outreach to students and community	source of volunteers for stream cleanups, etc.
Students Working in the Environment for Active Transformation	Student Organization		environmental education and outreach to students and community	source of volunteers for stream cleanups, etc.

APPENDIX 3: STREAM STRESSOR PROFILES

Appendix 3: Stream Stressor Profiles

Stressor	Water Quality Effects	Indicators and Assessment Tools
Bacteria-Sewage	• Water becomes unsuitable or dangerous for human contact, can be a source of communicable diseases • Contaminates drinking water sources, requires greater/more extensive water purification • Organic materials are digested by aquatic bacteria, greatly reducing dissolved oxygen (high biochemical oxygen demand or BOD)	• Measurement of fecal coliform levels in water - indicator of fecal contamination and disease organisms • Measurement of other chemicals common to sewage such as fluoride, detergents, optical brighteners, pH, specific conductivity (ionic strength) • Measurement of biochemical oxygen demand (BOD) - indicator of amount of organic matter, or direct measurement of dissolved oxygen • Stormdrain and outfall reconnaissance and surveys - record smells, colors, water turbidity, etc. • Measurement of nitrogen compounds common to human waste in water • Information on locations of sanitary sewer lines and septic systems, sanitary sewer density, age of systems, pipe material
Bacteria-Animal Waste/Other	• Water becomes unsuitable or dangerous for human contact, can be a source of communicable diseases • Contaminates drinking water sources, requires greater/more extensive water purification • Organic materials are digested by aquatic bacteria, greatly reducing dissolved oxygen (high biochemical oxygen demand or BOD)	• Measurement of fecal coliform levels in water - indicator of fecal contamination and disease organisms • Measurement of nitrogen compounds common to mammal and avian waste in water • Measurement of biochemical oxygen demand (BOD) - indicator of amount of organic matter, or direct measurement of dissolved oxygen • Reported waterfowl populations, other wildlife • Areas near greenway trails and other dog-walking locations • Locations of stormdrain networks (hiding places for urban wildlife)
Toxic Leaks	• Chemicals are directly absorbed/consumed by aquatic organisms, negatively affect health, behavior, or reproduction or killing them outright • Contaminate and move through groundwater, affecting receiving streams and drinking water sources, requires very expensive water	• Measurement of specialty chemicals and compounds such as petroleum compounds, dry cleaning chemicals, metals, pesticides/herbicides, cleaning agents, etc. in water • Measurement of pH and specific conductivity (ionic strength)

Stressor	Water Quality Effects	Indicators and Assessment Tools
	• Chemicals may deplete oxygen in streamwater through chemical or biological means	• Measurement of biochemical oxygen demand (BOD) - indicator of amount of organic matter, or direct measurement of dissolved oxygen
	• Chemicals may settle into or attach to stream and lake sediments or be absorbed into food sources, becoming a chronic, long-term source of stress to organisms	• Toxicity assay (LD-50) with aquatic organisms
		• Aquatic organism deformities or disease • Groundwater monitoring • Stream/lake-bed sediment chemical analysis
Soaps and Detergents	• Can be directly toxic to aquatic organisms	• Measurement of detergents, surfactants, optical brighteners, and other cleaning agents in water
	• Disrupt mucus membranes in/on aquatic organisms that protect them from injury, disease, etc.	• Stormdrain and outfall reconnaissance and surveys - record smells, colors, water turbidity, etc.
	• Can change water's pH depending on the cleanser	• Measurement of pH and specific conductivity (ionic strength)
		• Surveys of stormdrains and outfalls for indicators
Streamside (Riparian) Deforestation	• Reduced inputs of natural organic matter for food, habitat, or refuge for aquatic organisms	• Measurement of temperature, especially with in-situ data loggers
	• Reduced shade increases stream temperatures, reduces water's ability to carry oxygen	• Stream walks and similar surveys - collect information on tree cover, solarization, channel stability and erosion
	• Destabilizes streambanks, allowing erosion and scour	• Satellite remote sensing and aerial photography
	• Reduced filtering of pollutants from runoff coming to the stream from uphill	• Aquatic species tolerant of higher temperatures, lower dissolved oxygen
	• Reduced nutrient uptake in runoff and floodwater	• Information on locations of utility lines, roads, and other land uses
	• Increases rate of microbial activity, especially in the presence of organic materials (such as sewage, trash, and yard waste), greatly reducing dissolved oxygen (high biochemical oxygen demand or BOD)	
Scouring & Erosion of Stream Banks	• Changes channel shape and stability	• Streamwalks and similar surveys - qualitative characterization
	• Generates large amounts of fine sediment	• Semi-quantitative characterization such as Bank Erosion Hazard Index or SVAP

Stressor	Water Quality Effects	Indicators and Assessment Tools
	• Changes or outright removes aquatic habitats	• Quantitative measurements such as bank pins and scour
	• Can deeply incise stream channel and cut stream off from floodplain	• Cross-section surveys
	• Lowers local groundwater and base flows	• Exposure of utilities buried in adjacent floodplain
	• Lower groundwater below floodplain can lead to changes in forest community to be more upland	• Structures in floodplain threatened with undermining
	• Stream cut off from floodplain experiences faster, flashier stormflows with even greater stress on banks	
Nutrients - excessive algal growth	• Causes dangerous swings (very high every day, then very low at night) in dissolved oxygen and pH	• Measurements of nitrogen and phosphorus compounds in water
	• May be inedible for aquatic organisms or outcompete other organisms that are the base of the food chain	• Measurement of biochemical oxygen demand (BOD) - indicator of amount of organic matter, or direct measurement of dissolved oxygen
	• May produce chemicals that are toxic to other aquatic organisms or even to humans	• Stream walks and similar surveys - algal density on surfaces, masses, etc.
	• Create unsightly, unpleasant stream/lake conditions for recreation	• Measurement of chlorophyll a in water (suspended algal density)
	• May smother, fill in, or otherwise reduce habitats for other organisms	• Measurements of turbidity, secchi disk depth, or other measure of light penetration
	• Create unpleasant tastes in drinking water that are difficult to remove	• Measurement of pH over the course of a day
	• Increases activity of bacterial decomposers, especially in the presence of organic materials (such as sewage, trash, and yard waste, or overgrown algae), greatly reducing dissolved oxygen (high biochemical oxygen demand or BOD)	• Aquatic organism disease or fish kills
		• Smells and water colors
Fine Sediment	• Directly affects aquatic organisms through inhibited oxygen exchange and other health effects	• Measurement of total suspended solids
	• Covers over aquatic organisms, smothering them or their food sources	• Measurements of turbidity, secchi disk depth, or other measure of light penetration
	• Creates unsightly, unpleasant stream conditions for recreation	• Characterization of embeddedness of streambed (covering of bed materials with fine sediment)

Stressor	Water Quality Effects	Indicators and Assessment Tools
	• Fills in and eliminates places for organisms to find food, hide from predators, and seek refuge during storm flows - simplifies or eliminates habitats	• Quantitative measurements such as scour chains, channel cross-section surveys, and direct sediment collection and analysis • Habitat characterization - types, condition, heterogeneity
Automotive fluids (oil, gasoline, antifreeze, transmission fluid, etc.)	• Directly toxic to aquatic organisms • Coat gills and prevent sufficient oxygen exchange in aquatic organisms • Disrupt mucus membranes in/on aquatic organisms that protect them from injury, disease, etc.	• Measurements of petroleum compounds, ethylene glycol, etc. in water • Measurement of pH and specific conductivity (ionic strength) • Toxicity assay (LD-50) with aquatic organisms • Surveys of stormdrains and outfalls • Aquatic organism deformities and disease
Heavy Metals	• Toxic to organisms to varying amounts depending on the substance and organism • Accumulate in sediments, creating chronically toxic conditions • Contaminate drinking water for people • Accumulate in aquatic organisms, and are magnified up the food chain, affecting wildlife and making fish unsafe to eat	• Measurements of dissolved or suspended metals in water • Measurement of pH and specific conductivity (ionic strength) • Toxicity assay (LD-50) with aquatic organisms • Aquatic organism deformities and disease • Measurements of metals in bed sediments • Measurements of metals in aquatic organism (fish) tissue • Surveys of stormdrains and outfalls
Coal tar sealants, wood preservatives, paint, etc.	• Directly toxic to aquatic organisms • Accumulate in aquatic organisms, and are magnified up the food chain, affecting wildlife and making fish unsafe to eat	• Measurements of polycyclic aromatic hydrocarbons (PAHs) in water and bed sediments • Measurements of other specialty compounds in water and bed sediments • Measurement of pH and specific conductivity (ionic strength) • Toxicity assay (LD-50) with aquatic organisms • Aquatic organism deformities and disease • Surveys of stormdrains and outfalls

Stressor	Water Quality Effects	Indicators and Assessment Tools
Litter and trash dumps	• Can cause all kinds of long-term toxic effects to organisms • Can contaminate groundwater, affecting wells, stream water quality, and drinking water • Create unsightly, unpleasant, and unsafe stream conditions for recreation for miles downstream • Can harbor pests and transmit diseases • When directly along a stream leads to bank failure and erosion • Organic materials are digested by aquatic bacteria, greatly reducing dissolved oxygen (high biochemical oxygen demand or BOD)	• Stream walks and similar surveys • Historical records • Stream cleanups and other citizen observations of trash • Measurements of specialty compounds in water and bed sediments • Measurement of pH and specific conductivity (ionic strength) • Toxicity assay (LD-50) with aquatic organisms • Aquatic organism deformities and disease
Pesticides (insecticides, herbicides, rodenticides, fungicides, etc.)	• Directly toxic to aquatic organisms depending on the substance, concentration, additives, and aquatic organism • Contaminate drinking water for people • Can accumulate in sediments, creating chronically toxic conditions • Can accumulate in aquatic organisms, becoming magnified up the food chain, affecting wildlife and making fish unsafe to eat	• Measurements of pesticides, herbicides, etc. in water, bed sediments, and fish tissue • Measurement of pH and specific conductivity (ionic strength) • Toxicity assay (LD-50) with aquatic organisms • Aquatic organism deformities and disease
Low Base Flow (lower water flow in between storms)	• Reduces available area for organisms to find food, hide from predators, and seek refuge • Allows higher water temperatures and lower dissolved oxygen • Allows greater streambed area to freeze in cold weather, reducing available habitat further • Lower groundwater below floodplain can lead to changes in forest community to be more upland	• Direct in-situ flow/discharge monitoring • Stream gage/level monitoring • Floodplain groundwater level monitoring • Habitat characterizations - wetted streambed width/percentage
"Flashy" Storm Flows, greater volume, greater velocity	• Scours and erodes stream bed and banks • Changes channel shape and stability	• Direct in-situ flow/discharge monitoring • Stream gage/level monitoring, crest stage monitoring

Stressor	Water Quality Effects	Indicators and Assessment Tools
	• Generates large amounts of fine sediment • Changes or outright removes places for organisms to find food, hide from predators, and seek refuge during storm flows • Can deeply incise stream channel and cut stream off from floodplain, leading to low base flows and even higher, faster storm flows • Creates more likely, extensive, or dangerous flash flood conditions • Puts greater pressure on culverts, bridges, and other stream crossings, potentially experiencing more backups and flooding, or even infrastructure damage • Stream channel becomes incised and unable to reach the floodplain, preventing nutrient processing by floodplain forest	
Urban stormwater runoff (contaminants)	• Includes nitrogen compounds, heavy metals, automotive fluids, soaps, "dumpster juice", and pretty much all the other stressor contaminants listed in this chart (see those entries for their effects) • Compound effects from multiple contaminants, presence of some contaminants can increase toxicity of other contaminants	• "first flush" and flow-weighted sampling below stormwater outfalls and in streams
Invasive Terrestrial Species	• Alter forest plant species in streamside (riparian) zone - changing forest ecological community and functions • Pull down/outcompete forest in streamside zone, exposing stream and organisms to more sunlight, higher temperatures, and lower dissolved oxygen • Create unsightly, unpleasant forest conditions for recreation	• Stream walks and similar surveys - riparian conditions and species • Individual reports of infestations
Invasive Aquatic Species	• Outcompete or eat native aquatic species, changing ecological community and functions • Clog up water intake pipes • Produce chemicals that alter health of or kill native aquatic species • Create unsightly, unpleasant stream conditions for recreation	• Invasive species captured during ecological surveys • Individual reports of infestations
Instream Structures Like Culverts, Pipes, Raised Stream Crossings, and Dams	• Present migration and colonization barriers to organisms moving upstream or downstream	• Stream walks and similar surveys - instream habitat and channel conditions

Stressor	Water Quality Effects	Indicators and Assessment Tools
	• Changes water flow patterns, creating more/larger pools and slow-water areas (in turn causing higher temperatures and lower dissolved oxygen)	• Information on utility lines and road culverts
	• Creates permanent areas of channel instability above the structure (sedimentation) and below (erosion and scour) through changes in water flow	• Locations of ponds and lakes
	• Interrupts normal movement of sediment and woody debris habitats that naturally move down stream corridors - creates clogs (and flooding) above and scour/lack of habitat below	
	• Interrupts natural channel processes and forms, reducing available habitat	
Poor Aquatic Habitat	• Reduced organism species diversity	• Stream walks and similar surveys - habitat characterization and condition
	• Reduced absolute numbers of organisms or biomass	• Aquatic organism collection and monitoring
	• Decreased resilience of aquatic organisms to other stresses	
	• Simplified food web	
	• Poor recreational opportunities due to lack of specific organisms	
Increased Water Temperatures	• Reduces water's capacity to hold dissolved oxygen, limits oxygen availability for organisms	• In-situ monitoring of water temperature with data loggers
	• Increases organisms' metabolisms, which increases need for oxygen, increases sensitivity to toxins and diseases	• Spot checks of water temperature

APPENDIX 4: STRESSOR SOURCE PROFILES AND ALTERNATIVE BEHAVIORS

Appendix 4: Stressor Source Profiles and Alternative Behaviors			
Stressor	**Sources / Source Activities**	**Who can detect and/or change?**	**Alternative behaviors?**
Bacteria-Sewage	Sanitary sewer overflows	residents, renters, businesses	Prevent clogs: Don't put FOG (fats, oils, grease) down the drain
			Keep deep-rooting plant species away from sewer lines. Regularly clean out sewer laterals.
		OWASA	Video older lines to monitor condition; educate the public on methods to reduce sewer clogs
	Sanitary sewer leaks	property owners, property managers, UNC	regularly clean out sewer laterals; prevent deep-rooting plants from growing right above lateral line; avoid digging above or disturbing line
		OWASA	video older lines to monitor condition; replace or slipline damaged or leaking lines; protect lines from sagging or damage with proper siting and installation
		plumbers and contractors	properly site, install, and seal new sewer lateral lines to sewer main
	Dumping into stormdrain and other illicit discharges	residents, renters, businesses	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		property owners, property managers, UNC	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		local governments	provide education and outreach to the general public and to specific potential sources (such as restaurants and other commercial establishments) on effects of dumping, proper disposal of materials, proper cleanup of spills, etc.; create ordinances regarding illicit discharges and enforce them
	Septic system leaks and malfunctions	Septic system owners	Regular septic system pumping and maintenance replace system at appropriate time (approximately 30 years)
		local governments	Require inspections at regular intervals or mail out reminders
	Encampments	local governments	provide adequate clean, safe shelter for local homeless population
		social services agencies	provide adequate clean, safe shelter for local homeless population
		Campers, homeless	Shelter with social service agencies; locate encampment away from streams and ponds
	Sanitary sewer cross-connections (connections to stormdrain system)	property owners, property managers, UNC	contract with certified plumber to ensure proper connection of new drain lines; keep up-to-date records of locations of sanitary sewer drains and lines as well as locations of stormdrainage features such as French drains, underdrains, etc.; correct cross-connections as quickly as possible when discovered
		OWASA	provide assistance to low-income property owners to correct cross-connections; coordinate with local governments on identification, investigation, and correction of cross-connections
		local governments	get staff training on methods to detect, trace, and identify sewer cross-connections; conduct stormdrain outfall monitoring to detect cross-connections; map stormdrain networks to enable easier tracing of potential cross-connections; identify sewage constituents that can be used to detect diluted sewage; coordinate with OWASA on identification, investigation, and correction of cross-connections

Appendix 4: Stressor Source Profiles and Alternative Behaviors			
Stressor	**Sources / Source Activities**	**Who can detect and/or change?**	**Alternative behaviors?**
		plumbers and contractors	use standard identification for new plumbing to ensure future upgrades correctly identify sanitary sewer lines; properly install new connections
Bacteria-Animal Waste/Other	Outdoor kennels	veteranarians, kennels, pet care services	Proper animal waste management; make sure drains are plumbed to sanitary sewer system rather than stormdrain system
		pet owners, pet sitters	Proper animal waste management; make sure drains are plumbed to sanitary sewer system rather than stormdrain system
	Urban wildlife, feral animals	local governments	Minimize stormdrain networks that provide hiding places for urban wildlife and feral animals
		animal control agencies	Manage feral animal populations
	Properties with ponds and geese or waterfowl	property owners, property managers, UNC	Replace pondside mowed lawns with taller landscaping to discourage geese, use other geese deterrents; don't feed waterfowl
		property owner associations	encourage property owners to use geese deterrents; discourage feeding geese
	Dogs	pet owners, pet sitters	Pick up after your dog (carry baggies) and dispose in trash cans; encourage others to do so
		local governments	provide sufficient trash cans where people commonly walk dogs; install receptacles that dispense baggies; install signage encouraging people to pick up after their dog
		property owner associations	provide sufficient trash cans where people commonly walk dogs; consider receptacles that dispense baggies; install signage encouraging people to pick up after their dog
	"Dumpster juice" from dumpsters	Waste management companies/agencies	Inspect dumpsters for leaks and missing lids and repair them; do not locate dumpsters over stormdrains; direct dumpster drainage to treatment area or sanitary sewer; make sure dumpster lids and doors are kept closed prevent rain getting in; educate people where dumpsters are improperly used; educate dumpster owners to minimize rainfall into
		property owners, property managers, UNC	Inspect dumpsters for leaks and missing lids and repair them; do not locate dumpsters over stormdrains; direct dumpster drainage to treatment area or sanitary sewer; make sure dumpster lids and doors are kept closed prevent rain getting in; educate residents/rentesr where dumpsters are improperly used
		local governments	educate people where dumpster in proper use; education in proper dumpster use and care for property owners, waste management companies, and renters/residents
		residents, renters, businesses	close dumpster doors and lids after putting trash in; report leaking dumpsters to property owner or management; do not overfill dumpsters
	"Dumpster juice" from trash trucks	Waste management companies/agencies	Inspect trash trucks for leaks and repair them; regular washing of trucks and collection of washwater into sanitary sewer system; store trucks and maintenance areas under cover; education of dumpster owners to minimize rainfall into dumpsters
		local governments	Inspect trash trucks for leaks and repair them; regular washing of trucks and collection of washwater into sanitary sewer system; store trucks and maintenance areas under cover; education of dumpster owners to minimize rainfall into dumpsters
	Farms	Farmers	Proper animal manure management (training available through NC Cooperative Extension); fencing livestock away from streams

Appendix 4: Stressor Source Profiles and Alternative Behaviors

Stressor	Sources / Source Activities	Who can detect and/or change?	Alternative behaviors?
Toxic Leaks	Underground and Aboveground Storage Tanks	property owners, property managers, UNC	monitor tanks for leaks; repair leaks and conduct cleanup of area when found; use alternative materials or sources that don't require on-site storage
		local governments	provide education to property owners regarding proper care and maintenance of storage
	Poor materials management at commercial establishments and industrial facilities	businesses and industrial facilities	have pollution prevention and spill cleanup plans in place; make sure staff are trained in proper materials handling and spill cleanup and have adequate equipment; properly store materials; keep Materials Safety Data Sheets easily available; use less-toxic or non-toxic alternatives; make sure materials are properly labeled and stored in proper containers; inspect containers or storage areas for leaks or tracking and repair immediately
		local governments	design and provide pollution prevention training and materials for commercial and industrial facilities in the jurisdiction
	"Dumpster juice" from dumpsters	Waste management	Inspect dumpsters for leaks and missing lids and repair them; do not locate dumpsters over
		property owners, property managers, UNC	Inspect dumpsters for leaks and missing lids and repair them; do not locate dumpsters over stormdrains; direct dumpster drainage to treatment area or sanitary sewer; make sure dumpster lids and doors are kept closed prevent rain getting in; educate residents/rentesr where dumpsters are improperly used
		local governments	educate people where dumpster in proper use; education in proper dumpster use and care for property owners, waste management companies, and renters/residents
		residents, renters, businesses	close dumpster doors and lids after putting trash in; report leaking dumpsters to property owner or management; do not overfill dumpsters
	Dumping into stormdrains and other illicit discharges	residents, renters, businesses	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		property owners, property managers, UNC	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		local governments	provide education and outreach to the general public and to specific potential sources (such as restaurants and other commercial establishments) on effects of dumping, proper disposal of materials, proper cleanup of spills, etc.; create ordinances regarding illicit discharges and enforce them
	Sewer cross-connections	property owners, property managers, UNC	contract with certified plumber to ensure proper connection of new drain lines; keep up-to-date records of locations of sanitary sewer drains and lines as well as locations of stormdrainage features such as French drains, underdrains, etc.; correct cross-connections as quickly as possible when discovered
		residents, renters, businesses	notify property owner or management company of strange smells coming from stormdrains or known improper sewage connections
		OWASA	provide assistance to low-income property owners to correct cross-connections; coordinate with local governments on identification, investigation, and correction of cross-connections

Appendix 4: Stressor Source Profiles and Alternative Behaviors

Stressor	Sources / Source Activities	Who can detect and/or change?	Alternative behaviors?
		local governments	get staff training on methods to detect, trace, and identify sewer cross-connections; conduct stormdrain outfall monitoring to detect cross-connections; map stormdrain networks to enable easier tracing of potential cross-connections; identify sewage constituents that can be used to detect diluted sewage; coordinate with OWASA on identification, investigation, and correction of cross-connections
		plumbers and contractors	use standard identification for new plumbing to ensure future upgrades correctly identify sanitary sewer lines; properly install new connections
	"Dumpster juice" from trash trucks	Waste management companies/agencies	Inspect trash trucks for leaks and repair them; regular washing of trucks and collection of washwater into sanitary sewer system; storing trucks and maintenance areas under cover; education of dumpster owners to minimize rainfall into dumpsters
		local governments	Inspect trash trucks for leaks and repair them; regular washing of trucks and collection of washwater into sanitary sewer system; storing trucks and maintenance areas under cover; education of dumpster owners to minimize rainfall into dumpsters
	Dumps and landfills (legal and illegal)	See Litter and Trash Dumps	
Soaps and Detergents	Car washing	Mobile car washers	Use biodegradable soap and direct washwater to absorbent grassy/landscaped area; capture washwater and deposit into sanitary sewer system (with arrangement with OWASA)
		car owners	wash cars at car wash establishments; wash cars in grassy areas, or where soapy water can soak into the ground; use biodegradeable soaps
		volunteer and charity organizations	wash cars in grassy areas or where soapy water can soak into the ground; use biodegradable soaps; use spill containment kits to direct soapy water to a sanitary sewer manhole and away from stormdrains; coordinate with OWASA on collection of soapy water and access to sanitary sewer network
		local governments	provide spill containment kits for capturing soapy water and directing to sanitary sewer system; advertise availability of such kits; educate residents and civic groups as to effects of soapy water; coordinate education campaign with OWASA
		car wash establishments	make sure drains are plumbed to sanitary sewer system rather than to stormdrain network
		fire/EMS organizations	wash vehicles in grassy areas or where soapy water can soak into the ground; use biodegradable soaps; use spill containment kits to direct soapy water to a sanitary sewer manhole and away from stormdrains; coordinate with OWASA on collection of soapy water and access to sanitary sewer network
		OWASA	coordinate with local governments to educate residents and civic groups on proper collection of soapy water; provide no/low cost sanitary sewer access for charity events
	Pet washing	veteranarians, kennels, pet care services	make sure drains are plumbed to sanitary sewer system rather than to stormdrain network
		pet owners, pet sitters	wash pets indoors; wash pets in grassy areas, or where soapy water can soak into the ground; use biodegradeable soaps

Appendix 4: Stressor Source Profiles and Alternative Behaviors			
Stressor	**Sources / Source Activities**	**Who can detect and/or change?**	**Alternative behaviors?**
		volunteer and charity organizations	wash pets in grassy areas or where soapy water can soak into the ground; use biodegradable soaps; use spill containment kits to direct soapy water to a sanitary sewer manhole and away from stormdrains; coordinate with OWASA on collection of soapy water and access to sanitary sewer network
		local governments	provide spill containment kits for capturing soapy water and directing to sanitary sewer system; advertise availability of such kits; educate residents and civic groups as to effects of soapy water; coordinate education campaign with OWASA
		OWASA	coordinate with local governments to educate residents and civic groups on proper collection of soapy water; provide no/low cost sanitary sewer access for charity events
	Dumping into stormdrains and other illicit discharges	residents, renters, businesses	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		property owners, property managers, UNC	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		local governments	provide education and outreach to the general public and to specific potential sources (such as restaurants and other commercial establishments) on effects of dumping, proper disposal of materials, proper cleanup of spills, etc.; create ordinances regarding illicit discharges and enforce them
	Camping - hygiene and cooking	Campers	Locate encampment away from streams and lakes; use biodegradable soaps; direct/pour washwater over absorbent soil area away from streams and lakes
	Cleaning - General	residents, renters, businesses	dispose of cleaners and soapy water into sanitary sewer system; make sure residents/employees properly dispose soapy water and know which drains lead to sanitary sewer and which lead to stormdrainage
		property owners, property managers, UNC	make sure drains are labeled or it is otherwise clearly known which drains connect to sanitary sewer and which lead to stormdrain
		local governments	provide outreach and education to businesses and the public about effects of soap on aquatic organisms, how to safely use biodegradable soaps, and clear identification of sanitary sewer vs. stormdrains
	Sewer cross-connections	property owners, property managers, UNC	contract with certified plumber to ensure proper connection of new drain lines; keep up-to-date records of locations of sanitary sewer drains and lines as well as locations of stormdrainage features such as French drains, underdrains, etc.; correct cross-connections as quickly as possible when discovered
		residents, renters, businesses	notify property owner or management company of strange smells coming from stormdrains or known improper sewage connections
		OWASA	provide assistance to low-income property owners to correct cross-connections; coordinate with local governments on identification, investigation, and correction of cross-connections

Appendix 4: Stressor Source Profiles and Alternative Behaviors

Stressor	Sources / Source Activities	Who can detect and/or change?	Alternative behaviors?
		local governments	get staff training on methods to detect, trace, and identify sewer cross-connections; conduct stormdrain outfall monitoring to detect cross-connections; map stormdrain networks to enable easier tracing of potential cross-connections; identify sewage constituents that can be used to detect diluted sewage; coordinate with OWASA on identification, investigation, and correction of cross-connections
		plumbers and contractors	use standard identification for new plumbing to ensure future upgrades correctly identify sanitary sewer lines; properly install new connections
Streamside (Riparian) Deforestation	Development	local governments	design and enforce ordinances that restrict clearing of riparian forest; require mitigation for development that can't avoid removing forest; require reforestation where forest has been cleared
		property owners, property managers, UNC	design development to stay out of riparian zone; reforest already-cleared riparian zones
	Trail building/blazing	local governments	require that trails be located outside of riparian zones except when access to a stream or waterbody is required; provide trail-locating and -building guidance to volunteer organizations to reduce streamside deforestation
		volunteer and charity organizations	learn the locations of riparian zone boundaries and stay clear of them when possible; when stream or waterbody access is required clear the narrowest path possible; use trail-building methods that reduce impacts to forest
	Paved Greenways	local governments	select paved greenway locations outside of riparian zones; design narrower paths; allow native forest vegetation to grow close to greenway path
	Utility easement clearing	aboveground utility companies	require that new utility lines stay away from sensitive environmental areas, cross streams perpendicularly, or affect the minimum area possible; work with other utilities to create shared utility corridors, or similar co-placement that reduces area that needs to be maintained free of trees and other vegetation; work with local governments to educate public on appropriate plants to place above/under different kinds of utilities and how to properly manage vegetation growth; work with local governments to relocate lines away from sensitive environmental areas; work with pedestrian/streetscape representatives and planners to reduce utility-tree conflicts along streets; use root barriers and other methods to reduce utility-tree conflicts; use mechanical vegetation removal rather than herbicides; allow low growing shrubs at stream crossings; control the spread of invasive plant species along utility corridors
		property owners, property managers, UNC	contact utility companies for appropriate plants to put in utility corridors and proper vegetation management

Appendix 4: Stressor Source Profiles and Alternative Behaviors

Stressor	Sources / Source Activities	Who can detect and/or change?	Alternative behaviors?
		local governments	require that new utility lines stay away from sensitive environmental areas, cross streams perpendicularly, or affect the minimum area possible; encourage shared utility corridors, or similar co-placement that reduces area that needs to be maintained free of trees and other vegetation; work with utility companies to educate public on appropriate plants to place above/under different kinds of utilities and how to properly manage vegetation growth; work with utility companies to relocate lines away from sensitive environmental areas; work with pedestrian/streetscape representatives and planners to reduce utility-tree conflicts along streets; use root barriers and other methods to reduce utility-tree conflicts
		belowground utility companies	require that new utility lines stay away from sensitive environmental areas, cross streams perpendicularly, or affect the minimum area possible; work with other utilities to create shared utility corridors, or similar co-placement that reduces area that needs to be maintained free of trees and other vegetation; work with local governments to educate public on appropriate plants to place above/under different kinds of utilities and how to properly manage vegetation growth; work with local governments to relocate lines away from sensitive environmental areas; work with pedestrian/streetscape representatives and planners to reduce utility-tree conflicts along streets; use root barriers and other methods to reduce utility-tree conflicts; use mechanical vegetation removal rather than herbicides; use hardened ford stream crossings designed to maintain channel stability and function, including upstream and downstream effects; avoid the use of or replace aerial stream crossings; avoid the use of or remove culverted stream crossings; control the spread of invasive plant species along utility corridors; use non-invasive species to stabilize cleared easements; select and install plant species that will stabilize stream banks where the line crosses or nears
	Landscaping (clearing)	property owners, property managers, UNC	design development to stay out of riparian zone; reforest already-cleared riparian zones
		residents, renters, businesses	design development to stay out of riparian zone; reforest already-cleared riparian zones
	Other infrastructure (roads, sidewalks, buildings, etc.)	local governments	select locations for infrastructure away from riparian zones; clear the minimum area possible; use designs that allow for lesser impact
Scouring & Erosion of Stream and Banks	Direct piping of roofdrains into creek, or directly into stormdrain system	property owners, property managers, UNC	disconnect roofdrains, downspouts, and yard drains from direct connection with larger stormdrain networks or nearby stream channels, direct them to open areas of property that are landscaped to slow velocity and absorb water; when adding new roofs do not concentrate drainage into a single pipe, disperse into multiple instead
		local governments	programs to encourage downspout and other yard drainage disconnection from the stormdrain network and stream channels; education and outreach to encourage property owners to do this independently
	Direct outlet of stormdrain system into creek	Local governments	stream restoration / BMP retrofit projects that daylight stormdrains further away from stream channels and install energy dissipators in between

Appendix 4: Stressor Source Profiles and Alternative Behaviors			
Stressor	**Sources / Source Activities**	**Who can detect and/or change?**	**Alternative behaviors?**
	Dams/improper bank structures	property owners, property managers, UNC	do not install dams on intermittent or perennial channels; remove dams on existing intermittent or perennial channels (with guidance from local government); redesign dam outlets to allow minimum flow during dry weather and to avoid scour below dam; redesign dam overflows to prevent downstream scour
		local governments	dam retrofit or removal projects in cooperation with property owners
	See Streamside (Riparian) Deforestation above	See Streamside (Riparian) Deforestation above	See Streamside (Riparian) Deforestation above
	See "Flashy" Storm Flows below	see "Flashy" storm flows below	see "Flashy" storm flows below
	Culverts/road crossings	NCDOT	minimize number of street/road crossings; minimize width of crossings; use bridges rather than culverts for large streams; use stream-stable fords rather than culverts on small streams; where culverts are necessary design crossings to be inline with stream flow (don't bend the channel), similar (or even lower) slope than stream channel to prevent increased velocity at the downstream end, artificial riffle structures at downstream end if necessary to maintain a pool above the invert elevation (for fish passage), wide enough to encompass natural stream channel width and natural bank function, add floodplain culverts to reduce channel scour during highest flows
		OWASA	use hardened fords rather than culverts where easements cross streams, make sure fords are designed to mimic natural channel processes but be stable; replace existing culverts with fords where possible
		property owners, property managers, UNC	avoid creating stream crossings; use narrowest crossing necessary and culverts designed to allow natural channel processes and fish passage
		local governments	culvert retrofit projects, or even replacement with hardened ford crossings designed to maintain channel stability; have developers use culvert designs that allow natural channel functions (wider than channel, floodplain culverts, low slopes, etc.) and fish passage
Nutrients - excessive algal growth	Fertilizers	Lawn and Garden stores	stock long-acting fertilizers; get fertilizer management training for staff and management; provide information to customers on soil testing
		residents, renters, businesses	hire licensed landscaping services that have had fertilizer management training; use plant species that require less fertilizer; target fertilizing to proper time of year; use lawn alternatives; use non-chemical fertilizer or other long-acting fertilizer; get soils tested prior to fertilizing to select proper fertilizer type
		landscaping services	use plant species that require less fertilizer; target fertilizing to proper time of year for plant species; create fertilizer management plans customized for individual properties' needs
		property owners, property managers, UNC	hire licensed landscaping services that have had fertilizer management training; use plant species that require less fertilizer; target fertilizing to proper time of year; use lawn alternatives; use non-chemical fertilizer or other long-acting fertilizer; get soils tested prior to fertilizing to select proper fertilizer type

Appendix 4: Stressor Source Profiles and Alternative Behaviors			
Stressor	**Sources / Source Activities**	**Who can detect and/or change?**	**Alternative behaviors?**
		local governments	conduct education campaigns for property owners and residents on the proper use of fertilizers, how to get soils tested, alternatives to lawns, alternatives to chemical fertilizers
	Yard and lawn waste stuffed in stormdrains, dumped in ditches or streams	residents, renters, businesses	bag, compost, or properly store yard waste until it can be picked up by the appropriate company or agency; keep loose leaves away from ditches, gutters, and stormdrains
		landscaping services	bag, compost, or properly store yard waste until it can be picked up by the appropriate company or agency; keep loose leaves away from ditches, gutters, and stormdrains
		local governments	conduct education campaigns for property owners and residents on the negative effects of these behaviors; create ordinances to prohibit these behaviors and enforce them
		property owners, property managers, UNC	bag, compost, or properly store yard waste until it can be picked up by the appropriate company or agency; keep loose leaves away from ditches, gutters, and stormdrains
	Sewage and animal waste (see Bacteria above for sources)	see Bacteria information above	see Bacteria information above
	See Streamside (Riparian) Deforestation above	See Streamside (Riparian) Deforestation above	See Streamside (Riparian) Deforestation above
	Stream channel incised and unable to reach floodplain, preventing nutrient processing by floodplain forest	local governments	do stream restoration projects to reconnect stream to floodplain; do upstream stormwater management projects to reduce hydrologic impacts and reduce scour and erosion; see Scouring & erosion of streambanks
	Atmospheric deposition from combustion sources (coal power plants, vehicle emissions) onto impervious surfaces and subsequent washoff	Everyone	Encourage State and Federal regulation that requires scrubbing of industrial atmospheric emissions and/or replacement of obsolete equipment with cleaner, modern equipment; reduce vehicle miles traveled; encourage mass transit
	Dumping and other illicit discharges	residents, renters, businesses	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		property owners, property managers, UNC	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		local governments	provide education and outreach to the general public and to specific potential sources (such as restaurants and other commercial establishments) on effects of dumping, proper disposal of materials, proper cleanup of spills, etc.; create ordinances regarding illicit discharges and enforce them
	sewer cross-connections	property owners, property managers, UNC	contract with certified plumber to ensure proper connection of new drain lines; keep up-to-date records of locations of sanitary sewer drains and lines as well as locations of stormdrainage features such as French drains, underdrains, etc.; correct cross-connections as quickly as possible when discovered

Appendix 4: Stressor Source Profiles and Alternative Behaviors			
Stressor	**Sources / Source Activities**	**Who can detect and/or change?**	**Alternative behaviors?**
		residents, renters, businesses	notify property owner or management company of strange smells coming from stormdrains or known improper sewage connections
		OWASA	provide assistance to low-income property owners to correct cross-connections; coordinate with local governments on identification, investigation, and correction of cross-connections
		local governments	get staff training on methods to detect, trace, and identify sewer cross-connections; conduct stormdrain outfall monitoring to detect cross-connections; map stormdrain networks to enable easier tracing of potential cross-connections; identify sewage constituents that can be used to detect diluted sewage; coordinate with OWASA on identification, investigation, and correction of cross-connections
		plumbers and contractors	use standard identification for new plumbing to ensure future upgrades correctly identify sanitary sewer lines; properly install new connections
	Evaporation from animal waste lagoons and subsequent aerial deposition	State government	regulations and programs to treat manure or prepare for reuse of some kind
Fine Sediment	Erosion at construction sites	contractors	become familiar with proper installation and maintenance of erosion and sedimentation control methods; follow approved E&SC plans; request client clarify E&SC plan if it is unclear; make sure employees are properly trained
		local governments	require phased development plans, minimal clearing, minimal mass grading, rapid seeding and strawing, and other techniques found to reduce incidents of severe erosion most effectively; require clear erosion and sediment control plans; conduct sufficiently frequent inspection to ensure methods are installed and maintained correctly
		developers	phase development plans to avoid having large areas uncovered at one time; minimize area to be cleared; work with existing topography (refrain from mass grading); have a clear erosion and sedimentation control plan and make sure contractors understand it; ensure proper installation and maintenance of erosion control measures; seed and stabilize cleared areas
	Erosion at non-construction sites - See Streamside (Riparian) Deforestation above (even for areas away from the stream)	See Streamside (Riparian) Deforestation above	See Streamside (Riparian) Deforestation above (even for areas away from the stream)
	See Scouring & Erosion of Stream and Banks	See Scouring & Erosion of Stream and Banks	See Scouring & Erosion of Stream and Banks
Automotive fluids (oil, gasoline, antifreeze, transmission fluid, etc.)	Auto repair shops (via street/parking washoff and direct dumping)	automotive service stations	Properly recycle used motor oil and other fluids; have spill kits available and make sure employees are trained in their proper use; drain fluids from cars in long-term storage
		local governments	educate businesses on effects of these materials on aquatic communities; provide training in proper spill control and cleanup; map stormdrain system to enable tracing to source; levy fines on repeat offenders

Appendix 4: Stressor Source Profiles and Alternative Behaviors			
Stressor	**Sources / Source Activities**	**Who can detect and/or change?**	**Alternative behaviors?**
	Home auto/motorcycle maintenance (via street/parking washoff and direct dumping)	Vehicle owners and DIYers	Properly recycle used motor oil, antifreeze, etc. at local household hazardous waste facility; take auto or motorcycle to repair shop if leaking; have clay cat litter on hand to absorb spills; drain fluids from cars in long-term storage
		local governments	educate public on effects of these materials on aquatic communities; have a functional Illicit Discharge program and ordinance that allows for detection, investigation, and fines as needed
	Dumping and other illicit discharges	residents, renters, businesses	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		property owners, property managers, UNC	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		local governments	provide education and outreach to the general public and to specific potential sources (such as restaurants and other commercial establishments) on effects of dumping, proper disposal of materials, proper cleanup of spills, etc.; create ordinances regarding illicit discharges and enforce them
	Combustion engines of all sizes - cars, trucks, boats, motorcycles, lawnmowers, leaf blowers, generators (via street washoff and direct dumping)	Owners of this kind of equipment	Replace with electric- or battery-powered equipment; properly maintain, check for leaks, and repair; store equipment over paved area to prevent seepage into soil; store equipment under cover to prevent rain washoff into soil; properly recycle used motor oil and other fluids
Heavy Metals (zinc, mercury, lead, cadmium, copper, arsenic, chromium, thallium, selenium, antimony, nickel)	Dust from engines, auto brakes, and other automotive systems (generated in large amounts in properly functioning systems) (via street washoff)	residents, renters, businesses	Drive less; find alternative means of transportation; carpool
		automotive service stations	properly dispose of waste materials from servicing; recycle materials where possible
		local governments	Activities, incentives, and policies to reduce vehicle miles traveled by local population (mass transit, walking/biking options)
		regional planning agencies	Activities, incentives, and policies to reduce vehicle miles traveled by local population (mass transit, walking/biking options)
	Leaded gasoline (via street washoff, direct dumping, or groundwater contamination)	(No longer in use, but persistent in the environment)	
	Lead paint	property owners, property managers, UNC	take steps to control dust when removing paint from buildings; hire contractors familiar with such methods
	Elements naturally present in some geologic formations and soils, slowly eroded, or more	Residents with well water	laboratory testing of well water; install filters; check pipes and replace as necessary
		local governments	monitor streams for very low pH conditions, these conditions dissolve more heavy metals into water and make them bioavailable; address low pH situations as discovered

Appendix 4: Stressor Source Profiles and Alternative Behaviors

Stressor	Sources / Source Activities	Who can detect and/or change?	Alternative behaviors?
	Emissions from coal-fired power plants and refineries of various materials (via atmospheric deposition and street washoff)	Everyone	Encourage State and Federal regulation that requires scrubbing of industrial atmospheric emissions and/or replacement of obsolete equipment with cleaner, modern equipment
	Toxic or potentially toxic chemicals leached from consumer goods being used (Flame retardants, paint and dyes/pigments, ceramics, cigarettes, corrosion inhibitors, pipes)	Everyone	select products that use non-toxic materials; replace existing products that may be leaching toxins or perform maintenance to seal against leaching
	Toxic materials in trash (e.g. batteries, electronics, construction waste, etc.) (via dumping/trash, groundwater contamination)	Everyone	Properly recycle batteries, electronics, and other cosumer goods that contain metals and chemicals that are toxic; contact local waste management agency for proper disposal methods
	Dumping and other illicit discharges	residents, renters, businesses	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		property owners, property managers, UNC	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		local governments	provide education and outreach to the general public and to specific potential sources (such as restaurants and other commercial establishments) on effects of dumping, proper disposal of materials, proper cleanup of spills, etc.; create ordinances regarding illicit discharges and enforce them
Coal tar sealants, wood preservatives, paint, cement, etc.	Coal tar sealants for roads, driveways, and parking lots	residents, renters, businesses	select non-coal-tar sealants or pave with concrete or paving stones
		contractors	select non-coal-tar sealants or pave with concrete or paving stones
		property owners, property managers, UNC	select non-coal-tar sealants or pave with concrete or paving stones
	Dumping and other illicit discharges	residents, renters, businesses	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		contractors	properly dispose of waste materials and wash water, including that from painting, laying concrete, and other jobs; contact local government for assistance in determining proper disposal technique

Appendix 4: Stressor Source Profiles and Alternative Behaviors			
Stressor	**Sources / Source Activities**	**Who can detect and/or change?**	**Alternative behaviors?**
		property owners, property managers, UNC	properly dispose of sewage wastes (which may include bodily wastes, food waste, soaps, etc.) into the sanitary sewer rather than stormdrain; positively identify where small drains connect to (stormwater vs. sanitary sewer)
		local governments	provide education and outreach to the general public and to specific potential sources (such as restaurants and other commercial establishments) on effects of dumping, proper disposal of materials, proper cleanup of spills, etc.; create ordinances regarding illicit discharges and enforce them; provide outreach to contractors regarding proper cleaning and disposal practices
Litter and trash dumps	Loose street litter including cigarette butts, fast food wrappers and cups, plastic bags, etc.	residents, renters, businesses	Put litter in its place; participate in litter cleanups; participate in adopt-a-stream or adopt-a-highway; keep trash cans secured against animals; keep a small trash bag handy in your car, bag, or purse; pick up trash as you find it; encourage others to properly throw trash/cigarettes
		local governments	Provide more trash cans in more types of places (including residential zones); organize community litter cleanups; increase fines for littering; conduct more outreach to encourage greater awareness and sense of pride in a clean community
	Legal trash landfills	waste disposal agencies	Practice proper lining and sealing of landfills; maintain underdrainage systems that direct seepage to treatment facilities; divert hazardous and recyclable materials to appropriate facilities
	Illegal trash dumps	property owners, property managers, UNC	Do not allow dumping on your property; No Dumping / No Tresspassing signage where appropriate; fencing and restricted access to larger properties; clean up dump sites to discourage greater accumulation of trash
		residents, renters, businesses	report dumps and incidents of dumping to local governments
		waste disposal agencies	provide incentives for recycling
		local governments	increase fines for dumping; hold property owners responsible for trash dumps found on their property; have plans for dealing with dumps on properties of low-income owners; have assistance programs to help property owners clean up old dump sites; run volunteer cleanups as part of community outreach to highlight the problem
		trash haulers	properly charge customers to cover tipping fees
		contractors	properly charge customers to cover trash disposal fees; work with agencies like Habitat for Humanity to strip houses destined for demolition and reduce what must be hauled away as trash
Pesticides (insecticides, herbicides, rodenticides, fungicides, etc.)	Weed control, plant disease control	residents, renters, businesses	lay out gardens, especially their complexity and high-maintenance species, to reflect the time you have available for gardening (simplify or pick different species if necessary); weed by mechanical methods; use organic disease control methods; contact NC Cooperative Extension and/or County Master Gardeners for advice
		property owners, property managers, UNC	Use Integrated Pest Management and create pest management plan for long-term; use disease-/pest-resistant plants; contract with landscapers that use fewer pesticides

Appendix 4: Stressor Source Profiles and Alternative Behaviors			
Stressor	**Sources / Source Activities**	**Who can detect and/or change?**	**Alternative behaviors?**
		landscaping services	Use Integrated Pest Management and create pest management plan for long-term; use disease-/pest-resistant plants; weed by mechanical methods; use organic disease control
		farmers	use integrated pest management practices specific to agriculture; create a pest management plan for the long term; stay informed of latest methods through NC Cooperative Extension and other state services
	Building/household pest control	Pest control contractors	Use minimal pesticide methods of control; offer clients advice on non-chemical means for prevention
		property owners, property managers, UNC	Use Integrated Pest Management and create a pest management plan for the long term; hire pest control experts who will use minimal pesticide methods of control; design buildings to resist attack by pests
		residents, renters, businesses	learn about less toxic methods to kill, disperse, or discourage pests
	Utility and road easement clearing	NCDOT	Use mechanical methods to clear areas of woody vegetation or prune away from roads; select species that can be managed by mechanical means
		utility companies	Use mechanical methods to clear areas of woody vegetation or prune away from lines; mow once a year to maintain herbaceous vegetation; select species that can be managed by mechanical means
		landscaping services	provide clients with plant species that can be managed with mowing or other mechanical means
Low Base Flow (lower water flow in between storms)	Reduced groundwater recharge due to impervious surfaces	property owners, property managers, UNC	Remove unnecessary impervious surfaces (especially target impervious surfaces in stream corridors which cause the most hydrologic problems); reorient walkways to reduce area of paved paths; creation of small topographic depressions to store and infiltrate small amounts of rainfall; creation of larger infiltration areas (bioretention, rain gardens, bioswales, etc.); practices to maximize infiltration in permeable areas to offset impervious surfaces
		local governments	regulations that encourage vertical development; encourage redevelopment of brownfield sites; discourage development of greenfield sites; impervious surface limit regulations; require stormwater management in new development that has an infiltration component, or other opportunity for water to soak into ground; retrofit programs to help property owners retain water on site and infiltrate
	Reduced groundwater recharge due to compacted soils, watershed deforestation, and poor infiltration	property owners, property managers, UNC	plant woody plants (preferably trees) where possible to improve soil condition and infiltration capacity; do not clear leaf mulch from under trees (increase soil organic matter); add mulch regularly to landscaped areas to improve soil organic matter; create small topographic depressions to store and infiltrate small amounts of rainfall; increase surface roughness, increase surface hydraulic resistance; create larger infiltration areas (bioretention, rain gardens, bioswales, etc.)

Appendix 4: Stressor Source Profiles and Alternative Behaviors			
Stressor	**Sources / Source Activities**	**Who can detect and/or change?**	**Alternative behaviors?**
		local governments	require reforestation of as much area as possible; require reduce disturbed areas during construction; reduce or restrict mass grading of construction sites; require "soil ripping" or soil restoration after construction; minimize lawn area, especially where using riding lawn mowers; assist property owners with retrofit projects that increase surface roughness, create topographic depressions, create larger infiltration or detention areas, convert lawn to trees/shrubs, etc.
	Streams dredged, straightened, or channelized drain water away from watershed faster and lowers groundwater level	local governments	stream restoration practices that re-establish channel form and profile, slow velocity, raise streambeds and restore hyporheic zones
	Excessive groundwater pumping in area	local governments	restrictions on pumping rate and monitoring to enforce restrictions
	Severe erosion and stream channel incision lowers groundwater level, cuts stream off from floodplain storage	local governments	stream restoration practices that raise streambeds and restore hyporheic zones; practices that reconnect stream to floodplain; practices that restore floodplain function (vernal pools, off-channel storage, side-channels, topographic depressions, etc.)
	reduced valley/floodplain soil infiltration, storage, and interflow due to floodplain impacts/development	property owners, property managers, UNC	avoid compaction of floodplain soils; reforest floodplains to increase soil function; remove driving surfaces and compacted trails from floodplain area and take steps to repair compaction
		local governments	remov/limit development, fill, or compaction in floodplains and valley floors, especially long linear impacts that act as dams between upland interflow and the stream (and practices that mitigate these changes); protect/restore soil infiltration and storage in alluvial/floodplain settings; install cross-drains at depth below surface under roads, greenways, and compacted trails; retrofit projects that restore floodplain function (vernal pools, off-channel storage, side-channels, topographic depressions, etc.)
		OWASA	install cross-draining pipes at depth below surface to enable shallow soil water to cross compacted sanitary sewer easement driving surfaces
	reduced soil permeability along roads due to effects of sodium ions on soil colloids (high road density increases effects of this)	NCDOT	practices which minimize the amount of salt used for de-icing, particularly minimizing sodium-based salts
		local governments	practices which minimize the amount of salt used for de-icing, particularly minimizing sodium-based salts
	faster runoff/drainage of an area due to extensive ditching, french/subsurface drains, tile drainage, or large numbers of	property owners, property managers, UNC	convert ephemeral channels to infiltration zones by slowing down runoff, preventing channel formation/maintenance; protect "ephemeral zone" to provide areas for infiltration; remove/fill in extensive ditching/drains and allow some areas of a property to be "soggy" for a while after rainfall

Appendix 4: Stressor Source Profiles and Alternative Behaviors			
Stressor	**Sources / Source Activities**	**Who can detect and/or change?**	**Alternative behaviors?**
	naturally-formed ephemeral channels (higher drainage density)	local governments	cooperate with property owners to retrofit ephemeral zones and channels to "regenerative stormwater design"
	dams and flow regulation without minimum release requirements	local governments	minimum release standards for inline ponds and lakes (stormwater retention and otherwise)
	leakage of shallow groundwater into stormdrain networks	local governments	repair of stormdrain network to prevent inflow; wrap stormdrain infrastructure with washed gravel and fabric to enable slower GW movement without inflow
	infiltration BMP engineering designs that require rapid drawdown of stored water in order to make room for subsequent storm events	local governments	oversize infiltration BMPs to allow more infiltration of stormwater in highly clayey areas; allow BMPs to take longer to drain (do not use for retention, use specifically for long-term infiltration); require treatment trains that outlet retention BMPs to infiltration areas
"Flashy" Storm Flows (very fast, high rise and fall of flow after rain), greater volume, greater velocity	Increased speed and volume of storm runoff due to impervious surfaces	property owners, property managers, UNC	Remove unnecessary impervious surfaces (especially target impervious surfaces in stream corridors which cause the most hydrologic problems); reorient walkways to reduce area of paved paths; creation of small topographic depressions to store and infiltrate small amounts of rainfall; creation of larger infiltration areas (bioretention, rain gardens, bioswales, etc.); practices to maximize infiltration in permeable areas to offset impervious surfaces
		local governments	regulations that encourage vertical development; encourage redevelopment of brownfield sites; discourage development of greenfield sites; impervious surface limit regulations; require stormwater management in new development that has an infiltration component, or other opportunity for water to soak into ground; retrofit programs to help property owners retain water on site and infiltrate
	Increased speed and volume of storm runoff due to compacted soils, watershed deforestation, and poor infiltration	property owners, property managers, UNC	plant woody plants (preferably trees) where possible to improve soil condition and infiltration capacity; do not clear leaf mulch from under trees (increase soil organic matter); add mulch regularly to landscaped areas to improve soil organic matter; create small topographic depressions to store and infiltrate small amounts of rainfall; increase surface roughness, increase surface hydraulic resistance; create larger infiltration areas (bioretention, rain gardens, bioswales, etc.)
		local governments	require reforestation of as much area as possible; require reduce disturbed areas during construction; reduce or restrict mass grading of construction sites; require "soil ripping" or soil restoration after construction; minimize lawn area, especially where using riding lawn mowers; assist property owners with retrofit projects that increase surface roughness, create topographic depressions, create larger infiltration or detention areas, convert lawn to trees/shrubs, etc.
	Reduced interception and evapotranspiration of runoff due	property owners, property managers, UNC	plant woody plants (preferably trees), as many as possible; consider converting lawn to forest

Appendix 4: Stressor Source Profiles and Alternative Behaviors			
Stressor	**Sources / Source Activities**	**Who can detect and/or change?**	**Alternative behaviors?**
	to too few trees, lack of forest	local governments	require reforestation of as much area as possible; guide property owners and developers to designs that incorporate more trees
	Extensively networked stormdrain systems	local governments	break up extensive stormdrain networks into much smaller networks with opportunities in between to retain or infiltrate stormwater
	Building/roof runoff connected directly to stormdrain system or even directly to stream	property owners, property managers, UNC	disconnect roofdrains, downspouts, and yard drains from direct connection with larger stormdrain networks or nearby stream channels, direct them to open areas of property that are landscaped to slow velocity and absorb water; when adding new roofs do not concentrate drainage into a single pipe, disperse into multiple instead
		local governments	programs to encourage downspout and other yard drainage disconnection from the stormdrain network and stream channels; education and outreach to encourage property owners to do this independently
	Streams in pipes or concrete channels, and streams that are dredged, straightened or channelized run faster than natural-bed streams	local governments	stream restoration projects; watershed-wide retrofits of stormwater management
Urban stormwater runoff (contaminants)	more contaminants washed off of impervious surfaces (than permeable), particularly those with a "direct connection" to the stream system (i.e. no opportunity to run through a permeable area or filtration zone prior to reaching the stream)	local governments	retrofit stormwater into existing developed areas and streets; enact ordinances to prevent new direct inputs of stormwater to streams; retrofit or modify stormdrain networks to outlet a distance away from streams to allow water to flow over vegetated areas
		property owners, property managers, UNC	direct stormwater on property to lawn or landscaped areas
Invasive Terrestrial Species	Utility and road easement clearing and maintenance	NCDOT	Site utilities away from stream corridors, or to cross perpendicularly at as few points as possible; Co-locate utility/road easements to reduce forest disturbance; clean landscaping maintenance equipment between sites to avoid transporting invasive plant species seeds; select mowing times to occur just before invasive plants in an area go to seed; plant native herbs that compete well with invasives; mow narrower easements where possible to maintain closed tree canopy
		public utilities, OWASA	Site utilities away from stream corridors, or to cross perpendicularly at as few points as possible; Co-locate utility/road easements to reduce forest disturbance; clean landscaping maintenance equipment between sites to avoid transporting invasive plant species seeds; select mowing times to occur just before invasive plants in an area go to seed; plant native herbs that compete well with invasives; mow narrower easements where possible to maintain closed tree canopy

Appendix 4: Stressor Source Profiles and Alternative Behaviors			
Stressor	**Sources / Source Activities**	**Who can detect and/or change?**	**Alternative behaviors?**
		contractors and construction companies	clean construction and landscaping equipment between sites to avoid transporting invasive plant species seeds; plant native herbs that compete well with invasives
		landscaping services	clean landscaping maintenance equipment between sites to avoid transporting invasive plant species seeds; select mowing times to occur just before invasive plants in an area go to seed; plant native herbs that compete well with invasives; mow narrower easements where possible to maintain closed tree canopy
		local governments	Site utilities away from stream corridors, or to cross perpendicularly at as few points as possible; Co-locate utility/road easements to reduce forest disturbance; clean landscaping maintenance equipment between sites to avoid transporting invasive plant species seeds; select mowing times to occur just before invasive plants in an area go to seed; plant native herbs that compete well with invasives; mow narrower easements where possible to maintain closed tree canopy; advise property owners and public utilities where invasive plant infestations are found; provide guidance on control of these species
	Landscaping, gardening, uncontrolled growth on properties	property owners, property managers, UNC	Do not plant species on invasive plant lists; become familiar with common invasive plants in your area; remove/kill invasive plants found on your property; prevent invasive plants from going to seed where full removal is not possible; encourage neighbors to remove invasive plants and not to plant them
		local governments	provide incentives to encourage planting native plants; enact and enforce ordinances to restrict planting invasives or require removal; cooperation with plant suppliers to develop/sell native plants or non-obnoxious non-natives and direct shoppers to replacement species for common applications; encourage reporting of potential new invasion locations or species; outreach to the public on the effects of invasive species on forest health and ecosystem functioning; manage publicly-owned property to reduce spread of invasive plants; identify and remove invasive noxious species as soon as possible; prevent invasive plants from going to seed; clean landscaping maintenance equipment between sites to avoid transporting invasive plant species seeds
		residents, renters, businesses	Do not plant species on invasive plant lists; become familiar with common invasive plants in your area; remove/kill invasive plants found on your property; prevent invasive plants from going to seed where full removal is not possible; encourage neighbors to remove invasive plants and not to plant them
		landscaping services	use native alternative plants or non-obnoxious exotic plants instead of noxious invasive species; remove invasive species that are found on customer's properties when not deliberately planted or wanted by the customer; cooperate with plant suppliers to develop/sell native plants or non-obnoxious non-natives and direct shoppers to replacement species for common applications; clean landscaping maintenance equipment between sites to avoid transporting invasive plant species seeds

Appendix 4: Stressor Source Profiles and Alternative Behaviors

Stressor	Sources / Source Activities	Who can detect and/or change?	Alternative behaviors?
		Lawn and garden stores	develop/sell native plants or non-obnoxious non-natives and direct shoppers to replacement species for common applications
	Construction projects in, around, or near streams	local goverments	clean construction and landscaping equipment between sites to avoid transporting invasive plant species seeds; advise contractors of need to control invasive species
		public utilities, OWASA	clean construction and landscaping equipment between sites to avoid transporting invasive plant species seeds; plant native herbs that compete well with invasives
		property owners, property managers, UNC	clean construction and landscaping equipment between sites to avoid transporting invasive plant species seeds; plant native herbs that compete well with invasives
	Feral animals	Pet owners	Do not release unwanted animals; find other owners or look for "rescue" organizations
		Pet breeders	Select traits that reduce an animal's survival in the wild, such as albinism and other showy colors; offer assistance to owners who no longer can care for their animals to find another caretaker; do not release unwanted animals
		animal control agencies	programs that manage feral animal populations; outreach to veterinarians and pet owners to not release pets, how to find a home for them when the owner can no longer care for them
Invasive Aquatic Species	Boating, canoeing, rafting, kayaking	Boaters and other watercraft users	Inspect boats for any plant materials prior to leaving the boat ramp or access point; brush off any foreign materials and allow to dry before entering another waterbody; educate public to recognize worst species; encourage reporting of potential new invasion locations or species; fully purge any bilge water in large boats over dry land or in the ocean
	Poor health of native aquatic organisms due to stress	Everyone	Reduce other stressors to increase resilience of local ecosystems
	Transferring microbes on felt-bottomed waders	Anglers and fishermen, water resources specialists	Use rubber-bottom waders only; bleach felt bottomed waders before visiting another waterbody
	Superior competition of invasive fish species	Anglers and fishermen, water resources specialists, local and state governments	Allow more extensive fishing of invasive fish species; put bounties on invasive fish species
	Released pets and their diseases	Pet owners (especially fish, amphibians, and reptiles)	Do not release unwanted animals; find other owners or look for "rescue" organizations
	Nutrient overenrichment and algae blooms change physical, chemical, and biological conditions to be unfavorable to native organisms (see Nutrients	see Nutrients information above	see Nutrients information above

Appendix 4: Stressor Source Profiles and Alternative Behaviors

Stressor	Sources / Source Activities	Who can detect and/or change?	Alternative behaviors?
Instream Structures Like Culverts, Pipes, Raised Stream Crossings, and Dams	culverts and piped streams for roads, driveways, and other crossings	NCDOT	minimize number of street/road crossings; minimize width of crossings; use bridges rather than culverts for large streams; use stream-stable fords rather than culverts on small streams; where culverts are necessary design crossings to be inline with stream flow (don't bend the channel), similar (or even lower) slope than stream channel to prevent increased velocity at the downstream end, artificial riffle structures at downstream end if necessary to maintain a pool above the invert elevation (for fish passage), wide enough to encompass natural stream channel width and natural bank function, add floodplain culverts to reduce channel scour during highest flows
		OWASA	use hardened fords rather than culverts where easements cross streams, make sure fords are designed to mimic natural channel processes but be stable; replace existing culverts with fords where possible
		property owners, property managers, UNC	avoid creating stream crossings; use narrowest crossing necessary and culverts designed to allow natural channel processes and fish passage
		local governments	culvert retrofit projects, or even replacement with hardened ford crossings designed to maintain channel stability; have developers use culvert designs that allow natural channel functions (wider than channel, floodplain culverts, low slopes, etc.) and fish passage
	recreational stream impacts (crossings including fords, culverts, bridges)	local governments	minimize number of trail crossings; locate crossings at stable, low-erosion points; make bridges and culverts large/wide enough to pass sediment and debris; use fords rather than
		property owners, property managers, UNC	minimize number of trail crossings; locate crossings at stable, low-erosion points; make bridges and culverts large/wide enough to pass sediment and debris; use fords rather than
	sanitary sewer crossings - both aerial and buried	OWASA	minimize number of stream-sewerline crossings; bury and encase lines well below streambed elevation; bury aerial lines; use hardened, stream-stable fords that behave like riffles (rather than behaving like dams, rather than using culverts); create stepped grade control downstream of buried lines where incision is working headward on a stream; work with property owners to properly run sewer laterals under streams
		property owners, property managers, UNC	work with OWASA and local government to minimize crossing streams with lateral sewer lines and to properly install and protect them from erosion; bury aerial sewer later crossings
		local governments	work with OWASA and property owners to bury aerial crossings; work with OWASA to convert culverted crossings to stream-stable fords that behave like riffles; create stepped grade control downstream of buried lines where incision is working headward on a stream
	dams (farm ponds, improperly placed stormwater ponds, other impoundments)	property owners, property managers, UNC	do not install dams on intermittent or perennial channels; remove dams on existing intermittent or perennial channels (with guidance from local government); redesign dam outlets to allow minimum flow during dry weather and to avoid scour below dam; redesign dam overflows to prevent downstream scour
		local governments	dam retrofit or removal projects in cooperation with property owners

Appendix 4: Stressor Source Profiles and Alternative Behaviors

Stressor	Sources / Source Activities	Who can detect and/or change?	Alternative behaviors?
Poor Aquatic Habitat	Deliberate changes in channel shape due to structures crossing the channel, dredging, straightening, moving, piping, or armoring channel or banks	local governments	stream restoration projects; watershed-wide retrofits of stormwater management
	Deforested riparian zone - few/no inputs of natural organic matter for food or habitat	See Streamside (Riparian) Deforestation above	See Streamside (Riparian) Deforestation above
	Changes in stream flow and channel shape due to flashy storm flows, low base flow, structures crossing the channel, dredging/straightening	local governments	stream restoration projects; watershed-wide retrofits of stormwater management
Increased Water Temperatures	Cleared riparian zones allow direct solarization - see Streamside (Riparian) Deforestation above	See Streamside (Riparian) Deforestation above	See Streamside (Riparian) Deforestation above
	Direct stormwater inputs, especially from hot parking lots and streets	local governments	retrofit stormwater into existing developed areas and streets; enact ordinances to prevent new direct inputs of stormwater to streams; retrofit or modify stormdrain networks to outlet a distance away from streams to allow water to flow over vegetated areas
		property owners, property managers, UNC	direct stormwater on property to lawn or landscaped areas

APPENDIX 5: SELECTED MANAGEMENT AND RESTORATION METHODS

Appendix 5: Selected Management and Restoration Methods			
Type	**Subtype**	**Description**	**Benefits (sources and stressors addressed)**
Engineered Stormwater Control Structures	wet retention ponds	permanently wet ponds designed with extra storage capacity to hold runoff and slowly release it	slow down runoff through retention, reduce runoff volumes through evaporation, reduce downstream streambank/bed scour (reduction in velocity and volume), increase GW recharge when the outlet opens to a good place for infiltration; provide settling time for sediment and solid particles, adsorption of metals to pond bottom sediments, adsorption and uptake of nitrogen and phosphorus in pond bottom sediiments and aquatic plants
	dry detention	basins designed to hold temporarily hold runoff and release it slowly, but drain out entirely	slow down runoff through detention, reduce downstream streambank/bed scour (reduction in velocity and volume) (where outlet is properly designed), provide settling time for sediment and solid particles, adsorption of metals to soil
	bioretention	basins filled with a porous soil media, with internal drainage designed to hold runoff temporarily and slowly release it; some varieties maintain a permanent saturated zone to take advantage of natural soil processes that happen in saturated conditions	slow down runoff through retention, reduce runoff volumes through evapotranspiration, reduce downstream streambank/bed scour (reduction in velocity and volume), increase GW recharge; provide settling time for sediment and solid particles, adsorption of metals to soil media, adsorption and uptake of nitrogen and phosphorus in soil media, soil organisms, and plants
	underground retention	underground structures to temporarily retain runoff and slowly release it over time (basically very large cisterns)	slow down runoff through detention, reduce downstream streambank/bed scour (reduction in velocity and volume) (where outlet is properly designed), provide settling time for sediment and solid particles, adsorption of metals to soil
	open-bottom underground retention	like regular underground retention, but bottom is open to underlying soil, usually with layer of gravel and filter fabric in between	similar to underground retention, but also allows some infiltration and GW recharge, ultimately reducing total runoff volume
	level spreaders	flat concrete structures that diffuse concentrated runoff over a large area to reduce its erosivity	reduce velocity/energy of concentrated runoff, disperse flow

Type	Subtype	Description	Benefits (sources and stressors addressed)
	stormwater wetlands	complex bio-engineered areas combining multiple levels of inundation and runoff storage, taking advantage of the pollutant processing of heterogenous wetland systems	slow down runoff through retention, reduce runoff volumes through evaporation, reduce downstream streambank/bed scour (reduction in velocity and volume), increase GW recharge when the outlet opens to a good place for infiltration; provide settling time for sediment and solid particles, adsorption of metals to pond bottom sediments, adsorption and uptake of nitrogen and phosphorus in pond bottom sediiments and aquatic plants, total reduction of nitrogen through denitrifying processes, provides wetland habitat
	vegetated swales	stormwater conveyances that slow water down with the roughness of the vegetation, allowing some amount of runoff filtration and sometimes infiltration into underlying soil	provides filtration of runoff to remove solids, metals; infiltration and GW recharge; evapotranspiration by soil organisms and plants; nutrient reduction through uptake by soil organisms and plants
	vegetated filter strips	broad vegetated areas with high roughness to disperse and reduce the energy of stormwater, usually as released from a stormwater conveyance, stormwater treatment system, or other stormwater structure	slows down runoff velocity; provides filtration of runoff to remove solids, metals; infiltration and GW recharge; evapotranspiration by soil organisms and plants; nutrient reduction through uptake by soil organisms and plants
	rain barrels / cisterns	collection of rainfall from roofs and other impervious areas for use in watering gardens or landscapes, or for "grey water" uses such as toilet flushing	acts to temporarily detain or reduce runoff provided barrel is empty prior to rain, runoff is detained and reduced through landscape watering or as a "grey-water" source for things like flushing toilets, when used for landscape watering offers GW recharge; to the degree solids settle out while in storage, and to the degree they are used by plants for watering
	porous/permeable pavement	poured asphalt or concrete, or laid permeable stonework, that is designed to allow rainfall to penetrate to an open subbase where water is temporarily detained or allowed to infiltrate underlying soil	slow down runoff through retention, reduce downstream streambank/bed scour (reduction in velocity and volume), increase GW recharge when the outlet opens to a good place for infiltration (or if designed to infiltrate directly from under-pavement storage); provide settling time for sediment and solid particles, adsorption of metals to soil media

Type	Subtype	Description	Benefits (sources and stressors addressed)
	green roofs	reinforcement of a roof combined with an intensive (deep, small-area) planting arrangement or extensive (shallow, large-area) planting arrangement	retains and slowly releases rain falling onto roof, in most cases reducing total runoff through extensive evapotranspiration; Chemical - treates nitrogen and phosphorus to the degree that roof plants use it; reduces urban heat island effect, insulates building roofs and provides longer roof life
	green walls	system designed to ennable the vertical arrangement of plants along a building's wall or fence, may be composed of "growing cells" embedded into the wall or fence filled with small plant species, may be composed of a planter box and trellis/scaffolding for vines and climbing plants, may be composed of carefully pruned and trained woody plants (espalier)	insulates building walls, provides similar benefits to small-scale planter boxes
	planter boxes	depending on complexity of design, may simply be a plant under a grate; may include some "structural soil" to allow water and air movement and root growth; may have roof runoff directed to it to maintain plant health; may have a complex water capture and release system combined with soil media to imitate larger bioretention cells	depending on configuration, may simply offer urban greenery (demonstrated effects on public safety and health, area attractiveness, and urban heat island effect), capture roof runoff while maintaining plant health, provide for some storage and possible infiltration of runoff, or provide benefits similar to bioretention systems
Pollution Prevention Measures	using alternative materials	in many (most?) cases there are alternative products that are less toxic	reduce toxicity of potentially spilled materials
	spill prevention and cleanup		reduce amounts of toxic materials reaching streams
	install more trash cans / cigarette canisters		reduce trash and dumping
	increased recycling opportunities		reduce trash and dumping

Type	Subtype	Description	Benefits (sources and stressors addressed)
	pick up pet waste	picking up pet waste in plastic bags when taking animals out for a walk or to play, disposing in trash rather than allowing it to decay out in the open	reduce nutrients and fecal coliforms
Ecosystem Function Rehabilitation and Restoration	stream-floodplain reconnection	streambed may be raised up, or floodplain is carved down to allow 2-year stormflow to reach floodplain	all benefits of streambank benching but for a much larger amount of flow and greater habitat area, usually in conjunction with riparian reforestation/enhancement to improve plant survivorship, greater floodwater storage and slow release which increases base flow
	streambank benching	existing streambank is reshaped to provide a lower, flat area to imitate floodplain functions (carving out a small floodplain, essentially)	reduce water velocities by spreading out flow, can reduce downstream flooding by providing floodwater storage, reduce stress on banks and subsequent erosion, provide habitat for organisms requiring floodplain inundation
	laying back streambanks	existing streambank is reshaped to decrease bank angle	reduce water velocities by spreading out flow, reduce stress on banks and subsequent erosion
	vegetative streambank stabilization	planting directly into streambanks (live stakes, seedlings, grass, etc.), usually combined with some erosion control matting to help establishment	reduce water velocities by increasing surface roughness, reduce direct erosive action of flow on bank sediments, hold underlying sediments together with roots, provide root-mat and other habitat
	vegetative - organic structure streambank stabilization	use of plants in combination with structural plant materials	reduce water velocities by increasing surface roughness, reduce direct erosive action of flow on bank sediments, hold underlying sediments together with roots, provide root-mat and other habitat
	armored streambank stabilization	primary use of hardened, non-living materials	reduce direct erosive action of flow on bank sediments, may reduce or increase water velocities depending on roughness, may deflect erosion to other areas, may be combined with some interstitial plantings to improve ecological function
	reestablishing hyporheic function	rebuilding streambed by replacing or augmenting bed materials to provide subsurface voids; or relocating stream to past stream location where coarse sediments are present	imitates natural filtering and hydrologic functions of streambed, provides habitat conditions most conducive for organisms

Type	Subtype	Description	Benefits (sources and stressors addressed)
	regenerative stormwater conveyance	similar to reestablishing hyporheic function, but used exclusively for ephemeral channels	filters runoff through coarse sediments, supports GW recharge, reduces velocity and energy of runoff, protects downstream channels
	riparian reforestation or enhancement	replanting forest entirely, or increasing diversity and forest structure with multiple species	provide runoff filter zone between developed areas and stream to remove pollutants, provide soil infiltration to improve base flow, nutrient processing of runoff by plants, provide shade to stream, reduces water temperatures and increases stream dissolved oxygen, reducing algae growth, includes all benefits of vegetative streambank stabilization
	watershed reforestation or enhancement	replanting forest or increasing forest cover in upland areas of watershed	increases infiltration of rainfall, decreases total volume of runoff, decreases runoff rate
	soil restoration or rehabilitation	deep plowing and amendment with organic and other materials to encourage redevelopment of healthy soil community	improve local soil ecosystem; improve rainfall infiltration (and possible increase in groundwater recharge or base flows); increase water storage for plants; improve nutrient processing and retention; improve plant health; increase habitat
	rebuilding stream meanders and channel structure	complete reshaping of stream, often by relocating it, to create self-sustaining lateral meanders, channel features such as riffles, runs, pools, and glides, improved floodplain access, and stable bank angles	usually done in conjunction with stream-floodplain reconnection, or at least streambank benching (and thus includes those benefits); provides greater habitat heterogeneity, total area, and quality; mimics natural geomorphic processes to create stable channel (if designed correctly); may disperse flow velocities more effectively (or in a less erosive fashion) than bank-surface methods
	floodplain restoration or enhancement	creation/recreation of vernal pools, backwaters, oxbows, floodplain wetlands, side-channels and other temporary areas to store water, may include removal of structures or roads to improve lateral soil water movement	requires reconnection of stream to floodplain (thus has similar benefits), additional benefits of more types of habitats made available, locations for extended retention and infiltration of runoff, wetland nutrient processing, usually done in conjunction with riparian reforestation/enhancement
	invasive plant management	control of plant species that outcompete native forest species	maintains or reestablishes internal forest structure and health, maintains forest cover and shade, usually done in conjunction with riparian reforestation/enhancement, or to prevent need for reforestation/enhancement

Type	Subtype	Description	Benefits (sources and stressors addressed)
	in-channel structural elements	installation of weirs, J-hooks, root wads, and other materials/objects that direct flow in a particular way	similar structures often have different purposes, but generally installed to take erosive stress off of banks, create particular habitats, improve channel stability, maintain channel location
Cleanup, Remediation, or Mitigation Measures	piped stream daylighting	unearthing piped streams, creating new open channels	provides more habitat area, new stream channel is rougher than pipes, slows down runoff and provides area for infiltration or filtration, exchange with groundwater, oxygenation of flow
	removal of stream culverts	removal of culverts	allows natural geormophology of stream to reestablish, allows transport of bed sediments and organic debris, allows fish passage
	groundwater pumping and treatment	groundwater is pumped out and sent to treatment facilities	removes toxic materials directly from environment
	injection of groundwater treatment chemicals	chemicals designed to degrade or treat contaminants in-situ that themselves pose lower or no toxicity	reduces toxic materials in soil, contributions to groundwater
	cleanup of small trash dumps	trash dumps that can be cleaned up with volunteer labor and simple equipment	removes trash and potential sources of toxins from environment, reduces contributions of toxins to groundwater
	excavation of large trash dumps	trash dumps that require more extensive excavation with heavy equipment	removes trash and potential sources of toxins from environment, reduces contributions of toxins to groundwater
	stream cleanups	walks along streams to collect trash, not as dense as cleaning up at a trash dump	removes trash and potential sources of toxins from environment
	removal of structures in riparian zone or floodplain	removal of structures in riparian zone or floodplain	removes structures that get in the way of floodwaters, restores floodplain soil functions, interflow, movement of groundwater to streams, provides space for floodplain forest
	removal of pavement in riparian zone or floodplain	removal of pavement in riparian zone or floodplain	restores floodplain soil functions, interflow, movement of groundwater to streams, provides space for floodplain forest
	excavation of contaminated soil	contaminated soil is removed and replaced with clean soil	removes toxic materials directly from environment
	in-situ treatment of contaminated soil	use of plants or other organisms to convert contaminants or remove them	reduces toxic materials in soil, contributions to groundwater
Policy Measures	stormwater fee credit policies	reduction of stormwater utility fee in response to implementation of desired practices	addresses problems related to volume and rate of runoff, contaminants in runoff, offers opportunity for runoff treatment

Type	Subtype	Description	Benefits (sources and stressors addressed)
	incentive programs	programs that offer cash or other incentive to install stormwater management retrofits or other practices	addresses problems related to volume and rate of runoff, contaminants in runoff, offers opportunity for runoff treatment
	reverse auctions		encourages installation of stormwater retrofits in the absence of a stormwater utility credit system, attracts volunteers
Planning Measures and Techniques	cluster development	impervious surfaces in a development are clustered together rather than distributed evenly throughout a site	reduces infrastructure needed to service buildings; reduces pavement required for access to buildings; can be used in conjunction with stream buffers and other methods to protect sensitive areas
	site fingerprinting	highly customized development design that selects and locates particular uses depending on a site's particular physical and biological features	maximizes harmonization of development with ecological functions of site
	low impact development/design	stormwater-oriented development and design that aims to mimic natural hydrologic processes to the maximum extent practicable	reduces hydrologic effects of development significantly, including protecting downstream areas from scour/erosion, maintaining natural hydrograph, maintaining GW recharge, etc.
	"new urbanism"	development oriented towards minimizing the amount of impervious surface required for the maximum number of people through high density land use	when used in combination with preservation of existing natural area, cluster development, or brownfields development it minimizes the increase in impervious surfaces as the population increases; usually combined with transit oriented development to reduce the need for private automobiles and the number of vehicle miles traveled (reduces local air pollution, including production of NOx, ozone, and particulates that are then deposited on impervious surfaces and get into stormdrain system)
	transit oriented development	concentrated, mixed-use development that emphasizes and enables easy transit connections and non-personal-automobile modes of transportation	reduces the need for private automobiles (easier access for non-driving populations and those without resources); reduces vehicle miles traveled (reduces local air pollution, including production of NOx, ozone, and particulates that are then deposited on impervious surfaces and get into stormdrain system)

Type	Subtype	Description	Benefits (sources and stressors addressed)
	brownfields development	redevelopment of existing developed areas rather than development on open, vegetated areas	slows conversion of working greenspace to developed land
	preservation of existing natural area	identification and protection (through acquisition, restrictive covenants, or other means) of natural areas of particular sensitivity, ecological value, or civic value	slows/prevents conversion of working greenspace to developed land
	greenspace or "greenscape" requirements	requirements for inclusion of vegetation or natural elements into the built environment	provides opportunities for small-scale stormwater management, such as with planter boxes
Erosion Control and Soil Protection or Rehabilitation Practices	staging of grading and construction	project areas may only clear portions of the whole project at one time to minimize the area of unstabilized ground	minimizes amount of a project area that has unprotected or disturbed soil at any one time; reduces area prone to erosion
	shorter time limit for establishing vegetation in construction areas	requiring that land cleared for construction has groundcover or vegetation established in shorter timeframes than currently required	ground cover and vegetation is the most effective method of keeping very fine and otherwise not-easily-removed particles from moving off of construction sites; shorter establishment times reduce the opportunity for storms to happen prior vegetation establishment; groundcover and vegetation work well beyond the minimum storm intensity that erosion control systems are required to control
	design erosion control for higher-intensity/lower-frequency storms	design sediment retention ponds and other erosion control devices to control runoff from storms more intense than or less frequent than the 10-year return-period storm	reduce instances where erosion control systems are overwhelmed by more-intense-than-designed-for storms
	prohibition on mass grading during construction	projects must be designed to require less grading and reshaping of the land's surface to minimize soil exposure, soil compaction, and removal of critical soil horizons (layers)	restricts soil compaction and destruction of soil structure to a greatly limited area; maintains developed topsoil in place

Type	Subtype	Description	Benefits (sources and stressors addressed)
	use of polyacrylamide (PAM)	erosion control devices are "doped" with PAM, which creates colloids with super-fine clay particles, making filtration and settling much more effective	dramatically reduces turbidity of runoff leaving construction sites
	minimize clearing on individual lots	reduces area of individual lots that may be cleared of trees to a bare minimum required for the structures themselves and the equipment used to build them	reduces the area of disturbed and compacted soil, encourages building methods that reduce mass grading and soil compaction
	topsoiling	saving or replacing topsoil removed when site undergoes mass grading	allows mass grading while ensuring that there is a minimal soil layer for healthy plant growth
	soil amendment	shallow plowing or mixing in of various materials to improve soil carbon (organic matter), pH (lime), macro- or micro-nutrients, etc.	depending on the material, improve soil carbon (which in turn improves soil structure and permeability); optimize pH (pH may be very low or high depending on underlying geology and activities in the area); provide necessary nutrients
	soil restoration or rehabilitation	deep plowing to cut through compacted soil layers; usually combined with soil amendment to rebuild lost soil carbon stores, adjust pH values, or otherwise improve soil fertility or function; sometimes includes inoculation with beneficial microorganisms	addresses problems of soil compaction, low soil carbon, poor structure/stability, low fertility, poor growing environment, poor hydraulic conductivity
	soil inoculation	application of encysted or dormant symbiotic microorganisms that enhance plant growth and survival and/or improve soil nutrient processing and cycling, usually done in combination with soil restoration, especially when upper soil horizons (layers) have been removed entirely	helps to accelerate the process of soil development in areas where the upper soil horizons have been removed and what remains is subsoil; helps establishment and growth of some plants; improves soil nutrient processing and recycling

Type	Subtype	Description	Benefits (sources and stressors addressed)
	minimize winter road salt use	road salt use in winter may be minimized by targeted use of brine rather than salt granules; application and timing appropriate to the type of frozen precipitation and freeze-thaw conditions	reduces damage to soil structure in clayey soils next to roads by sodium; reduces roadside plant toxicity; reduces damage to infrastructure and vehicles from corrosion
Infrastructure Mitigation Techniques	road/path/easement cross-drains	cross-drains installed under roads, paths, or easements that run on floodplains	prevent compacted areas like this from preventing normal interflow and GW-surface water relationships in floodplains, allows soil water to travel more "normally" in a floodplain
	stream ford designs	hardened stream fords designed to blend with natural geomorphology (like an artificial but stable riffle), designed to allow passage of fish, bed sediment, and organic debris, and to maintain natural channel dimensions	allows natural movement of bed sediment and organic debris, which prevents clogging upstream and scouring downstream, allows channel to maintain natural morphology through the crossing, allows fish passage
	alternative culvert designs	culverts designed to be at least the width of the natural stream channel, or larger; designed for fish passage at low water	allows natural movement of bed sediment and organic debris, which prevents clogging upstream and scouring downstream, allows channel to maintain natural morphology through the crossing, allows fish passage
	floodplain culverts	smaller culverts under roads placed at the elevation of a stream's floodplain	takes additional pressure off of main channel culvert when flow gets up onto floodplain, reduces erosive forces on main channel below culvert during flood flows, imitates natural floodplain hydrologic functioning
	conversion of culverts to hardened fords	removal of culvert and replacement with a ford designed to be stable and sturdy yet not create a dam, downstream scouring, or other geomorphic problems (see stream ford designs above)	allows natural movement of bed sediment and organic debris, which prevents clogging upstream and scouring downstream, allows channel to maintain natural morphology through the crossing, allows fish passage
	conversion of culverts to bridges	replacing culvert road crossings with bridges	allows natural movement of bed sediment and organic debris, which prevents clogging upstream and scouring downstream, allows channel to maintain natural morphology through the crossing, allows fish passage

Type	Subtype	Description	Benefits (sources and stressors addressed)
	improve compatibility of trees with underground utilities	use a combination of expanded rock and engineered soil media (to provide good places for roots to grow that can tolerate traffic or weight) and root barriers (to block intrusion of roots into underground utilities)	allows street trees to act like planter boxes or bioretention cells (with regard to stormwater absorption/retention), but still be in close proximity to other urban elements

APPENDIX 6: OUTREACH METHODS

Appendix 6: Outreach Methods					
Problems	**Sources**	**Who can detect and/or change?**	**Perceived Barriers to Fixing**	**Perceived Benefits to Fixing**	**Outreach Methods/Tools**
Bacteria-Sewage	Sewage overflows or leaks	OWASA, residents, businesses, schools	• Reporting may be delayed due to isolated location • Problems with sewer pipes and stormwater drains may be confused • Small leaks may be undetectable • Protocol for reporting may be unknown • Neglect of rental property • Expense of fixing leaks if on private property • People may think someone else will report	• Avoids State fines for OWASA • Allows immediate, emergency repair when leaks found • Removes sewer odors • May prevent sewage backup in house or apartment • OWASA regains sewer usage fees • Protects public health & environment • Plumbers get work	• OWASA Newsletters, e-mails, billing notices • Good, detailed communication between OWASA managers and Stormwater engineers when field checking reports • FOG education through OWASA & Stormwater& CWEP: written materials plus printed can lids for grease can containment • Smoke tests & notices FOG education through both OWASA & Stormwater& CWEP: written materials plus instructional can lids for grease cans • Food service training on pollution prevention
Bacteria-Sewage Overflows and Backups	Septic Systems either operating or improperly abandoned	Renters, Property owners, Plumbers	• Expense of pumping septic tank or replacing septic field • Ignorance of proper septic maintenance • Motivation to call for service	• Avoids State fines for leasing communities with community septic system • Protects public health & drinking wells • Plumbers and septic tank pumpers get work • Maintains pleasant environment	• FOG education through both OWASA & Stormwater& CWEP: written materials plus instructional can lids for grease cans to prevent clogs by fats, oil, and grease • Orange County Health Department • Handouts • Targeted direct mailings
Bacteria-Human Waste	Encampments Intoxicated individuals	Homeless and their resource givers, Public Groundskeepers, Bars and Restaurants, Friends of individuals	• Apathy • Intoxication • Homeless often derelict with few resources and insurmountable personal challenges - "saving the environment" may not be high on the priority list	• Cleaner streams • Cleaner storm drains • Cleaner streets & Buildings	• Presentations and guides to fraternities, sororities, new students (could be partnership with UNC Stormwater) • Strategically placed port-a-jons and community education • Encampments: Information gathering and homeless encampment outreach (proper entrenchment) through police, ministries, IFC Community House

Appendix 6: Outreach Methods					
Problems	**Sources**	**Who can detect and/or change?**	**Perceived Barriers**	**Perceived Benefits**	**Outreach Methods/Tools**
Bacteria-Animal Waste	Outdoor kennels Properties with ponds & geese Pets Wildlife	Vets, Kennels, HOAs, Residents, Dog walkers, Cat owners, Landscapers, Pet waste removal services	• Extra effort or cost of labor to clean up and dispose of waste • Overcoming disgust of waste cleanup • Keeping cats contained • Ponds & Lakes- people want to have clear view of water • Ponds & Lakes- shoreline plantings may be expensive to plant and maintain	• Modeling environmental protection is good for business • Self respect for being responsible pet owner Happier neighbors • Cleaner and healthier kennel/yard/walking area/streams for you, your family, your pets, your neighbors • Provides jobs to poop scooper companies • Provides jobs to "catio" builders (enclosed patios for cats)	• Ordinances to require pickup of pet waste (Carrboro has for dog waste) • Orange County Animal Shelter partnership to hand out information and Mutt Mitts with new dog adoptions (done, but needs annual replenishment) • Provide pet waste signs to HOAs (done) and along greenways (done) • Set up and maintain dog waste stations (done in some neighborhoods and at all dog parks) • Direct mail to HOAs with lakes and ponds re: goose management • Workshops for lakefront property owners
Toxic Leaks	UGSTs Aquifer Plumes Old dumps	Property owners+, Government, Citizens (Detect only)	• Extreme expense and protocol for remediation • Bad publicity	• Compliance with regulations • Protect public health and streams • Make land available to use	• Publicity on cleanups that have been completed or are in progress to raise awareness Publicize reporting protocol • Work with real estate agents and property managers on awareness
Riparian Habitat Loss	Development Trail Building Residential Clearing Beavers	Local Government- Ordinances, Inspections, Citizens	• Loss of buildable or farmable land • Anti-government control sentiment • Ignorance of / confusion with regulations • People want clear view of streams • Beavers: both protection from citizens and difficulty in removal	• Protection of stream banks resulting in less erosion, fewer nutrients in waterways, protection of land, filtering and slowing down of runoff	• Work with real estate agents to inform property buyers and sellers about the need and protection of riparian buffers/tree ordinances • Outreach to property managers and owners through workshops, newsletters, handouts, Newcomer Guides, Town of Chapel Hill A-Z Guide • Ordinances in place or proposed for Jordan Lake protection

Appendix 6: Outreach Methods					
Problems	**Sources**	**Who can detect and/or change?**	**Perceived Barriers**	**Perceived Benefits**	**Outreach Methods/Tools**
Scouring & Erosion of Stream Banks	Direct outfalls into creek Dams/improper bank structures Bridges/road crossings	Municipality, Property owners/managers, DOT or property owners, DOT or municipality	• Expense to fix outlet pipes or add BMP		
Nutrients	Fertilizers, organic waste, leaking septic & sewage, pet, goose & wildlife poop, soil	Residents, garden stores, landscaping businesses, greenway walkers, pet owners, pond owners, restaurants	• Complex chemistry to understand proper fertilizing • Impatience of polluter to "just get the job done" • un-trained employees in garden stores • economics to fix septic • renters may not care • some don't believe pet waste will cause harm	• Healthier streams • Jordan requirements met • Possibly permanent change in practices	• Restaurant training • Newsletters • Articles in paper • Advertisements • Point of sale tags/ flyers • Landscaper training • State requirements • OC Coop Extension • Soil & Water grants and outreach
Sedimentation	Construction Sites Property Owners (See Scouring & Erosion)	Inspectors, Muddy Water Watch, Citizens, Property Owners, Local Governments	• Untrained or careless EC&S workers • Too few inspectors • NC clay particles impossible to trap	• Healthier streams • Keep soil in place	
Automotive Fluids, PAHs	Auto repair shops Roadways/driveways Paving/asphalt companies Dumping (oil, etc.)	Mechanics, Street Sweepers Vehicle Owners, DIYers, Pavement sealers, Municipalities (contracts)	• "Just a little" mentality • Difficult removal • Multiple users of space • Language barriers • Accidental leaks • Expense to fix vehicles	• Educate people about proper disposal of hazardous wastes • Impress violators with their contribution toward the whole of pollution	• Recycling Program • Auto Shop Education • Newsletters • Citations

APPENDIX 7: CHAPEL HILL TARGETED RESTORATION IMPLEMENTATION STEPS AND PROPOSED MILESTONES

Appendix 7: Chapel Hill Targeted Restoration Implementation Steps and Proposed Milestones

Step #	*Implementation Category*	Step	Approximate start date	
1	*Public Education, Outreach, Involvement*	Public watershed stewardship activities - see Watershed Stewardship chapter for details	ongoing	
2	*Stream condition assessment, targeted ID of stressors and sources*	stormdrain network mapping - Tanyard Branch	completed as part of 319 project (alternatives analysis)	
3		send out mailers to property owners with description of detailed studies and purpose	Winter2013	
4		info item to Town Council~~,~~ and affected utilities outlining detailed studies and purpose	Winter 2013	
5		stormdrain network mapping - Mill Race	Summer 2013	
6		detailed streamwalks - Tanyard (collect stream geomorphic, riparian, and instream habitat condition information; rate culverts; conditions of OWASA crossings; ID stormdrain outfalls and smaller straightpipes; ID other small potential pollution sources or problems)	Winter 2013	
7		detailed streamwalks - Mill Race (collect stream geomorphic, riparian, and instream habitat condition information; rate culverts; conditions of OWASA crossings; ID stormdrain outfalls and smaller straightpipes; ID other small potential pollution sources or problems)	Winter 2014	
8		(Tanyard only) BEHI/NBS (at selected locations)	Spring 2013	
9		(Tanyard only) selected cross-section surveys for hydraulic modeling	Spring 2013	
10		(Tanyard only) placement of bank pins and/or scour chains at areas identified as high erosion rate/potential	Spring 2013	
11		(Tanyard only) summarize and report results to Town staff, to Town Council, representatives of utilities, area property owners, other stakeholders?, event held with Friends of Bolin Creek? - request comments and issue published response to comments *(at every one of these reporting steps, SW staff should inquire with other Town divisions and external utilities as to whether there are potential conflicts and/or combinations with other potential projects)*	Fall 2013	
After this point milestones are for Tanyard Branch only. Add one year to each milestone for Mill Race if it is done after Tanyard Branch (serially), or add one season to each milestone if Tanyard Branch and Mill Race are done together (parallel).				
12	*Monitoring*	set up MOU with Carrboro and USGS for ongoing maintenance of USGS stream gage on Bolin Creek at Village Drive (starting Fed Year 2014)	Spring 2013	
13		annual macroinvertebrate monitoring	Spring 2013	
14		bug monitoring QAPP to DWQ	Winter 2013	
15		ID of best long-term monitoring location(s) for ISCOs (Tanyard and Mill Race) and request for permission of property owners	Spring 2013	
16		placement of ISCO monitors, initial calibration	Summer-Fall 2013	
17		placement of temperature sensors	Summer-Fall 2013	
18		devise water chem monitoring plan and set up QAPP with DWQ assistance	Summer-Fall 2013	
19		request quotes from labs for nitrogen, phosphorus, fecal coliform, and other constituent analysis	Winter 2013	
20		set up ongoing contract with selected laboratory for water sample analysis	Summer-Fall 2013	
21		start collecting biweekly samples at Tanyard, Mill Race, Bolin at Village Dr, and Bolin at Franklin (need to decide exactly which constituents)	Fall 2013	
22		start collecting quarterly/seasonal high flow samples at all 4 locations	Fall 2013	

Appendix 7: Chapel Hill Targeted Restoration Implementation Steps and Proposed Milestones

Step #	*Implementation Category*	Step	Approximate start date	
23		Initial reporting of monitoring planning and results to Town staff, Town council, representatives of utilities, area property owners, other stakeholders? Hold event in concert with Friends of Bolin Creek? - request comments and issue published response to comments	Fall 2013	
24		Annual reporting of monitoring results	Fall 2014 and after	
25	*Initial Detailed Analysis and Stormwater Treatment Concepts*	initial area/subwatershed property owner information letter/outreach/status report	Fall 2013	
26		develop RFQ and select consultant	Fall 2013 - Winter 2014	
27		summarization of stream and riparian conditions, presentation to CH Stormwater Engineers, discussion of potential alternatives for stormwater management, discuss stormwater management targets/needs	Spring 2014 - Fall 2015	contractor
28		calculation of SW drainage network areas, impervious surfaces Other	Spring 2014 - Fall 2015	
29		hydraulic modeling if needed?	Spring 2014 - Fall 2015	
30		SW engineers prepare concept plans for regional stormwater treatment, and concept plans for alternatives if possible	Spring 2014 - Fall 2015	
31		evaluation of additional monitoring needs	Spring 2014 - Fall 2015	
32		determination of additional studies needed (such as alternatives analysis)	Spring 2014 - Fall 2015	
33	*Valuation of Bolin Creek Ecosystem Services*	Discussion with DWQ on economic valuation of a CLEAN Bolin Creek	Spring 2014	
34		pursue grant funding for environmental economic study (maybe NCSU?)	Spring - Fall 2014	
35		grant for environmental economics study	Winter 2015 - Fall 2015	contractor
36	*Initial Concept Cost Estimation*	calculate costs for BMP design, construction, and annual maintenance	Spring 2014 - Fall 2015	contractor
37		estimate costs for BMP permitting only (not including mitigation needs)	Spring 2014 - Fall 2015	
38		estimate costs for potential studies needed	Spring 2014 - Fall 2015	
39		ID minimum set of parcels needed for BMP AND/OR specific area of SW easement needed for structure, construction access, and maintenance access	Spring 2014 - Fall 2015	
40		discuss property valuation and/or SW easement valuation/costs with lawyer or other specialist	Spring 2014 - Fall 2015	
41		calculate cost alternatives for full property acquisition, partial property acquisition, and easement acquisition	Spring 2014 - Fall 2015	
42	*Initial Concept ID of Complicating Factors*	get utility locate in potential SW treatment area to determine extent of utility moves that may be needed	Spring 2014 - Fall 2015	contractor
43		discuss with each utility service potentials for moving utility line, potential alternative locations	Spring 2014 - Fall 2015	
44		calculate costs for utility re-locate	Spring 2014 - Fall 2015	
45		ID parcels and/or easement areas needed for utility moves	Spring 2014 - Fall 2015	
46		calculate cost alternatives for full property acquisition, partial property acquisition, and easement acquisition	Spring 2014 - Fall 2015	

Appendix 7: Chapel Hill Targeted Restoration Implementation Steps and Proposed Milestones				
Step #	***Implementation Category***	**Step**	**Approximate start date**	
47		If digging is required for BMP installation, how to determine depth to bedrock? Depth to high water table? Soil stability? (particular issue for upper Mill Race where there is considerable fill material) other evaluations of geophysical technical feasibility - modify BMP construction costs accordingly	Spring 2014 - Fall 2015	
48		Contractor provides results to Town	Fall 2015	
49		**DECISION POINT:** review of technical feasibility with Stormwater staff - *IF NEGATIVE: revisit watershed restoration approach and revise Bolin Creek Watershed Restoration Plan, go back to "start"*	Winter 2016	
50		IF POSITIVE: summarize and report results of BMP concept planning and cost estimation, including utility issues, to Town staff, Town Council, representatives of utilities, area property owners, other stakeholders?, event held with Friends of Bolin Creek? - request comments and issue published response to comments	Winter 2016	
51	*Stream restoration/mitigation planning*	identify areas that appear to be in greatest need of stream restoration or stabilization - calculate linear feet of each	Winter 2016	
52		set meeting with Army Corps of Engineers (COE) to discuss overall project approach	Spring 2016	
53		visit BMP sites or review concept plans with COE to determine probable amount of impacted stream length requiring mitigation, calculate mitigation length requirements	Spring 2016	
54		visit stream sites with COE to review potential stream resto and stream stabilization areas, determine potential ecological uplift and potential credits available for mitigation	Spring 2016	
55		determine if Alternatives Analysis would be required for Mill Race	Spring 2016	
56		determine if there is enough length for restoration on stream for meeting mitigation requirements, or if alternative mitigation sites need to be found	Spring 2016	
57		draft up stream restoration concept plans based on COE guidance/mitigation requirements	Summer 2016	
58		ID parcels that would be involved in stream restoration construction (including construction access and maintenance access)	Summer 2016	
59		ID specific area needed for perpetual stormwater easements	Summer 2016	
60		get utility locate done in potential construction areas, determine whether utility moves will be required, add area for new utility easements if necessary OR modify stream restoration design to avoid utility moves	Summer 2016	
61		calculate costs for stream restoration permitting, design, construction, and annual maintenance	Fall 2016	
62		calculate costs for easement acquisition or property acquisition	Fall 2016	
63		determine whether any other additional studies would be required	Fall 2016	
64		**DECISION POINT:** review of technical feasibility with Stormwater staff - *IF NEGATIVE: revisit watershed restoration approach and revise Bolin Creek Watershed Restoration Plan, go back to "start"*	Fall 2016	
65		IF POSITIVE: summarize and report results of stream restoration/mitigation planning and costs to Town staff, to Town Council, representatives of utilities, area property owners, other stakeholders?, event held with Friends of Bolin Creek? - request comments and issue published response to comments	Winter 2017	
66	*Jordan Retrofit Credit Calculations*	calculate Jordan retrofit credits that would be generated from BMP installation AND stream restoration **(part of above contract)**	Spring 2014 - Fall 2015	contractor

Appendix 7: Chapel Hill Targeted Restoration Implementation Steps and Proposed Milestones				
Step #	***Implementation Category***	**Step**	**Approximate start date**	
67		identify retrofits in less dense/other parts of Town to do thorough BMP retrofit cost calculation including property/easement acquisition, determine Jordan retrofit credits (should be done with the same detail as proposed Tanyard and Mill Race BMPs for proper cost comparison - this should be expected to take a considerable amount of time, only a small number of BMPs may need to be "worked up" for an initial cost comparison and evaluation of retrofit credit efficiency)	Spring-Fall 2017	
68		estimation of total Jordan retrofit burden based on Jordan nutrient allocation, determine what percentage of total retrofit burden is addressed by Tanyard and Mill Race projects	Fall 2017	
69		summarize and report results of Jordan retrofit crediting to Town staff, Town Council, representatives of utilities, area property owners, other stakeholders?, event held with Friends of Bolin Creek? - request comments and issue published response to comments	Fall 2017	
70	*Summary and Presentation*	**DECISION POINT:** review of total costs and benefits with Stormwater staff, potential barriers and pitfalls, potential "nonstarters", evaluation of whether Tanyard/Mill Race BMP/restoration approach is in fact technically feasible, politically feasible, and is superior to alternative retrofit options outside of Bolin Creek Watershed - *IF NEGATIVE: revisit watershed restoration approach and revise Bolin Creek Watershed Restoration Plan, go back to "start"*	Winter 2018	
71		IF POSITIVE: initial presentation of results and recommendations to (other) Town staff and representatives of utilities	Winter 2018	
72		initial presentation of results and recommendations to potentially affected property owners	Winter 2018	
73		revision of retrofit/restoration plans as necessary in response to property owner concerns	Spring 2018	
74		revision of Bolin Creek Watershed Restoration Plan to reflect results of studies and public outreach efforts, sent to DWQ and EPA	Spring 2018	
75		organize event (with Friends of Bolin Creek) to formally present findings and recommendations, in concert with presentation (or publication) to Town Council	Spring-Summer 2018	
76		gain formal statements of support from Town staff, Town Council, representatives of utilities, Friends of Bolin Creek, other stakeholders	Spring-Summer 2018	
77		gain signed statements of tentative agreement to cooperate from property owners (or investigate possibility for 5 year temporary construction easement/agreement)	Spring-Summer 2018	
78	*Project Funding and Contractor Selection*	Town contracts out formal BMP and stream restoration engineering design (funds?), utility moves, and detailed calculation of construction costs	Fall 2018 - Winter 2019	
79		Town contracts out appraiser for determining costs to acquire needed easements and/or property	Fall 2018 - Winter 2019	
80		Contractor presents formal BMP and stream restoration engineering design, utility moves, and detailed cost calculation	Fall 2019	
81		SW staff identify appropriate grants, grant combinations, potential external match partners, internal match sources, potential cooperative non-SW projects (like greenways), potential property/easement donation and apply for all of them to cover easement/property acquisition costs and construction/utility move costs	Winter 2020 (may be shifted depending on when grant applications are due)	

Appendix 7: Chapel Hill Targeted Restoration Implementation Steps and Proposed Milestones				
Step #	***Implementation Category***	**Step**	**Approximate start date**	
82		Town issues RFP or requests bids for construction of BMP(s), stream restoration, and any other needed activity (invasive plant control, utility moves, etc.)	at time of notification of grant awards to ensure contractor can start at very beginning of grant period- may need to see if multiple grant contract start dates can be coordinated	
83		Town staff, Town Council, property owners, representatives of utilities, any other cooperators and stakeholders formally notified of grant awarding and detailed project schedule	at time of notification of grant awards	
84		Town starts process for acquisition of easements and/or properties (may need to wait until grant is actually awarded and contract signed)	at time of notification of grant awards	
85	*Project Implementation*	Town signs contract(s) with granting agency(ies)		
86		Town starts process for acquisition of easements and/or properties (if there is a requirement to start after grant is actually awarded and contract signed)		
87		construction or related preparatory activity begins (such as invasive plant control, utility moves, etc.)		

APPENDIX 8: GEODATABASE OF PROJECTS - ATTRIBUTES AND DOCUMENTATION

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Following are a list of attributes developed for describing and comparing proposed stormwater retrofit and stream restoration projects. Attributes are associated with a polygon project feature class in the geodatabase. Additional feature classes include drainage area to project and disturbed area of project. These are useful in determining the number and types of property owners that may be affected by a project.

PROJECTS GIS FEATURE CLASS:

Project ID: *(unique key)*

Project Type:

- *Bioretention w/IWS*
- *Bioretention w/o IWS*
- *Wet Detention Basin*
- *Sand Filter*
- *Stormwater Wetland*
- *Level Spreader + Filter Strip*
- *Dry Extended Detention Basin*
- *Grassed Swale*
- *Green Roof*
- *Permeable Pavement*
- *Rainwater Harvesting*
- *Infiltration devices/basins*
- *Floating Wetlands*
- *Mass Soil Amendment*
- *Offline Regional Treatment*
- *Proprietary Devices*
- *Underground/Other Storage/Retention*
- *Improvement of Existing BMP*
- *Priority 1 stream restoration – new stable channel connected to floodplain*
- *Priority 2 stream restoration – new floodplain and stable channel at present elevation*
- *Priority 3 stream restoration – widen floodplain, new bankfull bench, leave stream in place*
- *Priority 4 stream restoration – stabilize existing streambanks in place, no improved access to fp*
- *raising of stream bed and rebuild of hyporheos (stream restoration technique)*
- *instream grade control (to prevent downcutting or rebuild – includes step-pools, engineered riffles, and other instream structures for highly localized flow and grade control management)*
- *stream channel rerouting – restore natural pattern, move away from eroding areas or infrastructure*

- *rebuild instream structure and heterogeneity – riffle-pool structures, increased heterogeneity, hyporheos, emplaced large woody debris*
- *streambank erosion control and stabilization (includes streambank reshaping/new bankfull bench, accelerated streambank evolution, live stakes and other plantings, hard engineered surfaces, green-engineered combo methods)*
- *gully/erosion repair or prevention (includes all kinds of stormwater outfall energy dissipation)*
- *Stream daylighting and culvert removal*
- *Stream ford repair/improvement*
- *Culvert modification, enlargement, realignment, or other improvement*
- *Floodplain fill removal, legacy sediment removal*
- *Large dam removal*
- *Dam repair, replacement*
- *Targeted direct stormwater input removal (illicit discharges and cross-connections)*
- *High-density urban stormwater BMPs*
- *Floodplain restoration/vernal pools*
- *Groundwater remediation*
- *Street sweeping*
- *Leaf collection/management (gross solids control)*
- *Riparian buffer enhancement*
- *Riparian buffer reforestation*
- *Invasive species management and control*
- *Trash/debris cleanup*
- *Dump/trash excavation*
- *Septic system repair/replacement/retirement*
- *Stream fencing*
- *Vegetative erosion control*
- *Floodplain structure removal*
- *Soil restoration, amendment, ripping*
- *Small dam removal*
- *Residential rain garden (i.e. non-engineered bioretention/bioinfiltration)*
- *Upland reforestation/lawn replacement*
- *Conversion of impervious surface to pervious*
- *Illicit discharge enforcement*
- *aboveground storage tank removal, replacement, covering, ground covering, maintenance*
- *Industrial/Commercial Pollution Prevention – dumpsters, restaurant practices, etc.*

Project Description:

Location Description and Driving Directions:

Name of Receiving Water:

Receiving Water DWQ classification:

Receiving Water rating:

Town Subwatershed ID/Name:

Jordan Rules Creditable: *yes, pending, no, unknown*

Drainage Area to Project:

Property owner types in Drainage area and % (for assigning credits): *named jurisdiction, NCDOT, other federal/state (name), private*

Area available for Project:

Proposed Disturbed Area (ac/sqft?):

Disturbed Area current land cover (describe in detail):

Final Project Footprint Area:

Property Owners in Disturbed Area:

Property Owner Cooperation:

Property restrictions: *covenants, easements, regulated floodplain, regulated stream buffers, setbacks of all kinds, deed restrictions, etc. (or "unknown" or "partial listing")*

Construction Accessibility:

Est. Construction Costs:

Est. Utility Move Costs:

Other Implementation Costs:

Design complications: *like fully connected impervious (incl roofdrains), extensive/large network, deep existing network, low slope, limited daylighting opportunities, dedicated rainwater use/management*

Design analyses: *like flood studies, geotechnical testing, 401/404 alternatives analysis, other professional analyses, dedicated rainwater use/management*

Special Design notes: *such as for experimental university studies, improvement of existing underfunctioning BMP, reduce downstream erosion, or other changes to standard design to improve functionality, efficiency, resilience, reduce maintenance, etc.*

Maintenance Accessibility:

Maintenance Responsibility:

Maintenance Funding: *available? Guaranteed how?*

Est. Annual Maintenance costs:

Maintenance description:

Project Protection: *funds/restrictions in place to protect project?*

Drainage Area Average Slope:

Project Area Average Slope:

Soils in Drainage Area: (%?)

Soils in Project Area: *(hydrologic group or estimated or measured permeability)*

Estimated depth to groundwater table: (*some rough indication of whether it's on the order of 1-2 feet or >5 ft might be helpful for some types of BMPs, especially stormwater wetlands)*

Environmentally Sensitive Areas: *floodplain, stream buffers, E/I species habitat, wetlands, Natural Heritage, etc.*

Invasive Plant Species and Severity:

Utility conflicts: *"not investigated", "partial investigation - (list)", and full list*

Other Barriers to Implementation:

Est. Water Quality Volume:

Est. annual Drainage loading – N:

Est. annual Drainage loading – P:

Est. annual Drainage loading – other:

Potential N reduction:

Potential P reduction:

Potential other pollutant reduction:

Potential Runoff reduction:

Volume/rate control: *(List design storms used)*

Addressing Identified Problem: *(Problem IDs – for linkage to Problem ID table)*

Problem types addressed: *pollutants (list), sediment source, stream instability, instream erosion, poor aquatic habitat, poor terrestrial habitat, riparian forest, floodplain function, habitat heterogeneity, hyporheic exchange, connectivity/migration barrier, GW recharge, flashiness/hydrologic modification, low base flow, high water temp, low DO, BOD/COD, algae, drainage complaint, sanitary/septic*

Other Potential Benefits: *park space, pond amenity, support stream or watershed restoration, support another project, support plant community reconstruction, highway/road/public area beautification, wildlife habitat/food/cover, remove invasive plant seed source, address known drainage problem, public ed/involvement (like community garden, demonstration space), ongoing/planned/past academic study*

Feasibility Conclusions:

RETROFIT WQ CALCULATIONS ASSOCIATED TABLE:

Project ID: (parent key)

Land Use Type: *Roadway, Driveway, Parking Lot, Roof, Sidewalk/Patio, Lawn, Managed Pervious, Forest, Other*

Soil type

Drainage Landuse and Impervious types and %: *(do as a separate table or fields for each land use type)*

Soils in Drainage Area: (%'s by hydrologic soil groups)

Fields for each land use:

- TN EMC
- TP EMC
- Area
- Rv
- Annual #N
- Annual #P
- N Load per Ac
- N Reduction per Ac
- P Load per Ac
- P Reduction per Ac
- Total annual runoff for the watershed
- Projected retrofit volume capture
- Projected volume reduction

APPENDIX 9: LOOKUP TABLE FOR SUBDIVISION AND NEIGHBORHOOD NAMES

Appendix 9: Lookup Table for Subdivision and Neighborhood Names

1	Chesley
2	Chandler's Green
3	Silver Creek
4	Springcrest
5	Springcrest-Birtchett
6	Covington Place
7	Englewood
8	Birch Meadow
9	Ironwoods
10	Kent Woodlands CH
11	Culbreth Subd.
12	Coble Ridge
13	Southbridge
14	Glenmere
15	Culbreth Park
16	Highgrove
17	Culbreth Middle School
18	Graylyn
19	Dogwood Acres
20	Carlton Dr
21	Village West
22	Glenbrooke
23	New Homestead Place
24	Avalon Park
25	Horace Williams Property
26	Link Rd
27	Homestead Village
28	Billabong Ln
29	Vineyard Square
30	Northwood V
31	Northwood
32	Larkspur
33	Glen Heights
34	Wave Road - Rolling Hills
35	Tandler West
36	Morgan Creek Hills
37	Creekside
38	Clark Lake
39	Blairwood
40	The Oaks Villas
41	The Oaks II
42	The Oaks III
43	Montessori School
44	Colony Woods East
45	Ephesus Church
46	Lassiter Currie
47	Colony Woods
48	Parkside
49	Glenhaven
50	North Haven
51	Shadowood Apts
52	Coker Woods
53	Timber Hollow Apts
54	Ashley Forest
55	Coker HIlls West
56	North Forest Hills
57	Elkin Hills
58	Frank Umstead Property
59	Sherwood Forest
60	Finley Forest
61	Pearl Ln Barbee Chapel Rd
62	Meadowmont
63	Farrington Hills
64	Laurel Hill
65	The Reserve Estates
66	The Reserve
67	The Woods at Laurel Hill
68	The Reserve Phase 2
69	Hunt's Reserve
70	Beechridge
71	The Highlands
72	Manning Heights
73	Winter Hill
74	Goose Farm
75	Glen Lennox
76	The Oaks
77	Greenwood
78	Gimghoul
79	Coker Hills
80	Kirkwood
81	Booker Creek IV
82	Booker Creek
83	Windover
84	McGregor Place
85	Erwin Village
86	Booker Cr Village
87	Old Oxford Green
88	Foxcroft Apts
89	Summerfield Crossing
90	Franklin Square Offices
91	Oxford Hills
92	Clark Hills
93	Tandler North
94	Adelaide Walters Housing
95	Forsyth Subdivision
96	Abbott's Colony
97	Forsyth Subdivision
98	Cooper Square
99	Legion Rd Townhomes
100	University Heights
101	Pickard Oaks
102	Standish Townhomes
103	Colony Lake
104	Franklin Grove
105	Milton Ave
106	Pine Knob
107	Vernon Hills
108	Sunrise Rd
109	Coventry
110	Carol Woods
111	Countryside
112	Steeple Chase
113	Cedar Hills
114	Windsor Park
115	Cross Creek
116	Kensington Trace
117	Weatherstone Apts
118	Timberlyne
119	Freeland Place
120	Barrett Subdivision
121	Jefferson Square
122	Argonne Hills
123	Forest Creek
124	Partin Hills
125	Brookview
126	Glenview
127	Nunn Mtn
128	Riggsbee Heights Piney Mt
129	Fern Creek
130	Eastwood Rd Johnson Farm
131	Lake Forest
132	East Chapel Hill High
133	Presque Isle
134	Pinegate Apts
135	Eastowne
136	Eastowne Hills
137	Dry Creek Natural Area
138	Notting Hill Apts
139	Providence Glen

140 Walden at Greenfields Apt
141 Dobbins Hill Apts
142 Willowbrook Apartments
143 White Oak Park
144 Knollwood
145 White Oak
146 Stratford Glen
147 Cedar Terrace Lakeview
148 Patterson Property
149 Bolin-Booker-Little Confl.
150 Briarcliff
151 Deerwoods
152 Ridgefield
153 Ridgefield North
154 Colony Apts
155 King's Arms Apts
156 Oxford
157 Themis Apartments
158 The Meadows
159 Turnberry
160 Hidden Hills
161 Estes Hills
162 Norem Subdivision
163 Mt Bolus
164 Winding Ridge
165 Jay Street
166 Pinebrook Estates
167 Colonial Heights
168 University Garden Apts
169 Columbia Place
170 Hillview
171 Howell's Folly
172 Hargraves Terrace
173 Valley Park
174 Hillcrest
175 Glendale
176 Davie Circle
177 Village Green
178 Mill Race
179 Lone Pine Hill
180 North Street Development
181 Tenney Circle
182 Stratford Hills Apts
183 Bolin Creek Greenway
184 Franklin Hills
185 Pine Knolls
186 Cameron Glen
187 UNC Cogeneration Plant
188 Westwood
189 Forest Hills
190 Morgan Estates
191 Hundred Oaks
192 Old Bridge
193 Sycamore Run
194 Lystra Woods
195 Zapata Lane
196 Hillside
197 Woodhaven Hills
198 Woodhaven
199 Logan Grove
200 Chase Park Apts
201 Whitehead Circle
202 Morgan Creek
203 Coolidge North
204 Westwood Terrace
205 Forest Hills Place
206 Coolidge South
207 Purefoy Road
208 Chase Avenue
209 Laurel Ridge Apts
210 Cameron-McCauley
211 Edwards St
212 Little Hill
213 Laurel Hill - Rocky Ridge
215 Greene Tract
216 Rusch Road - Rusch Hollow
217 Purefoy Drive
218 Land Fill
219 Rogers Road North
220 Neville Tract
221 Northside
222 Noble Heights
223 Hamlin Park
224 Greene Hills
225 Eastwood PH
227 Quail Run
228 The Estates at Chapel Hil
229 Arlen Park
230 Southern Village
231 Kings Mill
232 Mason Farm Subdivision
233 Kingswood Apts
234 Moody Trailer Park
235 Camelot Village Apts
236 East 54 (Univ Village)
237 Greenbridge
238 UNC Central Campus
239 Chancellor's View
240 Southern Community Park
241 Montclair
242 Chapel Hill North
243 Timberlyne Village
244 Vilcom
245 Blue Cross Blue Shield
246 South Estes Public Housing
247 OWASA WWTP
248 Boulder Hill
249 Sun Forest
250 Sparrow Estates
251 Seawell-Smith-CH High Sch.
252 Chapel Ridge
253 Brookstone
254 Orange Human Services
255 Timberlyne Office Park
256 Chapel Watch
257 Town Operations Center
258 Bolinwood Condos
259 Mill Creek Condos
260 Brookside Condos
261 Shepherd Lane Condos
262 Brookwood Condos
263 Trinity Court
264 Northampton Terrace
265 Townhouse Apartments
266 Town Police Station
267 Phillips Junior High
268 Ram's Plaza
269 University Square
270 Merritt Pasture
271 Botanical Garden
272 Friday Center
273 Finley Golf Course
274 Mason Farm
275 UNC Faculty/Staff Club
276 Willow Terrace Condos

277 Eastgate
278 Village Plaza
279 Chapel Hill Library
280 Community Center
281 Dickerson Court
282 University Mall
283 Ephesus School
284 American Legion
285 New Town Cemetery
286 Old Town Cemetery
287 Lincoln Center
288 Frank Porter Graham School
289 Hillsong Church
290 St. Thomas More Church
291 Montessori School
292 Ephesus Baptist Church
293 Kingston Place Condos
294 Fire Station North
295 Cedar Falls Park
296 Chalet Condos
297 Hillside Condos
298 Woodglen Condos
299 Prince William Townhouses
300 Dumbarton Walk Condos
301 The Gables Condos
302 Danziger Townhomes
303 Springlen Condos
304 Carriage Row
305 Town Hall & Fire Station 1
306 Stephens Court
307 Hilltowne Square
308 Creekside Townhouses
309 Umstead Park
310 Battle Park & Forest Theatre
311 The Oaks Condos
312 Woodmont
313 Rizzo Center
314 The Cedars of Chapel Hill
316 Old Chapel Hill Hwy East
317 Carroll Property
318 Charterwood
319 Chapel Hill Industrial Pk
320 The Edge
321 Phoenix Place
322 Sandberg Woods
323 Piney Mtn Trailer Court
324 Burch Kove
325 Edge Towne Condos
326 Orange United Methodist Ch
328 Freedom House
329 Homestead Park
331 Gugelman Property
332 E Franklin-Carolina Ave
333 Townside Terrace Condos
334 Downtown Townhomes
335 Pines Community Center
336 Cosgrove Hill
337 Obey Creek
338 Duke Stone Tr
339 Pearson Estates
340 Reuben Cole
341 Dixie Garden
342 Stratford Apartments
343 Salem Court Townhouses
344 Airport Gardens Apartments
345 Greene Hills/Green Street
346 Colonial Arms Apartments
347 Frat court
348 Franklin Woods
349 Winchester Court Condos
350 The Retreat at Franklin
351 Sparrow Trailer Park
352 Weaver Dairy Trailer Park
353 Town Center
354 Franklin-Rosemary Hist Dist
355 Sunstone Apartments
356 North Columbia Street
357 Chapel Hill Bible Church
358 Northampton Plaza
359 Oak Terrace Apartments
360 Columbia Park Place Condos
361 Cobb Terrace
362 Bolin Heights
363 Mill Creek/Booker
364 Rosemary Village Condos
365 Warehouse Apartments
366 140 West
367 The Fountains Condos
368 Chancellor's Square
369 Welsh Court Condos
370 CH Housing - Lindsay St.
371 CH Housing - Gomains W
372 CH Housing - Sykes N
373 CH Housing - Craig
374 CH Housing - Church
375 Nicholson Apartments
376 Mercia Apartments
377 Cider 4 Apartments
378 Jones Park
379 HICKORY FOREST
380 KAREN WOODS
381 LUCY LANE
382 ROBERT DICKS
383 MORRIS GROVE ELEM
384 TALBRYN
385 MORRIS GROVE
386 TWIN CREEKS PARK
387 TUPELO RIDGE
388 MEADOW RUN
389 ROGERS ROAD
390 FOX MEADOW
391 Conservation Easement
392 BRITTON WOODS
393 OWASA
394 UTILITY
395 HIGHLANDS NORTH
396 COLLETON CROSSING
397 ORANGE COUNTY
398 HIGHLAND MEADOWS
399 HIGHLANDS

400 CAROLINA COMMONS
401 NEVILLE
402 CAMDEN PLACE
403 STONY HILL
404 CALVANDER MHP
405 HOMESTEAD ROAD
406 HOMESTEAD HILLS
407 Homestead Acres Trailer Pk
408 LITCHFIELD
409 WEXFORD
410 UNC
411 SUNSET CREEK
412 ARCADIA
413 WILLIAMS WOODS
414 COBBLESTONE
415 BARINGTON HILLS
416 HORNE HOLLOW
417 CATES FARM
418 CARRBORO GREENS
419 TRIANGLE ACRES
420 HILLSBOROUGH ROAD
421 RIGGSBEE
422 WINSOME LANE
423 MCDOUGLE ELEM
424 SPRING VALLEY
425 BOLIN FOREST
426 TOWN OF CARRBORO
427 WAVERLY FOREST
428 FAIROAKS
429 SUDBURY
430 MCDOUGLE MIDDLE
431 CASTALIA COURT
432 THE HOLLOW
433 QUARTERPATH TRACE
434 ANDERSON PARK
435 PLANTATION ACRES
436 MLK PARK
437 WEBBWOOD
438 LLOYD SQUARE
439 FOREST COURT
440 ADAMS TRACT
441 RANGEWOOD
442 PACIFICA
443 HANNA STREET
444 THE CEDARS
445 STORY
446 THE SHIRE
447 WATTERS ROAD
448 ESTES PARK
449 LLOYD
450 ESTES DRIVE
451 TREE TOP
452 HUNTER PLACE
453 JONES LAKE ROAD
454 WILSON PARK CONDOS
455 HARWARD
456 WILSON PARK
457 BEL ARBOR
458 CHEEK
459 PICKET PLACE
461 MORGAN GLEN
462 THE WILSON
463 OAKWOOD APTS
464 CARRBORO PLAZA
465 PLEASANT DRIVE
466 PINE HILL
467 HILLCREST
468 SOMERSET PLACE
469 THE FLATS
470 MORGAN FIELDS
471 PINE HILL CONDO
472 Carolina Blue Village
473 STONEYBROOK
474 BERKSHIRE MANOR
475 OLD CARRBORO
476 CEDAR ROCK
477 GOLDSTON
478 CARRBORO ELEM
479 LLOYD-BROAD STREET
480 OASIS GROVE
481 CHESWICK
482 WILDWOOD SPRINGS
483 BERKSHIRE MANOR W
484 CEMETERY - MAIN ST
485 BRIGHTON SQUARE
486 CEDAR COURT
487 BALDWIN PARK
488 SYLVIA SQUARE
489 CENTRAL BUS DIST
490 OLD FAYETTEVILLE RD
491 WEST PARK
492 RUSSELL SQUARE
493 CHATEAU APARTMENTS
494 503 N GREENSBORO Apts
495 CAROLINA SPRING
496 POPLAR WEST
497 ANDREWS HEIGHTS
498 200/202 W POPLAR APTS
499 W B GLENN
500 605 W MAIN
501 ANN CLAY CARMICHAEL
502 OLD POPLAR VILLAGE
503 ELLINGTON PLACE
504 KEITH & KIOWA DIXON
505 CARR MILL
506 WINDWOOD
507 SPARROW
508 HILLMONT
509 THE CREST
510 BIM-LAUREL
511 WHITE OAK
512 VILLAGE SQUARE
513 WESTWOOD CEMETERY
514 708 ROSEMARY ST APTS
515 FIDELITY COURT
516 LIONS CLUB
517 CRESTWOOD
518 FENWAY PARK
519 ART CENTER
520 CLUB NOVA
521 HARRIS
522 OLD CARRBORO CMTY
523 AUTUMN WOODS
524 BREWER LANE
525 TWIN MAGNOLIAS
526 LINCOLN PARK
527 CARR STREET
528 HISTORIC DISTRICT
529 RIDGEWOOD
530 CARR COURT
531 RED DOOR
532 ROBERSON PLACE
533 ALABAMA AVENUE
534 OLD PITTSBORO
535 CLIFTON-OFFICE
536 Morningside Ministorage
537 Shoppes at Jones Ferry

538 Willow Creek Shopping
539 Carr Court Townhomes
540 S GREENSBORO ST
541 CHARLIE DAVIS CMTY
542 ABBEY COURT
543 UNIVERSITY LAKE APTS
544 GLEN GREENSTREET
545 CAROLINA APTS
546 WHISPERING HILLS
547 WILLOW CREEK CONDO
548 CRESCENT GREEN
549 ASHBROOK
550 ROYAL PARK
551 POPLAR PLACE
552 ROCKY POINT MHP
553 Weatherhill Townhouses
554 WILD SPRING
555 CHAMBERS RIDGE
556 TENNIS CLUB ESTATES
557 CANTERBURY
558 WEATHERHILL POINT
559 BERRYHILL
560 COLONIAL VILLAGE
561 UNIVERSITY COMMONS
562 Chapel Hill Tennis Club
563 Triangle Land Conservancy
564 THE BRIDGES
565 RAY ROAD
566 BPW CLUB
567 THE VILLAGES
568 SMITH LEVEL RD
569 COVENANT PLACE
570 THE STRATFORD
571 CARRBORO HIGH
572 TEAL PLACE
573 KENT WOODLANDS
574 ROCK CREEK
575 CARAMORE
576 THE ENCLAVE
577 RIDGEHAVEN
578 ROCK HAVEN CENTER
579 MT CARMEL SPRING
580 WOODCREST
581 RAY ESTATE
582 ANTLER POINT
583 COLE'S CROSSING
584 HERITAGE HILLS
585 LEGENDS
586 BALLENTINE
587 LAKE HOGAN FARMS
588 THE FELLS
589 UNIVERSITY LAKE
590 ROSES WALK
591 POPLAR-DAVIE
592 CREST STREET
593 CLAREMONT
594 WINMORE
595 CLAREMONT SOUTH
596 SMITH SOCCER FIELD
597 FIRE STATION
598 N GREENSBORO STREET
599 WEST END COMMONS
600 UNCOMMON GARDENS