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.

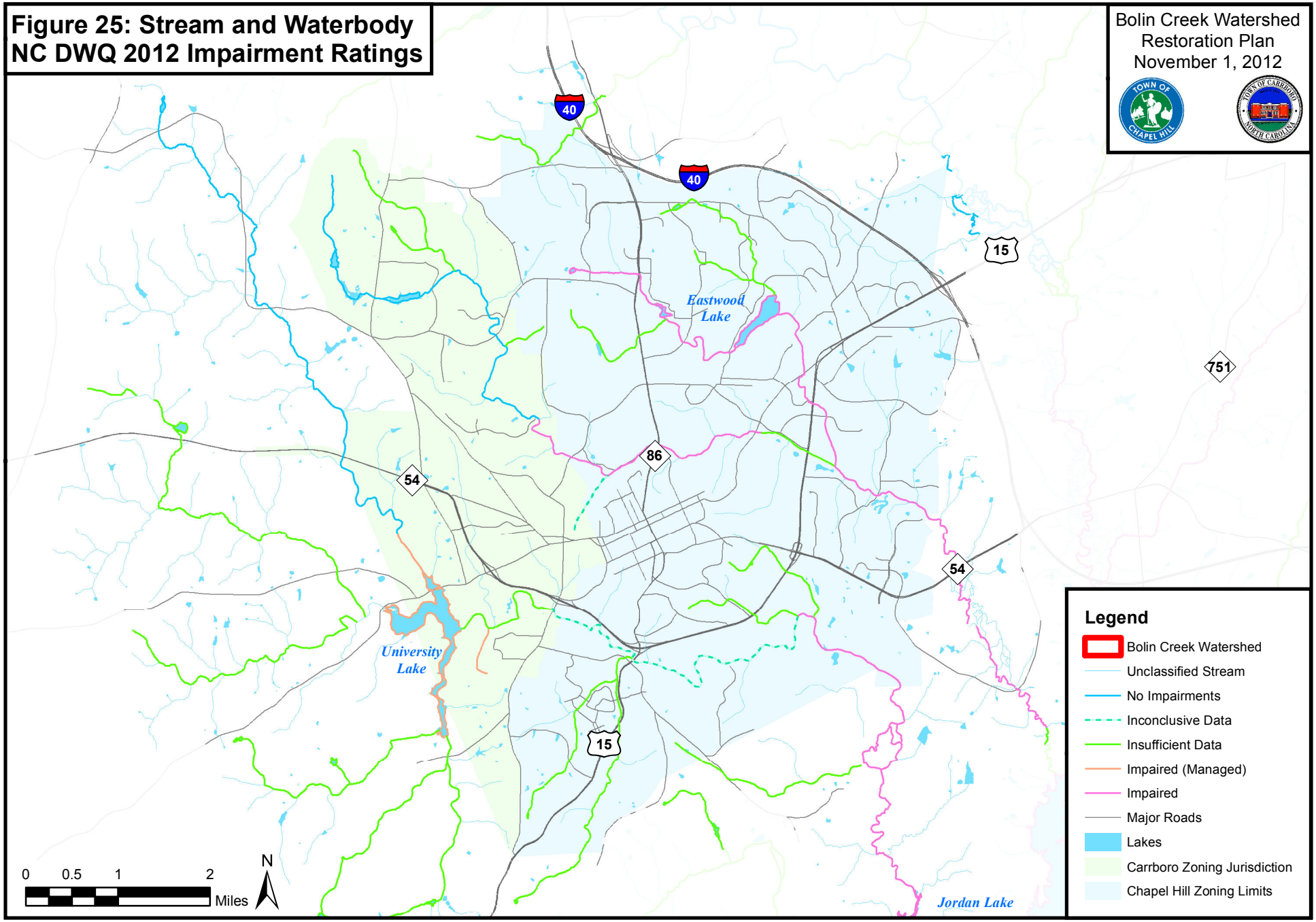


Figure 25: Stream and Waterbody
NC DWQ 2012 Impairment Ratings
Bolin Creek Watershed
Restoration Plan
November 1, 2012
40
40
15
751
86
54
54
15
Eastwood
Lake
University
Lake
Jordan Lake
0
0.5
1
2
Miles
N
Legend
Bolin Creek Watershed
Unclassified Stream
No Impairments
Inconclusive Data
Insufficient Data
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 has 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.

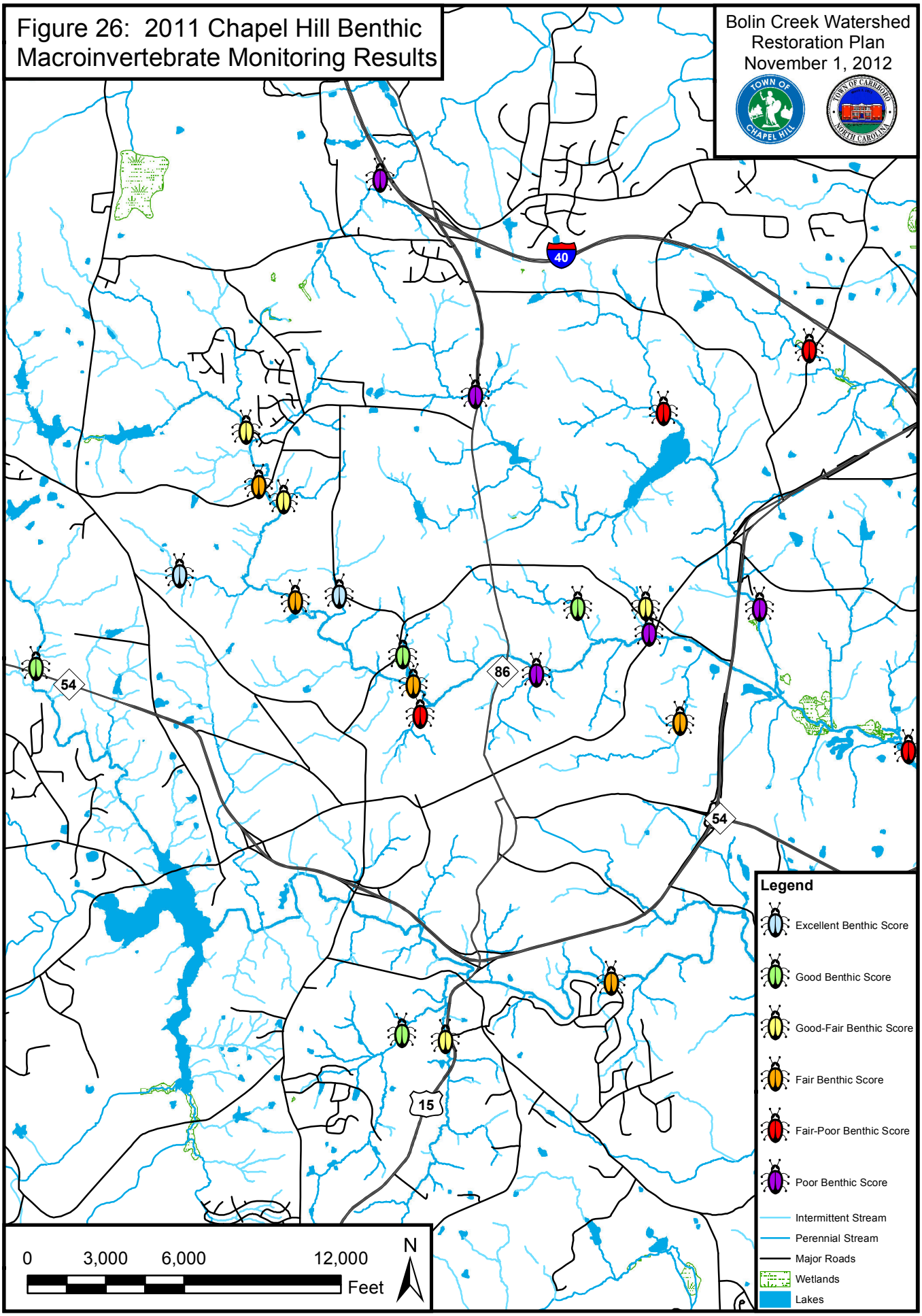


Figure 26: 2011 Chapel Hill Benthic Macroinvertebrate Monitoring Results
Bolin Creek Watershed Restoration Plan
November 1, 2012
40
54
86
54
15
Legend
Excellent Benthic Score
Good Benthic Score
Good-Fair Benthic Score
Fair Benthic Score
Fair-Poor Benthic Score
Poor Benthic Score
Intermittent Stream
Perennial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

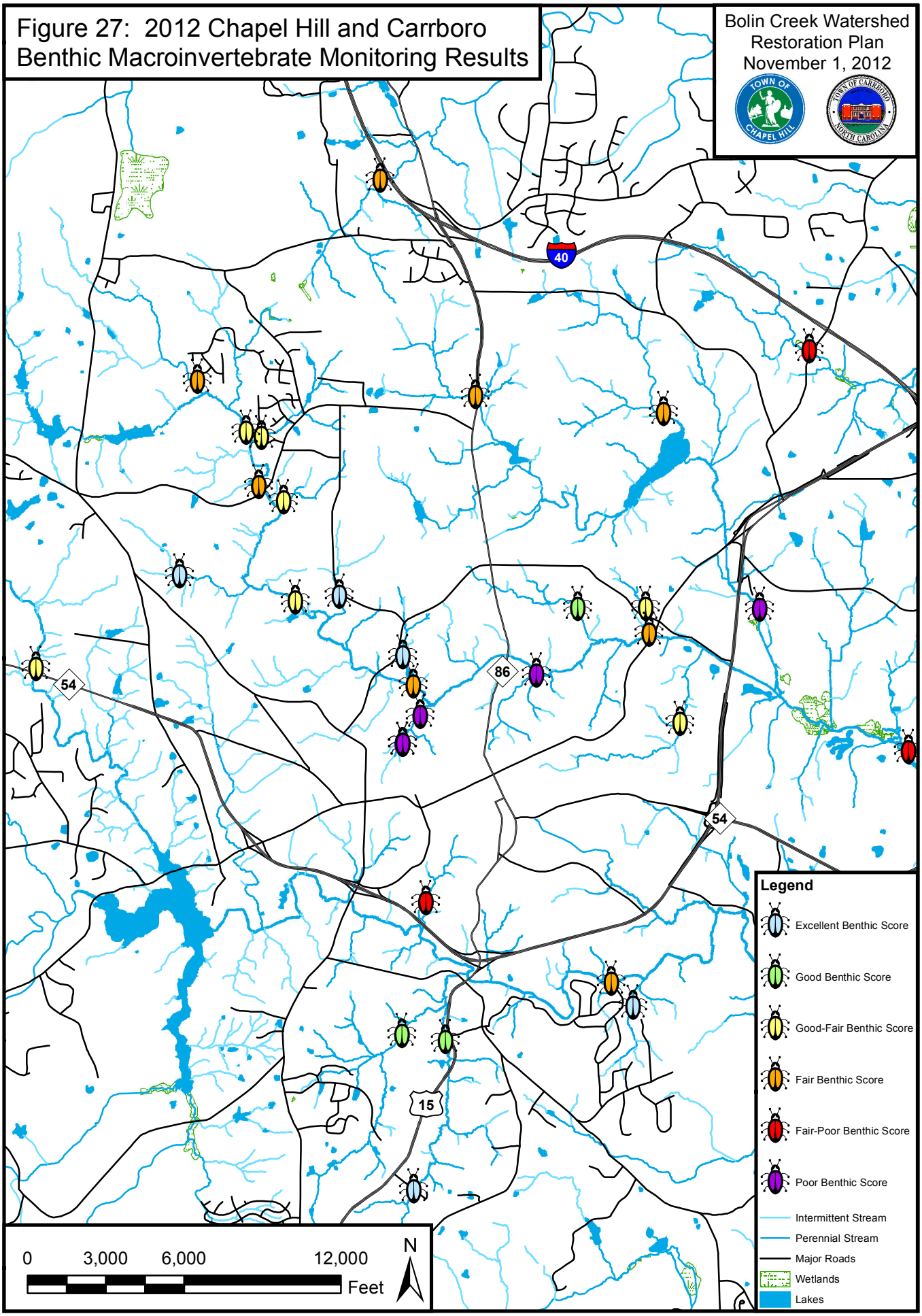


Figure 27: 2012 Chapel Hill and Carrboro Benthic Macroinvertebrate Monitoring Results
Bolin Creek Watershed Restoration Plan
November 1, 2012
40
54
86
54
15
Legend
Excellent Benthic Score
Good Benthic Score
Good-Fair Benthic Score
Fair Benthic Score
Fair-Poor Benthic Score
Poor Benthic Score
Intermittent Stream
Perennial Stream
Major Roads
Wetlands
Lakes
0
3,000
6,000
12,000
Feet
N

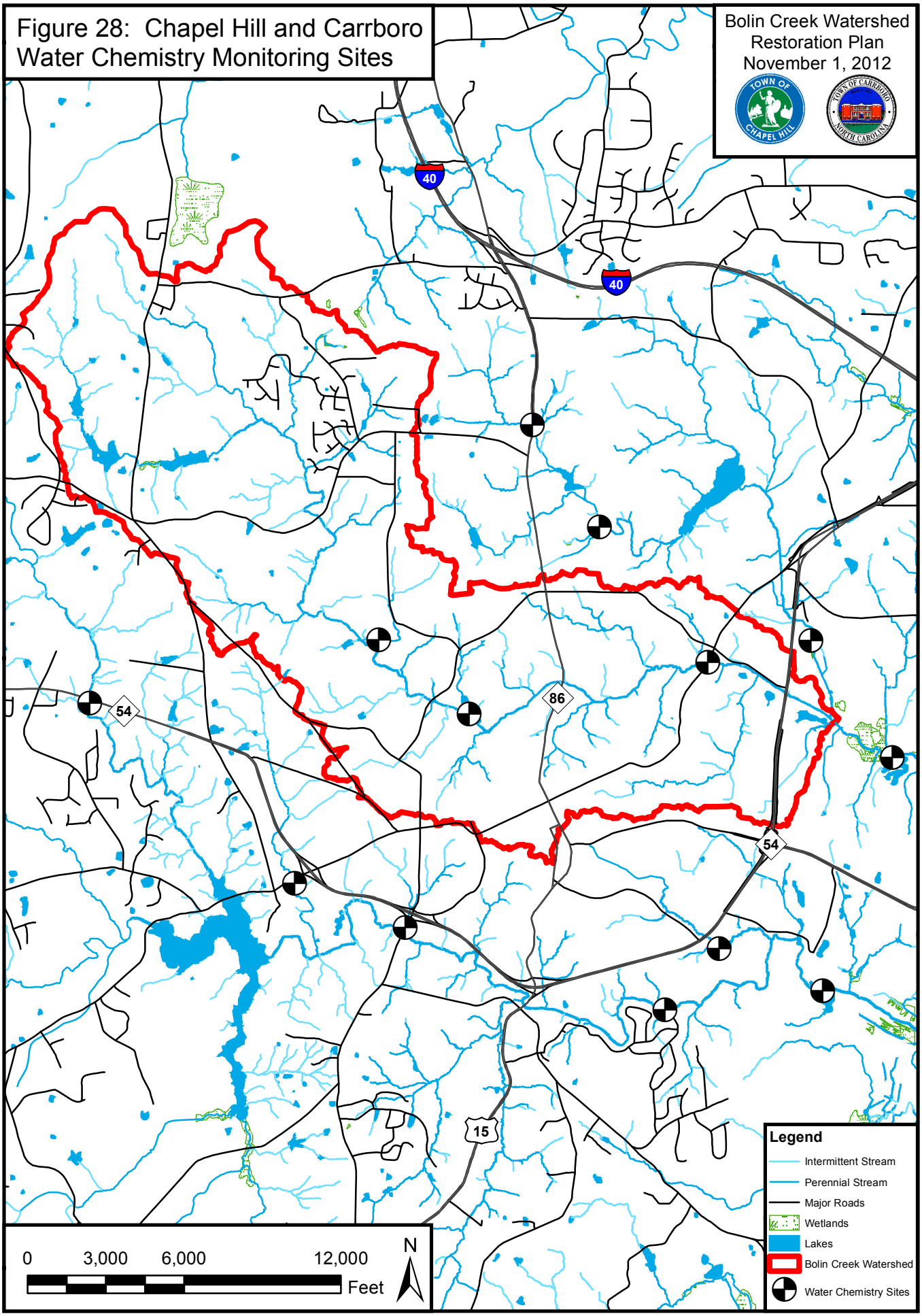


Figure 28: Chapel Hill and Carrboro Water Chemistry Monitoring Sites
Bolin Creek Watershed Restoration Plan
November 1, 2012
40
40
54
86
54
15
Legend
Intermittent Stream
Perennial Stream
Major Roads
Wetlands
Lakes
Bolin Creek Watershed
Water Chemistry Sites
0
3,000
6,000
12,000
Feet
N

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.

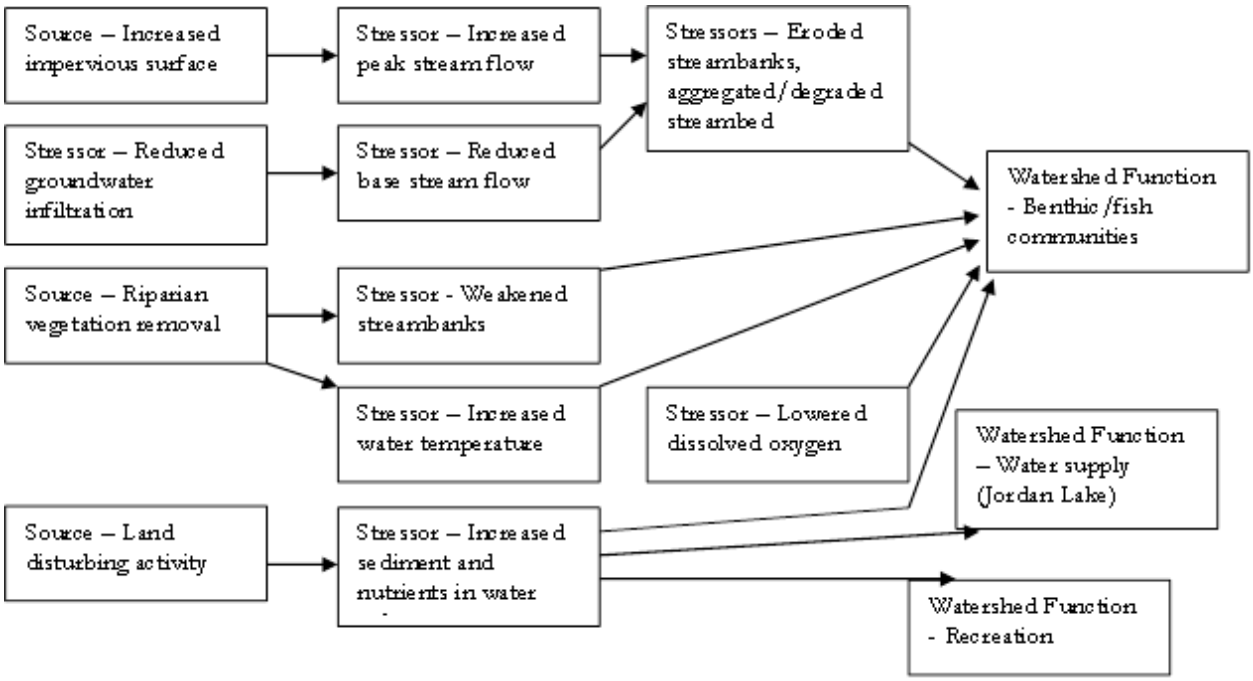


Figure 29: How Stressors and Sources Impact Watershed Functions

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 %	BL2 A %	BL2B %	BL3A %	BL3B %	BL4 A %	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

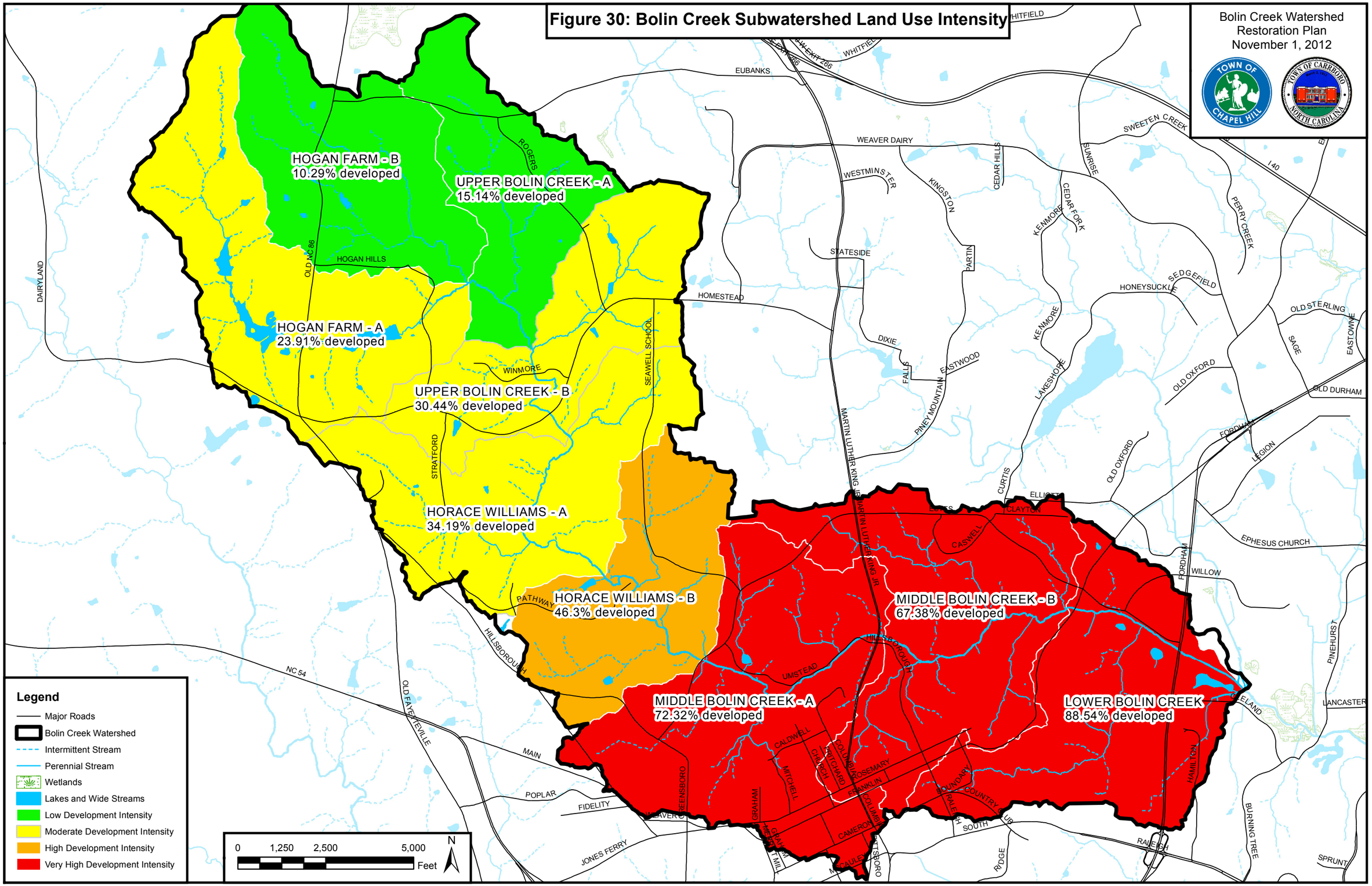
In order to examine the degree to which stream buffers are impacted by development and deforestation, a series of buffers were created in GIS for intermittent and perennial streams: 5 foot buffers to approximate vegetation directly on the banks, 30 foot buffers to represent Zone 1 Jordan buffers, 50 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



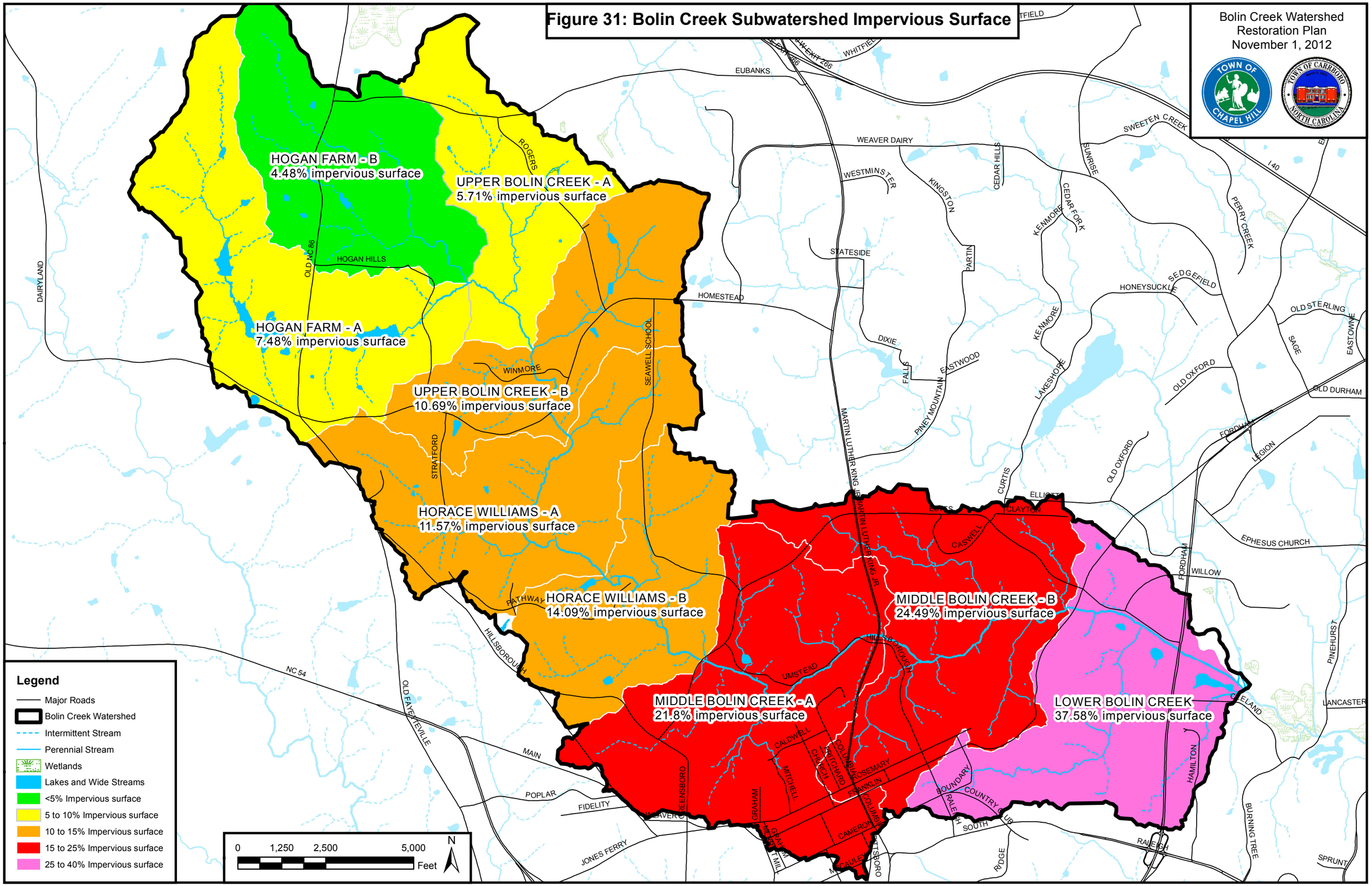


Figure 31: Bolin Creek Subwatershed Impervious Surface
Bolin Creek Watershed
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HOGAN FARM - B
4.48% impervious surface
UPPER BOLIN CREEK - A
5.71% impervious surface
HOGAN FARM - A
7.48% impervious surface
UPPER BOLIN CREEK - B
10.69% impervious surface
HORACE WILLIAMS - A
11.57% impervious surface
HORACE WILLIAMS - B
14.09% impervious surface
MIDDLE BOLIN CREEK - B
24.49% impervious surface
MIDDLE BOLIN CREEK - A
21.8% impervious surface
LOWER BOLIN CREEK
37.58% impervious surface
Legend
Major Roads
Bolin Creek Watershed
Intermittent Stream
Perennial Stream
Wetlands
Lakes and Wide Streams
<5% Impervious surface
5 to 10% Impervious surface
10 to 15% Impervious surface
15 to 25% Impervious surface
25 to 40% Impervious surface
0
1,250
2,500
5,000
Feet
N

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)

Bolin Creek Watershed Restoration Plan
November 1, 2012

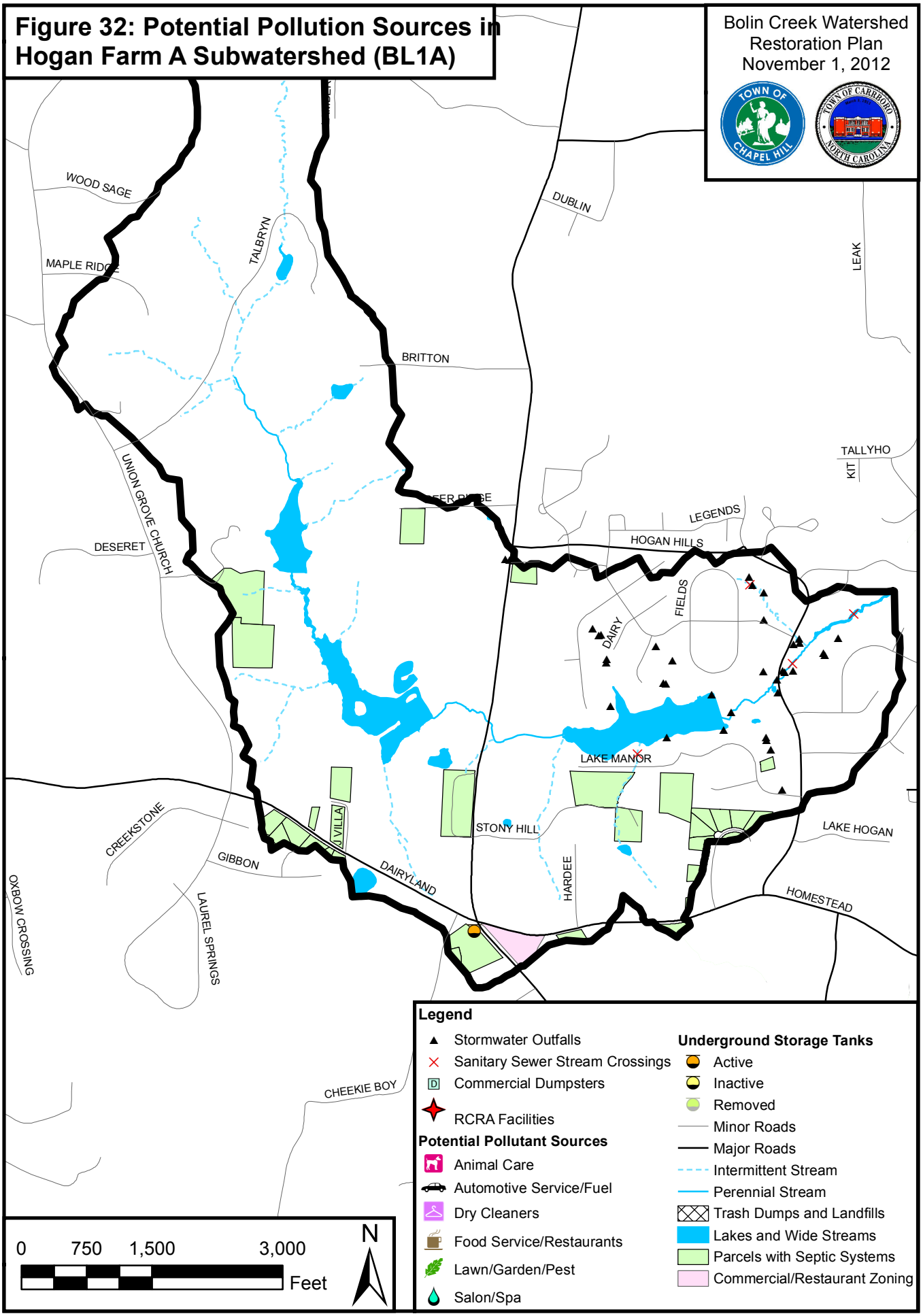

Figure 33: Potential Pollution Sources in Hogan Farm B Subwatershed (BL1B)

Bolin Creek Watershed Restoration Plan
November 1, 2012

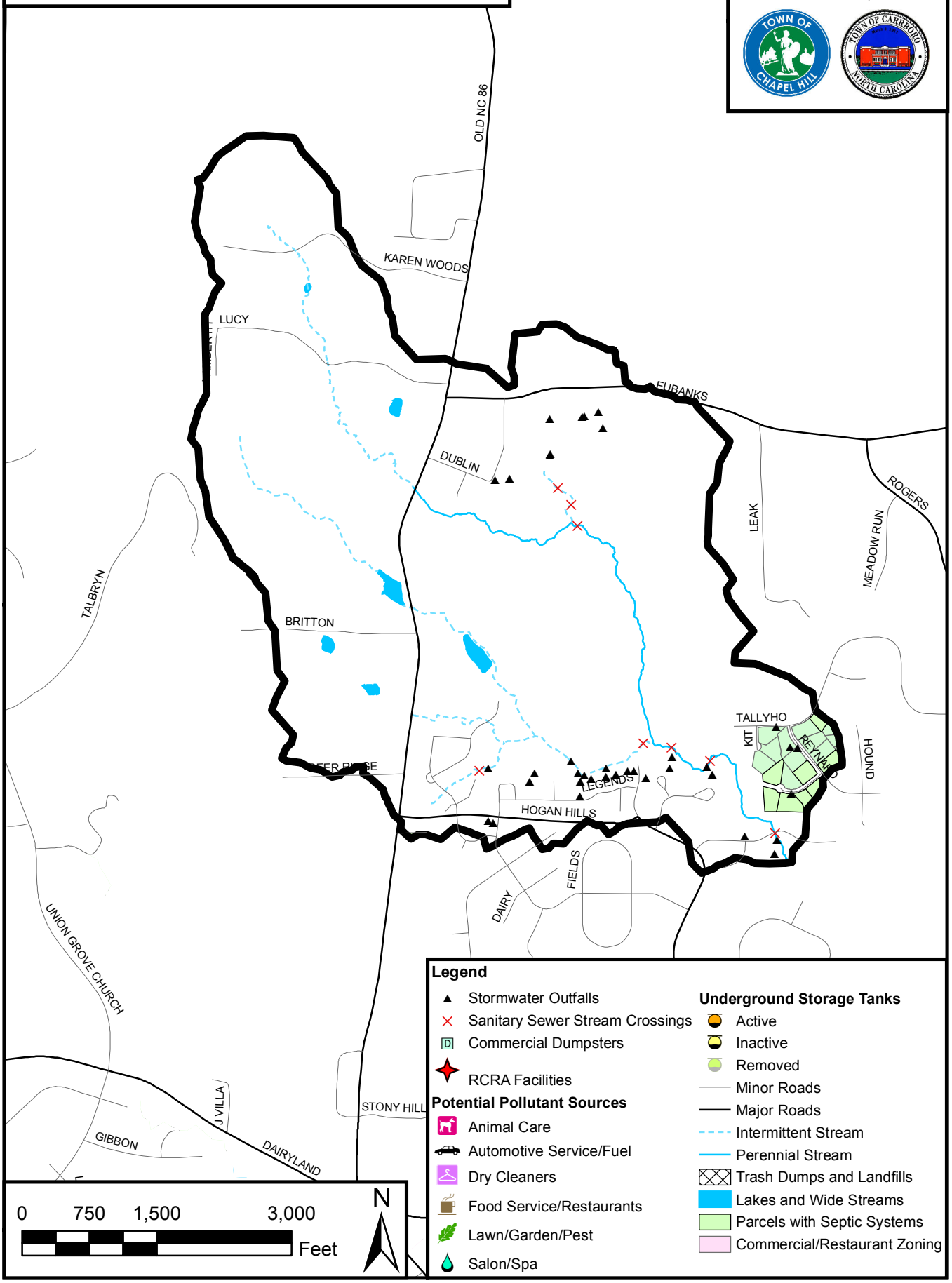

Figure 34: Potential Pollution Sources in Upper Bolin Creek A Subwatershed (BL2A)

Bolin Creek Watershed Restoration Plan
November 1, 2012

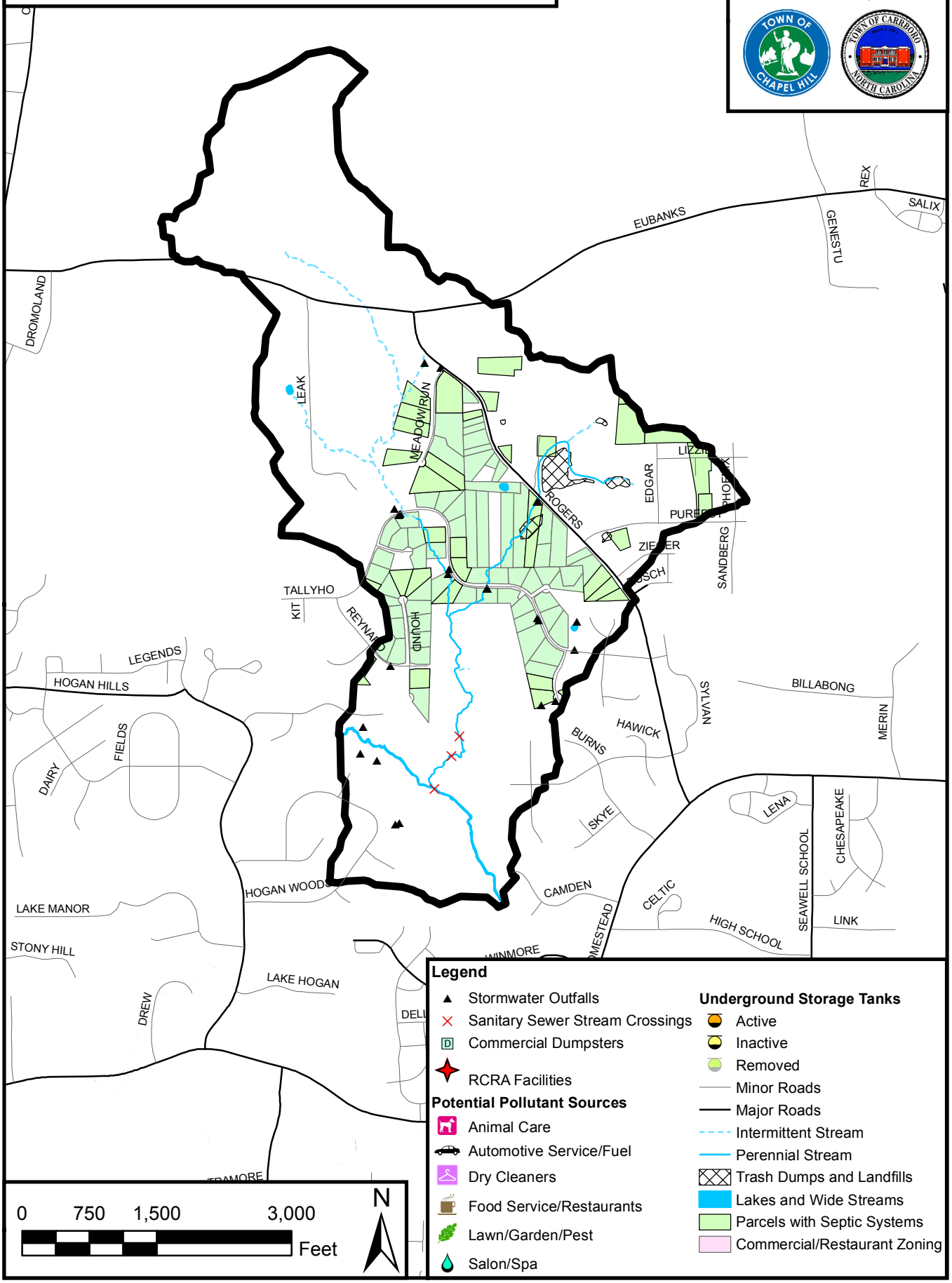

Figure 35: Potential Pollution Sources in Upper Bolin Creek B Subwatershed (BL2B)

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November 1, 2012

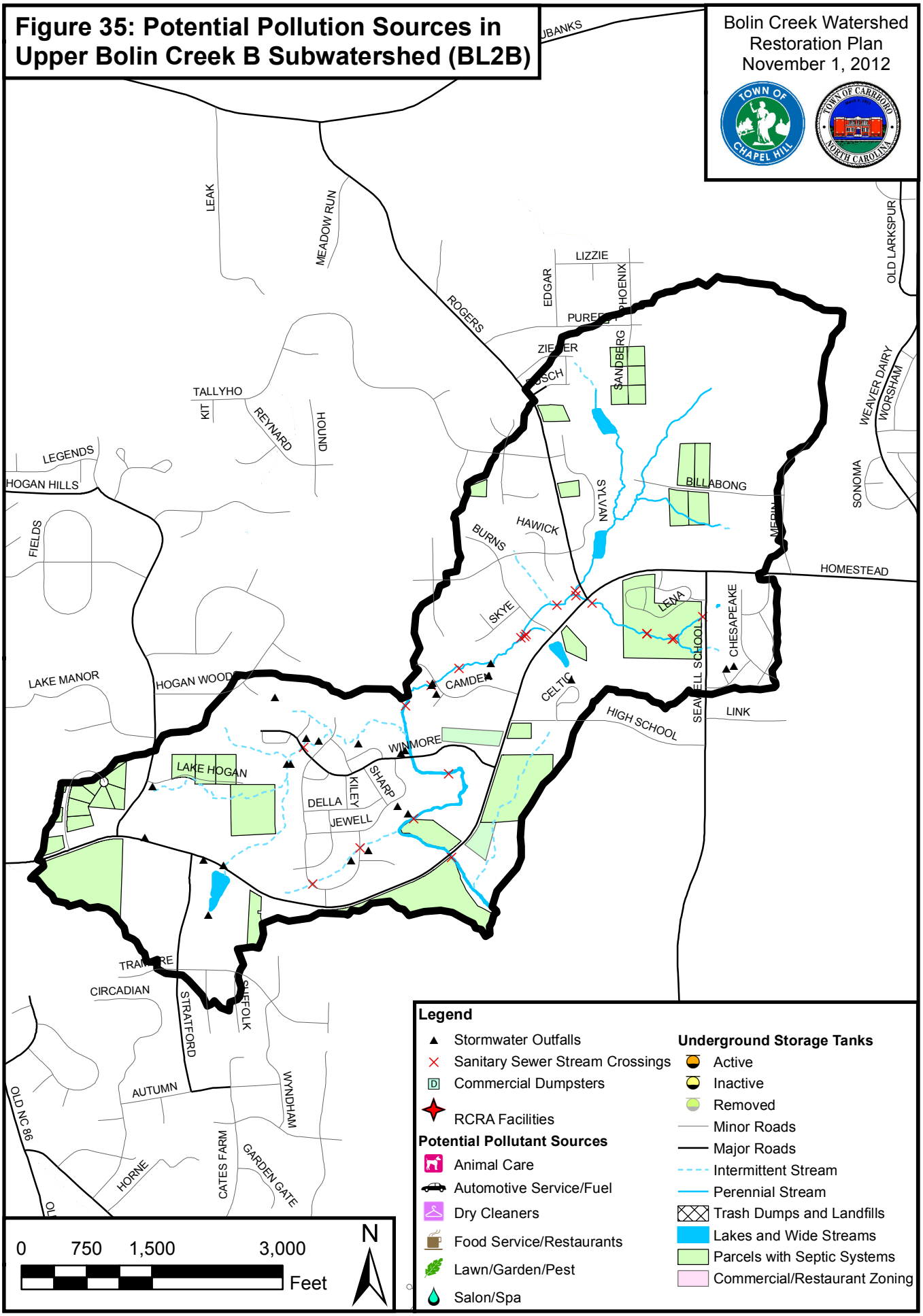

Figure 36: Potential Pollution Sources in Horace Williams A Subwatershed (BL3A)

Bolin Creek Watershed Restoration Plan
November 1, 2012

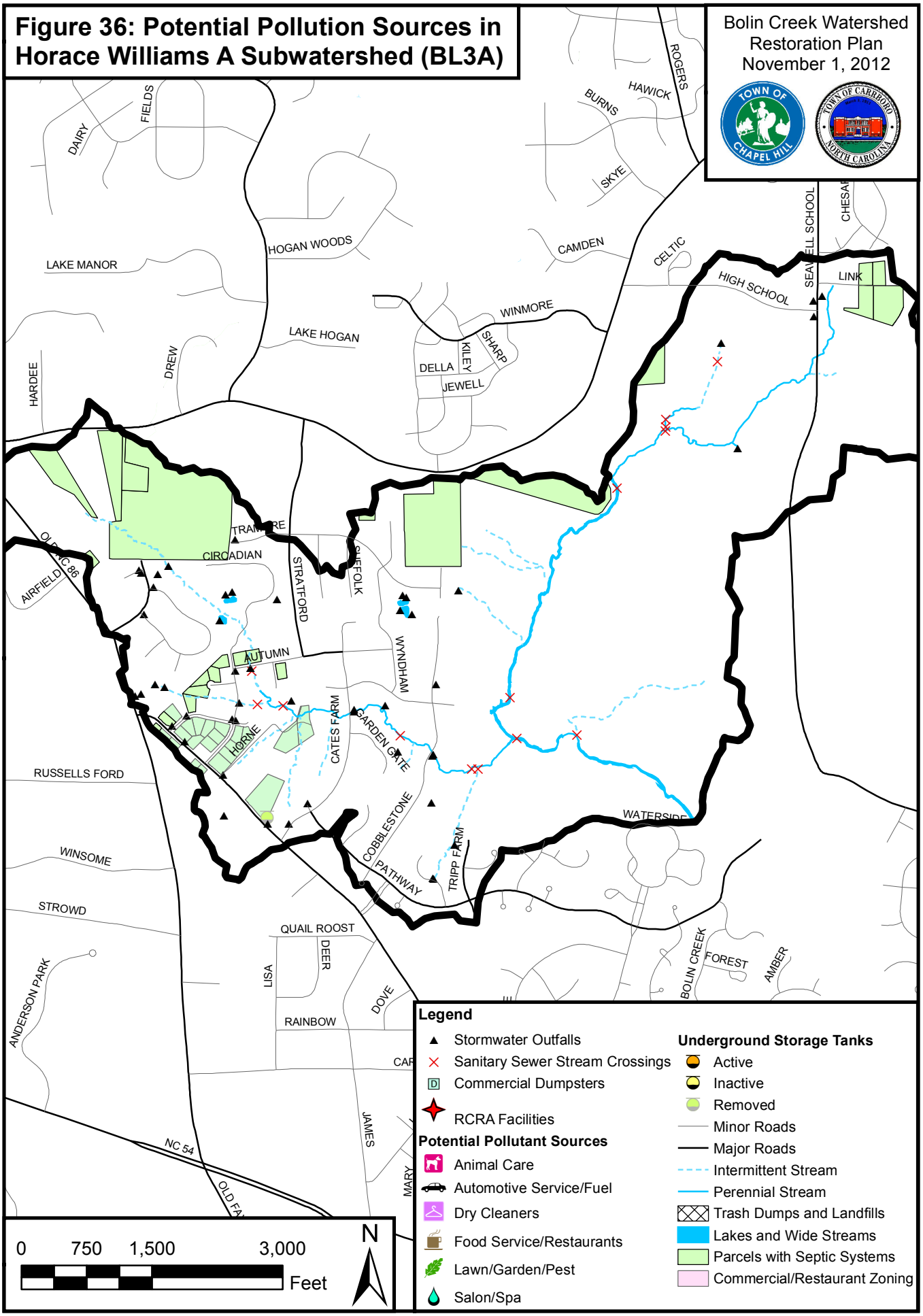

Figure 37: Potential Pollution Sources in Horace Williams B Subwatershed (BL3B)

Bolin Creek Watershed Restoration Plan
November 1, 2012

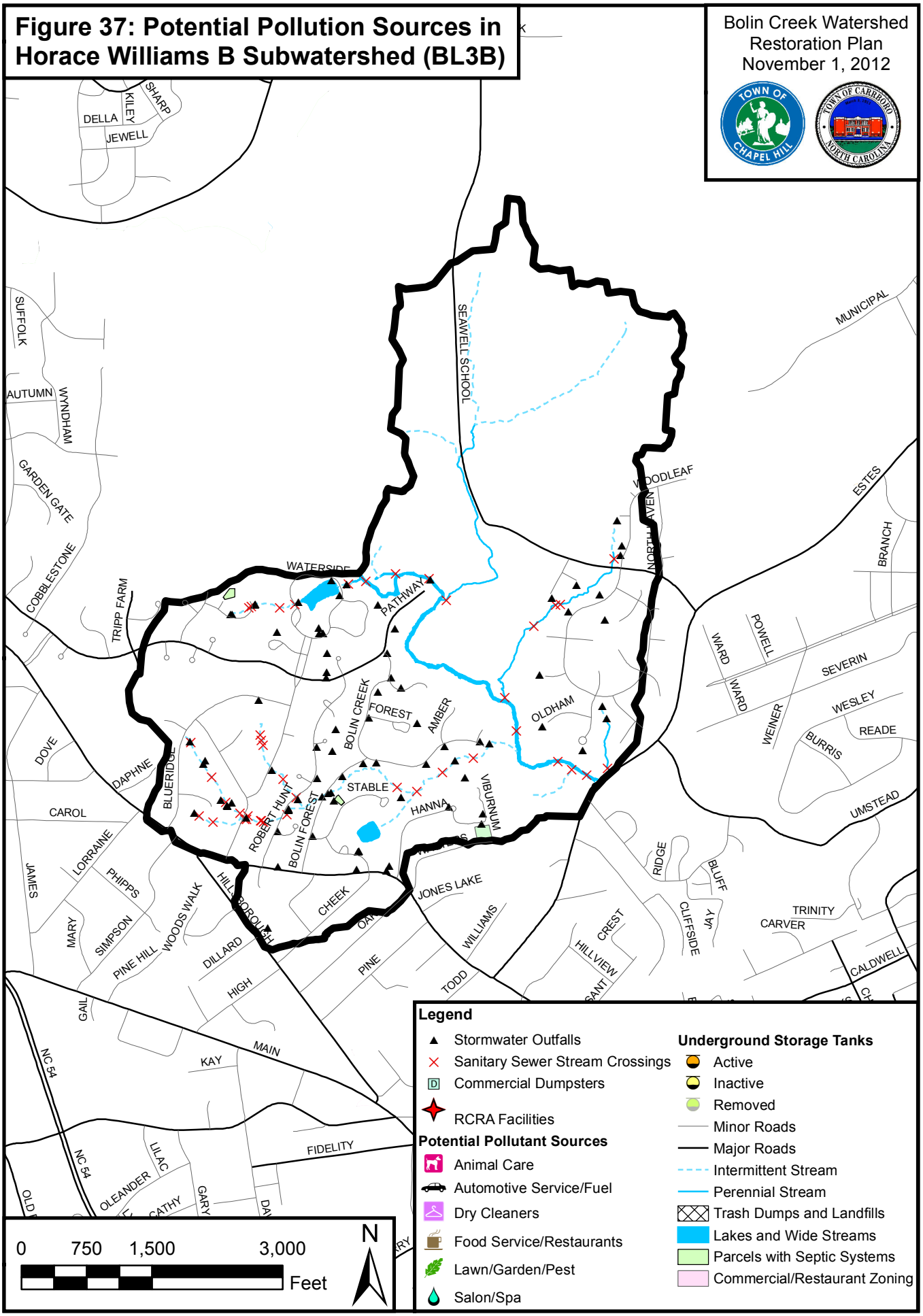

Figure 38: Potential Pollution Sources in Middle Bolin Creek A Subwatershed (BL4A)

Bolin Creek Watershed Restoration Plan
November 1, 2012

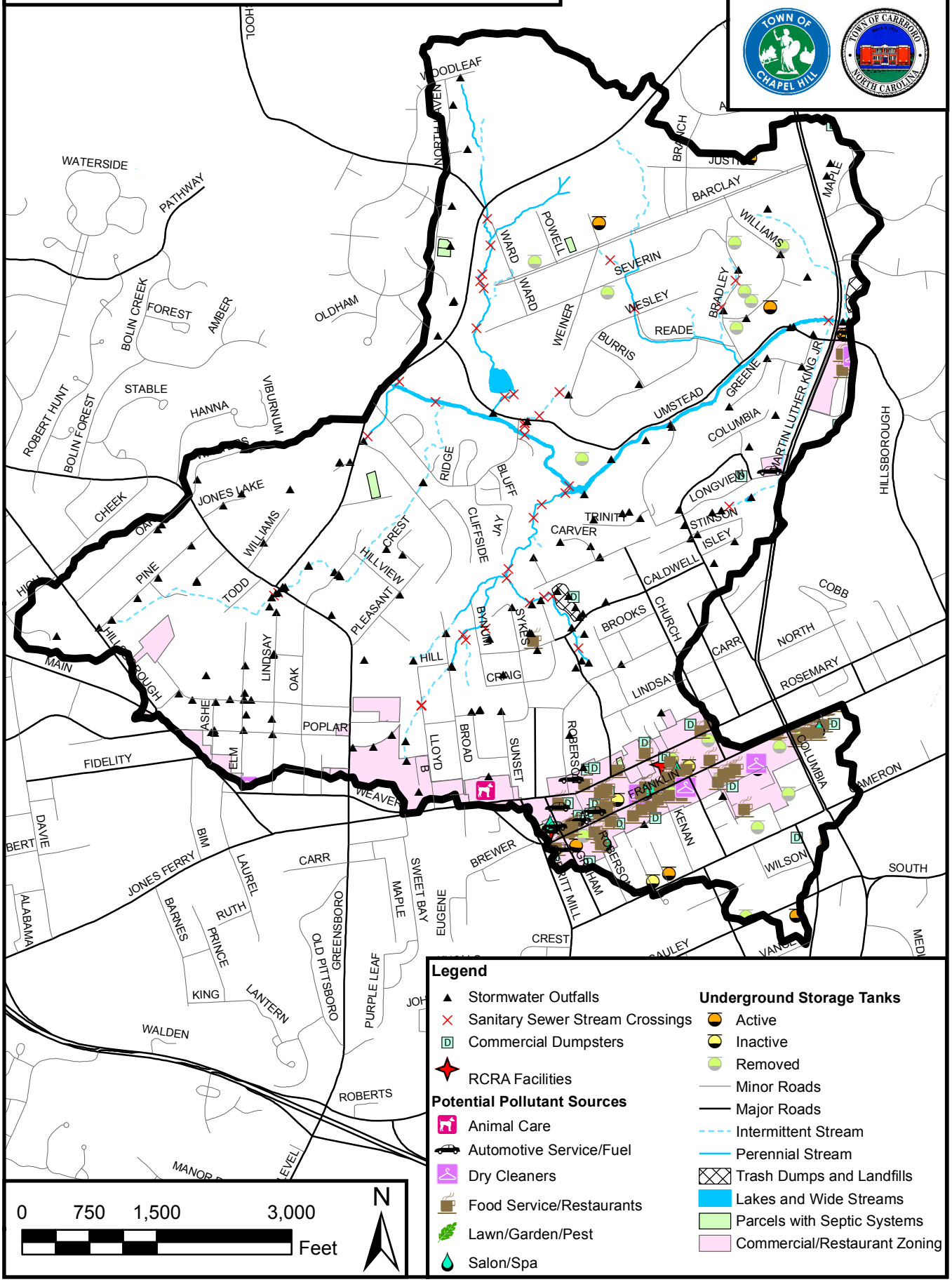

Figure 39: Potential Pollution Sources in Middle Bolin Creek B Subwatershed (BL4B)

Bolin Creek Watershed Restoration Plan
November 1, 2012

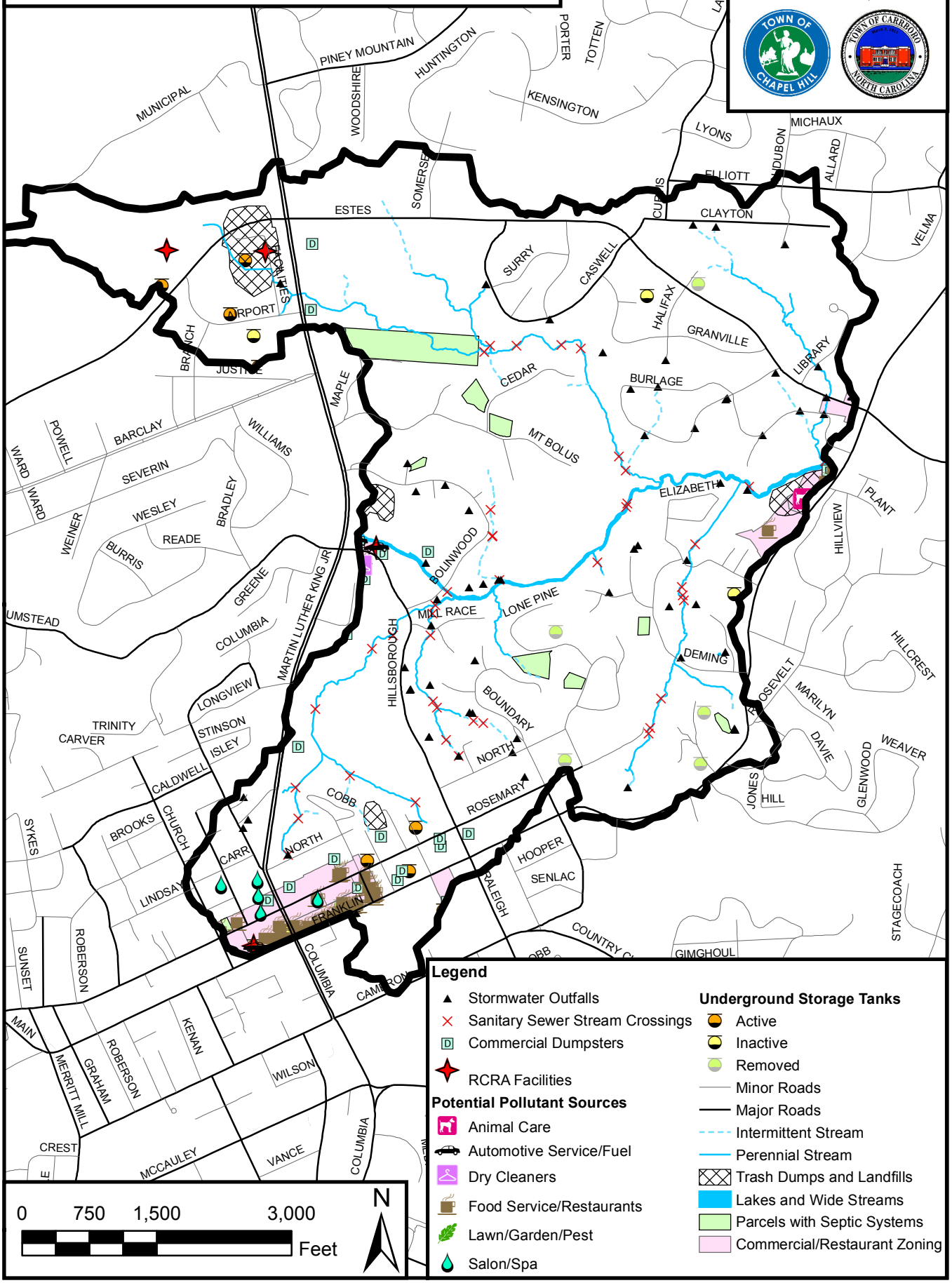

Figure 40: Potential Pollution Sources in Lower Bolin Creek Subwatershed (BL5)

Bolin Creek Watershed Restoration Plan
November 1, 2012

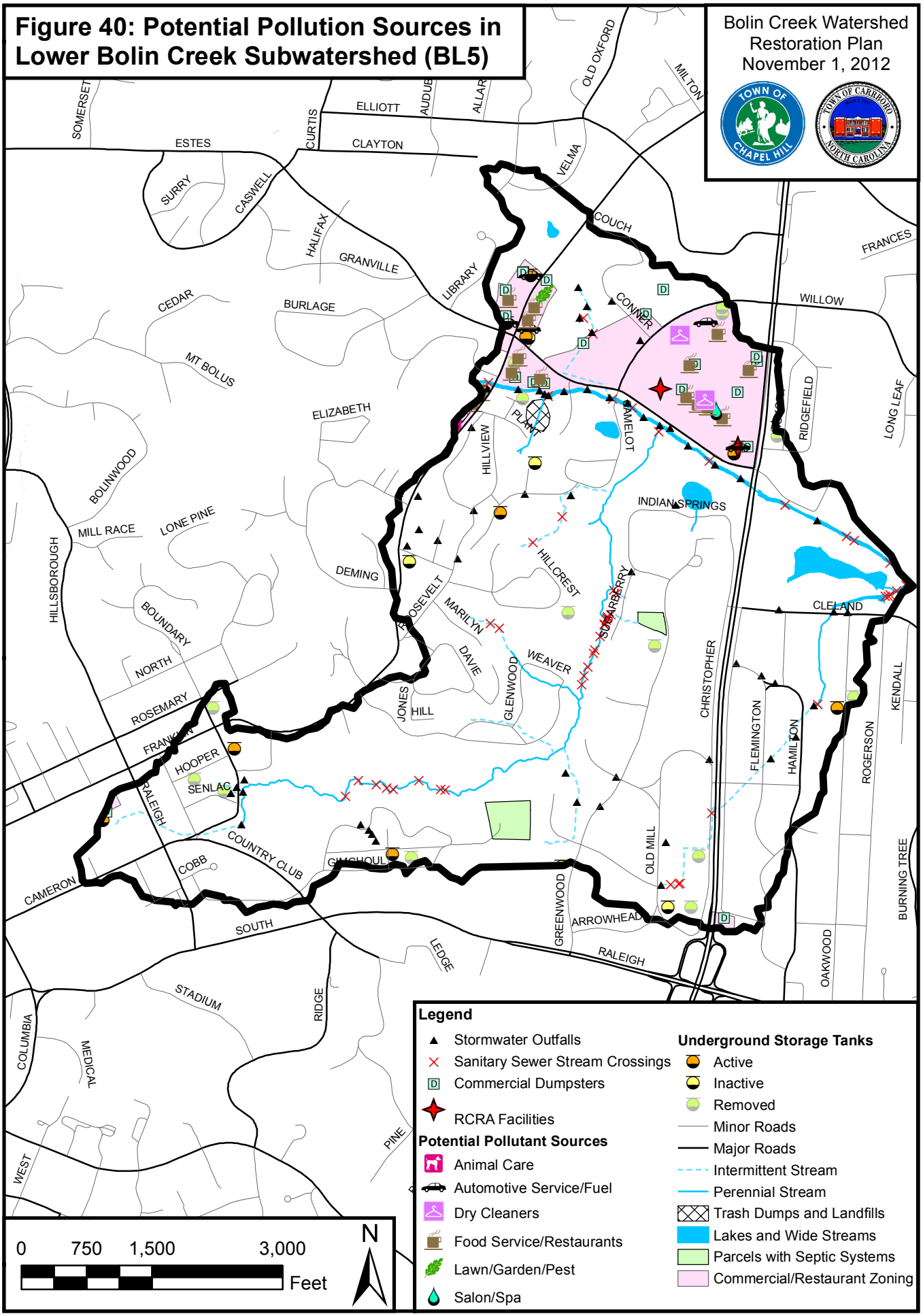

Figure 41: Riparian and Stream Channel Stressors in Hogan Farm A Subwatershed (BL1A)

Bolin Creek Watershed Restoration Plan
November 1, 2012

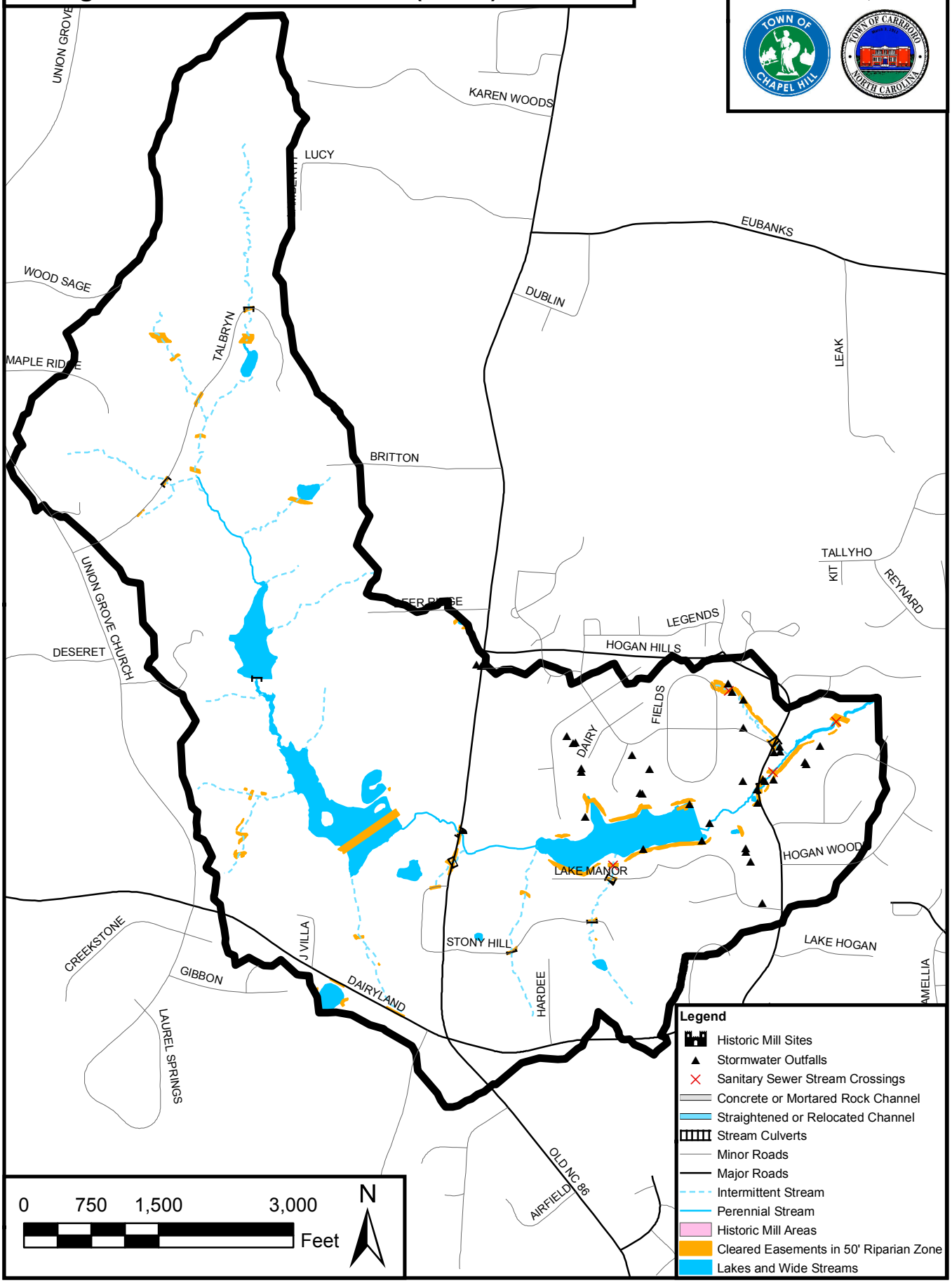

Figure 42: Riparian and Stream Channel Stressors in Hogan Farm B Subwatershed (BL1B)

Bolin Creek Watershed Restoration Plan
November 1, 2012

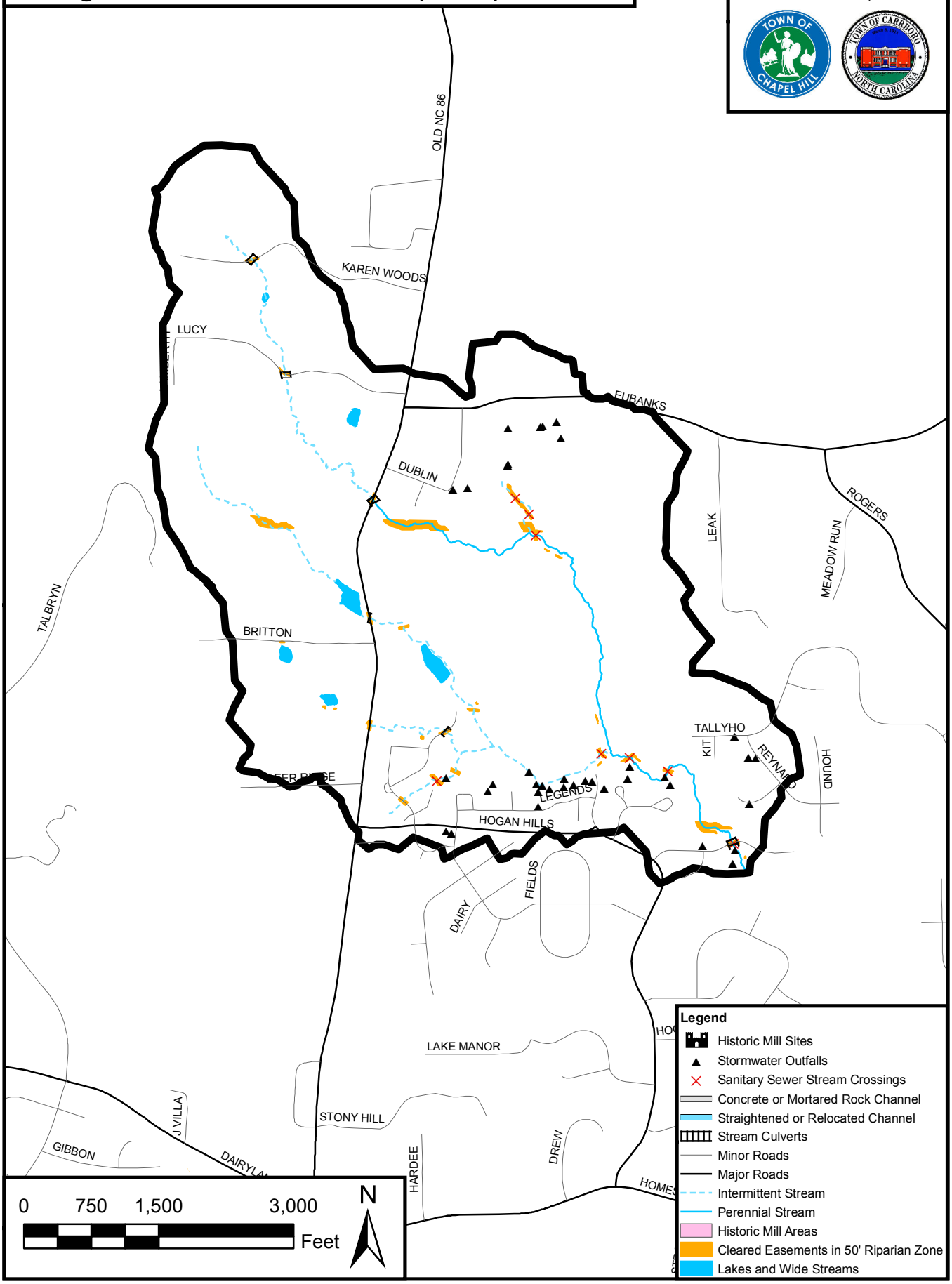

Figure 43: Riparian and Stream Channel Stressors in Upper Bolin Creek A Subwatershed (BL2A)

Bolin Creek Watershed Restoration Plan
November 1, 2012

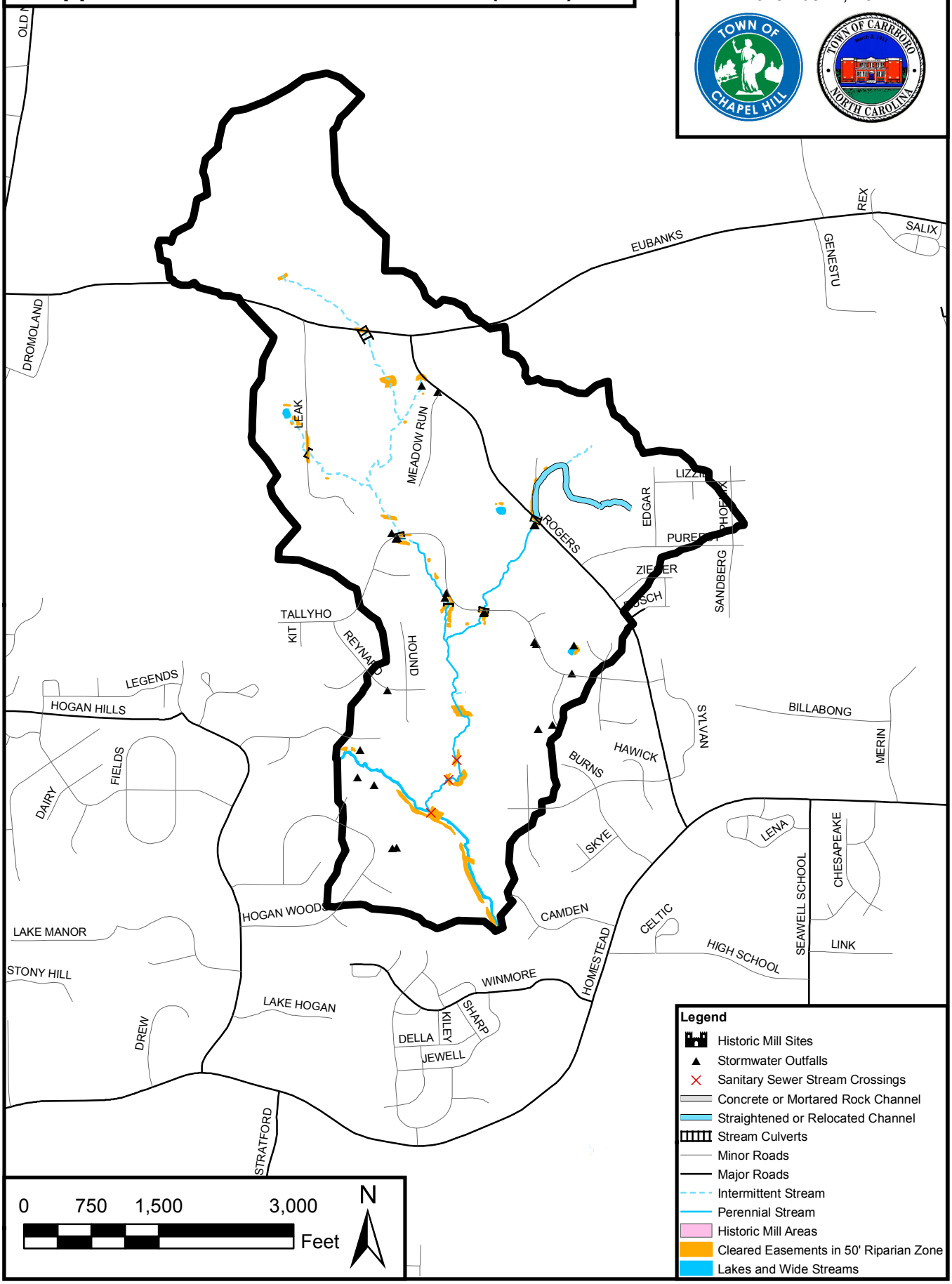

Figure 44: Riparian and Stream Channel Stressors in Upper Bolin Creek B Subwatershed (BL2B)

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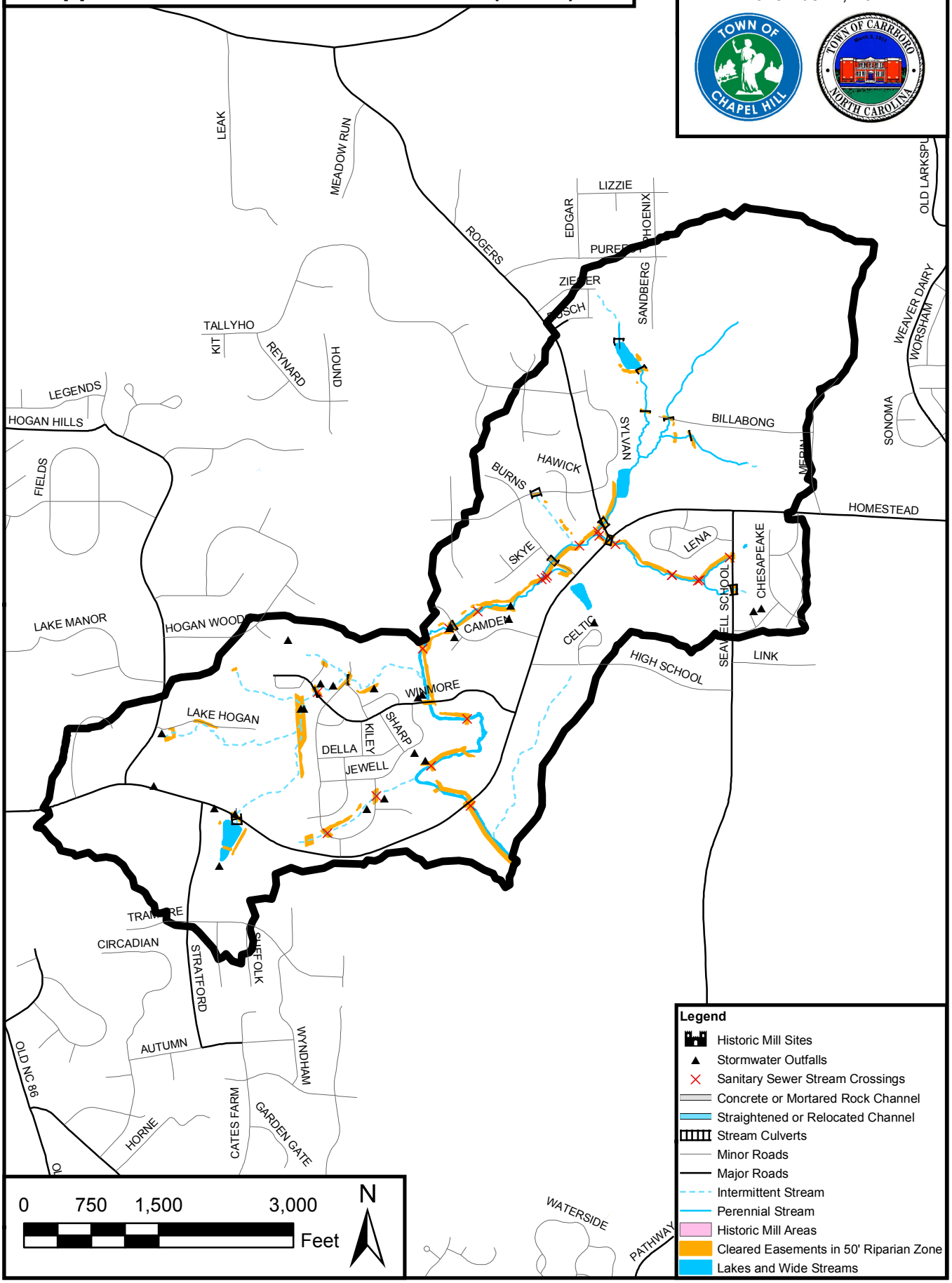


Figure 45: Riparian and Stream Channel Stressors in Horace Williams A Subwatershed (BL3A)

Bolin Creek Watershed
Restoration Plan
November 1, 2012

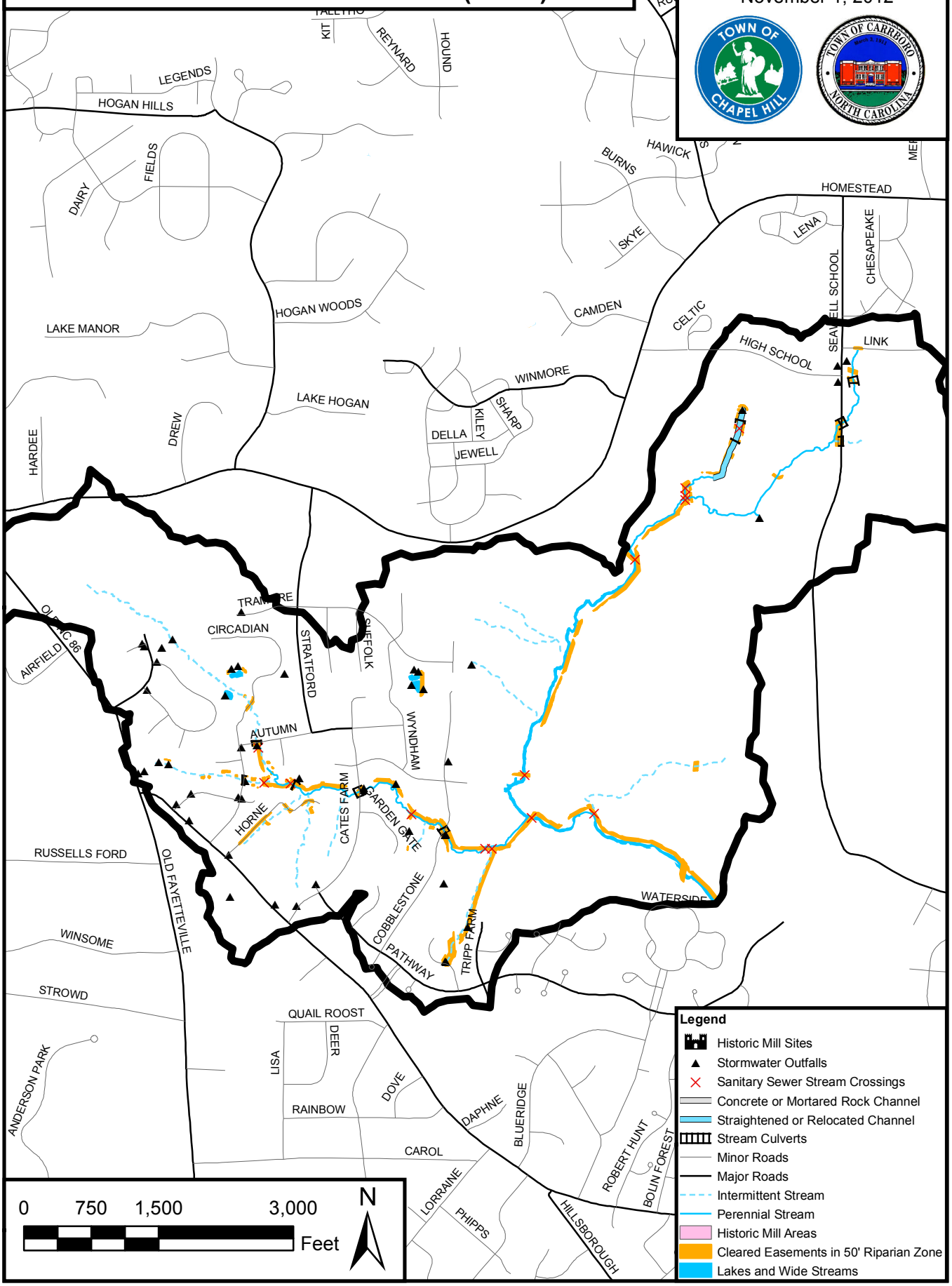


Figure 46: Riparian and Stream Channel Stressors in Horace Williams B Subwatershed (BL3B)

Bolin Creek Watershed
Restoration Plan
November 1, 2012

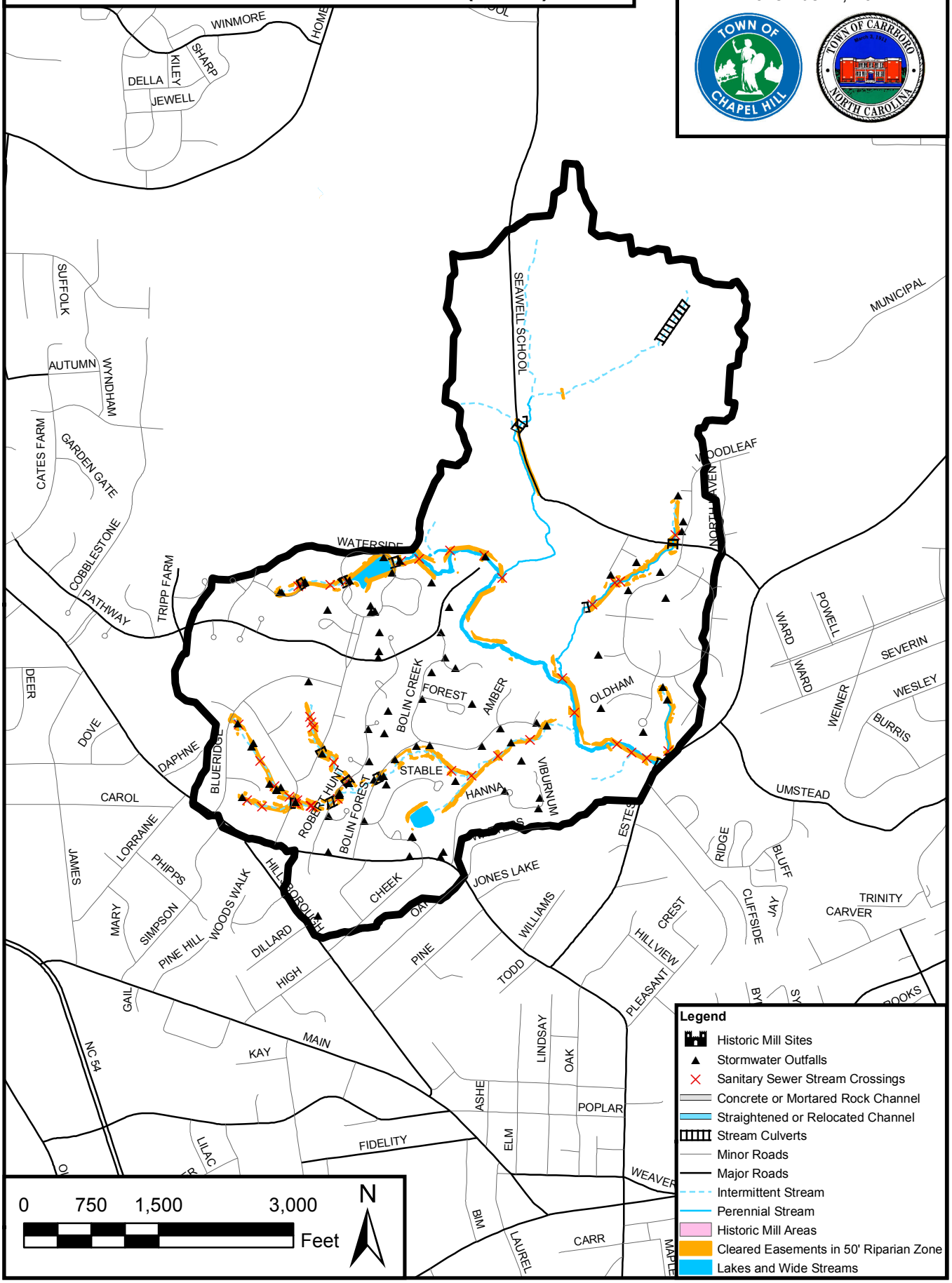


Figure 47: Riparian and Stream Channel Stressors in Middle Bolin Creek A Subwatershed (BL4A)

Bolin Creek Watershed
Restoration Plan
November 1, 2012

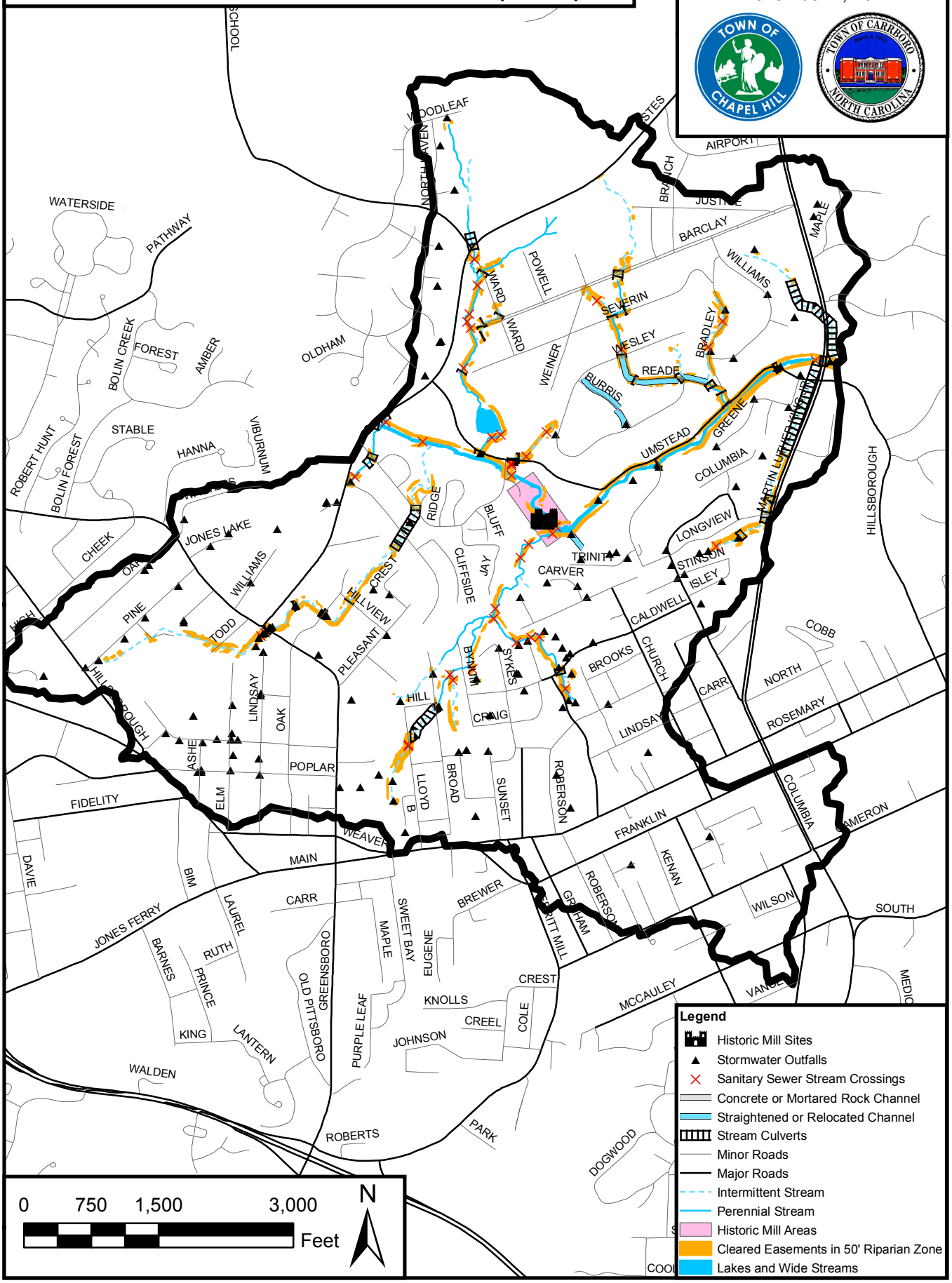


Figure 48: Riparian and Stream Channel Stressors in Middle Bolin Creek B Subwatershed (BL4B)

Bolin Creek Watershed Restoration Plan
November 1, 2012

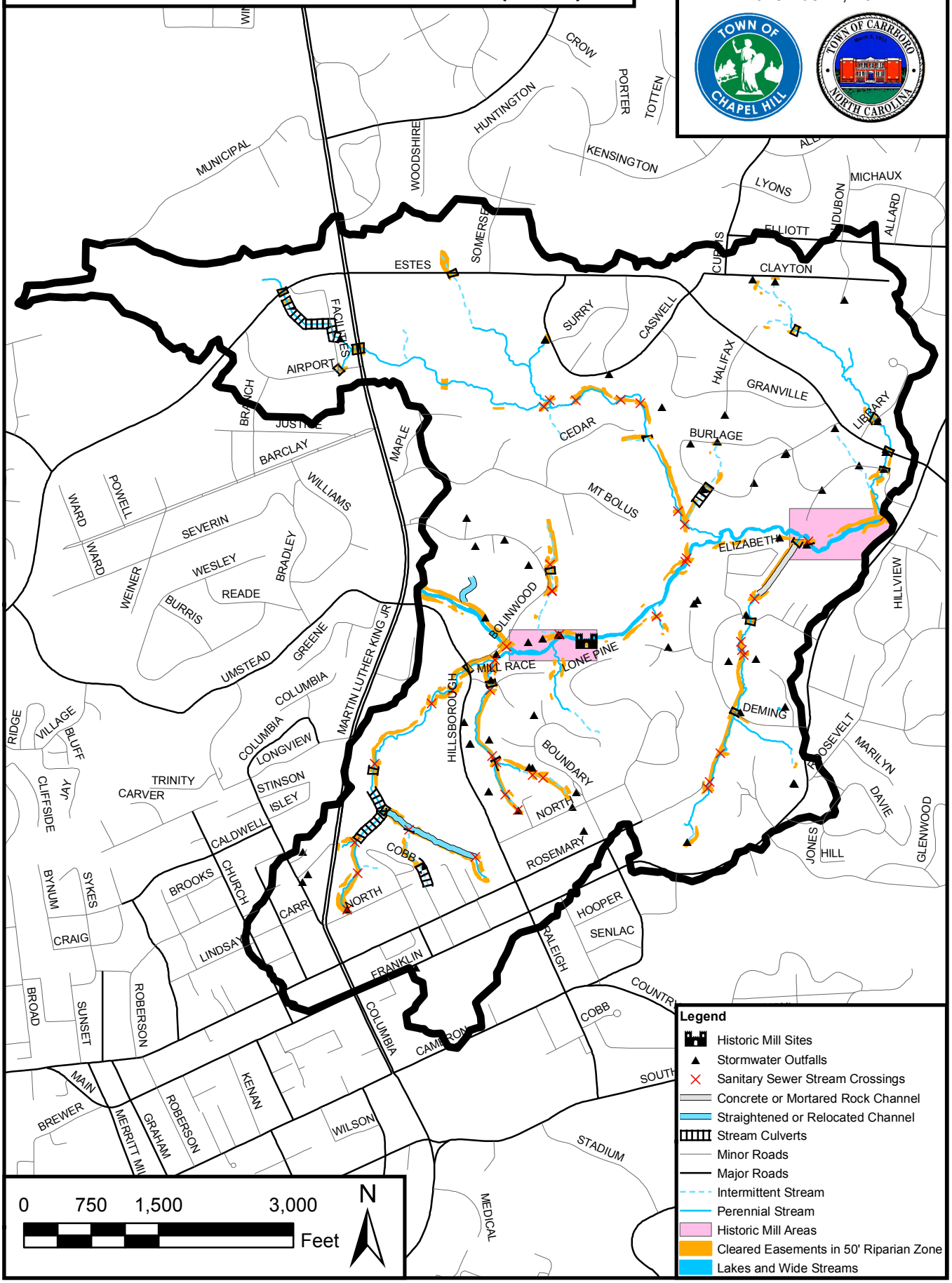
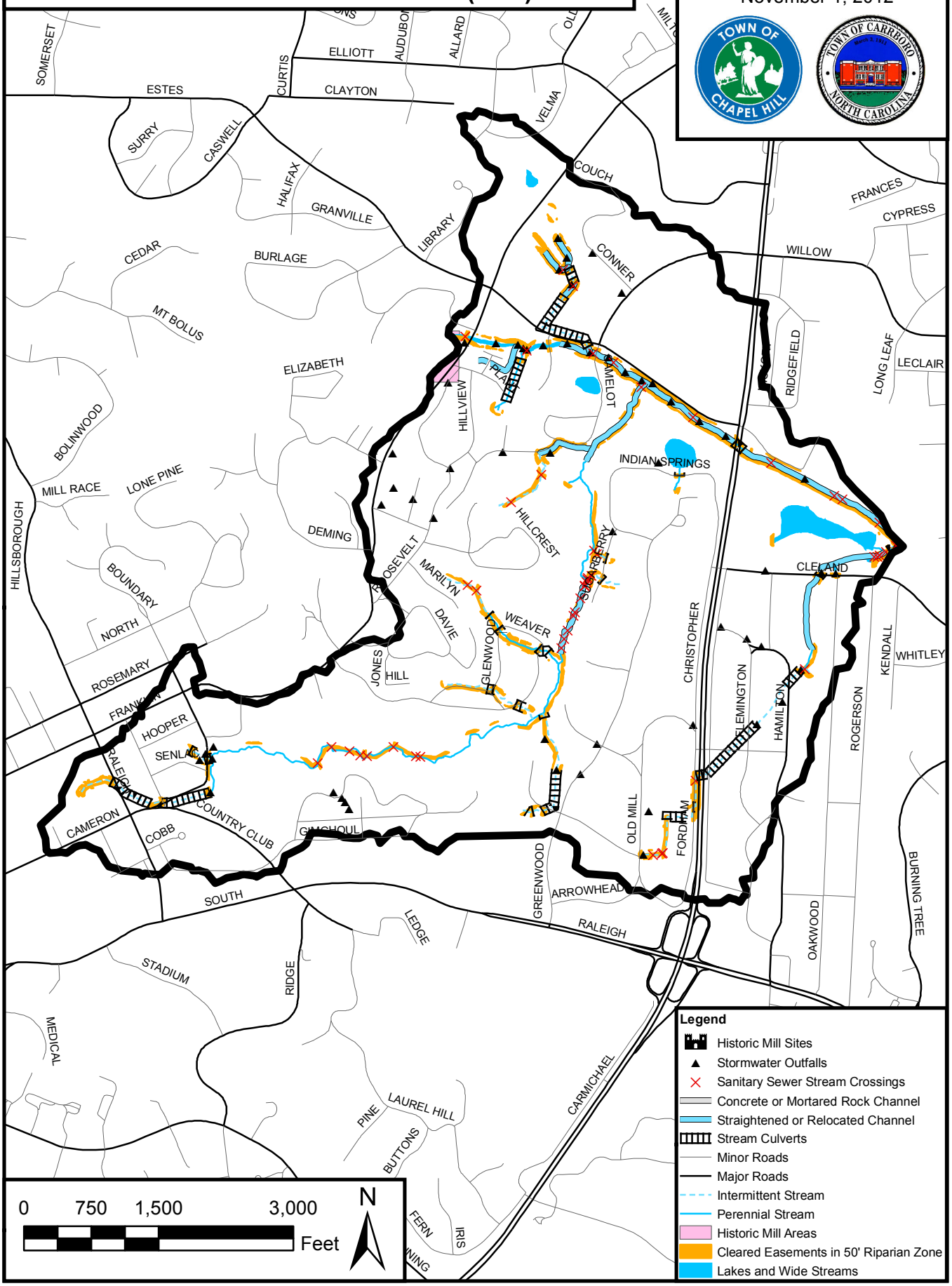


Figure 49: Riparian and Stream Channel Stressors in Lower Bolin Creek Subwatershed (BL5)

Bolin Creek Watershed Restoration Plan
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