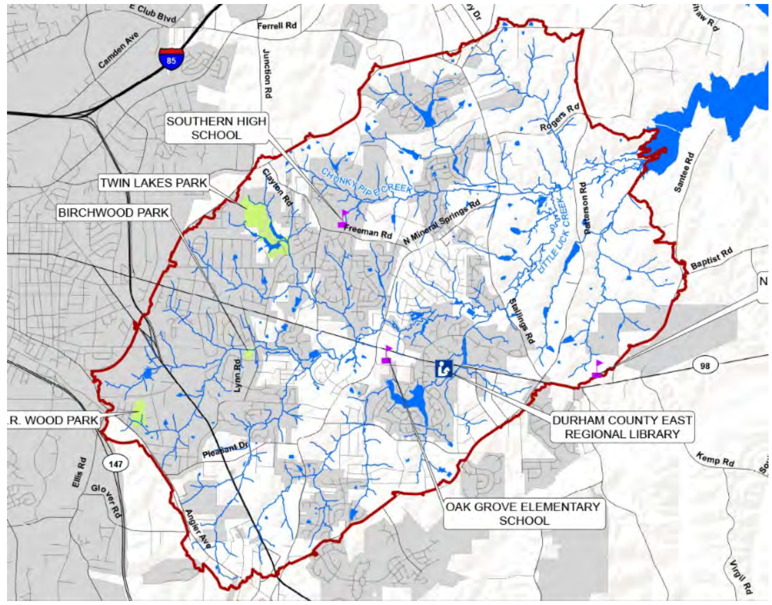

WATERSHED ASSESSMENT REPORT

September, 2015

Little Lick Creek Watershed Improvement Plan

Durham, North Carolina

PREPARED FOR:

DURHAM
1869
CITY OF MEDICINE

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Section 1: INTRODUCTION

1.1 Introduction to City of Durham's Watershed Improvement Plans

The City of Durham (City) implemented their watershed planning program in 2007 to protect and improve the water quality of streams, ponds, and small lakes in the City's watersheds and to comply with water quality regulations instituted by the State of North Carolina and the federal Clean Water Act to improve and protect the rivers and water supply reservoirs to which they flow. To date, the City has completed Watershed Improvement Plans (WIPs) for four of the City's major watersheds: Ellerbe Creek (2010), Third Fork Creek (2012), Crooked Creek (2013), and Northeast Creek (2013). Each WIP includes the following major steps:

1. Characterize the existing watershed conditions, including likely development trends that will occur in the future
2. Evaluate the water quality found within the local streams and the health of these streams
3. Identified sources of pollution that can negatively affect water quality and watershed health
4. Identify potential projects or actions the City can implement to reduce pollution to the local streams and to the rivers and water supply reservoirs into which they flow
5. Solicit input from the public, City officials, and key stakeholders on the recommended projects and actions
6. Select and prioritize the most cost-effective and beneficial projects or actions for implementation

The Little Lick Creek watershed represents another major watershed in the City of Durham (Figure 1). The City initiated the Little Lick Creek WIP in early 2014 to address degraded water quality and aquatic habitat conditions in Little Lick Creek, and to address state water quality regulations for Falls Lake. Sections of Little Lick Creek have been on the North Carolina list of "impaired" waters, known as the 303(d) list, for low dissolved oxygen and high turbidity since 2008. The Little Lick Creek watershed drains into Falls Lake, which is regulated as a "Nutrient Sensitive Water" by the North Carolina Department of Environment and Natural Resources (NCDENR). In an effort to reduce pollution entering the lake, the State of North Carolina adopted special regulations called the Falls Water Supply Nutrient Strategy in 2010, commonly referred to as the "Falls Lake Rules." These regulations require local communities to implement measures to reduce the annual load of nutrients to Falls Lake from upstream sources such as urban stormwater runoff, wastewater effluent, septic systems and discharging sand filters, and runoff from agricultural lands. There are no municipal wastewater treatment plants discharging effluent in the watershed, and the City has limited agricultural land within the current Durham city limits. Therefore, the Little Lick Creek WIP will mainly focus on measures that will reduce the negative effects of urban stormwater runoff, septic systems, and discharging sand filters on water quality and watershed health, and will also improve the stability and health of the natural streams.

This Watershed Assessment Report provides a summary of the results of several of the steps listed above needed to complete the Little Lick Creek WIP, including:

- Watershed characteristics such as hydrology, topography, soils, climate, and land use (Section 2)
- Existing water quality data (Section 3)
- Potential sources of pollution and negative impacts to water quality (Section 3)

- Identification of opportunities to improve water quality and ecological function (Section 4), such as:
  - Stormwater control measure (SCM) retrofits
  - Stream restoration, enhancement, and preservation
  - Improvements to on-site wastewater systems (i.e., septic and discharging sand filter systems)
- Identification of Pilot Study Areas (PSAs) that will be used to evaluate the effectiveness of a variety of water quality improvement measures (Section 5)
- Discussion of the next steps to complete the WIP (Section 6)

1.2 Documentation of Durham's Watershed Improvement Plans

The complete Little Lick Creek WIP is documented in several volumes that contain a summary of the overall approach used to evaluate the watershed, the data used for and results of the watershed characterization, the development and application of the watershed modeling tools, the water quality improvement measures that were evaluated, the results for each watershed improvement scenario, and the final recommendations for the WIP. These documents consist of:

1. **Watershed Assessment Report –** As stated above, this report presents the watershed characteristics such as hydrology, topography, soils, climate, and land use, a summary of existing water quality and stream conditions, potential sources of pollution that are having negative impacts on water quality, and identification of opportunities to improve water quality and watershed health.
2. **Watershed Improvement Plan Volume I (Executive Summary) –** Provides a brief description of the project goals, the watershed evaluation methods, the water quality improvement measures that were evaluated, the results for each watershed improvement scenario, the final recommendations, and next steps for implementing the WIP. This is the only volume that contains the specific high-priority stormwater SCM retrofits, new stormwater SCMs, and the stream restoration and stabilization projects recommended in the WIP for the Little Lick Creek Watershed.
3. **Watershed Improvement Plan Volume II (Main Report)** – Summarizes the overall approach used to evaluate the Little Lick Creek Watershed, the data used to complete the watershed characterization, the development and application of the watershed modeling tools, the water quality improvement measures that were evaluated, the results for each watershed improvement scenario, and the final recommendations for the WIP.
4. **Watershed Improvement Plan Volume III (Technical Appendices) –** Contains a series of memoranda prepared throughout the project that describe in more detail the technical approach used to complete the watershed characterization, develop the watershed modeling tools, and evaluate each watershed improvement scenario.
5. **Critical Area Protection Plan** – Healthy riparian buffers along streams are vitally important for protecting stream banks and lake shorelines from erosion during storms, improving and protecting water quality, dissipating flood flows, and providing fish and wildlife habitat. This document presents the data and methods used to identify and prioritize privately-owned high quality riparian areas that should be protected and preserved through acquisition, easements, or

restrictive covenants to help maintain water quality and watershed health. This City-wide document presents the high-priority riparian areas in each watershed in separate appendices.

6. **Riparian Area Management Plan** represents a second City-wide document focused on maintaining or improving the quality of riparian areas. This document focuses on riparian buffer management and maintenance recommendations for publicly-owned property that should be followed by City management, design, and maintenance staff in parks, utility easements, and greenway corridors. To date, the report contains specific recommendations for riparian areas maintained by the Parks and Recreation Department and the Water Management Department.

When completed, the Little Lick Creek WIP will contain the information required to meet the nine key elements of U.S. Environmental Protection Agency (EPA) watershed-based plans. These nine elements comprise the primary planning framework for watershed improvement projects funded under Section 319 of the Clean Water Act, as described in the Handbook for Developing Watershed Plans to Restore and Protect Our Waters (EPA, 2005). At a minimum, EPA requires that projects funded under Section 319 be guided by a watershed plan that addresses these nine elements.

The Little Lick Creek WIP will also integrate the information relevant to the North Carolina Division of Mitigation Services (formerly Ecosystem Enhancement Program) watershed planning program as described in the Division's Local Watershed Planning Manual (EEP, 2011). Local watershed plans (LWPs) are conducted in four phases: Phase I - Characterization of Current Watershed Conditions, Phase II - Detailed Watershed Assessment, Phase III – Watershed Plan Development, and Phase IV – Watershed Plan Implementation. Each phase generally includes certain elements, though these are less definitive than the nine EPA watershed-based planning elements. The Little Lick Creek WIP process will not follow the four-phased approach typically used for LWPs, however, the information contained in a LWP will be included in the Little Lick Creek WIP documents.

Section 2: WATERSHED OVERVIEW

2.1 Overview of Watershed

The 17.2 square mile Little Lick Creek watershed is located east of downtown Durham, NC (Figure 1). Approximately 42% of the watershed area lies within the limits of the City of Durham, with the remainder of the watershed contained within Durham County (Figure 2). The Little Lick Creek watershed is located within the Upper Neuse River Basin, defined as Hydrologic Unit Code 03020201. The City of Durham lies to the west, Research Triangle Park lies to the southwest, and it is bounded by the Ellerbe Creek watershed to the north and the Lick Creek watershed to the south. NC-98 runs east-west through the center of the watershed, and US-70 runs north-south in the southwestern headwaters. Angier Avenue generally forms the western boundary of the watershed, Sherron Road and Baptist Road form the southeastern boundary, Cheek Road forms the northern boundary, and Patterson Road forms the eastern boundary. Three City parks are located within the watershed - Twin Lakes, Birchwood, and C.R. Wood, as well as two schools – Southern High School and Oak Grove Elementary School. A few of the major residential neighborhoods within the watershed include Ashton Hall, Grove Park, and Stonehill Estates (Figure 1).

2.2 Data Sources

A Geographic Information System (GIS) database was obtained from the City of Durham to conduct a detailed watershed characterization study. The database contained information on existing and future land use, a hydro-enforced digital elevation model (DEM), land cover, administrative boundaries, water, stormwater and sanitary sewer utilities, parcel-based impervious cover, roads (as street centerlines), topography, soils, and FEMA-regulated floodplain boundaries. Additional watershed data were gathered from the City, Durham County, and state and federal agencies including stream monitoring gauge locations and water quality data gathered from United States Geologic Survey (USGS) and North Carolina Division of Water Resources (DWR). This data is described in more detail in Section 3.2. The data catalog for our analysis of the Little Lick Creek watershed is provided in Appendix A.

2.3 Climate

The Little Lick Creek watershed is located in the Piedmont physiographic province of North Carolina. Annual rainfall for the City of Durham, based on the Automated Surface Observing System (ASOS) station located at the Raleigh-Durham Airport (KRDU) measures between 32-54 inches per year, with precipitation amount and intensity varying seasonally. Winter precipitation is associated with southern and eastern frontal systems not normally associated with very cold weather. Precipitation during winter and spring occurs in connection with migratory low pressure systems which provide more evenly distributed rainfall. Winter snowfall generally ranges from 1-10 inches per year. Summer precipitation is characterized by convective storms producing local high intensity showers. The Atlantic hurricane season is between June 1 and November 30, during which there is a chance for large and widespread individual precipitation events.

Monthly data gathered from North Carolina Climate Retrieval and Observations Network of the Southeast Database (CRONOS) and United States Geologic Survey (USGS) gauges are presented in Table 1. The location and data period used for analysis for each station are provided below.

- EcoNET Station: North Durham Water Reclamation Facility (DURH). Location: Latitude 36.02896, Longitude -78.85851. Data Collection Period: Jan 2009- June 2014.
- EcoNET Station: Raleigh-Durham Airport (KRDU). Location: Latitude 35.8776389, Longitude -78.7874722. Data Collection Period: July 1996-June 2014.
- USGS Station: 355856078492945 LITTLE LICK CR AT NC HWY 98 OAK GROVE, NC. Data Collection Period: Aug 2008-June 2014.

Table 1. Average Monthly and Annual Precipitation Data

Month	EcoNETCRONOS Rain Gauge DURH[1] (inches)	EcoNET CRONOS Rain Gauge KRDU[2] (inches)	USGS Rain Gauge 355856078492945[3] (inches)
January	2.2	3.0	2.1
February	2.6	2.7	2.4
March	4.1	4.3	4.4
April	2.5	3.3	2.7
May	5.5	2.9	4.8
June	4.3	3.8	4.1
July	3.7	4.8	4.3
August	3.7	4.7	4.5
September	4.9	5.9	5.6
October	2.4	2.7	2.2
November	3.4	3.1	3.2
December	4.1	3.3	3.4
Annual	**43.4**	**44.4**	**43.7**

[1] Jan 2009- June 2014, [2] July 1996-June 2014, [3] Aug 2008-June 2014

2.4 Geology and Soils

The geology and soils in the Little Lick Creek watershed are important factors that affect stormwater runoff volumes and quantity. The Little Lick Creek watershed falls within the Durham Subbasin of the Deep River Triassic Basin in the Piedmont physiographic province. The Triassic Basin sedimentary geology is distinct from the rest of the Piedmont, which is comprised mostly of resistant metamorphic rocks. The Triassic Basins are underlain by layered sedimentary rocks (primarily sandstones and mudstones with some clay, shale, and conglomerate) that originated from alluvial sediments and lacustrine deposits that settled during the late Triassic period when the areas were lakes and lowlands. The Triassic Basin sedimentary rocks provide the parent material for the soils in the basin.

Triassic Basin soils contain expansive clays that swell when wet and shrink upon drying. In winter, the wet clay turns the soil into somewhat of an impervious surface, with low permeability, low infiltration rates, and reduced groundwater transmittance. Research has found that roughly 30% of rainfall that falls in a forested area during the wet season can produce runoff (Dreps, C., et al., 2014). Conversely, these soils can produce little runoff in the summer due to shrinkage and cracks. As a result, Triassic Basin streams are typically flashy and often go dry during summer months (Griffith et. al. 2002).

Triassic Basin floodplains are characteristically broader due to their more highly erodible soils. These wide floodplains have higher incidence of wetlands than other portions of the Piedmont and smaller streams often develop unique ecological communities of bottomland hardwoods typically only found in larger riverine systems (NatureServe, 2005). The erodibility of soils and underlying rock in the watershed often lead to sandy substrates in streams similar to those of the coastal plain. However, gravel bars, clayey areas, and bedrock may be integrated with the sandy alluvium (DWQ 2003; NatureServe 2005).

The Natural Resources Conservation Service (NRCS) assigns soil types into hydrologic groups based on soil infiltration rate and water storage capacity, which have a direct effect on stormwater runoff volume and quality. There are four hydrologic soil groups based on these soil properties.

- **Group A soils:** high infiltration rates, low runoff potential and are primarily well-drained sandy soils.
- **Group B soils:** have moderate infiltration rates and runoff potential. They consist primarily of moderate to well-drained soils such as loams.
- **Group C soils**: low infiltration rates and moderately high runoff potential. These soils are typically sandy clays or clay loams.
- **Group D soils**: low infiltration rates and have high runoff potential. Most D soils are clays, contain a confining layer near the surface, or consist of shallow soils over bedrock. Urban complex and gullied areas are also typically classified as group D soils.

The presence of hydric soils, defined by the National Technical Committee for Hydric Soils, is also an important factor that has a direct effect on stormwater runoff volume and quality. Hydric soils form under conditions of saturation, flooding, or ponding that last long enough during the growing season to develop anaerobic conditions in the upper zone of soil (Federal Register, 1994). The NRCS defines hydric soil ratings based on the permeability of the soil map unit and the estimated position of the water table to determine the percentage of the soil map unit which is likely to contain hydric soils. This is an interpretative rating which must be confirmed by on-site investigations. Triassic Basin soils can be problematic for identification of hydric soil indicators as many Triassic soils have red parent materials (USDA, NRCS. 2006).

Based upon the data provided by City of Durham database and NRCS Web Soil Survey, the primary soil types in the watershed are listed in Table 2 with USDA soil texture classification, Hydrologic Soil Group (HSG), and the presence of hydric soil indicators.

Table 2. Common Soils in the Watershed

Soil Type	USDA Soil Texture	NRCS Hydrological Soil Group	Potentially Hydric	Percent of Watershed
White Store	sandy loam and clay loam	D	No	69%
Creedmoor	sandy loam	C/D	No	9%
Chewacla and Wehadkee	loam	B/D	Yes	9%
Granville	sandy loam	B	No	2%
Iredell	loam	C/D	No	2%
Mayodan	sandy loam	B	No	2%
Urban complex	undefined	D	No	2%
Chewacla and Cartecay	silt loam	A/D	Yes	1%
Altavista	silt loam	C	No	1%
Pinkston	fine sandy loam	B	No	1%
Wehadkee	silt loam	B/D	Yes	< 1%
Roanoke	silt loam	D	Yes	< 1%
Mecklenburg	loam	C	No	< 1%
Wilkes	sandy loam	D	No	< 1%
Helena	sandy loam	D	No	< 1%
Cecil	fine sandy loam	A	No	< 1%

Table 3 presents the acreage of each Hydrologic Soil Group in the Little Lick Creek watershed. The soil infiltration capacity and water storage properties of a soil can vary depending on how well a soil is drained, so some of the primary soil groups in Table 3 have a combination grouping, (A/D etc.). For these combinations, the first letter represents the soil in a drained condition and the second letter represents the soil in its natural condition. Approximately 22 percent of the Little Lick Creek watershed falls into one of these combinations of groupings.

Table 3. Hydrologic Soil Group

Hydrologic Soil Group	Area (acres)	Percent
A	**3**	**< 1%**
B	**441**	**4%**
C	**187**	**2%**
D	**6,993**	**71%**
A/D[1]	**123**	**1%**
B/D[1]	**963**	**10%**
C/D[1]	**1,097**	**11%**
Gullied Land (D soils)	**66**	**< 1%**
Urban Complex (D soils)	**23**	**< 1%**
Borrow Pits	**17**	**< 1%**
Water	**69**	**< 1%**

[1]First letter is for drained areas only. Otherwise, these areas have D soils.

As shown in Table 3, less than 5% of the watershed is characterized by well drained soils (Groups A and B) and over 95% is characterized by poorly drained soils. The distribution of the hydrologic soil groups in the Little Lick Creek watershed are shown on Figure 3. The upland soils are primarily in Group D, while the floodplains of Little Lick Creek are dominated by Group B and C soils and combination soil groups B/D and C/D.

2.5 Little Lick Creek Watershed Hydrology

The main stem of Little Lick Creek flows generally east and northeast for approximately 9.8 miles from the southwestern corner of the watershed to Falls Lake. The main tributary to Little Lick Creek (and the only other named stream in the watershed) is Chunky Pipe Creek, which flows from the northwest corner of the watershed generally east to its confluence with Little Lick Creek, approximately one mile upstream of the confluence with Falls Lake. For the purposes of this study, the watershed was divided into 25 subwatersheds, LLC01 through LLC25, based primarily on hydrology and topography. Existing land use, future development potential, and the type of drainage system (e.g., pipe, ditch, or natural stream) were other factors used to delineate the subwatersheds. The subwatersheds range in size from 0.2 square miles to 1.5 square miles (Figure 2). The 2006 Little Lick Creek Local Watershed Plan, which covered a larger study area of 20.8 square miles, delineated fewer subwatersheds (13 total) that varied in size from 1.15 to 2.07 square miles.

The USGS has operated two stream flow gauging stations in the Little Lick Creek watershed (Figure 4). The active USGS stream flow gauge in the watershed, gauge number 0208700550, is located on Little Lick Creek at NC-98 in Oak Grove, NC. The drainage area at this gauge is 4.1 square miles (23% of the study watershed). This gauge, which has been operational since July 2008, measures the water surface elevation relative to gauge datum but not the stream flow.

An inactive USGS gauge, gauge number 0208700780, is located on Little Lick Creak at SR-1814 at Oak Grove, NC. This gauge was operational from October 1982 to September 1995. The drainage area at this gauge is 10.1 square miles (58 % of the study watershed). The 13-year gauge record provides the longest record of the hydrology of the watershed. Based on this 13-year record of data, Table 4 shows the stream flow (in cubic feet per second, or cfs) at the gauge for various flood frequencies.

Table 4. Estimated Flood Frequency Stream Flows for Little Lick Creek (USGS Gauge 0208700780 near Oak Grove, NC)

Flood Frequency	Stream Flow (cfs)
1 yr	251
1.5 yr	706
2 yr	873
5 yr	1330
10 yr	1662
25 yr	2112
50 yr	2468
100 yr	2842
500 yr	3788

Table 5 presents the mean annual stream flow for each of the 13 years of record. The values range from less than 5.8 cfs in 1985 to 18.4 cfs in 1989. However, there appears to be no increasing or decreasing trends in mean annual stream flow during this period that would indicate that development or other causes are significantly affecting stream flow.

Table 5. Mean Annual Stream Flow for Little Lick Creek (USGS Gauge 0208700780 near Oak Grove, NC)

Year	Mean Annual Discharge (cfs)
1983	13.7
1984	17.8
1985	5.9 (min)
1986	9.4
1987	12.6
1988	6.0
1989	18.4 (max)
1990	14.0
1991	9.0
1992	8.4
1993	16.3
1994	10.1
1995	10.6

Table 6 shows monthly mean stream flows for Little Lick Creek and average monthly rainfall for the City of Durham. Stream flow varies widely throughout the year but is highest in the winter and early spring and lowest in the summer, as expected due to the prevalence of Triassic Basin soils in the watershed but in contrast to typical rainfall patterns. March, the month with the highest mean stream flow, follows two of the driest months of the year while the month with the highest monthly rainfall is May, which is when stream flow begins to recede and continues through the summer and early fall. The phenomenon of lower runoff during the summer months when rainfall is often the highest is well documented for southeastern U.S. streams, and is primarily related to two factors: (1) higher evapotranspiration rates during the summer months (Benke and Cushing, 2005); and (2) the prevalence of Triassic Basin soils which contain expansive clays that swell when wet and shrink upon drying. As a result, Triassic Basin streams have the lowest low flow values of any geologic province in North Carolina. The lowest seven-day flow rate expected once every 10 years, referred to as 7Q10 values, is typically zero in the Triassic Basin for all but the largest gauged streams (Giese and Mason, 1993).

Table 6. Mean Monthly Stream Flow for Little Lick Creek 1982 - 1995 (USGS Gauge 0208700780 near Oak Grove, NC)

Month	Mean of Monthly Stream Flow (cfs)	Percentage of Max Mean Monthly Stream Flow	Monthly Average Rainfall[1] (in)	Percentage of Max Monthly Average Rainfall
January	20.0	77%	2.2	40%
February	25.0	96%	2.6	47%
March	26.0	100%	4.1	75%
April	14.0	54%	2.5	45%
May	9.1	35%	5.5	100%
June	8.1	31%	4.3	78%
July	3.0	12%	3.7	67%
August	4.7	18%	3.7	67%
September	2.4	9%	4.9	89%
October	7.0	27%	2.4	44%
November	9.7	37%	3.4	62%
December	12.0	46%	4.1	75%

[1]Source: EcoNET Station: North Durham Water Reclamation Facility (DURH)

2.6 Land Use

Land use conditions, which affect land cover, impervious areas, the type of drainage system, and stormwater runoff volumes and quality, play an important role in assessing current and future watershed health. Durham County actively maintains existing land use information as part of their property database. Each parcel in the watershed has been assigned an appropriate land use code. Similarly, future land use data is available from Durham County and City Planning Departments. To simplify the analysis of land use conditions, the land use data were merged into the eleven land use categories shown in Table 7. With both existing and future land use codes based on the same land use categories, a comparative analysis of potential development trends from existing to future build-out conditions can be performed. The future land use data are based on the City and County's zoning data that predicts the level of build-out that is forecast to occur in the next 20 years.

Table 7. Simplified Land Use Categories based on Durham City/County Land Uses

Land Use Code	Land Use Category Definition
AGR	Agriculture
COM	Commercial
IND	Industrial
INT	Institutional
HDR	High Density Residential (<0.125 acres)
MDR	Medium Density Residential (0.125-0.33 acres)
LDR	Low Density Residential (0.33-1.0 acres)
VLR	Very Low Density Residential (>1.0 acre)
POS	Parks and Open Space
VAC	Vacant Land

2.6.1 Existing Land Use

To develop the existing land use conditions (Figure 5), specific adjustments were made to the Durham County land use data:

- Utilities were designated as commercial
- Recreation and Open Space were designated as Parks and Open Space
- Vacant Lands were designated as Parks and Open Space
- Recreation and Open Space on private land outside of a FEMA floodplain were designated the adjacent, existing land use (e.g., small open space areas within a residential development were added to the residential area) to maintain the density, hydrologic characteristics, and pollutant loading rates typical for these residential areas
- Recreation and Open Space on private land within a FEMA floodplain was coded as Parks and Open Space
- Public Land consisting of churches, schools, and government buildings were coded as Institutional
- Public Land with impervious cover of less than 10% was coded as Parks and Open Space
- Road right-of-ways were developed from an overlay of parcel polygons within the Little Lick Creek watershed using the 'Erase' geoprocessing tool in ArcMap to generate polygons for the road right-of-ways. The resulting data includes areas where roadways were built or cleared to be built that are recorded in the County's parcel database.

In addition, residential land use codes were re-assigned based on parcel acreage as follows:

- Parcels <0.125 acres were assigned to High Density Residential
- Parcels between 0.125-0.33 acres were assigned to Medium Density Residential
- Parcels between 0.33-1.0 acres were assigned to Low Density Residential
- Parcels >1.0 acre were assigned to Very Low Density Residential

The adjustments listed above are consistent with the approach applied in the previous watershed improvement plans developed for Ellerbe Creek, Third Fork Creek, Northeast Creek, and Crooked Creek.

As shown in Table 9 and on Figure 5, the existing land use within the Little Lick Creek watershed is predominantly very low to low density residential, parks and open space, vacant land, and agricultural land. Areas of commercial and industrial land use fall primarily within the City of Durham limits along NC-98 and US-70. The watershed has more development occurring in the western headwaters areas that are within the City limits, compared to the eastern portions of the watershed near Falls Lake that remain within Durham County.

2.6.2 Impervious Cover

The City's planimetric data served as the basis for the impervious cover for the watershed (Figure 6). This data set contains impervious areas within parcels, such as buildings, homes, driveways, and parking lots. The data set also contains the pavement width within the right-of-way for many of the roads constructed prior to 2000. For roads constructed after 2000, pavement widths were generated by buffering the roadway centerlines. Pavement widths were estimated based on the number of travel lanes, with shoulders and curb lanes added as needed. Table 8 provides a breakdown of the impervious area data by subwatershed.

Table 8. Impervious Cover for Little Lick Creek Subwatersheds

Subwatershed	Subwatershed Area (acres)	Impervious Area (acres)	Impervious Percentage (%)	Cumulative Impervious Percentage (%)
LLC01	590	54	9%	9%
LLC02	290	61	21%	13%
LLC03	439	85	19%	19%
LLC04	355	66	19%	19%
LLC05	412	112	27%	22%
LLC06	398	62	16%	18%
LLC07	390	123	32%	32%
LLC08	452	70	15%	15%
LLC09	508	100	20%	19%
LLC10	445	83	19%	19%
LLC11	177	27	15%	15%
LLC12	330	35	10%	10%
LLC13	234	22	9%	9%
LLC14	184	16	9%	11%
LLC15	507	81	16%	13%
LLC16	355	48	14%	13%
LLC17	338	48	14%	17%
LLC18	421	63	15%	15%
LLC19	377	30	8%	12%
LLC20	137	7	5%	11%
LLC21	582	52	9%	9%
LLC22	299	31	10%	9%
LLC23	408	22	5%	5%
LLC24	276	7	3%	4%
LLC25	972	27	3%	13%
TOTAL:	**9,876**	**1,332**	**13%**	**9%**

In general, as development occurs, more impervious surface areas are added in a given watershed. Studies indicate that water quality and aquatic habitat conditions in streams begin to degrade when its contributing watershed exceeds 10 percent impervious areas (Schueler, 2009). The degree of degradation is highly dependent upon characteristics within the watershed, including the extent of clearing of riparian buffer areas, the use of stormwater control measures, soil types, and watershed slope. Although a conservative break point occurs at approximately 10% impervious area, some streams may continue to have good water quality and habitat beyond a threshold of 10% impervious area within the watershed. Based on the existing land use data and the impervious cover data, the impervious area for the Little Lick Creek watershed is over 12 percent. The subwatersheds that are predominately within the City limits have experienced the most development, with impervious percentages ranging from 9% to over 27%. This suggests that the level of existing development in the watershed may be contributing to the degraded water quality conditions in Little Lick Creek, Chunky Pipe Creek, and their headwater tributaries. Water quality conditions will be reported and discussed in Section 3.4.

2.6.3 Future Land Use

The future land use data provided by City of Durham/Durham County Planning Department was adjusted on a parcel basis to match the existing land use categories shown in Table 7. As shown in Table 9, over the next 20 years, most of the vacant, agricultural land, and very low density residential areas will transition to medium to high density residential land uses, with commercial development centered around US-70 and NC-98 (Figure 7). The eastern portion of the watershed, where agricultural, forested, and very low density residential are common, will experience a more dramatic change in land use as compared to the western portion of the watershed.

Table 9. Projected Land Use Change

Land Use	Existing Land Use (Acres)	Future Land Use (Acres)	Percent Change
Agriculture (AGR)	1015 (11%)	0	-100%
Very Low Density Residential (VLR)	1634 (18%)	2050 (23%)	25%
Low-Density Residential (LDR)	1742 (19%)	3529 (39%)	103%
Medium-Density Residential (MDR)	1020 (11%)	1200 (13%)	18%
High-Density Residential (HDR)	64 (1%)	200 (2%)	213%
Commercial (COM)	197 (2%)	326 (4%)	65%
Institutional (INT)	305 (3%)	433 (5%)	42%
Industrial (IND)	67 (1%)	203 (2%)	203%
Parks and Open Space (POS)	1331 (15%)	1040 (12%)	-22%
Vacant (VAC)	1606 (18%)	0	-100%

Projected land use changes by subwatershed are presented in Table 10. Several land use trends over the next 20 years are apparent from the data:

- Several subwatersheds that have a high level of development under existing conditions (e.g., LLC02, LLC05, LLC09, LLC10, and LLC11), will see small areas of vacant and very low density residential land convert to low, medium, and high density residential land use
- Land use changes in most subwatersheds consists of the transition of agricultural, vacant, and very low density residential land into low, medium, and high density residential development
- Most new commercial development will occur along US-70 and NC-98 in subwatersheds LLC01, LLC05, LLC06, and LLC12
- Most new industrial development will occur along the proposed route of the East End Connector in subwatersheds LLC03 and LLC04
- The eastern portion of the watershed, in subwatershed LLC19 through LLC28, will see a significant transition of agricultural and vacant land into very low and low density residential development

Appendix B provides a detailed summary on the specific land use changes projected within each subwatershed.

Table 10. Projected Land Use Change by Subwatershed

	Projected Land Use Change (± acres)									
	AGR	COM	HDR	IND	INS	LDR	MDR	POS	VAC	VLR
LLC01	-36	45	1	13	n/a	237	-1	0	-249	-10
LLC02	n/a	0	7	n/a	0	64	-1	-21	-30	-19
LLC03	-51	0	21	22	55	23	44	-56	-53	-5
LLC04	-15	7	14	92	37	16	15	-36	-130	0
LLC05	n/a	15	10	0	12	27	1	-9	-52	-3
LLC06	n/a	30	7	n/a	0	38	19	6	-30	-70
LLC07	n/a	1	72	0	0	68	-27	-5	-71	-38
LLC08	-35	2	n/a	8	0	103	64	-24	-113	-7
LLC09	n/a	1	n/a	0	5	32	42	-41	-24	-15
LLC10	n/a	1	0	n/a	0	10	1	0	-11	0
LLC11	-3	n/a	n/a	n/a	n/a	41	2	-6	-16	-18
LLC12	-10	26	n/a	0	0	101	0	-3	-112	-2
LLC13	-67	n/a	n/a	n/a	1	102	0	-1	-25	-10
LLC14	n/a	0	n/a	n/a	0	92	n/a	0	-67	-25
LLC15	-80	0	0	n/a	1	115	19	-9	-43	-4
LLC16	-15	1	n/a	n/a	-1	121	1	-47	-38	-23
LLC17	0	0	0	0	0	6	0	0	-9	3
LLC18	-137	0	n/a	0	4	138	0	-10	-46	51
LLC19	-78	n/a	3	n/a	0	47	-9	-7	-87	130
LLC20	-14	n/a	n/a	n/a	n/a	16	0	0	-36	35
LLC21	-20	0	0	n/a	n/a	191	7	-4	-173	-1
LLC22	-28	0	1	n/a	1	87	1	-3	-68	8
LLC23	-168	0	n/a	n/a	0	105	0	0	-89	151
LLC24	-82	0	n/a	n/a	12	2	n/a	-12	-22	102
LLC25	-177	0	0	n/a	n/a	7	3	-4	-16	187

Land use changes impact water quality and stream habitat conditions. Urbanized areas and agricultural lands under cultivation tend to contribute more pollutants than forested areas, and increasing impervious area can further degrade the local streams. However, as development proceeds in the future throughout the watershed, stormwater control measures (SCMs) will be required for most new development to protect the quality of Little Lick Creek and Falls Lake. The Falls Lake Rules, the Water Supply Watershed Rules around Falls Lake, and the City's Stormwater Performance Standards for Development require the use of SCMs to control the quantity and quality of stormwater runoff leaving residential, commercial, and industrial areas. The Water Supply Watershed Rules (Figure 9) also limit development densities and require buffers on streams. These regulations will help control water quality and quantity within this watershed, and help mitigate the impacts of future development.

2.7 Floodplains

To help protect property and mitigate the damages caused by flooding, the City of Durham developed Flood Damage Protection Standards to regulate floodplain development. Current City standards were developed in conjunction with the 2007 Federal Emergency Management Agency (FEMA) Flood Insurance Study and Flood Insurance Rate Maps (FIRM) revisions. FEMA is currently in the process of revising the floodplain mapping boundaries and anticipates that the updated maps will become effective in 2017.

The FEMA regulated 100-year floodplain (Figure 8), represents the area within the Little Lick Creek watershed susceptible to flooding during a large storm event that has a one percent chance of occurring in a given year or, stated another way, is likely to occur approximately once during a 100-year period (referred to as a 100-year event). The 100-year floodplain and floodway run along the main stem of Little Lick Creek, the main stem of Chunky Pipe Creek, and several of their larger tributaries. The regulated floodplain zones in the headwater subwatersheds contain more developed areas (residential, industrial, and commercial areas) whereas the regulated floodplain zones in the subwatersheds closer to Falls Lake are less developed with more agricultural land and lower density residential areas. Since construction in the 100-year floodplain and floodway is regulated, the floodplain (Figure 8) is a good indication of land that will less likely be developed in the future as the Little Lick Creek watershed continues to convert from agricultural and very low density residential land uses to more dense urban development.

Section 3: WATER QUALITY ASSESSMENT

Water quality is a vital component of healthy aquatic ecosystems. Understanding the current water quality conditions in Little Lick Creek is important to understanding its overall health and ability to support a healthy population of aquatic species. Protecting and improving water quality is a major goal of the Little Lick Creek Watershed Improvement Plan (WIP).

This section reviews the surface water classifications assigned in the watershed, describes the applicable water quality standards and criteria, summarizes the observed water quality information available in the watershed, discusses the potential impacts stream conditions and the septic and sanitary sewer collection and treatment systems may have on water quality, and presents the benefits of existing SCMs on stormwater quality.

3.1 Surface Water Classifications, Uses, and Standards

The North Carolina Division of Water Resources (DWR) is responsible for implementing and interpreting the State's water quality standards and water body classifications and operating the State's ambient monitoring system (AMS) stations. Surface water classifications are designations applied to surface water bodies that define the uses of these water bodies (e.g., fishing, swimming, water supply) and, therefore, the water quality standards to protect the designated uses. The classifications are explained in detail on DWR's website at: http://portal.ncdenr.org/web/wq/ps/csu/classifications.

The three primary and one supplemental classifications that apply to water bodies within the Little Lick Creek watershed are (Figure 9):

- **Class C:** All water bodies in North Carolina must meet the standards for Class C uses. These uses include recreation, fishing, wildlife, fish consumption, aquatic life, and agriculture.
- **Class B:** Since Falls Lake is a popular destination for recreational activities, the lake is classified as a Class B water. Class B uses include primarily recreational uses of swimming, skin diving, water skiing, and similar uses involving frequent human contact.
- **Water Supply IV (WS-IV):** Since Falls Lake serves as a water supply reservoir for the City of Raleigh, DWR has implemented water supply regulations that affect the Little Lick Creek watershed. WS-IV uses include water used for drinking, culinary, or food processing purposes. Drinking water sources are classified as WS-IV when the more stringent WS-I to WS-III classifications are not feasible in moderate to highly developed watersheds. The WS-IV regulations define two areas for protection around the lake: (1) the Critical Area, which is defined as an area which extends one half mile upstream from the normal pool elevation of Falls Lake; and (2) the Protected Area, which is defined as the area within five miles of the normal pool elevation (Figure 9). The Protected Area in Little Lick Creek covers the entire watershed except a small area west of US-70. The Unified Development Ordinance (UDO) that covers the City and Durham County has extended the Critical Area to one mile upstream of the normal pool elevation of Falls Lake. A number of regulations in the UDO have been established to protect Falls Lake as a water supply reservoir are in effect for the Little Lick Creek watershed, including limits on development density and protection of riparian areas. More detail on the local regulations contained in the UDO are provided in Section 4.4.

- **Nutrient Sensitive Waters (NSW):** The entire Neuse River Basin has been classified as Nutrient Sensitive Waters. This is a supplemental classification for waters where nutrient management is required to improve water quality.

The surface water uses described above require that standards for certain water quality parameters be met. A complete summary of DWR's surface water standards for designated uses can be found at the following website: http://portal.ncdenr.org/web/wq/ps/csu/swstandards. The following water quality standards are relevant within the Little Lick Creek watershed:

- *Dissolved Oxygen*: The standard for the protection of aquatic life is not less than a daily average of 5 mg/L with a minimum instantaneous value of not less than 4 mg/L
- *Fecal Coliform Bacteria*: The standard for the protection of human health is a geometric mean of no more than 200 colony forming units per 100 ml (cfu/100 ml) based upon at least five consecutive samples collected during a 30-day period, nor exceeding 400 cfu/100ml in more than 20 percent of the samples examined during the same period
- *Turbidity*: The standard for the protection of aquatic life is not to exceed 50 Nephelometric Turbidity Units (NTUs)
- *Copper:* Copper is a naturally occurring element that is common at trace levels in surface waters in North Carolina. At higher concentrations, copper can become toxic to aquatic life. The water quality criteria for copper is based on the Biotic Ligand Model (BLM), which is a metal bioavailability model that uses surface water characteristics to develop site-specific water quality criteria. The BLM requires ten input parameters to calculate a freshwater copper criterion: temperature, pH, dissolved organic carbon (DOC), calcium, magnesium, sodium, potassium, sulfate, chloride, and alkalinity. There are two criteria for copper that are applied to aquatic communities: Criteria Maximum Concentration (CMC), which is an estimate of the highest concentration of copper in surface water that an aquatic community can be exposed briefly, and the Criterion Continuous Concentration (CCC), which is an estimate of the highest concentration of copper in surface water that an aquatic community can be exposed indefinitely without resulting in toxicity. Since Little Lick Creek is a flowing water body, the City applies the CCC for copper to assess water quality.
- *Zinc:* Similar to copper, the City applies the CCC for zinc to determine potential toxicity for aquatic communities. The CCC for Zinc is expressed as a function of hardness (mg/L) in surface water body. As an example, for a hardness of 100 mg/L, the CCC for zinc equals 120 ug/L.
- *Durham Water Quality Benchmarks:* The City applies locally-developed benchmarks for biochemical oxygen demand (BOD), total nitrogen, and total phosphorus along with state water quality standards for DO, turbidity, and fecal coliform to assess water quality. The benchmarks used in each watershed are:
    - BOD less than 3 mg/L
    - Total nitrogen less than 1.0 mg/L
    - Total phosphorus less than 0.1 mg/L

The State of North Carolina has no numeric standards for total nitrogen or total phosphorus in lakes or streams. These water quality parameters are addressed by the Falls Lake Rules. More details are provided in Section 4.4.

3.2 Existing Water Quality Data

Two agencies and the City have operated water quality or biological monitoring stations in the Little Lick Creek watershed. DWR operates ambient water quality monitoring stations throughout the state to collect long-term water quality data on surface waters. Stations are visited regularly (monthly or more frequently for some stations) and a variety of physical, chemical, and biological parameters are collected. The primary objectives of the ambient monitoring program are to monitor water bodies of interest for comparison to the State's water quality standards, to identify water bodies where standards are exceeded, and to identify long-term spatial or temporal patterns in surface water quality. There are three inactive DWR ambient monitoring locations in the Little Lick Creek watershed. The last of these was decommissioned in 1996. The USGS collected limited water quality data at two stations in the watershed periodically between 1982 and 2001. Data collected by these agencies is available through EPA's STORET database.

The City's Stormwater and GIS Services Division also operates ambient water quality monitoring and biological monitoring stations throughout the city as part of its National Pollutant Discharge Elimination System (NPDES) stormwater permit and comprehensive stormwater management program. The City also monitors benthic data at multiple locations. Data collected by the City is also available through EPA's STORET database. The nine monitoring stations, described below, are shown on Figure 4:

- LL4.6LLT2: active City of Durham station located on an unnamed tributary to Little Lick Creek at Lynn Road; data at this site represents water quality from a 1,200 acre (1.9 square miles) mixed land use drainage area within the city limits
- LL3.4LLC: active City of Durham station located on Little Lick Creek at N Mineral Springs Road; data at this site represents water quality from a 3,800 acre (6.0 square miles) mixed land use drainage area
- 0208700712: inactive USGS station at the same location as LL3.4LLC
- J1490000: inactive DWR station located on Little Lick Creek at Oak Grove Parkway; data at this site represents water quality from a 1,790 acre (2.8 square miles) mixed land use drainage area
- LL2.3LLUT: active City of Durham station located on Little Lick Creek at Stallings Road; data at this site represents water quality from a 6,400 acre (2.8 square miles) mixed land use drainage area
- J1530000: inactive DWR station at the same location as LL2.3LLUT
- 0208700780: inactive USGS station at the same location as LL2.3LLUT
- LL1.6CPC: inactive City of Durham station located on Chunky Pipe Creek at Fletchers Chapel Road; data at this site represents water quality from a 830 acre (1.3 square miles) mixed land use drainage area
- J1570000: inactive USGS station located in Falls Lake near the outlet of Little Lick Creek

Data available from these nine DWR, USGS, and City monitoring stations are summarized in Table 11. As shown, only the data collected at the City monitoring stations represent current conditions in Little Lick Creek, since monitoring at the other sites ended in 1996. Summary tables of ambient and benthic monitoring results are published in the City's NPDES Annual Reports, with comparison to water quality standards and water quality benchmarks. The City's data are interpreted for the public in annual documents published by the City called "State of Our Streams" reports (described below in Section 3.3).

Table 11. Water Quality Sampling Stations and Dates of Available Information in the Little Lick Creek Watershed

Station ID	Agency	Nitrogen	Phosphorus	Dissolved Oxygen	Turbidity	Fecal Coliform	Benthic Macros
J1490000	DWR	N/A	N/A	1968-1975	1970, 1973, 1975	1970-1975	N/A
J1530000	DWR	1983-1996	1983-1996	1968-1996	1973, 1975, 1983-1996	1968, 1970-1986, 1994-1996	N/A
J1570000	DWR	N/A	N/A	1968-1975	1970, 1973, 1975	1968-1975	N/A
LL4.6LLT2	City	2004-2010, 2012, 2014	2004-2010, 2012, 2014	2001-2010, 2012, 2014	2004-2010, 2012, 2014	2004-2010, 2012, 2014	2001-2006, 2009
LL3.4LLC	City	2004-2015	2004-2015	2001-2015	2004-2015	2004-2015	1988, 1991, 1995, 2001-2006, 2009, 2011, 2012
LL1.6CPC	City	N/A	N/A	2009	2009	2009	N/A
LL2.3LLUT	City	2014	2014	2000, 2009-2010, 2012, 2014	2009-2010, 2012, 2014	2009-2010, 2012, 2014	1985, 1988, 1991, 1995, 2000
0208700780	USGS	1982-1994	1982-1994	1982-1994	N/A	1988-1998	N/A
0208700712	USGS	N/A	N/A	1993, 1994, 2001	N/A	N/A	N/A

3.2.1 Observed Water Quality Conditions

To assess the observed water quality conditions, several factors are importat to understand. First, several of the stations listed above have been inactive for several decades. The data at these stations no longer represents current conditons. Secondly, the former Little Lick Creek wastewater treatment plant located approximately one-half mile upstream of Stallings Road is no longer in service. It began operation in 1968, discharging treated wastewater to Little Lick Creek. The treatment plant was taken out of service in 1995 (Dreps, 2005) when a pumping station was installed to direct wastewater to the North Durham Water Reclamation Facility. Therefore, in order to best characterize current water quality conditions, monitoring results from the USGS and DWR stations have been excluded from this analysis. Only data from three City of Durham stations, LL3.4LLC, LL4.6LLT2, and LL2.3LLUT, will be used to assess current water quality. Data at LL1.6CPC, which is limited to only six observations in 2009, will be presented but is insufficient to draw any conclusions about water quality in Chunky Pipe Creek.

A summary of the data from all of the City's ambient monitoring stations is published in the annual report for the City's NPDES Municipal Stormwater Permit. The data is tabulated in the annual report to provide a comparison of the water quality at each station to applicable EPA water quality standards and criteria and the local Durham water quality benchmarks presented previously in Section 3.1. The data table also lists the number of water quality samples analyzed each year and the average Water Quality Index (WQI, described in more detail in Section 3.3.2) for each monitoring station. The data summary for the three Durham ambient monitoring stations located in the Little Lick Creek watershed, LL3.4LLC, LL4.6LLT2, and LL2.3LLUT, are shown in Table 12. Values shown in **bold** type indicate that the average concentration or a significant number of individual samples for the year exceed the standard or criteria. Based on the results shown in Table 12, water quality is degraded in Little Lick Creek for several parameters:

- Fecal coliform concentrations were reported above the geometric mean standard of 400 CFUs/100ml for seven out of ten years at station LL3.4LLC, all eight years at station LL4.6LLT2, and for one out of three years at station LL2.3LLUT
- A minimum of 20% of the individual samples had concentrations above the standard of 400 cfus/100 ml during the years in which the geometric mean was exceeded
- Although the average dissolved oxygen concentrations each year were above the standard of 4 mg/L, more than 10% of the samples were below the standard for seven out of ten years at station LL3.4LLC, two out of eight years at station LL4.6LLT2, and for two out of three years at station LL2.3LLUT
- Although not a widespread water quality problem, the average concentration of total phosphorus exceeded the Durham's local water quality benchmark of 0.10 mg/L for five out of ten years at station LL3.4LLC and one out of eight years at station LL4.6LLT2
- The CCC for copper was exceeded in more than 10% of the samples for six out of ten years at station LL3.4LLC and two out of eight years at station LL4.6LLT2
- The average turbidity concentration exceeded the water quality standard of 50 NTUs for two out of ten years at station LL3.4LLC and one out of three years at station LL2.3LLUT
- More than 10% of the samples analyzed for turbidity exceeded the water quality standard for seven out of ten years at station LL3.4LLC, for four out of eight years at station LL4.6LLT2, and for one out of three years at station LL2.3LLUT

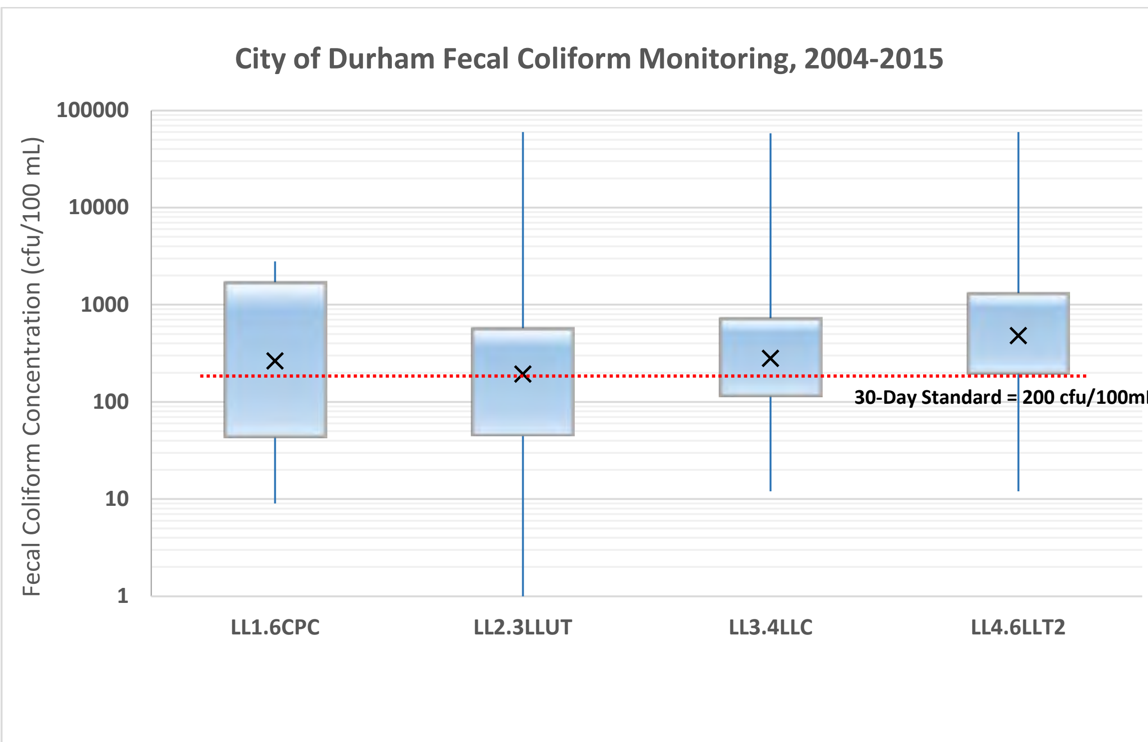
Table 12. Summary of Compliance with Water Quality Standards and Criteria

Year	Major Stream	Site ID	# of samples	Avg WQI	Fecal Coliform (FC)		Dissolved Oxygen (DO)		Average BOD (mg/l)	Nutrients		Dissolved Metals - EPA Continuous Chronic Criteria (CCC)		Turbidity		Average Conductivity (us/cm)
					GeoMean FC (cfu/ 100ml)	Percent of FC samples > 400	Percent of (DO) Samples Less than 4.0 mg/l	Average DO (mg/l)		Average Total Nitrogen (mg/l)	Average Total Phosphorous (mg/l)	Percent of dCu samples > EPA CCC for Cu	Percent of dZn samples > EPA CCC for Zn	Average Turbidity (nTu)	Percent of Samples Exceeding 50 nTu	
2004	Little Lick Crk	LL3.4LLC	12	70	**628**	**42%**	8%	7.2	**3.08**	0.79	**0.14**	**33%**	0%	**59**	**40%**	190
2005	Little Lick Crk	LL3.4LLC	12	71	**361**	**33%**	**33%**	6.6	2.83	0.69	0.09	0%	0%	45	**25%**	209
2006	Little Lick Crk	LL3.4LLC	12	72	**558**	**50%**	**17%**	6.5	2.58	0.72	0.06	8%	0%	**67**	**33%**	182
2007	Little Lick Crk	LL3.4LLC	10	72	170	22%	**60%**	5.0	2.67	0.43	0.06	**11%**	0%	49	**30%**	151
2008	Little Lick Crk	LL3.4LLC	12	78	**414**	**50%**	**25%**	6.1	1.75	0.54	0.04	**17%**	0%	20	0%	181
2009	Little Lick Crk	LL3.4LLC	10	79	**686**	**60%**	0%	8.2	1.8	0.82	0.02	**33%**	0%	47	**30%**	155
2010	Little Lick Crk	LL3.4LLC	11	71	**422**	**27%**	**27%**	7.1	2.09	**1.05**	**0.16**	9%	0%	37	**18%**	187
2011	Little Lick Crk	LL3.4LLC	12	80	140	25%	**42%**	6.4	1.08	0.68	**0.15**	0%	8%	14	0%	200
2012	Little Lick Crk	LL3.4LLC	12	76	**201**	**33%**	**25%**	6.5	1.93	0.68	**0.11**	**25%**	0%	31	**18%**	180
2013	Little Lick Crk	LL3.4LLC	12	80	195	25%	8%	7.0	1.98	0.65	**0.11**	**17%**	0%	25	8%	166
2004	Little Lick Crk	LL4.6LLT2	11	72	**937**	**73%**	9%	7.4	2.91	0.87	**0.19**	**27%**	0%	37	**33%**	248
2005	Little Lick Crk	LL4.6LLT2	11	76	**528**	**64%**	9%	7.5	**3.36**	0.71	0.08	0%	0%	47	9%	243
2006	Little Lick Crk	LL4.6LLT2	12	78	**726**	**50%**	8%	7.5	2.45	**1.36**	0.07	0%	0%	42	8%	258
2007	Little Lick Crk	LL4.6LLT2	5	77	**974**	**100%**	**20%**	9.7	1.20	0.49	0.08	0%	0%	21	0%	210
2008	Little Lick Crk	LL4.6LLT2	12	85	**370**	**50%**	**17%**	7.6	1.64	0.47	0.04	0%	0%	10	0%	273
2009	Little Lick Crk	LL4.6LLT2	9	78	**1152**	**89%**	0%	9.2	2	0.76	0.04	**22%**	0%	31	**22%**	230
2010	Little Lick Crk	LL4.6LLT2	10	76	**833**	**60%**	10%	9.0	1.9	0.87	0.08	10%	0%	29	**20%**	234
2012	Little Lick Crk	LL4.6LLT2	11	80	**600**	**73%**	0%	8.3	1.45	0.61	0.07	18%	0%	18	**18%**	281
2009	Little Lick Crk	LL2.3LLUT	9		**551**	**56%**	0%	8.6						**61**	**44%**	127
2010	Little Lick Crk	LL2.3LLUT	11		185	27%	**27%**	8.0						30	9%	148
2012	Little Lick Crk	LL2.3LLUT	12		116	25%	**33%**	5.8						24	8%	162

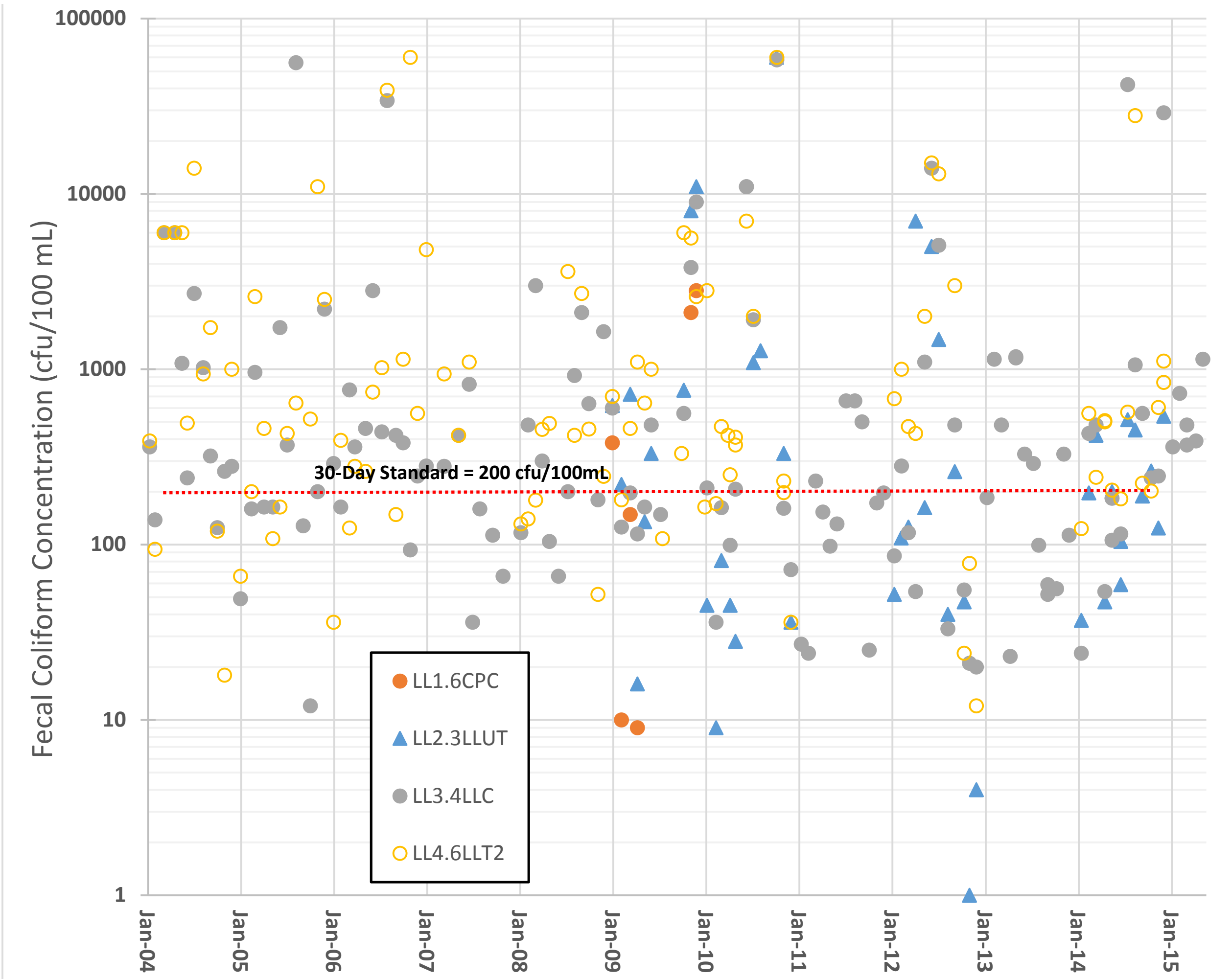
Further analyses of the water quality monitoring data at these three stations for fecal coliform, dissolved oxygen, total phosphorus, and turbidity are summarized on the following pages with box-and-whisker plots and scatter plots. On the box-and-whiskers plots, the median value is indicated by the "X" placed towards the center of the box, the 25th and 75th percentiles as the limits of the box, and the minimum and maximum observed values as the vertical lines (whiskers). The scatter plots show the individual observations at each monitoring station from 2004 through 2015. The scatter plots can provide a general sense of how the different parameters change with the seasons and over time.

Although the results for individual samples for fecal coliform are not directly comparable to the standard based on a 30-day geometric mean, it still represents a reasonable benchmark to evaluate water quality in Little Lick Creek. As shown below on Plots 1 and 2, fecal coliform concentrations at the three Durham stations are normally above the 30-day standard of 200 cfu/100ml for the protection of human health. The median values at stations LL3.4LLC and LL4.6LLT2 are above the 30-day standard while the median value for LL2.3LLUT is just below this standard. As shown on Plot 2, 176 of the 278 samples (63%) analyzed for fecal coliform at these three stations had concentrations above 200 cfus/100 ml. This indicates that fecal coliform concentrations above the 30-day standard are common throughout the year in Little Lick Creek.

Plot 1. Statistical Analysis of Fecal Coliform Concentrations at Durham Stations

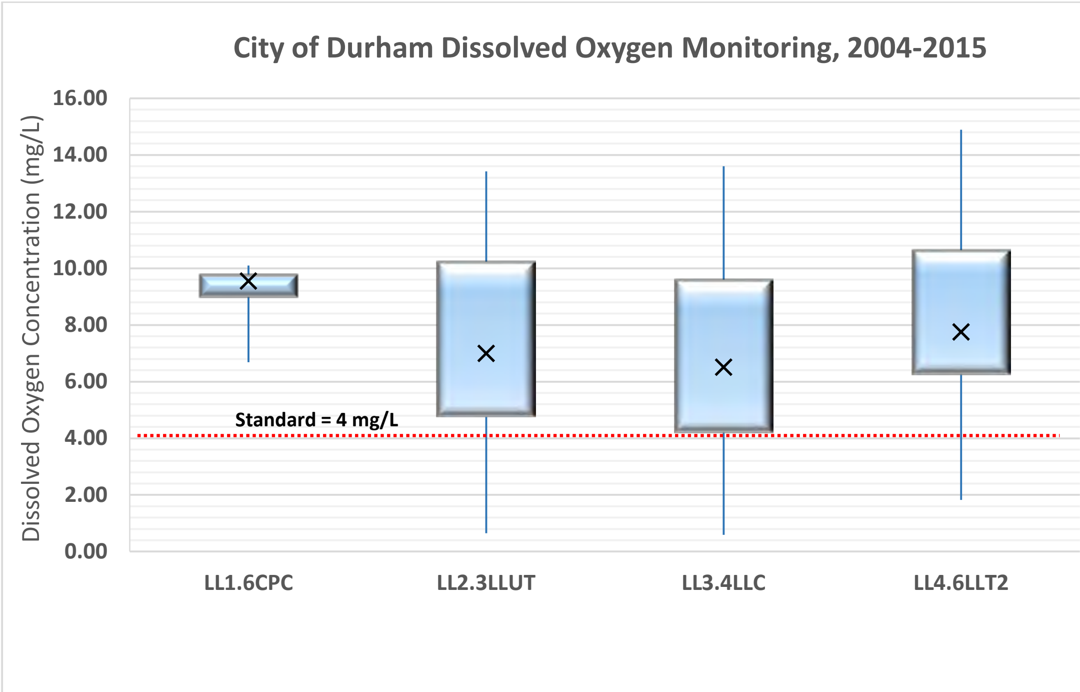


Plot 2. Observed Fecal Coliform Concentrations Durham Stations

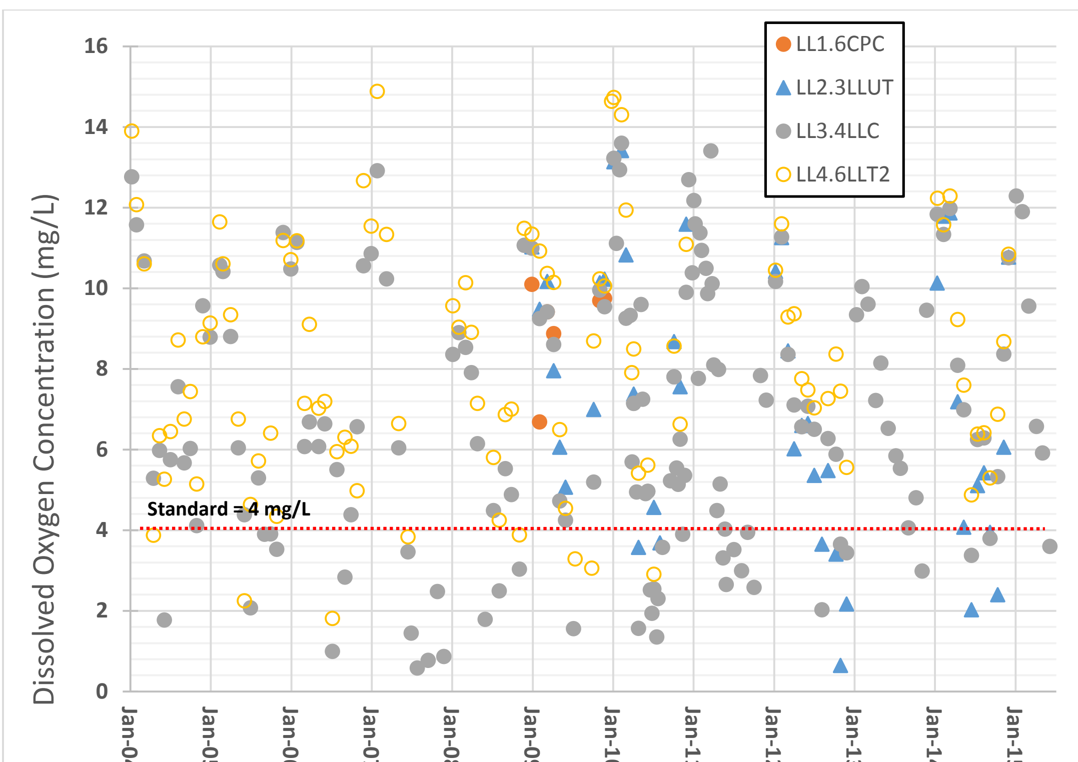


As shown below on Plots 3 and 4, dissolved oxygen (DO) concentrations at the three Durham stations are normally above the water quality standard of 4 mg/l for the protection of aquatic life. The 25th percentile for all three stations is above this standard, and the median values fall between 6.5 and 7.8 mg/l, which is well above the standard. However, instantaneous measurements of DO below the standard have been observed at all three stations, as shown on Plot 4. Of the 305 individual observations, DO has been measured below the standard in 55 samples (18%). This indicates that although low DO levels occur in Little Lick Creek, it is not a common occurrence.

Plot 3. Statistical Analysis of Dissolved Oxygen Concentrations at Durham Stations

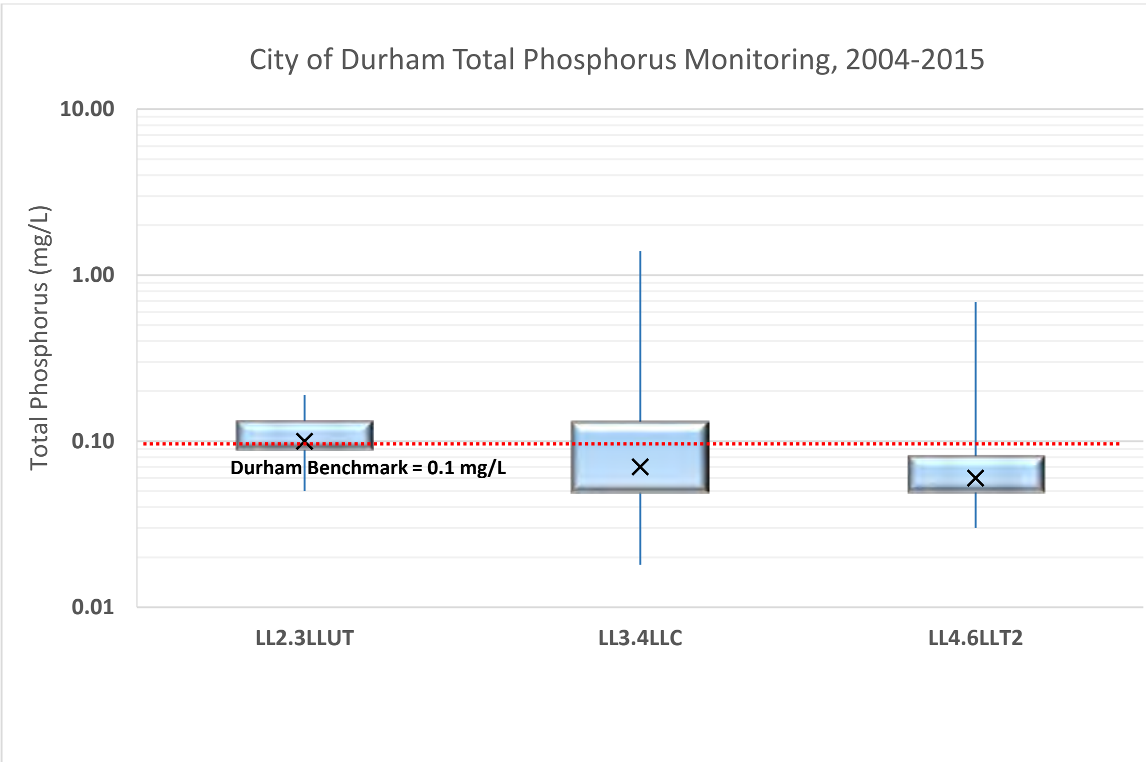


Plot 4. Observed Dissolved Oxygen Concentrations at Durham Stations

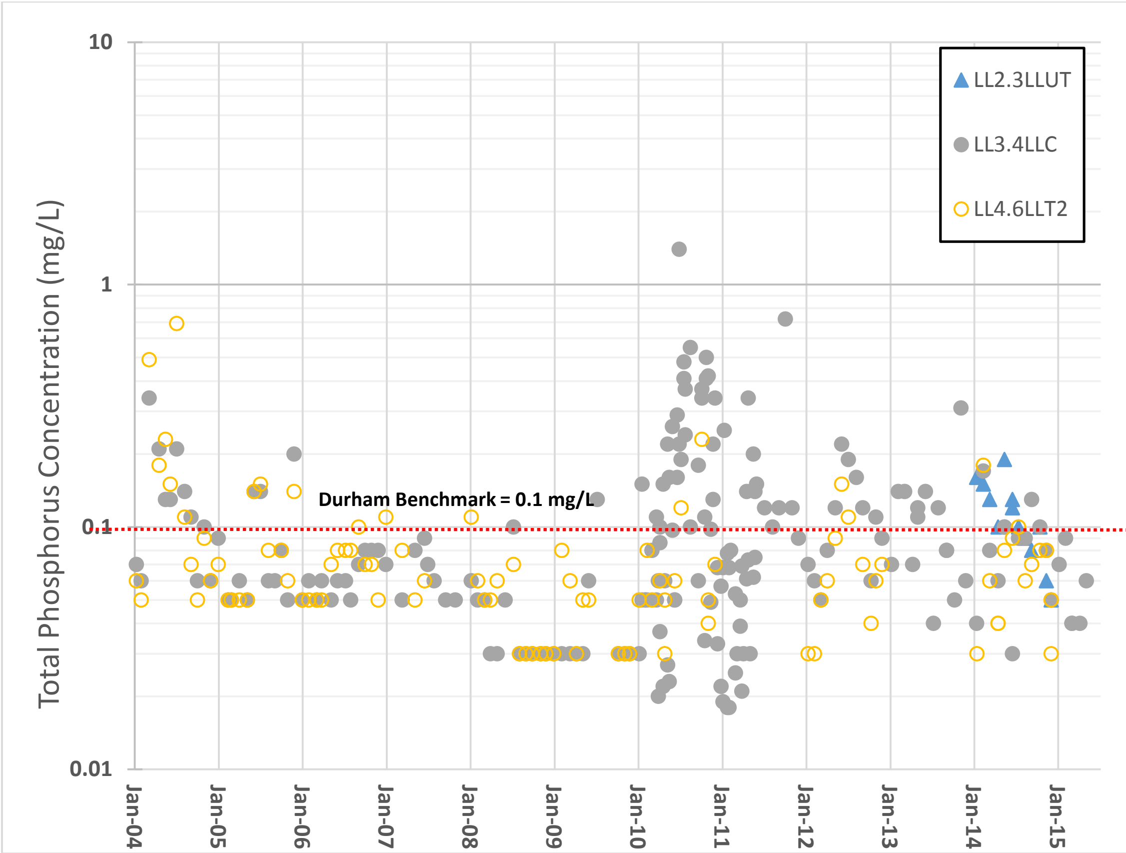


As shown below on Plots 5 and 6, the concentration of total phosphorus at the three Durham stations is typically just below the Durham benchmark of 0.10 mg/L. The median concentration at station LL2.3LLUT is equal to this benchmark, and the median concentrations at stations LL3.4LLC and LL4.6LLT2 are just below this benchmark. As shown on Plot 6, 97 of the 306 samples (32%) analyzed for total phosphorus at these three stations had concentrations above 0.10 mg/L. This indicates that median total phosphorus concentrations are typically just below the Durham benchmarks throughout the year in Little Lick Creek.

Plot 5. Statistical Analysis of Observed Total Phosphorus Concentrations

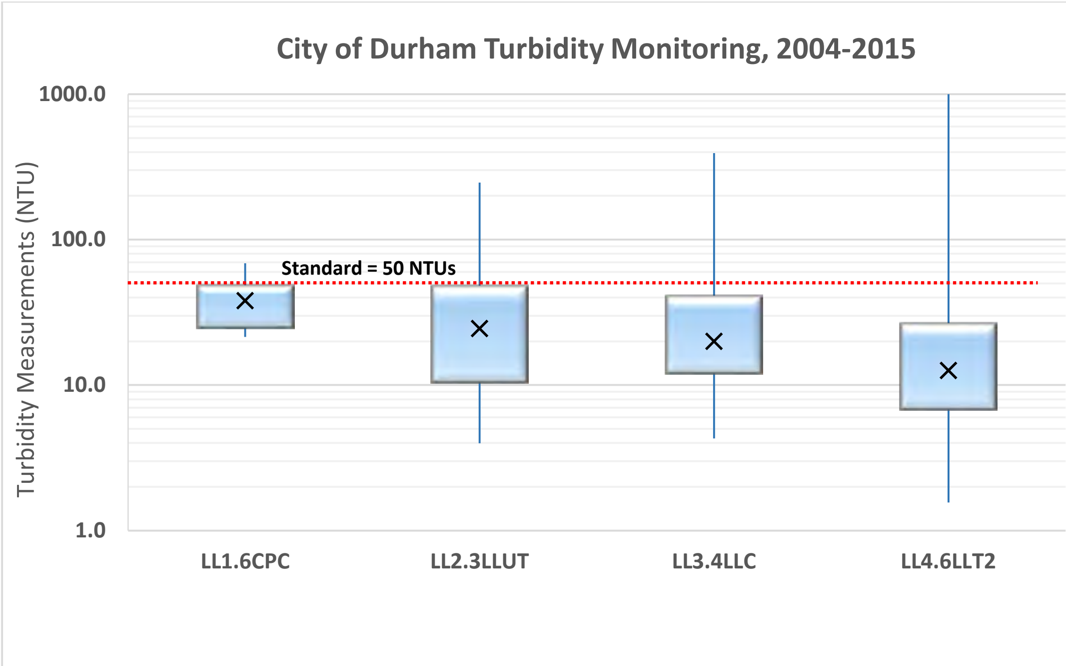


Plot 6. Observed Total Phosphorus Concentrations at City of Durham Monitoring Stations

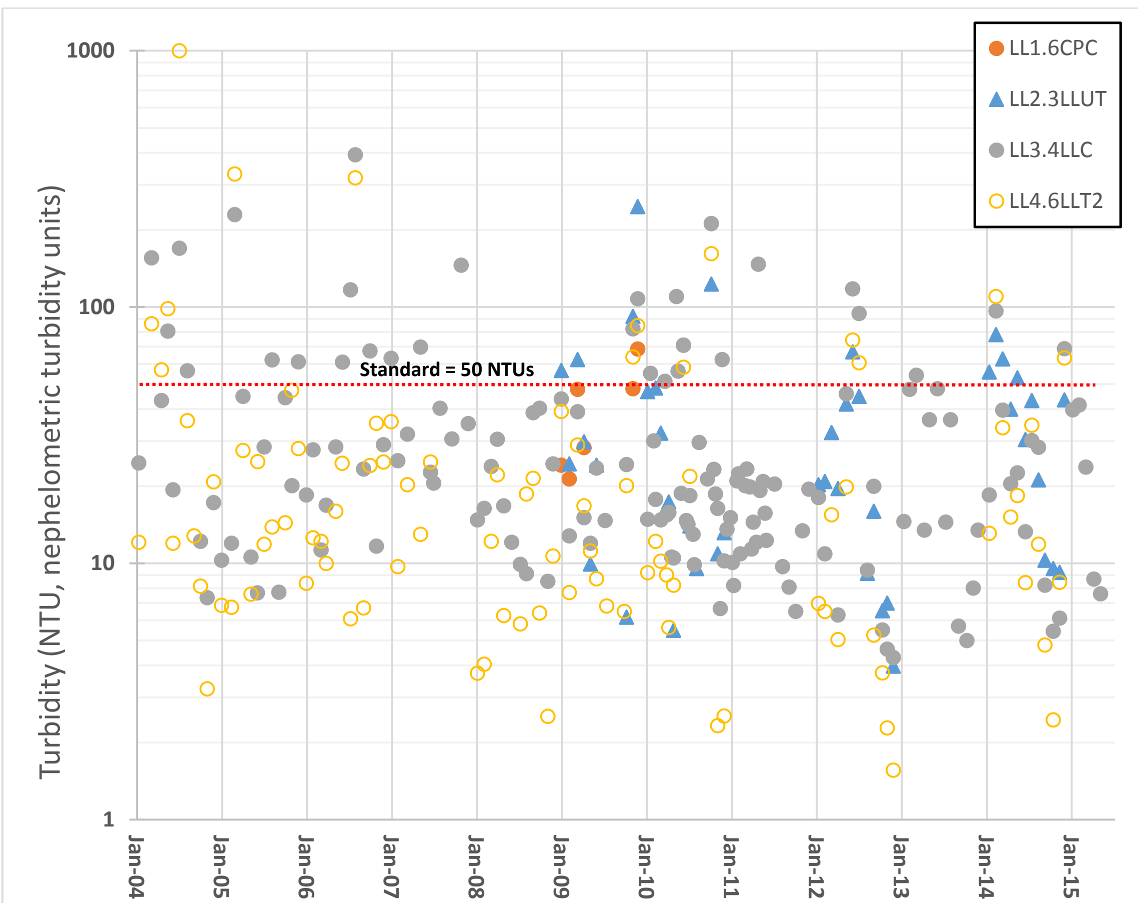


Turbidity, which in general terms describes the clarity of water, has typically been monitored monthly at all three Durham stations. As shown below on Plots 7 and 8, turbidity concentrations at the three Durham stations are normally below the water quality standard of 50 NTUs for the protection of aquatic life. The 25th, median, and 75th percentiles at all three stations are below this standard, with the median values between 12 and 25 NTUs. However, instantaneous measurements of turbidity above the standard have been observed at all three stations, as shown on Plot 8. Of the 299 individual observations, turbidity has been measured above the standard in 54 samples (18%). This indicates that although high turbidity levels have been observed in Little Lick Creek, it is not a common occurrence.

Plot 7. Statistical Analysis of Turbidity Measurements at Durham Stations



Plot 8. Observed Turbidity Measurements at Durham Stations



3.3 Summary of Previous Studies

This section describes the results of previous studies that have included Little Lick Creek and its watershed. Links to sources of additional information are also included.

3.3.1 303(d) List

DWR publishes a list of waters that do not meet their designated uses (described above in Section 3.1), and are therefore classified as "impaired." This list is required by the U.S. EPA to be updated every two years under Section 303(d) of the Clean Water Act. In some cases, such as when a total maximum daily load (TMDL) management strategy is in place to improve the water quality in a water body, impaired waters may be omitted from the 303(d) list. A list of categories used to determine which water bodies are listed is available at: http://portal.ncdenr.org/c/document_library/get_file?uuid=2dd49e8e-c5f5-41a6-90ca-dd72ad30327c&groupId=38364

The final 2014 303(d) list for North Carolina was available at the time this report was prepared. Little Lick Creek from its source to Falls Lake and two unnamed tributaries to Little Lick Creek are on the final 2014 303(d) list of impaired waters (Figure 10). They are on the 303(d) list as impaired for aquatic life, which means the streams do not support healthy communities of native aquatic species. In the case of Little Lick Creek, the impairment is due to low levels of dissolved oxygen and turbidity. For the two unnamed tributaries, impairment is due to low dissolved oxygen levels. A summary of the 303(d) list information for these streams is included in Table 13.

Table 13. Summary of 303(d)-Listed Water Bodies in Little Lick Creek Watershed

Reaches	Impairment	Parameters of Interest	Year Listed
Little Lick Creek from Source to Falls Lake – Reaches 27-9-(0.5) and 27-9-(2)	Aquatic Life	Dissolved Oxygen, Turbidity	2008
UT2 to Little Lick Creek from Sources to Little Lick Creek – Reach 27-9-(0.5)ut2	Aquatic Life	Dissolved Oxygen	2008
UT2 to Little Lick Creek from Sources to Little Lick Creek – Reach 27-9-(2)ut2	Aquatic Life	Dissolved Oxygen	2008

3.3.2 City of Durham State of Our Streams Report

Since 2004, the City has published annual summaries of water quality in streams throughout the City for the general public called "State of Our Streams" reports. The State of Our Streams reports summarize water quality conditions by using a numeric water quality index based on a scale of 0 to 100 that corresponds to a classification from Poor to Excellent, which is developed from the data collected during the year. The State of Our Streams reports also summarize identified pollution sources that contribute to degraded water quality. Each year between 2004 and 2011, one or more of the City's ambient stations in the Little Lick Creek watershed (Table 11) were monitored and an annual water quality index was developed for the watershed. An update for Little Lick Creek was not provided in the 2013 State of Our Streams Report.

The 2011 report summarizes water quality from only one station – LL3.4LLC, which is on the main stem off Little Lick Creek at Mineral Springs Road. According to the report, overall water quality in the watershed was better in 2011 compared to 2010, however, year-to-year comparisons should be used with caution because differences can be due to factors that are not related to changes in pollutant sources, such as differences in precipitation patterns. Nevertheless, at station LL3.4LLC bacteria and turbidity improved from 2010 to 2011 while nitrogen and phosphorus concentrations did not change significantly. The 2011 report states that copper concentrations were below the federal EPA standard indicating that high copper concentrations during the 2009 monitoring year were likely from a temporary source. The overall water quality index score for Little Lick Creek watershed for 2011 based on this one station was 80. In 2010, the overall water quality index score based on all three monitoring locations was 73. The State of Our Streams reports can be obtained from the following website: http://durhamnc.gov/ich/op/pwd/storm/Pages/State-of-Our-Streams-Reports.aspx.

3.3.3 North Carolina Division of Mitigation Services Local Watershed Plan

The North Carolina Division of Mitigation Services (formerly the Ecosystem Enhancement Program), funds development of local watershed plans (LWPs) to identify and prioritize high-quality and cost-effective compensatory mitigation projects for streams, wetlands, and riparian buffers throughout North Carolina (EEP, 2011). With funding from the Division of Mitigation Services (DMS), the Upper Neuse River Basin Association completed an LWP in the Little Lick Creek watershed in 2006 in cooperation with DMS, the Center for Watershed Protection, and the North Carolina Division of Water Resources (formerly the Division of Water Quality). This particular LWP focused on identifying nutrient reduction projects to support the State's Nutrient Offset Program. The plan included recommendations for stormwater control measure (SCM) retrofits, critical land protection, and other watershed improvement measures. The final Watershed Management Plan and other reports related to the study can be accessed at: http://archive.unrba.org/littlelick/downloads.shtml.

In addition to the Final LWP, a series of technical memorandum were produced that focused on specific aspects of the watershed. Technical Memorandum 1 from the LWP contained a summary of water quality findings:

- Benthic data indicate Little Lick Creek is biologically impaired;
- Data available at the time (as of 2005) did not provide enough information to identify the sources of the benthic impairment in Little Lick Creek; and
- Low concentrations of dissolved oxygen likely contribute to the benthic impairment but that the underlying causes of this condition were unknown.

Technical Memorandum 1 also identified potential causes of impairment which should be investigated further, including disturbance of stream channels, stream bed and bank erosion, sedimentation, and toxic contaminants.

Findings from the City's monitoring program in the watershed were also summarized and interpreted in the report. These findings indicated that the action level criterion for copper was exceeded for 38% of samples and the standard for fecal coliform was exceeded for 70% of samples. The technical memorandum states that the overall water quality sampling performed by the City indicate that sewage from leaking sanitary sewer lines or failing septic systems, and erosion and sedimentation were potentially significant water quality problems.

In addition, the North Carolina Division of Water Resources (formerly the Division of Water Quality) conducted a short-term monitoring program for the LWP effort. This monitoring program included physical and chemical parameter sampling at 11 sites and benthic macroinvertebrates sampling at four of those sites. The results of this sampling included frequent low dissolved oxygen concentrations and high levels of nutrients, fecal coliform, and metals at different sampling locations.

Other important points were also included in the Final LWP. Primary among these was a discussion of Triassic Basin hydrology's effect on aquatic life. The document indicated that because Triassic Basin streams typically have low or no baseflow during the summer months, low dissolved oxygen concentrations may be a naturally occurring condition affecting aquatic communities. Ways of addressing low or no flow in the summer include incorporating deep pools in the streams, and installing SCMs that promote infiltration and more even channel discharge. The LWP also states that urbanization will often lead to increased pollutant levels and further stress benthic communities.

3.3.4 Study of Sediment Sources to Falls Lake

Tracing the Sources of Suspended Sediment Inputs to Falls Lake Reservoir, Neuse River, North Carolina, a 2012 thesis prepared by Mark Voli while at North Carolina State University and subsequently published (Voli, 2013), estimated the primary sources of sediment from four drainage basins to Falls Lake, including Little Lick Creek. The research used a sediment fingerprinting technique to identify the sources of suspended sediment. Additionally, radiocarbon dating and magnetic susceptibility measurements were employed to confirm the presence of legacy sediments in the valley bottoms. Although the study did not estimate annual sediment loadings from these four watersheds, relevant conclusions drawn from the thesis include:

- Stream bank erosion of streams draining to Falls Lake is the leading contributor to sediment loading.
- In some instances, erosion is exacerbated by erodible legacy sediments deposited in valley bottoms; however, the thesis noted a lack of legacy sediments in the Little Lick Creek watershed due to poor soils for agriculture and also few dams, low stream gradients, and a lack of hard rock. This suggests that stream erosion is due to recent channel incision.
- The highest source of sediment in Little Lick Creek is stream bank erosion (33%), followed by commercial timber harvesting (31%), pasture (21%), and construction activities (16%).

3.3.5 Upper Neuse Clean Water Initiative Conservation Plan (UNCWI)

The Trust for Public Land, along with the City of Durham, City of Raleigh, and several other local jurisdictions and conservation organizations, published a report in 2006 that focuses on land conservation and preservation to protect water quality in the Upper Neuse River and Falls Lake. The Conservation Plan used a GIS-based evaluation to identify high-priority privately-owned land that, if preserved, will help protect Falls Lake as a drinking water source for the Triangle. The evaluation, which applied 21 criteria, identified over 6,800 acres for preservation in Durham County. Of this, a significant number of high-priority parcels are located within the Little Lick Creek watershed. These parcels will be evaluated further in the Critical Area Protection Plan that will be prepared at a later date as part of this Watershed Improvement Plan.

3.3.6 East Durham Open Space Plan

This Plan, adopted by the Durham City Council and the Durham County Board of Commissioners in 2007, describes the objectives and policies in the East Durham Open Space Plan Area to meet goals concerning the following seven issues:

1. Parks and Recreation
2. Habitat Preservation
3. Natural Beauty
4. Historic Preservation
5. Citizen Involvement and Coordination
6. Land Use and Development
7. Water Quality

Many of the objectives and policies in this Plan can aid the City to improve and protect the water quality and watershed health of Little Lick Creek and Falls Lake.

3.4 Potential Impacts Due to Stream Conditions

The physical condition of stream channels plays a significant role in water quality and stream ecological condition including the health of aquatic communities. As described above, the NCSU study determined that stream bank erosion is the single largest source of sediment to Little Lick Creek (Voli, 2012). This section describes the results of stream assessments performed for this Watershed Implementation Plan and the potential impacts on water quality and watershed health due to stream channel conditions.

3.4.1 General Overview of Streams

Physical characteristics of streams in the watershed are heavily influenced by the Triassic Basin geology, soils, and topography (see Section 2.4). Triassic basin soils erode more easily than other Piedmont soils (Griffith, 2002) and their low permeability results in reduced groundwater transmittance and low infiltration rates that increase surface runoff during storm events. As a result, Triassic Basin streams have flashy storm flows and often go dry during summer months. Section 2 contains further discussion of Triassic Basin soils and streams.

Development and past land use practices within the watershed have played a significant role in altering the physical conditions of the stream channels. Land clearing, agriculture, and development have altered the streams in the watershed since the area was first settled and continue to do so. Erosion and sedimentation, channelization, and altered hydrologic response related to land use change have occurred in the area and have affected most of the streams in the watershed.

Although areas of the watershed have urbanized and pipes have been installed to convey stormwater runoff from developed areas, the natural stream channels throughout the watershed are largely intact (i.e., have not been piped). Based on the stream hydrography GIS data provided by the City, the total stream length in the watershed is approximately 106 miles and the resulting drainage density is 6.2 miles/square mile. Drainage density is the total length of stream channel divided by the watershed area. It reflects how runoff moves through the watershed, whether it infiltrates, travels more overland, or more often through stream channels. Lower density indicates more infiltration and overland flow, while higher density indicates more flow through channels. Topography, geology, soils, and land cover determine drainage density. Table 14 shows the stream length and drainage density by subwatershed.

Table 14. Drainage Density for Little Lick Creek Subwatersheds

Watershed	Total Stream Length (mi)	Subwatershed Area (sq. mi.)	Drainage Density (mi/sq. mi.)
LLC01	4.98	0.92	5.4
LLC02	2.55	0.45	5.6
LLC03	3.77	0.69	5.5
LLC04	3.38	0.55	6.1
LLC05	3.83	0.64	6.0
LLC06	4.56	0.62	7.3
LLC07	3.45	0.61	5.7
LLC08	3.95	0.71	5.6
LLC09	4.89	0.79	6.2
LLC10	5.02	0.70	7.2
LLC11	1.37	0.28	4.9
LLC12	2.99	0.52	5.8
LLC13	2.05	0.36	5.6
LLC14	1.80	0.29	6.2
LLC15	3.89	0.79	4.9
LLC16	3.18	0.55	5.7
LLC17	3.77	0.53	7.1
LLC18	3.96	0.66	6.0
LLC19	3.88	0.59	6.6
LLC20	1.71	0.21	8.0
LLC21	5.30	0.91	5.8
LLC22	3.35	0.47	7.2
LLC23	3.78	0.64	5.9
LLC24	2.66	0.43	6.2
LLC25	11.97	1.52	7.9

3.4.2 Stream Assessment Methods

Stream channel conditions were assessed throughout the watershed by field crews, with support from City staff, as part of the Stream Inventory and Assessment. The assessment was performed to characterize existing conditions and identify potential projects to improve water quality and ecological health of streams. The specific objectives of the stream assessments were to:

1. Collect data on the physical condition of the streams and riparian buffers within the watershed
2. Identify stream reaches and riparian buffers which are degraded that are in need of restoration or enhancement
3. Identify potential sources of pollution along the stream corridors within the watershed
4. Identify issues with public utilities that cross or are adjacent to the streams
5. Identify high-quality stream reaches and riparian areas which are privately owned that should be protected and preserved
6. Collect information needed to support development of the watershed-scale water quality model
7. Collect detailed information on high priority stream reaches to estimate annual sediment loads due to stream bank erosion

Two levels of field-based stream assessments were performed. Level 1 stream assessments were conducted on a large number of streams throughout the watershed to meet objectives one through six listed above. The Level 2 stream assessments were performed on a subset of the Level 1 streams where higher rates of erosion were observed to accomplish objective number seven listed above. Methods for both levels are described below. More detailed information on the stream assessment methods can be found in the *Stream Assessment Field Plan* in Volume III - Technical Appendices of the Watershed Improvement Plan.

3.4.2.1 Level 1 Stream Assessments

The Level 1 stream assessments were designed to allow for rapid data collection on a large number of streams throughout the watershed. The stream assessments focused on the perennial and larger intermittent streams within:

- Candidate Pilot Study Areas, consisting of subwatersheds LLC02, LLC05, LLC09, LLC10, LLC12, LLC16, and LLC22 (See Section 5)
- Areas within the current City limits in other subwatersheds
- Mainstem of Little Lick Creek and Chunky Pipe Creek outside the City limits

During the assessments, field teams walked the designated stream reaches and recorded observations on Lenovo Thinkpad™ 2 tablets running ArcGIS Mobile software. The Level 1 assessments consisted of the following data:

<u>Physical Measurements</u>
Channel dimensions were recorded at one representative cross section along each reach. Measurements included overall channel dimensions including top width, bottom width, and bank height and bankfull channel dimensions including bankfull width, bankfull depth, bankfull width to bankfull depth ratio (calculated), and bank height ratio (calculated as bank height/bankfull depth). Dominant bed material type and sinuosity representative of each reach were also recorded.

<u>Rapid Stream Assessment Technique (RSAT)</u>
The Rapid Stream Assessment Technique (RSAT) is an overall assessment of stream function and health (Washington COG, 1992). The assessment consists of six factors that affect overall stream condition including:

1. Channel Stability
2. Channel Scouring and Sediment Deposition
3. Physical Instream Habitat
4. Water Quality Indicators
5. Riparian Habitat Condition
6. Biological Indicators

Each of these factors has a series of metrics that are rated for each stream reach assessed. The ratings for each metric are then summed to provide an overall score for each of the six factors. The scores for each factor are then used to generate an overall rating for the relative condition of the reach of "Excellent," "Good," "Fair," and "Poor." Detailed descriptions of the RSAT method, each of the six factors, and the series of metrics evaluated are included in the *Stream Assessment Field Plan* in Volume III - Technical Appendices of the Watershed Improvement Plan.

Stream Restoration, Enhancement, and Preservation Opportunities

Each reach assessed during Level 1 was evaluated as a potential stream restoration, enhancement, or preservation opportunity. These judgments were made in the field based on physical condition of the stream and feasibility of implementation. To be identified as a potential restoration project, degraded stream reaches had no significant impediments to implementation of a Priority I restoration project (such as the inability to raise the stream bed to reconnect the floodplain), utility conflicts, or encroachment by existing structures. In cases where restoration was not a viable consideration, enhancement was recommended for more limited improvement of channel condition. Preservation of the existing riparian corridor was recommended when channels and buffers appeared to be healthy and functioning at a high level.

Observed Water Quality Problems

Observed water quality problems were noted when encountered during the stream assessments and located with GPS on ArcGIS Mobile. Possible water quality problems included, but were not limited to, visual evidence of discharge, dumping of garbage or debris in the channel, leaking infrastructure, suspect odor, suspect water appearance, and erosion and sediment control (ESC) problems. Any observed water quality problems were reported immediately to City staff.

Condition of Utilities

The stability of the City's utility infrastructure were evaluated in locations where they are parallel to or cross streams as indicated by the City's infrastructure data. For sanitary sewer, water line, gas line, or other utilities, the type of utility, its condition and any problems with the utility line observed such as leaking, exposed, stability threatened, or broken were recorded. Any leaking or broken utility pipes were reported immediately to City staff.

Stormwater Control Measures Opportunities

Opportunities for stormwater control measure (SCM) retrofits to collect and treat stormwater runoff from areas with no existing SCMs were identified by stream assessment field crews. These potential SCM sites were then included with the SCM retrofits sites evaluated during the SCM assessments (described in Sections 3.5 and 4.3).

Photographs

All reaches assessed were photo documented. Photos included pollution sources, utility maintenance issues, areas of stream bank erosion, habitat features, and other noteworthy features along each reach assessed. At a minimum, photographs were taken at the upstream end of each reach looking downstream and at the downstream end of each reach looking upstream.

3.4.2.2 Level 2 Stream Assessments

The Level 2 stream assessments were performed on a limited subset of Level 1 reaches, which were selected based on the results of the Level 1 assessments. Level 2 stream reaches were prioritized based on the level of physical degradation and instability observed as well as potential to contribute sediment pollution to downstream waters. All Level 1 reaches that were rated "Poor" on both the overall RSAT rating and on the channel stability evaluation were included in the Level 2 assessments. The Level 2 assessments included:

Bank Erosion Hazard Index (BEHI)
A Bank Erosion Hazard Index, or BEHI (Rosgen, 2006), was developed for each reach. This involved dividing reaches into sub-reaches with similar stream bank characteristics and performing a detailed evaluation of bank stability on both the left and right banks of each sub-reach. The BEHI rating (e.g., very low, low, moderate, high, very high, or extreme) was recorded for each sub-reach. These data were then used with the near bank stress evaluation results (described below) to determine an estimate of annual sediment erosion rate for the reach and resulting sediment loads. Detailed information on the BEHI assessment is included in the *Stream Assessment Field Plan*.

Near Bank Stress (NBS)
In addition to the BEHI assessment, an analysis of near bank stress was done for each sub-reach. An NBS rating is an evaluation of the shear stress on the bank from stream flows and must accompany the BEHI ratings in order to estimate sediment loads from bank erosion. The NBS rating of very low, low, moderate, high, very high, or extreme was recorded for each BEHI sub-reach. Detailed information on the NBS assessment is included in the *Stream Assessment Field Plan*.

Large Woody Debris Counts
While performing the BEHI assessments on Level 2 reaches, field teams also counted large woody debris (LWD) along the reach. LWD and log-jams were tallied over the length of the reach in each of three zones: low flow channel cross section, bankfull channel cross section above low flow, and floodplain.

3.4.3 Results of Stream Assessments

The stream assessments were conducted during April and May of 2014. A total of 24.7 miles of streams, which consisted of 97 individual stream reaches, were assessed throughout the watershed during this period. The results of the assessments indicate that the streams throughout the watershed are significantly degraded. Specific results of the assessments are discussed below.

3.4.3.1 Results of Level 1 Assessments

RSAT Results
The Level 1 assessments were conducted on all 24.7 miles of stream assessed for the study, which was divided into 97 separate stream reaches based on the current conditions of the stream channel and the riparian corridor. Nearly all of the stream reaches assessed were rated “Fair” or “Poor” (the two lowest ratings) on the overall RSAT score (Figure 11). Of the overall streams miles assessed, 54% were rated “Poor” (see Photo 1), 41% were rated “Fair” (see Photo 2), and 5% were rated “Good” (see Photo 3). No stream reaches assessed were rated “Excellent.” This indicates widespread degradation of streams throughout the watershed has occurred. Table 15 shows the miles of streams rated in each subwatershed and the overall percentage in each stream quality category.

Photo 1. *Example of Poor Overall Stream Condition*

Photo 2. *Example of Fair Overall Stream Condition*

Photo 3. *Example of Good Overall Stream Condition*

Table 15. Results of Rapid Stream Assessment Technique (RSAT) by Subwatershed

Subwatershed	Length of Streams Assessed (mi)	Percentage of Stream Channel within Each Stream Quality Category		
		Poor	Fair	Good
LLC01	1.45	80%	20%	0%
LLC02	0.92	0%	100%	0%
LLC03	1.22	27%	73%	0%
LLC04	0.83	15%	85%	0%
LLC05	1.48	82%	18%	0%
LLC06	1.52	100%	0%	0%
LLC07	1.18	65%	35%	0%
LLC08	0.91	0%	59%	41%
LLC09	1.33	51%	49%	0%
LLC10	1.33	100.0%	0%	0%
LLC11	0.44	27%	73%	0%
LLC12	0.91	27%	73%	0%
LLC13	0.73	78%	22%	0%
LLC14	0.80	100%	0%	0%
LLC15	0.72	100%	0%	0%
LLC16	1.17	65%	35%	0%

Subwatershed	Length of Streams Assessed (mi)	Percentage of Stream Channel within Each Stream Quality Category		
		Poor	Fair	Good
LLC17	1.42	85%	15%	0%
LLC18	1.22	64%	36%	0%
LLC19	0.73	90%	10%	0%
LLC20	0.82	0%	100%	0%
LLC21	0.83	36.%	64%	0%
LLC22	1.28	10%	90%	0%
LLC23	Not assessed	N/A	N/A	N/A
LLC24	Not assessed	N/A	N/A	N/A
LLC25	1.46	0%	46%	54%
TOTALS:	**24.7 (97 reaches)**	**54%**	**41%**	**5%**

Of the 23 subwatersheds where streams were assessed, four had 100% of their streams rated as "Poor" quality – LLC06, LLC10, LLC14, and LLC15. Three of these, LLC06, LLC10, and LLC15, contain older areas of development and have a high percentage of impervious cover (greater than 16%), while LLC14 is moderately developed but is downstream of a rapidly developing subwatershed – LLC12.

Only two subwatersheds, LLC08 and LLC25, have streams considered to be of "Good" quality. LLC08 contains Twin Lakes Park and large forested areas surrounding the park which have provided some protection of the stream channels despite the level of development in the subwatershed (impervious cover at 15%). The good stream conditions in LLC25 are likely a result of the very low level of development that has occurred (impervious cover of only 2%).

Observed Water Quality Concerns

Potential water quality concerns that were identified by field teams during the Level 1 stream assessments were located with GPS (Figure 12). The most frequently observed issues were dumping of garbage and debris in or adjacent to streams, unidentified pipes discharging to streams (see Photo 4), debris or beaver dams creating backwater conditions, and potential sources of excess sediment. Table 16 includes a summary of the types of potential issues observed. Potential water quality issues related to utility crossings are addressed separately in Section 3.5.4.

Photo 4. *Example of Pipe Discharging to Stream from Unknown Source*

Table 16. Potential Water Quality Problems

Potential Water Quality Problems	Number of Observations
Dumping In or Near Streams	3
Pipes Discharging from Unknown Source	14
Beaver or Debris Dams	7
Potential Source of Excess Sediment	8

3.4.3.2 Results of Level 2 Assessments

The Level 2 assessments included analysis of Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) to develop an estimate of erosion rates (tons per foot per year) and sediment yield (tons per year), which can have a significant impact on water quality and aquatic habitat conditions. The Level 2 assessments were conducted on reaches with the highest potential to contribute sediment from bank erosion to downstream waters based on the results of the Level 1 assessments.

The Level 2 assessments were completed on 30 stream reaches, which totaled 7.6 miles of the 24.7 stream miles completed for Level 1. The reaches assessed were fairly well distributed throughout the watershed, but tended to be in more developed areas (Figure 13). Table 17 shows the results of the BEHI/NBS assessments for all 30 reaches. The BEHI/NBS assessments generate an erosion rate and sediment yield for each reach. Erosion rate (units of tons per foot per year) is the amount of bank erosion expected to occur each year estimated through the BEHI/NBS results multiplied by the average stream bank height. The sediment yield (units of ton per year) is the erosion rate multiplied by the length of the reach assessed, and represents the annual sediment load from that reach by stream bank erosion. The sediment yield estimates the amount of sediment that is *generated* from streambank erosion but does not specify the fate of the sediment. The sediment generated could deposit on point bars within the stream channel or the floodplain, or it could be transported to Falls Lake.

Table 17. Sediment Yields Based on Level 2 Assessments

Reach	RSAT Rating	Length (ft)	Estimated Erosion Rate (tons/ft/yr)	Estimated Sediment Yield (tons/yr)
LLC01-05	Poor	943	0.15	141
LLC04-04	Poor	642	0.08	51
LLC05-02	Poor	2,891	0.17	480
LLC06-01	Poor	1,779	0.03	53
LLC06-02	Poor	565	0.03	17
LLC06-03	Poor	4,336	0.04	173
LLC06-04	Poor	1,363	0.10	136
LLC07-02	Poor	1,788	0.11	197
LLC07-03	Poor	393	0.04	16
LLC07-05	Poor	1,831	0.03	55
LLC10-01	Poor	2,020	0.15	301
LLC11-05	Poor	634	0.07	44
LLC12-03	Poor	1,317	0.14	184
LLC14-02	Poor	995	0.06	60
LLC15-01	Poor	1,044	0.03	31
LLC15-02	Poor	2,783	0.01	28
LLC16-04	Poor	1,493	0.30	448
LLC16-05	Poor	2,474	0.03	74
LLC17-03	Poor	1,180	0.12	137
LLC17-06	Poor	1,872	0.09	172
LLC18-01	Poor	670	0.17	115
LLC18-02	Poor	1,215	0.18	213
LLC18-03	Poor	1,195	0.23	269
LLC18-05	Poor	249	0.31	78
LLC18-06	Poor	90	0.14	12
LLC18-07	Poor	698	0.16	111
LLC19-01	Poor	1,066	0.08	86
LLC19-03	Poor	1,042	0.05	53
LLC22-06	Poor	700	0.18	128
LLC22-05	Fair	816	0.08	65

While the Level 2 assessment was not completed on all stream reaches or in all subwatersheds, some general conclusions can be drawn from the results. As Table 18 indicates, there are five reaches that produce over 200 tons per year of sediment. These are located in subwatersheds LLC05, LLC16, LLC10, and LLC18. Of the subwatersheds assessed, LLC18 produces the most sediment from stream bank erosion (798.3 tons/year from six reaches assessed). Following LLC18 are LLC02 (522 tons/year), LLC05 (479.9 tons/year), LLC06 (380 tons/year), and LLC17 (309.1 tons/year). All of these subwatersheds are developed or developing with percentage of impervious cover values greater than 14%.

Potential measures to reduce stream channel erosion and sediment yield are discussed in Section 4.

3.4.4 Potential Factors Affecting Stream Quality

3.4.4.1 Historic Land Use Activities

To determine if historic land use activities may have caused impacts that are effecting the current quality of Little Lick Creek, aerial photographs from 1940, 1955, and 1964 were compared with aerial photographs from 2011 to determine the potential impacts on channel alignment and geomorphic development. The evaluation of historical aerial photos focused on subwatersheds LLC02 and LLC06, which differ slightly in their history of land use. For each subwatershed, factors which typically cause impacts on stream quality such as the alteration of stream channel alignment, installation of ponds or impoundments, and clearing of the riparian buffer were visually identified from the aerial photos. The ability and accuracy to identify these impacts varied on each set of aerial photos since the quality and clarity differs from year to year, therefore, the location of stream centerlines are estimates only. In addition, it is often not possible to distinguish between abandoned and active channels only from the aerial photo. With these caveats in mind, Figures 14 and 15 present a general indication of the hydrologic connections of headwater streams, ponds, and channel alignments as they have shifted over the past 60 years. A comparison of forest cover between 1940 and 2011 is also provided.

In general, both subwatersheds have experienced a progression from forested land use to agricultural to urban development. However, in some areas, another progression shows abandonment of agricultural use resulting in an increase in forest cover before urban development. In both cases, widespread modifications to the hydrologic regime have occurred, including re-routing or straightening stream channels, ditching and draining of wetlands, and elimination of natural channels altogether. In both subwatersheds, installation of small ponds on headwater tributaries have been common.

Approximately half of LLC02 was under agricultural use in 1940 (Figure 14), with large areas of the riparian buffer cleared and indications that several stream channels had been altered. Likely changes to sediment supply from agricultural practices and changes in hydrology from several small ponds present in headwaters tributaries also impacted the geomorphology and stability of the stream channels in this subwatershed. Since 1940, a trend of recovery from these agricultural impacts is noticeable. Forested area is lowest in 1940, and gradually increases as fields are abandoned. Although a number of riparian areas have been reforested, there is little evidence that altered stream channels have re-established a natural pattern. The 2011 aerial shows a dramatic increase in residential development, with the undeveloped portions of the subwatershed still forested. Within the developed areas of the subwatershed, the stream channels have been replaced with stormwater pipes. Four reaches in LLC02 totaling approximately 4,900 LF were assessed. All four reaches received an overall rating of “fair” condition, with poor-to-fair channel stability and generally poor aquatic habitat conditions. Given the relatively low level of development in

LLC02 (cumulative impervious percentage of 13%), historic land use practices have played an important role in the currently degraded stream conditions.

In subwatershed LLC06 (Figure 15), clearing of riparian areas, alteration of stream channels, and conversion to agricultural use occurred before 1940, with a slight increase between 1940 and 1955. Streams in this subwatershed underwent dramatic changes due to these land use activities, including rerouting and straightening of channels, installation of drainage ditches, draining of wetlands, and construction of several small impoundments. Since that time, several areas have been reforested and agricultural use has dropped dramatically as land has been converted into urban development. Currently, only a small portion of agricultural land remains and many of the small ponds have been removed. Within the developed areas of the subwatershed, the stream channels have been replaced with stormwater pipes. Four reaches in LLC06 totaling approximately 8,000 LF were assessed. All four reaches received an overall rating of "poor" condition, with poor channel stability and poor aquatic habitat conditions. Although LLC06 is impacted by a slightly higher level of overall development than LLC02 (cumulative impervious percentage equals 18%), historic land use practices have still played an important role in the currently degraded stream conditions.

The effect of historic land use practices exhibited in these two subwatersheds are typical in the Little Lick Creek watershed. Stream channels have exhibited significant alteration throughout the previous 65 years due to installation of small ponds, clearing of riparian areas for agricultural use, construction of ditches, realignment and rerouting stream channels, and urban development. Either direct or indirect human modification occurred throughout the past 65 years, with evidence of prior modifications as well. Due to this, poor to fair channel conditions are commonly found throughout the watershed, despite forested conditions.

3.4.4.2 Effect of Impervious Cover

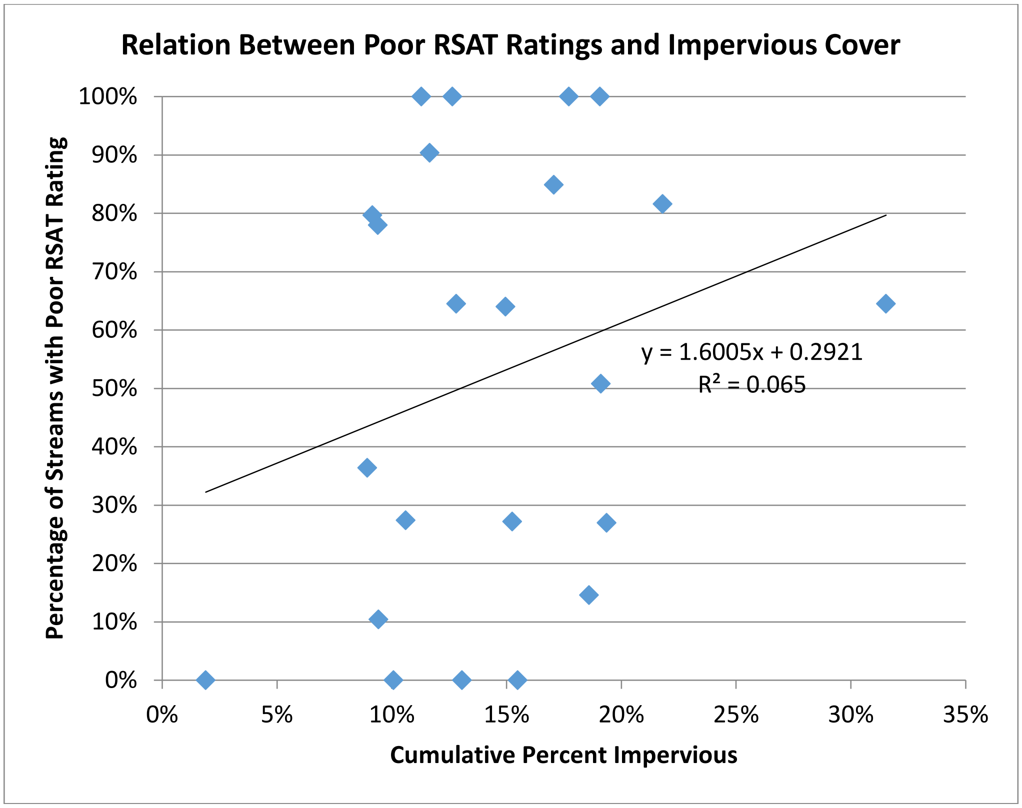
Often, impervious cover is cited as a primary factor for generally poor stream channel conditions (i.e., low RSAT scores). To verify this assumption, a comparison of impervious cover and stream quality observed in the Little Lick Creek watershed was conducted. To assess how strong the relationship is between impervious cover and stream quality, two plots of the RSAT ratings described in Section 3.4.2 versus the cumulative impervious cover were generated. Table 18 presents the cumulative impervious percentage for each subwatershed and the percentage of stream channels within that subwatershed that rated "poor," "fair," and "good." Plot 9 shows the relationship between stream channels with an overall RSAT rating of "poor" to cumulative impervious cover, and Plot 10 shows the relationship for stream channels with an overall RSAT rating of "fair."

As shown in Table 18 and on Plots 9 and 10, there is a poor correlation between cumulative impervious cover and stream quality rating in the Little Lick Creek watershed. Five subwatersheds with a cumulative impervious cover of 10% or less lack streams with a "good" quality rating. Two subwatersheds with a cumulative impervious cover of 9%, LLC01 and LLC13, actually have a higher percentage of "poor" quality streams than subwatershed LLC07, which has the highest cumulative impervious cover of 32%. This indicates that although impervious cover and legacy valley sediments are often cited as the primary reasons for channel degradation, they do not appear to be driving factors in the Little Lick Creek watershed. The low RSAT results found throughout Little Lick Creek may be partially explained by historic human disturbance, such as channel alteration, hydrologic changes due to construction of ponds in headwater areas, and clearing of riparian buffers.

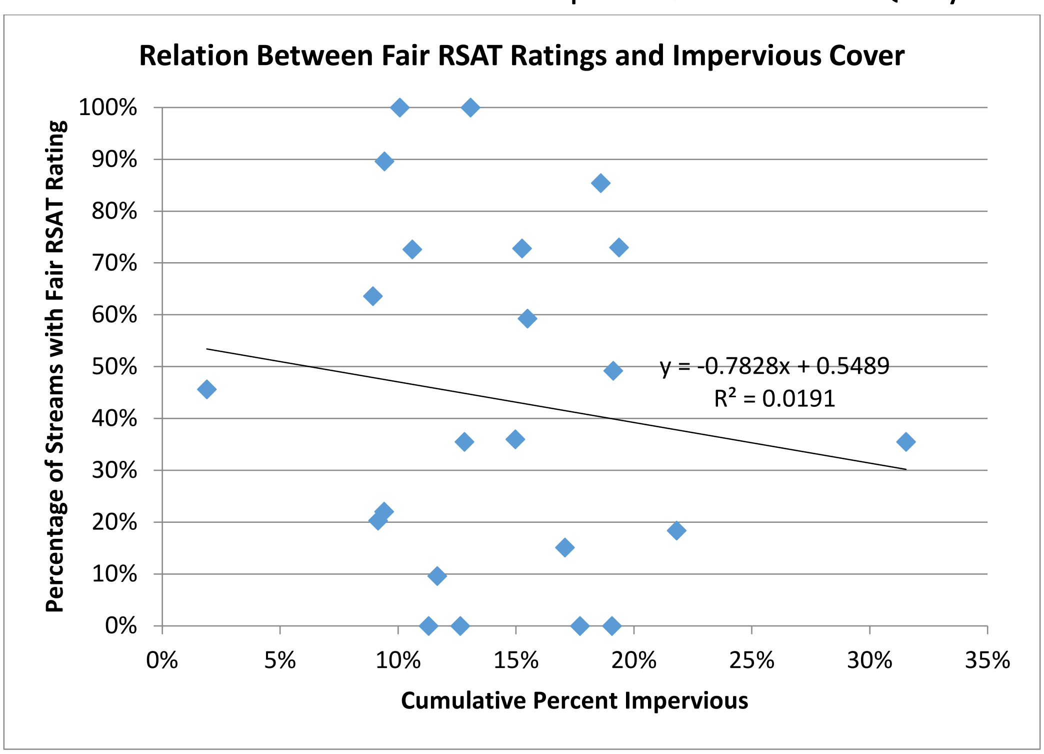
Table 18. Comparison of Impervious Cover and Stream Quality

Subwatershed	Subwatershed Impervious Percentage	Cumulative Impervious Percentage	Stream Quality Ratings		
			Poor	Fair	Good
LLC25	2%	2%	0%	46%	54%
LLC24	3%	4%	N/A	N/A	N/A
LLC23	5%	5%	N/A	N/A	N/A
LLC21	9%	9%	36.%	64%	0%
LLC01	9%	9%	80%	20%	0%
LLC13	9%	9%	78%	22%	0%
LLC22	10%	9%	10%	90%	0%
LLC20	5%	10%	0%	100%	0%
LLC12	10%	11%	27%	73%	0%
LLC14	9%	11%	100%	0%	0%
LLC19	8%	12%	90%	10%	0%
LLC15	16%	13%	100%	0%	0%
LLC16	14%	13%	65%	35%	0%
LLC02	21%	13%	0%	100%	0%
LLC18	15%	15%	64%	36%	0%
LLC11	15%	15%	27%	73%	0%
LLC08	15%	15%	0%	59%	41%
LLC17	14%	17%	85%	15%	0%
LLC06	16%	18%	100%	0%	0%
LLC04	19%	19%	15%	85%	0%
LLC10	19%	19%	100%	0%	0%
LLC09	20%	19%	51%	49%	0%
LLC03	19%	19%	27%	73%	0%
LLC05	27%	22%	82%	18%	0%
LLC07	32%	32%	65%	35%	0%

Plot 9. Correlation between Cumulative Impervious % and Poor Stream Quality



Plot 10. Correlation between Cumulative Impervious % and Fair Stream Quality



3.5 Potential Impacts from City Sanitary Sewer and Septic Systems

In order to comply with the Falls Lake Rules, municipalities were required to develop inventories and characterize load reduction potentials from wastewater collection systems by January 2013. The inventory for the City of Durham is summarized in "City of Durham Submission of Falls Lake Inventory and Characterization of Load Reduction Potential" (Brown and Caldwell, 2013). The report includes information on septic systems, discharging sand filter sanitary systems, and reported sanitary sewer overflows (SSOs) and sewer leaks within the City and County in the Little Lick Creek Watershed (depicted in Figure 16).

The NC Division of Water Resources (DWR) funded the North Carolina Piedmont Nutrient Load Reducing Measures Technical Report (Tetra Tech, 2013), a nutrient credit study that looked specifically at septic systems and discharging sand filter systems. The City's credit for nutrient reductions is likely to be predicated on this study. The following analysis uses data from the City of Durham inventory together with the Nutrient Credit Study to assess loads and load reductions from these systems with City limits.

Annual nutrient loads from these sources are derived from data provided in the Nutrient Credit Study and the results of the field investigations, which are tabulated in Table 19 below. All nutrient load calculations are based on a 3-bedroom home occupied by 2.2 people.

More details on how these estimates were derived are provided in the following sections.

Table 19. Inventory of Wastewater Collections Systems and Estimated Nutrient Loads

Sanitary System Component	Number Within City	Annual TN Loading (lb/year)	Annual TP Loading (lb/year)
Septic Systems	123	118	5
City Sand Filter Systems (7% not functioning)	29	470	112
Reported SSOs and pipe leaks (2010-2013)	15	13	3
	Total:	**601**	**120**

3.5.1 Malfunctioning Septic Systems

Septic systems and their corresponding sand filters can be a highly effective means of on-site wastewater treatment. When functioning optimally, their nutrient discharges of total nitrogen (TN) and total phosphorus (TP) to surface water are minimal. Issues arise when septic systems are designed or implemented improperly, the on-site soil characteristics are unsuitable, or they are not regularly inspected and maintained. There are 123 septic systems within the City limits located in the Little Lick Creek watershed, which discharge into the surrounding soil at a rate of 24.2 lbs/yr for TN and 4.0 lbs/yr for TP for each septic tank. Based on monitoring data, attenuation rates for nutrients in the Piedmont region are 97% for TN and 100% for TP for functioning septic systems.

Due to maintenance issues or problems with the drain field, 3% of the septic systems are expected to fail. The malfunctioning septic system discharges to local surface waters at a rate of 7.9 lbs/yr for TN and 1.2 lbs/yr for TP. Based on these assumptions, the total annual nutrient loads associated with septic systems within the City limits of the Little Lick Creek Watershed are approximately 118 lbs/yr for TN and 5 lbs/yr for TP. Methods to reduce nutrient loads from septic systems are discussed in Section 4.2.

3.5.2 Discharging Sand Filters

Sand filter septic systems are another common method for on-site wastewater disposal for rural residential properties. Discharging sand filters pass septic tank effluent through perforated pipes and into 18" of filter media prior to discharge into the gravity drainfield. In some cases, the sand filters are also fitted with an outlet pipe for discharge into a nearby stream. Typical nutrient loading rates for functioning sand filters septic systems are 16.2 lbs/yr TN and 2.0 lbs/yr TP per sand filter.

Currently, there are 29 sand filter septic systems within the City limits. DWR has typically found that 7% of these types of sand filter system are functioning poorly and discharging to surface waters (i.e. not all of the wastewater is infiltrated into the media). The Nutrient Credit Study recommends using an equivalent loading rate for functioning and poorly functioning systems for TN, but increasing the loading rate for TP to 4.0 lbs/yr. Based on 27 functioning and two poorly functioning sand filter septic systems discharging to surface waters, the total annual nutrient loads within the City limits of the Little Lick Creek watershed are approximately 470 lbs TN/year and 112 lbs TP/year.

3.5.3 Sanitary Sewer Overflows (SSOs) and Pipe Leaks

Leaky sanitary sewer pipes and SSOs can contribute large nutrient loads to a watershed. A sanitary sewer overflow can occur when a sewer pipe is damaged, when the wastewater flow in the sewer is blocked by grease, roots or debris, or when the flow in a sewer exceeds the pipe's capacity.

The City's Water Management Department tracks sewage leaks and SSOs. For the Little Lick Creek watershed, the database contains information on sewage spills that occurred between 2010 and 2013. There were 15 sewage spill incidents investigated by the City during that time, with an associated total discharge volume of 156,040 gallons. If the discharge volume is averaged over the four years (39,010 gal) and sewage nutrient concentrations of 40 mg/L for TN and 10 mg/L for TP (Metcalf and Eddy, 1991) are applied, the resulting average annual loading rates are approximately 13 lb TN/year and 3 lb TP/year. Compared to other watersheds in Durham (e.g., Ellerbe Creek), leaky sewers and SSOs are a less significant source of nutrients.

There are over 1,400 locations where stormwater pipes and sanitary sewer pipes cross one another in the Little Lick Creek watershed. Where the stormwater pipe is above the sewer pipe, if there are open joints, stormwater may enter the sewer pipe as inflow, and if the additional flow exceeds the pipe's capacity, the result will be a wet weather sewer overflow. Where the sewer pipe is above the stormwater pipe, if there are open joints, sewage make leak into the stormwater pipe. These crossings create potential issues that are unavoidable. However, the Stormwater and GIS Services Division operates a program to inspect stormwater outfalls during dry weather to detect and eliminate illicit connections and illicit discharges, including leaks from sewers to stormwater pipes. The Water Management Department operates a program to identify and eliminate infiltration and inflow, such as stormwater leaking into a sanitary sewer system.

3.5.4 Stability of Utilities in Stream Corridors

Gravity-flow sanitary sewer pipes are typically installed along streams since the stream valley represents the lowest point of topography within a developed area. To collect sanitary sewage from surrounding homes and businesses, sanitary sewer lines can cross streams on a regular basis. At most stream crossings, the sewer pipe is initially installed several feet below the stream bed to protect the pipe from high flows and debris in the stream.

As urban areas develop, new impervious surfaces are added that lead to changes in watershed hydrology, leaving streams prone to stream bed and bank erosion and stream migration. Vertical erosion of stream beds and lateral erosion of a stream channel parallel to an easement can expose pipes and cause instability, resulting in sanitary sewer pipe leaks or an increase in stream bank erosion.

Utility lines that cross or run adjacent to streams were inspected by field teams and the conditions of the utility lines were noted during the Stream Inventory and Assessment (summarized in Section 3.4). This inspection revealed locations where utility lines are being encroached on or completely exposed (Figures 12 and 16). A scenario commonly observed by field crews (Photo 5) involves bed erosion migrating upstream (known as a headcut) in a gully formed on a floodplain in a sanitary sewer easement. If the headcut becomes deep enough, the sewer line could become exposed and create a point of potential failure for the sewer collection system, leading to significant water quality problems and public health issues in the stream.

Though many occurrences of utilities crossing or running adjacent to streams were inspected, none had obvious signs of leaking. At several locations, utility lines are exposed or unstable due to stream bed and bank erosion that has occurred since the original installation of the utility (Photo 6). In several locations, these newly-exposed sewer lines were temporarily protected with riprap, but a permanent solution had not been implemented. Table 20 summarizes the utilities that are currently exposed or vulnerable to due erosion. During the field inspection, no signs of leaks were reported by field crews, therefore, no additional contribution to the annual nutrient load will be assigned to exposed utilities. To prevent potential water quality impacts, this information has been submitted to the City's Water Management Department to investigate potential stabilization measures that could be undertaken at each location.

Photo 5. *Drainage channel with headcut progressing across utility easement*

Photo 6. *Exposed sanitary sewer line due to bed and bank erosion.*

Table 20. Threatened or Unstable Utilities Observed

ID Number on Figure 12	Type	Problem	Current Condition
6	Sanitary Sewer	Exposed	Old terra cotta pipe is exposed.
12	Sanitary Sewer	Exposed	Exposed sanitary sewer immediately downstream of perched culvert.
18	Sanitary Sewer	Exposed	Exposed sanitary sewer line creating dam effect.
22	Sanitary Sewer	Exposed	Sanitary sewer line exposed that runs parallel to stream channel.
29	Unknown	Exposed	Exposed PVC and small diameter ductile iron pipes in stream.
35	Fiber Optic	Exposed	Fiber optic line. Casing possibly exposed.
42	Sanitary Sewer	Vulnerable Due to Erosion	Headcut encroaching on sanitary sewer.
43	Sanitary Sewer	Vulnerable Due to Erosion	Sanitary sewer line exposed full width of channel due to bed erosion.
47	Sanitary Sewer	Exposed	Sanitary sewer line exposed due to bed erosion.
52	Sanitary Sewer	Vulnerable Due to Erosion	Headcut encroaching on sanitary sewer. Potential ford crossing.
54	Sanitary Sewer	Vulnerable Due to Erosion	Stream encroaching on sanitary sewer. Not yet exposed.
55	Gas Line	Vulnerable Due to Erosion	Headcut encroaching into gas easement.
62	Sanitary Sewer	Vulnerable Due to Erosion	Ditch with active headcut.
64	Sanitary Sewer	Vulnerable Due to Erosion	Stream bed and banks unstable.
68	Sanitary Sewer	Vulnerable Due to Erosion	Tributary downcutting. Potential ford location.
73	Sanitary Sewer	Exposed	Sanitary sewer line exposed full width of channel due to bed erosion.

ID Number on Figure 12	Type	Problem	Current Condition
78	Sanitary Sewer	Vulnerable Due to Erosion	Eroding bed and banks.
79	Sanitary Sewer	Vulnerable Due to Erosion	Headcut encroaching into sanitary sewer easement. Potential ford crossing.
82	Sanitary Sewer	Vulnerable Due to Erosion	Riprap placed to cover exposed sanitary sewer.
84	Sanitary Sewer	Vulnerable Due to Erosion	Ditch with active headcut.
91	Sanitary Sewer	Vulnerable Due to Erosion	Sanitary sewer line exposed full width of channel due to bed erosion.

3.6 Existing SCM Conditions

The Stormwater Control Measure (SCM) Inventory and Assessment, completed by field crews in May 2014 with support from City staff, characterized the type and performance of SCMs currently in use within the Durham city limits. The goals of the inventory were to characterize stormwater treatment in the watershed, to evaluate individual SCMs on their treatment capabilities for control of nutrients and sediment, and to identify potential SCM retrofit opportunities to enhance water quality in the watershed. The inventory provided insight into which neighborhoods are receiving adequate stormwater treatment, which areas may need retrofits to existing SCMs to improve stormwater treatment, and which areas are receiving little to no stormwater treatment. The assessment also identified existing SCMs that were not properly functioning due to design issues or inadequate maintenance. The City's inspection and maintenance team will be following up on those SCMs to request corrective action by the owners.

3.6.1 Evaluation Methods

The City provided data on 98 existing SCMs within the Little Lick Creek watershed. Each SCM site, identified by a unique Facility Identification Number (FID), contained information on the type of SCM, its geographic location, and the SCM's current status (e.g. installed, site plan submitted, sedimentation/erosion control, or under construction). A desktop pre-screening was completed in order to select sites for further evaluation by field crews. Out of the 98 existing SCMs, 46 were omitted from further evaluation through pre-screening due to the following conditions:

- Serve only a single small parcel on private property - 5 SCMs
- Consists of a level spreader (stand-alone or connected to another SCM) – 8 SCMs
- Not constructed (still under site plan or construction drawing review) – 25 SCMs

The remaining 52 existing SCMs were evaluated by field crews in May 2014.

A geodatabase was developed in ArcGIS Mobile® to facilitate the collection and processing of georeferenced field data. Field staff used a GPS enabled Lonovo Thinkpad™ 2 tablets loaded with the geodatabase for data collection. Information collected for the evaluation of existing SCMs consisted of:

- A description of the location, surrounding land use, and physical constraints
- Measurements of physical attributes and components of the SCM including inlets, riser structures, outlets, etc.
- An evaluation of the current condition and functionality
- Photo documentation of each component of the SCM
- A recommendation for retrofit potential to enhance water quality benefits of the SCM

The protocol followed during field evaluation is described in detail in the *SCM Inventory and Assessment Field Plan* in Volume III - Technical Appendices of the Watershed Improvement Plan.

3.6.2 Characterization of Stormwater Treatment

Areas Receiving Stormwater Treatment

The majority of SCMs in the Little Lick Creek watershed are dry ponds (28) and wet ponds (24), six of which have level spreaders located at the outlet. Stormwater wetlands are much less common, with only two installed in the watershed. Construction drawings and site plans have been approved for an additional seven dry ponds, three wet ponds, two level spreaders and two constructed wetlands to control stormwater from several new developments in the watershed. At the time of the field assessment, these SCMs had not been installed.

The existing SCMs are highly concentrated in subwatersheds LLC02, LLC06, LLC09, LLC14, LLC19, LLC21, and LLC21 in more recently built subdivisions, such as Ridgefield, Ashton Hall, Lynn Hollow and Ganyard Farms. For example, the Ridgefield subdivision uses several small dry ponds and a few wet ponds for stormwater treatment (Photo 7). Ganyard Farms has large scale dry ponds that collect drainage from several parcels (Photo 8) while Lynn Hollow treats similar drainage areas with wet ponds (Photo 9). The Ashton Hall neighborhood has the most recent SCMs for water quality treatment (Photo 10). These SCMs typically consist of wet ponds with forebays and vegetated littoral shelves. Several also have level spreaders at the outlets to create diffuse flows leaving the wet pond.

Photo 7. *Typical small dry pond in Ridgefield subdivision*

Photo 8. *Large scale dry pond in Ganyard Farms subdivision*

Photo 9. *Wet pond in Ashton Hall subdivision*

Photo 10. *Large wet pond in Lynn Hollow subdivision*

Developed Areas That Lack Stormwater Controls

Large portions of the Little Lick Creek watershed receive little to no stormwater treatment. Of the 28 subwatersheds to Little Lick Creek, 11 contain no SCMs and six contain less than two (Figure 17). The five easternmost subwatersheds are predominantly forested with very low levels of development that do not have any on-site stormwater treatment (Figure 6). However the remaining untreated subwatersheds are typically comprised of very low or low density residential land that contain no stormwater controls that address either stormwater quantity or quality. These developed residential areas can be separated into three groups:

- Older single family residential developments: typically contain parcels over a quarter acre and a low percentage of impervious area. Instead of curb and gutter stormwater drainage networks, they have vegetated roadside swales that direct stormwater into stream systems.
- Newer single family residential developments: typically contain parcels over a quarter acre but tend to be constructed with curb and gutter and piped stormwater drainage systems. The drainage systems route stormwater to outfalls that direct flow into a riparian buffer. There is no treatment of stormwater and there is often erosion occurring at the pipe discharge point.
- Older high density residential developments: typically older apartment complexes are highly impervious, frequently with large parking lots. Some apartments have curb and gutter directing water towards discharge pipes at riparian buffer edges while others are graded such that water sheet flows off the property. Of the three types of developed areas receiving little to no stormwater treatment, the high density residential areas would benefit the most from stormwater retrofits.

Controlling stormwater runoff from these areas would greatly benefit Little Lick Creek by reducing peak flows that cause stream bed and bank erosion and by reducing pollutant loads. Opportunities to treat these areas are discussed in more detail in Section 4.

3.6.3 SCMs Requiring Maintenance

SCMs can be a highly effective means of reducing nutrient and sediment loads in a watershed, however they require proper design, implementation, and maintenance to function optimally. The performance of each SCM was evaluated as part of the SCM Inventory and Assessment. Field crews identified 16 SCMs, presented in Table 21, that need improved maintenance to function more effectively (see Figure 18).

Table 21. SCMs Requiring Maintenance

Subwatershed	FID	Land Use	SCM Type	Maintenance Issues
LLC02	00125	LDR	Wet Pond	Pond level full to primary outlet. Outlet orifice likely plugged.
LLC02	00126	LDR	Wet Pond	Pond level full to primary outlet. Outlet orifice likely plugged.
LLC06	00748	COM	Dry Pond	Designed as a dry pond, but functioning as wetland (may improve water quality benefits but this sacrifices storage volume)
LLC09	00249	LDR	Dry Pond	Steep slopes into wetland with some erosion on side slopes; trash at inlet; thick vegetation within footprint has reduced SCM capacity.
LLC09	00250	LDR	Dry Pond	Overgrown with vegetation; has lost significant capacity.
LLC11	00390	LDR	Wet Pond	Wet pond fairly dry and heavy algae growth; no access to riser structure; Orifices likely clogged with thick algae growth
LLC11	00393	LDR	Wet Pond	Thick algal growth in pond limiting capacity of riser; orifice likely clogged.
LLC11	00394	LDR	Wet Pond	Orifice likely buried in construction sediment; sediment buildup and tree growth limiting capacity of SCM; reported to County for potential E&SC violation
LLC11	00772	LDR	Wet Pond	Outlet pipe is partially full of sediment; outflow capacity limited by half.
LLC11	00774	LDR	Wet Pond	Outlet pipe is partially full of sediment; outflow capacity limited by half.
LLC17	00101	LDR	Dry Pond	Completely vegetated within SCM; has lost significant capacity
LLC21	00380	LDR	Wet Pond	Inlets submerged; orifice (if any) is also submerged and likely clogged, which has limited capacity.
LLC21	00441	LDR	Dry Pond	All outlet orifices clogged; pond inundated which may limit capacity; trees on embankment of dam.

Clogged orifices on riser structures from sedimentation and leaf litter was the leading maintenance issue. Blockages of lower orifices on riser structures are problematic because they raise the normal pool elevation, thereby lowering the storage volume during storm events. This results in reduced residence time of water within the SCM and decreases the water quality performance of the SCM at retaining sediment and nutrients. The inability of level spreaders to reduce flow velocity at the inlet and outlet of several ponds was observed due to sediment buildup that reduces the size of the forebay and the performance of the level spreader. Overgrown vegetation in the footprint of an SCM was also a commonly observed issue with maintenance. Vegetation that isn't properly maintained can lower the storage capacity of an SCM and the root systems can damage infrastructure or weaken an embankment of a pond. Photos 11, 12, and 13 below depict some of the conditions at locations of poorly functioning SCMs.

Photo 11. *SCM 00777 – Inlet pipe to level spreader clogged with 2"sediment*

Photo 12. *SCM 00390 – Clogged riser orifice leading to heavy algae growth and limited capacity*

Photo 13. *SCM 00420 – Woody vegetation growing in footprint and endangering riser structure*

Owners of the facilities' will be notified to take corrective action as part the City's Inspection and Maintenance Certification which is required to be submitted to the City on an annual basis for each facility (http://durhamnc.gov/695/BCE-As-Builts-BCM-Maintenance-Programs). Erosion and sediment control issues will be reported to Durham County Sediment and Erosion control. Durham County implements the sediment and erosion control program for the City.

3.6.4 Water Quality Performance of Existing SCMs

The data on existing SCMs collected during the Field Inventory and Assessment will be used to develop a water quality model for the Little Lick Creek watershed. The water quality model, based on the PC-SWMM program, will apply removal efficiencies for sediment, nutrients, and bacteria to each existing SCM to estimate their pollutant removal performance. Based on the maintenance issues presented in Table 21 and other observations made by the field crews, it is apparent that not all existing SCMs are functioning equally. To account for their variable performance, a water quality multiplier will be assigned to each SCM to reflect its water quality performance based on observations by field staff. This multiplier will be applied to the sediment, nutrient, and bacteria reduction rates to obtain a pollutant removal efficiency for each SCM that reflects existing conditions.

A water quality multiplier of 1.0 will reflect optimal performance of an SCM. If field crews observed one or more of the following conditions, the multiplier was adjusted accordingly to reflect actual water quality performance:

- If the SCM does not have a forebay, a factor of 0.2 will be subtracted from the water quality multiplier. The exception is dry ponds that are not required to have a forebay.
- If the SCM was marked as “not functioning” during SCM field evaluations, a factor of 0.75 will be subtracted from the water quality multiplier.
- If the SCM was noted as “functioning” but the notes indicated the level of sedimentation or growth of vegetation within the SCM is affecting its performance, then a factor of 0.2 will be subtracted from the water quality multiplier.

If more than one factor could be assigned to an SCM, only the largest factor was applied to represent its current water performance. Table 20 presents the modifications made to the water quality multiplier for existing SCMs that have observed performance issues. Water quality modeling under “existing” watershed conditions will account for the reduction in performance presented in Table 22; however water quality modeling conducted to represent “future” watershed conditions will assume that the design and maintenance issues have been corrected (i.e., water quality multiplier equals 1.0 for all SCMs).

Table 22. Water Quality Multiplier for Existing SCMs

Site FID	Watershed	SCM Type	Presence of Forebay?	Is the SCM Functioning?	Sedimentation or Overgrown Vegetation?	Water Quality Multiplier
00033	LLC02	Wet Pond	No	Yes	No	0.8
00125	LLC02	Wet Pond	No	No	No	0.25
00126	LLC02	Wet Pond	No	No	Yes	0.25
00748	LLC06	Dry Pond	No	No	Yes	0.25
00250	LLC09	Dry Pond	No	No	Yes	0.25
00420	LLC09	Wet Pond	No	Yes	No	0.8
00390	LLC11	Wet Pond	No	No	Yes	0.25
00393	LLC11	Wet Pond	Yes	No	Yes	0.25
00394	LLC11	Wet Pond	No	No	Yes	0.25
00773	LLC11	Wet Pond	Yes	Yes	Yes	0.8
00101	LLC17	Dry Pond	No	No	Yes	0.25
00217	LLC21	Wet Pond	No	Yes	No	0.8
00357	LLC21	Wet Pond	No	Yes	No	0.8
00380	LLC21	Wet Pond	Yes	No	Yes	0.25
00441	LLC21	Dry Pond	No	No	Yes	0.25
00649	LLC21	SW Wetland	Yes	Yes	Yes	0.8
00156	LLC22	Wet Pond	No	Yes	No	0.8

Section 4: POTENTIAL WATER QUALITY IMPROVEMENT MEASURES

4.1 Potential Stream Corridor Improvement Measures

The stream assessments described in Section 3.4 were conducted to characterize watershed conditions and to gather data to identify potential stream corridor improvement projects. The high-priority stream corridor projects will be included in the Volume I - Executive Summary of the Watershed Improvement Plan once additional analyses, such as evaluating their water quality benefits and costs, is complete. However, an overview of the potential stream projects identified by the field crews during the Stream Inventory and Assessment to improve watershed conditions is provided in this Section.

As described in Section 3.4, field crews assessed approximately 24.7 miles of streams in the Little Lick Creek watershed, which consisted of 97 individual stream reaches. Sixty-three reaches are located within the City limits, the remaining 34 reaches are located in Durham County. All 97 stream reaches were classified as potential restoration, enhancement, or preservation projects based on their existing condition and any constraints that would limit their restoration. The U.S. Army Corps of Engineers defines stream restoration as "the process of converting an unstable, altered, or degraded stream corridor…to its natural stable condition (USACE, 2003)." In order to be considered a potential *stream restoration* project (Photo 14), the stream had to be degraded to a point at which full restoration of cross-sectional dimensions, channel alignment, and stream bed profile was deemed justifiable and implementation of a restoration project was considered to be feasible. For full restoration to be considered justifiable and feasible, the field teams considered several factors:

- Stream reach scored "fair" or "poor" on the overall RSAT assessment
- Evidence of active erosion was observed
- Adequate space is available to reconstruct a meandering stream through the floodplain without removing existing infrastructure or other obstacles
- Opportunity exists to raise the existing stream bed without increasing flood risk to surrounding property
- No significant utility conflicts
- Reasonable access for construction and maintenance

Photo 14. *Potential Stream Enhancement Reach*

Reaches that were determined to be unsuitable for restoration were then considered for enhancement (Photo 15). *Stream enhancement* refers to "activities undertaken to improve water quality or ecological function of a fluvial system" but fall short of full restoration (USACE, 2003). Stream enhancement includes

Photo 15. *Potential Stream Restoration Reach*

a range of potential treatments from heavier intervention such as reconstructing the longitudinal profile and cross-sectional geometry by raising the stream bed (referred to as Enhancement I) to relatively minimal intervention such as stabilizing stream banks and reestablishing native riparian vegetation (referred to as Enhancement II). In both cases, the enhancement measures are typically completed along the channel's current alignment. Enhancement I and II are most appropriate for stream reaches where active erosion is not widespread but where spot repairs and habitat improvements would benefit the ecology of the system.

Any stream reaches that received a "good" overall RSAT rating (no reaches were rated "excellent"), have an intact riparian buffer of mature trees on both sides of the channel, and were not observed to be actively eroding were considered for recommendation for stream preservation (Photo 16). *Stream preservation* generally involves placing a conservation easement on the stream and riparian zone to preserve it in its current condition and prevent encroachment or alteration by future development.

Photo 16. *Potential Stream Preservation Reach*

A total of 40 reaches (10.5 miles) were identified as potential restoration projects, 52 reaches (13.2 miles) were identified as potential Enhancement I and II projects, and 5 reaches (1 mile) were identified as potential preservation projects. The length of each stream corridor project type, total number of reaches, and location within either the City limits or Durham County are summarized in Table 22.

Table 23. Stream Project Categories by Jurisdiction

Jurisdiction	Stream Corridor Project Category				Totals
	Restoration	Enhancement II	Enhancement I	Preservation	
City of Durham	41,434 LF (29 reaches)	24,493 LF (13 reaches)	17,437 LF (19 reaches)	1,694 LF (2 reaches)	85,058 LF (63 reaches)
Durham County	13,880 LF (11 reaches)	6,944 LF (14 reaches)	20,814 LF (6 reaches)	3,732 LF (3 reaches)	45,371 LF (34 reaches)
TOTALS:	55,314 LF (40 reaches)	38,251 LF (27 reaches)	31,438 LF (25 reaches)	5,426 LF (5 reaches)	130,429 LF (97 reaches)

Figure 19 presents the distribution of these reaches within the Little Lick Creek watershed. Potential restoration reaches of significant size were identified in several watersheds including LLC01, LLC06, LLC10, LLC17, and LLC20. Both stream restoration and enhancement reaches were spread throughout the watershed. The few preservation reaches identified were located in LLC25 and LLC11. It should be noted that all reaches assessed were assigned to one of the three categories (i.e. restoration, enhancement, or preservation), therefore, not all of these stream reaches are expected to be viable potential projects due to issues such as landowner disapproval, site constraints, or costs. The high-priority stream corridor projects will be presented in Volume I – Executive Summary of the *Watershed Improvement Plan*.

4.2 Sanitary Sewer and Septic Systems

As discussed in Section 3.5, when not properly designed, installed and maintained, wastewater collection systems, septic tanks, and sand filter septic systems can contribute nutrient loads to Little Lick Creek. The "City of Durham Submission of Falls Lake Inventory and Characterization of Load Reduction Potential" (Brown and Caldwell, 2013) and the North Carolina Piedmont Nutrient Load Reducing Measures Technical Report (Tetra Tech, 2013) highlight methods that can be used to reduce nutrient loads, quantifies the annual load reduction potential, and provides costs to implement these measures. Based on information provided in these two documents, the potential to reduce nutrient loads from these three sources are summarized in Table 24 for the Little Lick Creek Watershed. All nutrient load calculations are based on a 3-bedroom home occupied by 2.2 people. More details on how these estimates were derived are provided in the following sections.

Table 24. Nutrient Reduction Potential for Wastewater Collection and Treatment Systems

Sanitary Sewer System Component	Estimated Annual Load		Nutrient Reduction Activity	Load Reduction		Estimated Costs
	TN (lb/year)	TP (lb/year)		TN (lb/year)	TP (lb/year)	
Septic Systems	118	5	Connect 94 of 123 Parcels to City Sewer	98 (-87%)	4 (-80%)	$1,128,000
Sand Filters	470	112	Connect All Parcels to City Sewer	470 (-100%)	112 (-100%)	$348,000
Wastewater Collection System (SSOs and Leaks)	13	3.3	80% reduction in spills by replacing 20% of pipes	10 (-80%)	2.6 (-80%)	*TBD*

4.2.1 Septic Systems

One method of lowering nutrient loads from septic systems to Little Lick Creek is to connect parcels with septic systems to the City sanitary sewer collection system that conveys wastewater to the North Durham Water Reclamation Facility (NDWRF). This would remove this portion of the nutrient load from Little Lick Creek by transferring the nutrient load to NDWRF and ultimately to Ellerbe Creek, however with a much higher level of pretreatment provide by the NDWRF. On the assumption that 94 of the 123 parcels with septic systems can be connected to the City's sanitary sewer collection system at a cost of approximately $12,000 per connection, the total estimated cost equals $1,128,000. That would leave 29 septic systems within the City limits. Connecting the 94 parcels to the City sewer collection systems would provide an 87% reduction in annual load of TN and an 80% reduction in annual load of TP. This equals approximately $230 per pound of TN removed and over $5,600 per pound of TP removed based on a 50-year life cycle for the sewer connection.

4.2.2 Discharging Sand Filters

Similar to the septic systems, parcels with discharging sand filter systems could be connected to the City sanitary sewer collection system that conveys wastewater to NDWRF. Given that these types of systems can discharge nutrients directly to surface waters without an opportunity to attenuate in the soils, connecting all 29 parcels served by sand filter systems is a sensible measure. This seems feasible since 26 of the 29 sand filters in use in the Little Lick Creek watershed within the City limits are within 200 linear feet of road frontage. Assuming it would cost approximately $12,000 for each parcel to connect to the City's sanitary sewer collection system, the total estimated cost is $348,000. This equals approximately $15 per pound of TN removed and $62 per pound of TP removed based on a 50-year life cycle for the sewer connection, which represents a cost-effective water quality improvement measure especially compared to septic system elimination.

4.2.3 Wastewater Collection Systems

Reducing the leaks and SSOs from the wastewater collection system would provide water quality benefits to Little Lick Creek by reducing nutrient loads and lowering public health risks from releases of untreated wastewater. The primary method for reducing SSOs and leaks in a wastewater collection system is proper inspection and maintenance, including the rehabilitation and replacement of faulty sections of pipe or manholes. The Water Management Department has an on-going inspection and rehabilitation program for sanitary sewer pipes and manholes using primarily cured-in-place-pipe (CIPP) technology. To date, the Water Management Department has rehabilitated over 100,000 linear feet of pipes and manholes throughout Durham using this technology.

The 80:20 rule was applied in order to quantify a potential nutrient load reduction possible for the rehabilitation of the wastewater collection system. This generally accepted industry guideline assumes 80% of nutrient loads from untreated wastewater can be reduced if 20% of the sewer pipes are replaced, given that replacement is targeted at leaky and failing pipe systems. Based on this rule and the average annual nutrient load reported from SSOs and pipe leaks between 2010 and 2013 reported in Section 3.5.3, the potential load reduction in the Little Lick Creek watershed from repairing and upgrading the municipal wastewater collection system is 10.4 lbs/year for TN and 2.4 lbs/year for TP. This represents an 80% reduction in TN and TP loads from this source.

4.3 Stormwater Control Measures

The purpose of the SCM Inventory and Assessment (discussed in Section 3.6) was not only to characterize the current level of stormwater control and water quality treatment in the watershed, but to identify retrofit opportunities that would further reduce nutrient and sediment loads into Little Lick Creek. The SCM retrofit opportunities fall into two categories: (1) modifications to existing SCMs to improve their water quality performance, and (2) installation of new SCMs in developed areas that lack stormwater controls. Undeveloped areas in the watershed were not considered for SCM retrofits since the Unified Development Ordinance applied by the City and Durham County will require on-site stormwater controls that must meet the Falls Lake Rules for sediment and nutrient control. These on-site stormwater controls will be evaluated and approved by the City during the site plan review process.

4.3.1 Potential Retrofits to Existing SCMs

As described previously in Section 3.6, 52 existing SCMs were evaluated for their retrofit potential. All potential constraints that would hinder the installation of retrofits or the on-going maintenance activities were recorded during field evaluation. These included underground or above ground utilities, jurisdictional wetlands, potential encroachment into riparian buffers, and incompatible land use (i.e., parks and playgrounds). The field crews assessed the applicability of three types of retrofits:

- Structural: This type of retrofit focuses on the function of the outlet structure. It may be a simple control structure modification to alter the normal pool elevation, providing additional storage volume, or it may be a complex redesign of an entire SCM that involves converting a dry pond to a wet pond.
- Volume: This type of retrofit involves increasing the storage volume for an existing SCM so that it can treat a larger volume of water or provide a longer retention time.
- SCM Add-ons: This type of retrofit consists of adding components to an existing SCM to improve water quality treatment capabilities, such as a forebay, a level spreader, or internal berms to increase the flow path.

A complete lists of the options for structure, volume and add-on retrofits are contained in the *SCM Inventory and Assessment Field Plan,* which is located in Volume III – Technical Appendices of the Watershed Improvement Plan.

Field crews also evaluated the contributing drainage area and the drainage system (e.g., pipes, ditches) to each existing SCM site for retrofits to provide pre-treatment of stormwater before entering an SCM. The potential retrofits to the stormwater drainage system typically included proprietary stormwater devices (e.g., Filterra, CDS, Stormceptor, etc.), bioretention areas, vegetated filter strips, grassed swales, rainwater harvesting systems, removal or disconnection of impervious surfaces, and riparian buffer restoration.

Of the 52 sites evaluated, 16 are candidates for retrofits to improve their water quality benefits. One example of a potential retrofit is SCM 236 (Photo 17), where a structural retrofit would allow a very large dry pond to be converted to a wet pond, thereby increasing nutrient removing capabilities. Another example is SCM 149 (Photo 18), which is an example of a volume and structural retrofit combination. By reconstructing the pond's embankment downstream and adjusting the orifice on the control structure, SCM 149 could be converted to a stormwater wetland which would increase its nutrient removal capabilities. The specific retrofit opportunity for each of the 16 SCMs is presented in Table 25. The remaining 36 existing SCMs are not good candidates for retrofits, primarily since many have been installed within the past several years and meet current water quality design standards. The location of the existing SCMs that are candidates for retrofit are shown on Figure 20.

Photo 17. *SCM 00161 – Example of a potential volume and structural retrofit combination that would increase SCM volume and treatment time*

Photo 18. *SCM 00236 – Example of dry pond that could be converted to a stormwater wetland with a simple structural retrofit*

Three other existing ponds located within the City limits that are not contained within the City's database of SCMs were also evaluated for retrofits to provide stormwater quality benefits. These three ponds, identified as LLC05-18, LLC06-01, and LLC07-02 in Table 25, are private ponds in residential areas that appear to have been constructed for aesthetic and recreational purposes. Each of these are a candidate for a structural retrofit that would improve their stormwater quality performance.

Often, SCM add-on retrofits can offer simple and cost effective options for SCM improvements (Table 25). In many cases, small changes and enhancements may greatly improve the sediment or nutrient removal capability of an SCM. The most common recommendations were construction of a sediment forebay, which would improve sediment and nutrient removal, and installation of a level spreader at the outfall to reduce erosion. Several existing SCMs were constructed with an inlet pipe near the outlet structure. In this situation, an internal berm or baffle can be installed to increase the flow path, which increases the retention time in the SCM and its water quality benefits. An example of this type of add-on retrofit is proposed for SCM 354 (Photo 19).

Table 25. Potential Water Quality Retrofits to Existing SCMs

Existing SCM	SCM Type	Potential Structural or Volume Retrofits for Existing SCMs	Potential Add-On Retrofits
33	Wet Pond	New SCM, meets current standards	
34	Dry Pond	New SCM, meets current standards	
101	Dry Pond		Install internal berm to increase flow path; add level spreader
124	Dry Pond	Convert to stormwater wetland; may require relocating dam embankment downstream	Install internal berm to increase flow path; add forebay and level spreader
125	Wet Pond	New SCM, meets current standards	

Existing SCM	SCM Type	Potential Structural or Volume Retrofits for Existing SCMs	Potential Add-On Retrofits
126	Wet Pond	New SCM, meets current standards	
149	Dry Pond	Convert to stormwater wetland; may require relocating dam embankment downstream	Install internal berm to increase flow path; add forebay and level spreader
150	Dry Pond	Convert to stormwater wetland; may require relocating dam embankment downstream	Install internal berm to increase flow path; add forebay and level spreader
156	Wet Pond	New SCM, meets current standards	
157	Dry Pond	New SCM, meets current standards	
158	Dry Pond	Convert to wet pond	Build littoral shelf; add forebay and level spreader
159	Dry Pond	Convert to stormwater wetland	Install internal berm to increase flow path; add forebay and level spreader
160	Dry Pond	New SCM, meets current standards	
161	Dry Pond	New SCM, meets current standards	
162	Dry Pond	Convert to stormwater wetland	Install internal berm to increase flow path; add forebay and level spreader
217	Wet Pond	Retrofit outlet structure to improve water quality storage volume and treatment	Forebay
236	Dry Pond	Convert to wet pond	Install internal berm to increase flow path; add forebay
239	Dry Pond		Install internal berm to increase flow path; add level spreader
249	Dry Pond	New SCM, meets current standards	
250	Dry Pond	New SCM, meets current standards	
251	Dry Pond	New SCM, meets current standards	
252	Dry Pond	Covert to wet pond	Build littoral shelf; add forebay and level spreader
317	Dry Pond	New SCM, meets current standards; only receives runoff from several residential yards	
319	Dry Pond		Install internal berm to increase flow path; add level spreader
351	Dry Pond	New SCM, meets current standards; only receives runoff from several residential homes	
352	Dry Pond	New SCM, meets current standards	
353	Dry Pond	New SCM, meets current standards; only receives runoff from several residential yards	
354	Dry Pond	Rebuild outlet structure	Install internal berm to increase flow path; add level spreader

Existing SCM	SCM Type	Potential Structural or Volume Retrofits for Existing SCMs	Potential Add-On Retrofits
355	Dry Pond		Install internal berm to increase flow path; add level spreader
356	Dry Pond	Convert to wet pond	Install internal berm to increase flow path; add forebay and level spreader
357	Wet Pond	New SCM, meets current standards	
380	Wet Pond	New SCM, meets current standards	
390	Wet Pond	New SCM, meets current standards	
391	Wet Pond	New SCM, meets current standards	
392	Wet Pond	New SCM, meets current standards	
393	Wet Pond	New SCM, meets current standards	
394	Wet Pond	New SCM, meets current standards	
420	Wet Pond	New SCM, meets current standards	
441	Dry Pond	New SCM, meets current standards	
442	Wet Pond	New SCM, meets current standards	
629	Wet Pond	New SCM, meets current standards	
630	Wet Pond	New SCM, meets current standards	
631	Wet Pond	New SCM, meets current standards	
649	Stormwater Wetland	New SCM, meets current standards; appears to be located within a very active floodplain	
677	Stormwater Wetland	New SCM, meets current standards	
668	Dry Pond	Convert to stormwater wetland; may require relocating dam embankment downstream	Forebay and level spreader
748	Dry Pond	New SCM, meets current standards; only receives runoff from one commercial parcel	
746	Wet Pond	New SCM, meets current standards	
772	Wet Pond	New SCM, meets current standards	
773	Wet Pond	New SCM, meets current standards	
774	Wet Pond	New SCM, meets current standards	
775	Wet Pond	New SCM, meets current standards	
LLC05-18	Wet Pond	Modify outlet structure to retain stormwater runoff	Littoral shelf
LLC06-01	Wet Pond	Modify outlet structure to retain stormwater runoff	
LLC07-02	Wet Pond	Modify outlet structure to retain stormwater runoff	Littoral shelf

Photo 19. *SCM 00354 – Example of a short circuited flow path with inlet directly across from outlet*

4.3.2 Potential New SCM Opportunities

For potential new SCMs, field crews focused on developed areas within the City limits that lack stormwater controls or receive little stormwater treatment during the SCM Inventory and Assessment (Figure 17). A total of 95 potential sites for a new SCM were identified based on GIS data. Similar to the evaluation of existing SCMs, a geodatabase was developed in ArcGIS Mobile® and loaded onto GPS-enabled Lonovo Thinkpad™ 2 tablets to facilitate the collection and processing of field data. At each potential new SCM site, field crews collected the following information:

- Site characteristics including location, subwatershed, land use within the contributing drainage area, accessibility, and type of receiving water
- A recommendation for the type of SCM to install, including preferred and secondary options
- Potential site constraints, such as potential conflicts with known utilities (water and sewer), site access for construction and long-term maintenance, the number of property owners involved, and potential environmental issues and permits that may be required
- Length and Width of area available
- Photo documentation of site conditions

Each potential new SCM site was visited during the SCM Inventory and Assessment. Information was recorded in the geodatabase and the site was evaluated as suitable or unsuitable. If the site was marked as suitable, two potential new SCM types were recommended – a primary option and a secondary option.

The 95 potential new SCM sites were assessed by field staff in May 2014. Field crews identified 81 of these sites as suitable for a new SCM based on an initial visual observation of site conditions and potential constraints (Figure 20). The number of potential new SCMs retrofits by subwatershed is summarized in Table 26. The opportunities for new SCMs in developed areas were influenced by the following factors:

- Developed areas within subwatersheds LLC01, LLC06, LLC12, LLC13, LLC14, LLC16, LLC19, LLC20, LLC23, LLC24, and LLC25 are primarily located within Durham County and do not offer an opportunity for the City to improve stormwater controls
- Development within subwatersheds LLC11, LLC15, LLC17, LLC21, and LLC22 has mainly occurred after the regulations protecting Falls lake have been enacted, so on-site SCMs have been installed in these developed areas that meet current design standards
- Most of the new SCM opportunities were identified in nine subwatersheds that contain older development within the City limits: LLC02, LLC03, LLC04, LLC05, LLC07, LLC08, LLC09, LLC10, and LLC18

Table 26. Potential New SCM Retrofits by Subwatershed

Subwatershed	Wet Pond	Stormwater Wetland	Grassed Swale	Regenerative Stormwater Conveyance (RSC)	Total
LLC02	1	5			6
LLC03	1	1		5	7
LLC04		7		1	8
LLC05		15		2	17
LLC07		8		1	9
LLC08		3		1	4
LLC09		2		6	8
LLC10		3		1	4
LLC16		1		3	4
LLC17		1		2	3
LLC18		1	1	3	5
LLC19		2			2
LLC21		2			2
LLC22				1	1
TOTALS:	**2**	**51**	**1**	**26**	**80**

The 80 new SCM retrofits were further evaluated for site constraints or other implementation issues that may prevent their installation, such as conflicts with utilities, potential jurisdictional impacts to wetlands, or inadequate space available for the preferred SCM type. Based on this review, 21 potential new SCM retrofits were determined to be infeasible, and are not recommended for further evaluation. These sites and their site specific constraint are summarized in Table 27.

Table 27. Infeasible New SCM Retrofits Due to Site Constraints

Retrofit Site	SCM Type	Site Constraint
LLC02-04	Stormwater Wetland	Inadequate space due to conflict with gas utility
LLC04-09	Stormwater Wetland	Potential jurisdictional impacts to wetlands
LLC04-10	Stormwater Wetland	Potential jurisdictional impacts to wetlands
LLC05-01	Stormwater Wetland	Inadequate space due to conflict with adjacent homes
LLC05-02	Stormwater Wetland	Inadequate space due to conflict with sanitary sewer
LLC05-03	Stormwater Wetland	Inadequate space due to conflict with sanitary sewer
LLC05-05	Stormwater Wetland	Inadequate space due to conflict with sanitary sewer and adjacent homes
LLC05-09	Stormwater Wetland	Inadequate space due to conflict with sanitary sewer and adjacent homes
LLC07-05	Stormwater Wetland	In an active floodplain
LLC08-01	Stormwater Wetland	Inadequate space due to conflict with sanitary sewer and adjacent homes
LLC08-02	Stormwater Wetland	Inadequate space due to conflict with sanitary sewer
LLC10-01	Stormwater Wetland	Inadequate space due to conflict with sanitary sewer and adjacent homes
LLC10-03	Stormwater Wetland	Inadequate space due to conflict with sanitary sewer and adjacent homes
LLC10-04	Stormwater Wetland	Inadequate space due to conflict with sanitary sewer and adjacent homes
LLC16-03	Regenerative Stormwater Conveyance (RSC)	Inadequate space due to conflict with sanitary sewer; potential access issues due to steep slopes
LLC16-04	Regenerative Stormwater Conveyance (RSC)	Inadequate space due to conflict with sanitary sewer and adjacent homes
LLC16-05	Regenerative Stormwater Conveyance (RSC)	Inadequate space due to conflict with sanitary sewer and adjacent homes
LLC17-01	Stormwater Wetland	Inadequate space due to conflict with sanitary sewer and adjacent homes
LLC19-02	Stormwater Wetland	Inadequate space available
LLC21-01	Stormwater Wetland	Potential jurisdictional impacts to wetlands
LLC21-02	Stormwater Wetland	Inadequate space due to conflict with sanitary sewer and adjacent homes

The remaining 59 new SCM retrofits that are recommended for further evaluation, presented in Tables 26 and 28, consists of 2 wet ponds, 33 stormwater or pocket wetlands, 1 grassed swale, and 23 regenerative stormwater conveyance (RSCs). Details of each potential new SCM, including its subwatershed location, unique ID number, preferred SCM type, developed area that can be treated, and the dominant land use within the contributing drainage area outlined in Table 28. As shown on Figure 20, they are primarily located within the subwatersheds that contain older development within the City limits that currently lack stormwater controls.

Table 28. Potential New SCM Retrofits and Their Contributing Drainage Areas

New SCM Retrofit Site	SCM Type	Contributing Drainage Area (ac)	Predominant Land Use Type
LLC02-01	Stormwater Wetland	2.0	LDR
LLC02-02	Stormwater Wetland	1.0	LDR
LLC02-03	Stormwater Wetland	1.2	LDR
LLC02-05	Stormwater Wetland	2.0	LDR
LLC02-06	Wet Pond	3.3	HDR
LLC03-02	Stormwater Wetland	3.0	LDR
LLC03-03	RSC	1.1	HDR
LLC03-05	RSC	9.5	HDR
LLC03-07	Wet Pond	10.3	LDR
LLC03-08	RSC	7.7	LDR
LLC03-09	RSC	9.6	LDR
LLC03-11	RSC	11.5	LDR
LLC04-02	Stormwater Wetland	3.4	Mixed
LLC04-04	Stormwater Wetland	3.2	Mixed
LLC04-03	RSC	24.0	Mixed
LLC04-05	Stormwater Wetland	15.0	Mixed
LLC04-06	Stormwater Wetland	1.6	Mixed
LLC04-08	Stormwater Wetland	8.9	LDR
LLC05-04	RSC	12.7	LDR
LLC05-06	Stormwater Wetland	4.2	Mixed
LLC05-07	Stormwater Wetland	1.8	LDR
LLC05-08	Stormwater Wetland	3.0	LDR
LLC05-10	Stormwater Wetland	2.5	LDR
LLC05-11	RSC	14.1	LDR
LLC05-12	Stormwater Wetland	3.2	LDR
LLC05-13	Stormwater Wetland	5.2	COM
LLC05-14	Stormwater Wetland	12.7	COM
LLC05-15	Stormwater Wetland	25.1	LDR
LLC05-16	Stormwater Wetland	18.9	LDR
LLC05-17	Stormwater Wetland	9.5	LDR
LLC07-01	Stormwater Wetland	11.1	LDR
LLC07-03	Stormwater Wetland	2.7	LDR
LLC07-04	RSC	0.7	LDR
LLC07-06	Stormwater Wetland	11.1	LDR
LLC07-07	Stormwater Wetland	1.0	HDR
LLC07-08	Stormwater Wetland	5.3	HDR
LLC07-09	Stormwater Wetland	14.0	HDR
LLC07-10	Stormwater Wetland	1.8	HDR

New SCM Retrofit Site	SCM Type	Contributing Drainage Area (ac)	Predominant Land Use Type
LLC08-03	RSC	3.7	LDR
LLC08-04	Stormwater Wetland	4.1	LDR
LLC09-01	RSC	11.3	LDR
LLC09-02	Stormwater Wetland	6.3	LDR
LLC09-03	RSC	1.0	LDR
LLC09-04	RSC	5.2	LDR
LLC09-05	Stormwater Wetland	11.9	LDR
LLC09-06	RSC	4.7	LDR
LLC09-08	RSC	6.2	LDR
LLC09-10	RSC	3.4	LDR
LLC10-02	RSC	11.8	LDR
LLC16-02	Stormwater Wetland	3.9	LDR
LLC17-02	RSC	0.8	LDR
LLC17-03	RSC	2.9	LDR
LLC18-01	RSC	14.1	LDR
LLC18-03	RSC	27.9	LDR
LLC18-04	Stormwater Wetland	4.2	School
LLC18-05	Grassed Swale	42.4	School
LLC18-06	RSC	11.2	COM
LLC19-01	Stormwater Wetland	1.9	LDR
LLC22-01	RSC	0.7	LDR
	TOTAL	**458.5**	

The next step for the potential SCM retrofits will be to apply the information generated during the field inventory and assessment and this initial feasibility evaluation in a subsequent, more detailed evaluation and prioritization of these water quality improvement projects. This will include detailed modeling of their water quality benefits, generating construction and maintenance cost estimates, reviewing property ownership, assessing the impact of the loss of developable or desired land, consideration of impacts to stream or riparian buffers, and acceptance by local residents. The more detailed analysis will help the City determine which SCM retrofit opportunities to pursue in the future.

4.4 Watershed Protections Provided by City Ordinances

The Falls Water Supply Nutrient Strategy (Falls Lake Rules) was adopted by the North Carolina Rules Review Commission December 16, 2010 and went into effect January 15, 2011 (15A NCAC 02B.0275 through 02B.0282 and amended 02B.0235 and 02B.0315, www.fallslake.org). The purpose of the Falls Lake Rules is to protect the use of the Falls of the Neuse Reservoir (Falls Lake) as a water supply reservoir. To achieve this purpose, the Falls Lake Rules establishes the goal of attaining and maintaining nutrient-related water quality standards through a staged and adaptive implementation plan. The objective during Stage I is to meet nutrient-related water quality standards in the lower portion of Falls Lake no later than January 15, 2021 while also improving water quality in the upper portion of Falls Lake. The objective of Stage II is to meet nutrient-related water quality standards throughout Falls Lake, which is expected to require a 40 percent reduction in annual loads for nitrogen and a 77 percent reduction in annual loads of phosphorus from stormwater runoff from existing development, wastewater, and agriculture (compared to the baseline annual loads in 2006).

Although the Falls Lake Rules were recently enacted, the City has a long history of enacting ordinances and enforcing standards that require management of stormwater runoff to protect water quality:

- **1985** – City of Durham and Durham County enact Water Supply Overlay Requirements for new development, which are contained in Article 8 of the Unified Development Ordinance (UDO), that require water quality treatment based on the water supply critical and protection overlay zones and the amount of impervious cover proposed with the development. These requirements predated rules enacted by the State.
- **1997** – City requires Peak Flow Controls, which requires developers to analyze the effects of the 2- and 10-year discharges for each project.
- **2001** – City enacts the Neuse Basin Regulations that require stormwater quality treatment to limit nitrogen loads to 3.6 lbs per acre per year (lbs/ac/yr), control of the peak flow resulting from the 1-year design storm for stream channel protection, and riparian buffer preservation requirements.
- **2009** – In response to the NPDES Phase II Municipal Separate Stormwater Sewer Systems (MS4) regulations, the City adopts the Phase II Post-Construction Ordinance and Stormwater Performance Standards for Development. This replaces the Peak Flow Controls and Neuse Basin Regulations into one comprehensive set of standards. The Stormwater Performance Standards for Development require varying levels of nitrogen control depending on the amount of impervious area proposed. For a highly impervious site (> 37% impervious cover), controls for total suspended solids (TSS) are also required.
- **2010** – City updates the Phase II Post-Construction Ordinance and Stormwater Performance Standards for Development to reduce the allowable nitrogen load from new development to 2.2 lbs/ac/yr, add an interim limit for phosphorus of 0.5 lbs/ac/yr, and expands controls for TSS to any proposed site that contains more than 16% impervious cover.
- **2011** – City reduces the limit for phosphorus loads to 0.33 lbs/ac/yr to be consistent with the Falls Lake Rules.

Ordinances for stormwater controls and protection of riparian buffers are contained in the City Code of Ordinances (https://www.municode.com/library/nc/durham/codes/code_of_ordinances) within Part II, Chapter 70, Article X, and in Article 8 of the Unified Development Ordinance (http://durhamnc.gov/414/Unified-Development-Ordinance-UDO) adopted by the Durham City Council and the Durham County Board of County Commissioners.

<u>Water Quality Standards for New Development</u>

As shown previously on the existing land use map (Figure 5), there are areas of the Little Lick Creek watershed that are vacant, used for agricultural uses, or contain very low density development. Many of these area are expected to undergo urbanization as the population of Durham grows. As the development occurs, these areas will be subject to the stormwater controls required by City Ordinance and the Falls Lake Rules. The developers will be required to implement on-site stormwater controls or purchase off-site mitigation credits during the site review process with the City or Durham County that limits nutrient loads discharged from the site after construction to 2.2 lbs/ac/yr for TN and 0.33 lbs/ac/yr for TP. Therefore, it is anticipated that stormwater retrofits will not be needed in these newly developed areas, which have been defined for this study using the following approach:

- All vacant or agricultural parcels greater than ½ acre that are expected to develop as low density residential (LDR) land use
- All vacant or agricultural parcels greater than ¼ acre that are expected to develop as medium (MDR) or high density (HDR) residential or any non-residential land use (e.g., commercial, industrial)
- All very low density residential parcels located west of Stallings Road and Fletchers Chapel Road that will convert to LDR, MDR, HDR, or any non-residential land use
- All parcels east of Stallings Road and Fletchers Chapel Road are within the Falls Lake Critical Area (Zone F/J-A) and are not expected to convert to urban development

Adding to these parcels, subwatersheds LLC03 and LLC04 are expected to undergo a significant level of development regardless of the current status or future designation of each parcel due to the East End Connector transportation project. Subwatershed LLC11 has a significant level of residential development underway, and has several additional phases of residential development that are expected. Due to these factors, all three of these subwatersheds have also been identified as "New Development."

As shown on Figure 21, over 3,660 acres within the watershed (1,580 acres within the City limits and over 2,080 acres in Durham County) are expected to implement on-site controls or provide off-site mitigation for nutrient loads required by the stormwater standards implemented by the City and Durham County that are consistent with the Falls Lake Rules. For nutrient control, this will limit nutrient loads discharged from each proposed site after construction to 2.2 lbs per acre per year for TN and 0.33 lbs per acre per year for TP. If the proposed development exceeds 16% impervious cover, the on-site stormwater controls must also remove 85% of the TSS. The water quality model under development for the watershed will incorporate the level of on-site controls for nutrients and TSS described above by applying the limits to the areas shown on Figure 21.

Protection of Riparian Buffers

Riparian buffer protection standards for development in the City or Durham County are located in Section 8.5 of the UDO. As shown previously on Figure 9, almost the entire Little Lick Creek watershed is within Watershed Protection Overlay Zone F/J-B for Falls Lake. Protection of riparian buffers is required in Zone F/J-B along perennial streams, modified natural streams, intermittent streams, lakes, and ponds (including beaver ponds). Riparian buffers must be preserved and protected within 100 feet on each side of the stream for perennial streams and 50 feet on either side of the stream for intermittent channels. There is no minimum disturbed area required for the guidelines to take effect. All concentrated runoff and stormwater conveyances are required to diffuse flow before it enters into the riparian buffer in order to limit sediment erosion.

Section 5: PILOT STUDY AREAS

To evaluate the potential water quality improvement projects and measures described in Section 4, a computer simulation model will be developed for the watershed using the PC-SWMM program. This model has the ability to simulate hydrology, hydraulics, and water quality in the watershed under existing and future land use conditions, and to evaluate the benefits of individual or multiple water quality improvement projects, point source controls, or other water quality improvement measures. Due to the size of the study area, extensive input data requirements, and time and cost constraints, a detailed PC-SWMM model applied to analyze each of the individual water quality improvement projects or measures and all of the possible combinations of projects is not feasible. Therefore, the recommended modeling approach relies on the identification of “pilot study areas,” analyzing potential water quality improvement projects and measures within the pilot study areas, and then extrapolating the results to the entire watershed. Depending on the size of the study area, a pilot study area can consist of drainage areas ranging from a couple of acres to several square miles. For the Little Lick Creek WIP, a pilot study area will be defined as one of the 25 subwatersheds.

The major steps to implement this modeling approach are as follows:

1. Identify groupings of subwatersheds that share common characteristics, such as:
    a. Mixture of land use types under existing and future land use conditions
    b. Percentage of impervious area
    c. Type of drainage system (e.g., pipe, open channel, or natural stream)
    d. Number and type of existing stormwater control measures
    e. Opportunities for SCM retrofits, stream restoration projects, and other water quality improvement measures
2. Within each group of subwatersheds, identify one subwatershed that can serve as a “pilot study area” for the entire group
3. Analyze potential water quality improvement projects and measures individually and in combination within each pilot study area
4. Extrapolate the water quality results for each pilot study area to each group of subwatersheds
5. Extrapolate the water quality results to the entire watershed

The first two steps in this modeling approach are key to its success: grouping the subwatersheds based on common characteristics and identifying pilot study areas within each group where detailed hydrologic, hydraulic, and water quality modeling of SCM retrofits, stream restoration projects, and other stormwater quality measures will be completed (e.g., controls on point sources, Stormwater Performance Standards for Development). Since the results for the pilot study areas will be extrapolated to other areas of the watershed, it is important that the pilot study areas are representative of other subwatersheds, and the results that can be achieved in each pilot study area are realistic.

As described in Section 2.5, the Little Lick Creek watershed has been delineated into 25 smaller subwatersheds. Based on the criteria listed in Step #1 above, the 25 subwatersheds were group as follows (Figure 22):

Very Low to Low Density Residential: This group of subwatersheds, which consists of LLC06, LLC10, LLC14, LLC16, and LLC18, share these characteristics:

- Developed areas are primarily in Durham County with few existing SCMs, which limits the opportunity for the City to implement water quality improvement projects
- Current land use is primarily vacant areas and very low to low density residential
- Vacant and underdeveloped areas will convert primarily to very low to low density residential
- Stormwater control measures for new development will be required to meet the standards set forth in the UDO

Low to Medium Density Residential: This group of subwatersheds, which consists of LLC08, LLC09, LLC13, LLC15, LLC17, LLC19, LLC21, and LLC22, share these characteristics:

- The majority of these subwatersheds are within the City limits
- Current land use is primarily vacant and agricultural areas with low to medium density residential
- Vacant and underdeveloped areas will become primarily low to medium density residential
- Existing residential development is a mixture of older developments with no SCMs and newer developments with several existing SCMs, both of which provide opportunities for the City to implement SCM retrofits
- Stormwater control measures for new development will be required to meet the standards set forth in the UDO

Medium to High Density Residential: This group of subwatersheds, which consists of LLC02, LLC05, and LLC07, share these characteristics:

- These subwatersheds are almost completely within the City limits
- Current land use is low to high density residential with only small areas of vacant land
- Older low density neighborhoods in these three subwatersheds are expected to redevelop into medium to high density residential
- Existing residential development is primarily older developments with no SCMs, which provides opportunities for the City to implement water quality improvement projects
- Stormwater control measures for new development will be required to meet the standards set forth in the UDO

Residential and Commercial: This group of two subwatersheds, LLC01 and LLC12, share these characteristics:

- Contain very small areas within the City limits, which severely limits the City's ability to implement water quality improvement projects
- Current land use is primarily vacant areas and low to medium density residential, with several small areas of commercial development
- Very few existing SCMs are present, which severely limits opportunities for SCM retrofits
- Future development will consist of a mixture of low to medium density residential, with significant areas of commercial planned along US-70 and NC-98
- Stormwater control measures for new development will be required to meet the standards set forth in the UDO

New Development: This group of subwatersheds, which consists of LLC03, LLC04, and LLC11, share these characteristics:

- Each of these three subwatersheds is expected to undergo significant development and redevelopment within the next 10 years; it is already occurring in LLC11 and is expected to occur in LLC03 and LLC04 once the East End Connector is completed
- Stormwater control measures for new development will be required to meet the standards set forth in the UDO

Rural Residential Subwatersheds: This group of subwatersheds, which consists of LLC20, LLC23, LLC24, and LLC25, share these characteristics:

- Limited areas within these subwatersheds fall within the current City limits
- Current land use is predominately agriculture, forested, or very low density residential land use, with large conservation areas under Federal ownership along Little Lick Creek
- Mostly within the Falls Lake Water Supply Critical Area, which will limit future development to very low density to low density residential
- Stormwater control measures for new development will be required to meet the standards set forth in the UDO

Prior to initiating the SCM and stream inventories and assessments, candidate pilot study areas were identified for four of the groups of subwatersheds listed above:

- Very Low to Low Residential: candidate pilot study areas are LLC06, LLC10, and LLC16
- Low to Medium Density Residential: candidate pilot study areas are LLC09 and LLC22
- Medium to High Density Residential: candidate pilot study areas are LLC02 and LLC05
- Residential and Commercial Development: candidate pilot study area LLC12

Field staff focused on assessing the existing conditions, potential water quality problems, and opportunities for SCM retrofits and stream restoration projects in these eight candidate pilot study areas before proceeding with assessments in other areas of the watershed. This approach was intended to ensure that the sources of water quality problems in the candidate pilot study areas are well understood and the most effective and feasible water quality improvement projects are identified. This is a key step if extrapolating the results from the pilot study areas to other subwatersheds and the entire Little Lick Creek watershed are to be valid. For more detailed information, see the Candidate Pilot Study Area Fact Sheets in Appendix C.

Candidate pilot study areas were not identified in two of the subwatershed groups listed above – New Development and Rural Residential. For the three subwatersheds within the “New Development” group, an assessment of existing conditions and identification of opportunities for SCM retrofits would be largely invalid. These three subwatersheds are expected to undergo significant development and redevelopment over the next 10 years, which means the developers will implement on-site SCMs or provide off-site mitigation for nutrient loads required by the stormwater standards implemented by the City and Durham County that are consistent with the Falls Lake Rules. Field crews did complete assessments and recommend enhancement of several stream reaches in these subwatersheds to improve water quality. Candidate pilot study areas were also not identified for the “Rural Residential” group of subwatersheds located in the eastern portion of the watershed along Falls Lake. Future development in these subwatersheds is expected to consist of very low density, rural residential development. A large portion of this area lies within the Falls Lake Critical Area which places strict requirements on development related to density, stormwater controls, and preservation of riparian buffers.

After completion of the field inventories and a review of the existing conditions and opportunities for SCM retrofits and stream restoration projects, the recommended pilot study areas are subwatersheds LLC05, LLC06, LLC09, and LLC12. These subwatershed were selected as pilot study areas because they are representative of the conditions found throughout the entire watershed. Table 29 provides a summary of the recommended pilot study areas and their similar subwatersheds.

Table 29. Subwatershed Groups and Recommended Pilot Study Areas

Subwatershed Group	Recommended Pilot Study Area	Similar Subwatersheds
Very Low to Low Density Residential	LLC06	LLC10, LLC14, LLC16, and LLC18
Low to Medium Density Residential	LLC09	LLC08, LLC13, LLC15, LLC17, LLC19, LLC21, and LLC22
Medium to High Density Residential	LLC05	LLC02 and LLC07
Residential and Commercial	LLC12	LLC01
New Development	n/a	LLC03, LLC04, and LLC11
Rural Residential	n/a	LLC20, LLC23, LLC24. LLC25, LLC26, LLC27, and LLC28

Section 6: OBSERVATIONS AND NEXT STEPS

The watershed characterization and the results of the SCM and stream assessments have improved our understanding of the current conditions in the Little Lick Creek watershed, and have led to the identification of opportunities to improve its water quality and watershed health. Several conclusions can be drawn about Little Lick Creek from this information:

- Although it is less urbanized than several of the City's other major watersheds (e.g., Ellerbe Creek), historical land use activities and the current level of development in the Little Lick Creek watershed have already led to widespread degradation of water quality, stream conditions, and aquatic habitat:
  - Little Lick Creek is on the State's list of impaired waters due to high turbidity and low dissolved oxygen, which has been confirmed by monitoring conducted by the City.
  - Monitoring by the City has also measured exceedances of the water quality standard for fecal coliforms and the continuous chronic criteria for copper. However, fecal coliform levels have been improving since 2011
  - Field staff assessed 24.7 miles of streams for this study, and only 5% were rated "Good," with the other 95% of stream miles rated as "Poor" or "Fair." No streams assessed were judged to be in excellent condition. City monitoring data also indicates that aquatic habitat conditions remain poor.
  - A review of historical aerial photos dating back to the 1940s indicates that historical land use practices have had a significant impact on the stability and health of the streams and riparian buffers in the watershed.
  - Previous studies have indicated that stream bank and bed erosion is the primary source of sediment in the watershed. This conclusion appears to be supported by the BEHI/NBS evaluation carried out on 30 separate stream reaches. Annual erosion rates were estimated as high as 600 pounds of sediment per linear foot of stream.
  - Although the City's ambient monitoring program has recently observed improvements in turbidity, the erosion rates measured along many of the stream reaches indicate that further reductions in sediment are needed to reduce excess sediment.
- Stream restoration and enhancement projects can be an effective method of reducing excessive sediment load to Little Lick Creek and Falls Lake and will be evaluated further in the next phase of the Watershed Improvement Plan (WIP). These types of restoration projects can also greatly improve riparian and aquatic habitat conditions for wildlife, fish, and other aquatic species. Field staff identified 61 stream reaches for restoration or enhancement that total over 83,300 LF within the City limits.
- Many of the urbanized areas in the watershed were developed prior to adoption of regulations that require control of stormwater runoff quantity and quality. The installation of new SCM retrofits in areas that lack stormwater controls is a method of improving water quality in stormwater runoff from these areas. However, many of these areas are located in the portion of the watershed that currently lies within Durham County, which limits the City's ability to improve stormwater quality from these developed areas. Within the City limits, field staff identified 57 opportunities to install new SCM retrofits that can treat over 430 developed acres that lack any stormwater controls. The water quality benefits of these new SCM opportunities will be evaluated in the next phase of the WIP.

- Retrofitting existing SCMs can often be a cost-effective method of improving stormwater quality. However, in the Little Lick Creek watershed, the existing SCMs were recently installed and meet current design standards. These existing SCMs provide limited opportunities for retrofits to improve their water quality performance. Of the 52 existing SCMs, field staff identified only 17 opportunities for retrofits to improve their stormwater quality benefits. The water quality benefits of these SCM retrofit opportunities will be evaluated in the next phase of the WIP.
- Many rural residential homes within the City limits are served by traditional or sand filter septic systems. These systems can be a source of nutrients, in particular sand filter septic systems which can discharge directly to surface waters. Based on the presence of City sanitary sewer lines in areas within the City limits, it appears that these rural residential parcels can be connected to City sewer, which could reduce the nutrient loads from these sources. The feasibility and water quality benefits of connecting these rural residential parcels to City sewer will be evaluated in the next phase of the WIP.
- A significant portion of the watershed (over 3,660 acres) is expected to undergo urbanization over the next 20 years. Urbanization will cause a transition from agricultural and rural residential land uses to much higher density residential and commercial development. Regulations contained in the Falls Lake Rules, the City's Stormwater Performance Standards for Development, and the Unified Development Ordinance will require controls for stormwater runoff and protection of riparian buffers. These development standards will help to mitigate some of the effects that development can have on water quality and watershed health.

The data reported in this Watershed Assessment Report will serve as the foundation for the completion of the Watershed Improvement Plan. The next steps in that process involve applying the data to further evaluation and analysis. In general, the remaining steps are as follows:

1. Develop a computer simulation model of the Little Lick Creek watershed, using the PC-SWMM software, to evaluate the hydrology, hydraulics, and water quality in the watershed under current and future land use conditions
2. Apply PC-SWMM and WARMF under future land use conditions to evaluate the hydrologic, hydraulic, and water quality benefits of the following:
    a. SCM retrofit opportunities identified in this report
    b. Stream restoration opportunities identified in this report
    c. Point source control measures, such as connecting parcels served by septic and sand filter systems to the City sewer system, and reducing SSOs and leaks from the City sewer system
    d. Regulations on future development and redevelopment, such as the City's Stormwater Performance Standards for Development and the stormwater control requirements in the Falls Lake Rules
    e. Other non-point and point source control measures for stormwater
    f. Each of these measures in varying combinations to determine the most effective approach to improve water quality in Little Lick Creek
3. Apply the project evaluation criteria to each of the SCM retrofit and stream restoration opportunities to evaluate their costs and benefits (e.g., water quality, habitat and community benefits)
4. Prioritize and select the high-priority SCM retrofit and stream restoration projects based on the results from the project evaluation criteria
5. Continue to solicit feedback from Durham residents and key stakeholders through the Public Outreach program
6. Prepare the Little Lick Creek Watershed Management Improvement Plan

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