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Long Indian Creek Watershed Improvement Plan

City of Alpharetta

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EXECUTIVE SUMMARY

This report was prepared for the City of Alpharetta and provides a comprehensive Watershed Improvement Plan for the Long Indian Creek Watershed. Long Indian Creek extends approximately 4 miles from its headwaters in the City of Johns Creek downstream to the confluence with Big Creek. Its watershed area is approximately 3.6 square miles and consists predominately of residential land use with a smaller percentage of commercial, institutional, parks, and undeveloped land tracts. In general, half of the watershed is in the City of Alpharetta (City) and half is located in the City of Johns Creek. Long Indian Creek is listed as an impaired stream segment on the Georgia Environmental Protection Division (EPD) 303(d) list for fecal coliform for its entire 4 mile reach. EPD requires that the City conduct and/or update watershed studies for impaired stream on 5-year intervals through the City's National Pollutant Discharge Elimination System (NPDES) Permit. The EPD developed a Total Maximum Daily Load (TMDL) for Long Indian Creek in 2013 that recommends a 95-percent reduction in fecal coliform.

The main elements of this study included:

- Acquisition and development of data from the City of Alpharetta, the City of Johns Creek, and Fulton County. Data collected included 1) GIS standard data such as city limits, street centerlines, parcels, etc.; 2) Planimetrics including buildings, roads, wooded areas, open water, etc.; 3) Existing and future land use; 4) Stormwater inventory including closed conduits, structures, BMPs, ditches, lakes, etc.; 5) Aerial imagery; 6) Topography including bare earth LiDAR; 7) Fecal coliform monitoring data; 8) GIS data and models associated with previous studies; and 9) Drainage complains and BMP/MS4 inspection reports.
- Digitization of building, roads, and parking areas to update impervious surface data in watershed.
- Analysis of Bacterial Source Tracking (BST) to determine the main contributors of fecal coliform to the watershed.
- Conduct detailed field reconnaissance to pinpoint areas that exhibit 1) Reduced riparian buffers; 2) Active construction activity; 3) Intense stream bed or bank erosion; 4) Stream channel alterations; 5) Existing BMPs conditions and configurations; 6) Potential pollution sources such as broken or leaking sewer lines, SSOs, illicit discharges, illicit dumping, confined animal areas, areas with pet waste, poorly maintained land, and suspect odors, and; 7) Potential maintenance issues such as blocked or damaged culverts, bridge crossings, storm drains, etc.
- Development of PCSWMM hydrodynamic model based on EPA's SWMM5 program engine to model the entire Long Indian including the stormwater infrastructure owned by the City of Alpharetta in the watershed. Fecal coliform loading will also be integrated into the model in order to quantify benefits from proposed CIPs.
- Identification and prioritization of watershed CIPs with a goal of reducing fecal coliform loading by 95%. Prioritization and ranking will include a cost analysis for each proposed project.
- Identify potential partnerships and Federal and State grant funding opportunities.
- Development of a public outreach strategy in coordination with the City of Alpharetta to enhance public understanding of the project and encourage their participation in selecting, designing, and implementing the nonpoint source management measures to be implemented.

Based on this watershed improvement project, several major challenges were identified in the Long Indian Creek Watershed. Currently, dog waste is the most pressing challenge facing the watershed and has been determined to be the primary source of the elevated fecal coliform levels in the watershed. It can be best addressed with non-structural measures such as the installation and maintenance of dog waste stations and public education. The second challenge, sanitary sewer spills, is currently a much lower contributor to fecal coliform due to rehabilitation and preventive maintenance activities by Fulton County over the past few years. However, there are concerns about potential breaks or ruptures to the existing sanitary sewer infrastructure that has become exposed due to stream erosion and degradation. Unlike the other three goals, the third challenge of system flooding is not directly related to water quality. However, it is critical to the safety of residents in the watershed. Further, it helps prevent erosion of Long Indian Creek and surrounding land which can reduce the sediment load of the stream, improving the health of the watershed. In order to prevent system flooding, upgrades to stormwater systems can be completed in several critical areas. In order to best protect existing sanitary sewer infrastructure and to address the fourth challenge, ecology, stream restoration measures can be taken to reduce and even reverse the current stream degradation. A full project list and further details of recommended BMPs for Long Indian Creek is provided later in this section.

Regulations affecting the Long Indian Creek watershed span local, regional, state, and federal agencies. However, all of these regulations can be grouped into two primary driving categories: 1) those that regulate activities within the watershed (i.e. NPDES permitting) and drive the restoration effort (i.e. TMDL requirements); and 2) those that regulate how projects are implemented (i.e. the Georgia Stormwater Management Manual).

Based on the current challenges within the Long Indian Creek Watershed, the existing regulatory environment, and project limitations within the watershed, a series of non-structural and structural recommendations have been compiled for the watershed. Additionally, project sheets have been prepared for all projects requiring an outlay of capital costs.

This Watershed Improvement Plan addresses the Environmental Protection Agency's Nine Elements of a Watershed Based Plan and the Metropolitan North Georgia Water Planning District Watershed Management Plan requirements.

1 INTRODUCTION

This report presents the results of the Long Indian Watershed Improvement Project. It provides a thorough review of the defining characteristics of the watershed. From information gathered during stream walks, field visits, water quality monitoring data, and model simulation, a comprehensive picture of current conditions in the model is formed. Based on the current watershed conditions, solutions are developed using models and best management practices (BMPs). Finally, goals, critical milestones, and monitoring criteria are developed in order to track the progress of the Watershed Improvement Plan, and a capital improvement plan is formed that integrates all of proposed solutions in order to meet the plan goals.

1.1 Background and Description of Watershed

Long Indian Creek extends approximately 4 miles from its headwaters in the City of Johns Creek downstream to the confluence with Big Creek. Its watershed area is approximately 3.6 square miles and consists predominately of residential land use with a smaller percentage of commercial, institutional, parks, and undeveloped land tracts. In general, half of the watershed is in the City of Alpharetta (City) and half is located in the City of Johns Creek. **Figure 1.1** provides a vicinity map of the Long Indian Creek Watershed, and **Figure 1.2** provides a more detailed view of the watersheds that compose the Long Indian Creek and its drainage map.

Long Indian Creek is listed as an impaired stream segment on the Georgia Environmental Protection Division (EPD) 303(d) list for fecal coliform for its entire 4 mile reach. EPD requires that the City conduct and/or update watershed studies for impaired stream on 5-year intervals through the City's National Pollutant Discharge Elimination System (NPDES) Permit. EPD developed a Total Maximum Daily Load (TMDL) for Long Indian Creek in 2013 that recommends a 95-percent reduction in fecal coliform.

The City, in conjunction with the City of Johns Creek, entered a Sampling and Quality Assurance Plan (SQAP) in 2014 for testing and analysis of fecal coliform on Long Indian Creek. Samples are taken at 5 different locations along Long Indian Creek to identify potential sources and analyze trends. Furthermore, Fulton County is currently conducting water quality monitoring for fecal coliform on Long Indian Creek at Waters Road.

1.2 Study Purpose

The purpose of this project is to evaluate the results of the City's fecal coliform monitoring for the potential to delist the stream and to also develop a WIP that encompasses all areas in the watershed within the City Limits of Alpharetta. The City is proactively identifying and prioritizing projects for its capital improvement program on a 10-year forecast basis. The City's ultimate goal for the Long Indian Creek Watershed is to identify and implement all practicable improvement projects in their improvement program to improve water quality, reduce erosion, and improve stream habitat in Long Indian Creek in order to restore the stream to its intended use designation and have it delisted from EPD's 303(d) list.

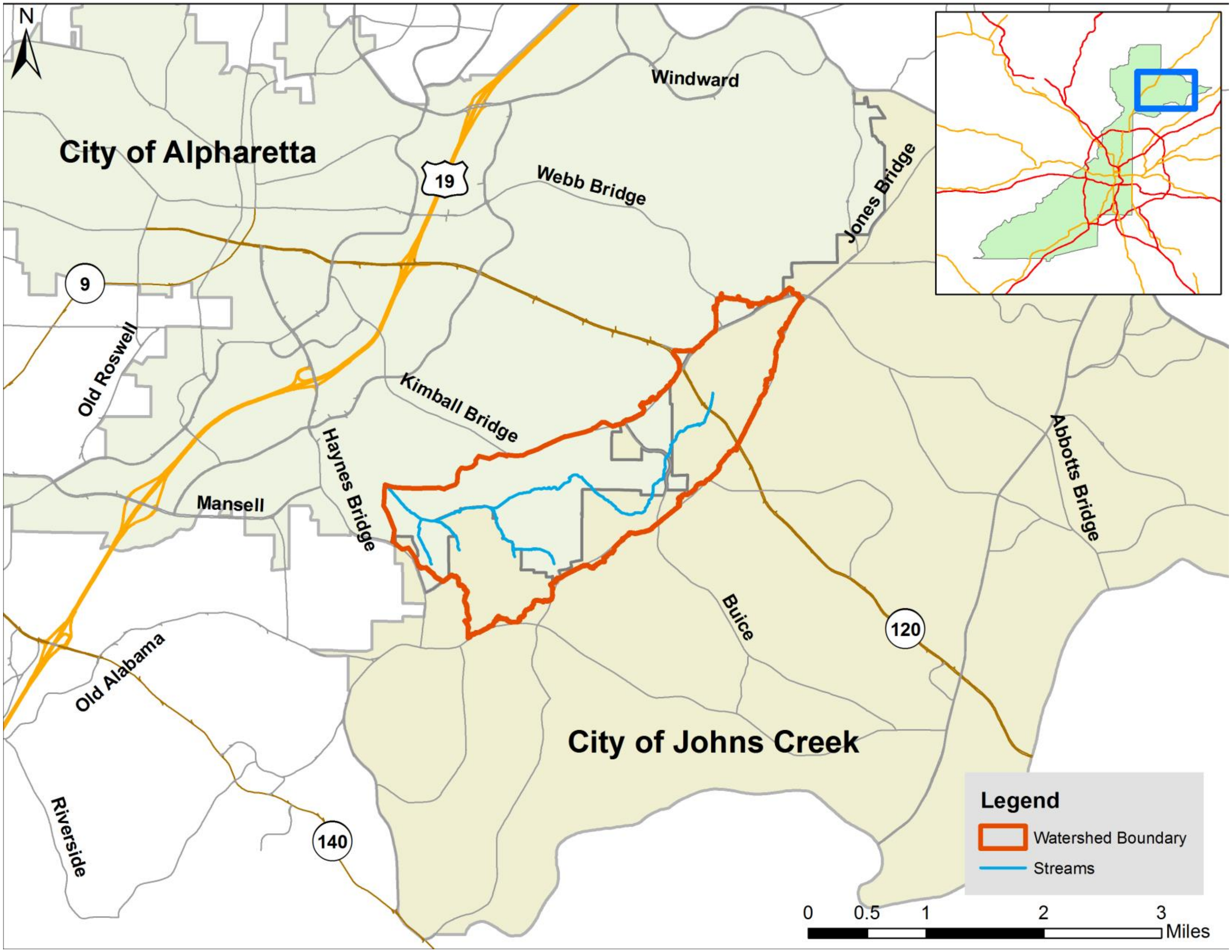

Figure 1.1 - Vicinity map showing the location of the Long Indian Creek Watershed within Fulton County, GA.

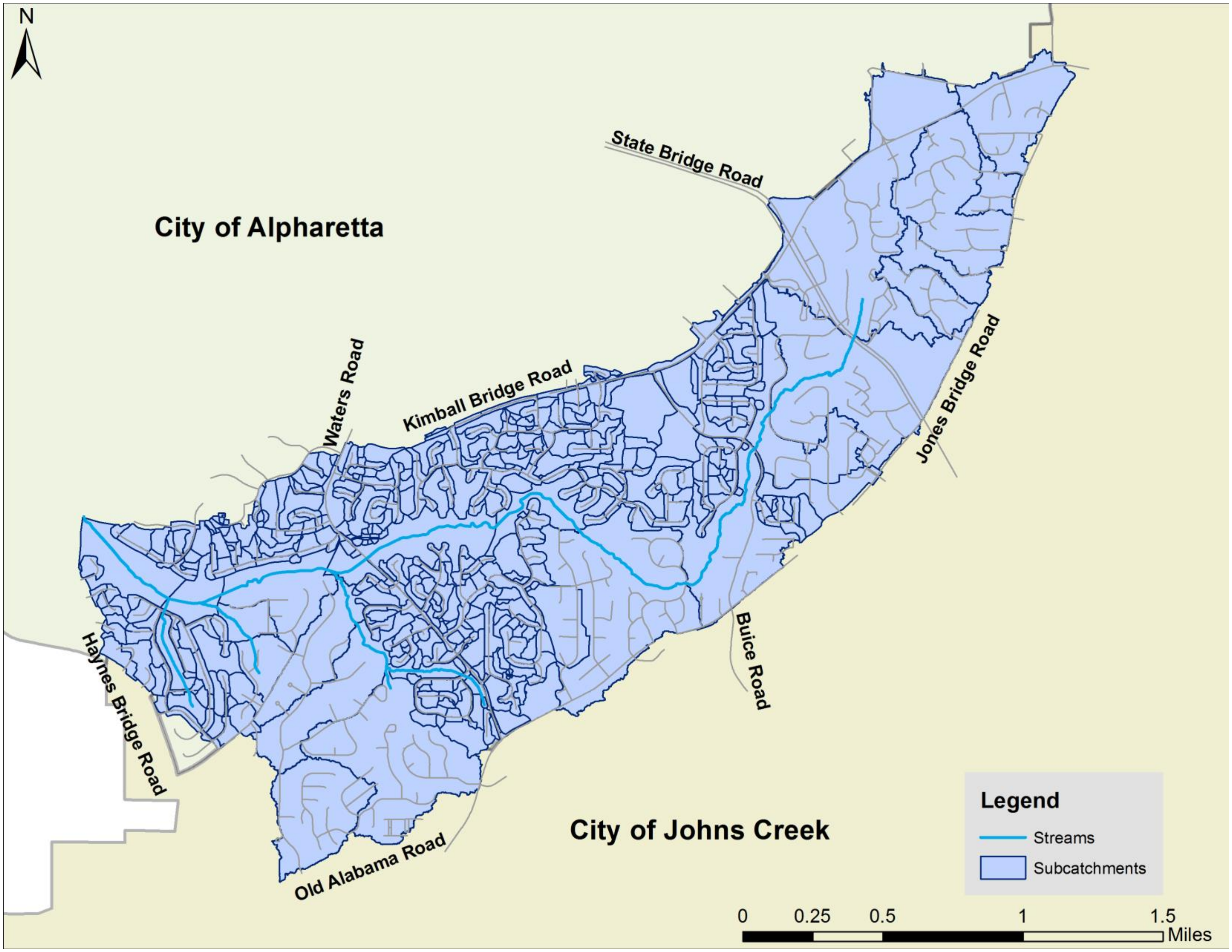

Figure 1.2 - Drainage map of the Long Indian Creek Watershed. More detailed subcatchments are provided where stormwater infrastructure was integrated into the model.

1.3 Study Elements

The main elements of this study included:

- Acquisition and development of data from the City of Alpharetta, the City of Johns Creek, and Fulton County. Data collected included 1) GIS standard data such as city limits, street centerlines, parcels, etc.; 2) Planimetrics including buildings, roads, wooded areas, open water, etc.; 3) Existing and future land use; 4) Stormwater inventory including closed conduits, structures, BMPs, ditches, lakes, etc.; 5) Aerial imagery; 6) Topography including bare earth LiDAR; 7) Fecal coliform monitoring data; 8) GIS data and models associated with previous studies; and 9) Drainage complains and BMP/MS4 inspection reports.
- Digitization of building, roads, and parking areas to update impervious surface data in watershed.
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- Conduct detailed field reconnaissance to pinpoint areas that exhibit 1) Reduced riparian buffers; 2) Active construction activity; 3) Intense stream bed or bank erosion; 4) Stream channel alterations; 5) Existing BMPs conditions and configurations; 6) Potential pollution sources such as broken or leaking sewer lines, SSOs, illicit discharges, illicit dumping, confined animal areas, areas with pet waste, poorly maintained land, and suspect odors, and; 7) Potential maintenance issues such as blocked or damaged culverts, bridge crossings, storm drains, etc.
- Development of PCSWMM hydrodynamic model based on EPA's SWMM5 program engine to model the entire Long Indian including the stormwater infrastructure owned by the City of Alpharetta in the watershed. Fecal coliform loading will also be integrated into the model in order to quantify benefits from proposed CIPs.
- Identification and prioritization of watershed CIPs with a goal of reducing fecal coliform loading by 95%. Prioritization and ranking will include a cost analysis for each proposed project.
- Identify potential partnerships and Federal and State grant funding opportunities.
- Development of a public outreach strategy in coordination with the City of Alpharetta to enhance public understanding of the project and encourage their participation in selecting, designing, and implementing the nonpoint source management measures to be implemented.

1.4 Scope of Report

This report summarizes the results of the work performed under this study and presents recommendations for the watershed improvement plan for Long Indian Creek. As there are no point source discharges in the Long Indian Watershed, the recommendations for this watershed improvement plan focus on management of nonpoint pollution discharges. The remaining chapters of the report are:

- Chapter 2 Watershed Characteristics
- Chapter 3 Watershed Conditions
- Chapter 4 New Data and Model Development
- Chapter 5 Watershed Management Goals and Objectives
- Chapter 6 Capital Improvement Plan

2 WATERSHED CHARACTERISTICS

Long Indian Creek extends approximately 4 miles from its headwaters in the City of Johns Creek and flows in downstream in a south-west direction to its confluence with Big Creek. Big Creek continues downstream to its confluence with the Chattahoochee River (HUC 03130001). The watershed for Long Indian Creek is approximately 3.6 square miles and consists predominately of residential land use with a smaller percentage of commercial, institutional, parks, and undeveloped land tracts. In general, half of the watershed is in the City of Alpharetta (Alpharetta) and half is located in the City of Johns Creek. Generally, the watershed is bounded to the north by Kimball Bridge Road, to the east by Jones Bridge Road, and to the south by Old Alabama Road. **Figure 2.1** provides an overview of the Long Indian watershed. The Cities of Alpharetta and Johns Creek are located in the northern metro Atlanta region which has experienced rapid growth starting in the 1970s. Although there are still several small areas of active construction in the Long Indian watershed, a large majority of the watershed is developed.

Figure 2.1 - Long Indian Creek and its watershed boundary.

2.1 Hydrology

The Long Indian Creek watershed spans the Cities of Alpharetta and Johns Creek which are located in northeast Fulton County and are part of the larger Upper Chattahoochee watershed. The watershed is located in a wet climate that has an average annual precipitation of 51.84 inches per year. On average, the wettest month of the year is January with 5.35 inches of rain and the driest month is October with 3.58 inches of rain (US Climate Data, 2016). The Long Indian Creek watershed is affected by severe thunderstorms and flooding as well as hurricanes and tropical storms. The most recent extreme event occurred in September 2009 in which a 500-year precipitation event affected several counties around the Atlanta metro area. In the City of Alpharetta, it was recorded that 9.14 inches fell from September 14, 2009, at 8 AM ending on September 22, 2009, at 8 AM (NOAA, 2016). Further, the most impactful tropical storms have been Hurricane Katrina in August 2005, Hurricane Floyd in September 1999, and Tropical Storm Alberto in July 1994 (GEMA, 2016). The age of development in the watershed ranges greatly in age from buildings built prior to current regulations to new construction. Therefore, a portion of the stormwater infrastructure in the watershed may not include BMPs. The lack of these BMPs can impair water quality in the watershed.

2.1.1 Surface Water

Long Indian Creek drains 3.6 square miles within the Cities of Alpharetta and Johns Creek, and it flows for approximately 4 miles before emptying into Big Creek. There are three main tributaries that flow into Long Indian Creek. They are named Long Indian Creek Tributary 1, Long Indian Creek Tributary 2, and Long Indian Creek Tributary 3. Long Indian Creek Tributary 1 has the furthest downstream confluence with Long Indian Creek, and Long Indian Creek Tributary 3 has the furthest upstream confluence. Additionally, there is a stream called Long Indian Creek Tributary 3.1 that flows into Long Indian Creek Tributary 3. The names and lengths of the tributaries to Long Indian Creek are shown in **Table 2.1** and a detailed image of the watershed can be seen in **Figure 2.1** in the previous section.

Long Indian Creek passes through primarily residential areas. Trash could be seen along the creek with increased debris in the more commercial area around State Bridge Road. Further, the riparian zone on either side of Long Indian Creek has been intruded upon by residents along the bank, and large numbers of invasive species were also noted along a majority of the banks. Additionally during field visits, fish and animals were seen in Long Indian Creek.

Table 2.1 - Length and stationing information for significant tributaries to Long Indian Creek.

Tributary Name	Length (feet)	Confluence Stationing (feet)
Long Indian Creek Tributary 1	2221	2288
Long Indian Creek Tributary 2	1902	2899
Long Indian Creek Tributary 3	2794	5604
Long Indian Creek Tributary 3.1	2276	2385 (Confluence with Tributary 3)

2.1.2 Climate

Long Indian Creek is located in north central Georgia within the Piedmont Region. The Piedmont Region experiences a variable climate with cool winters and hot summers. The hottest month in the Long Indian Creek watershed is July with an average temperature of 87 ^{o}F, and January is the coldest month with an average temperature of 50 ^{o}F (US Climate Data, 2016). Record temperatures are a high of 102 ^{o}F in July 1986 and -10 ^{o}F in January 1985 (Weather, 2016).

2.1.3 Flooding

Flooding has not been a major concern in the Long Indian Creek Watershed. BMPs were present and appeared to be functioning properly throughout the watershed. Additionally, there are very few commercial or industrial areas in the watershed, allowing for more pervious area in yards and parks that helps reduce rainfall runoff. System flooding has been reported to the City of Alpharetta via drainage complaints. However, the system flooding issues appeared to be isolated incidents and not related to watershed flooding.

2.2 Topography and Floodplains

The Long Indian Creek Watershed is located in the Piedmont Region of Georgia which is characterized by low hills and narrow valleys. Along the northern edge of the Piedmont Region, the rolling hills become more mountainous as the terrain transitions into the Blue Ridge Mountain Region. The elevation in the Long Indian Creek watershed ranges from 1180 feet NGVD at the upper end to 960 feet NGVD at the lower end. **Figure 2.2** shows the topography in the Long Indian Creek watershed.

There are three tributaries that enter Long Indian Creek in the bottom half of the watershed. The tributaries are named Long Indian Creek Tributary 1, 2, and 3, with Tributary 1 being furthest downstream and Tributary 3 being furthest upstream. Further, Long Indian Creek Tributary 3 has its own small tributary named Long Indian Creek Tributary 3.1. Updated flood studies were completed for Long Indian Creek and its tributaries in 2012 and have been incorporated into the Fulton County Unincorporated and Incorporated Flood Insurance Rate Maps (FIRMs) in 2013. Long Indian Creek is designated as a Zone AE (detailed study) floodplain from approximately 1,000-ft upstream of State Bridge Road downstream to the confluence with Big Creek. The tributaries and the most upper reaches of Long Indian Creek are designated as a Shaded Zone X (limited detail study) floodplain. The existing 100 year floodplain and the future 100 year floodplain from that study are shown in **Figure 2.3**.

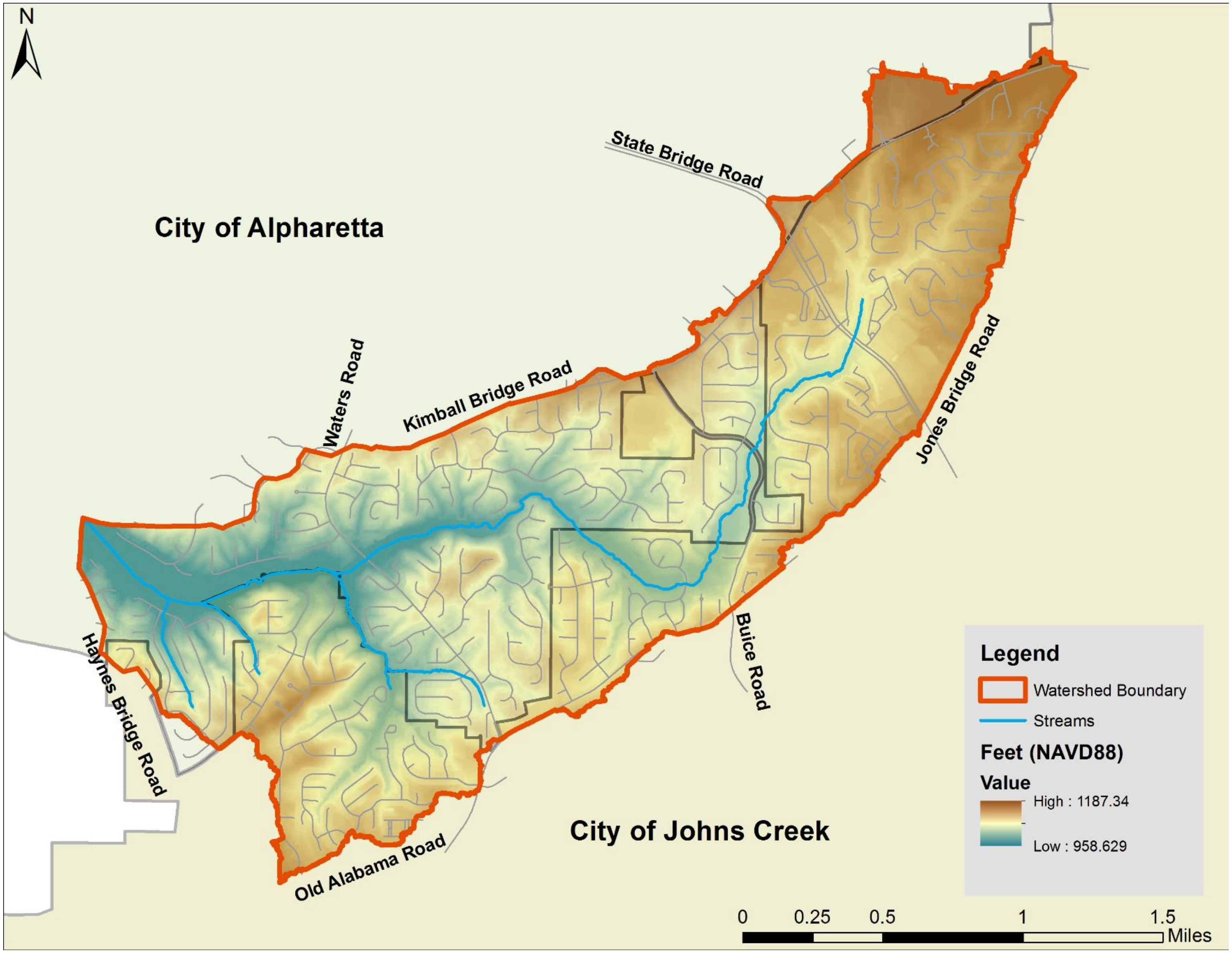


Figure 2.2 - Topography of the Long Indian Creek watershed.

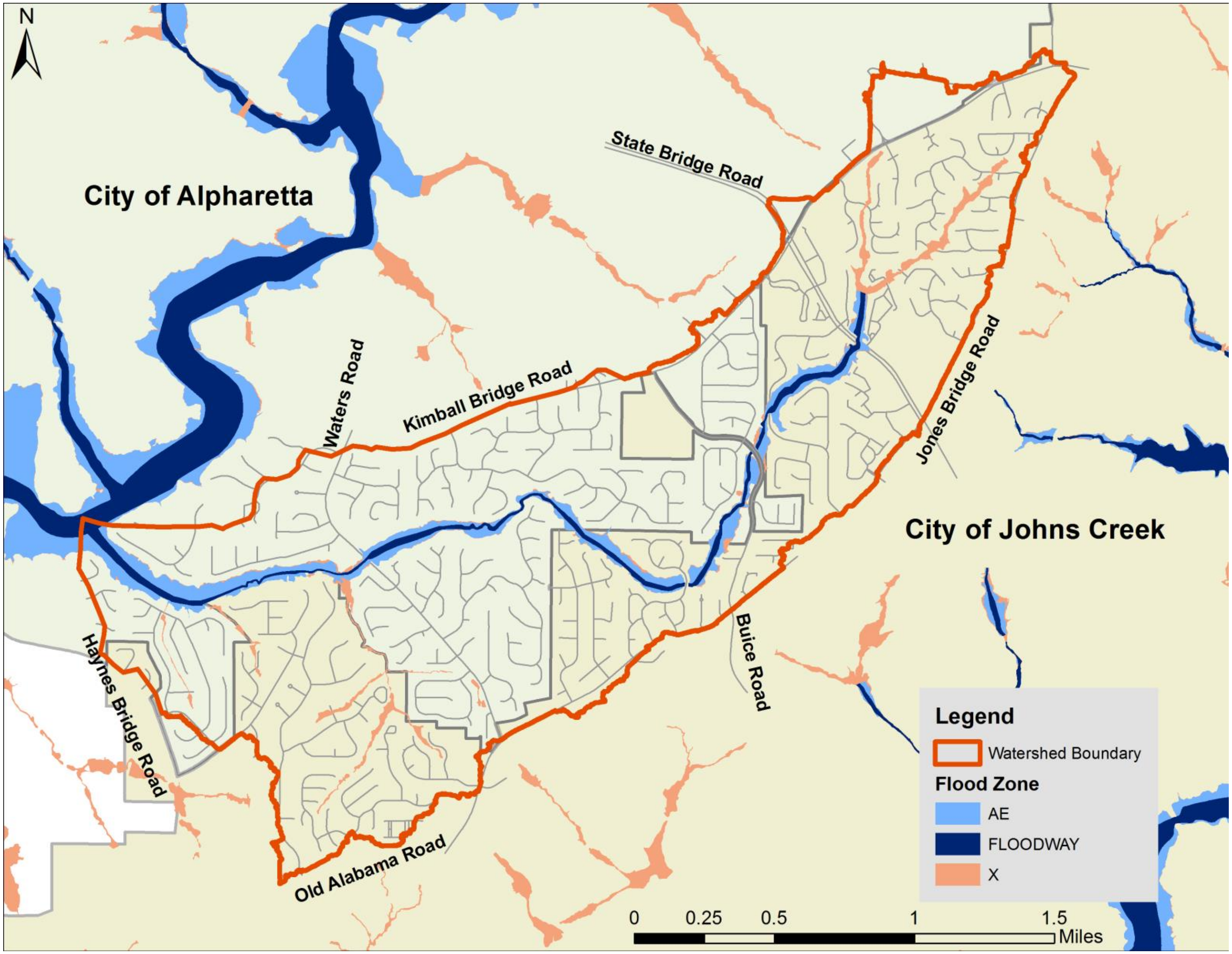


Figure 2.3 - Existing and Future 100 year floodplains for Long Indian Creek and Long Indian Creek Tributary 3.

2.3 Geology

The Long Indian Creek Watershed is located in the Piedmont Region of Georgia which is characterized by clayey-soils that are commonly red in color and consist of kaolinite, halloysite, and iron oxides. The soils are produced by the weathering of feldspar-rich igneous and metamorphic rocks. Further, the Piedmont Region contains moderate-to-high-grade metamorphic rocks, such as schists, amphibolites, gneisses, and migmatites as well as igneous rocks such as granite. In isolated areas there are granitic plutons that interrupt the Piedmont landscape. Stone Mountain is an example of one such pluton (UGA, 2016).

2.4 Soils

The Long Indian Creek Watershed has three predominant soil types Urban Land-Grover-Mountain Park complex (31.6%), Urban Land-Cecil complex (23.8%), and Urban Land-Madison-Bethlehem complex (15.8%) that constitute over 70% of the soil. Urban land indicated soil that has been altered by cutting, filling, and/or shaping. A majority of the soils in the Long Indian Creek Watershed are considered well drained. A complete breakdown of the U.S. Department of Agriculture (USDA), Natural Resources conservation Service classified soils in the watershed is provided in **Table 2.2** and the location of the soils can be seen in **Figure 2.4** (USDA, 2006).

Table 2.2 - Long Indian Creek Soils.

Soil Map Unit Names	Acres	Percent (%)
Altavista sandy loam, 2 to 6 percent slopes	16.2	0.70%
Appling-Hard Labor complex, 6 to 10 percent slopes	5.3	0.23%
Cartecay-Toccoa complex, 0 to 2 percent slopes, occasionally flooded	155.3	6.70%
Cecil sandy loam, 2 to 6 percent slopes, moderately eroded	7.4	0.32%
Cecil sandy loam, 6 to 10 percent slopes, moderately eroded	32.4	1.40%
Grover-Mountain Park complex, 2 to 10 percent slopes, stony	22.3	0.96%
Grover-Mountain Park complex, 10 to 20 percent slopes, stony	50.9	2.19%
Grover-Mountain Park complex, 20 to 60 percent slopes, stony	6.9	0.30%
Madison-Bethlehem complex, 2 to 6 percent slopes, moderately eroded	6.7	0.29%
Madison-Bethlehem complex, 6 to 10 percent slopes, moderately eroded	75.6	3.26%
Pacolet-Saw complex, 6 to 10 percent slopes, moderately eroded, bouldery	1.1	0.05%
Rion sandy loam, 10 to 15 percent slopes	3.5	0.15%
Urban Land	95.3	4.11%
Urban Land-Cecil complex, 2 to 10 percent slopes, moderately eroded	552.7	23.84%
Urban Land-Grove-Mountain Park complex, 2 to 10 percent slopes, stony	33.0	1.42%
Urban Land-Grover-Mountain Park complex, 10 to 25 percent slopes, stony	732.4	31.60%
Urban Land-Madison-Bethlehem complex, 2 to 10 percent slopes, moderately eroded	367.0	15.83%
Urban Land-Rion complex, 10 to 25 percent slopes	151.4	6.53%
Water	2.5	0.11%
Altavista sandy loam, 2 to 6 percent slopes	16.2	0.70%
TOTAL	2317.9	100%

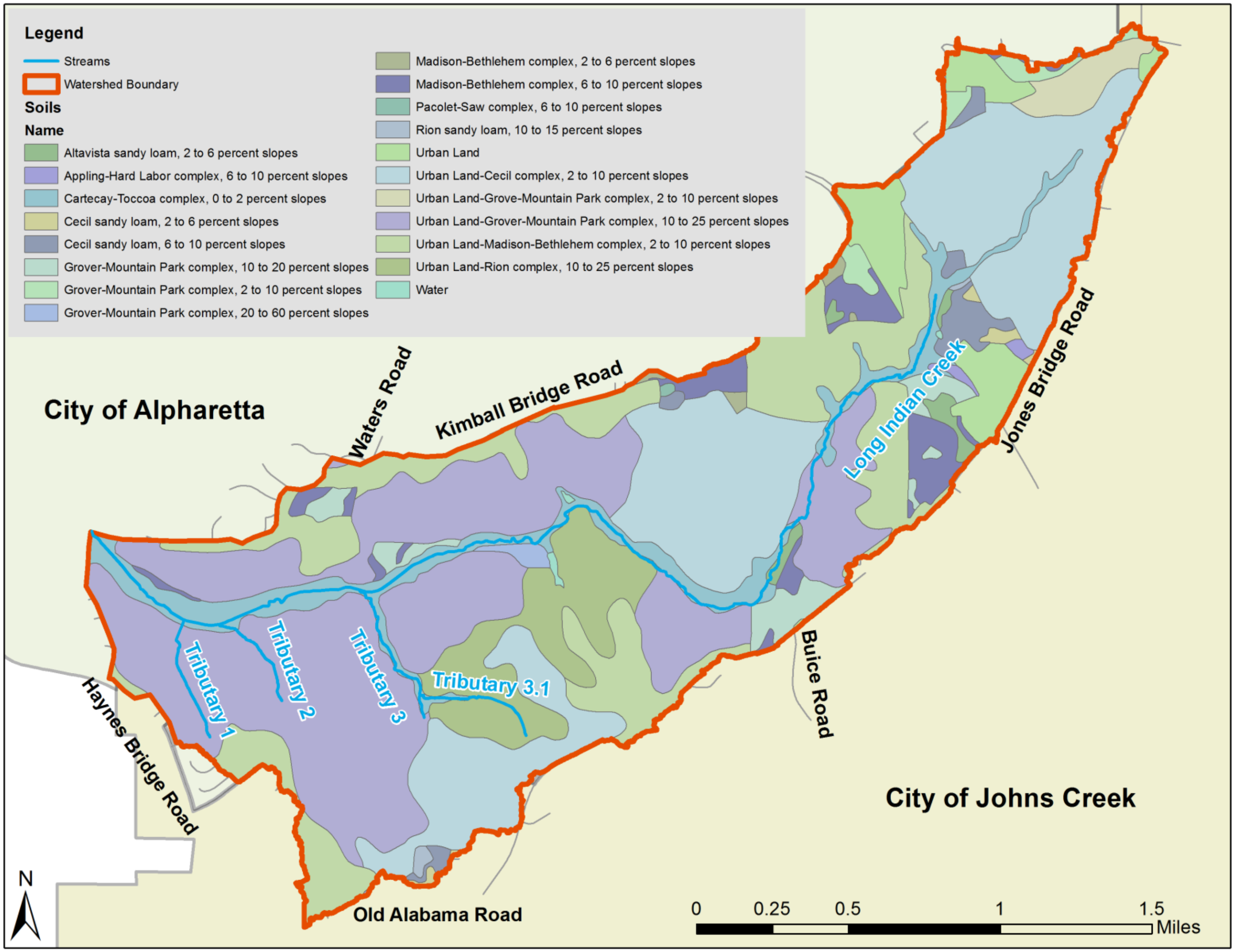


Figure 2.4 - Over 83% of the soils in the Long Indian Creek Watershed are Urban Land Complex.

2.5 Flora and Fauna

Georgia has been recognized as one of the most biologically diverse states in the nation. However due to anthropogenic actions, approximately 320 of Georgia's native species receive state or federal funding for protection. Furthermore, the draft 2015 State Wildlife Action Plan (SWAP) has identified 290 plant species and 349 animal species with high priority for conservation. The SWAP is a management plan to proactively conserve wildlife and habitats before it is too late or too costly to do so. Funding for the program comes from a State Wildlife Grant with matching funds from Georgia's Nongame Wildlife conservation Fund (GA DNR, 2016).

Despite the urbanization seen in the Long Indian Creek Watershed, it still provides an important habitat to several animals, such as the Tri-colored Bat, Yellow-crested Night-heron, Shinyrayed Pocketbook, and plants, such as the Large Witch-alder, Sweet Pinesap, Indian Olive, and American Ginseng, included in the most recent SWAP (GA DNR, 2015). **Figure 2.5** to the right shows a large snapping turtle that was found during the stream walk.

Further, several invasive plant species were noted in the watershed that dominated large portions of the stream banks. These species include Privet, Russian Olive, and Bamboo. These species are seen as highly detrimental to the watershed as they eliminate native plant species and often do not provide the necessary root depth and mass to secure the stream banks, resulting in greater erosion along the banks and higher total suspended solids in the stream.

2.6 Land Use and Land Cover

The impervious area for the City of Alpharetta is expected to increase from 23% in 1995 to 48% in 2020 according to the Big Creek Watershed Study (CDM, 2000), and the percent of undeveloped land in the City of Alpharetta is expected to decrease from 9% in 2000 to 0% in 2025 according to the Big Creek Watershed Study Update (R2T, 2011). According to a land use analysis performed by Dewberry, the impervious area within the Long Indian Creek Watershed is 627.2 acres or 27.1% of the watershed area. Dewberry completed the analysis by creating four types of land use: lawns, vegetation, water, and impervious. The impervious layer was generated by merging building, roadway, and parking area GIS data provided by the Cities of Alpharetta and Johns Creek and digitizing missing building footprints, driveways, roadways, and parking areas not included in the datasets. The lawn layer was developed by manually digitizing the areas that were free of woody brush based on aerial imagery. The water layer includes all significant wet ponds in the watershed. Finally, the vegetated layer was assumed to be any area of the watershed that was not considered lawn, water, or impervious. The creation of this land use layer involved a review of all areas within the watershed in order to manually digitize the most up-to-date land use data based on aerial imagery. **Table 2.3** summarizes the land use data from Dewberry's analysis and **Figure 2.6** shows the land use layer. The land use data created from this analysis was overlaid with the hydraulic soils group (HSG) to create a joined layer that was used to assign the appropriate curve number to each land area based on land use and HSG.

Table 2.3 - Long Indian Creek Watershed Existing Land Use.

City of Alpharetta	2015 Land Use (Acres)	2015 Land Use (%)
Lawns	1007.2	43.5%
Vegetation	680.3	29.3%
Water	3.2	0.1%
Impervious	627.2	27.1%
TOTAL	2317.9	100%

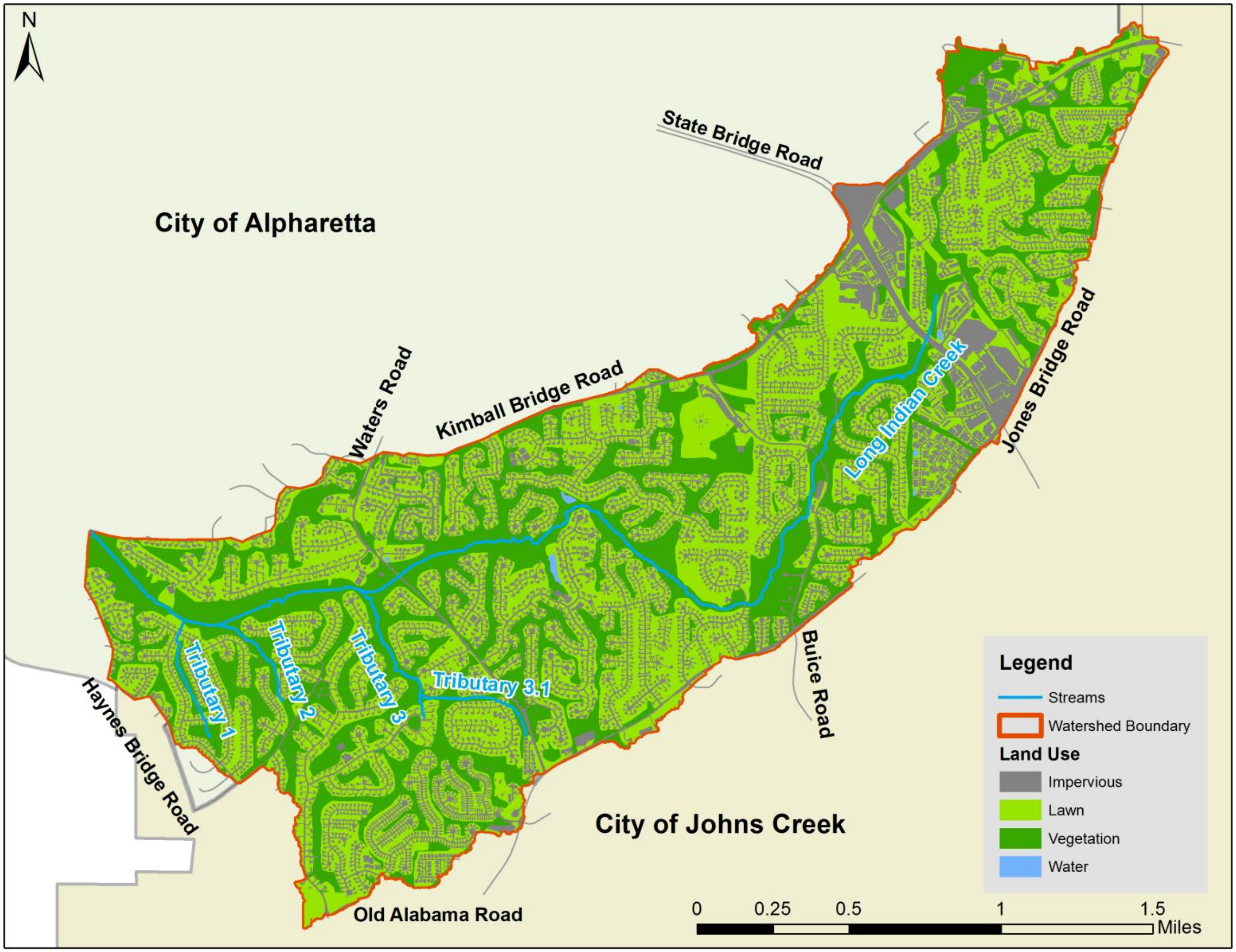


Figure 2.6 - Long Indian Creek Watershed Existing Land Use.

3 WATERSHED CONDITIONS

The Long Indian Watershed Improvement Project included two major parts. The first part was an extensive data collection phase to thoroughly assess the conditions of the watershed. The data collection phase involved coordination with the watershed stakeholders (City of Alpharetta, City of Johns Creek, and Fulton County) to gather any data that could impact the watershed such as sewer crossing locations, stormwater infrastructure, drainage complaints, etc. Further, streamwalks were completed for over five miles of Long Indian Creek and its tributaries. Data collected during these stream walks include Stream Reach Observation Summary Forms, Habitat Assessment Field Data Sheets, Bank Erosion Hazard Index Forms, and GIS inventory shapefiles with referenced photographs. Lastly, fecal coliform measurements and bacterial source tracking (BST) were utilized to quantify the pathogen levels in the stream and determine the source(s) of fecal coliform in Long Indian Creek.

The following section details and analyzes the information collected during the data collection review, as well as field sampling results gathered by the Dewberry Team and others.

3.1 Current Challenges

The major challenges facing the Long Indian Creek Watershed include:

1. Stormwater
    a. **Effects of stormwater runoff** – significant areas of impervious and lawn land cover generate increased stormwater runoff which contributes to erosion of the stream banks and potentially increases pathogen loads in the stream during wet weather.
    b. **Elevated fecal coliform levels in stream** – BST indicated dogs as a major source of fecal coliform in the watershed. Lawns and open space are the most likely land coverage to contribute heavily to fecal loading from dog waste.

2. Wastewater
    a. **SSOs and Septic Systems -** BST indicated humans as a source of minor contributor of fecal coliform in the watershed. The most likely sources are from sanitary sewer overflows in wet weather and improperly maintained septic systems in the watershed.

3. Ecology
    a. **Invasive species** – Kill off native species and provide insufficient root mass to secure stream banks from erosion. Bamboo, Privet, and Russian Olive were seen in the watershed.
    b. **Altered watershed hydrology** – increased impervious and lawn area
    c. **Altered stream geomorphology** – reduced length of stream flow path; and loss of connectivity with historic floodplain.

3.1.1 Water Quality Pollutants

Long Indian Creek is listed as an impaired stream on the Georgia Environmental Protection Division (EPD) 303(d) list for fecal coliform for its entire four mile reach. The EPD developed a Total Maximum Daily Load (TMDL) for Long Indian Creek in 2013 that recommends a 95% reduction in fecal coliform.

Excess water quality pollutants discharging into Long Indian Creek produce elevated pathogen levels. Elevated fecal coliform levels can impact human health and enjoyment by making the water unsafe for human contact. This is a concern in the Long Indian Creek Watersheds where residences have direct access to the stream. Additionally, the Long Indian Creek Watershed is part of the larger Upper Chattahoochee Watershed which is widely used by Georgia residents for drinking water, recreation, and fishing. In addition to the human impact, elevated fecal coliform levels in Long Indian Creek can have negative impacts on the surrounding flora and fauna.

The City of Alpharetta began consistently monitoring the water quality in Long Indian Creek in 2008. Further steps towards assessing the condition of the watershed began in 2014 when the City of Alpharetta and the City of Johns Creek entered into a Sampling and Quality Assurance Plan (SQAP) for testing and analysis of fecal coliform on Long Indian Creek. Samples are taken at 5 different locations along Long Indian Creek to identify potential sources and analyze trends. The sampling locations are:

- Site 1: State Bridge Road
- Site 2: Buice Road
- Site 3: Willow Meadow Circle
- Site 4: Waters Road
- Site 5: Park off of High Hampton Chase

The sampling locations are shown in **Figure 3.1**. Furthermore, Fulton County is conducting water quality monitoring for fecal coliform on Long Indian Creek at Waters Road (Site 4). All the results of these monitoring efforts have been combined in section 3.3.1 Fecal Coliform Monitoring Results of this report.

3.1.2 Bacterial Source Tracking

In addition to standard fecal coliform monitoring through quantification of counts per 100 mL (cfu/100mL), Dewberry worked with Source Molecular based in Miami, FL, to test water samples at the various sampling sites for the presence/absence of bird, dog, goose, Human (Dorei and EPA tests), and ruminant fecal coliform contamination. Bacterial Source Tracking (BST) sampling is a key part of this project as it identifies the main sources of fecal contamination, allowing Dewberry to design a more targeted watershed improvement plan to address the main sources of fecal contamination. **Table 3.1** shows the tests that were performed at each sampling location. Although this section presents the sampling locations and methodology, a full analysis of the BST results will be presented in Section 3.3.3 Bacterial Source Tracking Results.

Table 3.1 - Locations of BST tests performed for bird, dog, goose, Human (Dorei and EPA tests), and ruminant fecal contamination. BST tests are conducted to determine the presence/absence and quantification, if possible, of fecal contamination for each organism tested.

Test	Site 1	Site 2	Site 3	Site 4	Site 5
Bird	X	X	X	X	X
Dog	X	X	X	X	X
Goose	X			X	
Dorei (Human)	X	X	X	X	X
EPA (Human)	X	X	X	X	X
Ruminant		X	X		X

Figure 3.1 - Fecal coliform sampling locations for Long Indian Creek. Consistent sampling between Alpharetta and Johns Creek began in 2014.

3.1.3 SSOs and Septic Systems

Sanitary sewer overflows (SSOs) are a common problem for older urban sanitary sewer systems. Fulton County maintains the sanitary sewer system within the City of Alpharetta, and the County has been actively working to address SSOs. Although the sanitary sewer system within the City of Alpharetta is newer than other areas of the metro-Atlanta region, it could still suffer from SSOs. SSOs occur during wet events when sewage escapes the sanitary sewer system, most commonly due to a process called "Infiltration and Inflow" or I&I. I&I describes a process through which rainwater runoff and groundwater enter a sanitary sewer system through cracked pipes, leaky manholes, or improperly connected storm drains, down spouts, and sump pumps. The excess water that enters the sanitary system during wet events exceeds its design capacity and causes it to overflow.

Fulton County provided a record of sanitary sewer spills that have occurred within the Long Indian Creek Watershed. The spill dates range from October 1997 to February 2007. No spills were reported by the County after 2007. Additionally, all spills were reported as minor. **Figure 3.2** provides a map of the cataloged sanitary sewer spills. Although Long Indian Creek Watershed has not suffered an SSO in many years, it is important to remain vigilant of potential infiltration into the sanitary system and support a robust maintenance system to ensure the sanitary sewer system does not suffer future SSOs.

Another concern for the sanitary sewer systems is exposed sewer lines cause by stream bank erosion exposing pipes parallel to the stream or stream bed erosion exposing once-buried sewer pipes crossing the stream. Many exposed sewer pipes were noted during the stream inventory along Long Indian Creek and its tributaries. Exposed sanitary sewer pipes are at risk of being damaged during a storm event should debris strike or become caught on the pipe. Damage to sanitary sewer pipes could cause leaks in the system potentially resulting in SSOs, or extreme damage could break the pipe, causing a major spill. **Figure 3.3** and **Figure 3.4** show two examples of exposed sanitary sewer pipes in the Long Indian Creek Watershed.

Dewberry actively worked with Fulton County's Department of Water Resources, Finance Department, and Department of Health and Wellness to identify locations of septic systems in the Long Indian Creek Watershed. Information received from various County Departments was verified through visual inspect of the neighborhoods to pinpoint the most likely locations of septic tanks in the watershed. Based on this analysis 75 potential septic systems were identified within the watershed. Septic systems are primarily located in older neighborhoods in the south-western part of the watershed near Waters Road. Several systems may also be found along Jones Bridge Road and Kimball Bridge Road where there are several older properties. The existence and condition of these septic tanks was not confirmed in this report. However, the age of the developments suggest that many of the septic systems may be 20-years or older and may be contributing to the local contamination if not properly maintained. Even if the septic system is newer and within its design life, it still has the potential to contribute to local contamination if located or operated inappropriately. **Figure 3.5** provides a map of probably locations of septic systems within the Long Indian Creek Watershed.

Figure 3.2 - Locations of sanitary sewer spill reported by Fulton County. No spills have been reported since February 2007.

Figure 3.3 - A sanitary sewer pipe exposed due to channel and bank erosion. A large root ball can be seen behind the pipe and is an indication of the size of debris that can be transported in Long Indian Creek in storm events. Debris of this size could easily damage the exposed pipe.

Figure 3.4 - A sanitary sewer pipe running parallel to the stream has been exposed due to bank erosion. This pipe is subject to damage in storm events. Additionally, a damaged manhole can be seen on the bank of the stream. Further bank erosion could compromise the manhole.

Figure 3.5 – Probable locations of septic systems within the Long Indian Creek Watershed. Dewberry actively worked with Fulton County's Department of Water Resources, Finance Department, and Department of Health and Wellness to identify these locations.

3.1.4 Stormwater Runoff

Although no SSOs have been reported by Fulton County since 2007, non-point source pollution from surface runoff continues to be a concern for the Long Indian Creek Watershed. According to a land use study conducted by Dewberry, twenty-eight percent of the land area in the watershed is impervious. Significant amounts of impervious surfaces are a concern in a watershed because surface runoff collects pollutants that have accumulated on impervious surfaces, and unless the surface runoff is allowed to infiltrate into the ground, no cleaning is provided to the runoff water before it enters Long Indian Creek, contributing a large pollutant load. Additionally, increased surface runoff contributes to greater flows in the stream which can increase erosion and further impair water quality and stream health. In fact, a report by Hammock and Leo (2013) shows that streams within a watershed are most likely impaired when a watershed's impervious cover exceeds 20-25%. Stream impairment due to impervious areas can include increased stormwater runoff volume, increased ambient stream flow temperature; increased channel velocities contributing to bank and channel erosion; and increased pollutant loads from trash, sediment, grass clippings, fertilizer, pet waste, and heavy metals and petrochemicals from roadway and parking lot surfaces.

Based on the BST results, dog feces have been identified as a major source of fecal contamination in the watershed. This contamination occurs when surface runoff from yards transports fecal coliform from dog waste directly into Long Indian Creek. Although surface runoff volumes from lawns are less than runoff volumes from impervious areas, lawns still increase surface runoff compared to forests or undisturbed land. When lawns are covered in dog waste, the runoff from these areas can be highly contaminated. Since 43.5% of the Long Indian Creek Watershed is used for lawns, runoff from lawns with dog waste are likely a significant contributor of fecal coliform to the stream.

It should also be noted that BST results were collected for dry and wet weather events, and even in the dry weather samples, fecal coliform from dog waste was detected in low concentrations. In comparison, fecal coliform from dog waste was detected in much higher concentrations during wet weather events. Therefore, even in dry conditions, fecal coliform from dog waste is entering Long Indian Creek; however, it is entering the stream at a much reduced rate.

3.1.5 Altered Watershed Hydrology

The Long Indian Watershed is highly developed and lawns and impervious area constitute approximately 70% of the watershed's land use. This alteration from natural conditions increases the surface runoff. Further, the reduction in surface roughness caused by the removal of natural forests and replacement with lawns and impervious area shortens the time of concentration, causing the hydrograph to peak higher and faster than in predevelopment conditions. Both of these effects from altered watershed hydrology increase the volume of water in the stream channel during storm events. This increases volume causes channel velocities to increase which increases stream bank and bed erosion, further degrading the stream's water quality. The impacts of increase discharge volume and velocities were evident by the extent of channel and bank erosion seen in various locations along Long Indian Creek. **Figure 3.6** and **Figure 3.7** provide two examples of the extreme bank erosion seen in some areas. However, this additional sediment from channel bank and bed erosion drops out of the flowing water as it approaches its confluence with Big Creek. At this point, the stream velocity along Long Indian Creek slows, allowing larger particles eroded upstream to drop out of suspension and settled onto the channel bed, creating a soft, sandy, and highly unstable channel bottom near the confluence with Big Creek.

Figure 3.6 - Severe bank erosion has caused channel migration and has impacted a homeowner's fence on the stream bank.

Figure 3.7 - Excess flows and velocities have incised channel, creating nearly vertical banks that are approximately 10 feet high. Altered Stream Geomorphology

3.1.6 Altered Stream Geomorphology

Straightening of the stream channel, especially around bridges, and the addition of gabion baskets and riprap along stream banks are the two most obvious alterations to Long Indian Creek's geomorphology. Most likely, the stream channel was straightened to reduce flood risk by passing water through the channel more quickly and to minimize the risk of channel migration in the vicinity of bridges and culverts. However, straightening of the stream often has the effect of increasing the flow velocities within the channel. Increased flow velocities cause the banks to become incised which isolates the stream from its natural floodplain, further increasing velocities in the channel and increasing erosion. **Figure 3.8** shows an area of the channel that has been altered to be much straighter than it would be naturally.

In order to combat the increased erosion, gabion baskets and riprap were seen along some banks of the stream, either to protect private property or public infrastructure. These measures provide a poor habitat for fish, animals, and other organisms that live in the stream. Additionally although gabion baskets and riprap protect the area they cover, they tend to worsen erosion at either end. Therefore, these measures do not solve the issue of erosion along the streambank but, instead, relocate it to another area along the stream. **Figure 3.9** shows how gabion baskets have been used to protect the bank surrounding sanitary sewer infrastructure. Further, riprap can be noted on the right side of the photograph. It was potentially placed there to counteract the erosion caused by the gabion baskets.

Another alteration that was noticed in some areas of the watershed was the loss of the natural riparian buffer zone. In some neighborhoods, lawns extended to the very edge of the stream bank, allowing no buffer zone to prevent dog waste, fertilizer, and other pollutants from running off directly into the stream. Further, the lack of trees along the stream banks can cause increased erosion due to the lack of root mass to stabilize the banks. Additionally, natural habitats provided by tree roots are removed when the natural riparian buffer is eliminated.

Figure 3.8 - A segment of straighten streamway prior to entering a culvert. Streamways were straightened to reduce flood risk and channel migration around bridges and culverts. Reduction of the riparian buffer can be seen on the right side of the stream.

Figure 3.9 – Gabion baskets have been installed along the stream bank to protect the sanitary sewer pipe. Riprap has been installed to the right of the pipe to further protect against increased stream bank erosion.

3.1.7 Invasive Species

Four main invasive species were commonly seen within the Long Indian Creek Watershed. The species are Privet, Russian Olive, Bamboo, and Japanese Honeysuckle. Images of the invasive species for identification purposes are shown in **Figure 3.10** to **Figure 3.14**. Invasive species are a concern in the watershed due to their ability to compete with and displace native vegetation (USDA, 2016). Further, many invasive species have fast-growing, shallow root systems that provide poor stabilization for riparian soils, increasing erosion along stream banks (Bellinger Landcare Inc, 2006).

Figure 3.10 - Bamboo. Root systems are only 2 to 3 feet deep (Jurcik, 2016).

Figure 3.11 – Privet. Can be 30 feet tall and reproduces vigorously (Moorhead, 2016).

Figure 3.12 – Russian Olive fruit. Produces 8 pounds of fruit per plant (Sydnor, 2016).

Figure 3.13 – Russian Olive. Can alter local hydrology (Sydnor, 2016).

The most common invasive species seen in the Long Indian Creek Watershed is Privet (*Ligustrum sinense*). It is an evergreen shrub that can grow up to 30 feet tall (Bellinger Landcare Inc, 2006). However, it more commonly grows in the range of 5 to 12 feet tall, and plants of this size were most commonly seen in the watershed (USDA, 2016). The root system of privet is shallow but extensive, and it can reproduce by suckers from its extensive root system, contributing to its invasive nature (USDA, 2016). Privet also reproduces sexually through the production of fruit that ripens in later autumn and winter, providing a food source for birds when few others are available. Further, a mature plant can produce over one million seeds (Bellinger Landcare Inc, 2006). Once established, Privet is especially difficult to remove due to the massive seedbank produced by mature plants and the need to remove the entire root system to prevent vegetative reproduction (USDA, 2016). **Figure 3.15** shows an area along the bank of Long Indian Creek where Privet dominates. Intense erosion can be seen on the banks due to the lack of deep root systems that would normally be provided by native plants and trees.

Russian Olive (Elaeagnus angustifolia) is another invasive species commonly seen in the Long Indian Creek Watershed. The Russian Olive is native to western and central Asia, and is a woody, deciduous species that grows from 10-30 feet tall in the form of a large shrub or small tree (USDA Forest Service, 2016). Russian Olive can reproduce sexually and vegetatively via root crowns and suckers. Similar to Privet, Russian Olive reproduces vigorously, producing eight pounds of fruit per plant, and fruit remains on the plant throughout winter, providing an easy food source to animals when few other plants bear fruit (USDA Forest Service, 2016). Russian Olive will quickly outcompete native vegetation, and once established, it is difficult to eradicate and can interfere with new tree growth required to stabilize stream banks (USDA Forest Service, 2016). Further, Russian Olive has been shown to alter hydrology in lowland riparian forests through rapid evapo-transpiration which can stabilize formerly flooded soils, rendering the habitat inhospitable to native species (USDA Forest Service, 2016).

Bamboo was another invasive species seen in the Long Indian Creek Watershed (*Phyllostachys aurea*); however, it was less common than Privet or Russian Olive, and the clumps were contained to smaller areas along the stream banks. Bamboo is an evergreen plant that can grow as tall as 16 to 40 feet (Invasive Plant Atlas, 2016). Despite the height of bamboo plans, the root system is only 2 to 3 feet deep, providing very little stabilization for riparian soils along stream banks (Bamboo Garden, 2016). Bamboo is spread by rhizomes that can form dens, monocultural thickets that displace native plants and are difficult to remove (Invasive Plant Atlas, 2016). **Figure 3.16** shows an example of bamboo found along the stream bank of Long Indian Creek. The thicket has surrounded a sanitary sewer pipe that has been exposed due to bank erosion. Due to the limited soil stability provided by Bamboo, erosion around the sanitary sewer pipe is likely to continue.

Japanese Honeysuckle (*Lonicera japonica*) was the fourth main invasive species noted in the watershed. It is an evergreen, woody, twining vine that can grow in excess of 80 feet in length. It is known for its extremely fragrant white flowers that yield numerous small black berries which are distributed by birds. However, the plant can also reproduce vegetatively with underground rhizomes and ground-level runners. Therefore, Japanese Honeysuckle is seen as highly invasive because of its wide range of habitat, expansive seed dispersal, rapid growth, extended growing season, and a lack of natural enemies. For these reasons, it is able to rapidly and completely cover forest floors and canopies, chocking out native plants (UF, 2016).

Figure 3.14 - Japanese Honeysuckle (UF, 2016).

Figure 3.15 – Privet has completely displaced native plants from the stream banks along Long Indian Creek. Erosion can be seen along the stream bank where the Privet roots do not provide sufficient soil stabilization.

Figure 3.16 - Bamboo thicket surrounding an exposed sanitary sewer pipe on the bank of Long Indian Creek. The shallow root system of the Bamboo plants can be seen on the exposed bank. Field Data Collection

3.2 Field Data Collection

An extensive field reconnaissance effort was completed for the Long Indian Creek Watershed. The objective of the field work was to analyze existing streams, drainage features, BMPs, and erosion problems in the watershed in order to identify and select opportunities for future capital improvements that are most effective at improving water quality and stream conditions. Prior to fieldwork, Dewberry reviewed the data collection efforts with the City of Alpharetta in order to target specific areas of the watershed for field reconnaissance. The location and intensity of survey points evaluated by field teams was focused in the following areas of the watershed:

- Areas having the highest percentage of impervious area;
- Areas with a high concentration of drainage complaints;
- Areas with sanitary sewer infrastructure crossing or in close proximity to the stream;
- Areas with a concentration of septic systems;
- Bridges, culverts, and systems that indicate flooding per the hydrodynamic modeling in events less than the 100-year level of service for bridges and culverts and less than 25-year level of service for systems;
- Exiting BMPs on public facilities and existing BMPs on select commercial and residential properties agreed upon with the City of Alpharetta;
- Stream reaches with erosive velocities in the 1-year storm event, and;
- Steam reaches with visible erosion evident from aerial imagery.

Figure 3.17 provides a map of digitized drainage complaints provided by the City of Alpharetta from December 2007 through January 2015. Each drainage complaint has been categorized using the following descriptions:

Table 3.2 – Categorized drainage complaints provided by the City of Alpharetta.

Complaint Issue	Number of Complaints
BMP Maintenance	3
Bury Pit	14
Debris	6
Drainage Inquiry	7
Erosion	49
Flooding – Basement	2
Flooding – Landscaping	6
Flooding – System	5
Floodplain Inquiry	2
Sewer Spill	1
Sink Hole – Compaction	1
Sink Hole – Landscaping	8
Structure Maintenance	7
TOTAL	111

In the areas noted in the above bullets, the field teams focused on obtaining information at observation points that exhibited:

- Reduced riparian buffers;
- Areas of active construction activity near Long Indian Creek and its tributaries;
- Areas of intense stream bed or bank erosion;
- Stream channel alterations;
- Existing BMP conditions and configurations;
- Potential pollution sources such as broken or leaking sewer lines, SSOs, illicit discharges, illicit dumping, confined animal areas, areas with observed pet waste, poorly maintained land, and suspect odors, and;
- Potential maintenance issues such as blocked or damaged culverts, bridge crossings, or storm drains.

The data presented in this section was collected during a steam walk completed in March, 2016, and several field visits in June, 2016. Data for this section is provided in the Technical Memorandum "Long Indian Creek Stream Inventory" which is presented in full in APPENDIX D: LONG INDIAN CREEK STREAM INVENTORY TECHNICAL MEMORANDUM (Golder, 2016).

3.2.1 Stream Inventory

The Dewberry Team inventoried Long Indian Creek and its Tributaries in March 2016, and the inventory included the following components:

- Characterizing the stream conditions;
- Identifying maintenance issues, including severe erosion at construction sites, illicit discharge, and sanitary sewer pipe leaks and breaks, and;
- Collecting data on the physical condition and assessing the aquatic habitat of representative reaches throughout the watershed.

The Dewberry Team collected 61 data points over approximately 5.76 miles along Long Indian Creek and its Tributaries. Habitat assessments were completed using the methodologies specified in the *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish* (EPA, 1999). Additionally, the bank erosion hazard index was conducted using the Rosgen methodology, *Applied River Morphology* (Rosgen, 1996).

Further, the Dewberry Team measured stream cross-sections and performed habitat assessments and bank erosion hazard indexes at the five sampling sites showing in **Figure 3.1**. The cross-section measurements are needed to compute the entrenchment ratio and width-depth ratio for the Rosgen Stream Classification System. Additionally, the cross-sections can be compared to any historical or future stream cross-section measurements in order to assess channel erosion/deposition and migration.

Appendix A provides the following data collected during the inventory:

- Stream Reach Observation Summary Forms
- Habitat Assessment Field Data Sheets
- Bank Erosion Hazard Index Forms
- Stream Cross Sections

Further, a GIS stream inventory shapefile labeled "LongIndianCreek_GPS_20160311" and photographs from the stream inventory will be provided in a digital format to the City. A stream inventory parameter sheet is also included with the shapefile to define the parameter codes.

3.2.2 Field Findings

The observed stream conditions at each of the five sampling locations are described below:

- Site 1: State Bridge Road (34.050859 N, -84.227183 W)
    - Moderately stable, minimal stream bank erosion on both the left and right bank.
    - Invasive species (*Ligustrum sinense* and *Lonicera japonica*) were observed.
    - No human impact within 60 feet of the stream bank on the right bank.
    - Minimal human impact on left bank with a 20-40 foot riparian zone from the left bank.
    - Moderate bank erosion hazard index score of 21.9.

- Site 2: Buice Road (34.044721 N, -84.237667 W)
    - Chicken coop along the left bank.
    - Moderately to severely eroded left and right bank.
    - Invasive species (*Ligustrum sinense* and *Lonicera japonica*) were observed.
    - Very little riparian vegetation on both the left and right bank due to human impact.
    - Moderate bank erosion hazard index score of 24.6.

- Site 3: Willow Meadow Circle (34.038129 N, -84.257503 W)
    - Stream reach impounded by beaver dam.
    - Moderately stable, minimal stream bank erosion on both left and right bank.
    - No human impact within 60 feet of the stream bank on the right bank.
    - Minimal human impact on left bank with a 20-40 foot riparian zone from the left bank.
    - Suspicious discharge within stream reach.
    - Moderate bank erosion hazard index score of 27.2.

- Site 4: Waters Road (34.039325 N, -84.257503 W)
    - Unstable, many eroded areas on both left and right bank.
    - Very little riparian vegetation and no buffer due to human construction activity on right bank.
    - No human impact within 60 feet of the stream bank on the left bank.
    - Moderate bank erosion hazard index of 22.2.

- Site 5: Park off Hampton Chase (34.038031 N, -84.27144 W)
    - Park located on right bank.
    - Gabion baskets located at an exposed sewer pipe crossing.
    - Unstable, many eroded areas on right bank.
    - Moderately unstable bank erosion on left bank.
    - Large human impact on right bank with a 20-40 foot riparian zone from the right bank.
    - No human impact within 60 feet of the stream bank on the left bank.

- High bank erosion hazard index of 35.51.

Figure 3.18 provides an aid to visualize the stream bank areas suffering from erosion on the left and right banks of the stream. In the Figure, stream bank erosion is described as minor (25-50% eroded), moderate (50-75% eroded), and severe (75-100% eroded).

Other information gathered from field reconnaissance included locations of exposed pipes crossing the stream (**Figure 3.19**), damaged BMPs and pipes (**Figure 3.20**), and other areas of concern including beaver dams, debris, and trash found in the stream (**Figure 3.25**). When possible, images (**Figure 3.21** to **Figure 3.24** and **Figure 3.26** to **Figure 3.28**) have been included after maps to demonstrate the issues seen in the watershed.

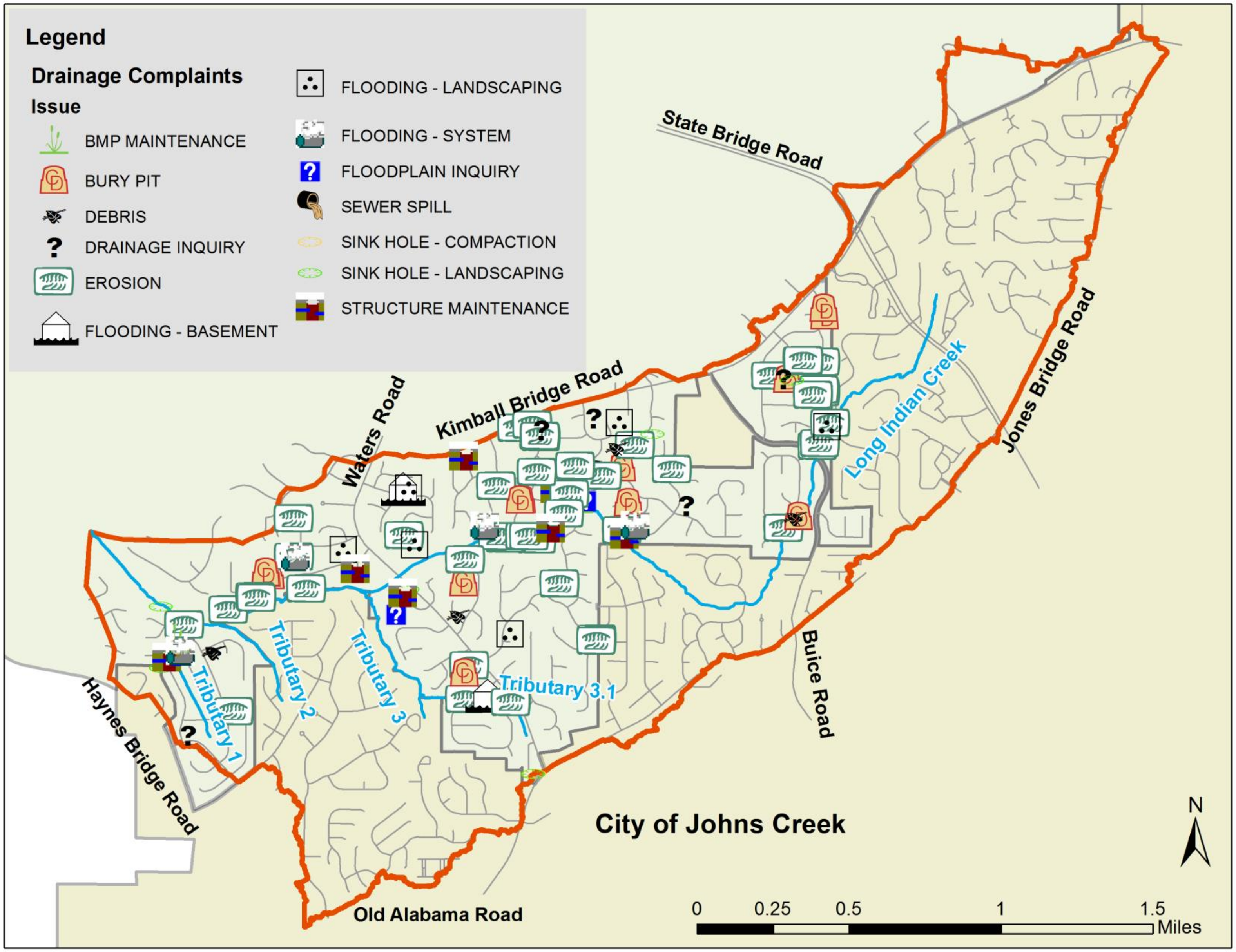


Figure 3.17 – Drainage complaints provided by the City of Alpharetta.

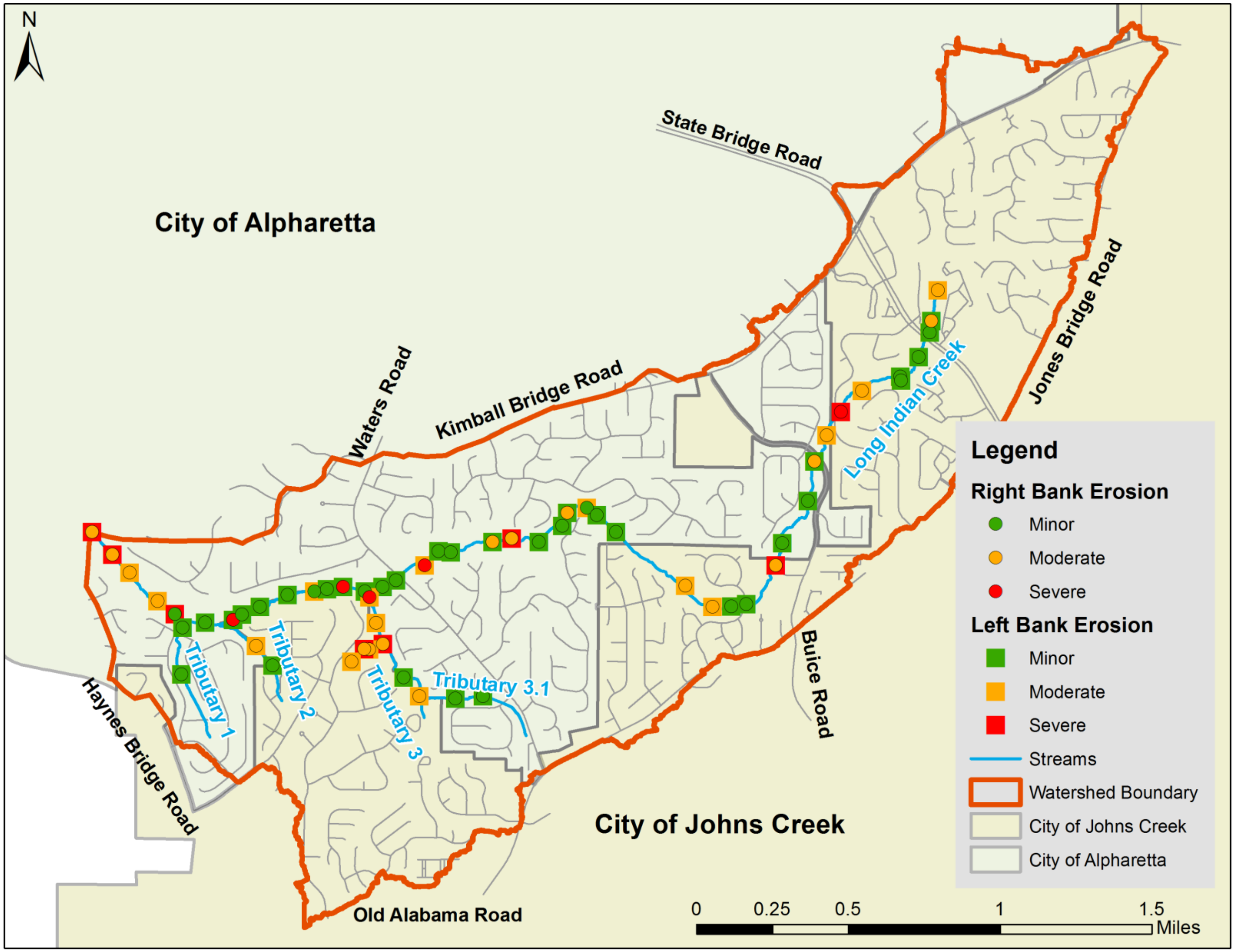


Figure 3.18 – Stream bank erosion on the left and right banks of Long Indian Creek and its Tributaries.

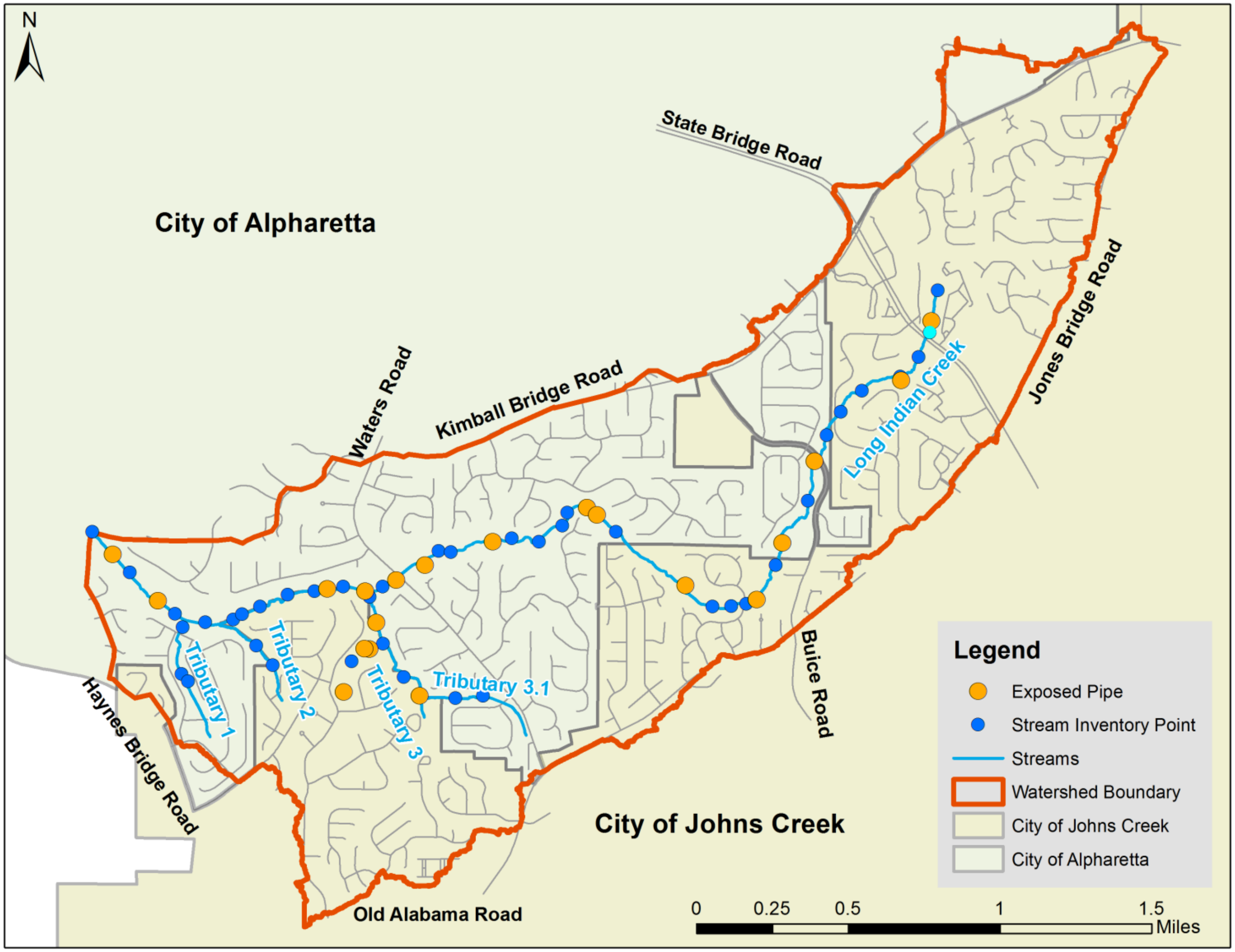


Figure 3.19 – Exposed pipes discovered crossing or parallel to Long Indian Creek and its Tributaries. Exposed pipes can be seen most commonly in areas of moderate to severe erosion.

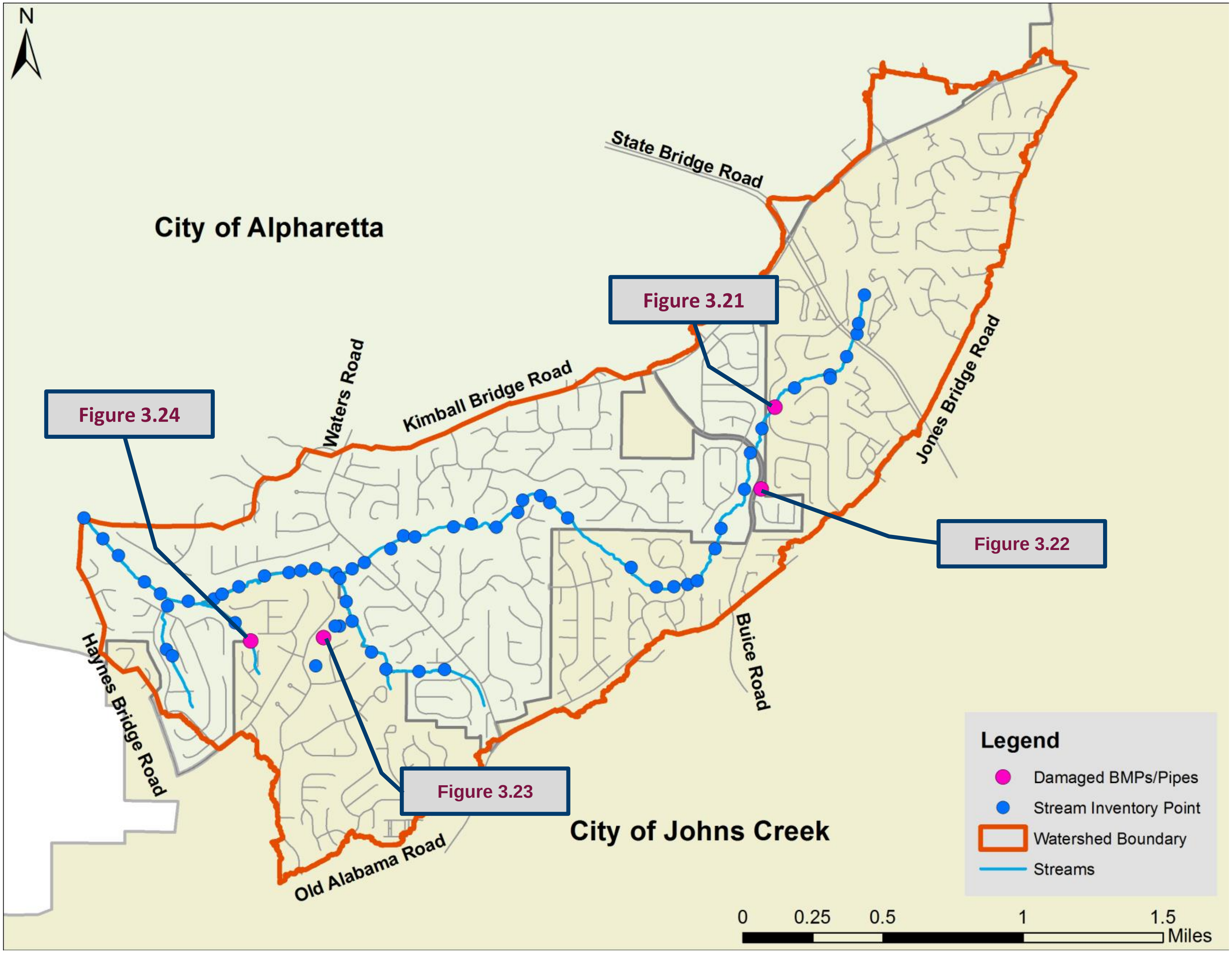


Figure 3.20 – Damaged BMPs and pipes discovered in the Long Indian Watershed. The following photos provide insight into the type of damage.

Figure 3.21 – A damaged BMP found outleting into Long Indian Creek. The flow attenuation provided by the BMP has been compromised by the damage.

Figure 3.22 – Sedimentation in a BMP found in a neighborhood detention pond leading into Long Indian Creek. The flow attenuation provided by the BMP has been compromised by the sedimentation.

Figure 3.23 – A broken sewer connection found in a Tributary of Long Indian Creek.

Figure 3.24 – A damaged pipe infrastructure. The headwall has become disconnected from the pipe due to scouring under the headwall.

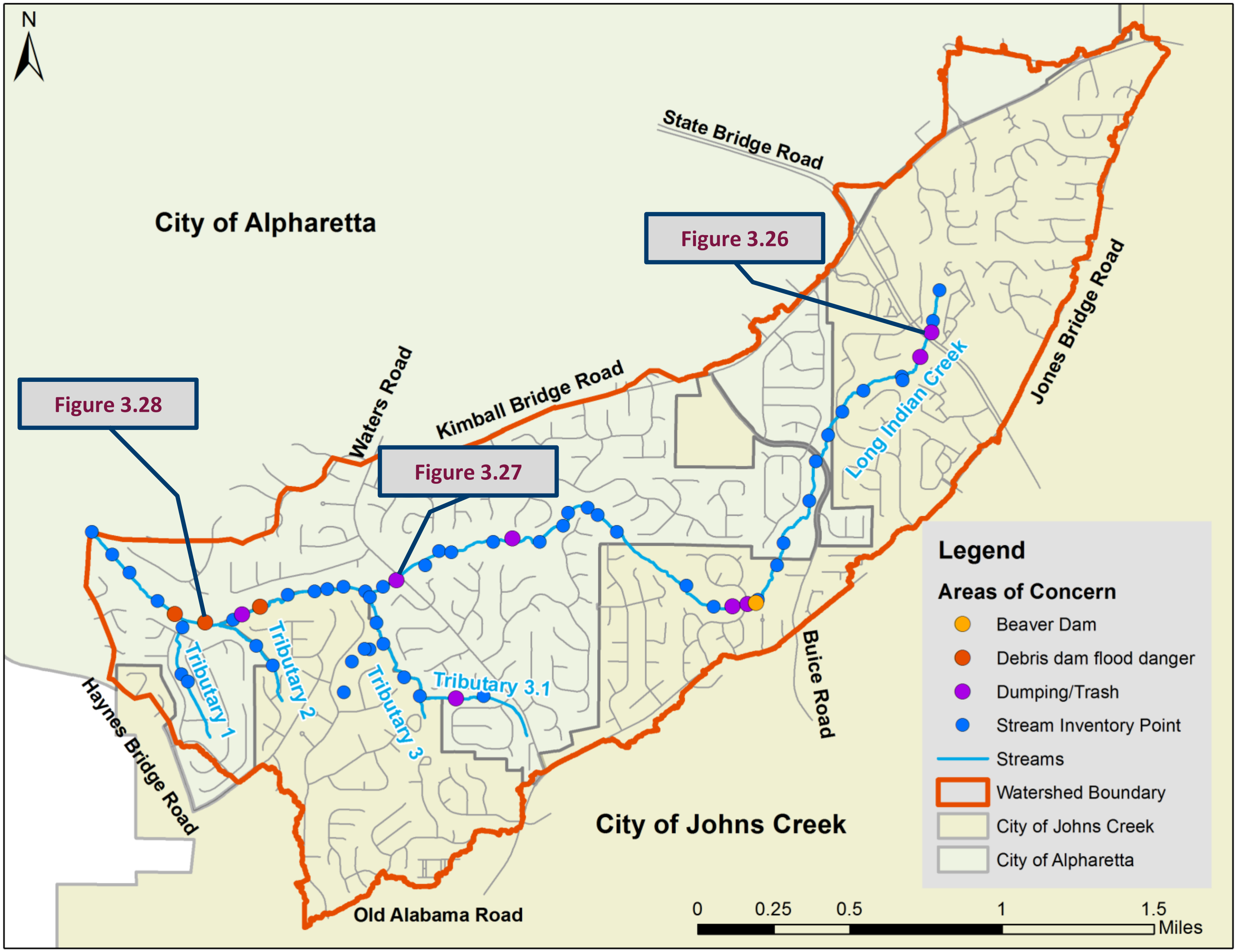


Figure 3.25 – Other areas of concern in Long Indian Creek. The most common/major issues noticed in the creek were debris dams, dumping/trash, and a beaver dam located just north of where Willow Meadow Circle crosses Long Indian Creek.

Figure 3.26 – Debris and trash blocking the entrance to the culvert. The debris could be a flooding concern and/or could damage the culvert during a flood event.

Figure 3.27 – A corrugated metal pipe is lodged under the bridge for Waters Road.

Figure 3.28 – A large debris dam has formed in Long Indian Creek. The debris dam is a flooding concern as it could cause a large flood hazard if it traps more debris, further blocking the flow of water, or is suddenly dislodged during a flooding event.

3.2.3 Field Inventory Recommendations

Based on observed field conditions, initial recommendations were made for each inventory point involving the suggested restoration measure, the ease of implementing the restoration measure, and the accessibility of the site to construct the suggested restoration measure. The restoration measures and anticipated level of effort described in this report are preliminary and further field visits are required to fully assess the feasibility of implementing the restoration method. However, these general recommendations can be used to rapidly identify and assess potential project options for restoring portions of Long Indian Creek and its Tributaries. **Figure 3.29** to **Figure 3.32** provide a map of inventory points that show the amount of effort and expense anticipated to complete the restoration measure, the ease of accessibility to construct the restoration measure, and the suggested restoration measure(s), respectively. Further, the rankings for restoration effort and accessibility issues have been additively combined to provide a more comprehensive image of the projects requiring the most extensive amount of input from both a resources and ease-of-access perspective. **Figure 3.31** provides the combined rankings for restoration effort and accessibility issues. Similarly to **Figure 3.29** and **Figure 3.30**, a lower ranking indicates more extensive project requirements, implying that more resources are needed to complete the project and that accessibility issues are more likely to arise during the project.

Table 3.3 to **Table 3.5** provide definitions and explanations for abbreviations and terminology seen in **Figure 3.29** to **Figure 3.32**.

Table 3.3 – Restoration effort ratings and descriptions.

Rating	Restoration Effort	Description
1	Extensive	Restoration efforts would be very expensive and require extensive permitting.
2	Major	Restorations efforts require resources between Moderate and Extensive efforts.
3	Moderate	Restoration efforts would address moderate problems that may require a moderate amount of equipment, planning, funding, and permitting.
4	Minor	Restorations efforts require resources between Minimal and Minor efforts.
5	Minimal	Restoration efforts would correct minor problems that could be corrected with minimal labor, planning, and funding.

Table 3.4 – Accessibility ratings and descriptions.

Rating	Accessibility Issues	No. Private Parcels Affected	Description
1	Extensive	>5	Site is difficult to reach by foot and vehicle
2	Major	3-4	Site is moderately accessible by foot and vehicle
3	Moderate	2-3	Site is easily accessible by foot but not easily accessible by vehicle
4	Minor	2	Site is easily accessible by foot and moderately accessible by vehicle
5	Minimal	1	Site is easily accessible by both foot and vehicle

Table 3.5 – Restoration measures, abbreviations, and descriptions.

Restoration Measure	Abbreviation	Measure Description
Riparian Buffers	BU	Plant trees and other woody vegetation in the riparian zone to enhance or widen the existing buffer. Each bank length is entered separately (i.e., a 100 foot restoration project with planted buffers on both sides is 200 feet).
Grade Control Group	CG	Designed to maintain a desired streambed elevation by either raising the bed or maintaining the bed at the current elevation. Measures include weirs, cross vanes, step pools, and drop structures and can be made of rock or log materials.
Debris Removal	DR	Measure used when large debris dams should be removed to alleviate the stress on the stream banks and upstream sedimentation.
Bank Protection Group	PG	Designed to protect the streambank from erosion or failure with structural measures. Use along banks where infrastructure protection is important or when space or erosive velocities are the constraint. Examples are rip-rap, rootwads, boulder revetments, lunkers, and A-jacks.
Mixed Bank Protection/Bank Stabilization	PS	Combination of PG and SG measures where structural measures are put along the toe of the bank and stabilization measures along the remainder of the bank. This is best used when the majority of the erosive velocities are undermining the toe of the bank, leading to bank failure or slumping.
Bank Stabilization/Bioengineering	SG	Non-structural measures to stabilize banks to protect against erosion by regrading the streambanks to a stable angle and geometry and planting with native plantings and use of biodegradable materials to stabilize the banks. Includes regrading, live stakes, branch packing or layering, mattresses, fascines, and joint planting.
Rosgen Priority 1 Channel Restoration	SR1	Re-establish the channel on the previous floodplain using the relic channel or construct a new bankfull discharge channel. The dimension, pattern and profile designed to a stable form. Fill the existing channel to the floodplain.

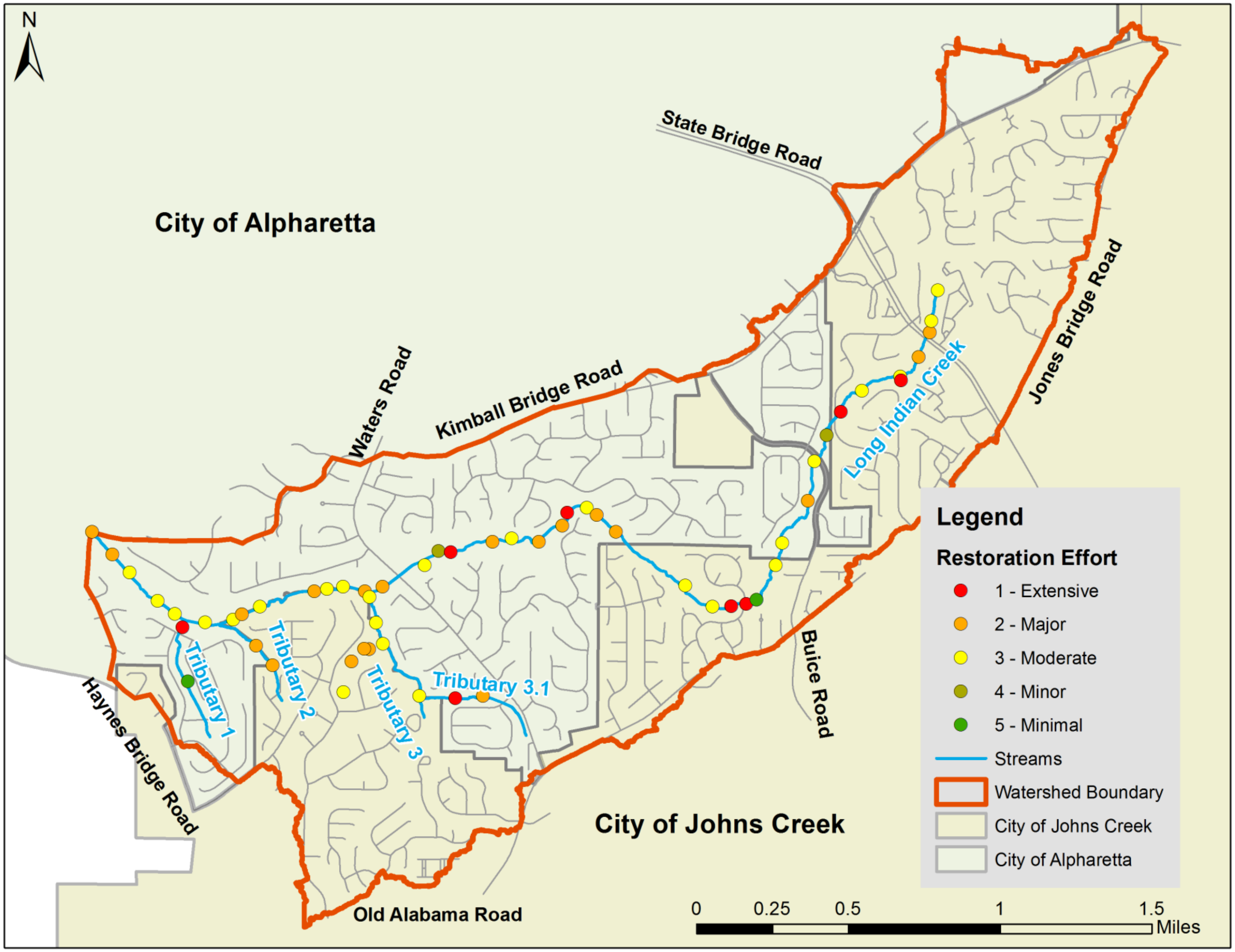


Figure 3.29 – Restoration effort required by each stream inventory point to implement restoration measures.

Figure 3.30 – Accessibility issues likely to be encountered at each stream inventory point in order to implement restoration measures.

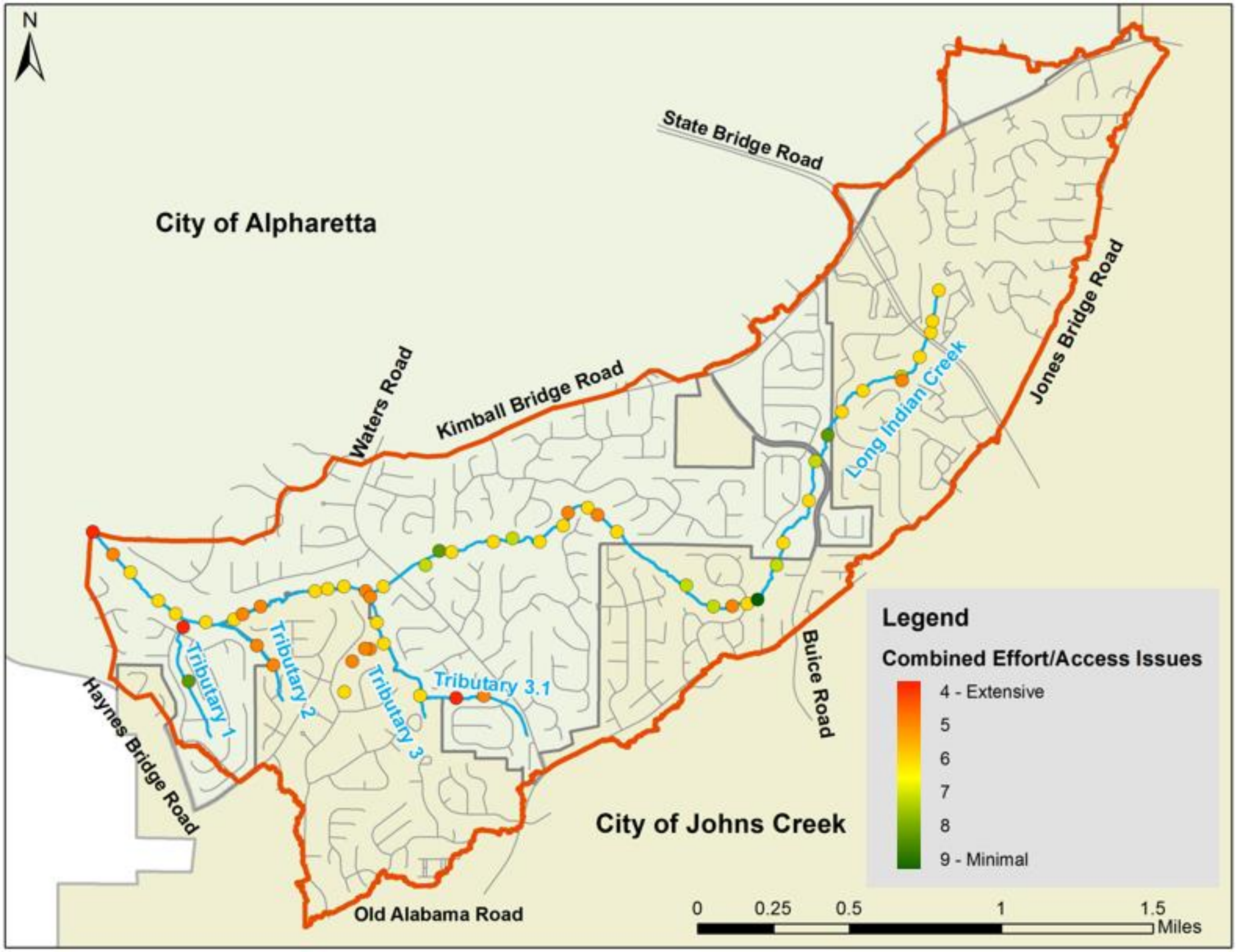


Figure 3.31 – Rankings for restoration effort and accessibility issues have been additively combined to provide a more comprehensive image of the projects requiring the most extensive amount of input from both a resources and ease-of-access perspective.

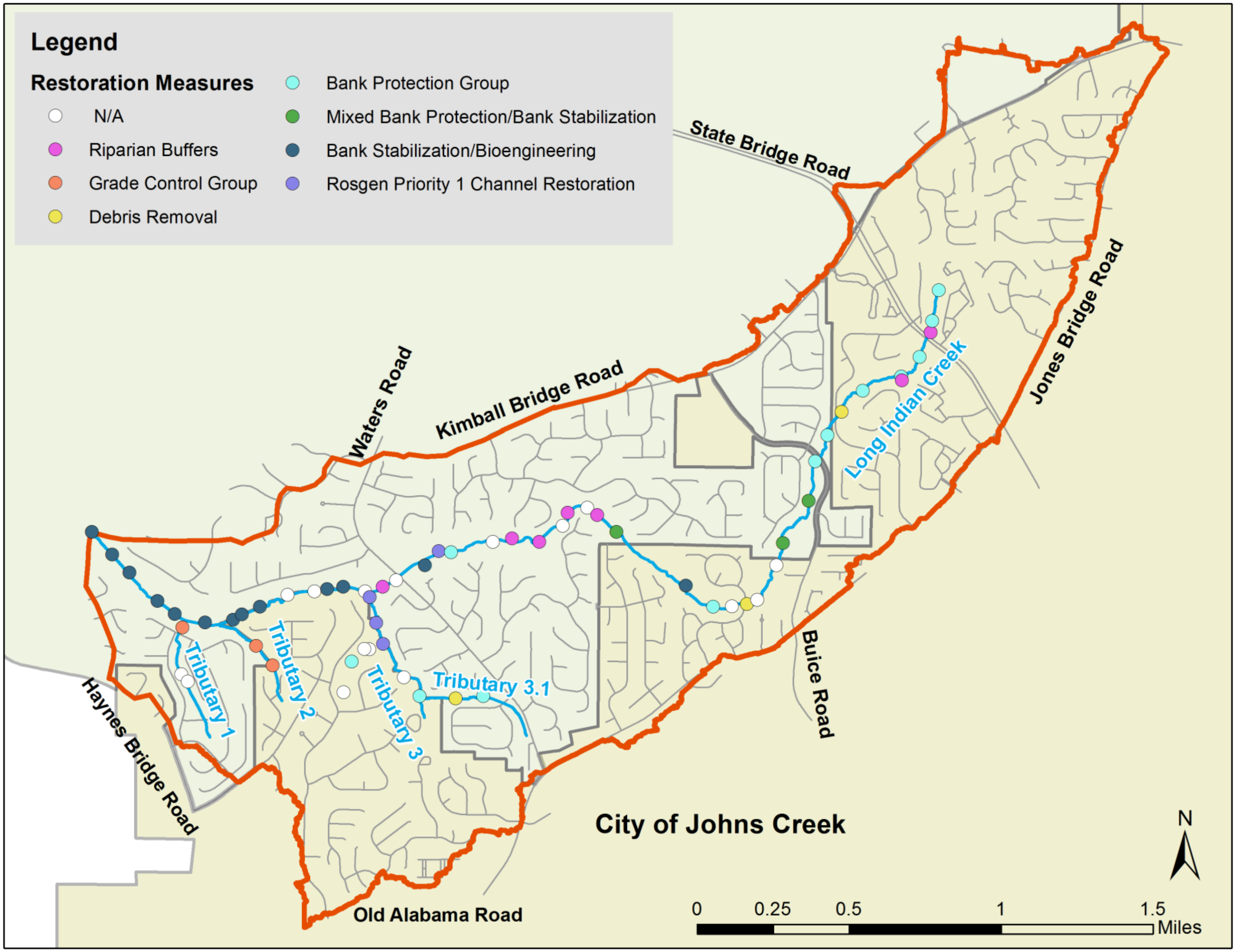


Figure 3.32 – Suggested restoration measures for each stream inventory point. Not all inventory points require restoration. These points are labeled as "N/A".

3.2.4 Field Reconnaissance Summary

During the stream inventory, several key areas of concern were identified that could potentially be contributing to elevated levels of fecal coliform in the Long Indian Creek Watershed. Common areas used for walking animals were noted as a major concern, especially parks, athletic fields, and walking trails directly bordering Long Indian Creek and its Tributaries. Along one of these parks in the Hampton Hall subdivision in the lower reach of Long Indian Creek, a bag of dog waste was found discarded in the creek. Further, several damaged BMPs were noted during the stream inventory. Although dry and dry extended detention basins are not credited for fecal coliform removal, they do provide flow attenuation of peak discharges, proving critical in protecting the overall health of the watershed. Once damaged, these BMPs no longer provide the necessary flow attenuation to reduce erosion and TSS loading in the watershed. Further, these damaged BMPs provide retrofit opportunities to easily improve the functioning of existing detention ponds, and potentially convert dry detention ponds to wet ponds or wetlands that can contribute to the reduction of fecal coliform loads in the watershed. The field inventory also documented major deficiencies including suspicious discharge, severely eroding stream banks, large debris jams, culvert maintenance issues, and possible stream water withdrawal points. All of these deficiencies negatively affect the health of the watershed and also have the ability to negatively affect the elevated fecal coliform in the watershed.

In order to begin addressing the deficiencies noted in the steam inventory, preliminary suggestions for stream restoration measures have been provided along with rankings for restoration effort and ease of site access. This information, when combined with modeling results showing the most impactful projects, can be used to prioritize and select watershed improvement projects.

3.3 Water Quality Data

Long Indian Creek is listed as an impaired stream on the Georgia Environmental Protection Division (EPD) 303(d) list for fecal coliform for its entire four mile reach. The EPD developed a Total Maximum Daily Load (TMDL) for Long Indian Creek in 2013 that recommends a 95% reduction in fecal coliform.

The City of Alpharetta began consistently monitoring the water quality in Long Indian Creek in 2008. Further steps towards assessing the condition of the watershed began in 2014 when the City of Alpharetta and the City of Johns Creek entered into a Sampling and Quality Assurance Plan (SQAP) for testing and analysis of fecal coliform on Long Indian Creek. Samples are taken four times a year at 5 different locations along Long Indian Creek to identify potential sources and analyze trends. The sampling locations are shown in **Figure 3.1**. Furthermore, Fulton County is conducting water quality monitoring for fecal coliform on Long Indian Creek at Waters Road (Site 4). All the results of these monitoring efforts have been combined in this report and are presented in the next section.

As an additional measure, the City of Alpharetta elected to utilize Bacterial Source Tracking (BST) sampling for human, dog, geese, bird, and ruminants as a part of this project in the fall of 2015 and spring of 2016 to identify the organisms contributing to the elevated fecal coliform levels in the Long Indian Creek Watershed. BST is a new technology used to identify the source of contamination based on DNA markers. BST copies and amplifies the DNA of the fecal coliform bacteria found in water samples and compares it with an existing DNA library to determine if the fecal coliform bacteria has human, dog, geese, bird, or goose origins. Samples were taken at the same five locations used for standard fecal coliform monitoring on four different days:

- November 12, 2015
- December 3, 2015
- April 12, 2016
- May 17, 2016

The November 12, 2015, sampling was conducted during dry weather conditions, defined as less than 0.1 inches of precipitation in the past 72 hours. All other samples were collected during wet weather conditions, defined as 0.3 or greater inches of precipitation within 24 hours of sampling. All precipitation measurements were based on USGS gage 02335700 on Big Creek near Alpharetta, GA. The results of the BST are presented in this section.

3.3.1 Fecal Coliform Monitoring Results

The below tables show the fecal coliform measurements for the five sampling locations on Long Indian Creek. The following results include both Fulton County's and the City of Alpharetta's results. It should be noted that the measurements become much more frequent beginning in 2014. It was at this time that the City of Alpharetta and the City of Johns Creek entered into a SQAP to further enhance testing and analysis of fecal coliform in Long Indian Creek. The City of Alpharetta measured many more water quality indicators in addition to fecal coliform counts. These additional data are provided in APPENDIX E: SAMPLED WATER QUALITY DATA.

Table 3.6 - Fecal coliform sampling results for Site 1 on State Bridge Road.

Sample Date	Fecal Coliform 9222D (cfu/100mL)	Sample Date	Fecal Coliform 9222D (cfu/100mL)	Sample Date	Fecal Coliform 9222D (cfu/100mL)
9/30/2014	900	4/28/2015	40	1/5/2016	205
10/9/2014	665	7/1/2015	330	1/12/2016	80
1/6/2015	200	7/7/2015	105	1/19/2016	90
1/13/2015	720	7/21/2015	130	1/26/2016	80
1/20/2015	45	7/28/2015	275	4/5/2016	320
1/27/2015	60	10/6/2015	185	4/11/2016	290
4/1/2015	120	10/13/2015	2950	4/19/2016	525
4/7/2015	1260	10/20/2015	25	4/26/2016	260
4/21/2015	195	10/30/2015	210		

Table 3.7 – Fecal coliform sampling results for Site 2 on Buice Road.

Sample Date	Fecal Coliform 9222D (cfu/100mL)	Sample Date	Fecal Coliform 9222D (cfu/100mL)	Sample Date	Fecal Coliform 9222D (cfu/100mL)
9/30/2014	900	4/28/2015	40	1/5/2016	205
10/9/2014	665	7/1/2015	330	1/12/2016	80
1/6/2015	200	7/7/2015	105	1/19/2016	90
1/13/2015	720	7/21/2015	130	1/26/2016	80
1/20/2015	45	7/28/2015	275	4/5/2016	320
1/27/2015	60	10/6/2015	185	4/11/2016	290
4/1/2015	120	10/13/2015	2950	4/19/2016	525
4/7/2015	1260	10/20/2015	25	4/26/2016	260
4/21/2015	195	10/30/2015	210		

Table 3.8 - Fecal coliform sampling results for Site 3 on Willow Meadow Circle in the City of Johns Creek.

Sample Date	Fecal Coliform 9222D (cfu/100mL)	Sample Date	Fecal Coliform 9222D (cfu/100mL)	Sample Date	Fecal Coliform 9222D (cfu/100mL)
10/9/2014	300	7/1/2015	110	1/5/2016	110
1/6/2015	30	7/7/2015	90	1/12/2016	30
1/13/2015	180	7/21/2015	50	1/19/2016	40
1/20/2015	70	7/28/2015	30	1/26/2016	60
1/27/2015	180	10/6/2015	210	4/5/2016	100
4/1/2015	30	10/13/2015	2300	4/11/2016	40
4/7/2015	80	10/20/2015	80	4/19/2016	360
4/21/2015	200	10/29/2015	170	4/26/2016	120
4/28/2015	70				

Table 3.9 – Fecal coliform sampling results for Site 4 on Waters Road.

Sample Date	Fecal Coliform 9222D (cfu/100mL)	Sample Date	Fecal Coliform 9222D (cfu/100mL)	Sample Date	Fecal Coliform 9222D (cfu/100mL)
7/30/2008	230	11/15/2011	60	1/20/2015	110
9/17/2008	130	2/9/2012	70	1/27/2015	40
10/1/2008	85	3/6/2012	105	4/1/2015	30
11/12/2008	20	3/29/2012	150	4/7/2015	30
12/17/2008	10	4/24/2012	760	4/21/2015	750
1/21/2009	53	6/20/2012	150	4/28/2015	50
2/26/2009	50	7/25/2012	280	6/2/2015	560
4/16/2009	57	9/27/2012	170	6/9/2015	300
4/29/2009	100	10/10/2012	662	6/18/2015	190
6/10/2009	150	11/5/2012	230	6/24/2015	80
6/24/2009	220	11/27/2012	90	7/1/2015	20
7/28/2009	2300	1/9/2013	40	7/7/2015	120
8/25/2009	110	1/29/2013	70	7/21/2015	140
10/21/2009	130	3/5/2013	40	7/28/2015	180
11/18/2009	150	4/10/2013	30	8/3/2015	350
12/28/2009	60	5/8/2013	200	8/18/2015	4800
1/7/2010	0	6/5/2013	415	8/20/2015	520
2/9/2010	30	7/8/2013	50	8/26/2015	460
2/19/2010	0	8/26/2013	170	10/6/2015	130
4/6/2010	0	9/17/2013	6600	10/13/2015	2300
4/21/2010	20	10/10/2013	130	10/20/2015	60
5/25/2010	50	10/22/2013	90	10/27/2015	90
7/7/2010	80	11/5/2013	30	11/4/2015	700
8/4/2010	70	11/25/2013	10	11/9/2015	3700
8/18/2010	440	3/5/2014	1	11/12/2015	170
10/12/2010	200	4/28/2014	20	11/17/2015	160
11/3/2010	320	5/21/2014	70	1/5/2016	140
12/20/2010	70	6/17/2014	80	1/12/2016	50
1/5/2011	50	7/2/2014	120	1/19/2016	120
2/15/2011	60	7/9/2014	100	1/26/2016	460
3/23/2011	50	7/9/2014	150	2/1/2016	180
5/2/2011	10	8/14/2014	140	2/8/2016	140
5/10/2011	75	8/26/2014	70	2/15/2016	50
5/23/2011	100	9/22/2014	190	2/26/2016	290
6/28/2011	40	9/30/2014	340	4/5/2016	170
7/19/2011	40	10/9/2014	160	4/11/2016	120
8/22/2011	4300	1/6/2015	130	4/19/2016	60
9/19/2011	50	1/13/2015	150	4/26/2016	60
10/26/2011	85				

Table 3.10 - Fecal coliform sampling results for Site 5 at the park on High Hampton Chase.

Sample Date	Fecal Coliform 9222D (cfu/100mL)	Sample Date	Fecal Coliform 9222D (cfu/100mL)	Sample Date	Fecal Coliform 9222D (cfu/100mL)
9/30/2014	120	4/28/2015	30	1/5/2016	40
10/9/2014	620	7/1/2015	130	1/12/2016	30
1/6/2015	100	7/7/2015	100	1/19/2016	10
1/13/2015	70	7/21/2015	140	1/26/2016	30
1/20/2015	40	7/28/2015	660	4/5/2016	120
1/27/2015	0	10/6/2015	180	4/11/2016	20
4/1/2015	10	10/13/2015	1000	4/19/2016	40
4/7/2015	60	10/20/2015	50	4/26/2016	20
4/21/2015	2100	10/29/2015	60		

3.3.2 Delisting Evaluation and Recommendation

Long Indian Creek is listed as an impaired stream on the Georgia Environmental Protection Division (EPD) 303(d) list for fecal coliform for its entire four mile reach. The EPD developed a Total Maximum Daily Load (TMDL) for Long Indian Creek in 2013 that recommends a 95% reduction in fecal coliform. Since the Long Indian Creek Watershed is located in both the City of Alpharetta and the City of Johns Creek, they entered into a SQAP in 2014 to better monitor the fecal coliform contamination in Long Indian Creek. During 2015, the City of Alpharetta collected 80 water quality grab samples in accordance with the SQAP. Additional samples were taken to establish ambient water quality and identify concentrated sources of fecal contamination. These samples were used to generate geometric mean values for each month in which samples were collected. These geometric means are presented in **Error! Reference source not found.**. The results from Technical Memorandum "Long Indian Creek Stream Delisting Evaluation and Summary" are compiled in this section, and the entire technical memorandum can be found in APPENDIX F: LONG INDIAN CREEK STREAM DELISTING EVALUATION AND SUMMARY TECHNICAL MEMORANDUM (R2T, 2015).

Table 3.11 - Geometric mean values for each sample site for the months in which sampling occurred. Values are presented in MPN/100mL. **BOLD** values exceed the Georgia 391-3-6 Water Use Classification and Water Quality Criteria Rule.

Date	SITE 1 State Bridge Road	SITE 2 Buice Road	SITE 3 Willow Meadow Road	SITE 4 Waters Road	SITE 5 High Hampton Chase
January 2015	58	140	91	96	23
April 2015	35	185	76	76	78
July 2015	62	188	**391**	88	186
October 2015	**285**	**231**	**406**	**200**	152
January 2016	57	104	53	140	25
April 2016	47	336	115	93	37
Fulton County Data					
June 2015	--	--	--	**225**	--
August 2015	--	--	--	**796**	--
November 2015	--	--	--	515	--
February 2016	--	--	--	138	--

The standards required by the Georgia Water Use Classification and Water Quality Criteria for freshwater streams, lakes and reservoirs is presented in **Table 3.12**. The table shows the minimum requirements that must be met by each geometric mean value depending on summer or winter conditions. From May to October (summer season) the geometric mean value limit is 200 MPN/100mL, and no single sample should exceed 500 MPN/100mL. From November to April (winter season), the geometric mean value limit is 1000 MPN/100mL (GAEPD, 2016). These values are based on the designated use of "Fishing" for Long Indian Creek.

Table 3.12 - Georgia Water Quality Criteria limits based on designation of "Fishing" for Long Indian Creek.

Season	Criteria[1]	Water Body
May - October	200 MPN/100mL	Stream/River
	300[2] MPN/100mL	Lakes and Reservoirs
	500[2] MPN/100mL	Flowing Freshwater Streams
November - April	1000 MPN/100mL	Streams/Rivers
	>4000 MPN/100mL for any one sample	

[1]Not to exceed value of 300 col/100mL for Lakes and Reservoirs and 500 col/100mL for streams

[2]Not to exceed value of 4,000 col/100mL

The amount of precipitation correlates strongly with fecal coliform levels. It was noted that heavy rainfall events or extended periods of wet weather seemed to elevate the levels of fecal bacteria in the water samples. Whereas samples collected during dryer weather had lower levels of fecal coliform. Since 2015 is considered a wet year with 56.97 inches of precipitation, some of the elevated fecal coliform levels can be attributed to the wetter weather. Additionally, three of the six months in which water samples were collected experienced rainfall totals in excess of five inches. **Table 3.13** shows the total rainfall for each month in which water samples were collected.

Table 3.13 – Precipitation totals from USGS Gage 02335700 Big Creek near Alpharetta, GA.

Month	Precipitation (inches)
January 2015	4.58
April 2015	6.70
June 2015	1.58
August 2015	3.36
October 2015	5.60
November 2015	6.10
January 2016	4.41
February 2016	4.34
April 2016	6.70

According to Georgia's 2014 305(b)/303(d) Listing Assessment Methodology, a stream can be delisted if it meets the following criteria (GAEPD, 2014).

If there is one year of available data:

> *"Waters were eligible for delisting for fecal coliform if 10% or less of the geometric means exceeded the water quality criteria. If fewer than 4 geometric means were available for assessment, GA EPD may have considered a water eligible for delisting if there were at least two summer geometric means available for assessment and they complied with the water quality criteria."*

If there are multiple consecutive years of available data:

> *"Waters were eligible for delisting for fecal coliform bacteria if 10% or fewer of the geometric means exceeded water quality criteria."*

Thirty-four geometric mean values could be computed from the water samples collected. Of those 34 values, 27 were within the water quality limits show in **Table 3.12** and 7 values exceeded the water quality criteria. Therefore, 21% of the geometric mean values exceeded the water quality standards established by Georgia. Twelve geometric mean values occurred in the summer season (May-October), and of those twelve values, seven exceeded the water quality limits of 200 MPN/100mL (summer season only). Therefore, 58% of the summer season geometric mean values were not within the water quality limits. Whereas in the winter season, none of the geometric mean values exceeded the water quality standards of 1000 MPN/100mL.

Figure 3.33 is presented to further help visualize the TMDL for Long Indian Creek. **Figure 3.33** shows the TMDL curve for the summer and winter season. Since the TMDL is affected by the creek discharge, a larger flow will increase the TMDL curve. Therefore, both the summer and winter fecal coliform loads increase as the flow increases. The average flow presented in **Figure 3.33** and **Table 3.14** are estimated based on flow at the Crooked Creek gage near Norcross, GA, (Station No. 02335350) which is noted as the representative watershed by the GAEPD report in the Total Maximum Daily Load Evaluation for the Chattachoochee River Basin (GAEPD, 2013).

The points in **Figure 3.33** represent the measured fecal coliform counts for each of the five sites for every sampling month. In agreement with **Table 3.11**, **Figure 3.33** shows seven measured summer load points exceeding the summer TMDL curve and no measured winter load points exceeding the winter TMDL curve. However, the values displayed in **Figure 3.33** differ from those in **Table 3.11** because the values form **Table 3.11** have been converted from daily geometric means to monthly fecal coliform loads measured in total fecal counts per 30 days. The monthly fecal coliform loads displayed in **Figure 3.33** are provided in **Table 3.14**.

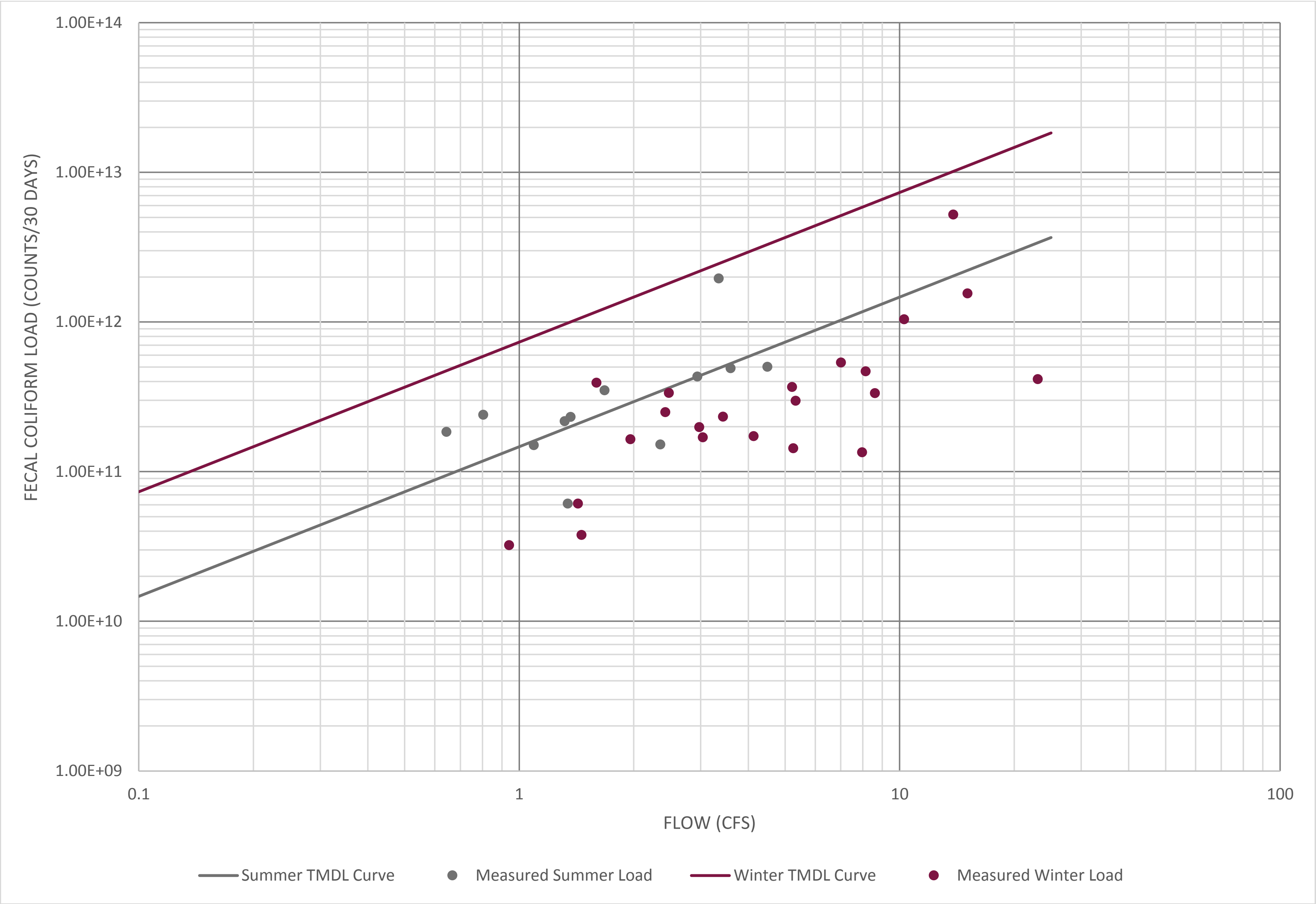


Figure 3.33 - Comparison of summer and winter TMDL curves to measured data from Long Indian Creek.

Table 3.14 – Measured summer and winter TMDLs.

Season	Sample Date	Site No.	Average Flow[1] (cfs)	TMDL (counts/30 days)
Winter	January 2015	1	1.4	6.12E+10
Winter	January 2015	2	2.4	2.49E+11
Winter	January 2015	3	3	1.98E+11
Winter	January 2015	4	5.2	3.68E+11
Winter	January 2015	5	8	1.34E+11
Winter	April 2015	1	1.5	3.77E+10
Winter	April 2015	2	2.5	3.36E+11
Winter	April 2015	3	3	1.70E+11
Winter	April 2015	4	5.3	2.98E+11
Winter	April 2015	5	8.1	4.68E+11
Summer	June 2015	4	1.3	2.17E+11
Summer	July 15	1	0.6	1.85E+11
Summer	July 15	2	1.1	1.50E+11
Summer	July 15	3	1.3	6.11E+10
Summer	July 15	4	2.3	1.52E+11
Summer	July 15	5	3.6	4.91E+11
Summer	August 2015	4	3.3	1.95E+12
Summer	October 2015	1	0.8	2.40E+11
Summer	October 2015	2	1.4	2.32E+11
Summer	October 2015	3	1.7	3.50E+11
Summer	October 2015	4	2.9	4.32E+11
Summer	October 2015	5	4.5	5.02E+11
Winter	November 2015	4	13.8	5.23E+12
Winter	January 2016	1	4.1	1.73E+11
Winter	January 2016	2	7	5.36E+11
Winter	January 2016	3	8.6	3.35E+11
Winter	January 2016	4	15.1	1.55E+12
Winter	January 2016	5	23.1	4.14E+11
Winter	February 2016	4	10.3	1.04E+12
Winter	April 2016	1	0.9	3.23E+10
Winter	April 2016	2	1.6	3.93E+11
Winter	April 2016	3	2	1.65E+11
Winter	April 2016	4	3.4	2.33E+11
Winter	April 2016	5	5.2	1.43E+11

[1]Estimated based on representative flow at the Crooked Creek gage near Norcross, GA (Station No. 02335350).

Based on these results it is recommended that the City of Alpharetta and the City of Johns Creek continue to monitor fecal coliform levels in the Long Indian Creek Watershed. The most crucial months for monitoring are May-October as these are the months in which Long Indian Creek is most likely to exceed the water quality limits. For this reason, further monitoring steps were taken by implementing BST in the watershed in order to determine the origin of the fecal contamination, allowing for proposed solutions to be more targeted and impactful. These targeted projects will assist the City of Alpharetta in reducing the summer season fecal loading to meet the water quality standards. Once fecal coliform levels are consistently below the summer and winter water quality standards, the City of Alpharetta can submit the data to the Georgia EPD for delisting consideration.

3.3.3 Bacterial Source Tracking Results

Dewberry worked with Source Molecular based in Miami, FL, to test water samples at the various sampling sites for the presence/absence of bird, dog, goose, Human (Dorei and EPA tests), and ruminant fecal coliform contamination. BST sampling is a key part of this project as it identifies the main sources of fecal contamination, allowing Dewberry to design a more targeted watershed improvement plan to address the main sources of fecal contamination. In section 3.1.2, **Figure 3.1** shows the location of the sampling sites, and **Table 3.1** shows the tests that were performed at each sampling location.

BST allows for the determination of the source(s) of fecal contamination because of variations in DNA sequences between living organisms that make it possible to distinguish one organisms from another through molecular biology techniques. This can be done through a process called Polymerase Chain Reaction (PCR) in which DNA sequences are extracted and amplified to identify and quantify the presence of microorganisms in water samples based on the unique genetic sequence of that organism (Source Molecular, 2016). This process is the preferred BST technology (Shanks , 2015), and Source Molecular is licensed by the EPA to use their patented genetic testing methods developed to identify Human, cattle, chicken, and dog fecal contamination. Samples were taken at the same five locations used for standard fecal coliform monitoring on four different days:

- November 12, 2015
- December 3, 2015
- April 12, 2016
- May 17, 2016

The November 12, 2015, sampling was conducted during dry weather conditions, defined as less than 0.1 inches of precipitation in the past 72 hours. All other samples were collected during wet weather conditions, defined as 0.3 or greater inches of precipitation within 24 hours of sampling. All precipitation measurements were based on USGS gage 02335700 on Big Creek near Alpharetta, GA. The BST results for the tests performed at the various sites along Long Indian Creek are displayed in **Table 3.15** to **Table 3.20**. A more detailed analysis is provided in the Technical Memorandum "Long Indian Creek Bacteria Source Tracking" found in APPENDIX G: LONG INDIAN CREEK BACTERIA SOURCE TRACKING TECHNICAL MEMORANDUM (R2T, 2016). If there was a sufficient amount of fecal contamination to quantify the fecal coliform count, a number is provided in the below tables. If contamination was present but not a sufficient amount to quantify, this result is labeled at "Trace" in the below tables. Finally where no fecal coliform was detected, this result is labeled as "Absent".

Table 3.15 – BST results for Bird in Long Indian Creek. Any quantification of fecal coliform is presented in copies/100mL.

Sample Date	Sampling Event	Site 1	Site 2	Site 3	Site 4	Site 5
11/13/2015	Dry	Trace	Absent	Absent	Trace	Absent
12/3/2015	Wet	Absent	Absent	Absent	Absent	Absent
4/13/2016	Wet	Trace	Trace	Trace	Absent	Absent
5/18/2016	Wet	Trace	Trace	Trace	Trace	Trace

Table 3.16 – BST results for Dog in Long Indian Creek. Any quantification of fecal coliform is presented in copies/100mL.

Sample Date	Sampling Event	Site 1	Site 2	Site 3	Site 4	Site 5
11/13/2015	Dry	Trace	Absent	Absent	356	Trace
12/3/2015	Wet	14,300	16,600	8,560	12,300	19,300
4/13/2016	Wet	2,600	29,600	12,200	17,200	24,900
5/18/2016	Wet	4,610	5,030	7,680	7,690	15,300

Table 3.17 – BST results for Goose in Long Indian Creek. Any quantification of fecal coliform is presented in copies/100mL.

Sample Date	Sampling Event	Site 1	Site 2	Site 3	Site 4	Site 5
11/13/2015	Dry	Absent	Not Tested	Not Tested	Absent	Not Tested
12/3/2015	Wet	Absent	Not Tested	Not Tested	Absent	Not Tested
4/13/2016	Wet	Absent	Not Tested	Not Tested	Absent	Not Tested
5/18/2016	Wet	Absent	Not Tested	Not Tested	Absent	Not Tested

Table 3.18 – BST results for Human Dorei in Long Indian Creek. Any quantification of fecal coliform is presented in copies/100mL.

Sample Date	Sampling Event	Site 1	Site 2	Site 3	Site 4	Site 5
11/13/2015	Dry	Absent	Trace	Absent	Trace	Absent
12/3/2015	Wet	387	377	251	294	330
4/13/2016	Wet	Trace	Trace	294	Trace	Trace
5/18/2016	Wet	599	758	739	693	1150

Table 3.19 – BST results for Human EPA in Long Indian Creek. Any quantification of fecal coliform is presented in copies/100mL.

Sample Date	Sampling Event	Site 1	Site 2	Site 3	Site 4	Site 5
11/13/2015	Dry	Absent	Absent	Absent	Absent	Absent
12/3/2015	Wet	Absent	Absent	Absent	Trace	Trace
4/13/2016	Wet	Absent	Absent	Absent	Absent	Absent
5/18/2016	Wet	Trace	Trace	Trace	320	371

Table 3.20 – BST results for Ruminant in Long Indian Creek. Any quantification of fecal coliform is presented in copies/100mL.

Sample Date	Sampling Event	Site 1	Site 2	Site 3	Site 4	Site 5
11/13/2015	Dry	Not Tested	Absent	Absent	Not Tested	Absent
12/3/2015	Wet	Not Tested	Trace	Absent	Not Tested	Trace
4/13/2016	Wet	Not Tested	Absent	Absent	Not Tested	Absent
5/18/2016	Wet	Not Tested	Trace	Absent	Not Tested	Trace

Both the Dorei and EPA tests were used to detect Human fecal contamination for purposes of quality assurance of the results. Although the Dorei test provides the best choice for detecting human fecal matter because of its sensitivity and specificity, it has occasionally been shown to "cross-react" with chicken or dog feces, providing a false positive for Human fecal contamination when none is present. For this reason, the Dorei test can be paired with the EPA test to corroborate results. As the EPA test is slightly less sensitive than the Dorei test, the absence of the EPA marker does not guarantee that no human fecal matter is present. However if both the Dorei and EPA tests detect Human fecal matter, it is a strong indicator that Human fecal matter is present, providing an additional level of quality assurance (SCCWRP, 2013).

Due to the possibility of the Dorei test to "cross-react" with dog feces, producing a false positive, dog fecal samples were collected on May 17, 2016, to determine if any human biomarkers could be identified within the dog feces which would suggest "cross-reaction" was occurring within the watershed. However, the Dorei and EPA tests for the dog feces did not come back positive for any human biomarkers.

The BST indicates that the two main contributors of fecal contamination in the Long Indian Creek Watershed are Humans and dogs, with dogs being the predominant fecal source. Results for dog feces were far more numerous than results for Human fecal matter, especially when the Dorei test was compared to the EPA test. Further, results for dog fecal contamination were often several orders of magnitude larger than results for Human fecal contamination.

Based on the results of the BST, it is recommended that the City of Alpharetta continues to monitor the source of fecal coliform in the Long Indian Creek Watershed, especially in the spring and summer of 2016 when humans and animals are most active in the watershed. Future BST monitoring efforts should be conducted during wet weather events which produce the most information about bacteria sources and can be used to further develop a bacteria source profile, especially to measure progress as projects are completed to address fecal contamination in the watershed. Ideally, fecal coliform contamination from dog waste can be reduced through a multipronged approach including social marketing, education, and low-cost structural best management practices (BMPs). Recommended solutions will be discussed later in this report.

4 NEW DATA AND MODEL DEVELOPMENT

In order to most effectively assess watershed conditions during a storm event and evaluate potential impact of new projects, Dewberry developed a hydrodynamic rainfall-runoff simulation model was created for the Long Indian Creek Watershed using PCSWMM software (EPA SWMM 5 engine). Hydrologic and hydraulic modeling is based on existing land coverage conditions using the dynamic wave hydraulic model formulation. This method also allows time varying rainfall to be routed through the system, accounting for timing of the hydrographs, conduit storage, backwater, and losses in the system. This is the most accurate representation of actual conditions during a storm event and allows multiple synthetic and observed events to be modeled. The following section will detail the process used to develop the model and the results generated by the model.

4.1 Model Setup

In order to create a model that closely represents real-world conditions, a wide range of data sources were utilized. The sources of information used are:

- City of Alpharetta GIS stormwater inventory ;
- City of Johns Creek GIS stormwater inventory ;
- HEC-RAS models and flood studies recently complete for the City of Johns Creek;
- Imagery provided by the City of Alpharetta to develop an existing land use scenario;
- Fecal coliform sampling results from the City of Alpharetta, the City of Johns Creek, and Fulton County;
- Stream inventory data which included flooding and erosion concerns noted during stream walks;
- Field survey of pipe network which involved collecting information for new systems and filling information gaps for older systems, and;
- Testimony from citizens familiar with local flooding and erosion issues.

Proper model development and calibration are critical to create a model that accurately represents storm events. A more accurate model allows for more confidence in results when estimating and comparing solutions to achieve fecal load reduction goals. The following sections explain the steps taken to develop and calibrate the model for the Long Indian Creek Watershed.

4.1.1 Model Development

To create the existing conditions model for the Long Indian Creek Watershed, the effective HEC-RAS model for Long Indian Creek and its Tributaries was converted into a SWMM model. A SWMM model was selected for the hydrologic and hydraulic simulation of the watershed because the method allows for time varying rainfall to be routed through the system, accounting for timing of the hydrographs, conduit storage, backwater, and losses in the system. SWMM models produce the most accurate representation of actual conditions during a storm event and allow multiple synthetic and observed events to be modeled.

Once Long Indian Creek and its Tributaries were modeled, models of the stormwater systems within the City of Alpharetta contributing flow to Long Indian Creek were developed. To develop these system models, connectivity was built from the outfalls along Long Indian Creek to the most upstream contributing pipes maintained by the City of Alpharetta. Within the GIS program, ArcMap, adjustments were made to each individual pipe to correct for pipe direction, pipe and inlet locations, and headwall locations based on aerial imagery, terrain information, and provided measure down values. Open channels were then added as non-conduits and updated to match the latest terrain, and the connections between inlets, junctions, conduits, and non-conduits were individually verified to ensure that the system elements were snapped. This ensured top to bottom system connectivity. Making these connectivity corrections to the inventory dataset was critical to providing an accurate representation of the effectiveness of the stormwater system. Sometimes situations would arise where the inventory did not match the information shown by the terrain or imagery. These situations often required further evaluation and corrections to the inventory, and several trips to the field were made to verify the system connectivity.

Additionally, modeling parameters were assigned to each pipe and associated shapefiles. These parameters included roughness values depending on pipe material, culvert entrance loss coefficients depending on upstream inlet type, exit loss coefficients based on downstream inlet type and downstream channel condition, and culvert codes depending on pipe material and pipe shape. Each element of the system was also assigned a unique Structure ID. Pipes and inlets with existing Structure IDs provided by the City of Alpharetta remained the same, but any junctions, natural channels, or newly added pipes and inlets were given a unique identifier. These unique Structure IDs allow the City to better keep track of their inventory, as well as eliminate any redundancies in the model.

Upon completion of the connectivity corrections, Dewberry conducted a spatial analysis that assigned the terrain elevation to each end of the pipe at the inlet/structure. Dewberry then subtracted the measure down value from the assigned terrain value, estimated the upstream and downstream inverts for each closed conduit, and populated the result in the closed conduit inventory database. For open-end sections such as headwalls, plain end pipes, and flared-end sections, Dewberry assigned a measure down value of 0.0' and used the terrain to approximate the closed conduit's invert elevation at that point. Correct placement of inlets and pipes was essential to assign the correct terrain and invert values for all structures.

Similar to connectivity corrections, the process to review and correct the upstream and downstream inverts is a pipe-by-pipe process. Many inaccessible pipes with no measure down values were assumed using engineering judgment so that they would tie into the pipes with known measure down values. Dewberry further checked for negative slopes, pipes that did not have enough ground cover above them, and any measure downs and inverts that did not seem representative of real systems. Engineering judgment was used to estimate the inverts for these cases. These vertical profile corrections were equally important to modeling the effectiveness of the system as correcting the connectivity.

Once inverts for the system in the watershed were estimated, the Dewberry Team implemented a hydrologic and hydraulic (H&H) analysis of the system to determine the flow capacity level of service for each pipe segment. H&H modeling begins with an automated ArcGIS custom applications for subcatchment delineation and hydrologic parameter development. Subcatchments were developed for each inlet/end section that captures surface runoff using the automated toolsets, but due to the high level of detail required to delineate basins as small as some of those that drain into the stormwater system, engineers reviewed each basin individually and made manual adjustments. Some of the considerations that guided engineers in these delineations include splitting subcatchments along the centerline of the roadway and along the rooflines of houses. Topology checks were run to ensure that there were no overlapping subcatchments or gaps between the subcatchments. Runoff potential was developed using Soil Conservation Service (SCS) hydrologic methodologies. Flow paths were developed for each inlet from a digital elevation model (DEM) using flow accumulation methodology, and each subcatchment area was delineated based on flow paths. Each subcatchment's longest flow path was then extracted and used to calculate each subcatchment's width and average slope.

Once each subcatchment area was delineated, curve number (CN) values were developed from the union of land cover with soils data. Land cover is broken down into four categories: Impervious Cover, Vegetation (forested area), Open Space (lawns), and Open Water. By merging land cover with each hydrologic soil type (HSG) in ArcMap, detailed CN and Impervious Area values were determined to provide a return of runoff potential for every square foot of the entire watershed. This is particularly critical in that it captures all impervious areas, thus providing the most accurate account of runoff potential for each subcatchment in the study scope. **Table 4.1** provides the CN values used based on land cover and HSG.

Table 4.1 – Curve number (CN) values used based on land use type and hydrologic soil type.

Hydrologic Soil Type	Runoff Curve Number by Land Cover for each Soil Type			
	Impervious Areas	Open Water	Vegetation	Lawn/Open Space
A	98	98	25	39
B	98	98	55	61
C	98	98	70	74
D	98	98	77	80

SWMM models treat each subcatchment as a non-linear reservoir. This means that surface runoff from a precipitation event is generated after depression storage, infiltration, and evaporation are accounted for. Outflow was then determined using Manning's equation by continuously updating the depth of runoff and numerically solving a water balance equation over the subcatchment. The Manning's n values provided in **Table 4.2** are to be used for each material defined in the data dictionary.

Table 4.2 – Mannings n values used for each material in the SWMM model.

Pipe Material	Symbol	Mannings Value (n)
Aluminized Steel	AS	0.024
Reinforced Concrete	RC	0.013
Coated Corrugated Metal	CO	0.024
Plain Corrugated Metal	PL	0.024
Plastic/PVC	PT/PVC	0.015
Relined	RL	0.015
Clay	CL	0.013
Cast Iron	CI	0.013
Plain concrete	CP	0.013

SWMM models for the Long Indian Creek watershed study were setup to allow ponding on all junctions that flood so that no runoff volume was lost from the system at the outfall. All flooding was ponded on top of the junction to a depth that is dependent on the surface area at the junction and reintroduced into the system as capacity permits. In reality, the excess water will pond and, in most cases, runoff overland to the next runoff accepting junction. In order to better represent flooding conditions both in the pipe and overland, overland flow was modeled to convey flooded water on the node to the next downstream runoff accepting node for non-city maintained pipes that flood in the 25-year storm or less. This modeling technique was primarily used to represent overland flow from extended detention ponds that overtop in the 25-year storm or less, ensuring that water was not artificially attenuated by the model. Overland flow was modeled with conduits with irregular channel transects that represented the overland flow path to the next downstream junction. The upstream elevation of each overland flow conduit was set at the elevation at which the water began conveying to the downstream junction, and the downstream invert was set at the rim elevation of the downstream junction. For the Long Indian Creek model, overland flow was incorporated into model during the upgrade scenario. Overland flow was only required for non-city maintained junctions that were overtopped to ensure that the maximum amount of water was conveyed downstream to best represent real-world conditions. No overland flow was required for city-maintained pipes because, for the upgrade scenario, city-maintained systems were upgraded to ensure that they would not overtop in the 25-year storm event and city-maintained culverts would not overtop in the 100-year storm event.

Once the existing conditions model was stabilized and the level of service (LOS) was assigned to each pipe segment, the following rehabilitation and replacement scenarios were developed. For all scenarios, it is assumed that the existing vertical horizontal and vertical alignment will be maintained. It also assumed that the existing structure type was maintained, except that plain end sections were assumed to be upgraded to headwalls or flared end sections.

- Cured-in-Place Pipe Rehabilitation (CIPP)
  - For all City-maintained CO/AS/PL
    - Set Manning's 'n' as 0.015
    - No improvements to non-City maintained pipe
  - Maintain same pipe diameter (lining negligible)
  - Determine the LOS for this rehabilitation scenario
- Upgrade Scenario - Replace pipe with HDPE or RCP to meet desired level of service
  - For pipes not meeting desired LOS from CIPP/Replace like size scenarios
  - Desired LOS is 25-yr for closed, lateral and longitudinal systems
  - Desired LOS is 100-yr for culverts
  - Replace arch/ellipse pipe with equivalent round diameter
  - HDPE limitations
    - 60-inch diameter maximum
    - Do not use for pipes under roads
    - Do not use where depth of the trench is greater than 20-feet

Once each of the rehabilitation and replacement model scenarios were stabilized and finalized, the results for each of these tasks were populated into an inventory database for use with a Stormwater System Cost Estimation Tool. The Stormwater System Cost Estimation Tool is designed to generate pipe and structure specific concept-level construction cost estimates by aggregating specific data for each pipe and structure from an ArcGIS inventory and rehab/replacement database and integrating that data with an Excel unit cost database for the following rehabilitation and replacement scenarios.

- CIPP
- Replace like size with HDPE
  - Return "Not Applicable" where limitations exists
- Replace like size with RCP
- Replace pipe to meet desired LOS HDPE
  - Return "Not Applicable" where limitations exists
- Replace pipe to meet desired LOS RCP

The inventory database contains information regarding each pipe's existing LOS and results from the rehabilitation and replacement scenarios. Construction related items associated with rehabilitation or replacement of each pipe and structure that can be quantified from inventory database and GIS feature classes are populated in the database to serve as input data for the Stormwater System Cost Estimation Tool. These items, in general, include the following:

- CIPP rehabilitation, inversion setup, and pipe cleaning
- Pipe removal and replacement
- Depth to top of the pipe for depths over 8'
- Structure removal and replacement
- Unsuitable haul-off allowances
- Driveway, sidewalk, and street cut replacement
- Silt Fence and Sod

4.1.2 Pollutant Model Creation and Calibration

Once a complete model, including all applicable tributaries and stormwater conveyance systems, is created for the watershed, the model can be hydrologically calibrated, and pollutant modeling can be incorporated and calibrated. Since the models are used to simulate the TMDL, each model was run for a 30-day period using rainfall totals from the representative gage on Crooked Creek (USGS Gage 02335350). In order to ensure that modeled flows closely resembled measured flows, the percent error formula was used to compare the modeled flows at the five bacterial sampling sites, shown in **Table 3.1**, with adjusted gage flows, scaled with respect to the basin area, from the Crooked Creek Gage. The flows for both the model and gage were averaged over the entire 30-day period before being compared with the percent error formula.

$$\%\ Error = \left|\frac{Measured - Modeled}{Measured}\right| * 100$$

In order to hydrologically calibrate the model to closely match the actual flows, the model baseflows were increased for wet months and decreased for drier months based on average daily gage flows for the modeled month. This process was repeated until the error percentage was minimized at each of the five sampling locations for each 30-day period that was modeled.

Once each model was hydrologically calibrated, the pollutant load in Long Indian Creek was simulated using event mean concentrations (EMC) which are applied to each land use type found in the model (vegetation, lawn, impervious, and open water). The EMC is the assumed average load that will be washed off from the specified land use during a precipitation event. The EMC used for the Long Indian Creek watershed are shown in **Table 4.3**.

Table 4.3 – Event mean concentration (EMC) used for each land use type in Long Indian Creek watershed.

Land Use Type	EMC
Vegetation	2000
Lawn	4000
Impervious	1000
Open Water	0

These values were determined through a series of model calibrations. Once again, the percent error formula was used, and the EMC for each land use was varied until it minimized the error percentage at each sampling location and closely matched the sampled results presented in **Table 3.14** and **Figure 3.33**. This process was repeated for each month in which a geometric mean could be calculated. A geometric mean requires three or more samples be collected within a 30-day time span in order to calculate a TMDL. For this report, geometric means area available for the following months: January 2015, April 2015, June 2015, July 2015, August 2015, October 2015, November 2015, January 2016, February 2016, and April 2016. The geometric mean combines data from Fulton County and the City of Alpharetta. Since Fulton County only samples at Waters Road (site 4), some of the months only contain data for the Waters Road sampling site. These months include: June 2015, August 2015, November 2015, and February 2016.

The results summary of the model calibration, including modeled versus measured errors, are presented in **Table 4.4**. Further, a visual comparison of modeled versus measured results is presented in **Figure 4.1**. The two parallel lines indicate the summer (lower curve) and winter (upper curve) TMDLs for Long Indian Creek. Measured values are represented by closed circles and modeled values are represented by open circles. Any red point falling above the winter TMDL curve (red line) represents a violation of the winter TMDL, and any gray point falling above the summer TMDL (gray line) represents a violation of the summer TMDL. The two curves are necessary because the winter months have a higher TMDL than the summer months.

Table 4.4 – Results summary from calibration of pollutant model for the Existing Conditions model.

Month	Site	Average Gage Flow (CFS)	Average Modeled Flow (CFS)	Flow Percent Error	Measured 30-day Fecal Load (Counts)	Modeled 30-day Fecal Load (Counts)	30-day Fecal Load Percent Error
January 2015	1	1.4	1.5	2%	6.12e10	1.63e11	167%
	2	2.4	2.4	3%	2.49e11	2.81e11	13%
	3	3.0	2.9	1%	1.98e11	3.14e11	58%
	4	5.2	4.7	9%	3.68e11	4.44e11	21%
	5	8.0	7.0	12%	1.34e11	6.32e11	370%
April 2015	1	1.5	1.7	18%	3.77e10	2.55e11	577%
	2	2.5	2.9	18%	3.36e11	4.39e11	31%
	3	3.0	3.5	15%	1.70e11	4.90e11	189%
	4	5.3	5.6	6%	2.98e11	6.88e11	131%
	5	8.1	7.9	3%	4.68e11	9.76e11	108%
June 2015	1	0.4	0.5	33%	N/A	7.81e10	N/A
	2	0.6	0.8	37%	N/A	1.33e11	N/A
	3	0.8	1.0	29%	N/A	1.46e11	N/A
	4	1.3	1.6	19%	2.33e11	1.94e11	17%
	5	2.0	2.1	6%	N/A	2.65e11	N/A
July 2015	1	0.6	0.9	46%	1.85e11	1.59e11	14%
	2	1.1	1.6	49%	1.50e11	2.71e11	81%
	3	1.3	1.9	43%	6.11e10	3.05e11	399%
	4	2.3	3.2	36%	1.52e11	4.30e11	183%
	5	3.6	4.5	25%	4.91e11	6.14e11	25%
August 2015	1	0.9	0.9	1%	N/A	1.21e11	N/A
	2	1.6	1.6	1%	N/A	2.09e11	N/A
	3	1.9	2.0	3%	N/A	2.32e11	N/A
	4	3.3	3.3	1%	2.98e11	3.18e11	7%
	5	5.1	4.8	6%	N/A	4.37e11	N/A
October 2015	1	0.8	1.1	38%	2.40e11	1.83e11	24%
	2	1.4	1.9	40%	2.32e11	3.11e11	34%
	3	1.7	2.3	35%	3.50e11	3.47e11	1%
	4	2.9	3.7	26%	4.32e11	4.82e11	12%

	5	4.5	5.2	15%	5.02e11	6.78e11	35%
November 2015	1	3.8	4.3	13%	N/A	6.63e11	N/A
	2	6.4	7.5	16%	N/A	1.13e12	N/A
	3	7.9	9.2	17%	N/A	1.30e12	N/A
	4	13.8	15.6	13%	5.23e12	1.90e12	64%
	5	21.1	22.3	6%	N/A	2.79e12	N/A
January 2016	1	4.1	4.4	7%	1.73e11	2.49e11	44%
	2	7.0	7.5	7%	5.36e11	4.34e11	19%
	3	8.6	9.9	15%	3.35e11	4.91e11	47%
	4	15.1	16.8	12%	1.55e12	6.97e11	55%
	5	23.1	24.8	7%	4.14e11	1.00e12	142%
February 2016	1	2.8	2.7	5%	N/A	3.75e11	N/A
	2	4.8	4.5	6%	N/A	6.30e11	N/A
	3	5.9	5.6	4%	N/A	7.14e11	N/A
	4	10.3	9.1	11%	1.04e12	1.01e12	3%
	5	15.7	13.4	15%	N/A	1.47e12	N/A
April 2016	1	0.9	0.9	2%	3.23e10	1.52e11	371%
	2	1.6	1.6	3%	3.93e11	2.68e11	32%
	3	2.0	1.9	1%	1.65e11	3.00e11	82%
	4	3.4	3.2	5%	2.33e11	4.24e11	82%
	5	5.2	4.6	12%	1.43e11	6.08e11	324%

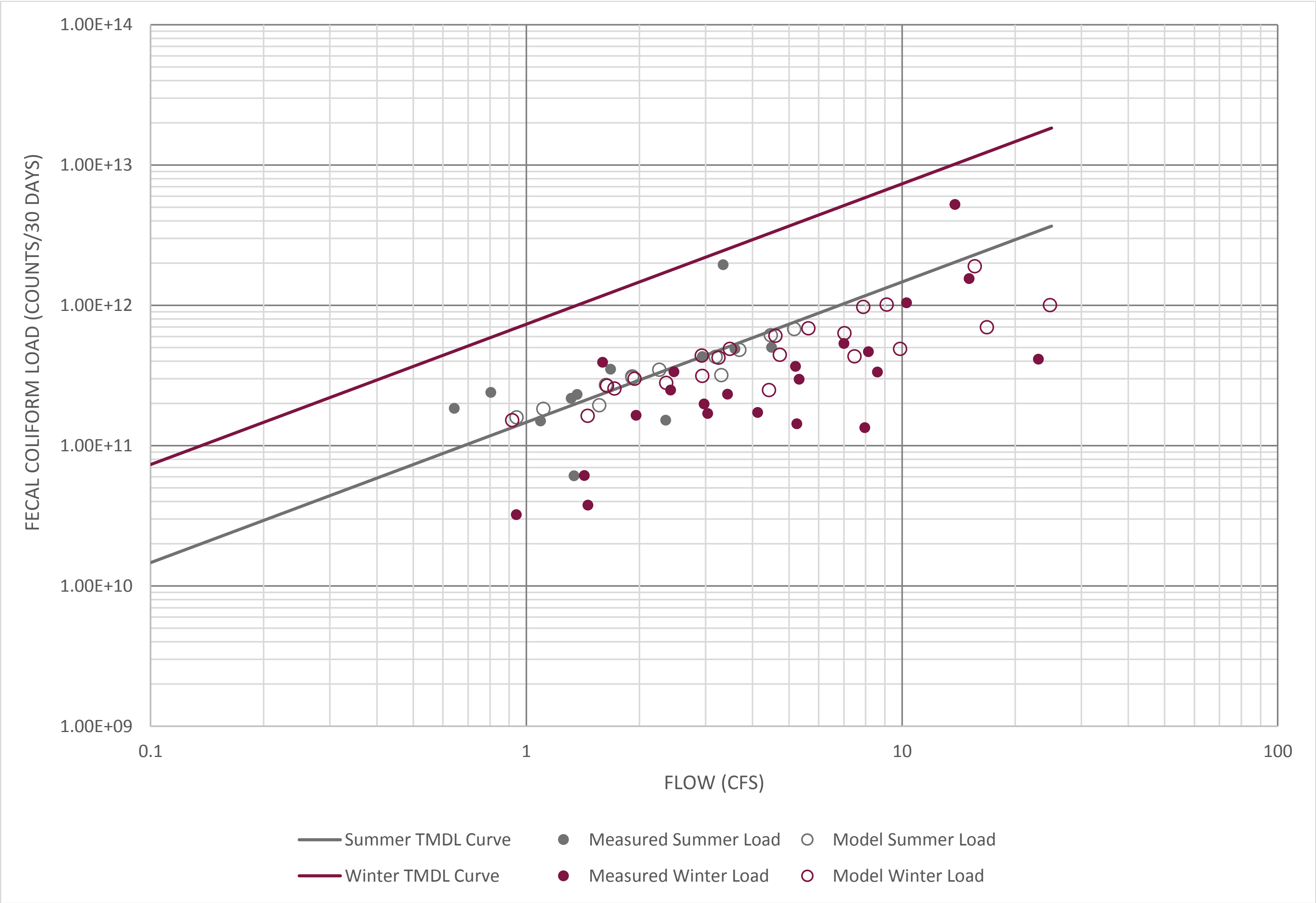


Figure 4.1 – Comparison of modeled and measured pollutant loads and TMDL curves. Measured values are represented by closed circles and modeled values are represented by open circles. The red line (upper curve) represents the winter TMDL limit and the grey line (lower curve) represents the summer TMDL limit.

Once the model has been fully calibrated for pollutants, it can be used to compare pre- and post-removal rates for various water quality treatment best management practices (BMPs). This allows for more accurate and more target measures to treat fecal coliform in the watershed. Additionally, it provides a means for an accurate cost-benefit comparison of various BMPs, allowing the modeler to view the total impact a single BMP can have on the entire watershed. This model-centric technique for selecting and testing BMPs ensures the most effective treatment measures can be implemented.

4.2 Evaluation of Solutions and Model Results

The hydrodynamic SWMM model offers the advantage of being able to rapidly compare and evaluate a series of options. For this report, improvements were focused in two main areas: system flooding reduction and fecal coliform load reduction. Initially, it was anticipated that any infrastructure improvements could address both flooding issues while reducing fecal coliform loading. However, the lack of publicly owned land within the watershed boundary, influenced the decision against incorporating and modeling any stormwater BMPs that could reduce the fecal coliform load.

Despite the omission of structural BMPs from the model, one infrastructure BMP that has the potential to reduce fecal coliform loading is an existing shallow dry detention basin at the corner of Buice Road and Pinehollow Court that has the potential to be converted into a stormwater wetland which provides a 70-85-pct removal rate for fecal coliform. However, the existing BMP is privately owned and is noted to be silted in as shown in **Figure 3.22**. Should the BMP property owners plan improvements in the future, it is recommended that the City communicate the watershed improvement opportunities associated with converting the BMP to a constructed wetland.

With the exception of this single project, all other project solutions involve increasing pipe sizes to solve flooding issues, installing dog waste stations in conjunction with public education to reduce fecal coliform loads, adding enhanced dry swales to reduce runoff volumes, and stream restoration along portions of Long Indian Creek to protect existing sanitary sewer infrastructure and prevent future risks of contamination.

4.2.1 Modeling Best Management Practices

The Georgia Stormwater Management Manual, commonly referred to as the Blue Book, is the guiding document used to determine the fecal coliform removal rates for each existing and proposed BMP in the Long Indian Creek model. BMPs are modeled by assigning a removal rate to the model node where the BMP exists or is to be implemented. Currently, there are two privately-owned wet ponds located within the Long Indian Creek watershed. One receives flow from the Tuxford neighborhood, and the other attenuates flow from the Dunmoor neighborhood. For each of these existing wet ponds, a fecal coliform reduction rate of 70%, in accordance with the Blue Book, has been applied to the outflow of the ponds for all modeling scenarios. With the exception of Ocee Park located in the City of Johns Creek, there is no publicly owned land within the Long Indian Creek Watershed. Therefore, construction/conversion large stormwater BMPs that reduce fecal coliform are not feasible within the watershed inside the City of Alpharetta. Further, Bacterial Source Tracking has indicated that the primary contributor of fecal coliform to the watershed is dog waste which can be better reduced with less expensive and more-easily installed non-structural solutions. For these reasons, it has been deemed highly unlikely that any large stormwater BMP projects will occur within the watershed, and no additional fecal reductions from proposed large stormwater BMP projects have been included in the model.

4.2.2 Dog Waste Stations and Community Education

Based on the Bacterial Source Tracking results indicating that dog waste is the main contributor of fecal coliform and the obstacles for constructing or improving large stormwater BMPs in the watershed, it was determined that installing dog waste stations and educating the community would be the best solution for reducing fecal coliform load in the Long Indian Creek watershed. In order to accurately model the implementation of non-structural treatment methods, such as installing dog waste stations and community education, reduced EMCs, shown in **Table 4.5**, are applied to the Lawns and Impervious Areas. Reductions have only been applied to Lawns and Impervious Areas since those are the only areas where residents are likely to have dogs on leashes and more likely to collect pet waste and dispose of it properly.

Based on a literature review of surveys from various location in the United States (Hillsborough, 2009; Montgomery County, 2014; NMSU, 2012), it was estimated that with the installation and proper community education, dog waste pollution could be reduced in areas by up to 60%. This particular number is based on a survey that reported that 44% of dog owners would not clean up their pet waste and "would refuse to do so in the face of fines and neighbors' complaints" (Hillsborough County, 2009). Therefore, it is anticipated that through the installation of dog waste stations and community education, the 56% of the population who are willing to properly dispose of their pet waste can be persuaded to do so. Due to a lack of before and after studies for dog waste station installations, this number is expected to vary from location to location and has the potential to vary greatly depending on how successful the community education component is.

Table 4.5 - Reduced event mean concentration (EMC) used for each land use type where dog waste stations can be installed in Long Indian Creek watershed.

Land Use Type	EMC
Lawn with Dog Stations	1600
Impervious Area with Dog Stations	400

Three model scenarios were created to compare the effectiveness of installing dog waste stations and community education. The first scenario is the existing conditions model which only includes fecal load reductions from dog waste stations currently installed at Ocee Park in the Johns Creek. The results from this model are presenting in **Table 4.4** and **Figure 4.1**. The second scenario assumes dog waste stations and community education are implemented in all areas of the watershed that are part of the City of Alpharetta and two 'hotspot' areas within Johns Creek which potentially have a high concentration of dogs based on visual observations. The 'hotspot' areas are a business corridor along State Bridge Road with numerous veterinarians and groomers along with a Petco, and the second area is the North Haven apartment complex off of State Bridge Road that allows pets. The locations of the 'hotspots' are shown below in **Figure 4.2**. The third scenario assumes that dog waste stations and community education are implemented throughout the entire watershed including the City of Johns Creek. This is the most comprehensive model and would require coordination and assistance from the City of Johns Creek. **Table 4.6** compares the modeled fecal coliform loading results from each scenario. To summarize the scenarios:

- **Scenario 1:** Existing conditions model
- **Scenario 2:** Dog waste stations and community education are implemented in all areas of the watershed that are part of the City of Alpharetta and two 'hotspot' areas within Johns Creek
- **Scenario 3:** Dog waste stations and community education are implemented throughout the entire watershed including the City of Johns Creek

Figure 4.2 - 'Hotspot' locations for pet waste identified in the City of Johns Creek. It is recommended that dog waste stations be installed in the areas covered by green polygons. Dog waste stations in these areas are included in the Scenario 2 and Scenario 3 models

Table 4.6 - Comparison of 30-day fecal load for each scenario run at each sampling site for every month in which there was a calibrated TMDL. The percent reductions indicate the expected fecal load reduction from each scenario when compared with scenario 1, the existing conditions model.

Month	Site	Scenario 1	Scenario 2	Scenario 2 Percent Reduction	Scenario 3	Scenario 3 Percent Reduction
January 2015	1	1.63E+11	1.61E+11	1.2%	8.45E+10	48.16%
	2	2.81E+11	2.57E+11	8.5%	1.44E+11	48.75%
	3	3.14E+11	2.82E+11	10.2%	1.63E+11	48.09%
	4	4.44E+11	3.64E+11	18.0%	2.30E+11	48.20%
	5	6.32E+11	5.10E+11	19.3%	3.31E+11	47.63%
April 2015	1	2.55E+11	2.52E+11	1.2%	1.32E+11	48.24%
	2	4.39E+11	4.02E+11	8.4%	2.25E+11	48.75%
	3	4.90E+11	4.40E+11	10.2%	2.55E+11	47.96%

	4	6.88E+11	5.66E+11	17.7%	3.56E+11	48.26%
	5	9.76E+11	7.88E+11	19.3%	5.10E+11	47.75%
June 2015	1	7.81E+10	7.71E+10	1.3%	4.05E+10	48.14%
	2	1.33E+11	1.23E+11	7.5%	6.83E+10	48.65%
	3	1.46E+11	1.32E+11	9.6%	7.59E+10	48.01%
	4	1.94E+11	1.62E+11	16.5%	9.93E+10	48.81%
	5	2.65E+11	2.16E+11	18.5%	1.36E+11	48.68%
July 2015	1	1.59E+11	1.57E+11	1.3%	8.23E+10	48.24%
	2	2.71E+11	2.50E+11	7.7%	1.39E+11	48.71%
	3	3.05E+11	2.76E+11	9.5%	1.59E+11	47.87%
	4	4.30E+11	3.59E+11	16.5%	2.23E+11	48.14%
	5	6.14E+11	5.04E+11	17.9%	3.22E+11	47.56%
August 2015	1	1.21E+11	1.19E+11	1.7%	6.26E+10	48.26%
	2	2.09E+11	1.92E+11	8.1%	1.07E+11	48.80%
	3	2.32E+11	2.08E+11	10.3%	1.20E+11	48.28%
	4	3.18E+11	2.60E+11	18.2%	1.62E+11	49.06%
	5	4.37E+11	3.49E+11	20.1%	2.24E+11	48.74%
October 2015	1	1.83E+11	1.81E+11	1.1%	9.47E+10	48.25%
	2	3.11E+11	2.85E+11	8.4%	1.59E+11	48.87%
	3	3.47E+11	3.13E+11	9.8%	1.81E+11	47.84%
	4	4.82E+11	3.99E+11	17.2%	2.50E+11	48.13%
	5	6.78E+11	5.52E+11	18.6%	3.55E+11	47.64%
November 2015	1	6.63E+11	6.56E+11	1.1%	3.42E+11	48.42%
	2	1.13E+12	1.04E+12	8.0%	5.78E+11	48.85%
	3	1.30E+12	1.18E+12	9.2%	6.81E+11	47.62%
	4	1.90E+12	1.60E+12	15.8%	1.00E+12	47.37%
	5	2.79E+12	2.32E+12	16.8%	1.50E+12	46.24%
January 2016	1	2.49E+11	2.46E+11	1.2%	1.29E+11	48.19%
	2	4.34E+11	3.97E+11	8.5%	2.22E+11	48.85%
	3	4.91E+11	4.40E+11	10.4%	2.55E+11	48.07%
	4	6.97E+11	5.75E+11	17.5%	3.61E+11	48.21%
	5	1.00E+12	8.11E+11	18.9%	5.25E+11	47.50%
February 2016	1	3.75E+11	3.71E+11	1.1%	1.94E+11	48.27%
	2	6.30E+11	5.82E+11	7.6%	3.23E+11	48.73%
	3	7.14E+11	6.49E+11	9.1%	3.74E+11	47.62%
	4	1.01E+12	8.54E+11	15.4%	5.32E+11	47.33%
	5	1.47E+12	1.22E+12	17.0%	7.85E+11	46.60%
April 2016	1	1.52E+11	1.51E+11	0.7%	7.84E+10	48.42%
	2	2.68E+11	2.45E+11	8.6%	1.37E+11	48.88%
	3	3.00E+11	2.68E+11	10.7%	1.56E+11	48.00%
	4	4.24E+11	3.48E+11	17.9%	2.20E+11	48.11%
	5	6.08E+11	4.91E+11	19.2%	3.20E+11	47.37%

The most notable result from **Table 4.6** is that scenario 2 results in increasing fecal coliform load reduction percentages as the flow travels downstream. This increasing reduction downstream is primarily due to the fact that more of the upstream portion of the watershed is located within the City of Johns Creek while a larger portion of the downstream watershed is located within the City of Alpharetta. It is important to note this result because fecal coliform reduction goals are unlikely to be met in the upper portions of the watershed without the cooperation of the City of Johns Creek. However in the lower portion of the watershed, reductions ranging from 16.8% to 20.1% are predicted.

As expected, the most substantial decreases in the fecal coliform load occurs when dog waste stations are installed throughout the City of Alpharetta and the City of Johns Creek. This results in an average decrease of 48% across the entire watershed. Additionally, scenario 3 produces a greater percent reduction in fecal coliform loading because the City of Johns Creek has more land area within the Long Indian Creek watershed.

The data shown in **Table 4.6** can also be visually displayed in **Figure 4.3**-**Figure 4.5**. The two parallel lines indicate the summer (lower curve) and winter (upper curve) TMDLs for Long Indian Creek. Modeled values are represented by open circles. Any red circle falling above the winter TMDL curve (red line) represents a violation of the winter TMDL, and any gray circle falling above the summer TMDL (gray line) represents a violation of the summer TMDL. The two curves are necessary because the winter months have a higher TMDL than the summer months. It should be noted that a greater number of modeled points drop below the summer TMDL line (gray) for each scenario, and scenario 3 results in a sufficient decrease in fecal coliform load where all of the points drop below the summer TMDL line.

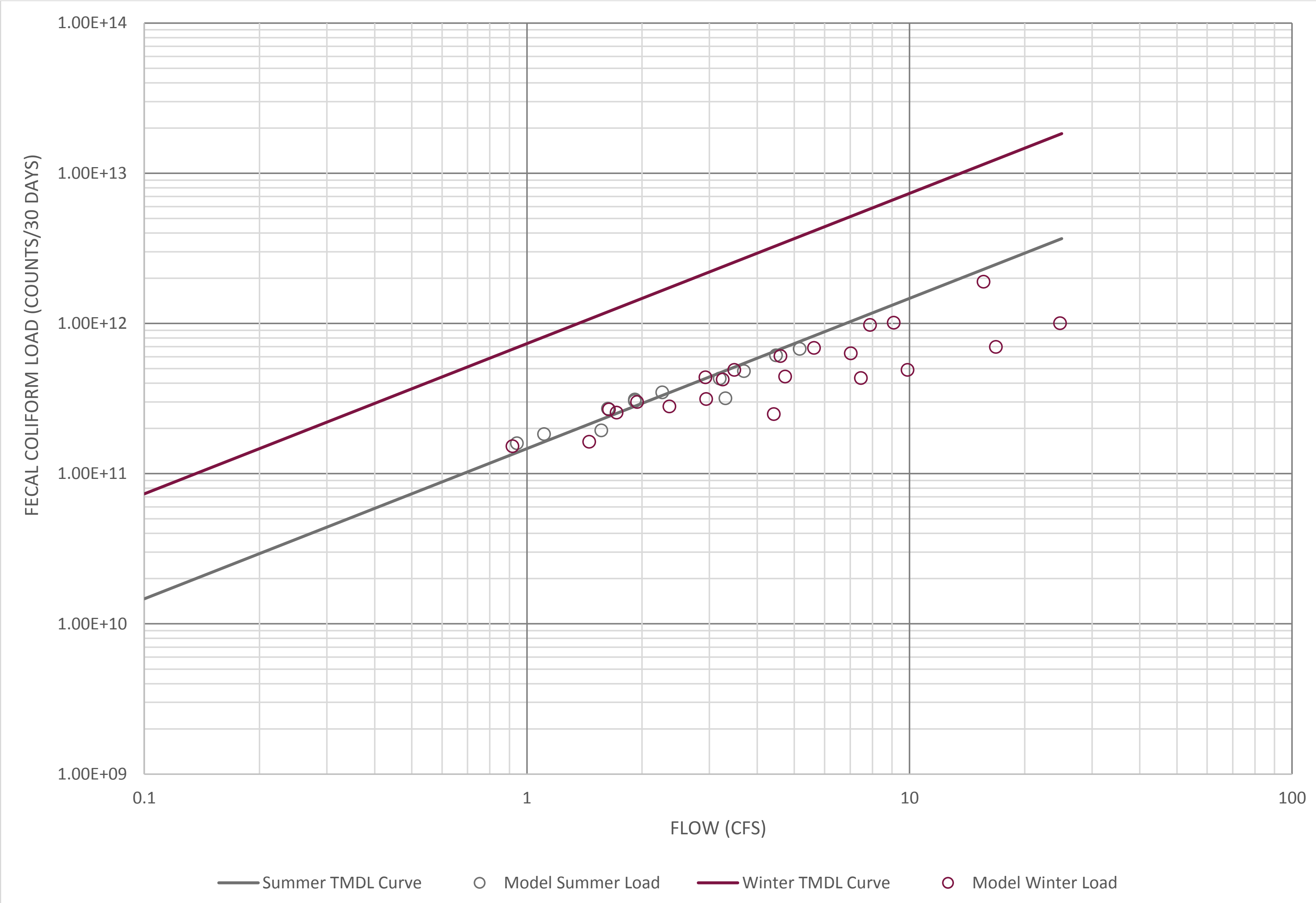


Figure 4.3 - 30-day fecal coliform load versus flow for Scenario 1. The top line represents the winter TMDL and the gray line represents the Summer TMDL. Red circles correspond with modeled winter values, and gray circles correspond with modeled summer values.

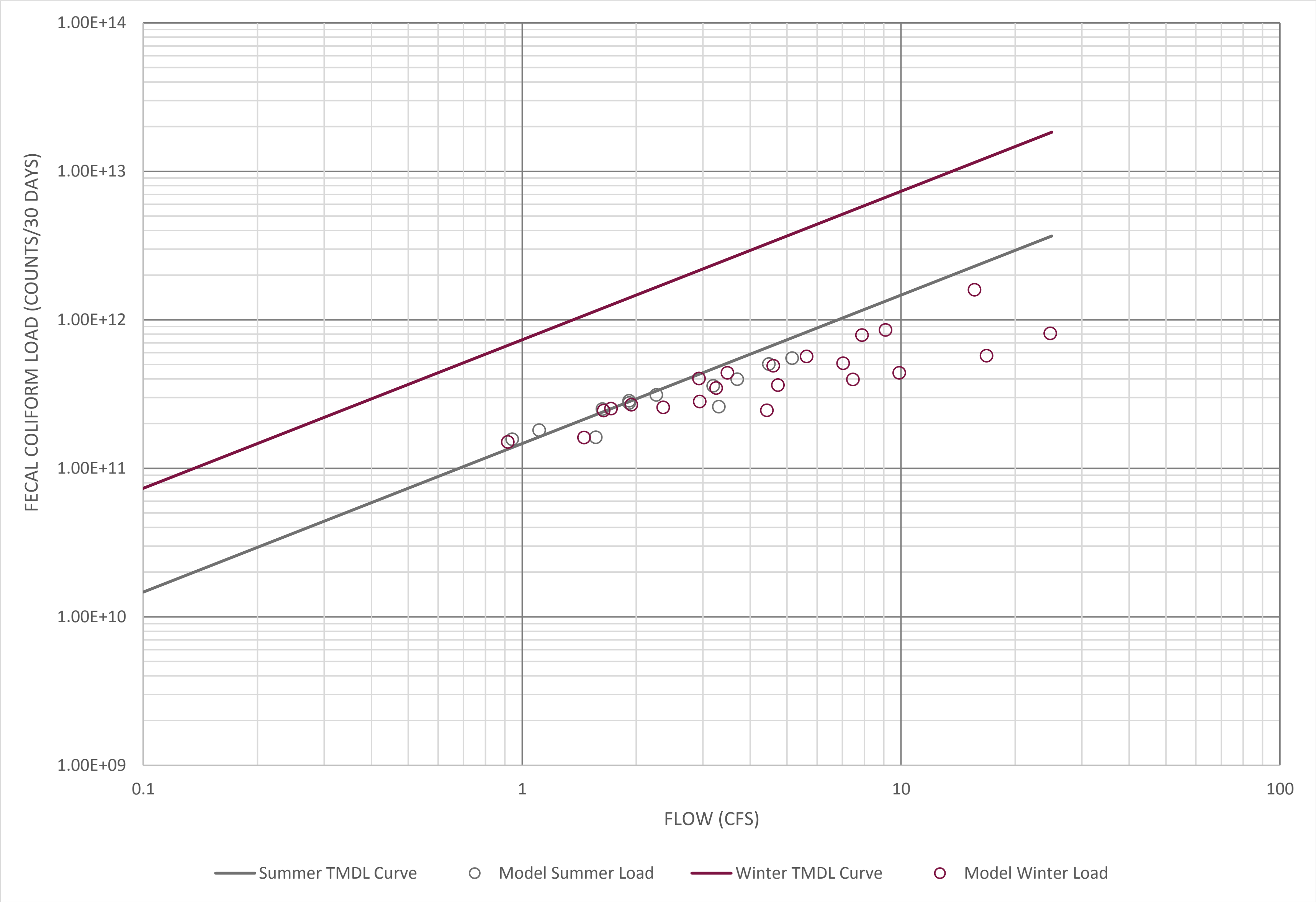


Figure 4.4 - 30-day fecal coliform load versus flow for Scenario 2. The top line represents the winter TMDL and the gray line represents the Summer TMDL. Red circles correspond with modeled winter values, and gray circles correspond with modeled summer values.

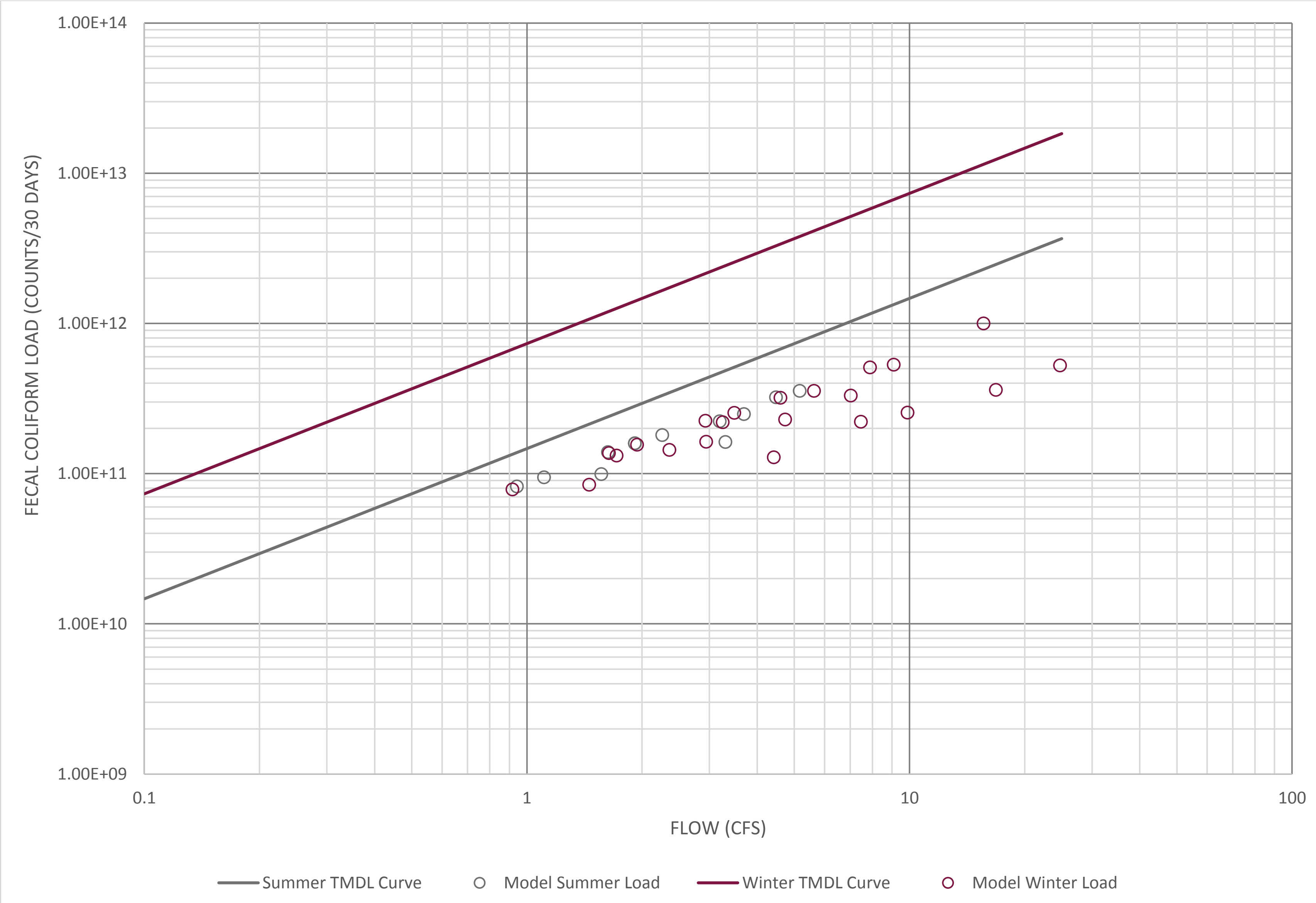


Figure 4.5 - 30-day fecal coliform load versus flow for Scenario 3. The top line represents the winter TMDL and the gray line represents the Summer TMDL. Red circles correspond with modeled winter values, and gray circles correspond with modeled summer values.

4.2.3 System Flooding Solutions

In addition to modeling the fecal coliform load and potential reductions from non-structural initiatives, the Dewberry team created a comprehensive geo-referenced database for each stormwater conveyance and structure maintained by the City of Alpharetta in the Long Indian Creek watershed. The database includes basic information about the conveyances, such as diameter, upstream and downstream invert, pipe material, pipe shape, etc., and the structures, such as invert depth, rim depth, structure shape, and structure type. Further any existing conveyance or structure identification numbers from the existing City of Alpharetta database have been maintained in the updated database to ensure consistency. Where new pipes or structures were added, a new identification number in the 100,000s was assigned to the pipe or structure. Further the database presents upgrade scenarios, detailing pipe size and pipe material, for the following five options:

- **Scenario 1:** Cured-in-Place Pipe (CIPP)
- **Scenario 2:** Replace like size with HDPE
    - Return "Not Applicable" where limitations exists
- **Scenario 3:** Replace like size with RCP
- **Scenario 4:** Replace pipe to meet desired Level of Service HDPE
    - Return "Not Applicable" where limitations exists
- **Scenario 5:** Replace pipe to meet desired Level of Service RCP

For the existing scenario and the five upgrade options, a level of service is extracted from the SWMM model results and provided in the database. Model runs were created for the 1-, 2-, 5-, 10-, 25-, and 100-year 24-hour duration storm events. Therefore, the level of service could fall into the following categories in the database, <1-year (represented by 0.5 in the database), 1-year, 2-year, 5-year, 10-year, 25-year, and 100-year or greater. In total, 819 pipes were analyzed in the model. Of the 819 pipes, 684 are maintained by the City of Alpharetta and 135 are privately maintained or maintained by another government entity. **Table 4.7** provides a summary of the existing level of service for pipes in the Long Indian Creek watershed and for only those pipes maintained by the City of Alpharetta.

Table 4.7 - Summary of the level of service for existing pipes maintained by the City of Alpharetta and for all pipes within the Long Indian Creek watershed based on the SWMM model results.

Level of Service	No. of Pipes Maintained by Alpharetta	Total No. of Pipes
<1-year	9	10
1-year	6	7
2-year	13	14
5-year	26	31
10-year	44	51
25-year	67	77
100-year or greater	519	629

If improvements to the existing level of service are needed, upgrades are made to each pipe in the model based on the five upgrade scenarios listed above until the desired level of service is reached. For stormwater systems, a 25-year level of service was achieved for city-maintained pipes. For culverts passing under roads, a 100-year level of service was achieved for city-maintained pipes. Although upgrades were required throughout the entire watershed, this report will focus on two neighborhoods that were identified as problem areas either by the City, by neighbors sharing past system flooding experience with the Dewberry field team, or by the model indicating substantially undersized pipe systems. Finally, existing Capital Improvement Projects (CIPs) were analyzed with the more granular SWMM model and results were compared to those found using the HEC-RAS model and reported in the Capital Improvements Project Report (Dewberry, 2011).

4.2.3.1 Pinehollow Court System Improvements

Pinehollow Court is a neighborhood, composed of two streets, located off of Buice Road. There are no drainage complaints within the neighborhood, and the Dewberry field team was not approached with system flooding complaints by any residents. However, the existing model indicates that 11 of the 15 pipes within the neighborhood are undersized. In the most severe case, an 18-inch pipe at the outlet of the system requires on upgrade to a 48-inch pipe to meet the 25-year level of service. Therefore despite the lack of City or resident complaints, the Dewberry team has identified the Pinehollow Court neighborhood as a candidate for system improvements based on model-indicated, neighborhood-wide flooding. The general location of the Pinehollow Court neighborhood along with its existing stormwater system are shown in **Figure 4.6**. Red pipes indicate existing pipes that do not meet the 25-year level of service, and blue pipes do meet the 25-year level of service. Further, each pipe's Facility ID Number is provided in the figure. This number corresponds to the pipe's database entry.

In order to meet the 25-year level of service, all five of the upgrade scenarios were explored for Pinehollow Court. **Table 4.8** provides a summary of pipe shape, material, size, and level of service for each upgrade scenario. Pipes are correlated to the database and **Figure 4.6** through their Facility ID Number, and pipe material symbols are referenced in **Table 4.2**. Additionally, a cost estimate has been provided in **Table 4.9** bases on the Stormwater System Cost Estimation Tool to complete the improvements for each scenario in the Pinehollow Court neighborhood. More detailed results and specifications can be found in the system analysis database for each upgrade scenario.

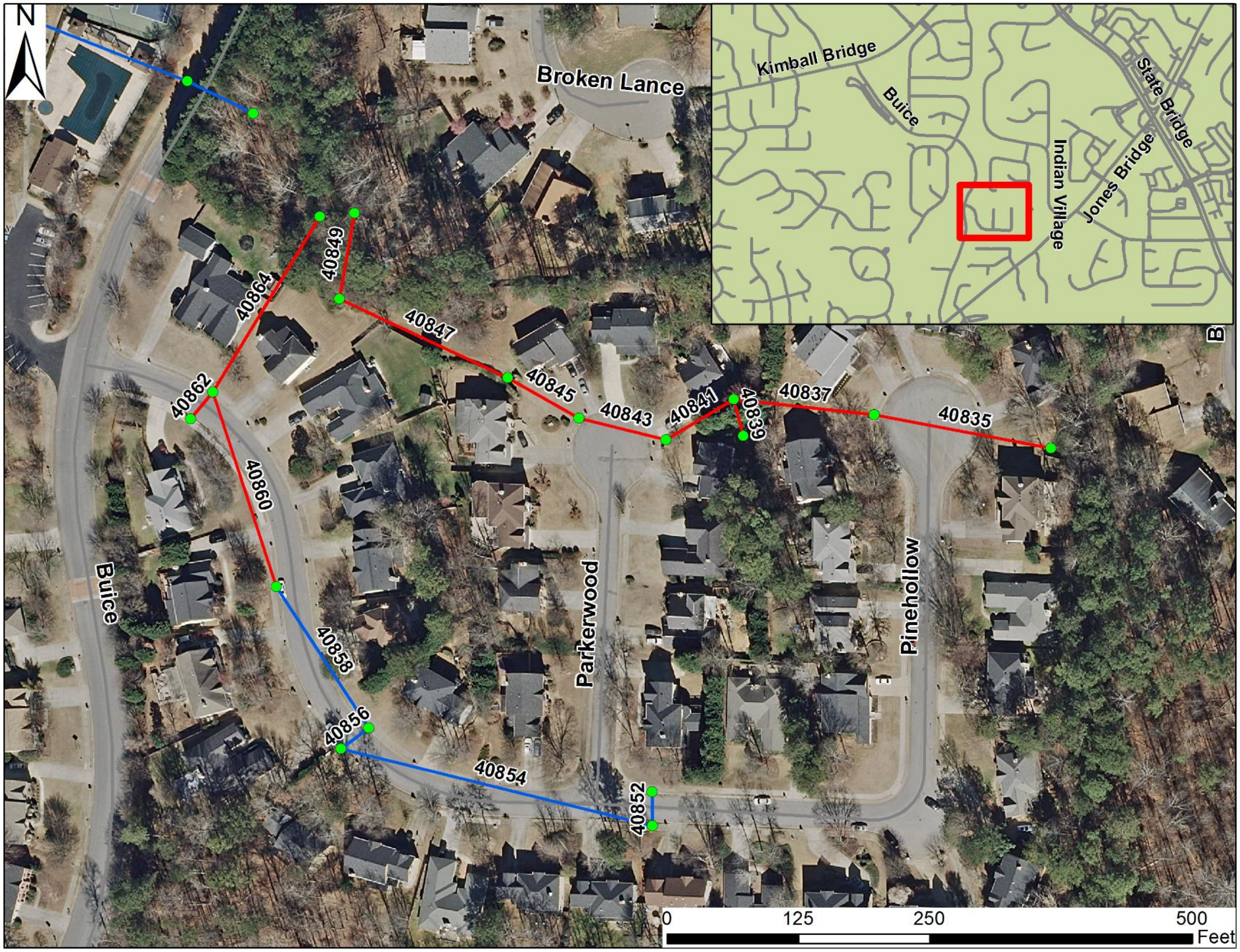


Figure 4.6 - Location of the Pinehollow Court Neighborhood and its existing stormwater system. Red pipes do not meet the 25-year level of service, and blue pipes do meet the 25-year level of service. Pipe Facility ID Numbers are displayed next to each pipe and can be related to the upgrade scenario tables and the system analysis database.

Table 4.8 - Summary of pipe shape, material, size, and level of service for each upgrade scenario.

	Existing Conditions				Scenario 1 - CIPP			Scenario 2 - Replace like size with HDPE		
Facility ID	Shape	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)
40835	Circular	RC	18	5	RL	18	10	RC	18	10
40837	Circular	CO	18	5	RL	18	10	PT	18	10
40839	Circular	PL	12	1	RL	12	2	PT	12	2
40841	Circular	CO	18	2	RL	18	5	PT	18	5
40843	Circular	RC	18	1	RL	18	2	PT	18	2
40845	Circular	CO	18	<1	RL	18	1	PT	18	1
40847	Circular	CO	18	<1	RL	18	<1	PT	18	<1
40849	Circular	CO	18	<1	RL	18	<1	PT	18	<1
40852	Circular	RC	18	100	RL	18	100	RC	18	100
40854	Circular	RC	18	100	RL	18	100	RC	18	100
40856	Circular	RC	18	100	RL	18	100	RC	18	100
40858	Circular	RC	18	100	RL	18	100	RC	18	100
40860	Circular	RC	18	5	RL	18	10	RC	18	10
40862	Circular	RC	18	1	RL	18	5	RC	18	5
40864	Circular	CO	18	2	RL	18	5	PT	18	5

Table 4.8 Continued

	Scenario 3 - Place like size with RCP				Scenario 4 - Replace pipe with HDPE to meet LOS			Scenario 5 -Replace pipe with RCP to meet LOS		
Facility ID	Shape	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)
40835	Circular	RC	18	10	RC	18	25	RC	18	25
40837	Circular	RC	18	10	PT	18	25	RC	18	25
40839	Circular	RC	12	2	PT	18	25	RC	18	25
40841	Circular	RC	18	5	PT	18	25	RC	18	25
40843	Circular	RC	18	2	PT	18	25	RC	18	25
40845	Circular	RC	18	1	PT	24	100	RC	24	100
40847	Circular	RC	18	<1	PT	24	25	RC	24	25
40849	Circular	RC	18	<1	PT	48	25	RC	48	25
40852	Circular	RC	18	100	RC	18	100	RC	18	100
40854	Circular	RC	18	100	RC	18	100	RC	18	100
40856	Circular	RC	18	100	RC	18	100	RC	18	100
40858	Circular	RC	18	100	RC	18	100	RC	18	100
40860	Circular	RC	18	10	RC	18	25	RC	18	25
40862	Circular	RC	18	5	RC	18	25	RC	18	25
40864	Circular	RC	18	5	PT	24	25	RC	24	25

Table 4.9 - Total cost estimates for each of the upgrade scenarios for the Pinehollow Court neighborhood.

Scenario	Total Cost of Each Scenario
1: CIPP	$215,716
2: Replace like size with HDPE	$525,410
3: Replace like size with RCP	$538,383
4: Replace pipe to meet desired LOS with HDPE	$539,504
5: Replace pipe to meet desired LOS with RCP	$550,637

4.2.3.2 Tuxford System Improvements

Tuxford is a neighborhood located off of Kimball Bridge Road. Stormwater runoff within the neighborhood is conveyed by a closed stormwater system. For this analysis, the focus will be on the pipes spanning Tuxford Drive between Dunoon Drive and Grenadier Lane. There are several drainage complaints in the area surrounding the pipes. Two complaints are for erosion and one complaint is for structure maintenance. Additionally, the Dewberry field team was approached by residents during their surveying. Several residents described persistent system flooding and erosion. Further, the existing model corroborates the accounts of residents and indicates flooding due to insufficient capacity in the four most downstream pipes of the system. Due to drainage complaints from the City, resident complaints, and model-verified system flooding, the Dewberry team has identified the Tuxford neighborhood as a candidate for system improvements. The general location of the Tuxford neighborhood along with its existing stormwater system are shown in **Figure 4.7**. Red pipes indicate existing pipes that do not meet the 25-year level of service, and blue pipes do meet the 25-year level of service. Further, each pipe's Facility ID Number is provided in the figure. This number corresponds to the pipe's database entry.

In order to meet the 25-year level of service, all five of the upgrade scenarios were explored for Tuxford. **Table 4.10** provides a summary of pipe shape, material, size, and level of service for each upgrade scenario. Pipes are correlated to the database and **Figure 4.7** through their Facility ID Number, and pipe material symbols are referenced in **Table 4.2**. Additionally, a cost estimate has been provided in **Table 4.11** bases on the Stormwater System Cost Estimation Tool to complete the improvements for each scenario in the Pinehollow Court neighborhood. More detailed results and specifications can be found in the system analysis database for each upgrade scenario.

It should be noted in **Table 4.10** that only pipe 36284 requires an upgrade from a 72-inch diameter pipe to a 90-inch diameter pipe in order to meet a 25-year level of service. Normally, this is an ideal solution as upgrades are limited to a single pipe in order to meet the requirements of the entire system. Unfortunately, the size of the pipe and its location between two houses could present construction site constraints. **Figure 4.8** shows that the trench cut (brown polygon) required to install the larger pipe would overlap with existing houses, making it impossible to install the larger pipe needed to meet the 25-year level of service. Therefore, alternate solutions, such as a parallel system would need to be explored as potential solutions.

Figure 4.7 - Location of the Tuxford Neighborhood and its existing stormwater system. Red pipes do not meet the 25-year level of service, and blue pipes do meet the 25-year level of service. Pipe Facility ID Numbers are displayed next to each pipe and can be related to the upgrade scenario tables and the system analysis database.

Table 4.10 - Summary of pipe shape, material, size, and level of service for each upgrade scenario.

	Existing Conditions				Scenario 1 - CIPP			Scenario 2 - Replace like size with HDPE		
Facility ID	Shape	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)
36191	Circular	CO	48	100	RL	48	100	PT	48	100
36195	Circular	CO	48	100	RL	48	100	PT	48	100
36241	Circular	RC	48	100	RL	48	100	PT	48	100
36272	Circular	CO	54	2	RL	54	2	PT	54	2
36276	Circular	CO	60	1	RL	60	1	PT	60	1
36280	Circular	RC	72	2	RL	72	2	RC	72	2
36284	Circular	CO	72	2	RL	72	2	RC	72	2
39983	Circular	CO	18	100	RL	18	100	PT	18	100
42107	Circular	CO	36	100	RL	36	100	PT	36	100
100060	Circular	PT	12	25	RL	12	25	PT	12	25

Table 4.10 Continued

	Scenario 3 - Place like size with RCP				Scenario 4 - Replace pipe with HDPE to meet LOS			Scenario 5 -Replace pipe with RCP to meet LOS		
Facility ID	Shape	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)
36191	Circular	RC	48	100	PT	48	100	RC	48	100
36195	Circular	RC	48	100	PT	48	100	RC	48	100
36241	Circular	RC	48	100	PT	48	100	RC	48	100
36272	Circular	RC	54	2	PT	54	100	RC	54	100
36276	Circular	RC	60	1	PT	60	100	RC	60	100
36280	Circular	RC	72	2	RC	72	100	RC	72	100
36284	Circular	RC	72	2	RC	90	100	RC	90	100
39983	Circular	RC	18	100	PT	18	100	RC	18	100
42107	Circular	RC	36	100	PT	36	100	RC	36	100
100060	Circular	RC	12	25	PT	12	25	RC	12	25

Table 4.11 - Total cost estimates for each of the upgrade scenarios for the Tuxford neighborhood.

Scenario	Total Cost of Each Scenario
1: CIPP	$682,290
2: Replace like size with HDPE	$519,760
3: Replace like size with RCP	$537,146
4: Replace pipe to meet desired LOS with HDPE	$473,046
5: Replace pipe to meet desired LOS with RCP	$490,732

Figure 4.8 - Trench cuts are shown as brown polygons. The area that the polygon covers is the approximate area required for a trench cut to replace each pipe.

4.2.3.3 City of Alpharetta Existing Capital Improvement Projects Analysis

A Capital Improvements Projects Report was prepared for the City of Alpharetta in December 2011. Floodplain modeling and mapping was performed for all streams within the City of Alpharetta up to a 100-acre drainage area for existing and future land conditions. Modeling was completed using HEC-RAS for Long Indian Creek and its Tributaries. Based on these models CIPs reports were generated for the following structures:

1. CIP No. LIC_0500: Waters Road over Long Indian Creek
2. CIP No. LIC_1300: Buice Road over Long Indian Creek
3. CIP No. LIC_100_1: Birch Rill Drive over Tributary 1 to Long Indian Creek
4. CIP No. LIC_0200_1: Glenn Knolle Court over Tributary 1 to Long Indian Creek
5. CIP No. LIC_0100_3_1: Laruen Hall Court over Tributary 3.1 to Long Indian Creek

Each of these CIPs were included in the updated SWMM model and were analyzed for changes or updates to the CIP report. Often the more granular, hydrodynamic SWMM model allows for improved routing and attenuation when compared to steady state HEC-RAS models. Therefore, it is not uncommon for the level of service to increase for CIPs when they are analyzed using a SWMM model. Updates to the CIP Report are documented in **Table 4.12** to **Table 4.16**. For each CIP, the design flood event is the 100-year existing conditions event.

The most important updates to know are that LIC_0500 for Waters Road and LIC_0200_1 for Glenn Knolle Court no longer require upgrades to meet the 100-year level of service, according to the SWMM model. Further, the Waters Road Bridge has 1.4 feet of freeboard between the 100-year water surface elevation at the structure and the low chord of the bridge. Therefore according to the SWMM model, the only CIP that requires an upgrade is LIC_0100_1 for Birch Rill Drive. Although the SWMM model does indicate an increase of the service level for LIC_0100_1 for Birch Rill Drive from a 5-year overtopping frequency to a 10-year overtopping frequency, an upgrade to a 48" pipe is required to meet the 25-year level of service.

Table 4.12 - Updates to the CIP Report for LIC_0500: Waters Road over Long Indian Creek. The '—' symbol indicates that no updates have been made.

	LIC_0500: Waters Road over Long Indian Creek	
	2011 CIP Report	2016 WIP Report
Frequency of Overtopping	10-year	100-year
Existing Structure	14' Span Bridge	--
100-year Water Surface Elevation at Structure	997.27	992.32
Minimum Top of Road Elevation	995.71	

Table 4.13 - Updates to the CIP Report for LIC_1300: Buice Road over Long Indian Creek. The '—' symbol indicates that no updates have been made.

	LIC_1300: Buice Road over Long Indian Creek	
	2011 CIP Report	2016 WIP Report
Frequency of Overtopping	>500-year	--
Existing Structure	Triple 10'x8' RCB	--
100-year Water Surface Elevation at Structure	1054.64	1053.34
Minimum Top of Road Elevation	1059.6	

Table 4.14 - Updates to the CIP Report for LIC_0100_1: Birch Rill Drive over Tributary 1 to Long Indian Creek. The '—' symbol indicates that no updates have been made.

	LIC_0100_1: Birch Rill Drive over Tributary 1 to Long Indian Creek	
	2011 CIP Report	**2016 WIP Report**
Frequency of Overtopping	5-year	10-year
Existing Structure	Single 36" CMP	--
100-year Water Surface Elevation at Structure	987.43	988.32
Minimum Top of Road Elevation	986.08	

Table 4.15 - Updates to the CIP Report for LIC_0200_1: Glenn Knolle Court over Tributary 1 to Long Indian Creek. The '—' symbol indicates that no updates have been made.

	LIC_0200_1: Glenn Knolle Court over Tributary 1 to Long Indian Creek	
	2011 CIP Report	**2016 WIP Report**
Frequency of Overtopping	2-year	100-year
Existing Structure	Single 24" CMP	--
100-year Water Surface Elevation at Structure	1061.08	1057.67
Minimum Top of Road Elevation	1059.48	

Table 4.16 - Updates to the CIP Report for LIC_0100_3_1: Laruen Hall Court over Tributary 3.1 to Long Indian Creek. The '—' symbol indicates that no updates have been made.

	LIC_0100_3_1: Laruen Hall Court over Tributary 3.1 to Long Indian Creek	
	2011 CIP Report	**2016 WIP Report**
Frequency of Overtopping	>500-year	--
Existing Structure	Single 54" CMP	--
100-year Water Surface Elevation at Structure	1055.67	1053.14
Minimum Top of Road Elevation	1062.47	

In conclusion, no upgrades are required for LIC_0500, LIC_1300, LIC_0200_1, and LIC_0100_3, and they will not be included in any recommended Capital Improvement Projects. However, an upgrade is required for LIC_0100_1, and it will therefore be included as a potential Capital Improvement Project.

5 WATERSHED MANAGEMENT GOALS AND OBJECTIVES

The Long Indian Watershed serves many important purposes to the local community from recreation to aesthetic beauty to flood protection. Additionally, it contributes to the health of all downstream systems, and therefore, provides a key opportunity improve watershed conditions on a scale larger than just the local watershed. This section will not only detail the vision and goals of this Watershed Improvement Plan but also explain the regulatory framework surrounding the watershed restoration effort and any suggested projects to achieve the plan objectives.

5.1 Vision

Long Indian Creek is a natural resource that provides enjoyment to residents of the Cities of Alpharetta and Johns Creek. Numerous parks and greenways as well as backyards of family-oriented neighborhoods share access to the stream and its tributaries. Further, Long Indian Creek contributes flow to Big Creek and, eventually, the Chattahoochee River, both important natural resources to the local and regional community, providing important access to greenspace, recreational activities, fishing, and other cultural contributions.

With these connections and contributions in mind when considering a future vision for Long Indian Creek, the health of the watershed becomes critically connected to the health of the local community and the health of the larger, regional community. For these reasons, the Long Indian Creek watershed offers an exceptional opportunity to not only protect the local watershed's health but to contribute to the health of important downstream resources.

5.2 Decision Framework

With a clear vision for the future of the Long Indian Creek watershed defined, Goals and Objectives can be created and executed to ensure that the vision becomes a reality and is maintained for years to come. Goals and objectives for the Long Indian Creek watershed are developed based on data gathers from a range of sources including, but not limited to:

- City of Alpharetta
- Residents
- Stream walks and field analysis of stormwater system
- Previous studies
- GIS analysis
- Hydrodynamic model analysis

Issues noted by the above sources include:

- Water Quality Issues
  - Excessive fecal coliform present
  - Trash in stream and overbanks
  - Dog waste noted throughout watershed
- Flooding Concerns
  - Resident complaints of system flooding and erosion
  - 113 pipes in watershed do not meet 25-year level of service
  - Damaged or failing BMPs
- Stream Degradation
  - Severe bank erosion in lower portion of watershed
  - Exposed sanitary sewer infrastructure
  - No stream buffer along portions of stream
  - Invasive species common throughout watershed
  - Beaver activity

The above issues and vision, along with stakeholder requests and preferences, were all considered when shaping the following goals and objectives.

Goals of the Long Indian Creek Watershed Improvement Plan:

1. Improve water quality
2. Protect and improve stream condition including health of residents, fish, and wildlife
3. Protect residents from flooding
4. Educate residents about water quality and how they can contribute to protecting the health of the watershed

Objectives of the Long Indian Creek Watershed Improvement Plan coordinated with the Goal it is indented to address:

1. Achieve fecal coliform TMDL reductions (Goal 1 & 4)
2. Protect existing sanitary sewer infrastructure through stream restoration efforts (Goal 1 & 2)
3. Meet desired 25-year level of service for stormwater systems (Goal 3)

5.3 Regulatory Environment

Regulations affecting the Long Indian Creek watershed span local, regional, state, and federal agencies. However, all of these regulations can be grouped into two primary driving categories: 1) those that regulate activities within the watershed (i.e. NPDES permitting) and drive the restoration effort (i.e. TMDL requirements); and 2) those that regulate how projects are implemented (i.e. the Georgia Stormwater Management Manual). Each set of regulations is expanded upon below.

5.3.1 Watershed Restoration Drivers

The primary regulations affecting activities within the watershed and driving the restoration effort include:

- NPDES municipal separate storm sewer system (MS4) permits which regulate stormwater discharge; and
- Georgia EPD issued Fecal Coliform TMDL for Long Indian Creek.

5.3.2 Project Implementation Drivers

The second part of the regulatory framework governs how projects can be implemented. Most permit requirements will be based primarily on the City's Unified Development Code. Current regulations implemented by the City of Alpharetta that could affect project implementation are listed in **Table 5.1**. Additionally for any construction that requires the disturbance of a state/federal jurisdictional surface water or wetlands, such as a stream restoration, a USACE Nationwide Permit will likely be required.

Table 5.1 - Current regulations implemented by the City of Alpharetta.

Measure	Description
Georgia Stormwater Management Manual	Requirement of the stormwater management ordinance. Sets design guidelines and requirements for stormwater systems.
Stormwater and Floodplain Management Ordinance (UDC Article III, Sections 3.3 and 3.4)	Protects streams by prohibiting illicit discharges, regulating post development runoff quality and quantity, managing stormwater systems, and managing floodplains. Revised to meet requirements of model ordinances.
Site Grading and Ordinance (UDC Article III, Section 3.1)	City is designated local issuing authority under memorandum of agreement with Georgia EPD. Requires erosion and sediment control using best management practices and stream buffers as required under Georgia Code section 12-7-6 and the Metropolitan River Protection Act (Georgia Code 12-5-440 et seq.).
Chattahoochee River Protection Ordinance (Alpharetta Code of Ordinances Chapter 5, Article VI)	Required under Metropolitan River Protection Act (Georgia Code 12-5-440 et seq.). Requires 35-foot buffer on flowing streaming draining to Chattahoochee.
MNGWPD Model Ordinances	Revised and amended existing ordinances to meet MNGWPD model ordinance requirements for post development stormwater (UDC Article III, Section 3.3), floodplain management (UDC Article III, Section 3.4), illicit discharge (UDC Article III, Section 3.3.9), and stream buffer (UDC Article III, Section 3.3.6). City minimum undisturbed natural stream buffer is 50 feet on non-perennial streams and 100 feet on perennial streams.
Illicit Discharge Program	Responds to complaints, including downstream inspection and sampling, locating violator, if possible, and requiring clean-up. Revised to match District Model Ordinance standards.
Stormwater Structural Control Maintenance	Inspect and maintain permanent control structures. The City is responsible for 70 BMPs, 4,440 catch basins, ½ mile of ditches, 130 miles of storm drain lines, and 3,797 other structures. 20% of all structures are inspected yearly. In FY2015, 2,992 stormwater structure inspections were completed, and there were 204 drainage repairs and maintenance to stormwater infrastructure.
Maintaining Roadside Drainage Systems	Remove excess sediment and debris from storm inlets, catch basins, pipes, and ditches. Maintain vegetation on roadside shoulders and ditches with City crews and under City annual contracts.
Roadside Litter Removal	Remove litter from right-of-way. Inspections done daily by full-time employees of Public Works Department. In the 2014-2015 reporting period, 269 miles of streets were swept, and 16,204 pounds of litter were removed from the right-of-ways. The City participates in Adopt-A-Mile program to remove roadside litter.
Dry Weather Screening	Under memorandum of agreement for NPDES permit requirements. City monitors 20% of the City's 751 outfalls each year. Maintains outfall inventory. Investigates detected discharges. Has found illicit connections and leaks through program.
Education Programs	The City has an Environmental Programs Coordinator who works with Regional Clean Water Campaign to provide educational material to residents and businesses on proper protection of their watershed. The City participates in stream and river cleanups and has active Adopt-A-Stream and Adopt-A-Mile programs. The City sponsors workshops, recycling programs, and environmental events. Participates in EverGreen schools program, and is a Gold Level Green Community through the ARC.

Although not directly related to the existing regulatory framework, the lack of public land located within the Long Indian Creek watershed will very directly limit the number and types of projects that can be implemented within the watershed.

6 CAPITAL IMPROVEMENT PLAN

This section provides the culminating recommendations, associated costs, implementation plan, and monitoring criteria to achieve the watershed goals and objectives. This plan and recommendations have been developed using the full knowledge of this report including understanding the watershed characteristics and conditions, interpreting the results from hydrodynamic and GIS analysis, and considering the wants and needs of all stakeholders in the Long Indian Creek Watershed.

6.1 Challenges in Long Indian Creek

This section will highlight each of the major challenges faced in the Long Indian Creek Watershed and recommend appropriate structural and non-structural BMPs to successfully address each challenge. Currently, dog waste is the most pressing challenge facing the watershed and has been determined to be the primary source of the elevated fecal coliform levels in the watershed. It can be best addressed with non-structural measures such as the installation and maintenance of dog waste stations and public education. The second challenge, sanitary sewer spills, is currently a much lower contributor to fecal coliform due to rehabilitation and preventive maintenance activities by Fulton County over the past few years. However, there are concerns about potential breaks or ruptures to the existing sanitary sewer infrastructure that has become exposed due to stream erosion and degradation. Unlike the other three goals, the third challenge of system flooding is not directly related to water quality. However, it is critical to the safety of residents in the watershed. Further, it helps prevent erosion of Long Indian Creek and surrounding land which can reduce the sediment load of the stream, improving the health of the watershed. In order to prevent system flooding, upgrades to stormwater systems can be completed in several critical areas. In order to best protect existing sanitary sewer infrastructure and to address the fourth challenge, ecology, stream restoration measures can be taken to reduce and even reverse the current stream degradation. A full project list and further details of recommended BMPs for Long Indian Creek is provided later in this section.

6.1.1 Dog Waste

Based on initial observations of the dog population and activities in the Long Indian Creek watershed, dog waste was identified early in the project as a potential contributor to elevated fecal coliform levels. This theory was later corroborated by bacterial source tracking tests which did show dog waste to be the major contributor of fecal coliform load to the watershed and was distantly followed by humans as the second largest contributor to the fecal load. Dog waste presents a unique challenge in that it is a nonpoint source pollutant and is often not recognized as a pollutant by dog owners. Therefore, any solution to the dog waste problem will need to involve a robust public education component.

6.1.2 Sanitary Sewer Spills

Although Fulton County has not recorded a sanitary sewer spill in the Long Indian Creek Watershed since February 2007, the challenge still persists due to the numerous exposed sanitary sewer pipes noted during the stream walk along Long Indian Creek and its Tributaries. Exposed sanitary sewer pipes are not sufficiently protected to prevent against damage leading to spills during major storm events. There are several especially vulnerable pipes located directly downstream of large debris jams on Long Indian Creek. If any sanitary sewer pipes are damaged during a storm event, the resulting spill could reverse progress made in the watershed to reduce fecal coliform loading.

6.1.3 System Flooding

Current flooding within the watershed puts roadway infrastructure and houses at risk. However as the City of Alpharetta owns no public land or BMPs in the Long Indian Watershed, its options are highly limited for providing additional stormwater attenuation within the watershed to reduce flooding. Therefore, solutions to address flooding are limited to improvements to the City-maintained stormwater system and to GI/LID measures where applicable. Due to these limited options to correct system flooding, potential BMP projects on public land are greatly limited within the Long Indian Creek Watershed.

6.1.4 Ecology

The ecological health of the watershed is closely linked to the flooding of the entire system. Increased development and impervious area in the watershed have resulted in larger flows entering the stream more frequently which has led to a widening of the channel and deeply incised bank, preventing the stream from connecting with its existing floodplain. Further degrading the watershed's health is the reduction or, in some cases, the complete elimination of the riparian buffer along certain reaches of the stream due to mowed lawns extending to the stream banks. In other portions of the watershed, the stream geomorphology has been altered due to past straightening of the stream channel. Further, invasive vegetation has overtaken portions of the stream banks, worsening erosion and TSS load in the watershed. All of these ecological issues contribute to degraded water quality and have a negative impact on the health and diversity of the watershed.

6.2 Recommended Project List

Below is a list of Watershed Improvement Projects (WIP) to reduce fecal coliform and improve overall watershed health within the Long Indian Creek watershed. More detailed project sheets are provided in APPENDIX C: PROJECT SHEETS.

- WIP #1 – Dog Waste Stations & Public Education
- WIP #2 – Stream Restoration and Sanitary Sewer Protection Project 1
- WIP #3 – Stream Restoration and Sanitary Sewer Protection Project 2
- WIP #4 – Stream Restoration and Sanitary Sewer Protection Project 3
- WIP #5 – Stream Restoration and Sanitary Sewer Protection Project 4
- WIP #6 – Stream Restoration and Sanitary Sewer Protection Project 5
- WIP #7 – Pinehollow Court Neighborhood Flooding
- WIP #8 – Tuxford Neighborhood Flooding
- WIP #9 – Birch Rill Drive Capital Improvement Project No. LIC_0100_1
- WIP #10 – Waters Road Enhanced Dry Swales Project 1 (North)
- WIP #11 – Waters Road Enhanced Dry Swales Project 2 (South)
- WIP #12 – Bacterial Source Tracking (BST)

Project selection was based on data collected from numerous sources, including but not limited to: 1) Bacterial Source Tracking; 2) GIS analysis; 3) SWMM modeling; 4) Field assessments; and 5) Identified capital improvement projects.

6.2.1 Prioritization Process of Management Measures

Once the 12 potential project were identified, they were ranked using predetermined criteria. The criteria was designed to capture the wide array of opportunities and obstacles presented by each project. However, it is chiefly important that two main criteria are most strongly considered: 1) Will the proposed project reduce fecal coliform loads which have resulted in an exceedance of the total maximum daily load for the entire stream; and 2) Is the proposed project located on public land, a requirement for constructability. With these goals in mind, the ranking criteria in **Table 6.1** were developed to assist in selecting the projects with the greatest potential to improve the watershed, considering costs and other limitations. The criteria uses a streamlined rating system of 0, 1, and 2 with 2 being the most desirable ranking and 0 being the least desirable ranking.

Table 6.1 - Criteria for ranking and prioritizing watershed improvement projects.

Criteria	Description	0	1	2
Public Land	Is the project situated on public land?	Land is privately owned.	Land is partially publicly owned or within an easement dedicated to a local government.	Land is entirely owned by or within an easement dedicated to the City of Alpharetta.
Fecal Coliform	Does the project reduce fecal coliform loading in the watershed?	No. The project does not reduce fecal coliform loading.	The project can prevent against future fecal loading.	Yes. The project will reduce fecal coliform loading.
Capital Cost	What is the capital costs required to construct the project?	Cost is >$1 million	Cost ranges from $100,000 to $1 million	Cost is <$100,000
Sediment	Does the project reduce sediment loading in the watershed?	No. The project does not reduce sediment loading.	The project can moderately reduce sediment loading.	The project can substantially reduce sediment loading.
Constructability	How difficult is the project to construct. I.e. permits, access, easement acquisition, utility conflicts?	The project requires extensive acquisition of easements and permitting from state/federal levels.	The project requires minimal easement acquisition and permitting on a local level.	The project requires no easement acquisition and no permitting.
Flood Risk Mitigation	Does the project reduce flooding concerns in the surrounding community?	The project provides no flood risk mitigation.	The project provides flood risk mitigation but at a level of service less than the 100-year event.	The project provides flood risk mitigation at a level of service equal or greater than the 100-year event.
Community Involvement	Does the community have direct stake in the success of the project and/or access to the project?	The community has no direct impact on the project.	The community has moderate interaction to and some influence over the success of the project.	The community has substantial access to and influence over the success of the project.
Aesthetics	Overall, will the project improve its surrounding environment?	The project will neither add nor detract from its environment.	The project will moderately improve the surrounding environment.	The project will substantially improve the surrounding environment.
Shared Cost	Are there cost sharing opportunities for the project including other governments, utilities, and/or grants?	There are no additional stakeholders and no potential for shared costs.	There is an additional stakeholder and/or moderate potential for shared costs.	There are numerous stakeholders and high potential for shared costs.

In order to determine a projects final score, the following equation was used to analyze each categories' score:

$$Points\ Total = (FC + C + S + E + FL + I + A + SC) \times L$$

Where:

L = Public Land Score
FC = Fecal Coliform Score
C = Capital Cost Score
S = Sediment Score
E = Constructability Score
FL = Flood Risk Mitigation Score
I = Community Involvement Score
A = Aesthetics Score
SC = Shared Cost Score

Based on the above scoring criteria and the ranking equation, the scores and ranks are provided for each project in **Table 6.2**. The maximum score a project could receive is 32 points.

Table 6.2 - Prioritization and Ranking Scores for Recommended Project List.

WIP No.	Description	Public Land L	Fecal Coliform FC	Capital Cost C	Sediment S	Construct-ability E	Flood Risk Mitigation FL	Community Invlvment I	Aesthetics A	Shared Cost SC	Score
1	Dog Waste Station & Public Education	2	2	2	0	2	0	2	0	2	20
2	Stream Restoration and Sanitary Sewer Protection Project 1	1	0	0	2	0	0	1	2	2	7
3	Stream Restoration and Sanitary Sewer Protection Project 2	1	0	1	2	0	0	1	2	2	8
4	Stream Restoration and Sanitary Sewer Protection Project 3	1	0	1	1	0	0	1	2	2	7
5	Stream Restoration and Sanitary Sewer Protection Project 4	1	0	1	2	0	0	1	2	2	8
6	Stream Restoration and Sanitary Sewer Protection Project 5	1	0	2	1	0	0	1	2	2	8
7	Pinehollow Court Neighborhood Flooding	1	0	1	0	1	1	0	0	0	3
8	Tuxford Neighborhood Flooding	1	0	1	0	0	1	0	0	0	2
9	Birch Rill Drive Capital Improvement Project No. LIC_0100_1	1	0	1	0	1	2	0	0	0	4
10	Waters Road Enhanced Dry Swales Project 1 (North)	2	0	2	2	1	1	0	1	1	16
11	Waters Road Enhanced Dry Swales Project 2 (South)	2	0	2	2	2	1	0	1	1	18
12	Bacterial Source Tracking (BST)	2	2	2	0	2	0	0	0	2	16

6.2.2 Management Measures for Nonpoint Source Pollution

Due to the difficulty of identifying and reducing nonpoint source pollution, any solution requires an integrated approach of non-structural and structural measures. This approach is especially true in the Long Indian Creek Watershed where the primary contributor of fecal coliform contamination is dog waste, a highly decentralized issue that requires large public education and buy-in to correct. As with any public education campaign, behavioral change can be slow, and this timeline challenge will be reflected in the project implementation schedule. However, public education campaigns also present the opportunity to correct a nonpoint source pollution issue for a relatively inexpensive cost if non-structural, or programmatic, measures are smartly partnered with effective structural measures. The following sections discuss the range of non-structural solutions and the most complementary structural solutions that can be implemented in order to reduce fecal coliform loading in the watershed in the most cost-effective manner possible.

6.2.2.1 Non-Structural Management Measures

Non-structural management measures can provide a wide range of options to address nonpoint source pollution. Additionally, non-structural measures tend to be less expensive than structural options. Therefore when working to reduce nonpoint source pollution, non-structural methods can initially be implemented, along with any complementary structural methods, to attempt to reach pollution reduction goals before making large investments in structural methods. Below is a list of non-structural management measures, and the following paragraphs describe the implementation process for each management measure:

1. Dog Waste Stations and Public Education
2. Bacterial Source Tracking
3. Before-and-After Fecal Coliform Monitoring
4. Repair Damage BMPs
5. Encourage Restoration of Stream Buffers
6. Remove Debris Jams
7. Collaborate with Private BMP Owners

Dog Waste Stations and Public Education

The City of Alpharetta already has a strong public education portion associated with its Stormwater Management Program through its partnership with the Clean Water Campaign. Key issues include, pet waste management, septic tank maintenance, stormwater stenciling, lawn care, and other critical issues involving watershed health. **Figure 6.1** provides a sampling of educational material provided by the City of Alpharetta.

The Solution

Picking up after your pet keeps waste out of nearby storm drains, drainage ditches, streams and lakes. It helps keep waters healthy for recreation. It protects human health and the plants and animals that depend on clean water.

Doing the right thing is easy. Whenever you walk your dog or take him outside in your yard, you can easily do the right thing. Simply scoop the poop or use a plastic bag and dispose of it in a garbage can.

It only takes a minute, and you'll have the satisfaction of knowing that you're being a good neighbor and protecting nearby waters.

Figure 6.1 - Examples of educational and outreach material provided by the City of Alpharetta to inform citizens about protecting stormwater.

Although the public education component is a non-structural measure, it could strongly benefit from the complementary structural measure of installing dog waste stations throughout the watershed. As the initial installation of the dog waste stations would require a capital cost, a project sheet has been included for dog waste stations and public education. More information specific to dog waste stations is provided in the project sheet inAPPENDIX C: PROJECT SHEETS. In the case of public outreach, the actual dog waste stations could provide a public education opportunity simply through their installation and signage. Further, dog waste stations provide an opportunity for Alpharetta to partner with homeowners associations and other civic groups in order to explain the necessity of dog waste stations to protect the Long Indian Creek watershed. Brochures from the Clean Water Campaign regarding dog waste could be distributed to residents of neighborhoods receiving dog waste stations, increasing the likelihood that the message will be heard. The fliers could be sent by mailer, but higher success could likely be achieved by hand delivering fliers by volunteers who are versed in discussing the importance of utilizing dog waste stations. Additionally, fliers and information could be provided to local veterinarians, dog groomers, and dog boarders to provide and discuss with their customers the importance of properly disposing of dog waste. Ultimately, the long-term involvement and commitment from homeowners associations and/or other dedicated groups/clubs of citizens will ensure that the dog waste stations are adopted, maintained, and well utilized, ensuring that pet waste cleanup becomes ingrained in residents' behavior.

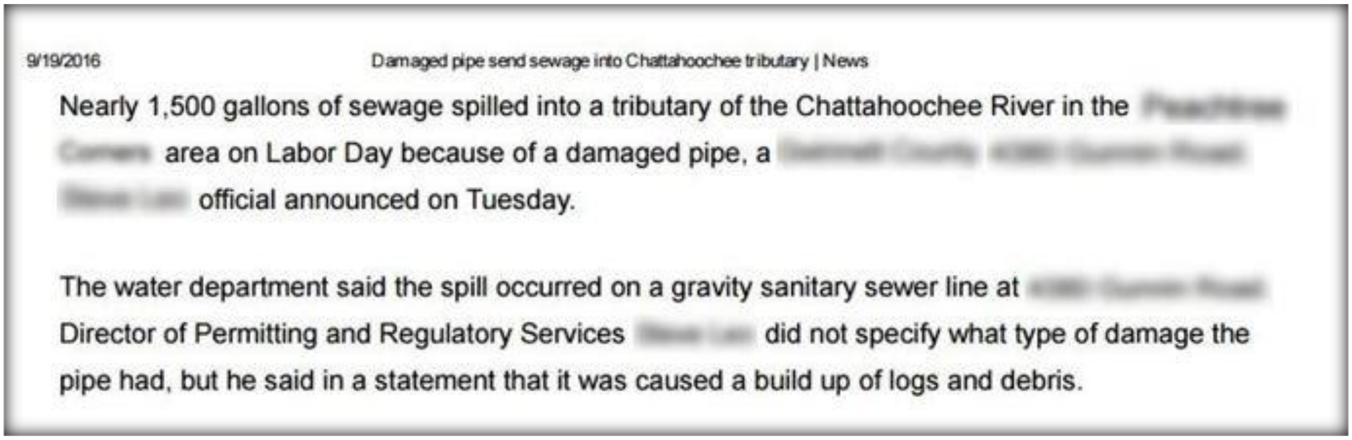
Bacterial Source Tracking
The City of Alpharetta implemented a BST program in the Long Indian Creek Watershed under this Plan to help identify the key contributors of fecal coliform in the watershed. It is recommended that Alpharetta continues the BST sampling after the completion of this Watershed Improvement Plan in order to track progress towards meeting the fecal coliform reduction goals and to ensure that there are no major changes in the main source of fecal coliform in the watershed, as a change in the main contributor of fecal coliform would result in a change of strategy to address the pollutant. The use of BST ensures that Alpharetta is efficient in the use of its resources to address the critical contributor of fecal coliform. As BST results change, so should the management measures used to address fecal coliform pollution. Since BST must be sent to an outside lab for analysis, an outlay of costs is required for lab testing, and therefore, a project sheet has been included for BST in APPENDIX C: PROJECT SHEETS.

Before-and-After Fecal Coliform Monitoring
In order to measure the effectiveness of management measures, it is recommended that the City of Alpharetta complete before-and-after fecal coliform monitoring of outfalls impacted by structural management measures. This sampling would be done in addition to the existing sampling schedule already completed by Alpharetta in the Long Indian Creek Watershed, and the costs of the additional tests could be incorporated into current operations. Since very little research exists with respect to the effectiveness of dog waste stations, this testing would be especially critical to quantify the fecal coliform reduction expected from the installation of dog waste stations when partnered with public education. Based on findings from a test installation of dog waste stations in a selected neighborhood, the City can decided if the results prove the investment to be effective at reducing fecal coliform and can guide the City on future installation decisions. Further, the results can help the City predict the reduction it will see in actuality from the installation of dog waste stations throughout the watershed versus the modeling results currently available. Based on these results, other management measures and be adjusted accordingly.

Repair Damaged BMPs
During the stream walk and field visits, several damaged BMPs were noted throughout the watershed. The location of these BMPs is noted in **Figure 3.20**. These damaged BMPs indicated areas where the stormwater system is not performing to level to which it was designed. In these areas, flow may not be sufficiently attenuated before entering the stream or erosion may be a concern from high velocity flows. For these reasons, damaged BMPs could be an indication of areas where the stormwater system and/or the stream is suffering from larger issues. Each damaged BMP can be seen as an easily identifiable project and could have immediate positive effects in its local area once repaired. However, BMPs are privately owned and any restoration efforts would have to be undertaken by private property owners. The City would have the opportunity to discuss improving the BMPs to provide additional water quality and channel protection benefits with the property owners during the planning stages.

Encourage Restoration of Stream Buffers
During the stream walk, it was noted that many private yards and parks associated with neighborhoods provided very little or no buffer around the stream banks. In these areas, stream bank erosion was especially prevalent. Unfortunately, there is no publicly owned land along the stream banks, and therefore, no opportunity for the City of Alpharetta to implement buffer protection and/or restoration measures. However, the City does support a program called Alpharetta's Wild Side with the goal of becoming a National Community Wildlife Habitat, a program supported by the National Wildlife Federation. In order to qualify for the program, the City must register at least 200 homes and 6 common areas that are designated as wildlife habitats, and in order to be designated as a wildlife habitat, the home or common area must provide food, water, and shelter that support wildlife. Therefore, homes and common areas located along streams are excellent opportunities for wildlife habitats, and through the Wild Side program, homeowners and homeowners associations could be encouraged to return stream buffers on their habitat to more natural habitats, improving the health of the watershed and the habitat for local wildlife.

Remove Debris Jams
Debris jams pose a large flooding threat upstream and have the potential to break exposed downstream sanitary sewer infrastructure when the jam becomes dislodged during flood events. Therefore, debris jams are a health and safety concern for multiple reasons. **Figure 6.2** shows a snippet from an article from a nearby community that recently experienced a sanitary sewer spill due to a debris jam.



9/19/2016 Damaged pipe send sewage into Chattahoochee tributary | News

Nearly 1,500 gallons of sewage spilled into a tributary of the Chattahoochee River in the [illegible] area on Labor Day because of a damaged pipe, a [illegible] official announced on Tuesday.

The water department said the spill occurred on a gravity sanitary sewer line at [illegible] Director of Permitting and Regulatory Services [illegible] did not specify what type of damage the pipe had, but he said in a statement that it was caused a build up of logs and debris.

Figure 6.2 - Article about a sanitary sewer spill cause by a debris jam in a nearby community.

For this reasons, the removal of debris jams should be seen as preventative maintenance for sanitary sewer infrastructure, and the City of Alpharetta can work with Fulton County and its contractors to ensure that debris jams are removed from Long Indian Creek and its Tributaries in a timely manner.

Collaborate with Private BMP Owners
There is no public land available in the Long Indian Creek Watershed within the City of Alpharetta. For this reason, construction or conversion of large stormwater ponds by the City of Alpharetta that could reduce the fecal coliform load are not feasible. However, the City can work closely with private BMP owners to help guide maintenance and retrofits to BMPs to ensure that the best steps to protect the watershed are being implemented by the BMP owners.

6.2.2.2 Structural Management Measures
The final list and ranking of all recommended projects is provided in **Table 6.3**, with a ranking of '1' being the highest ranking project and a ranking of '12' being the lowest ranking project. More detailed information on each project can be found in the project sheets provided in APPENDIX C: PROJECT SHEETS. The final ranking was most impacted by whether or not the project was located on public land and/or could be accessed via public land. If a proposed project was not located on public land, it was viewed as not feasible, and immediately bumped to the bottom of the ranking.

Although most recommended projects are free-standing and do not require additional non-structural measures to ensure their success, WIP No. 1 Dog Waste Stations & Public Education requires at least one non-structural measure to improve its success. Ideally, the installation of dog waste stations will be partnered with public education and before-and-after fecal coliform monitoring. When partnered with these two non-structural measures, it is expected that the success rate of each structural and non-structural measure will have a compounding effect, encouraging additional participation than any one measure implemented on its own. For this reasons, the structural measure of installing dog waste stations and the non-structural measures of public education and before-and-after fecal testing are seen as complementary measures.

Table 6.3 - Final ranking of suggested structural management measures.

WIP No.	Project Name	Final Ranking
1	Dog Waste Station & Public Education	1
11	Waters Road Enhanced Dry Swales Project 2 (South)	2
10	Waters Road Enhanced Dry Swales Project 1 (North)	3
12	Bacterial Source Tracking (BST)	3
2	Stream Restoration and Sanitary Sewer Protection Project 1	5
4	Stream Restoration and Sanitary Sewer Protection Project 3	5
3	Stream Restoration and Sanitary Sewer Protection Project 2	7
5	Stream Restoration and Sanitary Sewer Protection Project 4	7
6	Stream Restoration and Sanitary Sewer Protection Project 5	7
9	Birch Rill Drive Capital Improvement Project No. LIC_0100_1	10
7	Pinehollow Court Neighborhood Flooding	11
8	Tuxford Neighborhood Flooding	12

6.2.3 Critical Areas of Implementation

Although this Watershed Improvement Plan has been completed for the City of Alpharetta, only approximately half of Long Indian Creek's watershed falls within the political boundaries of Alpharetta. The other half of Long Indian Creek's watershed is contained within the City of Johns Creek. It is highly unlikely that the required reductions in fecal coliform can be reached by either City alone. Instead, Alpharetta and Johns Creek should continue to work together to implement the non-structural and structural management measures suggested in this Plan. **Figure 4.4** and **Figure 4.5** provide an excellent example of the limitations of only implementing a management measure in one City but not the other. **Figure 4.4** shows the expected fecal coliform loads in Long Indian Creek if dog waste stations are installed in only the City of Alpharetta (Scenario 2). In contrast, **Figure 4.5** presents the expected fecal coliform loads if dog waste stations are installed throughout the entire watershed (Scenario 3), including the City of Johns Creek. In Scenario 2, the maximum TMDL is still expected to be exceeded since half of the watershed will not see a reduction in fecal coliform levels from dog waste. However, when dog waste stations are implemented on a watershed-wide level, fecal coliform levels are expected to fall below the TMDL limit. This example enforces the importance that management measures must be jointly implemented by both the City of Alpharetta and the City of Johns Creek to the greatest extent possible to ensure the maximum impact of the management measure is seen.

6.3 Potential to Address Objectives

Although almost all of the proposed projects present a multitude of benefits to the Long Indian Creek Watershed, the most important object is the reduction of the fecal coliform load throughout Long Indian Creek and its Tributaries. The following measurable milestones and criteria used to measure load reductions will focus heavily on the reduction of fecal coliform in the watershed.

6.3.1 Measurable Milestones

This Watershed Improvement Plan is designed as a guiding document that the City of Alpharetta can use when determining non-structural and structural management measures to reduce the fecal coliform load in the Long Indian Creek Watershed. As new data arises and/or sources of fecal coliform change, this Plan and its management measures will need to adapt to ensure continued protection of the watershed. For this reason, the schedule proposed in the next section is based on information known at the time of the publishing of this report, and if any of that information is updated or adjusted, the schedule and measures recommended by this report will also need to be reassessed. Despite potential changes and/or adjustments to management measures suggested in this initial Watershed Improvement Plan, the City of Alpharetta commits to actively working to improve the conditions in the Long Indian Creek Watershed in order to meet the criteria set forth in the following section. Therefore, although the schedule set forth in this Plan may not be met, the City will still be progressing towards its goal of improved watershed health if the criteria are being achieved. In the City of Alpharetta's Annual Phase 1

MS4 Report to the EPD, it will note the milestones it has met with respect to this Watershed Improvement Plan or provide reasons why it has deviated from the plan and the alternate projects implemented to meet the changing pollution sources.

6.3.2 Criteria to Measure Load Reductions

Although several criteria are listed below, by far the most important criteria is the continued reduction of fecal coliform in the Long Indian Creek Watershed. However, it is acknowledge that a majority of the contamination is from dog waste which can be difficult to reduce rapidly as it requires a cultural shift rather than an investment in infrastructure in order to see noticeable reductions. Therefore, progress may be slow, and it is important to acknowledge other steps the City is taking in order to reduce pollution from dog waste, even if the results are not yet noticeable, and to improve the overall health of the watershed. For this reason, the criteria used to evaluate the progress towards improving the Long Indian Creek Watershed are:

- Report of fecal coliform monitoring results
    - Comparison of geometric means to TMDL and previous years' data
    - Before-and-after monitoring results for any implemented projects
    - Shifts in the major contributor of fecal coliform pollution
- Documentation of non-structural management measures started or continued
- Documentation of completed and in-progress structural management measures
- List of upgraded, retrofitted, or repaired BMPs
- In cases of water quality degradation, the City should:
    - Compare bacterial source tracking results in order to identify the source of the problem
    - Select an existing management measure or propose a new management measure to target the source of the pollution

6.3.3 Monitoring of Criteria

In order to most effectively track its progress towards meeting the criteria outlined in the previous section, it is recommended that the City of Alpharetta implement multiple monitoring avenues. First, the City will continue its Sampling and Quality Assurance Plan it entered with the City of Johns Creek in 2014. This program provides for sampling at 5 different locations along Long Indian Creek four times a year. This data will be the most important in determining long-term trends of water quality improvement or degradation within the watershed. Second, it is recommended that the City of Alpharetta implement a bacterial source tracking monitoring program. The BST monitoring implemented under this Plan has proved vital in identifying the major contributor of fecal coliform pollution to the watershed and, based on that knowledge, creating a pinpointed Watershed Improvement Plan. For this reason, it is recommended that the City continue to monitor the major fecal coliform contributors in the watershed so that the plan can be adjusted as needed to address changing needs. Third, it is recommended that the City of Alpharetta complete before-and-after sampling for initial dog waste station installations. This will allow the City to predict the amount of fecal coliform reduction it can expect from dog waste station installations located in other areas of the City. More information on each of these monitoring criteria has been provided in section 6.2.2.1 Non-Structural Management Measures.

6.4 Implementation Schedule

The schedule presented below provides a feasible implementation timeline for this Watershed Improvement Plan. Projects included in the implementation schedule were selected based their scores determined in **Table 6.2** - Prioritization and Ranking Scores for Recommended Project List. The ranking equation allowed for a maximum of 32 points to be awarded to any one project. Any projects receiving a score of 50% or greater (16 or more points) were included in the implementation schedule. The projects included are: 1) Dog Waste Station & Public Education; 2) Waters Road Enhanced Dry Swales Project 2 (South); 3) Waters Road Enhanced Dry Swales Project 1 (North); and 4) Bacterial Source Tracking (BST).

The remaining projects fall into two categories, stream restoration projects (WIP No. 2-6) and stormwater infrastructure capital improvement projects (WIP No. 7-9). The City of Alpharetta will refer all stream restoration projects identified to protect sewer infrastructure to Fulton County, and the stormwater infrastructure capital improvement projects will be added to the city-wide replacement and lining project list where they will be ranked and prioritized against all other city projects.

The implementation schedule presented in **Figure 6.3** recommends a staggered approach in order to provide breaks between projects for fecal coliform monitoring efforts. Based on the monitoring results, the schedule is subject to change and adjustment based on which projects prove to be most effective at reducing the fecal coliform loads in the watershed. For instance if only moderate reductions in fecal coliform loads are seen after one year of dog waste education, then dog waste stations are recommended to be installed in the third year. Then if substantial reductions are seen in fecal coliform levels after the installation of dog waste stations, funding for enhanced dry swale installations may be delayed in order to fund more dog waste stations as they would have already been proven successful. Although a set implementation timeline is shown in **Figure 6.3**, the schedule is designed to be a data-informed implementation schedule that allows for flexibility in project selection and scale decisions.

Despite potential changes and/or adjustments to management measures suggested in this initial Watershed Improvement Plan, the City of Alpharetta commits to actively working to improve the conditions in the Long Indian Creek Watershed in order to meet the criteria set forth in the previous section. **Figure 6.3** provides the suggested implementation schedule for the Long Indian Creek Watershed Improvement Plan.

	Long Indian Creek Watershed Improvement Implementation Plan					
Fiscal Year	FY '18	FY '19	FY '20	FY '21	FY '22	Estimated 5-year Cost
Date	July 2017 - June 2018	July 2018 - June 2019	July 2019 - June 2020	July 2020 - June 2021	July 2021 - June 2022	
Projects						
Dog Waste Education	$5,000	$5,000	$5,000	$5,000	$5,000	$25,000
Bacterial Source Tracking		$25,000		$25,000		$50,000
Dog Waste Station Installation			$25,000			$25,000
Dog Waste Station Maintenance			$39,000	$39,000	$39,000	$117,000
Enhanced Dry Swale Installation					$162,385	$162,835
					Total 5-year Cost	$379,835

Figure 6.3 – Long Indian Creek Watershed Improvement Plan implementation schedule.

6.5 Cost and Funding

This section summarizes the estimated cost required to complete this 5 year Watershed Improvement Plan and the potential technical and financial assistance sources that the City of Alpharetta can leverage to mitigate costs. This plan has a strong adaptability focus that allows the City of Alpharetta to adjust the schedule, budget, and management measures as it sees fit based on continued monitoring results. Despite potential changes and/or adjustments to management measures suggested in this initial Watershed Improvement Plan, the City of Alpharetta commits to actively working to improve the conditions in the Long Indian Creek Watershed in order to meet the criteria set forth in the previous section.

6.5.1 Cost Estimate

Capital cost estimates for each recommended project are shown in **Table 6.4**. Additionally, the project sheets in APPENDIX C: PROJECT SHEETS provide a break-down of the associated costs along with an estimated annual operations and maintenance cost.

Table 6.4 - Capital Costs for Recommended Projects.

WIP No.	Project Name	Capital Cost
1	Dog Waste Station & Public Education*	$50,000
10	Waters Road Enhanced Dry Swales Project 1 (North)	$79,826
11	Waters Road Enhanced Dry Swales Project 2 (South)	$83,009
12	Bacterial Source Tracking (BST)	$50,000

*Operational costs for dog waste stations will total $117,000. See the implementation schedule in **Figure 6.3** for annual cost information.

6.5.2 Partnership and Technical & Financial Assistance Opportunities

Although most funding for implementation of this Watershed Improvement Plan will come from the City of Alpharetta, multiple opportunities do exists on the local, state, and federal level for the sharing of project funding through partnerships in watershed management and technical and financial assistance through grants and loans.

Partnerships are most likely on a local level. One of the most obvious partnerships to address the challenges in Long Indian Creek is with the City of Johns Creek, as the Long Indian Creek Watershed spans both the political boundaries of Alpharetta and Johns Creek and a SQAP already exists between the two Cities. Additional local partners include local homeowners associations and/or other groups willing to sponsor dog waste stations. For instance, the City of Alpharetta could provide the initial funds for installation of the dog waste stations. These stations could then be adopted by homeowners associations or local businesses and/or community groups that could help maintain dog waste stations and provide continuing education to the public about proper disposal of dog waste. A further partnering opportunity includes private BMP owners as all BMPs in the Long Indian Creek Watershed within the City of Alpharetta are privately owned. The City could actively collaborate with these BMP owners so that the City can help guide upgrades as private owners elect to implement those measures. Additionally, the stream restoration projects are also focused on protecting sanitary sewer infrastructure which is operated and maintained by Fulton County. Therefore, there is the opportunity to jointly complete watershed improvement projects with the goal of minimizing costs for the City while maximizing the benefits for the watershed.

From a state funding level, there are two major grant opportunities:

1. Section 319(h) Georgia's Nonpoint Source Implementation Grant
2. Regional Water Plan Seed Grant Funds

The Section 319(h) Grants are actually federally funded and are further discussed in **Table 6.5**, but the funds are distributed by the state of Georgia. The Regional Water Plan Seed Grant Fund is designed to encourage the implementation of management practices from one of the Regional Water Plans. The maximum amount for the Regional Water Plan Seed Grant is $75,000 and is limited to 60% of the total project cost. Eligible activities and projects for the Regional Water Plan Seed Grant include: 1) Undertaking programs to address critical information and/or data needs identified in the Regional Water Plan(s); 2) Tracking and analyzing available monitoring data and reporting on water resource conditions as identified as needs in the Regional Water Plan(s); 3) Preparing and distributing technical guidance that can be shared by Regional Water Councils on management practices that affect common water resources; and 4) Providing technical assistance to support implementation of Regional Water Plan management practices. It is hoped that this grant money could help fund the recommended Bacterial Source Tracking project.

There are a multitude of funding options on the federal level with various requirements and eligibility. Based on a review of available funding sources, the most promising options for the Long Indian Creek Watershed have been compiled in **Table 6.5**.

Table 6.5 - Summary of technical and financial assistance provided by the federal government for which projects in the Long Indian Creek Watershed could apply.

Name	Agency	Eligible Parties	Program Overview	Technical Assistance	Match Amount	% of Applicants Funded	Typical Lowest Amount Awarded	Typical Highest Amount Awarded	Median Amount Awarded
Five-Star Restoration Program	EPA	Any public or private entity. Preference is shown to organizations connected to the local community who can monitor and sustain project for 5 years or more.	The program seeks to develop nation-wide-community stewardship of local natural resources, preserving these resources for future generations and enhancing habitat for local wildlife. Projects seek to address water quality issues in priority watersheds, such as erosion due to unstable streambanks, pollution from stormwater runoff, and degraded shorelines caused by development. Funding priorities include: 1) On-the-ground wetland, riparian, in-stream, and/or coastal habitat restoration; 2) Meaningful education and training activities; 2) Measurable ecological, educational, and community benefits; and 4) Partnerships that engage a diverse group of partners.	No	No	30%	$5,000	$45,000	$25,000
Urban Waters Small Grants	EPA	States, local governments, Indian Tribes, public and private universities and colleges, public or private nonprofit organizations, intertribal consortia, and interstate agencies	This program has an emphasis on engaging communities with environmental justice concerns. The objective of the grant is to fund projects that foster a comprehensive understanding of local urban water issues, identify and address these issues at the local level, and educate and empower the community. In particular, the Urban Waters Small Grants seek to help restore and protect urban water quality and revitalize adjacent neighborhoods by engaging communities in activities that increase their connection to, understanding of, and stewardship of local urban waterways.	No	$4,000	N/A	$40,000	$60,000	$60,000
Hazard Mitigation Grant Program	FEMA	States, U.S. Territories, Federally-recognized tribes, local governments	Climate Resilient Mitigation Activities are eligible under the Hazard Mitigation Assistance programs to support communities in reducing the risks associated with climate change. These activities are: Aquifer Storage and Recovery, Floodplain and Stream Restoration, Flood Diversion and Storage, and Green Infrastructure Methods. These activities can mitigate any natural hazard; however, the activities are focused on mitigating the impacts of flood and drought conditions.	No	25% (cash or in-kind resources)	N/A	$2,130	$36.3 million	$605,094

Name	Agency	Eligible Parties	Program Overview	Technical Assistance	Match Amount	% of Applicants Funded	Typical Lowest Amount Awarded	Typical Highest Amount Awarded	Median Amount Awarded
Clean Water State Revolving Fund (CWSRF)	EPA	Public, private, or nonprofit entity	The EPA's Clean Water State Revolving Fund (CWSRF) program provides a permanent source of low-cost financing for a wide range of water quality infrastructure projects. These projects include municipal wastewater treatment and collection, nonpoint source pollution controls, decentralized wastewater treatment systems, green infrastructure, water efficiency, and estuary management. Funds to capitalize the program are provided annually through federal grants and state matching funds (equal to 20 percent of federal grants). Monies are loaned to assistance recipients at below-market rates. In addition, states also have the ability to customize loan terms to benefit small and disadvantaged communities. Loan repayments are recycled back into the programs to fund additional projects. Since its inception, the CWSRF has provided over $111.2 billion in assistance to eligible borrowers, including communities of all sizes, farmers, small businesses, and nonprofit organizations.	No	Loan	N/A	No statutory limit	No statutory limit	N/A
Nonpoint Source Implementation Grants (319 Program)	EPA	States, territories, and tribes	The EPA provides formula grants to implement nonpoint source programs and projects in accordance with section 319 of the Clean Water Act (CWA). Nonpoint source pollution projects can be used for a wide range of activities including agriculture, forestry, construction, and urban challenges. When set as priorities within a state's nonpoint source management program, projects may also be used to protect source water areas and high quality waters. Examples of previously funded projects include installation of best management practices (BMPs) for animal waste; design and implementation of BMP systems for stream, lake, and estuary watersheds; and basin-wide landowner education programs. Most states provide opportunities for 3rd parties to apply for funds under a state request for proposal.	Yes	40% non-Federal	Variable	$422,000	$8.4 million	$2.8 million

Name	Agency	Eligible Parties	Program Overview	Technical Assistance	Match Amount	% of Applicants Funded	Typical Lowest Amount Awarded	Typical Highest Amount Awarded	Median Amount Awarded
Pulling Together Initiative	NFWF	State and local agencies, private landowners, and other interested parties	The initiative provides a means to develop long-term weed management projects within the scope of an integrated pest management strategy. The goals of PTI are: (1) to prevent, manage, or eradicate invasive and noxious plants through a coordinated program of public/private partnerships; and (2) to increase public awareness of the adverse impacts of invasive and noxious plants. PTI provides support for the formation of local weed management area (WMA) partnerships, allowing them to demonstrate successful collaborative efforts and develop permanent funding sources for the maintenance of WMAs from the involved parties. Successful projects will serve to increase public awareness and interest in future partnership projects.	Yes	1:1	40%	$25,000	$200,000	$75,000
Bring Back the Natives	NFWF	Local, state, federal, and tribal governments, special districts (e.g., conservation districts, planning districts, utility districts), non-profit 501(c) organizations, schools and universities.	The Bring Back the Natives initiative (BBN) funds on-the-ground efforts to restore native aquatic species to their historic range. Projects should involve partnerships between communities, agencies, private landowners, and organizations that seek to rehabilitate streamside and watershed habitats. Projects should focus on habitat needs of species such as fish, invertebrates, and amphibians that originally inhabited the waterways across the country. Funding for the BBN program is administered through NFWF from federal agencies cooperating to support this program. Cooperating agencies and organizations include the US Fish and Wildlife Service (FWS), Bureau of Land Management (BLM), USDA Forest Service (FS), and Trout Unlimited (TU).	No	2:1	30%	$20,000	$100,000	$60,000

Name	Agency	Eligible Parties	Program Overview	Technical Assistance	Match Amount	% of Applicants Funded	Typical Lowest Amount Awarded	Typical Highest Amount Awarded	Median Amount Awarded
Partners for Fish and Wildlife Program	FWS	Private landowners	The program provides technical and financial assistance to private landowners to restore fish and wildlife habitats on their lands via cooperative agreements. Since 1987, the program has partnered with more than 37,700 landowners to restore 765,400 acres of wetlands; over 1.9 million acres of grasslands and other upland habitats; and 6,560 miles of in-stream and streamside habitat. In addition, the program restores stream habitat for fish and other aquatic species by removing barriers to passage.	Yes	Yes (negotiable)	N/A	$1,000	$50,000	$25,000

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APPENDIX A: EPA'S NINE KEY ELEMENTS OF A WATERSHED-BASED PLAN

The Environmental Protection Agency's nine key elements of a watershed-based plan have been addressed throughout this watershed improvement plan. In order to provide ease of access and review, a summary of each element is provide below along with the section in which more information can be found.

1. Identify causes of impairments and pollutants sources or groups of sources that need to be controlled to achieve needed load reductions and any other goals identified in the watershed plan.

   Section 3.1.1 Water Quality Pollutants
   Section 3.2 Field Data Collection
   Section 3.3 Water Quality Data

   Long Indian Creek is listed as an impaired stream on the Georgia Environmental Protection Division (EPD) 303(d) list for fecal coliform for its entire four mile reach. The EPD developed a Total Maximum Daily Load (TMDL) for Long Indian Creek in 2013 that recommends a 95% reduction in fecal coliform.

   An extensive field reconnaissance effort was completed for the Long Indian Creek Watershed. The objective of the field work was to analyze existing streams, drainage features, BMPs, and erosion problems in the watershed in order to identify and select opportunities for future capital improvements that are most effective at improving water quality and stream conditions. Prior to fieldwork, Dewberry reviewed the data collection efforts with the City of Alpharetta in order to target specific areas of the watershed for field reconnaissance. The location and intensity of survey points evaluated by field teams was focused in the following areas of the watershed:

   - Areas having the highest percentage of impervious area;
   - Areas with a high concentration of drainage complaints;
   - Areas with sanitary sewer infrastructure crossing or in close proximity to the stream;
   - Areas with a concentration of septic systems;
   - Bridges, culverts, and systems that indicate flooding per the hydrodynamic modeling in events less than the 100-year level of service for bridges and culverts and less than 25-year level of service for systems;
   - Exiting BMPs on public facilities and existing BMPs on select commercial and residential properties agreed upon with the City of Alpharetta;
   - Stream reaches with erosive velocities in the 1-year storm event, and;
   - Steam reaches with visible erosion evident from aerial imagery.

   The City of Alpharetta began consistently monitoring the water quality in Long Indian Creek in 2008. Further steps towards assessing the condition of the watershed began in 2014 when the City of Alpharetta and the City of Johns Creek entered into a Sampling and Quality Assurance Plan (SQAP) for testing and analysis of fecal coliform on Long Indian Creek. Samples are taken four times a year at 5 different locations along Long Indian Creek to identify potential sources and analyze trends. Furthermore, Fulton County is conducting water quality monitoring for fecal coliform on Long Indian Creek at Waters Road (Site 4). All the results of these monitoring efforts have been combined in this report and are presented in the next section.

   As an additional measure, the City of Alpharetta elected to utilize Bacterial Source Tracking (BST) sampling for human, dog, geese, bird, and ruminants as a part of this project in the fall of 2015 and spring of 2016 to identify the organisms contributing to the elevated fecal coliform levels in the Long Indian Creek Watershed. BST is a new technology used to identify the source of contamination based on DNA markers. BST copies and amplifies the DNA of the fecal coliform bacteria found in water samples and compares it with an existing DNA library to determine if the fecal coliform bacteria has human, dog, geese, bird, or goose origins. As samples have indicated that dog waste is the primary contributor to the fecal coliform load in the Long Indian Creek Watershed.

2. An estimate of the load reductions expected from management measures.

Section 4.2.2 Dog Waste Stations and Community Education

Three model scenarios were created to compare the effectiveness of installing dog waste stations and community education. The first scenario is the existing conditions model which only includes fecal load reductions from dog waste stations currently installed at Ocee Park in the Johns Creek. The second scenario assumes dog waste stations and community education are implemented in all areas of the watershed that are part of the City of Alpharetta and two 'hotspot' areas within Johns Creek which potentially have a high concentration of dogs based on visual observations. The 'hotspot' areas are a business corridor along State Bridge Road with numerous veterinarians and groomers along with a Petco, and the second area is the North Haven apartment complex off of State Bridge Road that allows pets. The third scenario assumes that dog waste stations and community education are implemented throughout the entire watershed including the City of Johns Creek. This is the most comprehensive model and would require coordination and assistance from the City of Johns Creek. **Table 4.6** compares the modeled fecal coliform loading results from each scenario. To summarize the scenarios:

- **Scenario 1:** Existing conditions model
- **Scenario 2:** Dog waste stations and community education are implemented in all areas of the watershed that are part of the City of Alpharetta and two 'hotspot' areas within Johns Creek
- **Scenario 3:** Dog waste stations and community education are implemented throughout the entire watershed including the City of Johns Creek

The data shown in **Table 4.6** can also be visually displayed in **Figure 4.3-Figure 4.5**. The two parallel lines indicate the summer (lower curve) and winter (upper curve) TMDLs for Long Indian Creek. Modeled values are represented by open circles. Any red circle falling above the winter TMDL curve (red line) represents a violation of the winter TMDL, and any gray circle falling above the summer TMDL (gray line) represents a violation of the summer TMDL. The two curves are necessary because the winter months have a higher TMDL than the summer months. It should be noted that a greater number of modeled points drop below the summer TMDL line (gray) for each scenario, and scenario 3 results in a sufficient decrease in fecal coliform load where all of the points drop below the summer TMDL line.

Table 4.6 - Comparison of 30-day fecal load for each scenario run at each sampling site for every month in which there was a calibrated TMDL. The percent reductions indicate the expected fecal load reduction from each scenario when compared with scenario 1, the existing conditions model.

Month	Site	Average Gage Flow (CFS)	Average Modeled Flow (CFS)	Flow Percent Error	Measured 30-day Fecal Load (Counts)	Modeled 30-day Fecal Load (Counts)	30-day Fecal Load Percent Error
January 2015	1	1.4	1.5	2%	6.12e10	1.63e11	167%
	2	2.4	2.4	3%	2.49e11	2.81e11	13%
	3	3.0	2.9	1%	1.98e11	3.14e11	58%
	4	5.2	4.7	9%	3.68e11	4.44e11	21%
	5	8.0	7.0	12%	1.34e11	6.32e11	370%
April 2015	1	1.5	1.7	18%	3.77e10	2.55e11	577%
	2	2.5	2.9	18%	3.36e11	4.39e11	31%
	3	3.0	3.5	15%	1.70e11	4.90e11	189%
	4	5.3	5.6	6%	2.98e11	6.88e11	131%
	5	8.1	7.9	3%	4.68e11	9.76e11	108%
June 2015	1	0.4	0.5	33%	N/A	7.81e10	N/A
	2	0.6	0.8	37%	N/A	1.33e11	N/A
	3	0.8	1.0	29%	N/A	1.46e11	N/A

	4	1.3	1.6	19%	2.33e11	1.94e11	17%
	5	2.0	2.1	6%	N/A	2.65e11	N/A
July 2015	1	0.6	0.9	46%	1.85e11	1.59e11	14%
	2	1.1	1.6	49%	1.50e11	2.71e11	81%
	3	1.3	1.9	43%	6.11e10	3.05e11	399%
	4	2.3	3.2	36%	1.52e11	4.30e11	183%
	5	3.6	4.5	25%	4.91e11	6.14e11	25%
August 2015	1	0.9	0.9	1%	N/A	1.21e11	N/A
	2	1.6	1.6	1%	N/A	2.09e11	N/A
	3	1.9	2.0	3%	N/A	2.32e11	N/A
	4	3.3	3.3	1%	2.98e11	3.18e11	7%
	5	5.1	4.8	6%	N/A	4.37e11	N/A
October 2015	1	0.8	1.1	38%	2.40e11	1.83e11	24%
	2	1.4	1.9	40%	2.32e11	3.11e11	34%
	3	1.7	2.3	35%	3.50e11	3.47e11	1%
	4	2.9	3.7	26%	4.32e11	4.82e11	12%
	5	4.5	5.2	15%	5.02e11	6.78e11	35%
November 2015	1	3.8	4.3	13%	N/A	6.63e11	N/A
	2	6.4	7.5	16%	N/A	1.13e12	N/A
	3	7.9	9.2	17%	N/A	1.30e12	N/A
	4	13.8	15.6	13%	5.23e12	1.90e12	64%
	5	21.1	22.3	6%	N/A	2.79e12	N/A
January 2016	1	4.1	4.4	7%	1.73e11	2.49e11	44%
	2	7.0	7.5	7%	5.36e11	4.34e11	19%
	3	8.6	9.9	15%	3.35e11	4.91e11	47%
	4	15.1	16.8	12%	1.55e12	6.97e11	55%
	5	23.1	24.8	7%	4.14e11	1.00e12	142%
February 2016	1	2.8	2.7	5%	N/A	3.75e11	N/A
	2	4.8	4.5	6%	N/A	6.30e11	N/A
	3	5.9	5.6	4%	N/A	7.14e11	N/A
	4	10.3	9.1	11%	1.04e12	1.01e12	3%
	5	15.7	13.4	15%	N/A	1.47e12	N/A
April 2016	1	0.9	0.9	2%	3.23e10	1.52e11	371%
	2	1.6	1.6	3%	3.93e11	2.68e11	32%
	3	2.0	1.9	1%	1.65e11	3.00e11	82%
	4	3.4	3.2	5%	2.33e11	4.24e11	82%
	5	5.2	4.6	12%	1.43e11	6.08e11	324%

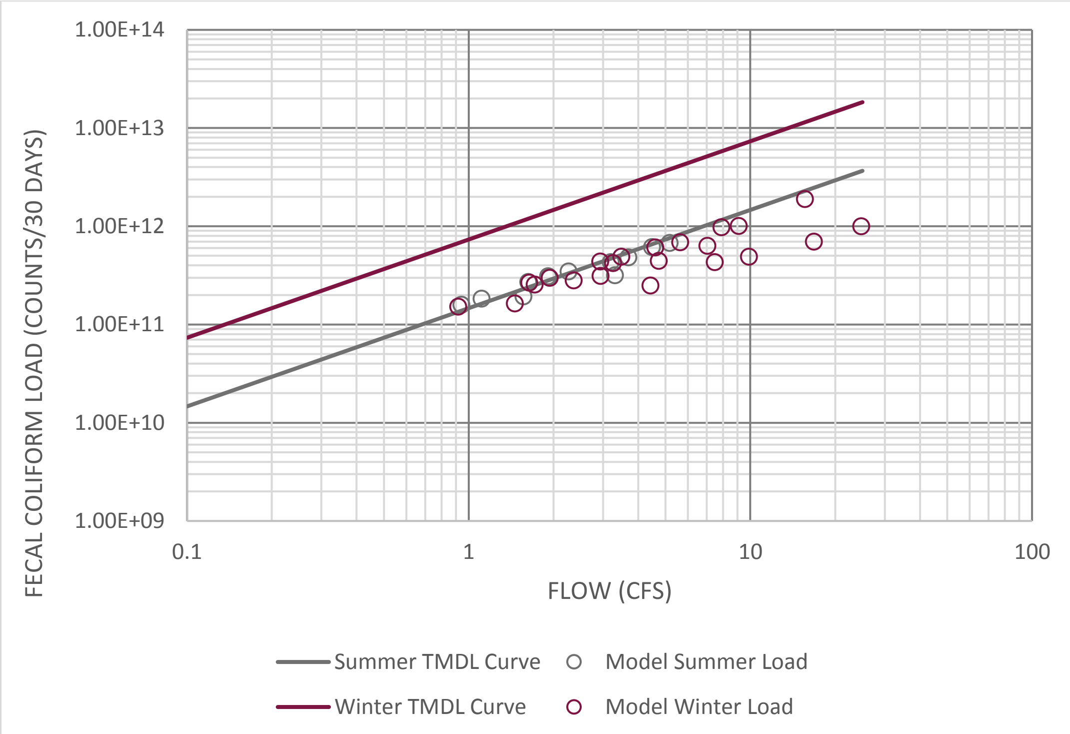


Figure 4.3 - 30-day fecal coliform load versus flow for Scenario 1. The top line represents the winter TMDL and the gray line represents the Summer TMDL. Red circles correspond with modeled winter values, and gray circles correspond with modeled summer values.

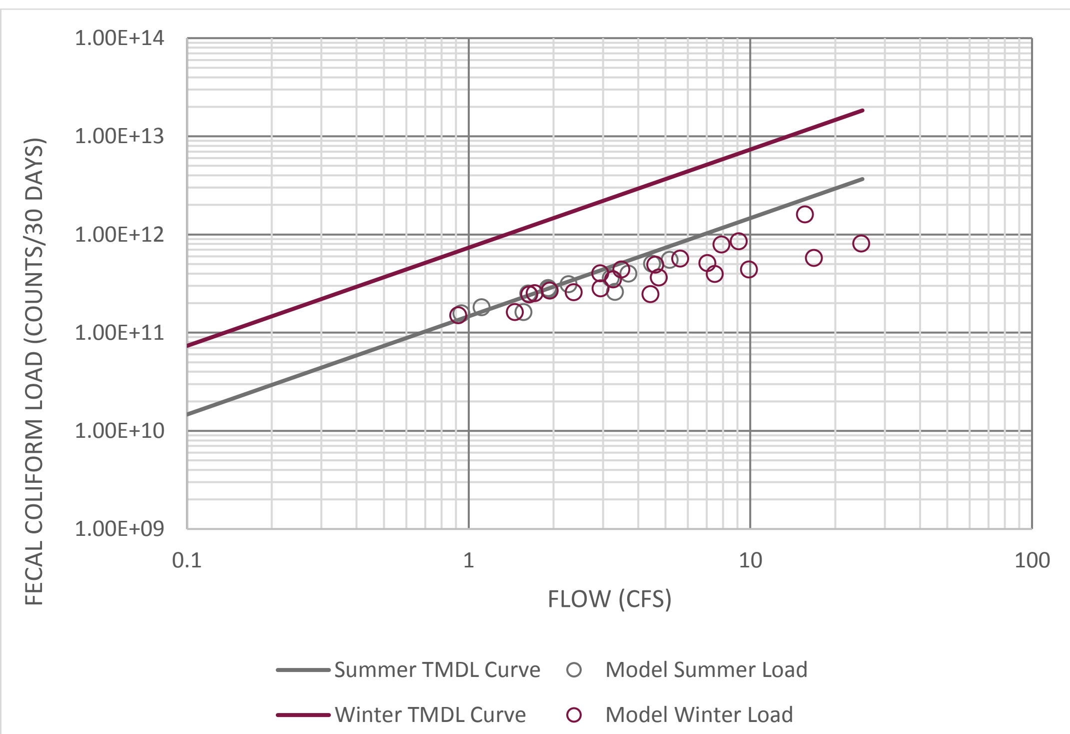


Figure 4.4 - 30-day fecal coliform load versus flow for Scenario 2. The top line represents the winter TMDL and the gray line represents the Summer TMDL. Red circles correspond with modeled winter values, and gray circles correspond with modeled summer values.

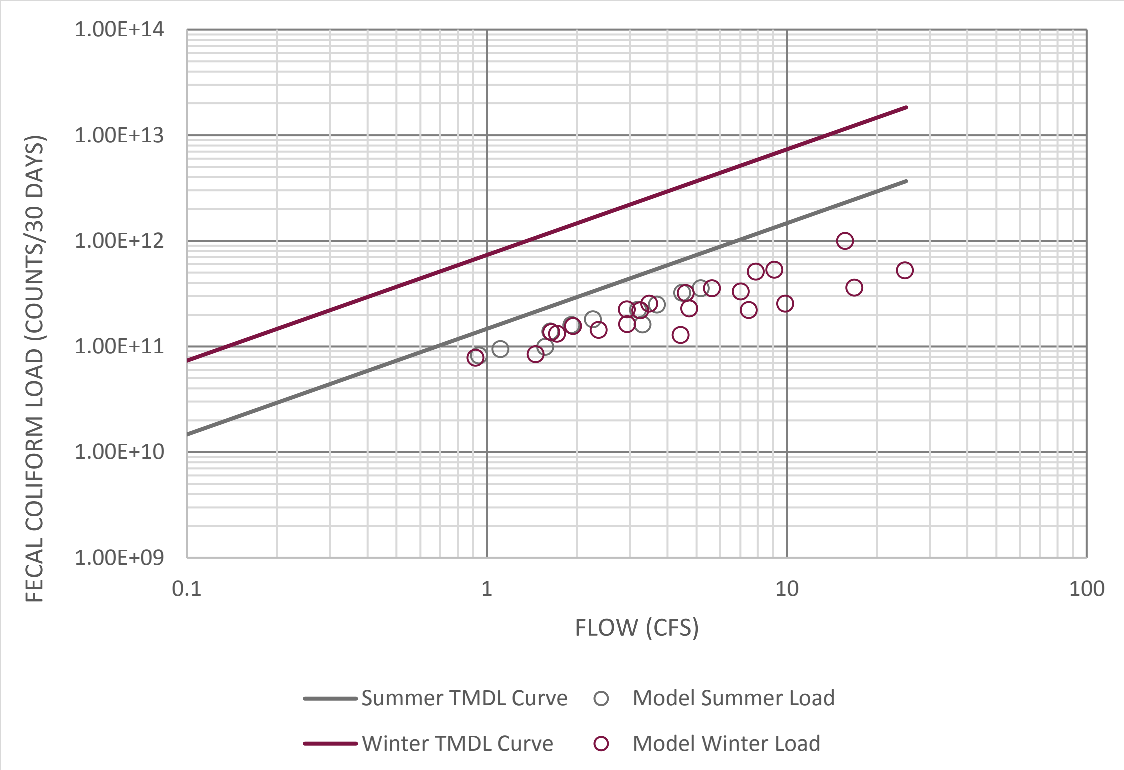


Figure 4.5 - 30-day fecal coliform load versus flow for Scenario 3. The top line represents the winter TMDL and the gray line represents the Summer TMDL. Red circles correspond with modeled winter values, and gray circles correspond with modeled summer values.

No other project recommendations are anticipated to create a substantial reduction in fecal coliform load. Although, stream restorations and enhanced swales are expected to reduce the total TSS loading in the watershed.

3. A description of the nonpoint source management measures that will need to be implemented to achieve load reductions, and a description of the critical areas in which those measures will be needed to implement this plan.

Section 6.2.2 Management Measures for Nonpoint Source Pollution
APPENDIX C: PROJECT SHEETS

Non-structural management measures can provide a wide range of options to address nonpoint source pollution. Additionally, non-structural measures tend to be less expensive than structural options. Therefore when working to reduce nonpoint source pollution, non-structural methods can initially be implemented, along with any complementary structural methods, to attempt to reach pollution reduction goals before making large investments in structural methods. Below is a list of non-structural management measures:

1. Dog Waste Stations and Public Education
2. Bacterial Source Tracking
3. Before-and-After Fecal Coliform Monitoring
4. Repair Damage BMPs
5. Encourage Restoration of Stream Buffers
6. Remove Debris Jams
7. Collaborate with Private BMP Owners

Table 6.3 - Final ranking of suggested structural management measures.**Error! Reference source not found.**

WIP No.	Project Name	Final Ranking
1	Dog Waste Station & Public Education	1
11	Waters Road Enhanced Dry Swales Project 2 (South)	2
10	Waters Road Enhanced Dry Swales Project 1 (North)	3
12	Bacterial Source Tracking (BST)	3
2	Stream Restoration and Sanitary Sewer Protection Project 1	5
4	Stream Restoration and Sanitary Sewer Protection Project 3	5
3	Stream Restoration and Sanitary Sewer Protection Project 2	7
5	Stream Restoration and Sanitary Sewer Protection Project 4	7
6	Stream Restoration and Sanitary Sewer Protection Project 5	7
9	Birch Rill Drive Capital Improvement Project No. LIC_0100_1	10
7	Pinehollow Court Neighborhood Flooding	11
8	Tuxford Neighborhood Flooding	12

4. Estimate of the amounts of technical and financial assistance needed, associated costs, and/or the sources and authorities that will be relied upon to implement this plan.

   Section 6.5.1 Cost Estimate
   Section 6.5.2 Partnership and Technical & Financial Assistance Opportunities

   Capital cost estimates for each recommended project are shown in **Table 6.4**. Additionally, the project sheets in APPENDIX C: PROJECT SHEETS provide a break-down of the associated costs along with an estimated annual operations and maintenance cost.

Table 6.4 - Capital Costs for Recommended Projects.

WIP No.	Project Name	Capital Cost
1	Dog Waste Station & Public Education*	$50,000
10	Waters Road Enhanced Dry Swales Project 1 (North)	$79,826
11	Waters Road Enhanced Dry Swales Project 2 (South)	$83,009
12	Bacterial Source Tracking (BST)	$50,000

*Operational costs for dog waste stations will total $117,000. See the implementation schedule in **Figure 6.3** for annual cost information.

Partnerships are most likely on a local level. One of the most obvious partnerships to address the challenges in Long Indian Creek is with the City of Johns Creek, as the Long Indian Creek Watershed spans both the political boundaries of Alpharetta and Johns Creek and a SQAP already exists between the two Cities. Additional local partners include local homeowners associations and/or other groups willing to sponsor dog waste stations. For instance, the City of Alpharetta could provide the initial funds for installation of the dog waste stations. These stations could then be adopted by homeowners associations or local businesses and/or community groups that could help maintain dog waste stations and provide continuing education to the public about proper disposal of dog waste. A further partnering opportunity includes private BMP owners as all BMPs in the Long Indian Creek Watershed within the City of Alpharetta are privately owned. The City could actively collaborate with these BMP owners so that the City can help guide upgrades as private owners elect to implement those measures. Additionally, the stream restoration projects are also focused on protecting sanitary sewer infrastructure which is operated and maintained by Fulton County. Therefore, there is the opportunity to jointly complete watershed improvement projects with the goal of minimizing costs for the City while maximizing the benefits for the watershed.

From a state funding level, there are two major grant opportunities:

1. Section 319(h) Georgia's Nonpoint Source Implementation Grant
2. Regional Water Plan Seed Grant Funds

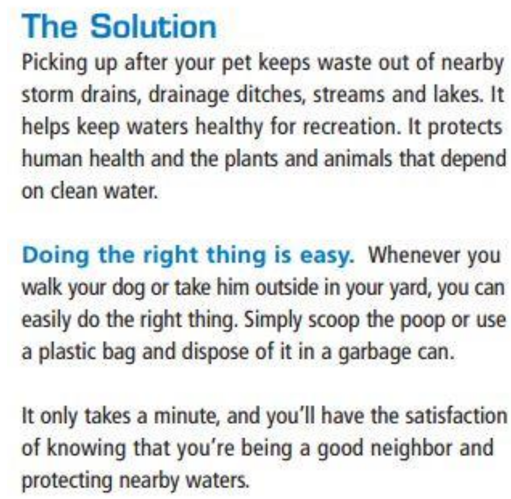
The Section 319(h) Grants are actually federally funded and are further discussed in **Table 6.5**, but the funds are distributed by the state of Georgia. The Regional Water Plan Seed Grant Fund is designed to encourage the implementation of management practices from one of the Regional Water Plans. The maximum amount for the Regional Water Plan Seed Grant is $75,000 and is limited to 60% of the total project cost. Eligible activities and projects for the Regional Water Plan Seed Grant include: 1) Undertaking programs to address critical information and/or data needs identified in the Regional Water Plan(s); 2) Tracking and analyzing available monitoring data and reporting on water resource conditions as identified as needs in the Regional Water Plan(s); 3) Preparing and distributing technical guidance that can be shared by Regional Water Councils on management practices that affect common water resources; and 4) Providing technical assistance to support implementation of Regional Water Plan management practices. It is hoped that this grant money could help fund the recommended Bacterial Source Tracking project.

There are a multitude of funding options on the federal level with various requirements and eligibility. Based on a review of available funding sources, the most promising options for the Long Indian Creek Watershed have been compiled in **Table 6.5**.

5. An information and education component used to enhance public understanding of the project and encourage their early and continued participation in selecting, designing, and implementing the nonpoint source management measures that will be implemented.

Section 6.2.2.1 Non-Structural Management Measures

Dog Waste Stations and Public Education
The City of Alpharetta already has a strong public education portion associated with its Stormwater Management Program through its partnership with the Clean Water Campaign. Key issues include, pet waste management, septic tank maintenance, stormwater stenciling, lawn care, and other critical issues involving watershed health. **Figure 6.1** provides a sampling of educational material provided by the City of Alpharetta.



The Solution

Picking up after your pet keeps waste out of nearby storm drains, drainage ditches, streams and lakes. It helps keep waters healthy for recreation. It protects human health and the plants and animals that depend on clean water.

Doing the right thing is easy. Whenever you walk your dog or take him outside in your yard, you can easily do the right thing. Simply scoop the poop or use a plastic bag and dispose of it in a garbage can.

It only takes a minute, and you'll have the satisfaction of knowing that you're being a good neighbor and protecting nearby waters.

Figure 6.1 - Examples of educational and outreach material provided by the City of Alpharetta to inform citizens about protecting stormwater.

Although the public education component is a non-structural measure, it could strongly benefit from the complementary structural measure of installing dog waste stations throughout the watershed. As the initial installation of the dog waste stations would require a capital cost, a project sheet has been included for dog waste stations and public education. More information specific to dog waste stations is provided in the project sheet in APPENDIX C: PROJECT SHEETS. In the case of public outreach, the actual dog waste stations could provide a public education opportunity simply through their installation and signage. Further, dog waste stations provide an opportunity for Alpharetta to partner with homeowners associations and other civic groups in order to explain the necessity of dog waste stations to protect the Long Indian Creek watershed. Brochures from the Clean Water Campaign regarding dog waste could be distributed to residents of neighborhoods receiving dog waste stations, increasing the likelihood that the message will be heard. The fliers could be sent by mailer, but higher success could likely be achieved by hand delivering fliers by volunteers who are versed in discussing the importance of utilizing dog waste stations. Additionally, fliers and information could be provided to local veterinarians, dog groomers, and dog boarders to provide and discuss with their customers the importance of properly disposing of dog waste. Ultimately, the long-term involvement and commitment from homeowners associations and/or other dedicated groups/clubs of citizens will ensure that the dog waste stations are adopted, maintained, and well utilized, ensuring that pet waste cleanup becomes ingrained in residents' behavior.

Encourage Restoration of Stream Buffers
During the stream walk, it was noted that many private yards and parks associated with neighborhoods provided very little or no buffer around the stream banks. In these areas, stream bank erosion was especially prevalent. Unfortunately, there is no publicly owned land along the stream banks, and therefore, no opportunity for the City of Alpharetta to implement buffer protection and/or restoration measures. However, the City does support a program called Alpharetta's Wild Side with the goal of becoming a National Community Wildlife Habitat, a program supported by the National Wildlife Federation. In order to qualify for the program, the City must register at least 200 homes and 6 common areas that are designated as wildlife habitats, and in order to be designated as a wildlife habitat, the home or common area must provide food, water, and shelter that support wildlife. Therefore, homes and common areas located along streams are excellent opportunities for wildlife habitats, and through the Wild Side program, homeowners and homeowners associations could be encouraged to return stream buffers on their habitat to more natural habitats, improving the health of the watershed and the habitat for local wildlife.

6. Schedule for implementing the nonpoint source management measures identified in this plan that is reasonable expeditious.

   Section 6.4 Implementation Schedule

   A recommended Watershed Improvement Plan Schedule is provided below.

	Long Indian Creek Watershed Improvement Implementation Plan					
Fiscal Year	FY '18	FY '19	FY '20	FY '21	FY '22	Estimated 5-year Cost
Date	July 2017 - June 2018	July 2018 - June 2019	July 2019 - June 2020	July 2020 - June 2021	July 2021 - June 2022	
Projects						
Dog Waste Education	$5,000	$5,000	$5,000	$5,000	$5,000	$25,000
Bacterial Source Tracking		$25,000		$25,000		$50,000
Dog Waste Station Installation			$25,000			$25,000
Dog Waste Station Maintenance			$39,000	$39,000	$39,000	$117,000
Enhanced Dry Swale Installation					$162,385	$162,835
					Total 5-year Cost	$379,835

Figure 6.3 – Long Indian Creek Watershed Improvement Plan implementation schedule.

7. A description of interim measurable milestones for determining whether nonpoint source management measures or other control actions are being implemented.

   Section 6.3.1 Measurable Milestones

   This Watershed Improvement Plan is designed as a guiding document that the City of Alpharetta can use when determining non-structural and structural management measures to reduce the fecal coliform load in the Long Indian Creek Watershed. As new data arises and/or sources of fecal coliform change, this Plan and its management measures will need to adapt to ensure continued protection of the watershed. For this reason, the schedule proposed in the next section is based on information known at the time of the publishing of this report, and if any of that information is updated or adjusted, the schedule and measures recommended by this report will also need to be reassessed. Despite potential changes and/or adjustments to management measures suggested in this initial Watershed Improvement Plan, the City of Alpharetta commits to actively working to improve the conditions in the Long Indian Creek Watershed in order to meet the criteria set forth in the following section. Therefore, although the schedule set forth in this Plan may not be met, the City will still be progressing towards its goal of improved watershed health if the criteria are being achieved. In the City of Alpharetta's Annual Phase 1 MS4 Report to the EPD, it will note the milestones it has met with respect to this Watershed Improvement Plan or provide reasons why it has deviated from the plan and the alternate projects implemented to meet the changing pollution sources.

8. A set of criteria that can be used to determine whether loading reductions are being achieved over time and substantial progress is being made toward attaining water quality standards.

   Section 6.3.2 Criteria to Measure Load Reductions

   Although several criteria are listed below, by far the most important criteria is the continued reduction of fecal coliform in the Long Indian Creek Watershed. However, it is acknowledge that a majority of the contamination is from dog waste which can be difficult to reduce rapidly as it requires a cultural shift rather than an investment in infrastructure in order to see noticeable reductions. Therefore, progress may be slow, and it is important to acknowledge other steps the City is taking in order to reduce pollution from dog waste, even if the results are not yet noticeable, and to improve the overall health of the watershed. For this reason, the criteria used to evaluate the progress towards improving the Long Indian Creek Watershed are:

   - Report of fecal coliform monitoring results
     - Comparison of geometric means to TMDL and previous years' data
     - Before-and-after monitoring results for any implemented projects
     - Shifts in the major contributor of fecal coliform pollution
   - Documentation of non-structural management measures started or continued
   - Documentation of completed and in-progress structural management measures
   - List of upgraded, retrofitted, or repaired BMPs
   - In cases of water quality degradation, the City should:
     - Compare bacterial source tracking results in order to identify the source of the problem
     - Select an existing management measure or propose a new management measure to target the source of the pollution

9. A monitoring component to evaluate the effectiveness of the implementation efforts over time, measured against the criteria established in the item above.

   Section 6.3.3 Monitoring of Criteria

   In order to most effectively track its progress towards meeting the criteria outlined in the previous section, it is recommended that the City of Alpharetta implement multiple monitoring avenues. First, the City will continue its Sampling and Quality Assurance Plan it entered with the City of Johns Creek in 2014. This program provides for sampling at 5 different locations along Long Indian Creek four times a year. This data will be the most important in determining long-term trends of water quality improvement or degradation within the watershed. Second, it is recommended that the City of Alpharetta implement a bacterial source tracking monitoring program. The BST monitoring implemented under this Plan has proved vital in identifying the major contributor of fecal coliform pollution to the watershed and, based on that knowledge, creating a pinpointed Watershed Improvement Plan. For this reason, it is recommended that the City continue to monitor the major fecal coliform contributors in the watershed so that the plan can be adjusted as needed to address changing needs. Third, it is recommended that the City of Alpharetta complete before-and-after sampling for initial dog waste station installations. This will allow the City to predict the amount of fecal coliform reduction it can expect from dog waste station installations located in other areas of the City. More information on each of these monitoring criteria has been provided in section 6.2.2.1 Non-Structural Management Measures.

APPENDIX B: MNGWPD'S ELEMENTS FOR A WATERSHED IMPROVEMENT PLAN

The Metropolitan North Georgia Water Planning District's elements for a watershed improvement plan have been addressed throughout this watershed improvement plan. In order to provide ease of access and review, a summary of each element is provide below along with the section in which more information can be found.

1. Introduction – Brief overview of the watershed being addressed, including watershed delineation and drainage maps.

   Section 1.1 Background and Description of Watershed
   Section 1.2 Study Purpose

   Long Indian Creek extends approximately 4 miles from its headwaters in the City of Johns Creek downstream to the confluence with Big Creek. Its watershed area is approximately 3.6 square miles and consists predominately of residential land use with a smaller percentage of commercial, institutional, parks, and undeveloped land tracts. In general, half of the watershed is in the City of Alpharetta (City) and half is located in the City of Johns Creek. **Figure 1.1** provides a vicinity map of the Long Indian Creek Watershed, and **Figure 1.2** provides a more detailed view of the watersheds that compose the Long Indian Creek and its drainage map.

   Long Indian Creek is listed as an impaired stream segment on the Georgia Environmental Protection Division (EPD) 303(d) list for fecal coliform for its entire 4 mile reach. EPD requires that the City conduct and/or update watershed studies for impaired stream on 5-year intervals through the City's National Pollutant Discharge Elimination System (NPDES) Permit. EPD developed a Total Maximum Daily Load (TMDL) for Long Indian Creek in 2013 that recommends a 95-percent reduction in fecal coliform.

   The City, in conjunction with the City of Johns Creek, entered a Sampling and Quality Assurance Plan (SQAP) in 2014 for testing and analysis of fecal coliform on Long Indian Creek. Samples are taken at 5 different locations along Long Indian Creek to identify potential sources and analyze trends. Furthermore, Fulton County is currently conducting water quality monitoring for fecal coliform on Long Indian Creek at Waters Road.

2. Problem Identification – Assessment of watershed impairments including flooding, bank/channel erosion and stability, hydraulic capacity, aquatic habitat/biological, and water quality. Field sampling, data collection and/or modeling may be used to evaluate existing or potential problems and impairments.

   Section 3.1 Current Challenges
   Section 3.2 Field Data Collection
   Section 3.3 Water Quality Data

   The Long Indian Watershed Improvement Project included two major parts. The first part was an extensive data collection phase to thoroughly assess the conditions of the watershed. The data collection phase involved coordination with the watershed stakeholders (City of Alpharetta, City of Johns Creek, and Fulton County) to gather any data that could impact the watershed such as sewer crossing locations, stormwater infrastructure, drainage complaints, etc. Further, streamwalks were completed for over five miles of Long Indian Creek and its tributaries. Data collected during these stream walks include Stream Reach Observation Summary Forms, Habitat Assessment Field Data Sheets, Bank Erosion Hazard Index Forms, and GIS inventory shapefiles with referenced photographs. Lastly, fecal coliform measurements and bacterial source tracking (BST) were utilized to quantify the pathogen levels in the stream and determine the source(s) of fecal coliform in Long Indian Creek.

The major challenges facing the Long Indian Creek Watershed include:

4. Stormwater
   a. **Effects of stormwater runoff** – significant areas of impervious and lawn land cover generate increased stormwater runoff which contributes to erosion of the stream banks and potentially increases pathogen loads in the stream during wet weather.
   b. **Elevated fecal coliform levels in stream** – BST indicated dogs as a major source of fecal coliform in the watershed. Lawns and open space are the most likely land coverage to contribute heavily to fecal loading from dog waste.

5. Wastewater
   a. **SSOs and Septic Systems -** BST indicated humans as a source of minor contributor of fecal coliform in the watershed. The most likely sources are from sanitary sewer overflows in wet weather and improperly maintained septic systems in the watershed.

6. Ecology
   a. **Invasive species** – Kill off native species and provide insufficient root mass to secure stream banks from erosion. Bamboo, Privet, and Russian Olive were seen in the watershed.
   b. **Altered watershed hydrology** – increased impervious and lawn area
   c. **Altered stream geomorphology** – reduced length of stream flow path; and loss of connectivity with historic floodplain.

3. Mitigation/Improvement Projects – Potential structural measures, infrastructure improvements, retrofits, and restoration efforts that will help address the problems identified in the watershed. Include conceptual plans and/or designs with a level of detail sufficient to prepare planning level cost estimates. Modeling can be used to evaluate the potential projects to meet the proposed objectives.

   Section 6.2.2 Management Measures for Nonpoint Source Pollution
   APPENDIX C: PROJECT SHEETS

   Non-structural management measures can provide a wide range of options to address nonpoint source pollution. Additionally, non-structural measures tend to be less expensive than structural options. Therefore when working to reduce nonpoint source pollution, non-structural methods can initially be implemented, along with any complementary structural methods, to attempt to reach pollution reduction goals before making large investments in structural methods. Below is a list of non-structural management measures:

   1. Dog Waste Stations and Public Education
   2. Bacterial Source Tracking
   3. Before-and-After Fecal Coliform Monitoring
   4. Repair Damage BMPs
   5. Encourage Restoration of Stream Buffers
   6. Remove Debris Jams
   7. Collaborate with Private BMP Owners

Table 6.3 - Final ranking of suggested structural management measures.

WIP No.	Project Name	Final Ranking
1	Dog Waste Station & Public Education	1
11	Waters Road Enhanced Dry Swales Project 2 (South)	2
10	Waters Road Enhanced Dry Swales Project 1 (North)	3
12	Bacterial Source Tracking (BST)	3
2	Stream Restoration and Sanitary Sewer Protection Project 1	5
4	Stream Restoration and Sanitary Sewer Protection Project 3	5
3	Stream Restoration and Sanitary Sewer Protection Project 2	7
5	Stream Restoration and Sanitary Sewer Protection Project 4	7
6	Stream Restoration and Sanitary Sewer Protection Project 5	7
9	Birch Rill Drive Capital Improvement Project No. LIC_0100_1	10
7	Pinehollow Court Neighborhood Flooding	11
8	Tuxford Neighborhood Flooding	12

4. Project Cost Estimates – Cost estimates for the potential projects.

   Section 6.5.1 Cost Estimate

   Capital cost estimates for each recommended project are shown in **Table 6.4**. Additionally, the project sheets in APPENDIX C: PROJECT SHEETS provide a break-down of the associated costs along with an estimated annual operations and maintenance cost.

Table 6.4- Capital Costs for Recommended Projects.

WIP No.	Project Name	Capital Cost
1	Dog Waste Station & Public Education*	$50,000
10	Waters Road Enhanced Dry Swales Project 1 (North)	$79,826
11	Waters Road Enhanced Dry Swales Project 2 (South)	$83,009
12	Bacterial Source Tracking (BST)	$50,000

*Operational costs for dog waste stations will total $117,000. See the implementation schedule in **Figure 6.3** for annual cost information.

5. Project Ranking and Prioritization – Evaluation of the potential watershed improvement project based upon a set of criteria.

   Section 6.2.1 Prioritization Process of Management Measures

   Once the 15 potential project were identified, they were ranked using predetermined criteria. The criteria was designed to capture the wide array of opportunities and obstacles presented by each project. However, it is chiefly important that two main criteria are most strongly considered: 1) Will the proposed project reduce fecal coliform loads which have resulted in an exceedance of the total maximum daily load for the entire stream; and 2) Is the proposed project located on public land, a requirement for constructability. With these goals in mind, the ranking criteria in **Table 6.1** were developed to assist in selecting the projects with the greatest potential to improve the watershed, considering costs and other limitations. The criteria uses a streamlined rating system of 0, 1, and 2 with 2 being the most desirable ranking and 0 being the least desirable ranking.

Table 6.1 - Criteria for ranking and prioritizing watershed improvement projects.

Criteria	Description	0	1	2
Public Land	Is the project situated on public land?	Land is privately owned.	Land is partially publicly owned or within an easement dedicated to a local government.	Land is entirely owned by or within an easement dedicated to the City of Alpharetta.
Fecal Coliform	Does the project reduce fecal coliform loading in the watershed?	No. The project does not reduce fecal coliform loading.	The project can prevent against future fecal loading.	Yes. The project will reduce fecal coliform loading.
Capital Cost	What is the capital costs required to construct the project?	Cost is >$1 million	Cost ranges from $100,000 to $1 million	Cost is <$100,000
Sediment	Does the project reduce sediment loading in the watershed?	No. The project does not reduce sediment loading.	The project can moderately reduce sediment loading.	The project can substantially reduce sediment loading.
Constructability	How difficult is the project to construct. I.e. permits, access, easement acquisition, utility conflicts?	The project requires extensive acquisition of easements and permitting from state/federal levels.	The project requires minimal easement acquisition and permitting on a local level.	The project requires no easement acquisition and no permitting.
Flood Risk Mitigation	Does the project reduce flooding concerns in the surrounding community?	The project provides no flood risk mitigation.	The project provides flood risk mitigation but at a level of service less than the 100-year event.	The project provides flood risk mitigation at a level of service equal or greater than the 100-year event.
Community Involvement	Does the community have direct stake in the success of the project and/or access to the project?	The community has no direct impact on the project.	The community has moderate interaction to and some influence over the success of the project.	The community has substantial access to and influence over the success of the project.
Aesthetics	Overall, will the project improve its surrounding environment?	The project will neither add nor detract from its environment.	The project will moderately improve the surrounding environment.	The project will substantially improve the surrounding environment.
Shared Cost	Are there cost sharing opportunities for the project including other governments, utilities, and/or grants?	There are no additional stakeholders and no potential for shared costs.	There is an additional stakeholder and/or moderate potential for shared costs.	There are numerous stakeholders and high potential for shared costs.

In order to determine a projects final score, the following equation was used to analyze each categories' score:

$$Points\ Total = (FC + C + S + E + FL + I + A + SC) \times L$$

Where:
L = Public Land Score
FC = Fecal Coliform Score
C = Capital Cost Score
S = Sediment Score
E = Constructability Score
FL = Flood Risk Mitigation Score
I = Community Involvement Score
A = Aesthetics Score
SC = Shared Cost Score

Based on the above scoring criteria and the ranking equation, the scores and ranks are provided for each project in **Table 6.2**. The maximum score a project could receive is 32 points.

Table 6.2 - Prioritization and Ranking Scores for Recommended Project List.

WIP No.	Description	Public Land L	Fecal Coliform FC	Capital Cost C	Sediment S	Construct-ability E	Flood Risk Mitigation FL	Community Invlvment I	Aesthetics A	Shared Cost SC	Score
1	Dog Waste Station & Public Education	2	2	2	0	2	0	2	0	2	20
2	Stream Restoration and Sanitary Sewer Protection Project 1	1	0	0	2	0	0	1	2	2	7
3	Stream Restoration and Sanitary Sewer Protection Project 2	1	0	1	2	0	0	1	2	2	8
4	Stream Restoration and Sanitary Sewer Protection Project 3	1	0	1	1	0	0	1	2	2	7
5	Stream Restoration and Sanitary Sewer Protection Project 4	1	0	1	2	0	0	1	2	2	8
6	Stream Restoration and Sanitary Sewer Protection Project 5	1	0	2	1	0	0	1	2	2	8
7	Pinehollow Court Neighborhood Flooding	1	0	1	0	1	1	0	0	0	3
8	Tuxford Neighborhood Flooding	1	0	1	0	0	1	0	0	0	2
9	Birch Rill Drive Capital Improvement Project No. LIC_0100_1	1	0	1	0	1	2	0	0	0	4
10	Waters Road Enhanced Dry Swales Project 1 (North)	2	0	2	2	1	1	0	1	1	16
11	Waters Road Enhanced Dry Swales Project 2 (South)	2	0	2	2	2	1	0	1	1	18
12	Bacterial Source Tracking (BST)	2	2	2	0	2	0	0	0	2	16

6. Capital Improvement Plan – Final recommended list of watershed improvement projects which includes the rationale for inclusion, overall potential to address objectives, estimated project costs, funding potential, and preliminary schedule for implementation.

   Section 6.2.2.2 Structural Management Measures
   APPENDIX C: PROJECT SHEETS
   Section 6.5.1 Cost Estimate
   Section 6.5.2 Partnership and Technical & Financial Assistance Opportunities
   Section 6.4 Implementation Schedule

   Non-structural management measures can provide a wide range of options to address nonpoint source pollution. Additionally, non-structural measures tend to be less expensive than structural options. Therefore when working to reduce nonpoint source pollution, non-structural methods can initially be implemented, along with any complementary structural methods, to attempt to reach pollution reduction goals before making large investments in structural methods. Below is a list of non-structural management measures:

   1. Dog Waste Stations and Public Education
   2. Bacterial Source Tracking
   3. Before-and-After Fecal Coliform Monitoring
   4. Repair Damage BMPs
   5. Encourage Restoration of Stream Buffers
   6. Remove Debris Jams
   7. Collaborate with Private BMP Owners

   Rankings are provided in **Table 6.3** and are shown in Element 3 of this Appendix. Each project's potential to address the Watershed Improvement Plan's objectives are further elaborated upon in APPENDIX C: PROJECT SHEETS.

   Capital cost estimates for each recommended project are shown in **Table 6.4** in Element 4 of this Appendix. Additionally, the project sheets in APPENDIX C: PROJECT SHEETS provide a break-down of the associated costs along with an estimated annual operations and maintenance cost.

   Partnerships are most likely on a local level. One of the most obvious partnerships to address the challenges in Long Indian Creek is with the City of Johns Creek, as the Long Indian Creek Watershed spans both the political boundaries of Alpharetta and Johns Creek and a SQAP already exists between the two Cities. Additional local partners include local homeowners associations and/or other groups willing to sponsor dog waste stations. For instance, the City of Alpharetta could provide the initial funds for installation of the dog waste stations. These stations could then be adopted by homeowners associations or local businesses and/or community groups that could help maintain dog waste stations and provide continuing education to the public about proper disposal of dog waste. A further partnering opportunity includes private BMP owners as all BMPs in the Long Indian Creek Watershed within the City of Alpharetta are privately owned. The City could actively collaborate with these BMP owners so that the City can help guide upgrades as private owners elect to implement those measures. Additionally, the stream restoration projects are also focused on protecting sanitary sewer infrastructure which is operated and maintained by Fulton County. Therefore, there is the opportunity to jointly complete watershed improvement projects with the goal of minimizing costs for the City while maximizing the benefits for the watershed.

   From a state funding level, there are two major grant opportunities:

   3. Section 319(h) Georgia's Nonpoint Source Implementation Grant
   4. Regional Water Plan Seed Grant Funds

   The Section 319(h) Grants are actually federally funded and are further discussed in **Table 6.5**, but the funds are distributed by the state of Georgia. The Regional Water Plan Seed Grant Fund is designed to encourage the implementation of management practices from one of the Regional Water Plans. The maximum amount for the Regional Water Plan Seed Grant is $75,000 and is limited to 60% of the total project cost. Eligible activities and projects for the Regional Water Plan Seed Grant include: 1) Undertaking programs to address critical information and/or data needs identified in the Regional Water Plan(s); 2) Tracking and analyzing available monitoring data and reporting on water resource conditions as identified as needs in the Regional Water Plan(s); 3) Preparing and distributing technical guidance that can be shared by Regional Water Councils on management practices that affect common water resources; and 4) Providing technical assistance to support implementation of Regional Water Plan management practices. It is hoped that this grant money could help fund the recommended Bacterial Source Tracking project.

There are a multitude of funding options on the federal level with various requirements and eligibility. Based on a review of available funding sources, the most promising options for the Long Indian Creek Watershed have been compiled in **Table 6.5**.

A recommended Watershed Improvement Plan Schedule is provided below.

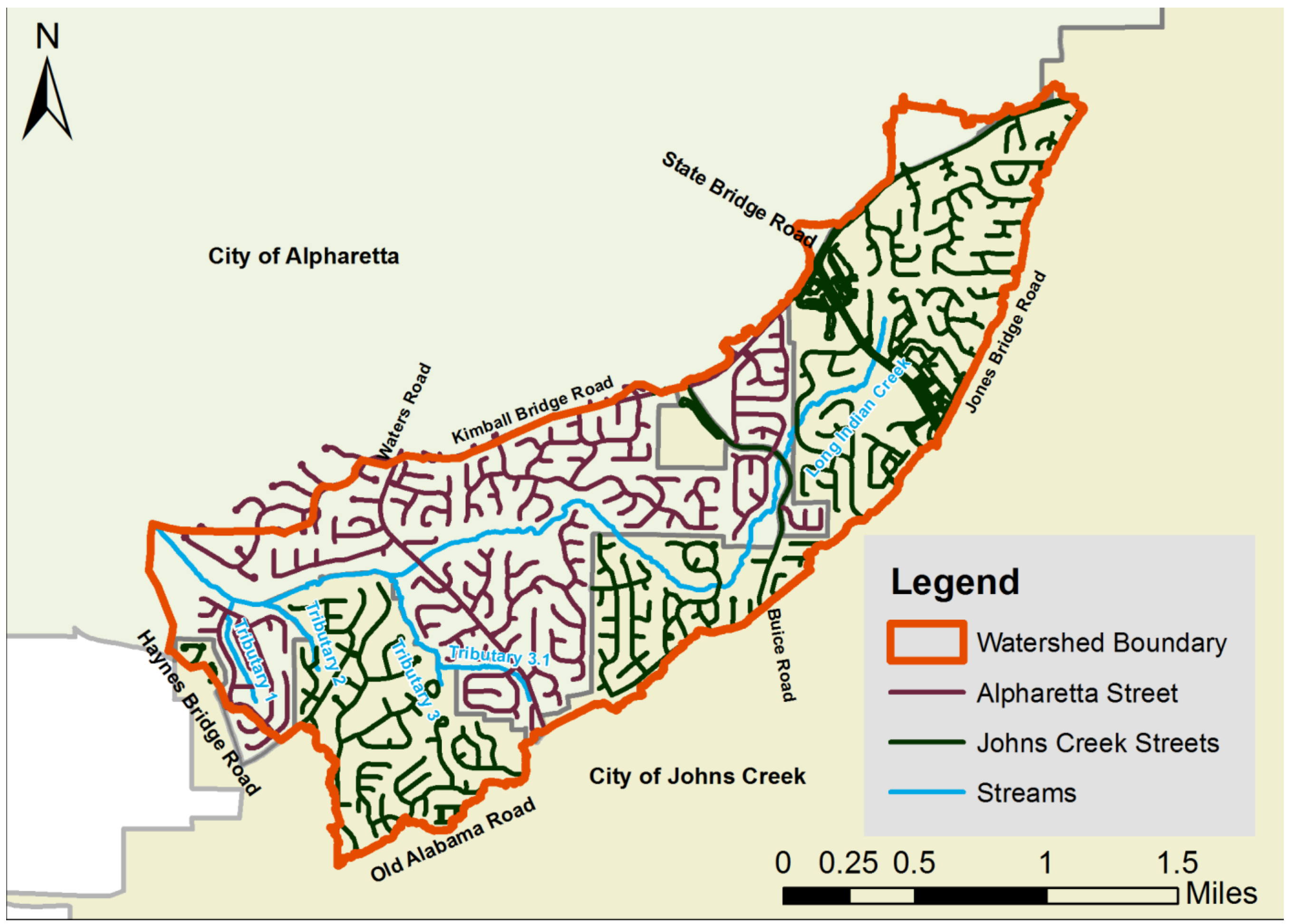
		Long Indian Creek Watershed Improvement Implementation Plan					
	Fiscal Year Date	FY '18 July 2017 - June 2018	FY '19 July 2018 - June 2019	FY '20 July 2019 - June 2020	FY '21 July 2020 - June 2021	FY '22 July 2021 - June 2022	Estimated 5-year Cost
Projects	Dog Waste Education	$5,000	$5,000	$5,000	$5,000	$5,000	$25,000
	Bacterial Source Tracking		$25,000		$25,000		$50,000
	Dog Waste Station Installation			$25,000			$25,000
	Dog Waste Station Maintenance			$39,000	$39,000	$39,000	$117,000
	Enhanced Dry Swale Installation					$162,385	$162,835
						Total 5-year Cost	$379,835

Figure 6.3 – Long Indian Creek Watershed Improvement Plan implementation schedule.

APPENDIX C: PROJECT SHEETS

Project Overview

The installation of dog waste stations partnered with robust community education provides the best and most cost-effective opportunity to reduce fecal coliform loads in the watershed. The most successful results are modeled when dog waste stations are installed throughout the entire watershed, including in the City of Johns Creek. It is recommended that dog waste stations are installed every ½ mile along all city streets, especially in neighborhoods where residents are most likely to walk their dogs.



City	Street Miles	No. Waste Stations
City of Alpharetta	25 Miles	50
City of Johns Creek	55 Miles	110

Cost

Costs are based on an initial cost of $500 per waste station with a predicted weekly maintenance cost of $15. Homeowner Associations provide potential partnering vehicles for the Cities to help defray the maintenance costs of dog waste stations located in neighborhoods.

Item	Alpharetta	Johns Creek
Initial Capital Cost	$25,000	$55,000
Annual Maintenance Cost	$39,000	$85,800
Annual Public Education Cost	$5,000	$5,000

Educational image from the City of Alpharetta and the Clean Water Campaign.

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #1 – Dog Waste Stations & Public Education

THE CITY OF ALPHARETTA
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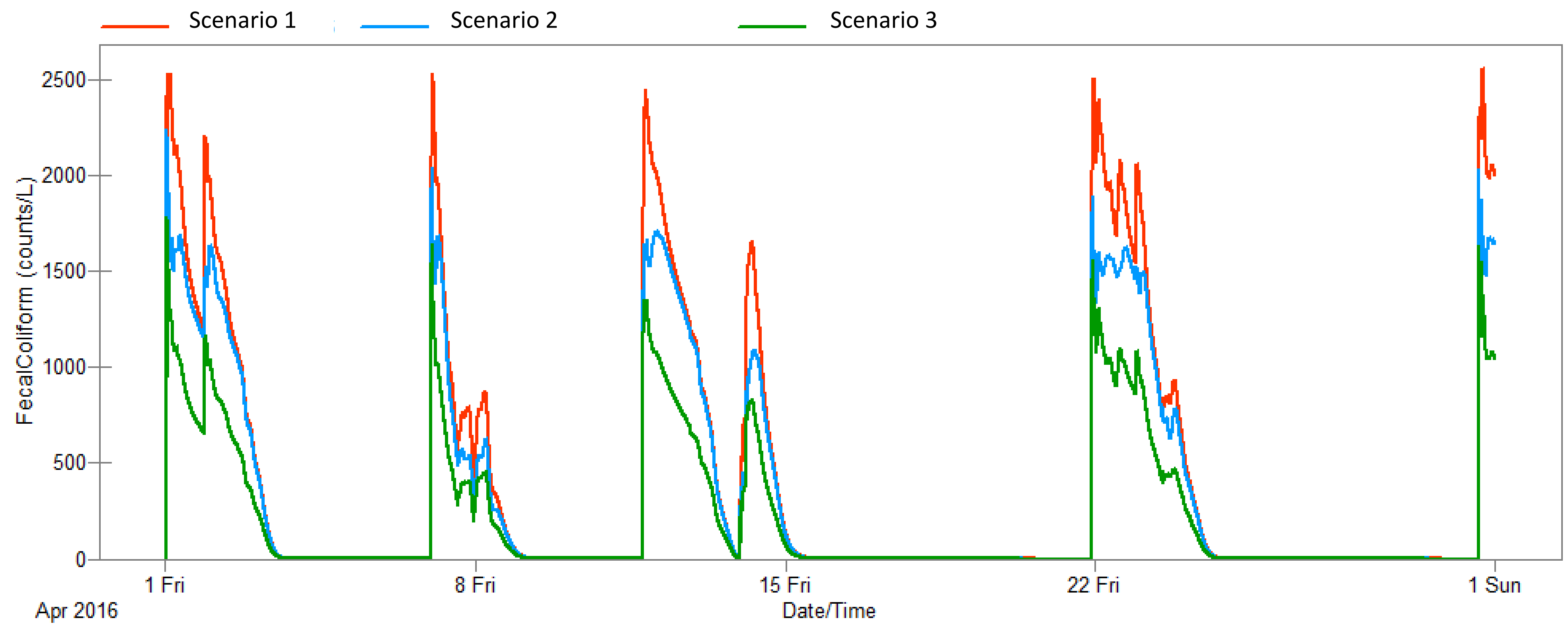
SHEET C.1

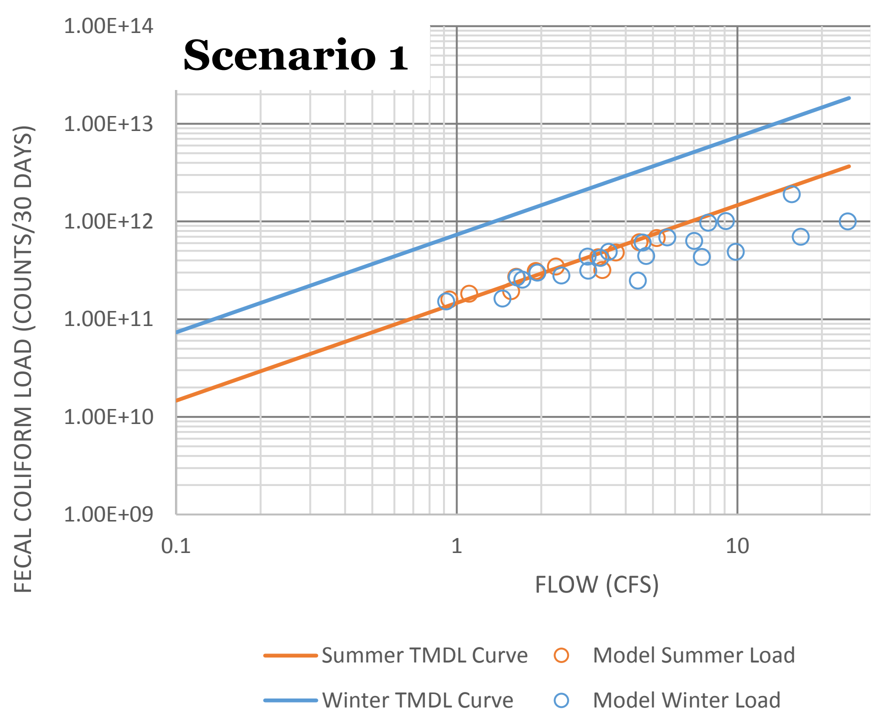
Benefits

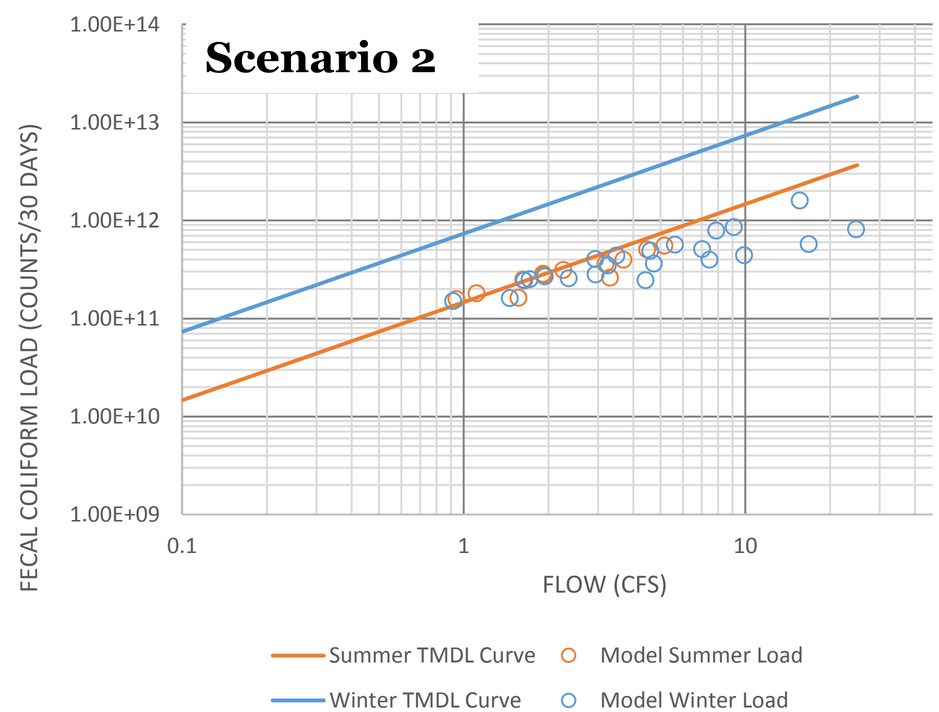
To demonstrate the expected benefits from installation of dog waste stations in the City of Alpharetta and Johns Creek, the following scenarios were compared :

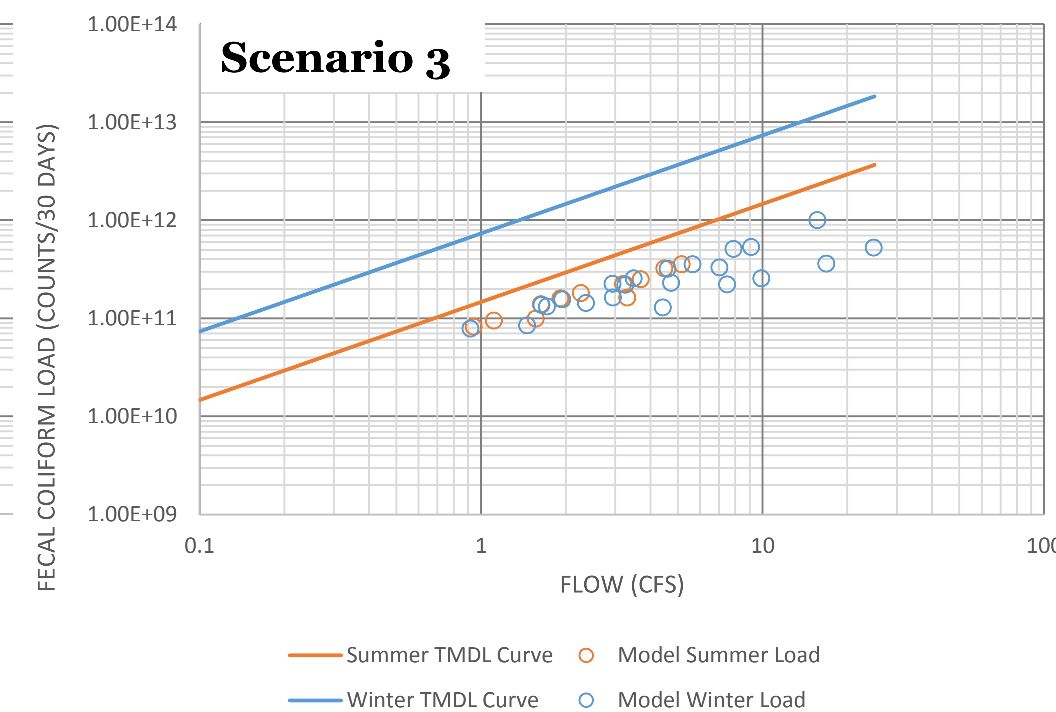
- **Scenario 1:** Existing conditions model
- **Scenario 2:** Dog waste stations and community education are implemented in all areas of the watershed that are part of the City of Alpharetta and two 'hotspot' areas within Johns Creek
- **Scenario 3:** Dog waste stations and community education are implemented throughout the entire watershed including the City of Johns Creek



Comparison of expected fecal coliform loads for Scenarios 1, 2, and 3 at the furthest downstream sampling site based on sampling results from April 2016. For April 2016, Scenario 2 is expected to reduce fecal loading by 19% and Scenario 3 is expected to reduce fecal loading by 47% at the most downstream site.







CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #1 – Dog Waste Stations & Public Education

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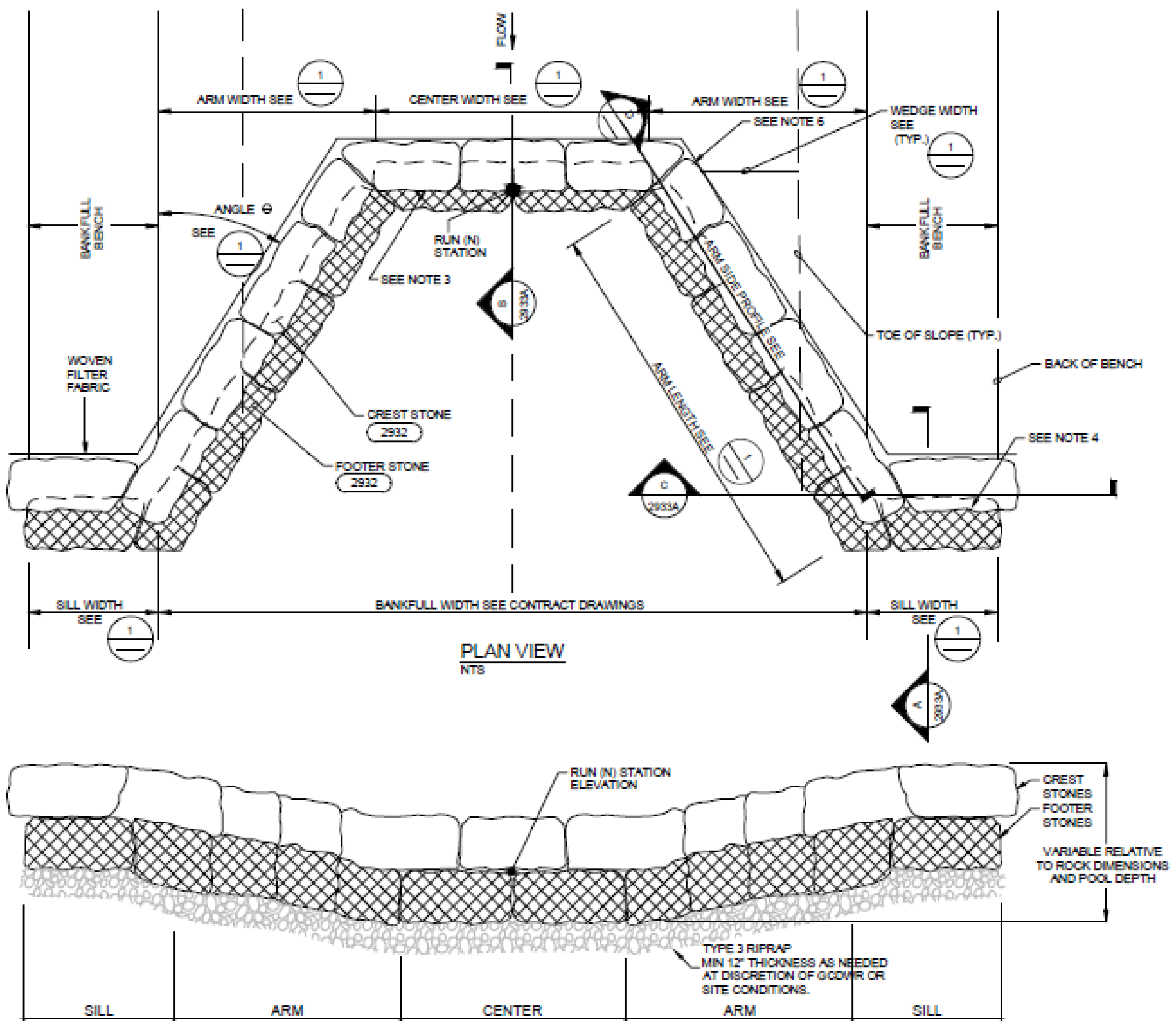
SHEET C.2

Project Overview

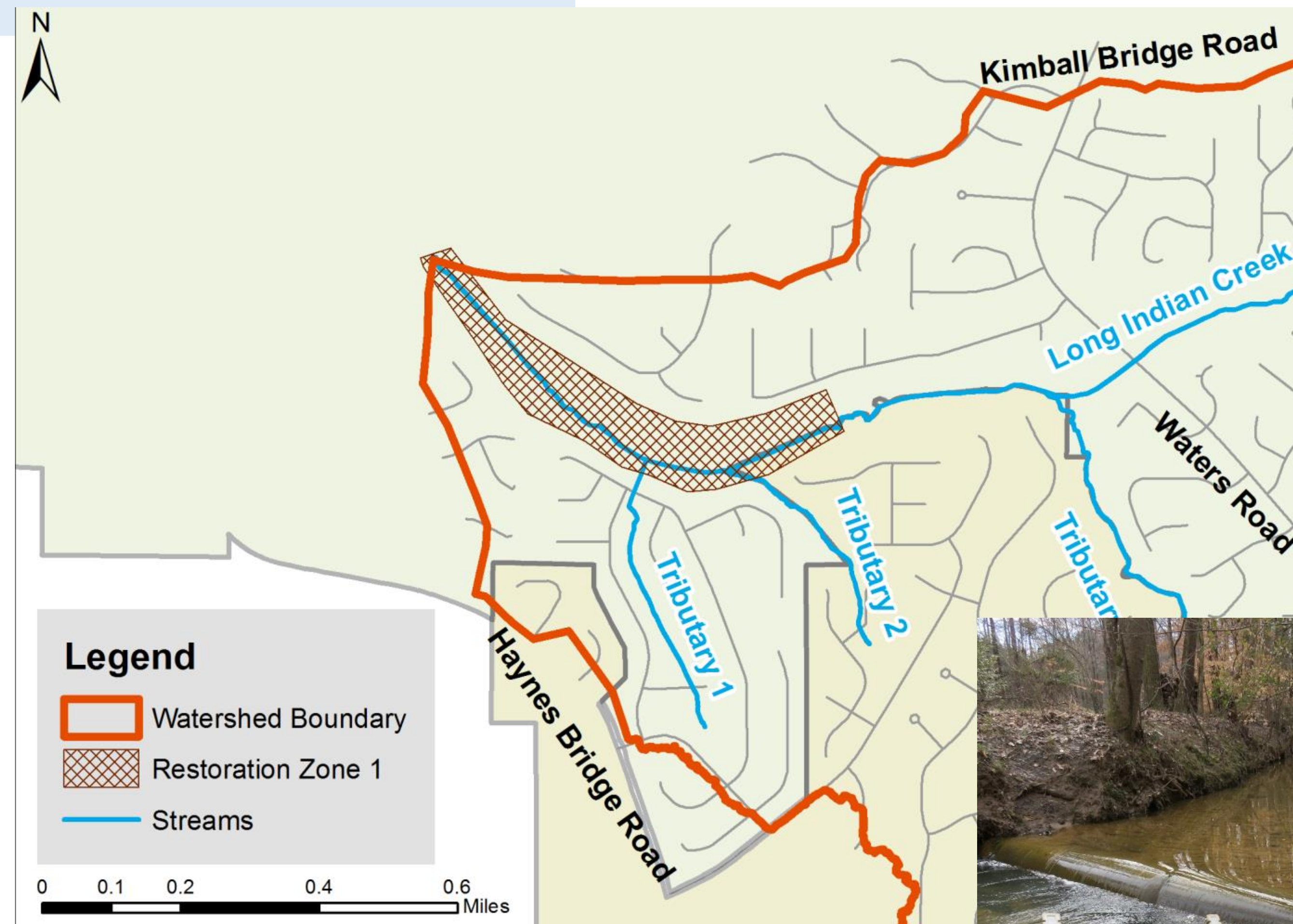
Project 1 of the Stream Restoration and Sanitary Sewer Protection Plan extends 3800 feet upstream from the confluence of Long Indian Creek with Big Creek (labeled Zone 1 in the map). The stream can be accessed from a park located on High Hampton Chase and via a sewer easement that traverses alongside the stream. Based on conditions observed during the stream walk, a Priority 3 Stream Restoration Project using natural channel design techniques is recommended to create a more stable plan form and profile and to reconnect the stream to the historic floodplain. Further, there are two exposed sanitary sewer pipes along this section of stream where cross vanes are recommended to be placed immediately downstream to raise the streambed and bury the pipes, protecting them against debris jams which could break the pipes.

Benefits

- Reduce TSS load by approximately 575 tons/year
- Reduce stream velocity
- Protect existing sanitary sewer infrastructure and prevent future fecal coliform contamination from damaged pipes
- Improve stream habitat
- Improve aesthetics of stream



A typical cross vane detail that would be installed to protect sanitary sewer infrastructure



Exposed pipe located at 600 feet upstream of the confluence.

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #2 – Stream Restoration and Sanitary Sewer Protection Project 1

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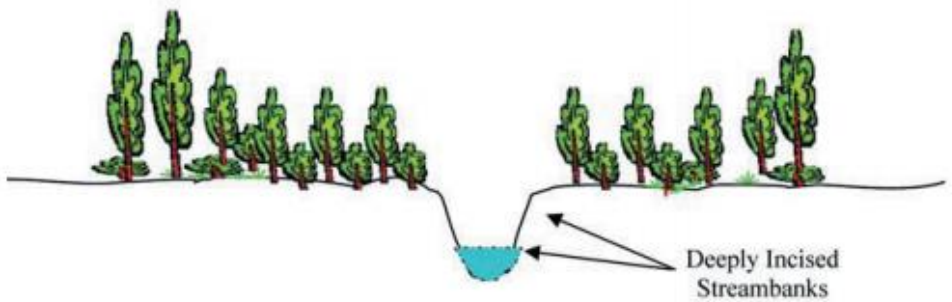
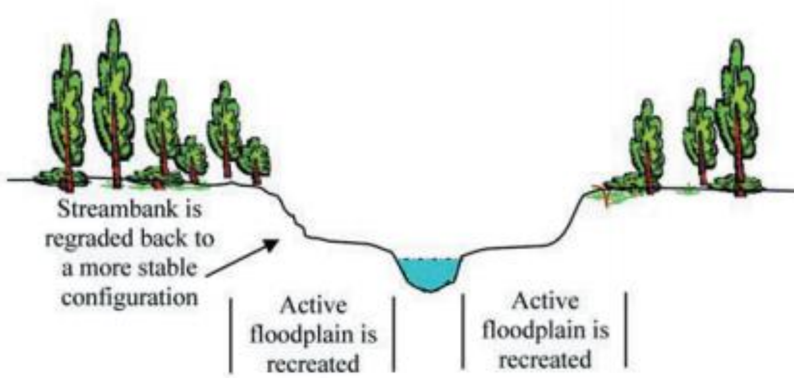
SHEET C.3

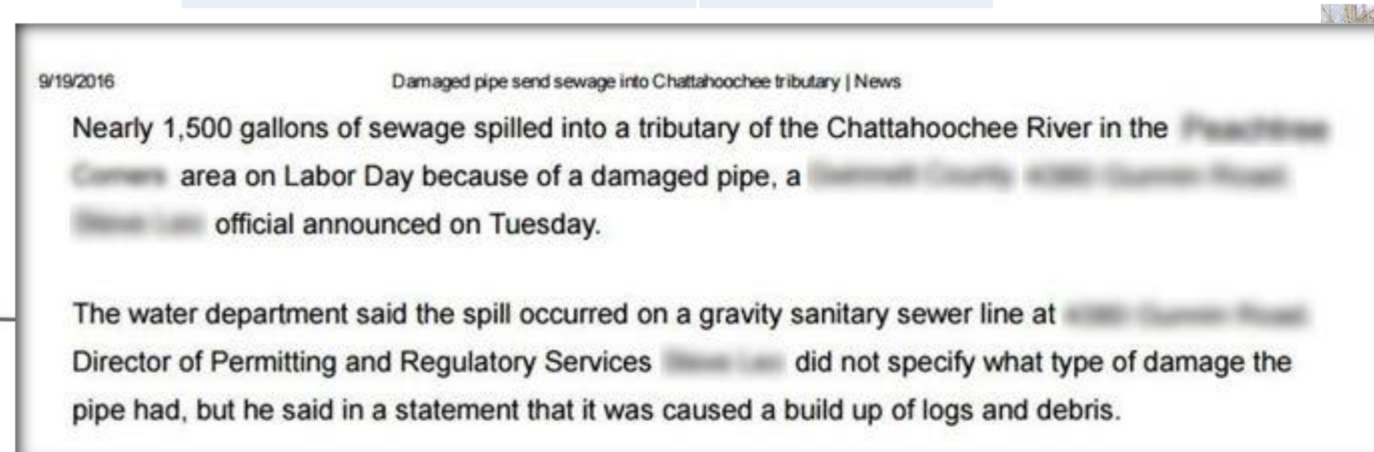
Item	Unit	Quantity	Unit Price	Total Price
Clearing & Grubbing	AC	7	$50,000	$350,000
Erosion Control	LF	3,800	$25	$95,000
Earthwork	CY	5,700	$15	$85,500
Riparian Buffer Plantings	LF	3,800	$35	$133,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Large	EA	2	$35,000	$70,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Medium	EA	0	$25,000	$0
Stream Structures (Cross-Vane, J-Hook, etc.) – Small	EA	0	$15,000	$0
			Construction Sub-Total	$733,500
			Engineering and Permitting (25%)	$183,375
			Contingency (20%)	$183,375
			Capital Cost	**$1,100,250**
			Annual Maintenance Cost	**$250**

A severely incised bank typical of the lower section of Long Indian Creek.





Graphic showing incised banks and ideal banks after regarding (Santa Clara Valley Water District, 2016).



9/19/2016 Damaged pipe send sewage into Chattahoochee tributary | News

Nearly 1,500 gallons of sewage spilled into a tributary of the Chattahoochee River in the [illegible] area on Labor Day because of a damaged pipe, a [illegible] official announced on Tuesday.

The water department said the spill occurred on a gravity sanitary sewer line at [illegible] Director of Permitting and Regulatory Services [illegible] did not specify what type of damage the pipe had, but he said in a statement that it was caused a build up of logs and debris.

A debris jam below an incised bank. Debris jams have the potential to cause flooding and damage infrastructure.

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #2 – Stream Restoration and Sanitary Sewer Protection Project

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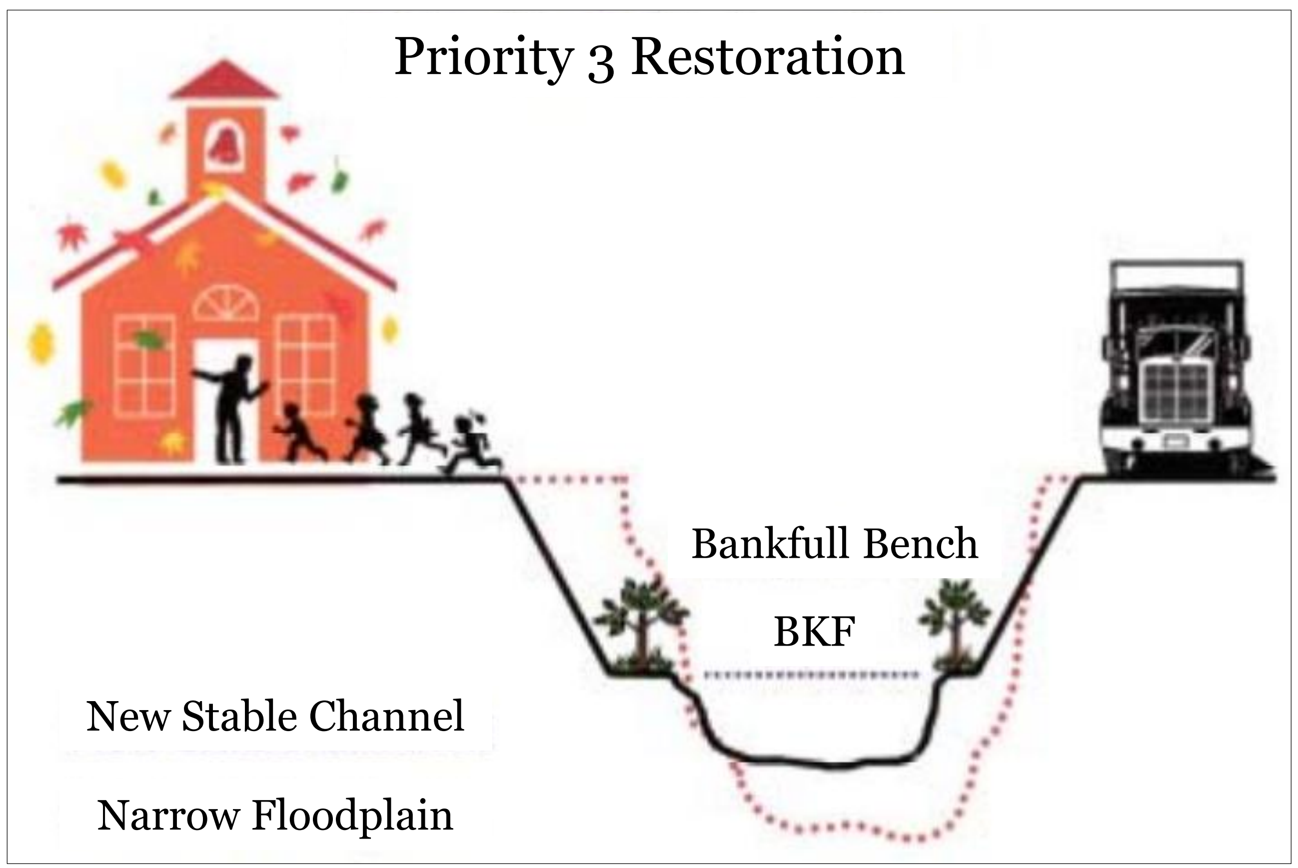
SHEET C.4

Project Overview

Project 2 of the Stream Restoration and Sanitary Sewer Protection Plan extends 2500 feet upstream along Long Indian Creek Tributary 3 from the confluence with Long Indian Creek (labeled Zone 2 in the map). Since there are no community open spaces near Tributary 3, the stream must be accessed through private property. The best entry point is off of New Heritage Drive where the lot sizes are larger and a sewer easement that runs parallel to the tributary can be easily reached. Based on conditions observed during the stream walk, a Priority 3 Stream Restoration Project using natural channel design techniques is recommended to create a more stable plan form and profile and to reconnect the stream to the historic floodplain. Further, there are two exposed sanitary sewer pipes along this section of stream where cross vanes are recommended to be placed immediately downstream to raise the streambed and bury the pipes, protecting them against debris jams which could break the pipes.



Graphic showing the construction of stabilized banks to help reconnect the stream with its historic floodplain (FWS, 2016).

An incised stream bank that has migrated laterally towards sanitary sewer running parallel to the stream. Further, migration could compromise the infrastructure.

Item	Unit	Quantity	Unit Price	Total Price
Clearing & Grubbing	AC	4	$50,000	$200,000
Erosion Control	LF	2,500	$25	$62,500
Earthwork	CY	3,750	$15	$56,250
Riparian Buffer Plantings	LF	2,500	$35	$87,500
Stream Structures (Cross-Vane, J-Hook, etc.) – Large	EA	0	$35,000	$0
Stream Structures (Cross-Vane, J-Hook, etc.) – Medium	EA	1	$25,000	$25,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Small	EA	1	$15,000	$15,000
			Construction Sub-Total	$446,250
			Engineering and Permitting (25%)	$111,563
			Contingency (20%)	$111,563
			Capital Cost	**$669,375**
			Annual Maintenance	**$250**

Benefits

- Reduce TSS load by approximately 220 tons/year
- Reduce stream velocity
- Provide grade control along the stream
- Protect existing sanitary sewer infrastructure and prevent future fecal coliform contamination from damaged pipes
- Improve stream habitat
- Improve aesthetics of stream

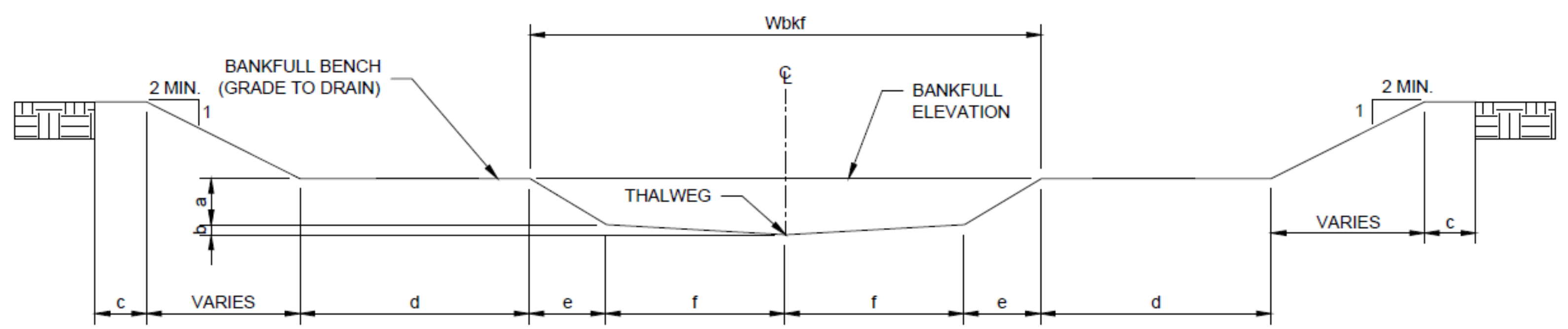
Exposed pipe in the upper part of the stream restoration zone. The stream is sufficiently degraded to expose the push-on joint.

Exposed pipe in the lower part of the stream restoration zone. The stream is sufficiently degraded to expose the push-on joint.

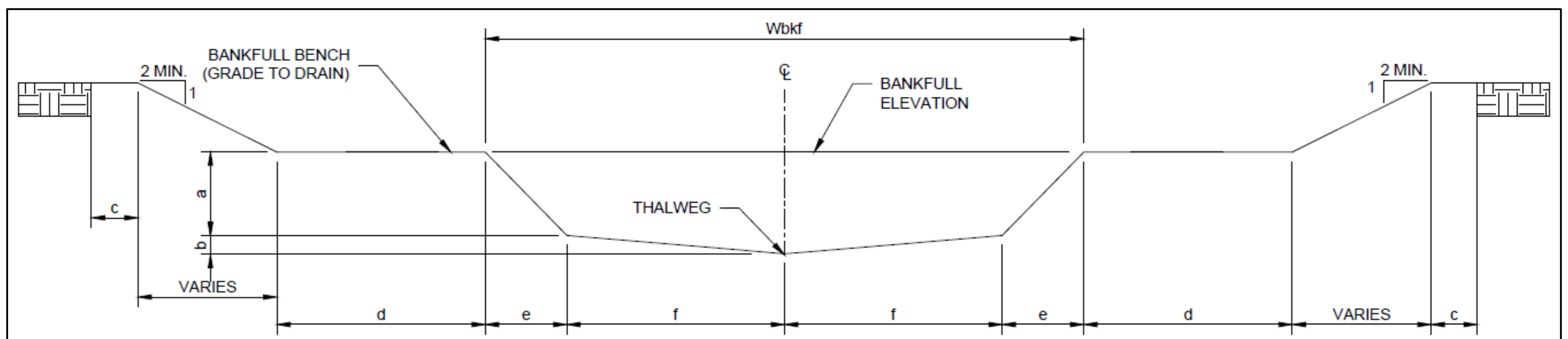
A sample cross vane from a completed project. The cross vane would be placed just downstream of the exposed sanitary sewer pipe. This would provide grade control for the stream, and protect the sanitary sewer pipe from future damage during flooding events.

Project Overview

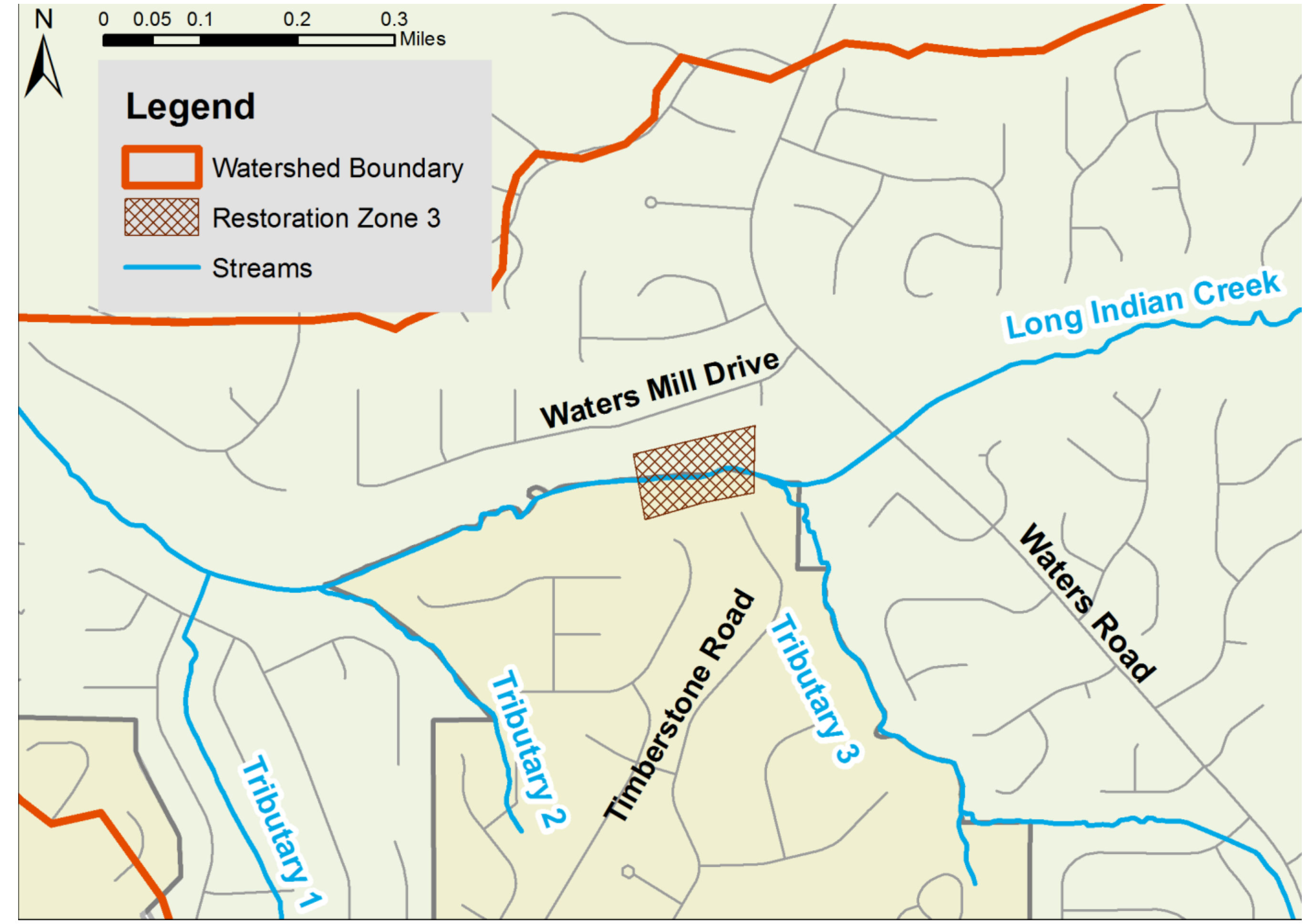
Project 3 of the Stream Restoration and Sanitary Sewer Protection Plan extends 500 feet downstream along Long Indian Creek from the confluence of Long Indian Creek with Tributary 3 (labeled Zone 3 in the map). The stream can be accessed from a park located on Waters Mill Drive and via a sewer easement that traverses parallel the stream. Based on the stream walk, the restoration measures called for include bank stabilization measures which involve using tree stumps, geotextile fabrics, plants, stone, and other materials to reduce erosion on banks that have been regarded to better connect the stream to its historic floodplain. Further, there is one exposed sanitary sewer pipe which requires protection with a cross vane.



1 TYPICAL RIFFLE CROSS SECTION
NTS



3 TYPICAL CENTER POOL CROSS SECTION
NTS

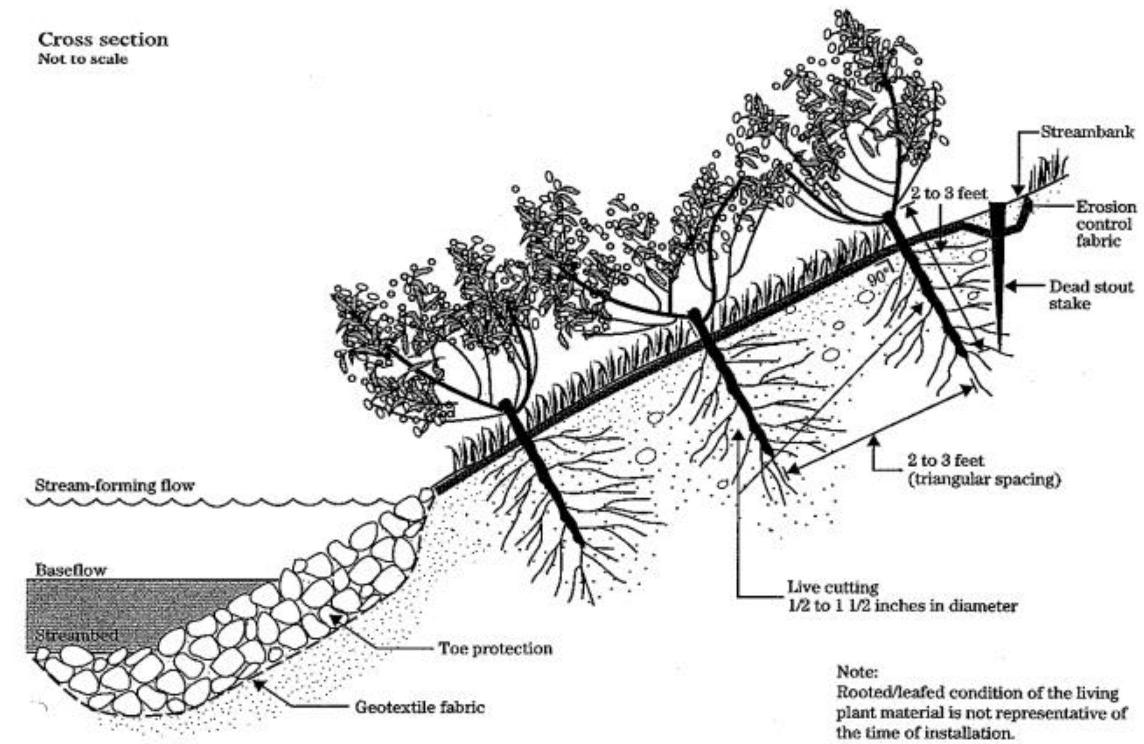


Benefits

- Reduce TSS load by approximately 55 tons/year
- Reduce stream velocity
- Provide grade control along the stream
- Protect existing sanitary sewer infrastructure
- Prevent future fecal coliform contamination from damaged pipes
- Improve stream habitat
- Remove of invasive plant species
- Improve aesthetics of stream

The two drawings to the left provide typical riffle and pool cross sections for regraded stream banks.

Item	Unit	Quantity	Unit Price	Total Price
Clearing & Grubbing	AC	1	$50,000	$50,000
Erosion Control	LF	500	$25	$12,500
Earthwork	CY	750	$15	$11,250
Riparian Buffer Plantings	LF	500	$35	$17,500
Stream Structures (Cross-Vane, J-Hook, etc.) – Large	EA	1	$35,000	$35,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Medium	EA	0	$25,000	$0
Stream Structures (Cross-Vane, J-Hook, etc.) – Small	EA	0	$15,000	$0
			Construction Sub-Total	$126,250
			Engineering and Permitting (25%)	$31,563
			Contingency (20%)	$31,563
			Capital Cost	**$189,375**
			Annual Maintenance Cost	**$250**



Live staking detail. Live staking is an effective bioengineering method to stabilize banks (GA DNR, 2011).

Exposed sanitary sewer pipe. A grade-control structure such as a cross vane can be installed to protect the pipe.

Severely eroded stream bank in section of Long Indian Creek recommended for stream restoration.

Live staking along stream bank (Kingsport, 2016).

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #4 – Stream Restoration and Sanitary Sewer Protection Project 3

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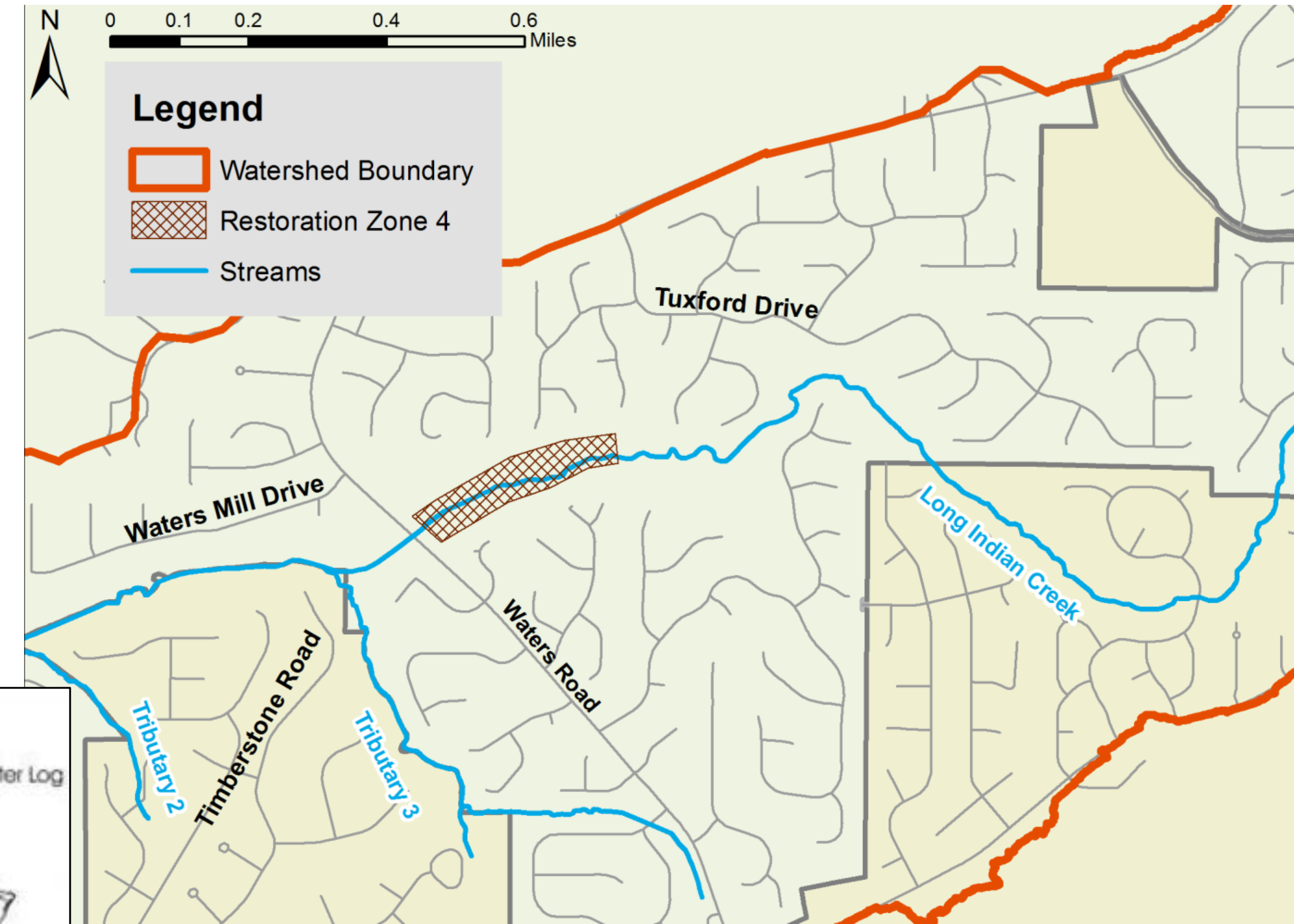
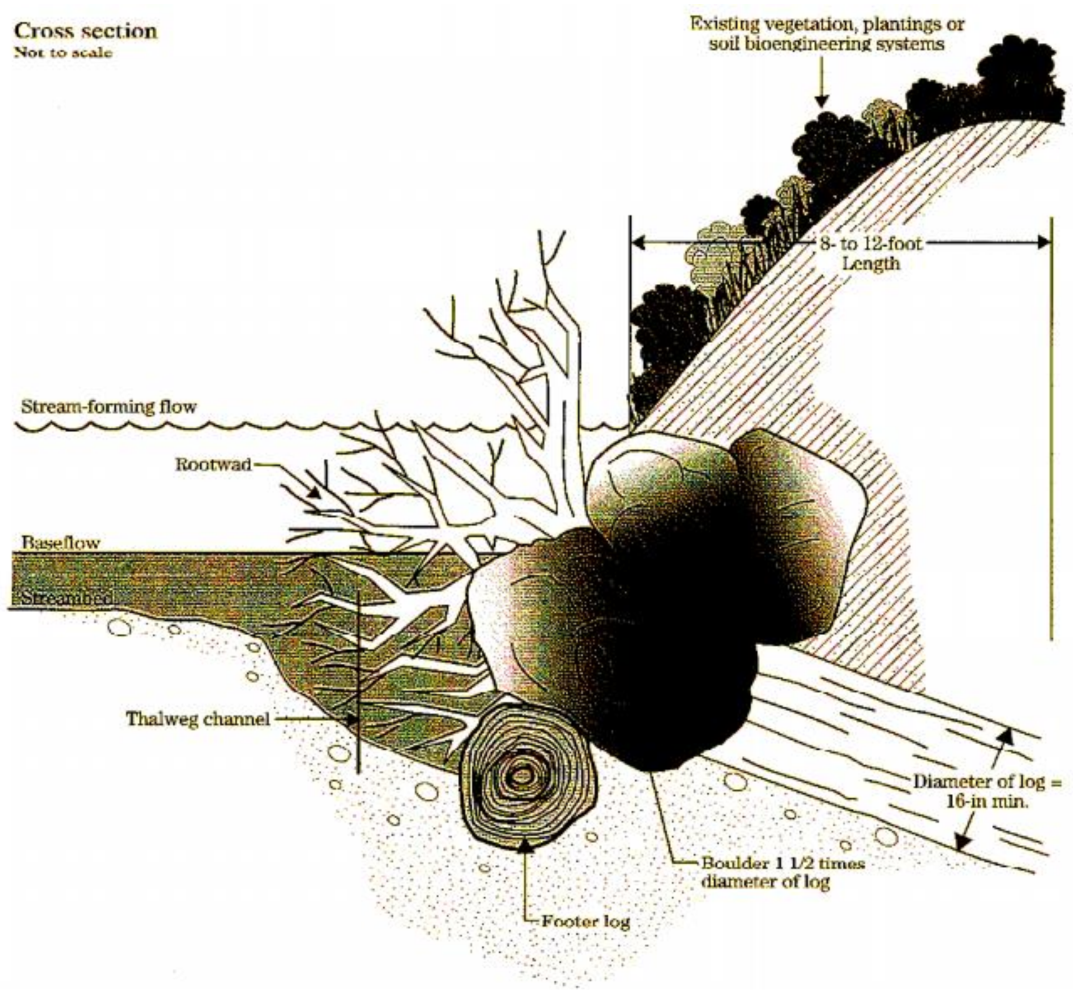
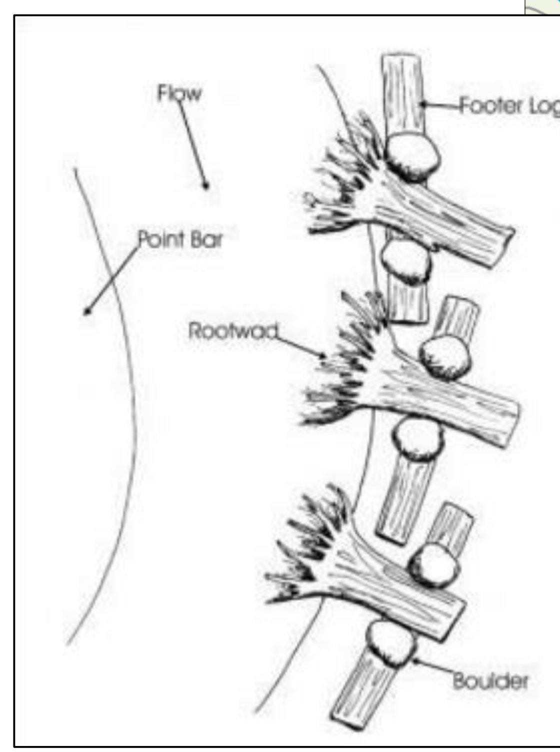
Project Overview

Project 4 of the Stream Restoration and Sanitary Sewer Protection Plan extends 2000 feet upstream along Long Indian Creek from Waters Road (labeled Zone 4 in the map). The site can be accessed from Waters Road, and then a sanitary sewer easement can be used to traverse the stream length. Based on the stream walk, the restoration measures called for are a mixture of Rosgen Priority 3 Channel Restoration, bank stabilization, and bank protection groups. Bank protection groups differ from bank stabilization because bank protection groups utilize structural methods to protect banks while bank stabilization employs non-structural techniques to resist bank erosion. Further, there are three exposed sanitary sewer pipes along this section of stream which require protection with cross vanes.

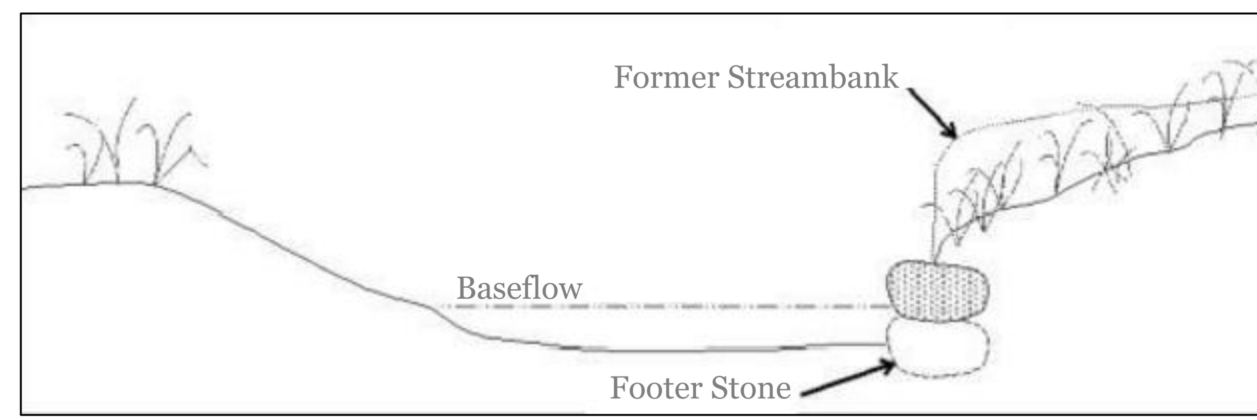




Log, rootwad, and boulder revetment. Example of a bank protection group (GA DNR, 2011).



Plan view of rootwad revetment. Rootwad revetments prevent bank erosion and provide excellent habitats (SMRC, 2016).



Profile view of single boulder revetment. Although boulder revetments do prevent erosion, they offer limited potential for improving in-stream habitats (SMRC, 2016).

Exposed sanitary sewer pipe near the downstream end of the project.

Benefits

- Reduce TSS load by approximately 220 tons/year
- Reduce stream velocity
- Provide grade control along the stream
- Protect existing sanitary sewer infrastructure
- Prevent future fecal coliform contamination from damaged pipes
- Improve stream habitat
- Remove of invasive plant species
- Improve aesthetics of stream

Item	Unit	Quantity	Unit Price	Total Price
Clearing & Grubbing	AC	3	$50,000	$150,000
Erosion Control	LF	2,000	$25	$50,000
Earthwork	CY	3,000	$15	$45,000
Riparian Buffer Plantings	LF	2,000	$35	$70,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Large	EA	3	$35,000	$105,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Medium	EA	0	$25,000	$0
Stream Structures (Cross-Vane, J-Hook, etc.) – Small	EA	0	$15,000	$0
			Construction Sub-Total	$420,000
			Engineering and Permitting (25%)	$105,000
			Contingency (20%)	$105,000
			Capital Cost	**$630,000**
			Annual Maintenance Cost	**$250**

Exposed sanitary sewer pipe near the center of the restoration project. The pipes are attached with a flange joint, and therefore not as susceptible to damage during flood events.

Exposed sanitary sewer pipe near the upstream end of the project. A large debris jam is located just upstream of the pipe which could damage the pipe during a flood event.

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Long Indian Creek Watershed Improvement Plan
WIP #5 – Stream Restoration and Sanitary Sewer Protection Project 4

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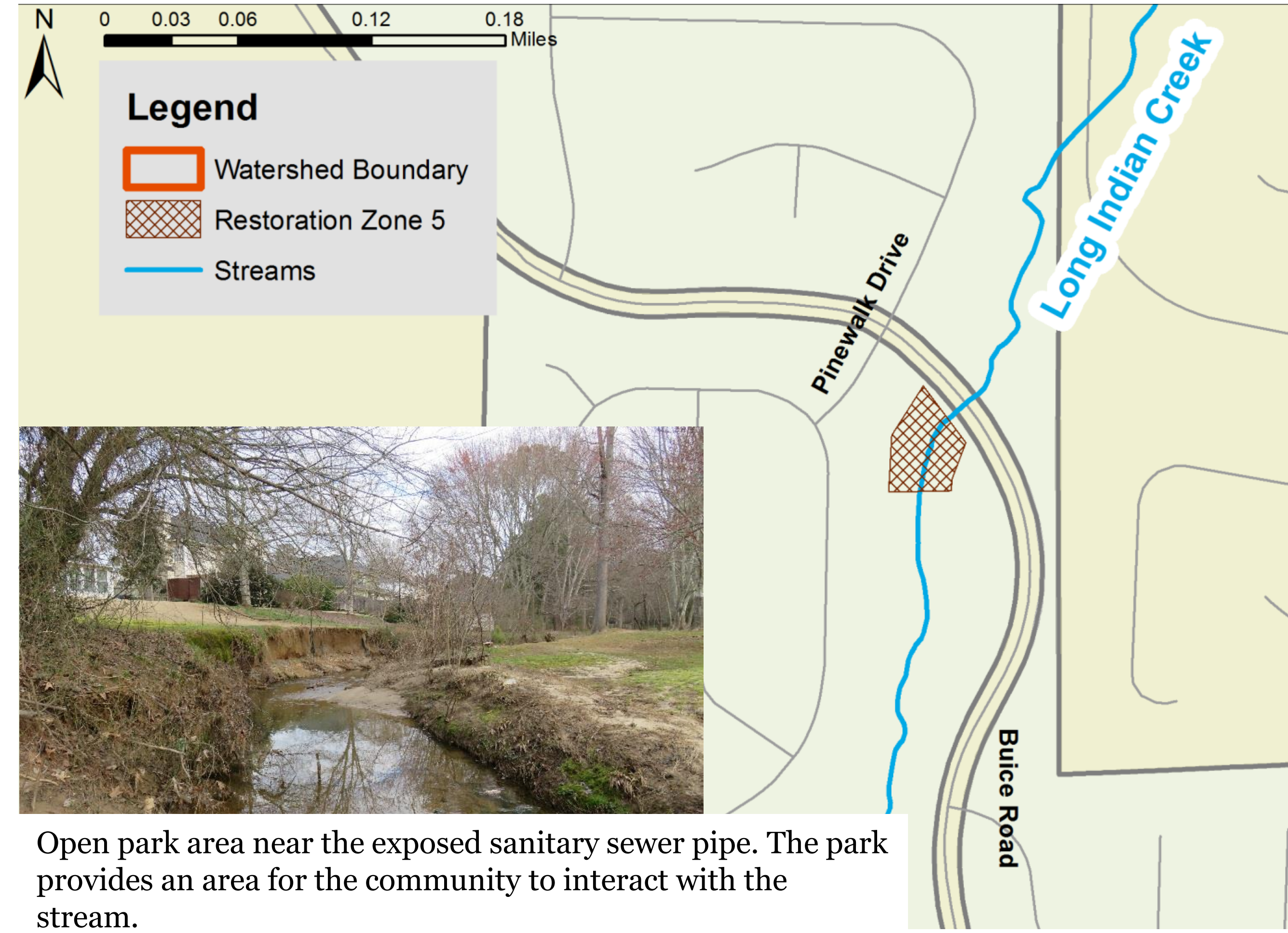
Project Overview

Project 5 of the Stream Restoration and Sanitary Sewer Protection Plan only incorporates the couple hundred feet of Long Indian Creek directly downstream of Buice Road (labeled Zone 5 in the map). Access to the site can be gained from a park off of Buice Road. The stream is in relatively good condition in this reach. Therefore, only a minor amount of grade control is suggested just downstream of the exposed sanitary sewer pipe to protect it from future damage and further reduce stream velocities in the affected area.

Item	Unit	Quantity	Unit Price	Total Price
Clearing & Grubbing	AC	0.5	$50,000	$22,957
Erosion Control	LF	200	$25	$5,000
Earthwork	CY	300	$15	$4,500
Riparian Buffer Plantings	LF	200	$35	$7,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Large	EA	0	$35,000	$0
Stream Structures (Cross-Vane, J-Hook, etc.) – Medium	EA	1	$25,000	$25,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Small	EA	0	$15,000	$0
			Construction Sub-Total	$64,457
			Engineering and Permitting (25%)	$16,114
			Contingency (20%)	$16,114
			Capital Cost	**$96,685**
			Annual Maintenance Cost	**$250**

Exposed sanitary sewer pipe. A cross vane can be installed downstream of the pipe to protect it from future damage and improve the aesthetics of the surrounding park.



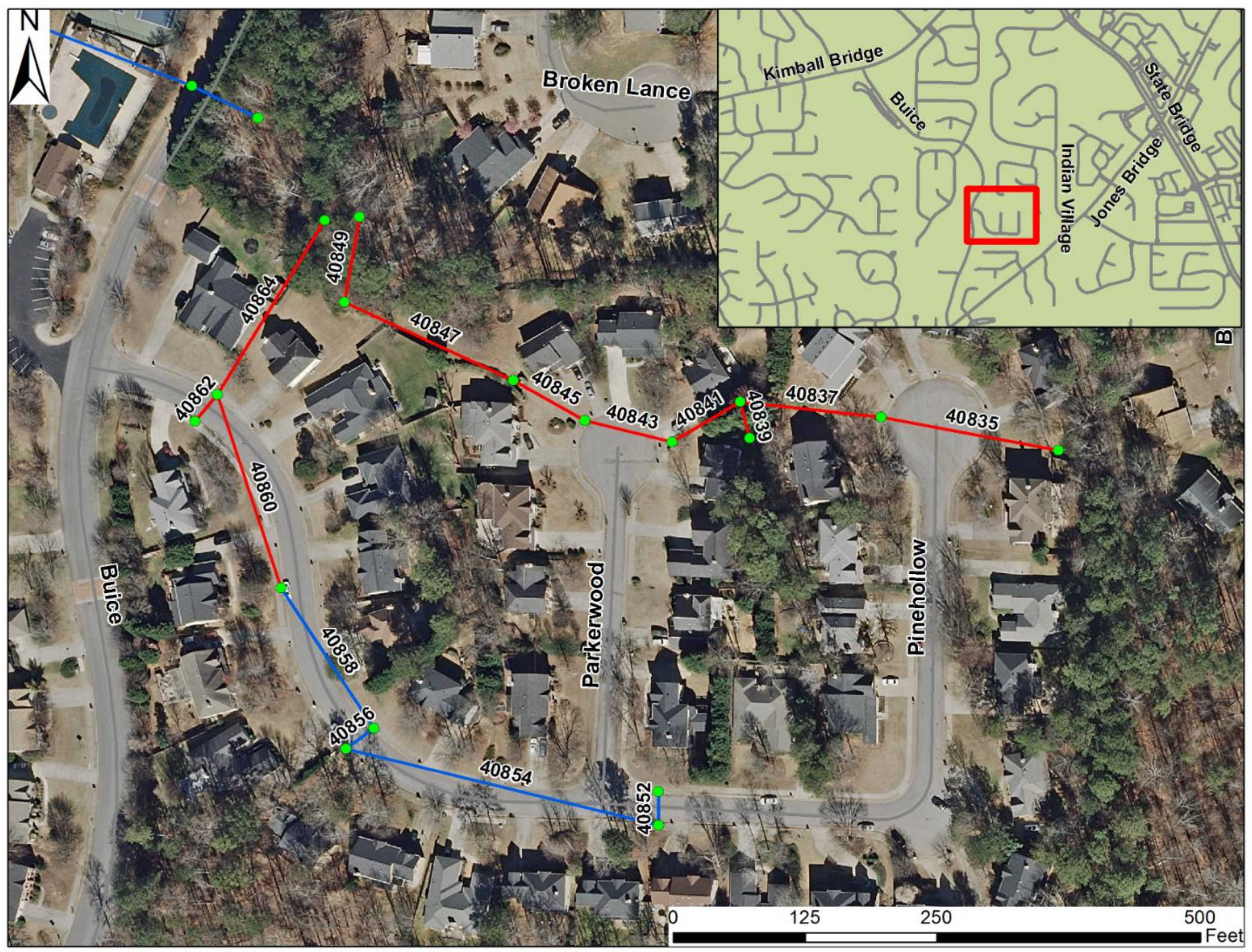
Open park area near the exposed sanitary sewer pipe. The park provides an area for the community to interact with the stream.

Benefits

- Reduce TSS load by approximately 15 tons/year
- Reduce stream velocity
- Provide grade control along the stream
- Protect existing sanitary sewer infrastructure
- Prevent future fecal coliform contamination from damaged pipes
- Improve stream habitat
- Improve aesthetics of stream
- Provide an opportunity for the community to interact with the stream
- Educate the public about the Long Indian Creek stream restoration in a highly visible location

Project Overview

Pinehollow Court is a neighborhood, composed of two streets, located off of Buice Road. There are no drainage complaints within the neighborhood, and the Dewberry field team was not approached with system flooding complaints by any residents. However, the existing model indicates that 11 of the 15 pipes within the neighborhood are undersized. In the most severe case, an 18-inch pipe at the outlet of the system requires on upgrade to a 48-inch pipe to meet the 25-year level of service. Therefore despite the lack of City or resident complaints, the Dewberry team has identified the Pinehollow Court neighborhood as a candidate for system improvements based on model-indicated, neighborhood-wide flooding.



Location of the Pinehollow Court Neighborhood and its existing stormwater system. Red pipes do not meet the 25-year level of service, and blue pipes do meet the 25-year level of service. Pipe Facility ID Numbers are displayed next to each pipe and can be related to the upgrade scenario tables and the system analysis database.

Cost

Construction related items are populated in the database to serve as input data for the Stormwater System Cost Estimation Tool. These items include the following:

- CIPP rehabilitation, inversion setup, and pipe cleaning
- Pipe removal and replacement
- Depth to top of the pipe for depths over 8'
- Structure removal and replacement
- Unsuitable haul-off allowances
- Driveway, sidewalk, and street cut replacement
- Silt Fence and Sod

Description	Quantity	Unit Cost	Total Cost
18" RCP Pipe (L.F.)	36	$60.0	$2,149.8
24" RCP Pipe (L.F.)	451	$65.0	$29,318.8
48" RCP Pipe (L.F.)	83	$150.0	$12,454.1
Catch Basin Complete, Group 1 or 2 (V.F.)	13	$500.0	$6,400.0
Headwall for 24" Pipe (Each)	1	$600.0	$600.0
Headwall for 48" Pipe (Each)	1	$1,400.0	$1,400.0
Manhole Complete, Type 1 or 2 (V.F.)	6	$500.0	$3,000.0
Yard Inlet All Types Complete, Group 1 or 2 (V.F.)	12	$600.0	$7,080.0
Depth to Top of Pipe (< 8.1') (L.F.)	570	$0.0	$0.0
Driveway (6" Concrete) (S.Y.)	1	$60.0	$68.1
Haul Off Unsuitables and Classified Stone Backfill (C.Y.)	397	$60.0	$23,816.2
Removal of Existing Drainage Structures (Each)	8	$500.0	$4,000.0
Remove Existing Pipe, All Types and Sizes (L.F.)	570	$25.0	$14,247.9
Silt Fence Type C, Complete (L.F.)	1615	$4.0	$6,458.4
Sodding Complete (S.Y.)	1418	$7.0	$9,928.3
Street Cut (Detail C) (S.Y.)	82	$75.0	$6,129.8
CIPP 18" (L.F.)	210	$102.0	$21,371.4
18" Pipe - Cleaning less than 25% full (L.F.)	210	$4.0	$838.1
Inversion Setup Charge 15"-36" CIPP (Each)	2	$1,740.0	$3,480.0
		Construction Sub-Total	$152,741
		Engineering and Permitting (20%)	$30,550
		Contingency (20%)	$36,658
		Capital Cost	**$219,950**
		Annual Maintenance Cost	**$500**

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #7 – Pinehollow Court Neighborhood Flooding

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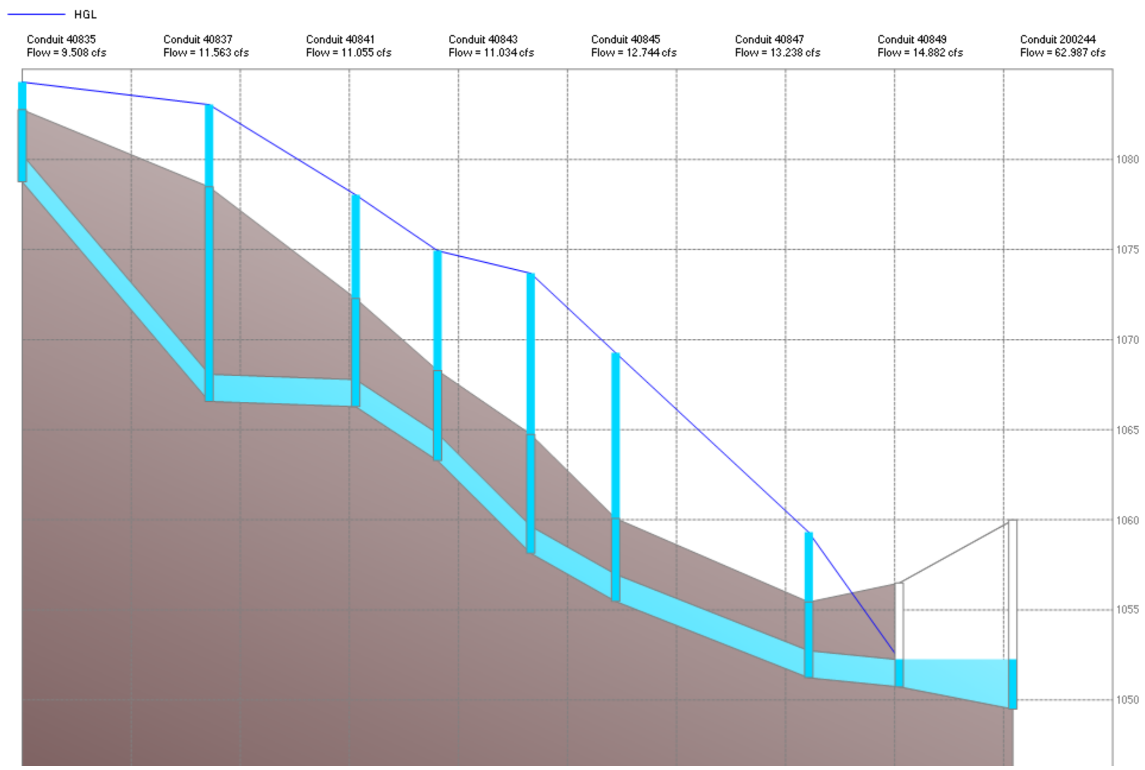
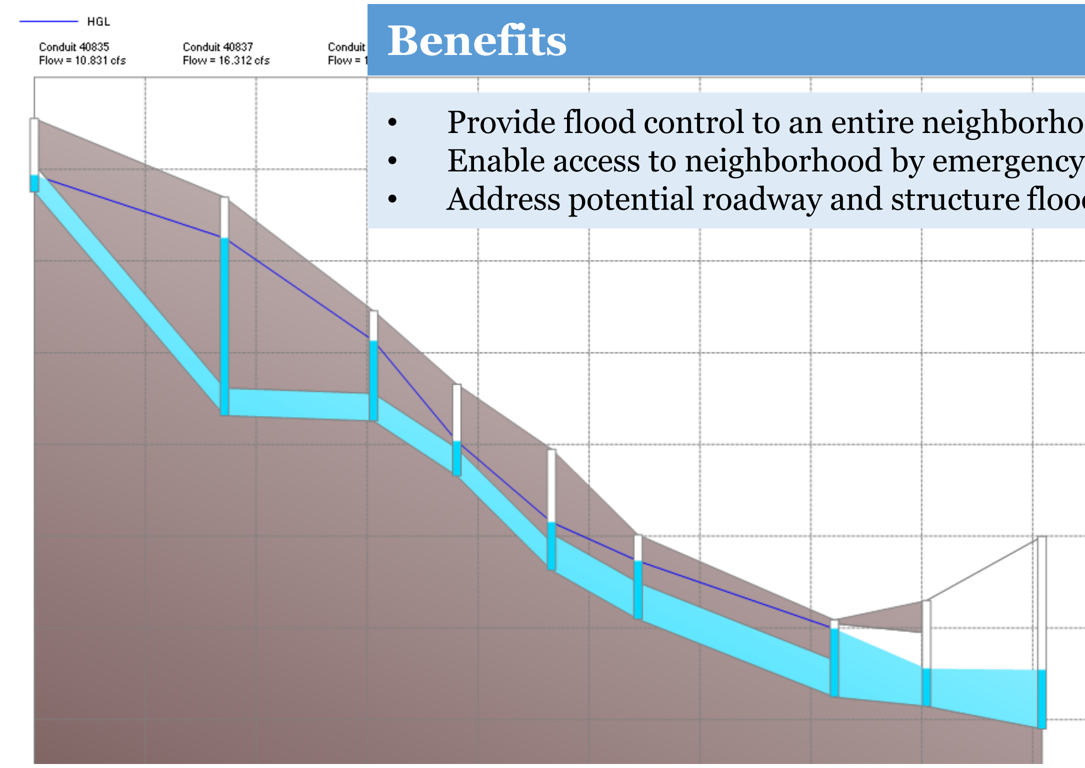


Maximum Hydraulic Grade Line (HGL) for an existing portion of the Pinehollow Court neighborhood stormwater system. Currently, all nodes flood in the 25-year storm event.



Maximum Hydraulic Grade Line (HGL) for an upgraded portion of the Pinehollow Court neighborhood stormwater system. In the upgrade scenario, none of the nodes flood during a 25-year storm event.

Benefits

- Provide flood control to an entire neighborhood
- Enable access to neighborhood by emergency vehicles during storm events
- Address potential roadway and structure flooding within neighborhood

The database presents upgrade scenarios, detailing pipe size and pipe material, for the following five options:

Scenario 1: Cured-in-Place Pipe (CIPP)
Scenario 2: Replace like size with HDPE
Return "Not Applicable" where limitations exists
Scenario 3: Replace like size with RCP
Scenario 4: Replace pipe to meet desired Level of Service HDPE
Return "Not Applicable" where limitations exists
Scenario 5: Replace pipe to meet desired Level of Service RCP

	Existing Conditions				Scenario 1			Scenario 2			Scenario 3			Scenario 4			Scenario 5		
Facility ID	Shape	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)
40835	Circular	RC	18	5	RL	18	10	RC	18	10	RC	18	10	RC	18	25	RC	18	25
40837	Circular	CO	18	5	RL	18	10	PT	18	10	RC	18	10	PT	18	25	RC	18	25
40839	Circular	PL	12	1	RL	12	2	PT	12	2	RC	12	2	PT	18	25	RC	18	25
40841	Circular	CO	18	2	RL	18	5	PT	18	5	RC	18	5	PT	18	25	RC	18	25
40843	Circular	RC	18	1	RL	18	2	PT	18	2	RC	18	2	PT	18	25	RC	18	25
40845	Circular	CO	18	<1	RL	18	1	PT	18	1	RC	18	1	PT	24	100	RC	24	100
40847	Circular	CO	18	<1	RL	18	<1	PT	18	<1	RC	18	<1	PT	24	25	RC	24	25
40849	Circular	CO	18	<1	RL	18	<1	PT	18	<1	RC	18	<1	PT	48	25	RC	48	25
40852	Circular	RC	18	100	RL	18	100	RC	18	100	RC	18	100	RC	18	100	RC	18	100
40854	Circular	RC	18	100	RL	18	100	RC	18	100	RC	18	100	RC	18	100	RC	18	100
40856	Circular	RC	18	100	RL	18	100	RC	18	100	RC	18	100	RC	18	100	RC	18	100
40858	Circular	RC	18	100	RL	18	100	RC	18	100	RC	18	100	RC	18	100	RC	18	100
40860	Circular	RC	18	5	RL	18	10	RC	18	10	RC	18	10	RC	18	25	RC	18	25
40862	Circular	RC	18	1	RL	18	5	RC	18	5	RC	18	5	RC	18	25	RC	18	25
40864	Circular	CO	18	2	RL	18	5	PT	18	5	RC	18	5	PT	24	25	RC	24	25

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #7 – Pinehollow Court Neighborhood Flooding

THE CITY OF ALPHARETTA
Dewberry

Project Overview

Tuxford is a neighborhood located off of Kimball Bridge Road. Stormwater runoff within the neighborhood is conveyed by a closed stormwater system. For this analysis, the focus will be on the pipes spanning Tuxford Drive between Dunoon Drive and Grenadier Lane. There are several drainage complaints in the area surrounding the pipes. Two complaints are for erosion and one complaint is for structure maintenance. Additionally, the Dewberry field team was approached by residents during their surveying. Several residents described persistent system flooding and erosion. Further, the existing model corroborates the accounts of residents and indicates flooding due to insufficient capacity in the four most downstream pipes of the system. Due to drainage complaints from the City, resident complaints, and model-verified system flooding, the Dewberry team has identified the Tuxford neighborhood as a candidate for system improvements.

Description	Quantity	Unit Cost	Total Cost
90" RCP Pipe (L.F.)	142	$490.0	$69,362.9
Catch Basin Complete, Group 1 or 2 (V.F.)	13	$500.0	$6,650.0
Headwall for 90" Pipe (Each)	1	$3,750.0	$3,750.0
Depth to Top of Pipe (8.1' - 12.0') (L.F.)	142	$50.0	$7,077.9
Haul Off Unsuitables and Classified Stone Backfill (C.Y.)	544	$60.0	$32,648.8
Removal of Existing Drainage Structures (Each)	2	$500.0	$1,000.0
Remove Existing Pipe, All Types and Sizes (L.F.)	142	$25.0	$3,538.9
Silt Fence Type C, Complete (L.F.)	414	$4.0	$1,655.0
Sodding Complete (S.Y.)	744	$7.0	$5,206.7
Street Cut (Detail C) (S.Y.)	64	$75.0	$4,765.8
CIPP 36" (L.F.)	236	$306.0	$72,067.0
CIPP 48" (L.F.)	237	$510.0	$121,007.2
CIPP 54" (L.F.)	95	$1,030.0	$97,766.6
CIPP 60" (L.F.)	25	$882.0	$21,657.5
36" Pipe - Cleaning Less Than 25% Full (L.F.)	236	$6.0	$1,413.1
48" Pipe - Cleaning Less Than 25% Full (L.F.)	237	$9.0	$2,135.4
54" Pipe - Cleaning Less Than 25% Full (L.F.)	95	$9.0	$854.3
60" Pipe - Cleaning Less Than 25% Full (L.F.)	25	$11.0	$270.1
Inversion Setup Charge 15"-36" CIPP (Each)	1	$1,740.0	$1,740.0
Inversion Setup Charge 42"-60" CIPP (Each)	4	$4,140.0	$16,560.0
		Construction Sub-Total	$471,128
		Engineering and Permitting (20%)	$94,226
		Contingency (20%)	$113,071
		Capital Cost	**$678,425**
		Annual Maintenance Cost	**$500**

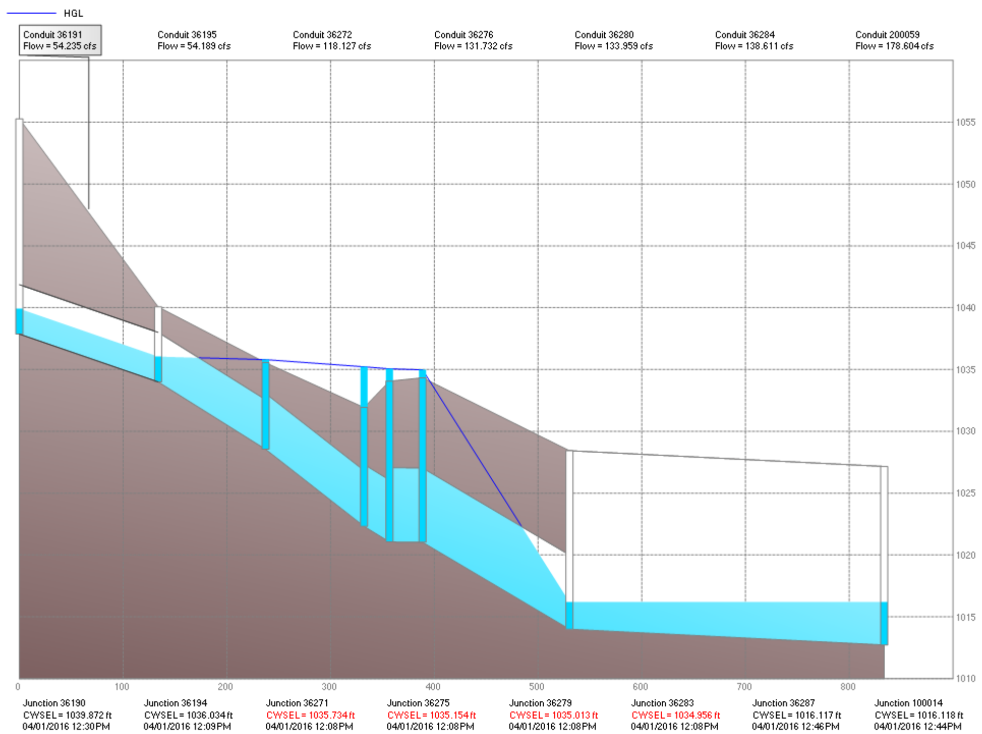
Location of the Tuxford Neighborhood and its existing stormwater system. Red pipes do not meet the 25-year level of service, and blue pipes do meet the 25-year level of service. Pipe Facility ID Numbers are displayed next to each pipe and can be related to the upgrade scenario tables and the system analysis database.

Cost

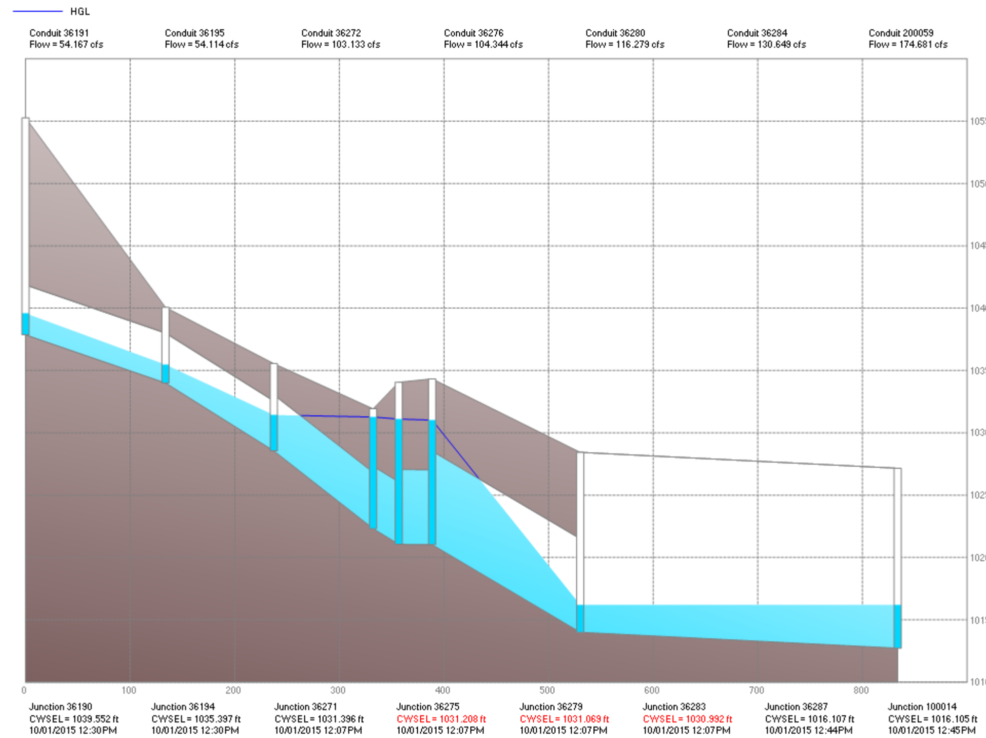
Construction related items are populated in the database to serve as input data for the Stormwater System Cost Estimation Tool. These items include: 1) CIPP rehabilitation, inversion setup, and pipe cleaning; 2) Pipe removal and replacement; 3) Depth to top of the pipe for depths over 8'; 4) Structure removal and replacement; 5) Additional excavation allowances; 6) Driveway, sidewalk, and street cut replacement; and 7) Silt Fence and Sod

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #8 – Tuxford Neighborhood Flooding

THE CITY OF ALPHARETTA
Dewberry



Maximum Hydraulic Grade Line (HGL) for an existing portion of the Tuxford neighborhood stormwater system. Currently, the four most downstream pipes have insufficient capacity.



Maximum Hydraulic Grade Line (HGL) for an upgraded portion of the Tuxford neighborhood stormwater system. In the upgrade scenario, none of the nodes flood during a 25-year storm event.

The database presents upgrade scenarios, detailing pipe size and pipe material, for the following five options:

Scenario 1: Cured-in-Place Pipe (CIPP)
Scenario 2: Replace like size with HDPE
Return "Not Applicable" where limitations exists
Scenario 3: Replace like size with RCP
Scenario 4: Replace pipe to meet desired Level of Service HDPE
Return "Not Applicable" where limitations exists
Scenario 5: Replace pipe to meet desired Level of Service RCP

	Existing Conditions				Scenario 1			Scenario 2			Scenario 3			Scenario 4			Scenario 5		
Facility ID	Shape	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)
36191	Circular	CO	48	100	RL	48	100	PT	48	100	RC	48	100	PT	48	100	RC	48	100
36195	Circular	CO	48	100	RL	48	100	PT	48	100	RC	48	100	PT	48	100	RC	48	100
36241	Circular	RC	48	100	RL	48	100	PT	48	100	RC	48	100	PT	48	100	RC	48	100
36272	Circular	CO	54	2	RL	54	2	PT	54	2	RC	54	2	PT	54	100	RC	54	100
36276	Circular	CO	60	1	RL	60	1	PT	60	1	RC	60	1	PT	60	100	RC	60	100
36280	Circular	RC	72	2	RL	72	2	RC	72	2	RC	72	2	RC	72	100	RC	72	100
36284	Circular	CO	72	2	RL	72	2	RC	72	2	RC	72	2	RC	90	100	RC	90	100
39983	Circular	CO	18	100	RL	18	100	PT	18	100	RC	18	100	PT	18	100	RC	18	100
42107	Circular	CO	36	100	RL	36	100	PT	36	100	RC	36	100	PT	36	100	RC	36	100
100060	Circular	PT	12	25	RL	12	25	PT	12	25	RC	12	25	PT	12	25	RC	12	25

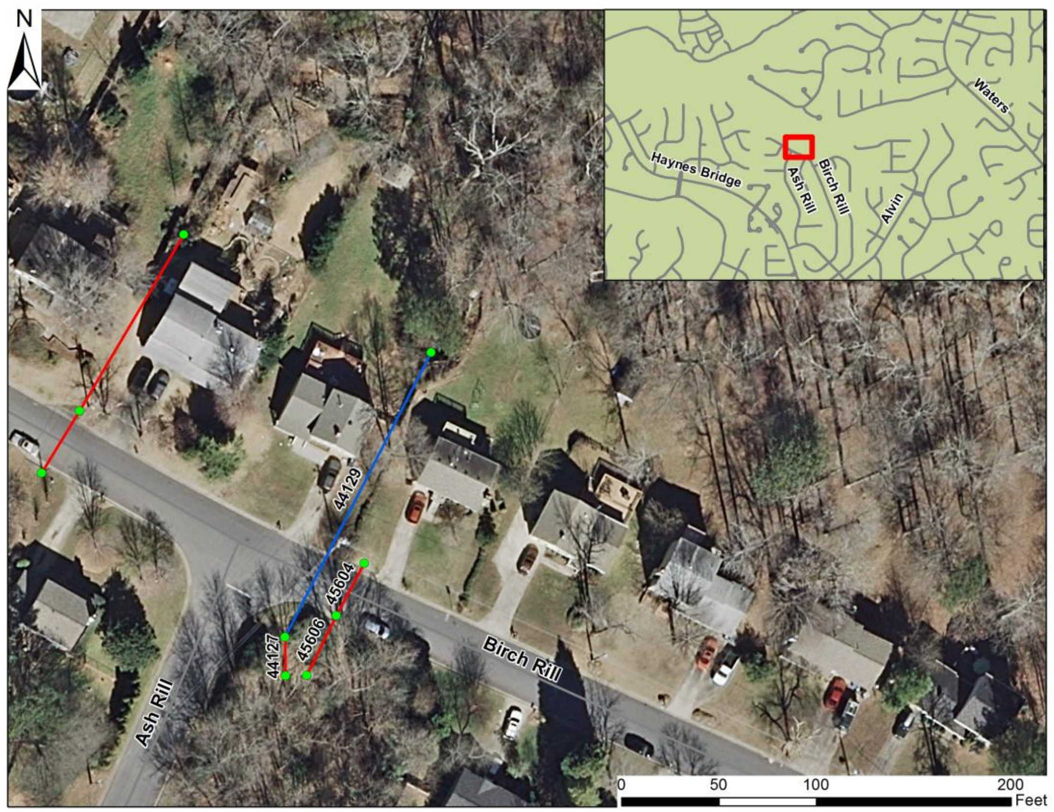
Only pipe 36284 requires an upgrade from a 72-inch diameter pipe to a 90-inch diameter pipe in order to meet a 25-year level of service. Normally, this is an ideal solution as upgrades are limited to a single pipe in order to meet the requirements of the entire system. Unfortunately, the size of the pipe and the its location between two houses could present construction site constraints. The trench cut required to install the larger pipe would overlap with existing houses, making it impossible to install the larger pipe needed to meet the 25-year level of service. Therefore, alternate solutions, such as a parallel system would need to be explored as potential solutions.

Project Overview

CIP No. LIC_0100_1 is the Birch Rill Drive Culvert that spans Long Indian Creek Tributary 1. In the December 2011 CIP Report, the HEC-RAS model indicated that the culvert overtops during the 5-year storm event. Due to this overtopping frequency, the CIP was ranked 5th. In this 2016 WIP Report, each CIP was reassessed using a SWMM model. Often the more granular, hydrodynamic SWMM model allows for improved routing and attenuation when compared to steady state HEC-RAS models. Therefore, it is not uncommon for the level of service to increase for CIPs when they are analyzed using a SWMM model. In the case of CIP No. LIC_0100_1, the SWMM model indicated an improved level of service from a 5-year overtopping frequency to a 10-year overtopping frequency. Although the SWMM model does indicate an increase of the service level for LIC_0100_1 for Birch Rill Drive, an upgrade to a 54" pipe is required to meet the 25-year level of service.

The database presents upgrade scenarios, detailing pipe size and pipe material, for the following five options:

Scenario 1: Cured-in-Place Pipe (CIPP)
Scenario 2: Replace like size with HDPE
Return "Not Applicable" where limitations exists
Scenario 3: Replace like size with RCP
Scenario 4: Replace pipe to meet desired Level of Service HDPE
Return "Not Applicable" where limitations exists
Scenario 5: Replace pipe to meet desired Level of Service RCP



Location of CIP No. LIC_0100_1. Red pipes do not meet the 100-year level of service, and blue pipes do meet the 100-year level of service. Pipe Facility ID Numbers are displayed next to each pipe.

Description	Quantity	Unit Cost	Total Cost
54" RCP PIPE (L.F.)	184	$175.0	$32,200.7
HEADWALL FOR 48" PIPE (EACH)	1	$1,400.0	$1,400.0
HEADWALL FOR 54" PIPE (EACH)	1	$1,600.0	$1,600.0
WEIR (EQUIV TO YI FOR PURPOSE OF COST) (V.F.)	10	$600.0	$6,084.0
DEPTH TO TOP OF PIPE (< 8.1') (L.F.)	184	$0.0	$0.0
DRIVEWAY (6" Concrete) (S.Y.)	39	$60.0	$2,365.8
Haul Off Unsuitables and Classified Stone Backfill (C.Y.)	938	$60.0	$56,255.6
REMOVAL OF EXISTING DRAINAGE STRUCTURES (EACH)	3	$500.0	$1,500.0
REMOVE EXISTING PIPE, ALL TYPES AND SIZES (L.F.)	184	$25.0	$4,600.1
SILT FENCE TYPE C, COMPLETE (L.F.)	479	$4.0	$1,915.1
SODDING COMPLETE (S.Y.)	567	$7.0	$3,969.4
STREET CUT (Detail C) (S.Y.)	100	$75.0	$7,533.7
CIPP 18" (L.F.)	65	$102.0	$6,589.6
18" PIPE - Cleaning less than 25% full (L.F.)	65	$4.0	$258.4
INVERSION SETUP CHARGE 15"-36" CIPP (EACH)	2	$1,740.0	$3,480.0
		Construction Sub-Total	$129,753
		Engineering and Permitting (20%)	$25,951
		Contingency (20%)	$31,141
		Capital Cost	**$186,845**
		Annual Maintenance Cost	**$500**

	Existing Conditions				Scenario 1			Scenario 2			Scenario 3			Scenario 4			Scenario 5		
Facility ID	Shape	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)
44127	Circular	CO	36	10	RL	36	10	PT	36	10	RC	36	10	PT	54	100	RC	54	100
44129	Circular	CO	48	100	RL	48	100	PT	48	100	RC	48	100	PT	54	100	RC	54	100
45604*	Circular	CO	18	<1	RL	18	<1	PT	18	<1	RC	18	<1	PT	18	25	RC	18	25
45606*	Circular	CO	18	<1	RL	18	<1	PT	18	<1	RC	18	<1	PT	18	25	RC	18	25

*Pipe 45604 and 45606 increase their LOS without any upgrades due to improved downstream hydraulics cause by upgrades to pipe 44127 and 44129.

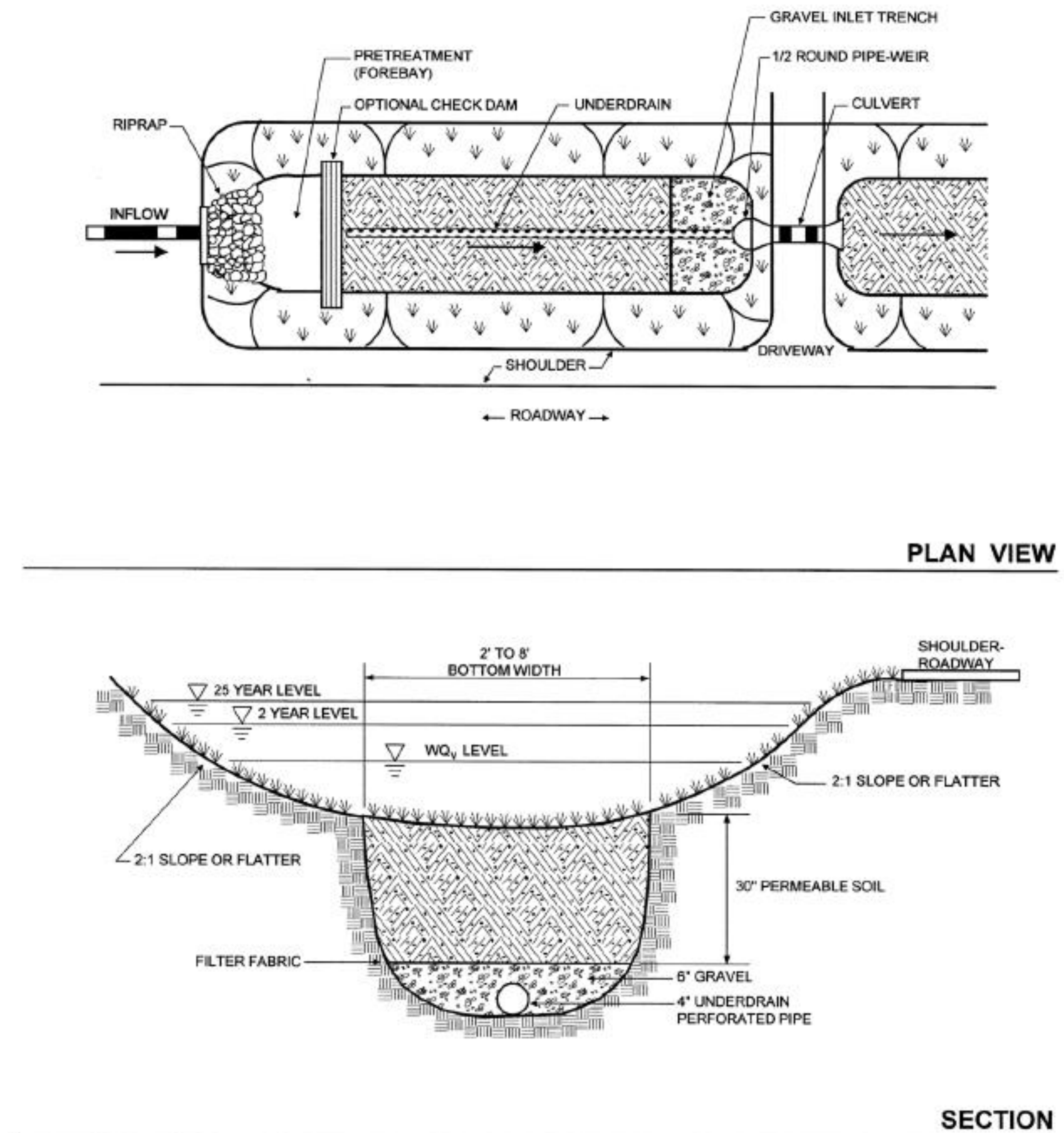
CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #9 – Birch Rill Drive Capital Improvement Project No. LIC_0100_1

SHEET C.16

Project Overview

An enhanced dry swales is recommended along the west side of Waters Road just north of where Long Indian Creek crosses the road. Due to the lack of public land within the Long Indian Creek watershed, swales are recommended for reducing runoff and total suspended solids loading into Long Indian Creek because of their linear nature and lesser land requirements. Based on the available land, it is estimated that approximately 350 linear feet of swale could be installed. In total, this installation would treat 2.4 acres of land, of which 0.65 acres (27%) is impervious cover. The Stormwater Quality Site Development Review Tool, version 2.2, from the Georgia Stormwater Management Manual was used to predict a runoff reduction volume of 2,559 cubic feet and a water quality treatment volume of 3,071 cubic feet from runoff from a 1-inch storm. This storage volume would remove 80% of the TSS from the contributing drainage area.

Location of proposed enhanced dry swale along Waters Road. A runoff reduction volume of 50% and a TSS removal rate of 80% is expected for the area treated by the swale.



Typical schematic for a dry swale from the Georgia Stormwater Management Manual (ARC, 2016)

Item	Unit	Quantity	Unit Price	Total Price
Clearing and Grubbing	AC	0.2	$25,000	$5,022
Erosion Control	LF	350	$20	$7,000
Earthwork - Haul off and Engineered Soils	CY	100	$75	$7,500
Sod Complete	SY	800	$10	$8,000
Check Dam	EA	6	$2,500	$15,000
Plastic Filter Fabric	SY	400	$10	$4,000
			Construction Sub-Total	$46,522
			Engineering and Permitting (25%)	$20,000
			Contingency (20%)	$13,304
			Capital Cost	**$79,826**
			Annual Maintenance Cost	**$500**

KEY CONSIDERATIONS

DESIGN CRITERIA
- Longitudinal slopes must be less than 4%
- Bottom width of 2 to 8 feet
- Side slopes 2:1 or flatter; 4:1 recommended
- Convey the 25-year storm event with a minimum of 6 inches of freeboard

ADVANTAGES / BENEFITS
- Combines stormwater treatment with runoff conveyance system
- Less expensive than curb and gutter
- Reduces runoff velocity

DISADVANTAGES / LIMITATIONS
- Higher maintenance than curb and gutter systems
- Cannot be used on steep slopes
- Possible resuspension of sediment
- Potential for odor / mosquitoes (wet swale)

MAINTENANCE REQUIREMENTS
- Maintain grass heights of approximately 4 to 6 inches (dry swale)
- Remove sediment from forebay and channel

POLLUTANT REMOVAL (DRY SWALE)
- 80% Total Suspended Solids
- 40% Metals - Cadmium, Copper, Lead, and Zinc removal
- 50/50% Nutrients - Total Phosphorus / Total Nitrogen removal
- N/A Pathogens – Fecal Coliform

POLLUTANT REMOVAL (WET SWALE)
- 80% Total Suspended Solids
- 20% Metals - Cadmium, Copper, Lead, and Zinc removal
- 25/40% Nutrients - Total Phosphorus / Total Nitrogen removal
- N/A Pathogens – Fecal Coliform

STORMWATER MANAGEMENT SUITABILITY
- ✓ Runoff Reduction
- ✓ Water Quality
- ★ Channel Protection
- Overbank Flood Protection
- Extreme Flood Protection

✓ suitable for this practice
★ may provide partial benefits

IMPLEMENTATION CONSIDERATIONS
- M Land Requirement
- M Capital Cost
- L Maintenance Burden

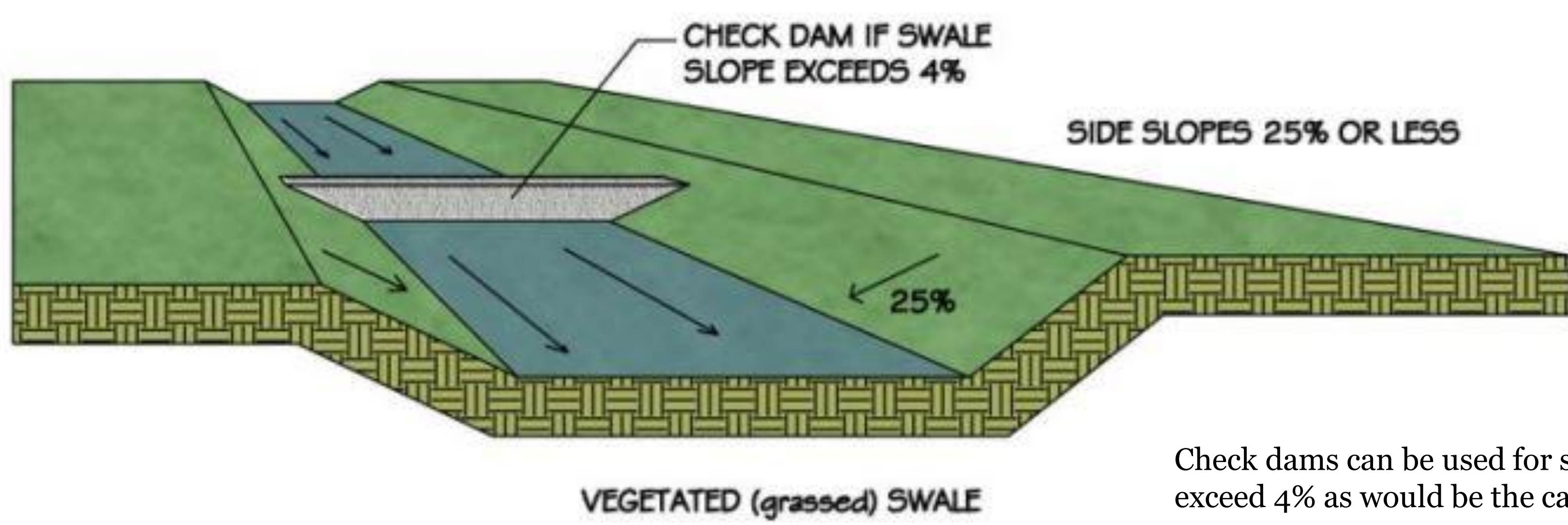
Residential Subdivision Use: *Yes*
High Density/Ultra-Urban: *No*
Drainage Area: *5 acres max*

Soils: *No restrictions*

Other Considerations:
- Permeable soil layer (dry swale)
- Wetland plants (wet swale)

L=Low M=Moderate H=High

RUNOFF REDUCTION CREDIT
- Dry Swale: 100% of the runoff reduction volume provided (no underdrain)
- Dry Swale: 50% of the runoff reduction volume provided (underdrain)
- Wet Swale: 0% of the runoff reduction volume provided



Check dams can be used for swales whose slopes exceed 4% as would be the case for this project.

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #10 – Waters Road Enhanced Dry Swale Project 1 (North)

THE CITY OF ALPHARETTA

Dewberry®

SHEET C.18

Project Overview

An enhanced dry swales is recommended along the east side of Waters Road south of where Long Indian Creek crosses the road. Due to the lack of public land within the Long Indian Creek watershed, swales are recommended for reducing runoff and total suspended solids loading into Long Indian Creek because of their linear nature and lesser land requirements. Based on the available land, it is estimated that approximately 500 linear feet of swale could be installed. In total, this installation would treat 2/3 acres of land, of which 0.38 acres (56%) is impervious cover. The Stormwater Quality Site Development Review Tool, version 2.2, from the Georgia Stormwater Management Manual was used to predict a runoff reduction volume of 1,347 cubic feet and a water quality treatment volume of 1,617 cubic feet from runoff from a 1-inch storm. This storage volume would remove 80% of the TSS from the contributing drainage area.

Example of a dry swale from the Georgia Stormwater Management Manual (ARC, 2016)

Location of proposed enhanced dry swale along Waters Road. A runoff reduction volume of 50% and a TSS removal rate of 80% is expected for the area treated by the swale.

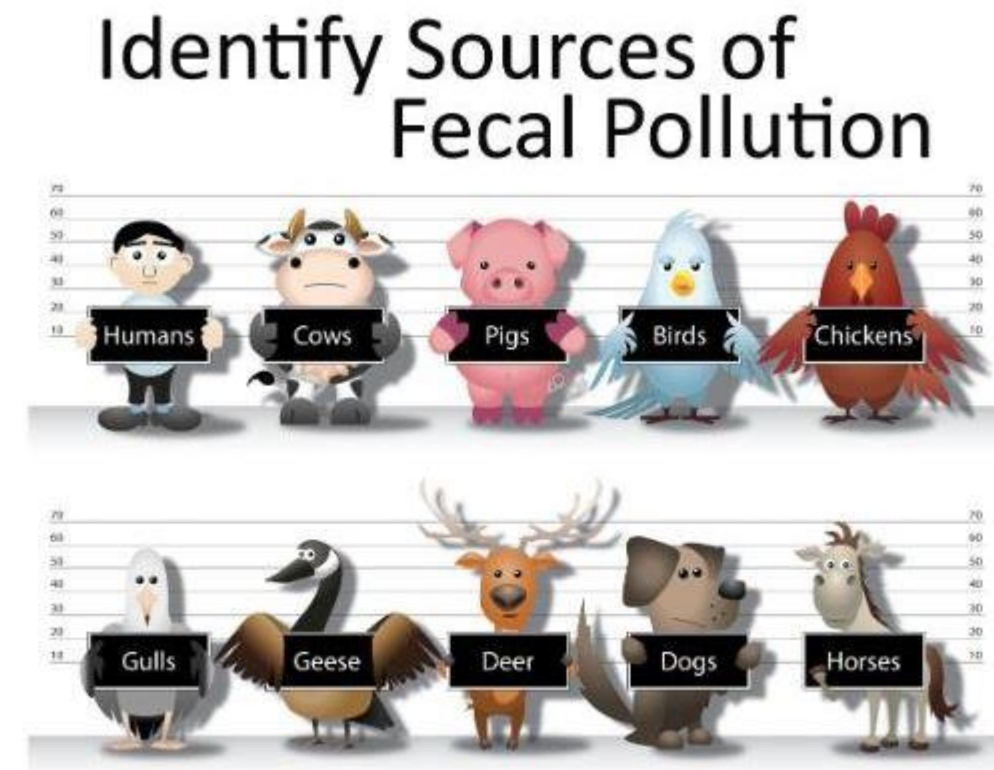
Item	Unit	Quantity	Unit Price	Total Price
Clearing and Grubbing	AC	0.3	$25,000	$7,174
Erosion Control	LF	500	$20	$10,000
Earthwork - Haul off and Engineered Soils	CY	200	$75	$15,000
Sod Complete	SY	1,200	$10	$12,000
Check Dam	EA	0	$2,500	$0
Plastic Filter Fabric	SY	500	$10	$5,000
			Construction Sub-Total	$49,174
			Engineering and Permitting (25%)	$20,000
			Contingency (20%)	$13,835
			Capital Cost	**$83,009**
			Annual Maintenance Cost	**$500**

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #11 – Waters Road Enhanced Dry Swale Project 2 (South)

THE CITY OF ALPHARETTA
Dewberry

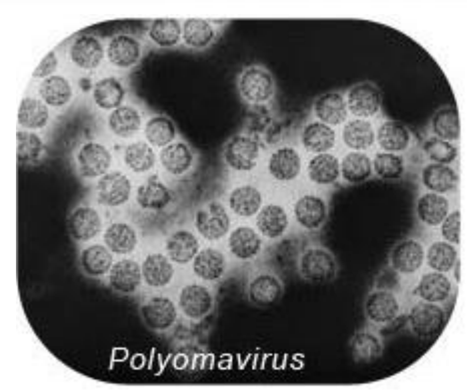
Project Overview

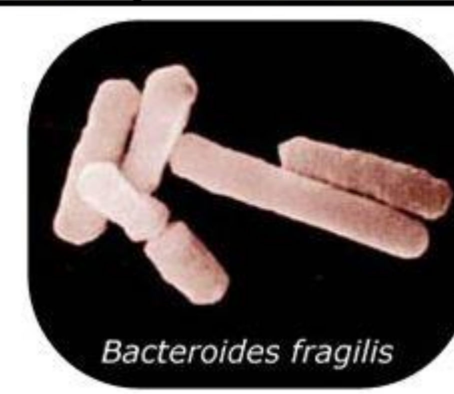
Bacterial Source Tracking, commonly referred to as BST, allows for the determination of the source(s) of fecal contamination because of variations in DNA sequences between living organisms that make it possible to distinguish one organisms from another through molecular biology techniques. This can be done through a process called Polymerase Chain Reaction (PCR) in which DNA sequences are extracted and amplified to identify and quantify the presence of microorganisms in water samples based on the unique genetic sequence of that organism (Source Molecular, 2016). This process is the preferred BST technology (Shanks , 2015), and Source Molecular is licensed by the EPA to use their patented genetic testing methods developed to identify Human, cattle, chicken, and dog fecal contamination. It is recommended that the City of Alpharetta continues to utilize BST technology to monitor the source(s) of fecal contamination in watersheds. Continued BST monitoring will ensure that the best and most targeted measures are being used to address fecal coliform contamination within the Long Indian Creek Watershed. It is anticipated that BST monitoring will cost $25,000 annually, but this cost can be customized to the City's needs by adjusting the number of samples and their sampling frequency.



Sample BST Results:

SM #	Client #	Analysis Requested	Marker Quantified (copies/100 ml)	DNA Analytical Results
SM-6D13021	Site 1	Dog Bacteroidetes ID	2.60E+03	Present
SM-6D13022	Site 2	Dog Bacteroidetes ID	2.96E+04	Present
SM-6D13023	Site 3	Dog Bacteroidetes ID	1.22E+04	Present
SM-6D13024	Site 4	Dog Bacteroidetes ID	1.72E+04	Present
SM-6D13025	Site 5	Dog Bacteroidetes ID	2.49E+04	Present





CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #12 – Bacterial Source Tracking (BST)

THE CITY OF ALPHARETTA

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SHEET C.20

APPENDIX D: LONG INDIAN CREEK STREAM INVENTORY TECHNICAL MEMORANDUM

1538603
LONG INDIAN CREEK
SITE 1
LEFT BANK

Worksheet 21. Summary of bank erosion hazard index (BEHI)

3/14/2016

Bank Erosion Hazard Rating Guide

Stream LONG INDIAN CREEK Reach SITE 1 Date 3/14/2016 Crew CB

Bank Erosion Potential			Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
Bank Height (ft): 6 Bankfull Height (ft): 3.5							
VERY LOW		Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
		Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
LOW		Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
		Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
		Choice	V: I:	V: I:	V: 60 I: 3.5	V: 45 I: 3.2	V: 70 I: 2.8
MODERATE		Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
		Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
		Choice	V: I:	V: 0.31 I: 5.9	V: I:	V: I:	V: I:
HIGH		Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
		Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
		Choice	V: 1.7 I: 6.5	V: I:	V: I:	V: I:	V: I:
VERY HIGH		Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
		Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
EXTREME		Value	>2.8	<0.05	<5	>119	<10
		Index	10	10	10	10	10
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
V = value, I = index						**SUB-TOTAL** (Sum one index from each column)	21.9

Bank Material Description:

Bank Materials

- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt Clay** (+ 0: no adjustment)

BANK MATERIAL ADJUSTMENT 0

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT 0

VERY LOW	LOW	MODERATE (circled)	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach (circled) Outside of Bend

GRAND TOTAL BEHI RATING 21.9

1538603
LONG INDIAN CREEK
SITE 2
RIGHT BANK

Worksheet 21. Summary of bank erosion hazard index (BEHI)

Bank Erosion Hazard Rating Guide

Stream LONG INDIAN CREEK Reach SITE 2 Date 3/14/2016 Crew CB

Bank Erosion Potential	Bank Height (ft): 4.0 Bankfull Height (ft): 2.5	Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
	Choice	V: I:	V: I:	V: I:	V: 60 I: 3.9	V: 65 I: 3.1
MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
	Choice	V: I:	V: I:	V: 54 I: 4.0	V: I:	V: I:
HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
	Choice	V: 1.6 I: 6.0	V: 0.25 I: 7.6	V: I:	V: I:	V: I:
VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
EXTREME	Value	>2.8	<0.05	<5	>119	<10
	Index	10	10	10	10	10
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	V = value, I = index				**SUB-TOTAL** (Sum one index from each column)	24.6

Bank Material Description:

Bank Materials

- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt Clay** (+ 0: no adjustment)

BANK MATERIAL ADJUSTMENT 0

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT 0

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach Outside of Bend

GRAND TOTAL BEHI RATING 24.6

1538603 3/14/2016
LONG INDIAN CREEK
SITE 3
LEFT BANK
BEAVER ACTIVITY

Worksheet 21. Summary of bank erosion hazard index (BEHI)

Bank Erosion Hazard Rating Guide

Stream LONG INDIAN CREEK Reach SITE 3 Date 3/14/2016 Crew CG3

Bank Erosion Potential	Bank Height (ft): 8.5 Bankfull Height (ft): 4.5	Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
	Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:
LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
	Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
	Choice	V: I:	V: I:	V: 60 I: 3.8	V: I:	V: 70 I: 3.2
MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
	Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
	Choice	V: I:	V: I:	V: I:	V: 80 I: 5.9	V: I:
HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
	Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
	Choice	V: 1.8 I: 6.5	V: I:	V: I:	V: I:	V: I:
VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
	Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
	Choice	V: I:	V: 0.1 I: 8.1	V: I:	V: I:	V: I:
EXTREME	Value	>2.8	<0.05	<5	>119	<10
	Index	10	10	10	10	10
	Choice	V: I:	V: I:	V: I:	V: I:	V: I:

V = value, I = index — **SUB-TOTAL** (Sum one index from each column): 27.2

Bank Material Description:

Bank Materials

- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt Clay** (+ 0: no adjustment) (circled)

BANK MATERIAL ADJUSTMENT: 0

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT: 0

VERY LOW	LOW	MODERATE (circled)	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach (circled) Outside of Bend

GRAND TOTAL BEHI RATING: 27.2

1538603 3/14/2016
LONG INDIAN CREEK

Worksheet 21. Summary of bank erosion hazard index (BEHI) SITE 4

Bank Erosion Hazard Rating Guide

Stream LONG INDIAN CREEK Reach SITE 4 Date 3/14/2016 Crew GS

Bank Erosion Potential	Bank Height (ft): 5.5 / Bankfull Height (ft): 3.5		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
	VERY LOW	Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
		Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	LOW	Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
		Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
		Choice	V: I:	V: 0.7 I: 3.5	V: I:	V: I:	V: 60 I: 2.4
	MODERATE	Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
		Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
		Choice	V: I:	V: I:	V: 50 I: 4.4	V: 80 I: 5.9	V: I:
	HIGH	Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
		Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
		Choice	V: 1.61 I: 6.0	V: I:	V: I:	V: I:	V: I:
	VERY HIGH	Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
		Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	EXTREME	Value	>2.8	<0.05	<5	>119	<10
		Index	10	10	10	10	10
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
	V = value, I = index					**SUB-TOTAL** (Sum one index from each column)	22.2

Bank Material Description:

Bank Materials

- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt Clay** (+ 0: no adjustment) (circled)

BANK MATERIAL ADJUSTMENT 0

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT 0

VERY LOW	LOW	MODERATE	HIGH	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5 (circled)	30-39.5	40-45	46-50

Bank location description (circle one)

Straight Reach (circled) Outside of Bend

GRAND TOTAL BEHI RATING 22.2

1538603 3/14/2016
LONG INDIAN CREEK
SITE 5
RIGHT BANK

Worksheet 21. Summary of bank erosion hazard index (BEHI)

Bank Erosion Hazard Rating Guide

Stream | Reach SITE 5 | Date 3/14/2016 | Crew CB

Bank Erosion Potential	Bank Height (ft): 6 / Bankfull Height (ft): 3		Bank Height/ Bankfull Ht	Root Depth/ Bank Height	Root Density %	Bank Angle (Degrees)	Surface Protection%
VERY LOW		Value	1.0-1.1	1.0-0.9	100-80	0-20	100-80
		Index	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9	1.0-1.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
LOW		Value	1.11-1.19	0.89-0.5	79-55	21-60	79-55
		Index	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9	2.0-3.9
		Choice	V: 2 I: 1.11	V: I:	V: I:	V: I:	V: I:
MODERATE		Value	1.2-1.5	0.49-0.3	54-30	61-80	54-30
		Index	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9	4.0-5.9
		Choice	V: I:	V: I:	V: I:	V: I:	V: I:
HIGH		Value	1.6-2.0	0.29-0.15	29-15	81-90	29-15
		Index	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9	6.0-7.9
		Choice	V: I:	V: 0.21 I: 7.5	V: I:	V: 90 I: 7.9	V: I:
VERY HIGH		Value	2.1-2.8	0.14-0.05	14-5.0	91-119	14-10
		Index	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0	8.0-9.0
		Choice	V: I:	V: I:	V: 5 I: 9.0	V: I:	V: I:
EXTREME		Value	>2.8	<0.05	<5	>119	<10
		Index	10	10	10	10	10
		Choice	V: I:	V: I:	V: I:	V: I:	V: 5 I: 10
	V = value, I = index					SUB-TOTAL (Sum one index from each column)	35.51

Bank Material Description:

Bank Materials

- **Bedrock** (Bedrock banks have very low bank erosion potential)
- **Boulders** (Banks composed of boulders have low bank erosion potential)
- **Cobble** (Subtract 10 points. If sand/gravel matrix greater than 50% of bank material, then do not adjust)
- **Gravel** (Add 5-10 points depending percentage of bank material that is composed of sand)
- **Sand** (Add 10 points)
- **Silt Clay** (+ 0: no adjustment) (circled)

BANK MATERIAL ADJUSTMENT 0

Stratification Comments:

Stratification

Add 5-10 points depending on position of unstable layers in relation to bankfull stage

STRATIFICATION ADJUSTMENT 0

VERY LOW	LOW	MODERATE	HIGH (circled)	VERY HIGH	EXTREME
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

Bank location description (circle one)
Straight Reach (circled) Outside of Bend

GRAND TOTAL BEHI RATING 35.51

Golder Associates

CALCULATIONS

Subject:	Stream Cross-Sections for Long Indian Creek		
Date	5/20/2016	**Made By:**	LDH
Project No.:	1538603	**Checked By:**	SSH
Project Short Title:	Long Indian Creek Watershed Improvement	**Reviewed By:**	CCB

INTRODUCTION

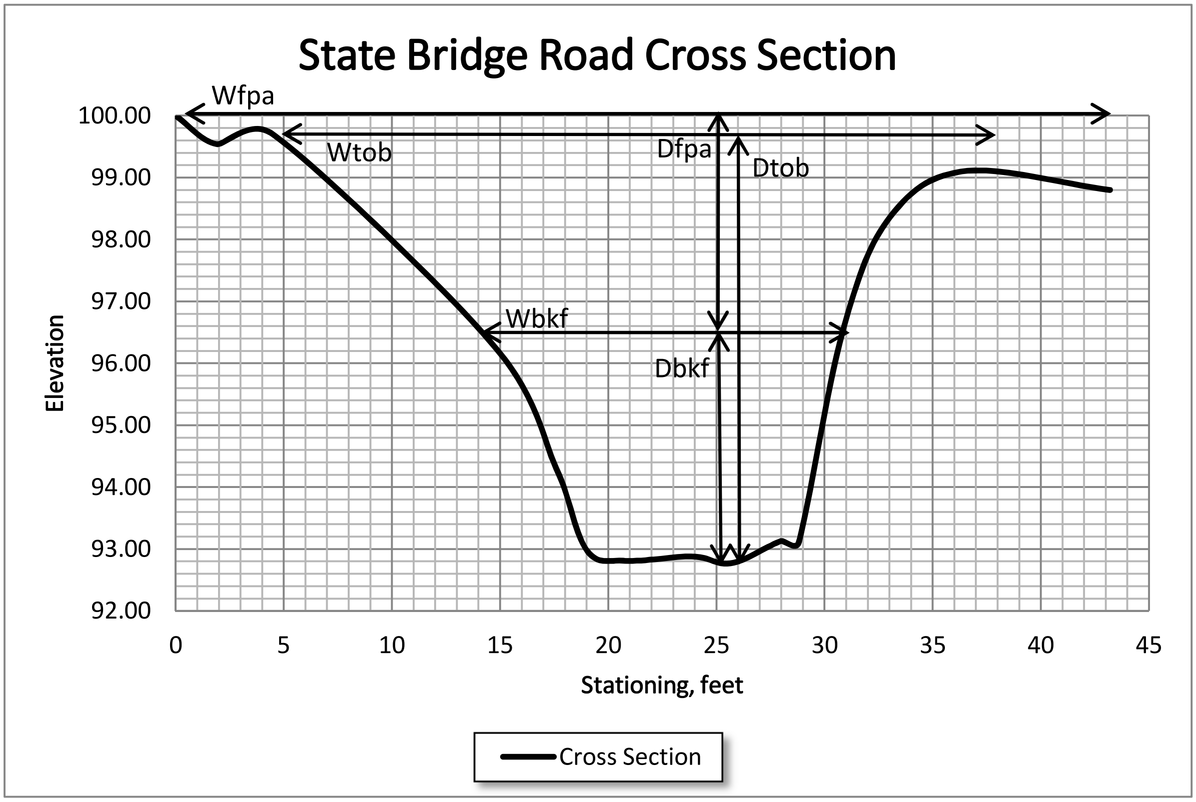
This calculation summarizes the survey data collected for Site 1-State Bridge Road of Long Indian Creek.

BS, feet	4.26	Latitude	34.04994
HI, feet	104.26	Longitude	-84.22768
Stream Name:	Long Indian Creek	Date Surveyed	3/14/2016

*Assumes 100' ground surface at instrument.

3/11/2016	Habitat Assessment Score	122	
3/14/2016	Bank Erosion Hazard Index Score	21.9	
Station, feet	FS, feet	Ground Surface Elevation (feet)	Description
0+00	4.26	100.00	Benchmark
0+1.9	4.72	99.54	Left Terrace
0+4.5	4.56	99.70	Left Top of Bank
0+14.7	7.97	96.29	Left Bankfull
0+17.6	9.96	94.30	Left Toe Slope
0+19.0	11.28	92.98	Left Edge of Water
0+20.8	11.45	92.81	Stream Point
0+23.9	11.38	92.88	Gravel Bar
0+25.7	11.49	92.77	Maximum Depth
0+28.0	11.13	93.13	Bedrock
0+28.8	11.16	93.10	Right Edge of Water
0+30.8	7.80	96.46	Right Bankfull
0+32.9	5.96	98.30	Right Top of Bank
0+36.4	5.16	99.10	Right Terrace 1
0+43.2	5.46	98.80	Right Terrace 2

CROSS SECTIONS



Bankfull Width (WBkf)=	16.1	feet
Bankfull Depth (Dbkf)=	3.65	feet
Floodprone width (Wfpa)=	43.2	feet
Floodprone depth (Dfpa)=	7.30	feet
Bank-top width (Wtob)=	28.40	feet
Bank-top depth (Dtob)=	6.93	feet

Dfpa = 2 x Dbkf

CALCULATIONS

Subject:	Stream Cross-Sections for Long Indian Creek		
Date	5/20/2016	**Made By:**	LDH
Project No.:	1538603	**Checked By:**	SSH
Project Short Title:	Long Indian Creek Watershed Improvement	**Reviewed By:**	CCB

INTRODUCTION

This calculation summarizes the survey data collected for Site 2-Buice Road of Long Indian Creek.

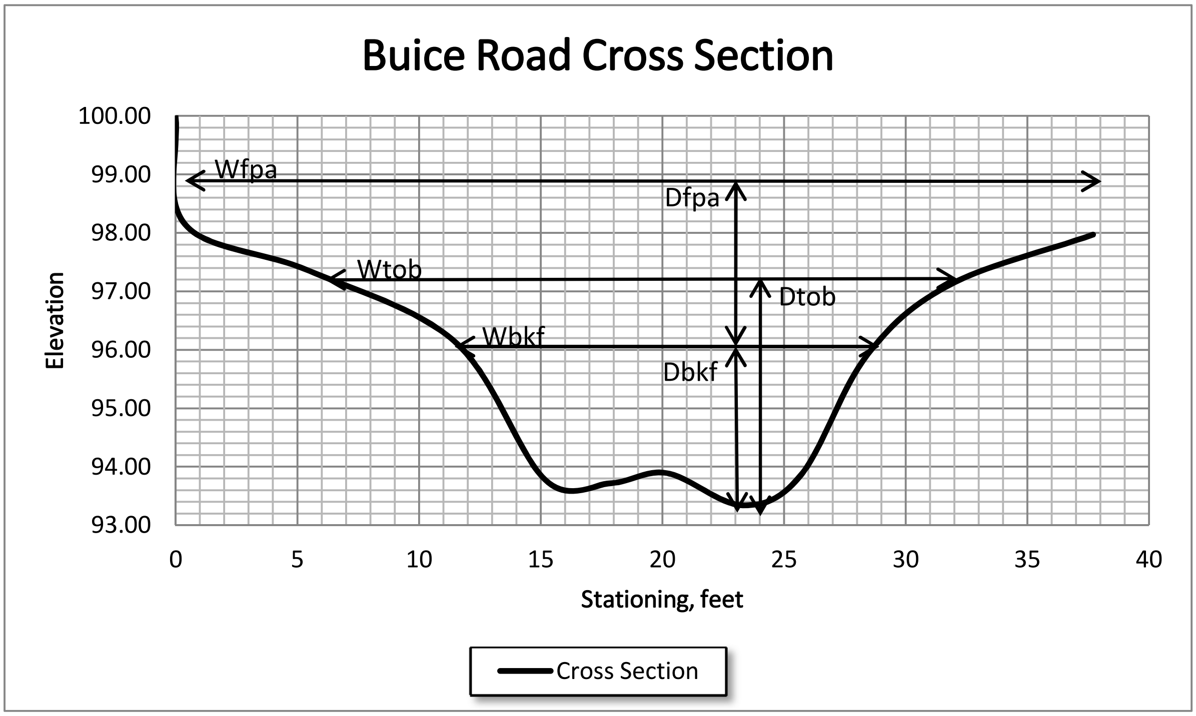
BS, feet	4.22	Latitude	34.04496
HI, feet	104.22	Longitude	-84.23360
Stream Name:	Long Indian Creek	Date Surveyed	3/14/2016

*Assumes 100' ground surface at instrument.

3/11/2016	Habitat Assessment Score	24.6
3/14/2016	Bank Erosion Hazard Index Score	111

Station, feet	FS, feet	Ground Surface Elevation (feet)	Description
0+00	4.22	100.00	Benchmark
0+0.4	6.08	98.14	Left Terrace
0+5.5	6.87	97.35	Left Top of Bank
0+11.5	8.09	96.13	Left Bankfull
0+15.2	10.45	93.77	Left Toe Slope/Edge of Water
0+17.9	10.50	93.72	Bedrock
0+20.2	10.33	93.89	Exposed Bedrock
0+23.3	10.88	93.34	Maximum Depth
0+25.7	10.36	93.86	Right Toe Slope/Edge of Water
0+28.4	8.32	95.90	Right Bankfull
0+31.8	7.11	97.11	Right Top of Bank
0+37.7	6.25	97.97	Right Terrace

CROSS SECTIONS



Bankfull Width (WBkf)=	16.9	feet
Bankfull Depth (Dbkf)=	2.56	feet
Floodprone width (Wfpa)=	37.7	feet
Floodprone depth (Dfpa)=	5.12	feet
Bank-top width (Wtob)=	26.30	feet
Bank-top depth (Dtob)=	4.01	feet

Dfpa = 2 x Dbkf

CALCULATIONS

Subject:	Stream Cross-Sections for Long Indian Creek		
Date	5/20/2016	**Made By:**	LDH
Project No.:	1538603	**Checked By:**	SSH
Project Short Title:	Long Indian Creek Watershed Improvement	**Reviewed By:**	CCB

INTRODUCTION

This calculation summarizes the survey data collected for Site 3-Willow Meadow Circle of Long Indian Creek.

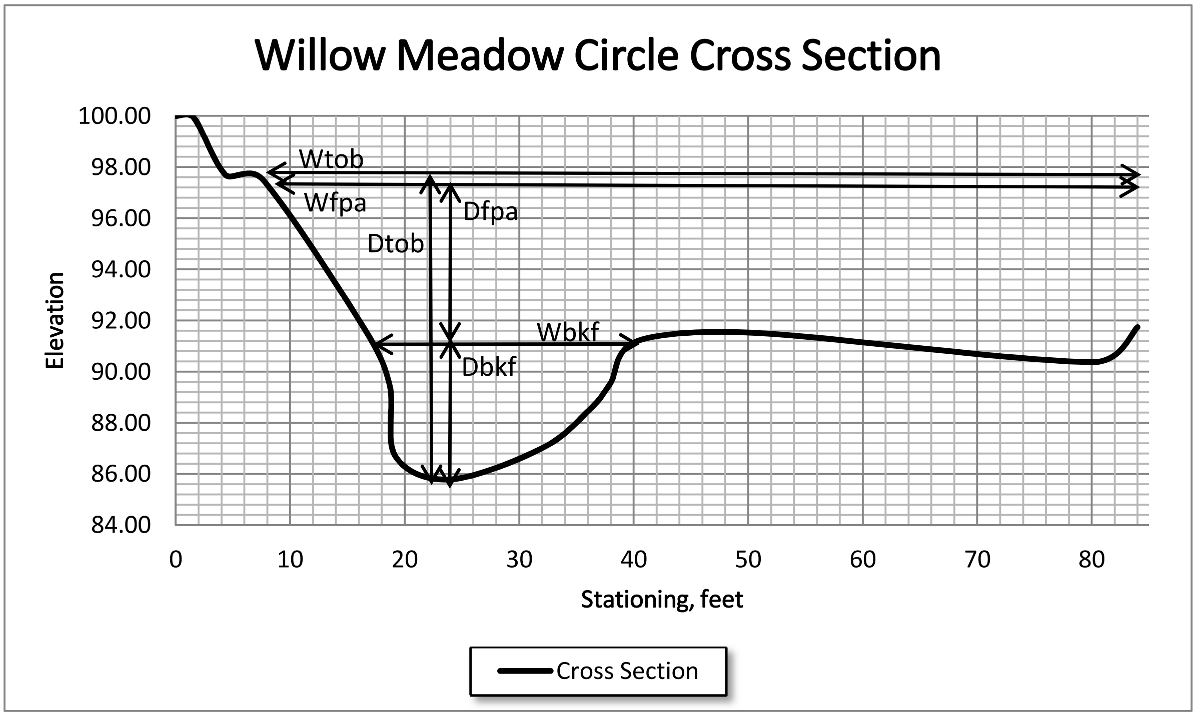
BS, feet	4.28	Latitude	34.03826
HI, feet	104.28	Longitude	-84.23692
Stream Name:	Long Indian Creek	Date Surveyed	3/14/2016

*Assumes 100' ground surface at instrument.

3/11/2016	Habitat Assessment Score	27.2
3/14/2016	Bank Erosion Hazard Index Score	77

Station, feet	FS, feet	Ground Surface Elevation (feet)	Description
0+00	4.28	100.00	Benchmark
0+1.6	4.36	99.92	Left Top of Terrace
0+4.4	6.60	97.68	Left Bottom of Terrace
0+7.6	6.76	97.52	Left Top of Bank
0+16.6	12.68	91.60	Left Bankfull
0+18.7	14.82	89.46	Left Edge of Water
0+19.2	17.59	86.69	Left Toe Slope
0+24.0	18.49	85.79	Maximum Depth
0+32.0	17.27	87.01	Stream Point
0+36.1	15.78	88.50	Right Toe Slope
0+37.9	14.78	89.50	Right Edge of Water
0+40.3	13.08	91.20	Right Bankfull
0+50.3	12.75	91.53	Right Flood Plain
0+80.2	13.90	90.38	Right Toe of Bank
0+84.0	12.54	91.74	Right Top of Bank

CROSS SECTIONS



Bankfull Width (WBkf)=	23.7	feet
Bankfull Depth (Dbkf)=	5.81	feet
Floodprone width (Wfpa)=	76.0	feet
Floodprone depth (Dfpa)=	11.62	feet
Bank-top width (Wtob)=	76.40	feet
Bank-top depth (Dtob)=	11.73	feet

Dfpa = 2 x Dbkf

CALCULATIONS

Subject:	Stream Cross-Sections for Long Indian Creek		
Date	5/20/2016	**Made By:**	LDH
Project No.:	1538603	**Checked By:**	SSH
Project Short Title:	Long Indian Creek Watershed Improvement	**Reviewed By:**	CCB

INTRODUCTION

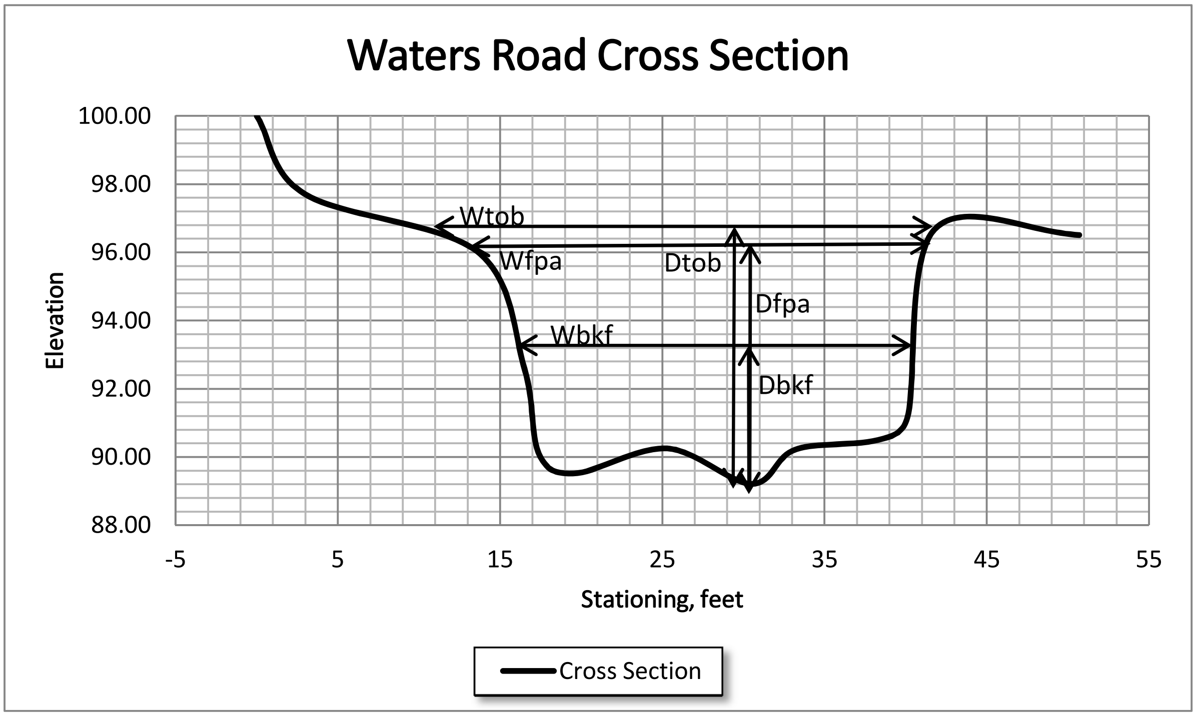
This calculation summarizes the survey data collected for Site 4-Waters Road of Long Indian Creek.

BS, feet	2.11	Latitude	34.03879
HI, feet	102.11	Longitude	-84.25873
Stream Name:	Long Indian Creek	Date Surveyed	3/14/2016

*Assumes 100' ground surface at instrument.

3/11/2016	Habitat Assessment Score		22.2
3/14/2016	Bank Erosion Hazard Index Score		59
Station, feet	FS, feet	Ground Surface Elevation (feet)	Description
0+00	2.11	100.00	Benchmark
0+3.0	4.41	97.70	Left Terrace
0+13.6	6.09	96.02	Left Top of Bank
0+16.5	9.52	92.59	Left Bankfull
0+17.4	12.02	90.09	Left Toe Slope/Edge of Water
0+19.6	12.59	89.52	Sand Bar
0+25.3	11.86	90.25	Cobble Bar
0+30.5	12.90	89.21	Maximum Depth
0+33.2	11.89	90.22	Gravel Bar
0+38.2	11.62	90.49	Right Edge of Water
0+40.1	10.97	91.14	Right Toe Slope
0+41.8	5.43	96.68	Right Top of Bank
0+50.7	5.60	96.51	Right Terrace

CROSS SECTIONS



Bankfull Width (WBkf)=	25.3	feet
Bankfull Depth (Dbkf)=	3.38	feet
Floodprone width (Wfpa)=	20.8	feet
Floodprone depth (Dfpa)=	6.76	feet
Bank-top width (Wtob)=	28.20	feet
Bank-top depth (Dtob)=	7.47	feet

Dfpa = 2 x Dbkf

CALCULATIONS

Subject:	Stream Cross-Sections for Long Indian Creek		
Date	5/20/2016	**Made By:**	LDH
Project No.:	1538603	**Checked By:**	SSH
Project Short Title:	Long Indian Creek Watershed Improvement	**Reviewed By:**	CCB

INTRODUCTION

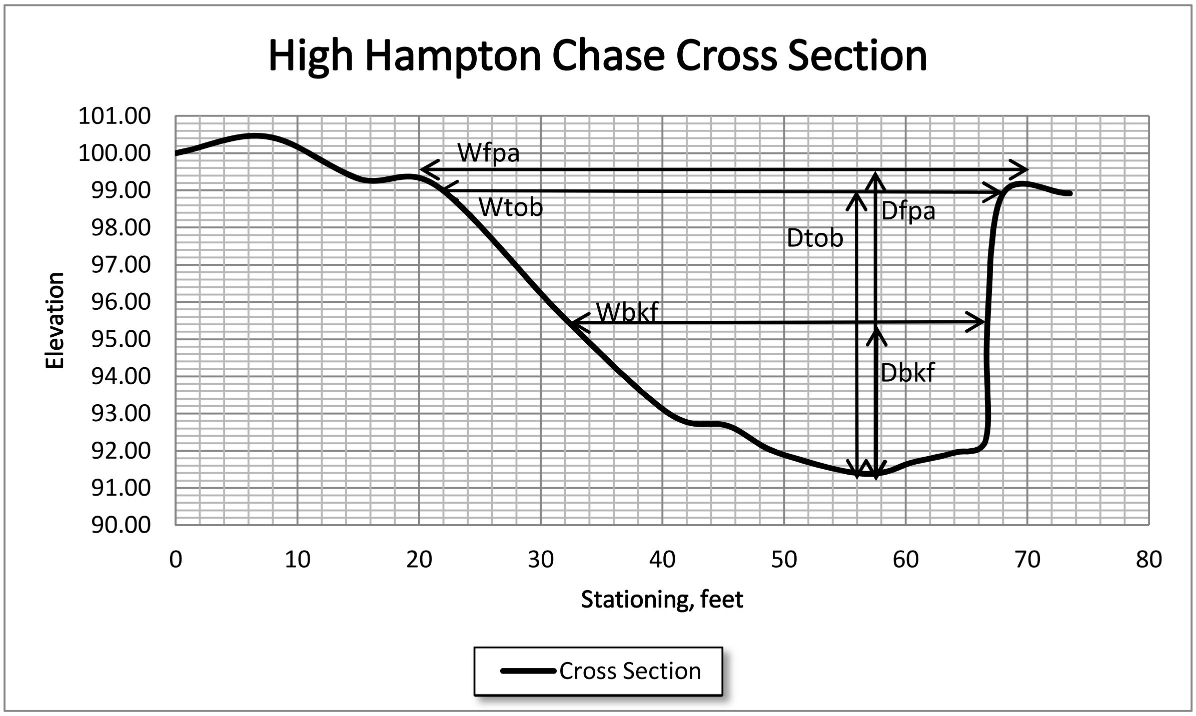
This calculation summarizes the survey data collected for Site 5-High Hampton Chase of Long Indian Creek.

BS, feet	3.40	Latitude	34.03823
HI, feet	103.40	Longitude	-84.27144
Stream Name:	Long Indian Creek	Date Surveyed	3/14/2016

*Assumes 100' ground surface at instrument.

3/11/2016	Habitat Assessment Score		35.51
3/14/2016	Bank Erosion Hazard Index Score		74
Station, feet	FS, feet	Ground Surface Elevation (feet)	Description
0+00	3.40	100.00	Benchmark
0+7.5	2.95	100.45	Left Top of Levee
0+15.2	4.10	99.30	Left Bottom of Levee
0+21.5	4.29	99.11	Left Top of Bank
0+32.0	7.85	95.55	Left Bankfull
0+40.7	10.43	92.97	Left Toe Slope
0+45.4	10.73	92.67	Gravel Bar
0+49.4	11.44	91.96	Left Edge of Water
0+56.6	12.02	91.38	Maximum Depth
0+60.7	11.70	91.70	Sand Bar
0+64.0	11.45	91.95	Right Edge of Water
0+66.6	11.09	92.31	Right Toe Slope
0+66.7	8.10	95.30	Right Bankfull
0+68.0	4.49	98.91	Right Top of Bank
0+73.5	4.48	98.92	Right Terrace

CROSS SECTIONS



Bankfull Width (WBkf)=	34.7	feet
Bankfull Depth (Dbkf)=	4.17	feet
Floodprone width (Wfpa)=	46.0	feet
Floodprone depth (Dfpa)=	8.34	feet
Bank-top width (Wtob)=	46.50	feet
Bank-top depth (Dtob)=	7.73	feet

Dfpa = 2 x Dbkf

1538603

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (FRONT)

STREAM NAME: Long Indian Creek		SITE (or ID) #: Site 1
LAT (DD): 34.04994	LONG (DD): -81.22768	
LAT (D,M,S):	LONG (D,M,S):	
INVESTIGATORS: AB & CB	FORM COMPLETED BY: AB	
PROJECT: Long Indian WIP	DATE 3/11/16 TIME 13:51 AM PM	REASON FOR SURVEY:
FIELD SEASON: Winter Wet	COMMENTS:	

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 17	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 16	20 19 18 17 (16)	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 14	20 19 18 17 16	15 (14) 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 16	20 19 18 17 (16)	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

81

1538603 SITE 1

HABITAT ASSESSMENT FIELD DATA SHEET – LOW GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 13	20 19 18 17 16	15 14 (13) 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 (7) 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 6 (LB)	Left Bank 10 9	8 7 (6)	5 4 3	2 1 0
SCORE 7 (RB)	Right Bank 10 9	8 (7) 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 1 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 (1) 0
SCORE 1 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 (1) 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 9 (LB)	Left Bank 10 (9)	8 7 6	5 4 3	2 1 0
SCORE 4 (RB)	Right Bank 10 9	8 7 6	5 (4) 3	2 1 0

Non-Native species Dominate

48

Total Score 122

1538603

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (FRONT)

STREAM NAME: Long Indian Creek	SITE (or ID) #: Site 2
LAT (DD): 34.04496	LONG (DD): -81.23360
LAT (D,M,S):	LONG (D,M,S):
INVESTIGATORS: CB & AB	FORM COMPLETED BY: AB
PROJECT: Long Indian WIP	DATE 3/11/16 TIME 12:59 AM PM — REASON FOR SURVEY: Water Quality
FIELD SEASON: winter wet	COMMENTS:

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 11	20 19 18 17 16	15 14 13 12 (11)	10 9 8 7 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 11	20 19 18 17 16	15 14 13 12 (11)	10 9 8 7 6	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 10	20 19 18 17 16	15 14 13 12 11	(10) 9 8 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 16	20 19 18 17 (16)	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

66

1538603 SITE 2

HABITAT ASSESSMENT FIELD DATA SHEET – LOW GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 13	20 19 18 17 16	15 14 (13) 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 (6)	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 8 (LB)	Left Bank 10 9	(8) 7 6	5 4 3	2 1 0
SCORE 7 (RB)	Right Bank 10 9	8 (7) 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 5 (LB)	Left Bank 10 9	8 7 6	(5) 4 3	2 1 0
SCORE 4 (RB)	Right Bank 10 9	8 7 6	5 (4) 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 1 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 (1) 0
SCORE 1 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 (1) 0

45

Total Score 111

1538603

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (FRONT)

STREAM NAME: Long Indian Creek	**SITE (or ID) #:** Site 3
LAT (DD): 34.03826	**LONG (DD):** -84.23692
LAT (D,M,S):	**LONG (D,M,S):**
INVESTIGATORS: AB + CB	**FORM COMPLETED BY:** AB
PROJECT: Long Indian WIP	**DATE** 3/11/16 **TIME** 14:23 **AM PM** — **REASON FOR SURVEY:** Water Quality
FIELD SEASON: Winter Wet	**COMMENTS:** STREAM REACH IMPOUNDED BY BEAVER DAM

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 1	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 (1) 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 (7) 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 2	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 (2) 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 2	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 (2) 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

30

1538603 SITE 3

HABITAT ASSESSMENT FIELD DATA SHEET – LOW GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 6 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 1 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE 1 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 7 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 1 0
SCORE 10 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 1 0

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Total Score 77

1538603

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (FRONT)

STREAM NAME: Long Indian Creek	SITE (or ID) #: Site 4
LAT (DD): 34.03879	LONG (DD): -84.25873
LAT (D,M,S):	LONG (D,M,S):
INVESTIGATORS: AB + CB	FORM COMPLETED BY: AB
PROJECT: Long Indian WIP	DATE 3/11/16 TIME AM PM
REASON FOR SURVEY: Water Quality	
FIELD SEASON: Winter Wet	COMMENTS:

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 5	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	(5) 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 (6)	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 1	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 (1) 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 1	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 (1) 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 15	20 19 18 17 16	(15) 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

28

1538603 SITE4

HABITAT ASSESSMENT FIELD DATA SHEET – LOW GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 11	20 19 18 17 16	15 14 13 12 (11)	10 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 1	20 19 18 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 (1) 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 1 (LB)	Left Bank 10 9	8 7 6	5 4 3	2 (1) 0
SCORE 2 (RB)	Right Bank 10 9	8 7 6	5 4 3	(2) 1 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 2 (LB)	Left Bank 10 9	8 7 6	5 4 3	(2) 1 0
SCORE 2 (RB)	Right Bank 10 9	8 7 6	5 4 3	(2) 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 9 (LB)	Left Bank 10 (9)	8 7 6	5 4 3	2 1 0
SCORE 2 (RB)	Right Bank 10 9	8 7 6	5 4 3	(2) 1 0

31

Total Score 59

1538603

HABITAT ASSESSMENT FIELD DATA SHEET—LOW GRADIENT STREAMS (FRONT)

STREAM NAME: Long Indian Creek		SITE (or ID) #: Site 5
LAT (DD): 34.03823	LONG (DD): -84.27144	
LAT (D,M,S):	LONG (D,M,S):	
INVESTIGATORS: LB; AB	FORM COMPLETED BY: AB	
PROJECT: Long Indian WIP	DATE 3/11/16 TIME 12:11 AM PM	REASON FOR SURVEY: Water Quality
FIELD SEASON: Winter Wet	COMMENTS: Gabion Baskets at Exposed Pipe crossing; Sewer line Easement; Park on Right Bank	

Parameters to be evaluated in sampling reach

Habitat Parameter	Condition Category			
	Optimal	Suboptimal	Marginal	Poor
1. Epifaunal Substrate/ Available Cover	Greater than 50% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, cobble or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient).	30-50% mix of stable habitat; well-suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of newfall, but not yet prepared for colonization (may rate at high end of scale).	10-30% mix of stable habitat; habitat availability less than desirable; substrate frequently disturbed or removed.	Less than 10% stable habitat; lack of habitat is obvious; substrate unstable or lacking.
SCORE 10	20 19 18 17 16	15 14 13 12 11	(10) 9 8 7 6	5 4 3 2 1 0
2. Pool Substrate Characterization	Mixture of substrate materials, with gravel and firm sand prevalent; root mats and submerged vegetation common.	Mixture of soft sand, mud, or clay; mud may be dominant; some root mats and submerged vegetation present.	All mud or clay or sand bottom; little or no root mat; no submerged vegetation.	Hard-pan clay or bedrock; no root mat or vegetation.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 (8) 7 6	5 4 3 2 1 0
3. Pool Variability	Even mix of large-shallow, large-deep, small-shallow, small-deep pools present.	Majority of pools large-deep; very few shallow.	Shallow pools much more prevalent than deep pools.	Majority of pools small-shallow or pools absent.
SCORE 6	20 19 18 17 16	15 14 13 12 11	10 9 8 7 (6)	5 4 3 2 1 0
4. Sediment Deposition	Little or no enlargement of islands or point bars and less than <20% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from gravel, sand or fine sediment; 20-50% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, sand or fine sediment on old and new bars; 50-80% of the bottom affected; sediment deposits at obstructions, constrictions, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 80% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 8	20 19 18 17 16	15 14 13 12 11	10 9 (8) 7 6	5 4 3 2 1 0
5. Channel Flow Status	Water reaches base of both lower banks, and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel, and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 10	20 19 18 17 16	15 14 13 12 11	(10) 9 8 7 6	5 4 3 2 1 0

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1538603 SITE 5

HABITAT ASSESSMENT FIELD DATA SHEET – LOW GRADIENT STREAMS (BACK)

Parameters to be evaluated broader than sampling reach

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Habitat Parameter	Condition Category: Optimal	Suboptimal	Marginal	Poor
6. Channel Alteration	Channelization or dredging absent or minimal; stream with normal pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	Channelization may be extensive; embankments or shoring structures present on both banks; and 40 to 80% of stream reach channelized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted. Instream habitat greatly altered or removed entirely.
SCORE 10	20 19 18 17 16	15 14 13 12 11	(10) 9 8 7 6	5 4 3 2 1 0
7. Channel Sinuosity	The bends in the stream increase the stream length 3 to 4 times longer than if it was in a straight line. (Note - channel braiding is considered normal in coastal plains and other low-lying areas. This parameter is not easily rated in these areas.)	The bends in the stream increase the stream length 2 to 3 times longer than if it was in a straight line.	The bends in the stream increase the stream length 1 to 2 times longer than if it was in a straight line.	Channel straight; waterway has been channelized for a long distance.
SCORE 7	20 19 18 17 16	15 14 13 12 11	10 9 8 (7) 6	5 4 3 2 1 0
8. Bank Stability (score each bank)	Banks stable; evidence of erosion or bank failure absent or minimal; little potential for future problems. <5% of bank affected.	Moderately stable; infrequent, small areas of erosion mostly healed over. 5-30% of bank in reach has areas of erosion.	Moderately unstable; 30-60% of bank in reach has areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 3 (LB)	Left Bank 10 9	8 7 6	5 4 (3)	2 1 0
SCORE 1 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 (1) 0
9. Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces and immediate riparian zone covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption through grazing or mowing minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 5 centimeters or less in average stubble height.
SCORE 2 (LB)	Left Bank 10 9	8 7 6	5 4 3	(2) 1 0
SCORE 1 (RB)	Right Bank 10 9	8 7 6	5 4 3	2 (1) 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 5 (LB)	Left Bank 10 9	8 7 6	(5) 4 3	2 1 0
SCORE 3 (RB)	Right Bank 10 9	8 7 6	5 4 (3)	2 1 0

Total Score 74

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	**Points:** ~~1296 - 1299~~ - 51	**Team:** CB - GAI
Stream: LONG INDIAN CREEK	**Photos:** 1296 - 1299	**Date:** 3/7/16
Reach: LOWER REACH AT BIG CREEK	**Length:** 500	**Investigators:** CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

PERENNIAL STREAM AT CONFLUENCE OF BIG CREEK. STREAM BED AGGRADING. SEVERE LEFT BANK EROSION. FLOODPLAIN DOMINATED BY INVASIVE SPECIES Ligustrum sinense.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 25	Golf	Undeveloped 75	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting ✓	Agriculture	Other ✓

Comment: RESIDENTIAL DEVELOPMENTS UPSTREAM

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

STREAM BANK EROSION, LANDSCAPING IN RES. DEVELOPMENTS AND ROAD CROSSINGS.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

STREAM BANK PROTECTION AND STABILIZATION. REMOVAL OF INVASIVE SPECIES.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

WALKING TRAIL ALONG RIGHT BANK OF BIG CREEK.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: 52	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1300 - 1303	Date: 3/7/16
Reach: DOWNSTREAM	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

PERENNIAL STREAM AT PERPENDICULAR SEWER CROSSING. EXPOSED 24" CONCRETE PIPE. REDUCED RIGHT BUFFER, LAWN. SEVERE EROSION ON LEFT STREAM BANK. EVIDENCE OF HUMAN AND DEER ACCESSING STREAM.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 34	Golf	Undeveloped 66	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area
Culvert/Bridge Crossing	Instream structures	Natural Setting ✓	Agriculture
			Other RES. DEV.

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

STREAM BANK EROSION. REDUCED RIGHT BANK BUFFER.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

RE-ESTABLISH RIPARIAN BUFFER ON RIGHT BANK; MAINTENANCE SEWER CROSSING; STREAM BANK PROTECTION AND STABILIZATION.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

VACANT LAND IN LEFT FLOODPLAIN.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form 1538603

Sub-watershed: LONG INDIAN CREEK	Points: S3	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1304 - 1308	Date: 3/7/2016
Reach: DOWNSTREAM - WATERS DR	Length: 500	Investigators: CB -

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

PERENNIAL STREAM WITH SAND, SILT & GRAVEL SUBSTRATE. DOG WASTE IN PLASTIC BAG OBSERVED IN STREAM. SEVERE LEFT BANK EROSION. SEVERE TO MODERATE RIGHT BANK EROSION. REDUCES RIGHT BANK RIPARIAN BUFFER. HUMANS, DEER & DOGS ACCESSING STREAM.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting ✓	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

STREAM BANK EROSION, REDUCED RIP. BUFFER.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

STREAM BANK STABILIZATION AND PROTECTION.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

ACCESS ALONG BOTH RIGHT & LEFT BANKS.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: 54	Team: GOLDEN
Stream: LONG INDIAN CREEK	Photos: 1309 - 1312	Date: 3/7/2016
Reach: DOWNSTREAM - WATERS RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

PERENNIAL STREAM WITH SAND, SILT & GRAVEL SUBSTRATE. EXPOSED PIPE. PERPENDICULAR CROSSING, 24" CAST IRON SEWER LINE. GABION BASKETS ALONG LEFT BANK. SEVERE TO MODERATE EROSION ALONG LB & RB. RIPARIAN BUFFERS INTACT. SOCCER FIELD ON RB. EVIDENCE OF HUMANS, DOGS & DEER ACCESSING STREAM.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting ✓	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

STREAM BANK EROSION. SOCCER FIELD ON RIGHT BANK - LAWN.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

RE MAINTENANCE SEWER LINE, STREAM BANK RESTORATION; RE-ESTABLISH RIGHT RIPARIAN BUFFER.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

PARK ON RIGHT BANK

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

153860 3

Sub-watershed LONG INDIAN CREEK Points: 55 Team: GOLDER
Stream: LONG INDIAN CREEK Photos: 1313 - 1316 Date: 3/7/2016
Reach: DOWN STREAM WATERS RD. Length: 500 Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

PERENNIAL STREAM WITH DEBRIS DAM. SEVERE EROSION ALONG LEFT BANK.
HUMANS, DOGS & DEER ACCESSING STREAM.
REDUCED RIPARIAN BUFFER ON LEFT BANK.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial | Apartment | Med-Den Res | Agriculture | Park | Barren
Commercial | High-Den Res | Low-Den Res ✓100 | Golf | Undeveloped | OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs | Land-clearing activity | Reduced riparian buffer ✓ | Impervious Area
Culvert/Bridge Crossing | Instream structures | Natural Setting ✓ | Agriculture | Other

Comment: LEFT BANK RIPARIAN

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

STREAM BANK EROSION, LAWNS ON LEFT BANK.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

STREAM BANK PROTECTION AND STABILIZATION.
RE-ESTABLISH LEFT RIPARIAN BUFFER. REMOVE DEBRIS.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

RIGHT BANK ACCESSIBLE.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: S6	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1317-1320	Date: 3/7/2016
Reach: DOWNSTREAM-WATERS RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

PERENNIAL STREAM AT DEBRIS DAM. MODERATE STREAM BANK EROSION. PARALLEL SEWER LINE ALONG RB. RIPARIAN BUFFERS INTACT. EVIDENCE OF HUMANS, DOGS AND DEER ACCESSING STREAM.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area
Culvert/Bridge Crossing	Instream structures	Natural Setting ✓	Agriculture
Other ✓			

Comment: SEWER LINE

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

STREAM BANK EROSION.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

REMOVE DEBRIS DAM.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

ACCESS AVAILABLE ON RIGHT BANK.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: 57	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1321-1324	Date: 3/7/2016
Reach: DOWNSTREAM - WATERS RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand and gravel substrate. EVIDENCE OF HUMANS AND DOG ACCESSING STREAM. DOG RUN ALONG TOP OF LEFT BANK.

SEVERE BANK EROSION ON RIGHT BANK.

RIPARIAN BUFFERS INTACT.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area
Culvert/Bridge Crossing	Instream structures	Natural Setting ✓	Agriculture
Other ✓ SEWER			

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

STREAM BANK EROSION, SEWER MAINTENANCE & CONSTRUCTION UP STREAM.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

STREAM BANK PROTECTION AND STABILIZATION.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

RIGHT BANK ACCESSIBLE.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: S8	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1325-1328	Date: 3/7/2016
Reach: DOWNSTREAM WATERS RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at perpendicular sewer crossing (aerial). 12" CAST IRON. Recently maintenanced. Gabion baskets on right bank.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting ✓	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion; erosion from sewer line maintenance.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Stream bank stabilization and protection.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Access along right bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK **Points:** 59 **Team:** GOLDER

Stream: LONG INDIAN CREEK **Photos:** 1329 - 1332 **Date:** 3/7/2016

Reach: DOWNSTREAM WATERS RD. **Length:** 500 **Investigators:** CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with major debris jam upstream. Reduced riparian buffer on right bank. Evidence of humans, dogs and deer accessing stream. Moderate stream bank erosion.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial | Apartment | Med-Den Res | Agriculture | Park | Barren

Commercial | High-Den Res | Low-Den Res 100 | Golf | Undeveloped | Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs | Land-clearing activity | Reduced riparian buffer ✓ | Impervious Area

Culvert/Bridge Crossing | Instream structures | Natural Setting ✓ | Agriculture | Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion and reduced riparian buffer.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Stream bank stabilization and protection; re-establish right riparian buffer.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Access along left stream bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

None.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: S10	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1333 - 1336	Date: 3/7/2016
Reach: DOWNSTREAM OF WATERS RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial Stream - MINOR Stream bank erosion.
Intact riparian buffers.
Invasive species: Eleagnus.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial		Apartment		Med-Den Res		Agriculture		Park		Barren	
Commercial		High-Den Res		Low-Den Res	100	Golf		Undeveloped		Ongoing Construction	

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting ✓	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Removal of Eleagnus.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Access Along rb.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	**Points:** ~~S12~~ S11	**Team:** GOLDER
Stream: LONG INDIAN CREEK	**Photos:** 1337-1340	**Date:** 3/7/2016
Reach: DOWNSTREAM WATERS RD.	**Length:** 500	**Investigators:** CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with gravel and sand substrate. Reduced right riparian buffer. BMP on left bank. Moderate stream bank erosion. Humans, dogs and deer accessing stream. Invasive Species: bamboo, Eleagnus.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting ✓	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion; reduced riparian buffer.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Remove invasive Species. Re-establish riparian buffer.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

—

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

BMP ON LB

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: ~~S13~~ S12	Team: GOLDEN
Stream: LONG INDIAN CREEK	Photos: 1341-1344	Date: 3/7/2016
Reach: DOWNSTREAM - WATERS RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with perpendicular sewer line crossing (exposed). 12" CAST IRON. Also, irrigation pvc pipe to Lawn on LB.
MODERATE STREAM BANK EROSION.
INVASIVE SPECIES - bamboo.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture / Other ✓

Comment: irrigation pipe

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion; reduced riparian buffers.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Sewer line maintenance. Remove irrigation pvc pipe; remove invasive species.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: ~~514~~ 513	Team: GOLDER
Stream: LONG INDIAN	Photos: 1345 - 1348	Date: 3/7/2016
Reach: DOWN STREAM - WATERS RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand and gravel. Exposed bedrock in channel. Severe erosion on right bank. Reduced riparian buffer. Common space on right bank. Evidence of human, dog and deer accessing stream.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other RES. DEV.

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion, upstream construction site.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Stream bank stabilization and protection. Re-establish riparian buffer.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Park on right bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: 514	Team: GOLDEN
Stream: LONG INDIAN CREEK	Photos: 1349-1352	Date: 3/7/2016
Reach: DOWN STREAM - WATERS RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at exposed sewer line crossing. Minor stream bank erosion. Intact riparian buffers.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water Inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other RES. DEV.

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion and upstream construction activity.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Maintenance sewer line.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Along right bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

None.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: 515	Team:_ GOLDER
Stream: LONG INDIAN CREEK	Photos: 1353-1356	Date: 3/7/2016
Reach: DOWNSTREAM - WATERS RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

PERENNIAL STREAM. CONSTRUCTION SITE ON RIGHT BANK.

MINOR STREAM BANK EROSION.

NO EVIDENCE OF HUMANS, DOGS OR DEER IN STREAM.

RIFFLE-POOL COMPLEX. MODERATE MACRO-INVERT & FISH HABITAT.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 50	Golf	Undeveloped	Ongoing Construction 50

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other ✓ CONSTRUCTION SITE

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

STREAM BANK EROSION, REDUCED BUFFER, CONSTRUCTION SITE, ROAD CROSSING UPSTREAM.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

EROSION CONTROL, Re-establish riparian buffer on right bank.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: S16	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1357-1362	Date: 3/7/2016
Reach: DOWN STREAM WATERS RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at Bridge crossing of WATERS ROAD.

EXPOSED/ABANDONED CMP LODGED INTO SEDIMENT UNDER BRIDGE.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 50	Golf	Undeveloped 25	OngoingConstruction 25

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing ✓	Instream structures	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

ROAD CROSSING, STREAM BANK EROSION.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

REMOVE ABANDONED CMP.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK
Points: S1
Team: GOLDER
Stream: LONGINDIAN CREEK
Photos: 1361 - 1364
Date: 3/8/2016
Reach: DOWNSTREAM BUICE RD.
Length: 500
Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, silt and gravel substrate. Perpendicular sewer line crossing, exposed. 12" CAST IRON pipe, in need of maintenance. Debris jam at pipe and immediately downstream, creating severe bank erosion.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area
Culvert/Bridge Crossing	Instream structures ✓	Natural Setting ✓	Agriculture	Other

Comment: SEWER LINE CROSSING

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Debris dam causing stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Maintenance sewer line crossing. Remove debris dams. Stream bank stabilization & protection.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Sewer line easement along right bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: 82	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1365-1368	Date: 3/8/2016
Reach: DOWNSTREAM BUICE RD	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream. Sand, silt & gravel substrate. Moderate stream bank erosion. Very channelized. EVIDENCE OF HUMANS, DOGS & DEER ACCESSING Stream. Riparian buffer intact.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting ✓	Agriculture	Other

Comment: SEWER LINE

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Stream restoration - create riffle/pool complex and sinuosity of pattern/profile.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Sewer line easement parallel to right bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form 1538603

Sub-watershed LONG INDIAN CREEK	**Points:** 53	**Team:**_ GOLDER
Stream: LONG INDIAN CREEK	**Photos:** 1369-1372	**Date:** 3/8/16
Reach: DOWN STREAM BRICE RD.	**Length:** 500	**Investigators:** CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

PERENNIAL STREAM AT WOODEN FOOT BRIDGE SPANNING STREAM. Reduced riparian buffers. Sewer line crossing perpendicular to stream. Exposed pipe, 12" cast iron. Minor to moderate stream bank erosion.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Sewer line crossing, stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Sewer line maintenance. Bridge inspection, stream bank protection.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Sewerline along right bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form 1538603

Sub-watershed LONG INDIAN CREEK	Points: S4	Team: GOLDEN
Stream: LONG INDIAN CREEK	Photos: ~~1363 - 1366~~ 1373 - 1376	Date: 3/8/2011
Reach: DOWN STREAM BUICE RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, silt and gravel substrate, some exposed bedrock. Sewer line crossing perpendicular to stream, exposed 12" cast iron pipe. Debris dam above and below pipe crossing. Moderate stream bank erosion.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res ✓ 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing	Instream structures ✓	Natural Setting	Agriculture	Other

Comment: SEWER LINE

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Sewer line crossing. Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Maintenance sewer pipe. Remove debris dams. Stabilize banks.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Sewer line easement parallel to right bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK
Points: 55
Team: GOLDER
Stream: LONG INDIAN CREEK
Photos: 1377-1380
Date: 3/8/2011
Reach: DOWNSTREAM BRICE RD.
Length: 500
Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sinuosity and riffle/pool complex. No riparian buffer on right bank, lawns. Rip rap along right bank. Storm water pipe discharges from right bank. Moderate to severe stream bank erosion. Evidence of Humans and dogs accessing stream

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial
Apartment
Med-Den Res
Agriculture
Park
Barren
Commercial
High-Den Res
Low-Den Res 100
Golf
Undeveloped
OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs
Land-clearing activity
Reduced riparian buffer ✓
Impervious Area
Culvert/Bridge Crossing
Instream structures ✓
Natural Setting
Agriculture
Other

Comment: Storm water pipe.

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Reduced riparian buffer. on right bank. Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Re- establish riparian buffer. Stream bank stabilization and protection.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: 56	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1381- 1384	Date: 3/8/2016
Reach: DOWNSTREAM BUICE RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, gravel and cobble substrate. Stream channel confluence on left bank from pond.
Moderate stream bank erosion. Reduced riparian buffer along right bank.
Evidence of humans and dogs accessing stream.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100.	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs ✓	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Reduced riparian buffer. Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

~~Along toe of dam at left bank.~~
Stream bank protection. Re-establish riparian buffer.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Along left bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form 1538603

Sub-watershed: LONG INDIAN CREEK	Points: S7	Team: GOLDEN
Stream: LONG INDIAN CREEK	Photos: 1585-1588	Date: 3/8/2016
Reach: DOWNSTREAM BUICE RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with gravel, cobble and bedrock Substrate. Stormwater outlet structure along left bank. Moderate stream bank erosion Intact buffers.

Evidence of Humans, dogs and deer accessing stream.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water Inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area
Culvert/Bridge Crossing	Instream structures ✓	Natural Setting ✓	Agriculture	Other

Comment: Stormwater

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Storm water outlet. Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Stream bank protection.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: 58	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1389-1392	Date: 3/8/16
Reach: DOWN STREAM BUICE RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand silt, gravel and some exposed bedrock. Rip rap along right bank. Storm water outlet along right bank. Sewer line parallel to left bank. Moderate stream bank erosion. Reduced right riparian buffer. Evidence of humans, dogs and deer accessing stream.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res LDR	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing	Instream structures ✓	Natural Setting	Agriculture	Other

Comment: Storm water

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Storm water outlet. Stream bank erosion. Reduced riparian buffer. Nearby impervious surfaces.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Re-establish right riparian buffer.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: 59	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1393-1396	Date: 3/8/2016
Reach: DOWNSTREAM BUICE RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at perpendicular sewer line crossing, exposed 12" cast iron pipe. Stormwater outlet along right bank. Sewer line parallel along right bank. Homeowner has pump along right stream bank.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓		Impervious Area
Culvert/Bridge Crossing	Instream structures ✓	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Reduced buffers. Stormwater outlet. Sewer line crossing. Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Sewer line maintenance. Re-establish riparian buffers.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: S10	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1397-1400	Date: 3/8/2016
Reach: DOWNSTREAM BUICE RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at exposed 12" cast iron pipe.

Evidence of Humans, dogs and dee accessing stream.

Minor to Moderate stream bank erosion.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing	Instream structures ✓	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Reduced buffers, Sewer crossing, stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Maintenance Sewer pipe.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: S11 NO PHOTOS	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: ~~[illegible]~~	Date: 3/8/2016
Reach: DOWNSTREAM BUICE RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, silt and gravel substrate. Localized areas along right bank with erosion and rip rap. Moderate stream bank erosion on both banks. Reduced riparian buffers. Evidence of humans, dogs and deer in stream.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓		Impervious Area
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Reduced riparian buffers

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Reestablish stream buffers. Stream bank protection.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK **Points:** S12 **Team:** GOLDER
Stream: LONG INDIAN CREEK **Photos:** ~~1405-1408~~ 1401-1404 **Date:** 3/8/2016
Reach: DOWNSTREAM BUICE RD. **Length:** 500 **Investigators:** CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, silt and gravel substrate, some exposed bedrock. Exposed sewer pipe, 12" clay, parallel along right bank. Moderate to severe stream bank erosion. Invasive species Ligustrum sinense on both riparian buffers. Evidence of human, dogs and deer accessing stream.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial | Apartment | Med-Den Res | Agriculture | Park 50 | Barren
Commercial | High-Den Res | Low-Den Res 50 | Golf | Undeveloped | OngoingConstruction

Comment: Park along right bank.

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs | Land-clearing activity | Reduced riparian buffer ✓ | Impervious Area
Culvert/Bridge Crossing | Instream structures | Natural Setting | Agriculture | Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Exposed sewer line.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Maintenance sewer line. Remove invasive speies. Stream bank restoration.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Park along right bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK
Points: 513
Team: GOLDER

Stream: LONG INDIAN CREEK
Photos: ~~1409-1412~~ 1405-1408
Date: 3/8/2016

Reach: DOWNSTREAM BULCE RD.
Length: 500
Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at Park along right bank. Moderate to severe stream bank erosion. Invasive species Ligustrum sinense. Humans, dogs and deer accessing stream.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park 50	Barren
Commercial	High-Den Res	Low-Den Res 50	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Reduced riparian buffers.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

STREAM BANK RESTORATION/STABILIZATION. REMOVE INVASIVE SPECIES.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

PARK ALONG RIGHT BANK.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: S14	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: ~~1413-1416~~ 1409-1412	Date: 3/8/2016
Reach: DOWN STREAM BUICE RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, silt & gravel substrate. Debris dam in channel. Evidence of beavers, humans, dogs and deer in stream. Moderately eroding stream banks. Reduced riparian buffers.

Invasive species: Ligustrum sinense and Lonicerica japonica.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park 50	Barren
Commercial	High-Den Res	Low-Den Res 50	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓		Impervious Area ✓
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other ✓ debris dam

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Debris dam in channel. Nearby impervious surfaces. Reduced riparian buffers.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Debris dam removal. Remove invasive species. Stream bank restoration/stabilization.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Park along right bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: S15	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: ~~1417-1422~~ 1413-1416	Date: 3/8/2016
Reach: DOWN STREAM BULCE RD	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at concrete box culvert with 4 boxes. BEAVER dam at upstream side of culvert. Moderate stream bank erosion. Reduced buffers. Evidence of humans, beavers, logs and deer in stream. Invasive species Ligustrum and Lonicera.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park 50	Barren
Commercial	High-Den Res	Low-Den Res 50	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area ✓	
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other ✓ BEAVER DAM.

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

BEAVER Dam, Road crossing/impervious surFaces. Reduced riparian buffers. Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Debris removal. Re-establish riparian buffers. Remove invasive species.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Park along right bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: 516	Team: GOLDEN
Stream: LONG INDIAN CREEK	Photos: ~~1423-1426~~ 1417-1420	Date: 3/8/2016
Reach: DOWNSTREAM BUICE RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with moderate to severely eroded stream banks. Reduced riparian buffer along left bank. Evidence of humans, dogs and deer. Chicken coop along left bank. Invasive species Ligustrum and Lonicera.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓		Impervious Area
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Reduced riparian buffer along right bank.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Re-establish riparian buffer. Stream bank stabilization and protection. Remove invasive species.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

ALONG RIGHT BANK.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form 1538603

Sub-watershed LONG INDIAN CREEK **Points:** S17 **Team:** GOLDER
Stream: LONG INDIAN CREEK **Photos:** ~~1427-1430~~ 1421-1424 **Date:** 3/8/2016
Reach: DOWNSTREAM BUICE RD. **Length:** 500 **Investigators:** CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at perpendicular sewer line crossing, exposed 12" cast iron. Moderate stream bank erosion. Evidence of deer, humans and dogs.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial / Apartment / Med-Den Res / Agriculture / Park / Barren
Commercial / High-Den Res / Low-Den Res 100 / Golf / Undeveloped / Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs / Land-clearing activity / Reduced riparian buffer / Impervious Area
Culvert/Bridge Crossing / Instream structures ✓ / Natural Setting ✓ / Agriculture / Other

Comment: SEWER

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

SEWER LINE CROSSING. Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

MAINTENANCE SEWER LINE. STREAM BANK STABILIZATION AND PROTECTION.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Along RIGHT Bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: 518	Team: GOLDEN
Stream: LONG INDIAN CREEK	Photos: ~~1431-1434~~ 1425-1428	Date: 3/8/2016
Reach: DOWNSTREAM BUICE ROAD	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

PERENNIAL STREAM with sand, silt and gravel substrate. Riffle/pool complex. Moderate stream bank erosion. Moderate habitat diversity. Reduced buffer along right bank. Evidence of humans, dogs and deer accessing stream. Invasive species Ligustrum and Lonicera.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Reduced riparian buffer. Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Remove invasive species. Re-establish riparian buffer. Stabilize stream banks

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Along left bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: 51	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1429-1432	Date: 3/9/2016
Reach: DOWNSTREAM BUICE RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, silt and gravel substrate. Reduced riparian buffers. Park along left bank. Moderately eroding stream banks. Localized areas of severe bank erosion and rip rap protection along banks. Evidence of humans and dogs accessing stream. Invasive Species: Ligustrum Sinense.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park 50	Barren
Commercial	High-Den Res	Low-Den Res 50	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area ✓	
Culvert/Bridge Crossing	Instream structures ✓	Natural Setting	Agriculture	Other

Comment: Parking lots, stream crossings

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Road crossing at Buice Road, Impervious surfaces. Reduced riparian buffers.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Re-establish riparian buffers. Remove invasive species. Stream bank protection.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Park along left bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

None.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: S2	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1433-1436	Date: 3/9/2016
Reach: DOWNSTREAM BUICE RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at Buice Road. Concrete box culvert. Exposed 12" cast iron sewer line, perpendicular with debris dam. Evidence of humans and dogs accessing stream. Reduced riparian buffers.
Moderate stream bank erosion.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park 50	Barren
Commercial	High-Den Res	Low-Den Res 50	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area ✓	
Culvert/Bridge Crossing	Instream structures ✓	Natural Setting	Agriculture	Other

Comment: Road, sewer line, culvert

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Impervious surfaces, stream bank erosion. Sewer line. Reduced buffers.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

RE-Establish riparian buffers. Maintenance Sewer line. Remove debris dams.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Park along left bank.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

None.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK	Points: 53	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1437-1440	Date: 3/9/2016
Reach: DOWN STREAM STATE BR.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, gravel and some exposed bedrock. Wooden footbridge spanning stream. Moderate to severely eroding stream banks. Reduced buffers. Evidence of Humans and dogs accessing stream.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures ✓	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Channel incising, stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Bridge inspection. Re-establish riparian buffers.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

None.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK
Points: 54
Team: GOLDER
Stream: LONG INDIAN CREEK
Photos: 1441-1446
Date: 3/9/2016
Reach: DOWNSTREAM STATE BRIDGE
Length: 500
Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at road crossing. 2 RCPs and weir structure BMP. BMP damaged. Severely eroding stream banks. Trash in stream. Invasive species: Ligustrum and Lonicera.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area ✓
Culvert/Bridge Crossing	Instream structures ✓	Natural Setting	Agriculture
			Other

Comment: Road crossing

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Maintenance BMP and culvert system. Stabilize and protect stream banks. Remove trash.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE

Stream Reach Observations Summary Form 1538603

Sub-watershed LONG INDIAN CREEK	Points: 55	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1447-1450	Date: 3/9/2016
Reach: DOWNSTREAM OF STATE BR.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with gravel, sand and silt substrate. Moderate to severely eroded stream banks. Reduced riparian buffer along left bank. Invasive species: Ligustrum and Lonicera. Evidence of humans and dogs accessing stream.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Re-establish riparian buffer. Stream bank stabilization and protection.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

None.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

None.

Stream Reach Observations Summary Form 153860 3

Sub-watershed LONG INDIAN CREEK	Points: 56	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1451 - 1454	Date: 3/8/2016
Reach: DOWN STREAM STATE BR.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with some exposed bedrock. Channel incising. Sinuosity with riffle/pool complex. Moderate habitat diversity. Moderate stream bank erosion. Evidence of Humans, dog and deer accessing stream. Riparian buffers in tact.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area
Culvert/Bridge Crossing	Instream structures	Natural Setting ✓	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Stream bank stabilization and protection.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

Vacant land along RIGHT BANK SEWER LINE.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK **Points:** S7 **Team:** GOLDER

Stream: LONG INDIAN CREEK **Photos:** 1455-1460 **Date:** 3/9/2016

Reach: DOWNSTREAM STATE BRIDE **Length:** 500 **Investigators:** CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at 4" corregated plastic drain pipe discharging clear liquid in stream from left bank. Water flowing from pipe at time of assessment. It appears pipe may be connected to inundated wetland along top of left bank.

34.04886 / 84.22871

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other ✓

Comment: discharge from pipe.

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Investigate source of discharge.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK
Points: 58
Team: GOLDER
Stream: LONG INDIAN CREEK
Photos: 1461 - 1464
Date: 3/9/2016
Reach: DOWNSTREAM STATE BRIDGE
Length: 500
Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, silt and gravel substrate. Filametous algae on substrate. Moderate stream bank erosion. Trash in stream. Evidence of Humans and dogs in stream. Invasive species: Ligustrum and Lonicera.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial 25	High-Den Res	Low-Den Res 75	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing ✓	Instream structures	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Stream bank stabilization and protection. Removal of invasive species.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

None.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK
Points: S1
Team: GOLDER
Stream: LONG INDIAN CREEK
Photos: 1465-1468
Date: 3/10/2016
Reach: UPSTREAM STATE BRIDGE
Length: 500
Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, silt & Gravel substrate. Double box culvert at State Bridge Road. Debris and trash blocking inlet. Rip rap along some of the stream banks, Moderate stream bank erosion. Invasive Species: Ligustrum sinense and Lonicera japonica.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment 50	Med-Den Res 50	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs ✓	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing ✓	Instream structures	Natural Setting	Agriculture	Other

Comment: Impervious surfaces

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Runoff from impervious surfaces nearby. Reduced riparian buffers. Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Remove debris & trash from inlet. Stream bank stabilization and protection.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

None

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

BMP downstream on left bank.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: 52	Team: GOLDER
Stream: LONG INDIAN CREEK	Photos: 1469 - 1472	Date: 3/10/2016
Reach: UPSTREAM STATE BRIDGE	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at exposed 12" PVC pipe perpendicular to channel. Trash in stream. No riparian buffer on right bank. Moderate stream bank erosion. Invasive species. Channel incised.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment 50	Med-Den Res 50	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing ✓	Instream structures ✓	Natural Setting	Agriculture	Other

Comment: EXPOSED PIPE

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion. Reduced right riparian buffer.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Pipe maintenance. Stream bank stabilization and protection.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

None

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

None

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: S3	Team:_ GOLDER
Stream: LONG INDIAN CREEK	Photos: 1473 - 1476	Date: 3/10/2016
Reach: UPSTREAM STATE BRIDGE	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, silt and gravel. Confluence of perennial stream. BMP upstream at Apartment complex. Moderate stream bank erosion. Invasive species: Ligustrum and Lonicera.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment 50	Med-Den Res 50	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Stream bank stabilization and protection.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

None

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

BMP. Wet pond AT Apartment complex.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: 54	Team:_ GOLDER
Stream: UNNAMED TRIBUTARY	Photos: 1477-1480	Date: 3/10/2016
Reach: DOWNSTREAM WATERS RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Unnamed perennial stream with sand, silt and cobble substrate. Reduced riparian buffers. Evidence of humans accessing stream. Minor stream bank erosion. Invasive Species: Ligustrum and English ivy.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Reduced buffers.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Buffer establishment.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

BMP - WET POND UPSTREAM.

Stream Reach Observations Summary Form 1538603

Sub-watershed LONG INDIAN CREEK	**Points:** 55	**Team:**_ GOLDEN
Stream: UNNAMED TRIBUTARY	**Photos:** 1481 - 1484	**Date:** 3/10/2016
Reach: DOWN STREAM WATERS RD.	**Length:** 500	**Investigators:** CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at head cut (2 ft.). Rip rap along right bank. Reduced buffers. Evidence of humans accessing stream. Concrete in channel.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures ✓	Natural Setting	Agriculture	Other

Comment: Co

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Concrete in channel creating head cut.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Remove concrete. Re-establish riparian buffers.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

BMP ALONG BOTH RIGHT & LEFT BANKS.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN **Points:** 56 **Team:** GOLDEN
Stream: UNNAMED TRIBUTARY **Photos:** 1485-1488 **Date:** 3/10/2016
Reach: DOWNSTREAM WATERS RD. **Length:** 500 **Investigators:** CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at confluence. Exposed 12" cast iron sewer line perpendicular to stream. Moderate stream bank erosion. Some areas of severe erosion. Reduced riparian buffers. Evidence of humans and dogs accessing stream.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing	Instream structures ✓	Natural Setting	Agriculture	Other

Comment: Sewer line

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Maintenance exposed pipe. Re-establish buffers.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

None.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

None.

Stream Reach Observations Summary Form 1538603

Sub-watershed LONG INDIAN CREEK	Points: S7	Team:_ GOLDER
Stream: UNNAMED TRIBUTARY	Photos: 1489 - 1492	Date: 3/10/2016
Reach: DOWNSTREAM WATERS RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, gravel, cobble and bedrock. Filamentous algae on substrate. Minor erosion along stream banks. Riparian buffers intact.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	OngoingConstruction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water Inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting ✓	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

NONE.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

NONE.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: S8	Team: GOLDEN
Stream: UNNAMED TRIBUTARY	Photos: 1493-1496	Date: 3/10/2016
Reach: DOWN STREAM WATERS ROAD	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, silt, gravel and cobble substrate. Some exposed bedrock. Abandoned culvert system along left bank. Severe stream bank erosion along left bank. Confluence of intermittent stream on left bank.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing ✓	Instream structures	Natural Setting ✓	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Rosgen level 1 stream restoration.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

Culvert system on intermittent stream on left bank.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK
Stream: UNNAMED TRIBUTARY
Reach: DOWNSTREAM WATERS RD.

Points: 59
Photos: 1497-1500
Length: 510

Team: GOLDER.
Date: 3/10/2016
Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with exposed 12" cast iron sewer pipe, perpendicular crossing. Moderate to severe stream bank erosion. Evidence of humans, dogs and deer accessing stream.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water Inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing	Instream structures ✓	Natural Setting	Agriculture	Other

Comment: SEWER LINE

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Sewer line maintenance. Stream restoration.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

None.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

None.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: 510	Team: GOLDER
Stream: UNNAMED TRIBUTARY	Photos: 1501-1504	Date: 3/11/2016
Reach: DOWN STREAM WATERS RD.	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, silt and gravel substrate. Severe stream bank erosion. Invasive species: Lonicera, Ligustrum, Eleagnus and Oregon grape. Evidence of humans, deer and dog accessing streams. Near confluence of Long Indian Creek.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting ✓	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Stream bank restoration. Removal of invasive species.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

None

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

~~[illegible]~~ BMP - Wet Pond on left bank.

Stream Reach Observations Summary Form 1538603

Sub-watershed LONG INDIAN CREEK | Points: 51 | Team: GOLDER
Stream: UNNAMED TRIBUTARY | Photos: 1515-1518 | Date: 3/11/2016
Reach: DOWNSTREAM PINE CLUB | Length: 500 | Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at downstream side of BMP structure. Headwall outlet damaged. Minor stream bank erosion. Intact riparian buffers. Evidence of humans accessing stream. Invasive species: Eleagnus and Oregon Grape. Headwall needs repair.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing ✓	Instream structures ✓	Natural Setting	Agriculture	Other

Comment: BMP

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Erosion around headwall of BMP.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

BMP Maintenance. Removal of invasive species.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

None

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

Immediate up Gradient and online.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	Points: S2	Team: GOLDER
Stream: UNNAMED TRIBUTARY	Photos: 1519-1522	Date: 8/11/2016
Reach: Downstream Pine Club	Length: 500	Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream immediately down stream of online BMP structure, concrete culvert and headwall.
Moderate stream bank erosion. Channelized and incising. Invasive species: Eleagnus. Evidence of humans accessing stream. Intact riparian buffers.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing ✓	Instream structures ✓	Natural Setting	Agriculture	Other

Comment: BMP

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

BMP maintenance.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

NONE

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

Immediately upstream, on line.

Stream Reach Observations Summary Form

1538603

Sub-watershed: LONG INDIAN CREEK
Stream: UNNAMED TRIBUTARY
Reach: DOWNSTREAM OF CULVERT

Points: 83
Photos: 1523-1526
Length: 500

Team: GOLDER
Date: 3/11/2016
Investigators: CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream at culvert & headwell outlet. Rip rap lined channel. Moderate to severely eroding stream banks. Debris and trash in channel. Reduced riparian buffers. Invasive species Ligustrum and English Ivy. Evidence of humans and dogs accessing stream

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer ✓	Impervious Area	
Culvert/Bridge Crossing ✓	Instream structures ✓	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Reduced buffers. Stream bank erosion. Runoff from near by impervious surfaces.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Remove debris and trash from channel. Culvert maintenance.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

None

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

None.

Stream Reach Observations Summary Form

1538603

Sub-watershed LONG INDIAN CREEK	**Points:** 54	**Team:** GOLDER
Stream: UNNAMED TRIBUTARY	**Photos:** 1527-1530	**Date:** 3/11/2016
Reach: DOWNSTREAM ALVIN RD.	**Length:** 500	**Investigators:** CB

REACH OBSERVATIONS

Summarize reach observations in the following catagories: Channel morphology, Bank stability, Sediment deposition, Riparian zone and Habitat diversity. Also, list any county maintenance issues observed.

Perennial stream with sand, silt, gravel and some exposed bedrock. Knickpoint.
Invasive species: Multiflora rose, Privet, English Ivy, and Eleagnus.
Intact buffers.

CAUSES

List types of land-use categories adjacent to the stream along this reach to the nearest 10%.

Industrial	Apartment	Med-Den Res	Agriculture	Park	Barren
Commercial	High-Den Res	Low-Den Res 100	Golf	Undeveloped	Ongoing Construction

Comment:

List the direct cause(s) of disturbance(s) in this reach. Check up to three.

Direct storm water inputs	Land-clearing activity	Reduced riparian buffer	Impervious Area	
Culvert/Bridge Crossing	Instream structures	Natural Setting	Agriculture	Other

Comment:

List the types of sedimentation/erosion processes observed in the channel and from upland sources - include erosion (caused instream and from lateral runoff), sediment inputs, and landscape influences

Stream bank erosion.

RESTORATION

Describe and give location of potential restoration projects that would be applicable for this reach.

Invasive Species removal.

Describe and give location of any vacant/undeveloped or public or park land adjacent to the stream.

None.

Describe and give location for any detention structures/BMP's observed or other areas for off-channel detention.

None.

APPENDIX A-6: STREAM INVENTORY PARAMETERS DEFINITIONS

Category **Code(s)**

CHANNEL ALTERATION

Manmade Alteration	**MMAlt1**	**MMAlt2**	**MMAlt3**	**MMLength1**	**MMLength2**	**MMLength3**	**OF_DD_Severity**
Channelized reach	CR	CR	CR	0-500	0-500	0-500	Minor
Piped reach	PR	PR	PR	0-500	0-500	0-500	Moderate
Rip-rap channel	RC	RC	RC	0-500	0-500	0-500	Severe
Floodplain build-up	FB	FB	FB	0-500	0-500	0-500	
Concrete channel	CC	CC	CC	0-500	0-500	0-500	

Channelized reach (CR) - Straightened/dredged sections of the channel and/or areas where the channel has been relocated.
Piped reach (PR) - Sections of the stream that have been piped over long distances, excluding bridge crossings.
Rip-rap channel (RC) - Areas where the channel or bank is lined with rip-rap, excluding sewer line crossings.
Floodplain built-up (FB) - Areas where the floodplain has been built up leaving the channel confined to a narrow valley.
Concrete channel (CC) - Reaches where the channel is now a concrete trapezoid. This excludes bridge crossings.

Hydrologic Alteration	**HydAlt1**	**HydAlt2**	**HydAlt3**	**HydrLength1**	**HydrLength2**	**HydrLength3**	**KP_HC_Height**
Channel incised	CI	CI	CI	0-500	0-500	0-500	2-4 ft
Channel widened	CW	CW	CW	0-500	0-500	0-500	4-6 ft
Channel incised and widened	IW	IW	IW	0-500	0-500	0-500	>6 ft
Channel aggraded	CA	CA	CA	0-500	0-500	0-500	
Headcut	HC	HC	HC	KP_HC_Height			
Knickpoint	KP	KP	KP	KP_HC_Height			

Channel incised (CI) - The channel has cut-down into the stream bed and/or the stream is actively head-cutting.
Channel widened (CW) - The channel has widened out or is in the process of widening, which is characterized by large point bars, fallen trees, and/or bank erosion.
Channel incised and widened (IW) - The channel has incised and widened.
Channel aggraded (CA) - The channel bed has built-up near the top of the channel, and is characterized by deep sand deposits.
Headcut (HC) - An abrupt (vertical) change in streambed elevation that is actively migrating upstream.
Knickpoint (KP) - An abrupt (vertical) stationary change in streambed elevation (usually >2 ft) due to natural or anthropogenic causes and are observed in the field such as bedrock outcrops or embedded logs.

STREAM BANK EROSION	**LB_Erosion**	**LB_Length**	**LB_Height**	**RB_Erosion**	**RB_Length**	**RB_Height**
25-50%	37.5	0-500	0-50	37.5	0-500	0-50
50-75%	62.5	0-500	0-50	62.5	0-500	0-50
75-100%	87.5	0-500	0-50	87.5	0-500	0-50

REMAINING BUFFER	**LB_BUFFER**	**LB_WIDTH**	**RB_BUFFER**	**RB_WIDTH**
Pastures & Croplands	AG	10-25 ft	AG	10-25 ft
Parallel Utility	AU	<10 ft	AU	<10 ft
Perpendicular Utility	EU	0 ft	EU	0 ft
Cleared & Grubbed	CG		CG	
Impervious Cover	IM		IM	
Landscaping	LA		LA	
Lawn	LN		LN	
Abandoned Land	OF		OF	

AG – Active pastures or croplands within the stream buffer;
AU – Cleared/maintained utilities parallel to the stream and within the stream buffer;
EU – Cleared/maintained utilities perpendicular to the stream;
CG – Recently cleared and grubbed for development;
IM – Impervious cover such as roads, sidewalks, buildings, or other structures;
LA – Landscaping such as small planted shrubs and landscaping plants and/or mulched beds;
LN – Grassed lawns; and
OF – Pastures or old residential areas that are revegetating but not considered a forested riparian buffer yet

WATER QUALITY, MISC, BMP

Point Source	**PtSource1**	**PtSource2**
Septic Tank	ST	ST
Sewer Line or SSO	SL	SL
Chemical Discharge	PC	PC
Unkown or Illicit Discharge	ID	ID
Nonpoint Source	**NPSource1**	**NPSource2**
Urban Runoff	UR	UR
Agricultural Runoff	AR	AR
Livestock	LS	LS
Kennels/Domestic Animals	KD	KD
Chemical Discharge	NC	NC
Miscellaneous	**Misc1**	**Misc2**
Reference reach	RR	RR
Riparian preservation	RP	RP
Debris dam	DD	DD
Beaver dam	BD	BD
In-channel wetland	WI	WI
Off-channel wetland	OW	OW
Water withdrawal	WW	WW
Backwater extent	BW	BW
Unusual/Comment	UC	UC
Invasive Species	US	US
Existing Structural BMP	**ExistingBMP**	
Dry Pond	DP	
Wet Pond	WP	
Constructed Wetland	SW	
Weir Structure	WS	
Off-channel Detention	OC	

Category	Code(s)

Point Sources:
Septic Tank (ST) - A septic discharge directly into or adjacent to the stream characterized by gray water and strong fecal odor.
Sewer Line or SSO (SL) - A sewer line has ruptured or a man-hole is overflowing.
Chemical Discharge (PC) - Any chemical discharge into the stream. This would include permitted discharges such a wastewater treatment facilities.
Unknown Illicit Discharge (ID) - Other discharges that cannot be readily identified in the field and do not fall in the above categories. The most common indicators are dry-weather discharges from an unknown source(s).

Non-point Sources:
Livestock (LS) - Livestock have access to the stream.
Kennels/Domestic Animals (KD) - Kennels or domestic animals kept near the stream (this includes dog pens next to the edge of the channel).
Chemical Discharge (NC) - Other chemical discharges that can be detected by smell, but the source is not directly seen.
Urban Runoff (UR) - Evidence of large overland flow events in the channel margin originating from upslope regions.
Agricultural Runoff (AR) - Evidence of overland flow or ditch draining active agricultural fields for crops or livestock (that don't have direct access to the stream, see LS).

BMPs:
Dry Pond (DP) - Detention basins intended to provide for the temporary storage of storm water runoff to reduce downstream flooding impacts.
Wet Pond (WP) - Detention basins that have a permanent pool of water.
Constructed Wetlands (SW) - These are shallow marsh systems designed to hold and treat storm water. Large amounts of land are needed.
Weir Structure (WS) - A concrete, brick, or other hard structure that has been placed in the stream that allows baseflows to pass through, but detains water in the channel during storm events.
Off-channel Detention (OC) - Forested areas that have space in the floodplain can be used for off-channel storage.

Miscellaneous:
Reference reach (RR). A reach of stream where the channel morphology appears stable and what would be expected in an undisturbed watershed.
Riparian preservation (RP). Areas of undeveloped land where the riparian buffer has not been disturbed and would be beneficial to protect.
Debris dam (DD). A debris dam that completely blocks the channel so as to cause significant bank erosion and/or upstream sedimentation.
Beaver dam (BD). Beaver dams are completely blocking the channel altering the hydrology and morphology of the channel.
In-channel wetland (WI). A non-constructed wetland that is located within the channel, often resulting in a braided stream channel.
Off-channel wetland (OW). A non-constructed wetland that is located adjacent to the stream channel. These are "backswamp" areas that appear to remain inundated most of the year.
Water withdrawal (WW). Intake pipes and pumps are observed in the stream; these are most often where homeowners are withdrawing water from the creek for irrigation purposes.
Backwater extent (BW). The upstream limit of the backwater/sedimentation zone due to downstream impoundments. This point marks a break in slope between a free-flowing channel and the backwater zone.
Unusual/comment (UC). A problem or point of interest that does not fall in any of the defined categories. The field crew s will keep the use of this code to a minimum, and take detailed field notes when it is utilized.
Invasive species (US). Dense stands of privet, kudzu, bamboo, or English ivy along the riparian corridor and/or streambanks.

COUNTY MAINTENANCE	**CountyMaint**	**MaintPhoto1**	**MaintPhoto2**
Debris blocks culvert	DC		
Sediment blocks culvert	SC		
Culvert maintenance	CM		
Erosion control	EC		
Dumping-Trash	DT		
Man-hole in channel	MS		
Exposed pipe	EP		
Broken pipe	BP		
Stressed pipe	SP		
Pond maintenance	PM		
Debris dam flood danger	DF		
Bridge inspection	BI		

Reference:
Gwinnett County Department of Water Resources, 2009, DRAFT Stream Inventory Plan Mulberry and Apalachee Watershed Improvement Plan, Prepared by Brown and Caldwell, April 2009.

APPENDIX E: SAMPLED WATER QUALITY DATA

	Date	Turbidity 2130 (NTU)	Fecal coliform 9222D (cfu/100 mL)	Fecalstrep 9230C (cfu/100 mL)	ColiStrep Ratio	Water Temp (F)	Depth (in)	Conductivity 2510 (µS/cm)	Dissolved Solids (ppm)	pH	Phosphate (ppm)	Flowrate	Dissoxy_meter 4500G(ppm@ºC)	Ammonia (mg/L)	Copper (ppb)
34 Long Indian Creek at Waters Rd off Kimball Bridge and Jones Br	4/26/2016		60												
	4/19/2016		60												
	4/11/2016		120												
	4/5/2016		170												
	2/26/2016		290												
	2/15/2016		50												
	2/8/2016		140												
	2/1/2016		180												
	1/26/2016		460												
	1/19/2016		120												
	1/12/2016		50												
	1/5/2016		140												
	11/17/2015		160												
	11/12/2015		170												
	11/9/2015		3700												
	11/4/2015		700												
	10/29/2015	2.4	90				17.5	90	40	6.41		0.21	6.45		
	10/20/2015	2.6	60				13.5	80	50	6.54		0.31	8.36		
	10/13/2015	22.00	2300				14.0	40.0		6.37		0.17	7.30		
	10/6/2015	4.70	130				14.0	70.0	50	6.57		0.29	6.93		
	8/26/2015		460												
	8/20/2015		520												
	8/18/2015		4800												
	8/3/2015		350												
	7/28/2015	3.96	180	710	0.25	76	9.0	80.0	50	6.41		0.29	4.81		
	7/21/2015	3.88	140		?	77	9.0	70.0	50	6.46		0.29	5.46		
	7/7/2015	3.16	120	280	0.43	73	9.5	70.0	50	6.59		0.24	6.05		
	7/1/2015	2.62	20		?	72	9.5	80.0	50	6.45		0.16	5.50		
	6/24/2015		80												
	6/18/2015		190												
	6/9/2015		300												
	6/2/2015		560												
	4/28/2015	3.51	50	210	0.24	58	7.0	80.0	50	6.13	0.07	0.45	7.51	0.00	0.012
	4/21/2015	19.80	750	940	0.80	58	10.0	70.0	40	6.45	0.05	0.50	7.51	0.00	0.020
	4/7/2015	4.54	30	230	0.13	60	11.0	60.0	40	6.63	0.04	0.38	8.27	0.00	0.022
	4/1/2015	2.21	30	130	0.23	59	10.0	80.0	50	6.96	0.07	0.20	8.18	0.00	0.016
	1/27/2015	3.34	40	30	1.33	42	12.0	80.0	50	7.18	0.04	0.25	9.86	0.04	0.021
	1/20/2015	2.69	110	60	1.83	45	9.5	80.0	50	6.82	0.10	0.21	8.83	0.00	0.015
	1/13/2015	3.27	150	100	1.50	46	12.0	80.0	50	6.62	0.05	0.69	8.95	0.00	0.003
	1/6/2015	11.90	130	170	0.76	45	14.5	70.0	50	6.76	0.05	0.30	9.42	0.00	0.015
	10/9/2014	4.36	160	260	0.62	66	9.0	80.0	50	5.98	0.07	0.07	5.95	0.03	0.006

9/30/2014	3.54	340	440	0.77	67	10.0	80.0	50	6.06	0.06	0.28	5.67	0.01	0.008
9/22/2014	2.96	190	250	0.76	69	9.0	80.0	50	6.15	0.05	0.27	6.64	0.00	0.011
8/26/2014		70	500	0.14	73	10.0	80.0	50	6.07	0.05	0.22	5.62	0.00	0.012
8/14/2014	3.92	140	310	0.45	71	9.0	70.0	50	5.80	0.06	0.18	5.77	0.00	0.015
7/9/2014	10.60	100	200	0.50	74	39.0	150.0	100	6.58	0.05	0.35	6.81	0.04	0.009
7/9/2014	3.38	150	330	0.45	75	9.5	70.0	50	6.05	0.04	0.17	5.65	0.01	0.006
7/2/2014	4.00	120	290	0.41	77	9.5	70.0	40	6.09	0.05	0.42	5.39	0.06	0.015
6/17/2014	6.63	80	610	0.13	74	6.5	70.0	50	6.08	0.03	0.30	5.53	0.00	0.029
5/21/2014	3.29	70	290	0.24	64	10.0	70.0	40	5.90	0.04	0.23	8.44	0.01	0.007
4/28/2014	3.22	20	110	0.18	64	10.5	70.0	50	6.13	0.03	0.21	8.56	0.00	0.009
3/5/2014	2.32	1		?	49	12.0	70.0	50	5.99	0.04	0.17	10.79	0.00	0.013
11/25/2013	2.12	10	250	0.04	44	14.0	80.0	50	6.36	0.05	0.34	9.85	0.00	0.018
11/5/2013	3.93	30	190	0.16	53	14.0	80.0	50	6.37	0.04	0.34	8.48	0.00	0.010
10/22/2013	2.10	90	220	0.41	62	11.0	70.0	50	6.28	0.05	0.11	6.59	0.00	0.002
10/10/2013	2.76	130	310	0.42	64	13.5	70.0	40	6.51	0.05	0.28	7.52	0.00	0.018
9/17/2013	1.96	6600	440	15.00	69	9.0	90.0	60	6.69	0.03	0.27	6.61	0.00	0.023
8/26/2013	2.98	170	210	0.81	68	9.5	70.0	50	6.66	0.04	0.50	7.48	0.00	0.014
7/8/2013	4.24	50	250	0.20	72	12.5	70.0	40	6.34	0.03	0.36	6.12	0.03	0.011
6/5/2013	4.02	415	180	2.31	70	9.5	70.0	50	6.73	0.02	0.23	7.08	0.00	0.014
5/8/2013	4.54	200	160	1.25	61	11.0	70.0	50	6.67	0.06	0.60	8.95	0.00	0.012
4/10/2013	2.78	30	20	1.50	66	14.5	60.0	40	6.87	0.07	0.45	9.46	0.00	0.028
3/5/2013	3.36	40	30	1.33	52	13.0	70.0	50	6.93	0.01	0.34	10.53	0.00	0.026
1/29/2013	3.02	70	40	1.75	48	10.0	80.0	50	6.82	0.06	0.62	10.53	0.00	0.010
1/9/2013	3.26	40	180	0.22	50	10.0	80.0	50	6.49	0.03	0.56	9.96	0.00	0.006
11/27/2012	1.99	90	160	0.56	49	12.5	110.0	70	6.79	0.05	0.11	8.37	0.01	0.016
11/5/2012	1.60	230	440	0.52	52	13.5	90.0	60	6.93	0.03	0.19	6.56	0.00	0.005
10/10/2012	4.14	662	270	2.45	59	12.0	80.0	50	6.87	0.01	0.15	7.59	0.00	0.012
9/27/2012	4.82	170	685	0.25	64	11.0	70.0	50	6.76	0.02	0.26	3.77	0.00	0.014
7/25/2012	4.42	280	310	0.90	79	10.0	70.0	40	4.45	0.03	0.23	4.28	0.00	0.023
6/20/2012	4.70	150	430	0.35	70	11.5	70.0	40	5.89	0.04	0.10	5.26	0.00	0.020
4/24/2012	4.06	760	4600	0.17	54	13.5	70.0	50	6.10	0.03	0.24	7.82	0.00	0.025
3/29/2012	4.32	150	220	0.68	62	12.5	120.0	80	5.80	0.06	0.23	7.98	0.00	0.033
3/6/2012	4.48	105	100	1.05	48	14.5	70.0	50	5.73	0.03	0.58	10.97	0.00	0.013
2/9/2012	3.09	70	20	3.50	47	11.5	70.0	50	6.30	0.14	0.33	11.29	0.00	0.008
11/15/2011	3.80	60	90	0.67	58	14.0	70.0	50	6.11	0.08	0.40	5.71	0.00	0.015
10/26/2011	3.98	85	90	0.94	54	11.5	70.0	50	6.80	0.10	0.52	5.01	0.01	0.006
9/19/2011	4.48	50	190	0.26	65	14.0	70.0	50	6.14	0.16	0.10	3.55	0.03	0.015
8/22/2011	9.40	4300	1144	3.76	76	15.5	70.0	50	6.54	0.08	0.06	3.91	0.03	0.008
7/19/2011	4.48	40	450	0.09	75	15.0	60.0	40	6.80	0.08	0.05	4.46	0.20	0.014
6/28/2011	4.99	40	280	0.14	75	18.0	60.0	40	6.79	0.11	0.09	5.88	0.00	0.024
5/23/2011	4.60	100	250	0.40	68	17.0	70.0	50	6.96	0.12	0.09	6.50	0.00	0.028
5/10/2011	6.72	75	280	0.27	65	14.5	70.0	40	6.92	0.05	0.31	6.98	0.01	0.019
5/2/2011	4.07	10	490	0.02	64	15.0	70.0	50	6.93	0.13	0.32	6.62	0.00	0.008
3/23/2011	4.00	50	120	0.42	59	18.0	70.0	50	7.03	0.11	0.31	8.12	0.00	0.014
2/15/2011	3.48	60	30	2.00	44	14.5	70.0	50	7.16	0.06	0.18	11.28	0.00	0.004
1/5/2011	3.64	50	50	1.00	42	15.5	60.0	40	7.29	0.06	0.42	11.43	0.03	0.011
12/20/2010	4.67	70	185	0.38	41	16.0	70.0	50	7.16	0.10	0.13	12.09	0.00	0.008
11/3/2010	3.88	320	3100	0.10	54	11.5	80.0	60	7.08	0.08	0.25	9.28	0.00	0.011
10/12/2010	4.42	200	220	0.91	63	15.0	70.0	50	7.06	0.08	0.17	8.02	0.03	0.009

	8/18/2010	7.43	440	3000	0.15	78	12.5	60.0	40	6.90	0.14	0.11	6.38	0.00	0.003
	8/4/2010	6.64	70	510	0.14	78	15.5	70.0	50	7.01	0.08	0.60	6.49	0.00	0.007
	7/7/2010	5.02	80	360	0.22	72	13.0	70.0	50	7.03	0.07	0.17	5.89	0.01	0.017
	5/25/2010	5.14	50	420	0.12	67	15.0	70.0	50	5.72	0.02	0.18	6.21	0.00	0.004
	4/21/2010	6.18	20	40	0.50	58	17.0	70.0	50	6.38	0.07	0.37	8.24	0.00	0.004
	4/6/2010	3.68	0	0	?	63	15.0	70.0	50	6.44	0.06	0.45	9.17	0.01	0.004
	2/19/2010	3.23	0	250	0.00	41	15.5	70.0	40	6.58	0.14	0.61	11.68	0.00	0.012
	2/9/2010	5.32	30	70	0.43	46	13.8	70.0	40	5.57	0.08	0.64	9.63	0.00	0.005
	1/7/2010	3.78	0	0	?	37	6.5	60.0	50	5.52	0.04	1.01	12.91	0.00	0.007
	12/28/2009	5.62	60	150	0.40	44	7.8	70.0	50	5.59	0.00	1.22	11.36	0.00	0.009
	11/18/2009	3.82	150	100	1.50	57	11.0	80.0	60	6.23	0.02	1.54	8.89	0.00	0.006
	10/21/2009	4.21	130	130	1.00	53	9.5	80.0	50	5.80	0.02	0.95	9.72	0.01	0.028
	8/25/2009	3.36	110	590	0.19	70	7.5	60.0	40	6.80	0.14	0.66	6.08	0.00	0.022
	7/28/2009	11.15	2300	3600	0.64	73	4.5	50.0	40	6.15	0.04	0.89	6.19	0.01	0.007
	6/24/2009	5.62	220	590	0.37	73	13.3	70.0	50	6.89	0.06	0.30	5.50	0.11	0.011
	6/10/2009	4.54	150	1275	0.12	70	14.8	70.0	50	6.68	0.12	0.09	6.79	0.04	0.010
	4/29/2009	4.00	100	390	0.26	61	15.5	70.0	50	6.87	0.07	0.59	7.46	0.21	0.013
	4/16/2009	4.10	57	150	0.38	56	16.0	70.0	50	6.80	0.06	0.29	9.54	0.07	0.005
	2/26/2009	2.40	50	70	0.71	50	16.0	70.0	50	7.32	0.06	0.15	11.30	0.11	0.020
	1/21/2009	3.20	53	93	0.57	35	12.5	80.0	60	7.35	0.12	0.07	14.20	0.11	0.016
	12/17/2008	3.40	10	180	0.06	55	14.0	70.0	50	7.04	0.13	0.22	8.90	0.00	0.007
	11/12/2008	2.20	20	90	0.22	50	11.0	70.0	50	7.15	0.12	0.01	7.00	0.18	0.013
	10/1/2008	6.00	85	285	0.30	64	10.5	80.0	50	6.63	0.12	0.01	3.73	0.15	0.035
	9/17/2008	6.00	130	560	0.23	68	10.0	80.0	50	6.98	0.09	0.05	5.31	0.10	0.002
	7/30/2008	8.00	230	825	0.28	75	8.3	80.0	50	7.01	0.04	0.00	2.39	0.28	0.029
	6/29/1995					62	5.0			7.00			8.00		
	11/8/1994					64	12.0			6.80	0.10		9.80		
	10/11/1994					58	11.8			6.50			9.00		
	8/9/1994					69	6.0			0.65			7.50		
52 Long Indian Ck @ Buice Rd	4/26/2016		260												
	4/19/2016		525												
	4/11/2016		290												
	4/5/2016		320												
	1/26/2016		80												
	1/19/2016		90												
	1/12/2016		80												
	1/5/2016		205												
	10/30/2015	2.8	210				13.0	60	40	6.18		0.29	7.51		
	10/20/2015	2.2	25				12.0	70	50	6.44		0.23	8.86		
	10/13/2015	24.00	2950				16.0	30.0	20	6.25		1.22	8.08		
	10/6/2015	3.90	185				13.5	60.0	40	6.43		0.36	7.76		
	7/28/2015	5.36	275	255	1.08	75	14.0	80.0	50	6.37		0.19	4.53		
	7/21/2015	3.78	130		?	74	14.0	70.0	50	6.20		0.17	5.62		
	7/7/2015	7.57	105	355	0.30	71	14.0	70.0	40	6.36		0.90	6.39		
	7/1/2015	2.87	330		?	70	13.0	70.0	50	6.20		0.68	6.31		
	4/28/2015	3.36	40	355	0.11	57	9.5	70.0	50	6.28	0.06	0.48	7.98	0.00	0.011
	4/21/2015	15.20	195	755	0.26	58	19.0	60.0	40	6.31	0.04	0.44	7.78	0.01	0.017
	4/7/2015	6.94	1260	2100	0.60	59	17.0	60.0	40	6.38	0.05	0.72	8.15	0.00	0.026

	4/1/2015	4.08	120	490	0.24	58	18.0	70.0	40	6.73	0.10	0.20	9.28	0.00	0.013
	1/27/2015	2.57	60	90	0.67	43	12.0	70.0	40	6.88	0.04	0.30	9.91	0.02	0.004
	1/20/2015	2.86	45	90	0.50	46	16.0	70.0	40	6.82	0.05	0.30	9.39	0.00	0.014
	1/13/2015	4.83	720	465	1.55	48	18.0	70.0	50	6.72	0.04	0.55	8.87	0.00	0.015
	1/6/2015	6.94	200	310	0.65	44	15.0	70.0	40	6.55	0.04	0.15	9.22	0.00	0.012
	10/9/2014	3.40	665	380	1.75	65	13.0	80.0	50	5.59	0.06	0.16	4.68	0.02	0.006
	9/30/2014	5.20	900	3250	0.28	66	15.0	60.0	40	5.42	0.04	0.17	4.61	0.02	0.011
53 Long Indian Creek			30												
@ State Bridge Rd															
(Johns Creek)	4/26/2016														
	4/19/2016		50												
	4/11/2016		40												
	4/5/2016		80												
	1/26/2016		40												
	1/19/2016		110												
	1/12/2016		40												
	1/5/2016		60												
	10/29/2015	3.10	95				11.0	60.0	40	6.09		0.20	7.26		
	10/20/2015	1.30	250				11.5	70.0	50	6.19		0.28	8.23		
	10/13/2015	20.00	4400				14.0	40.0	20	6.05		0.44	7.74		
	10/6/2015	2.30	260				11.5	70.0	40	6.23		0.25	6.41		
	7/28/2015	3.24	330		?	73	13.0	80.0	50	6.34		0.18	3.73		
	7/21/2015	6.28	1300		?	73	11.5	70.0	50	6.19		0.42	4.76		
	7/7/2015	2.50	320		?	71	14.0	70.0	50	6.32		0.25	6.11		
	7/1/2015	2.77	170		?	70	13.0	70.0	40	6.23		0.23	4.79		
	4/28/2015	2.86	10		?	57	17.0	70.0	40	6.34		0.27	6.81		
	4/21/2015	19.80	110		?	58	17.0	60.0	40	6.26		0.46	6.95		
	4/7/2015	5.48	140		?	59	17.0	60.0	40	6.30		0.72	7.26		
	4/1/2015	2.18	10		?	57	17.0	70.0	40	6.72		0.20	7.59		
	1/27/2015	2.31	50		?	44	11.5	70.0	40	6.82		0.54	9.37		
	1/20/2015	2.34	60		?	46	15.5	70.0	40	6.73		0.26	8.48		
	1/13/2015	4.08	130		?	48	15.0	70.0	40	6.74		0.32	8.94		
	1/6/2015	6.02	30		?	45	15.0	70.0	40	6.50		0.78	8.85		
	10/9/2014	4.62	150		?	65	11.0	80.0	50	5.81		0.26	4.38		
54 Long Indian Creek			120												
@ Willow Meadow															
Circle (Johns Creek)	4/26/2016														
	4/19/2016		360												
	4/11/2016		40												
	4/5/2016		100												
	1/26/2016		60												
	1/19/2016		40												
	1/12/2016		30												
	1/5/2016		110												
	10/29/2015	8.00	170				14.5	60.0	40	6.13		0.20	6.42		
	10/20/2015	6.40	80				20.0	80.0	50	6.29		0.22	6.96		
	10/13/2015	25.00	2300				8.5	30.0	20	6.12		0.26	7.52		
	10/6/2015	9.80	210				9.5	80.0	50	6.12		0.48	5.57		
	7/28/2015	12.70	30		?	76	9.0	100.0	70	6.20		0.25	3.15		

	7/21/2015	9.40	50		?	76	9.0	90.0	50	6.07		0.37	4.00		
	7/7/2015	9.74	90		?	72	10.0	70.0	50	6.23		0.38	4.50		
	7/1/2015	10.20	110		?	72	9.0	80.0	50	6.13		0.30	4.46		
	4/28/2015	6.16	70		?	58	9.5	80.0	50	6.15		0.47	6.99		
	4/21/2015	18.00	200		?	58	12.0	70.0	40	6.25		0.46	7.50		
	4/7/2015	10.60	80		?	60	10.0	60.0	40	6.33		0.55	7.12		
	4/1/2015	4.27	30		?	58	12.0	80.0	50	6.72		0.25	7.70		
	1/27/2015	4.14	180		?	43	12.0	80.0	50	6.88		0.25	9.08		
	1/20/2015	4.15	70		?	46	10.0	80.0	50	6.81		0.76	8.68		
	1/13/2015	4.66	180		?	47	8.0	80.0	50	6.76		0.50	8.87		
	1/6/2015	8.92	30		?	45	8.0	70.0	50	6.60		1.12	8.95		
	10/9/2014	3.00	300		?	65	8.5	70.0	50	5.42		0.55	5.78		
55 Long Indian Ck @			20												
The Park on High															
Hampton Chase	4/26/2016														
	4/19/2016		40												
	4/11/2016		20												
	4/5/2016		120												
	1/26/2016		30												
	1/19/2016		10												
	1/12/2016		30												
	1/5/2016		40												
	10/29/2015	3.10	60				15.5	60.0	40			0.55	7.72		
	10/20/2015	2.40	50				14.0	80.0	50	6.53		0.42	9.25		
	10/13/2015	13.00	1000				16.0	40.0	30	6.35		1.80	7.74		
	10/6/2015	3.70	180				6.0	70.0	50	6.50		0.59	7.30		
	7/28/2015	5.73	660	610	1.08	76	16.0	80.0	50	6.42		0.31	6.06		
	7/21/2015	3.86	140		?	76	5.0	70.0	40	6.39		0.24	6.12		
	7/7/2015	3.44	100	360	0.28	72	14.0	70.0	40	6.55		0.29	6.89		
	7/1/2015	3.18	130		?	72	12.0	70.0	50	6.48		0.87	6.48		
	4/28/2015	3.58	30	180	0.17	58	6.0	80.0	50	6.39	0.07	0.82	7.84	0.00	0.015
	4/21/2015	24.20	2100	7500	0.28	57	11.0	70.0	40	6.32	0.05	1.81	8.11	0.00	0.030
	4/7/2015	4.46	60	220	0.27	60	12.0	60.0	40	6.52	0.07	1.36	8.22	0.00	0.013
	4/1/2015	2.24	10	100	0.10	61	13.0	80.0	50	6.93	0.08	0.50	9.42	0.00	0.016
	1/27/2015	2.18	0	80	0.00	42	12.0	80.0	50	7.05	0.05	0.25	9.84	0.03	0.019
	1/20/2015	3.14	40	20	2.00	45	15.0	80.0	50	6.92	0.03	0.20	9.44	0.00	0.008
	1/13/2015	3.59	70	30	2.33	46	15.0	80.0	50	6.87	0.03	0.50	9.39	0.00	0.007
	1/6/2015	8.09	100	260	0.38	45	18.0	70.0	50	6.64	0.04	0.49	9.38	0.00	0.014
	10/9/2014	2.96	620	700	0.89	66	15.5	70.0	50	5.98	0.04	0.19	6.84	0.00	0.006
	9/30/2014	5.34	120	400	0.30	67	14.0	70.0	50	5.88	0.05	0.23	5.16	0.00	0.017

APPENDIX F: LONG INDIAN CREEK STREAM DELISTING EVALUATION AND SUMMARY TECHNICAL MEMORANDUM

a reservoir of expertise.

Technical Memorandum

To: Ms. Jill Bazinet

From: Amanda Lester - R2T, Inc. / Sam Fleming - Dewberry

Date: December 9, 2015

Re: Long Indian Creek Stream Delisting Evaluation and Summary

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The bacteria data collected for Long Indian Creek by the City of Alpharetta and City of Johns Creek is being evaluated for potential delisting with the Georgia Environmental Protection Division (GA EPD). Johns Creek and Alpharetta prepared a joint Sampling and Quality Assurance Plan (SQAP) and submitted it to Georgia Department of Natural Resources Environmental Protection Division in 2014. The SQAP was approved by EPD and specifically called for quarterly sampling at five sites shown below (**Figure 1**).

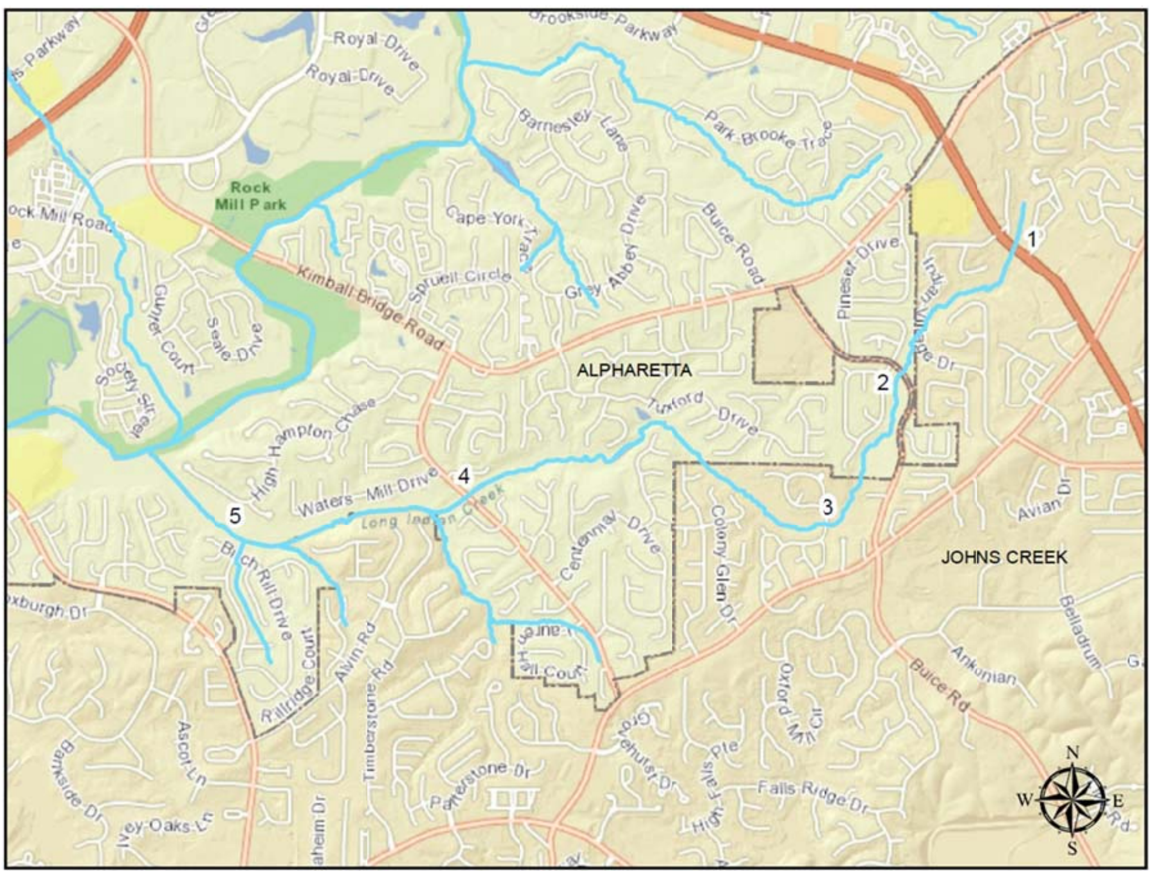

Figure 1 – Long Indian Creek SQAP Monitoring Locations

Site 1: Long Indian Creek near State Bridge Road – Johns Creek
GPS Coordinates: 34.050859 N, -84.227183 W

Site 2: Long Indian Creek near Buice Road
GPS Coordinates: 34.044721 N, -84.233267 W

Site 3: Long Indian Creek near Willow Creek Circle – Johns Creek
GPS Coordinates: 34.038129 N, -84.237667 W

Site 4: Long Indian Creek near Waters Road
GPS Coordinates: 34.039325 N, -84.257503 W

Site 5: Long Indian Creek near Big Creek at Hampton Hall
GPS Coordinates: 34.038031 N, -84.27144 W

Long Indian Creek, which is located in both the City of Alpharetta and the City of Johns Creek, is listed on Georgia's 303(d) list of impaired waters. The cause of this listing is due to elevated fecal coliform bacteria, a water quality and public health concern for both Cities. The presence of fecal coliform bacteria in aquatic environments may indicate that the water has been contaminated with the fecal material of man or other animals.
A portion of the Watershed Improvement Plan is dedicated to genetic testing of bacteria in water samples to determine whether the potential sources of fecal coliform bacteria are due to direct discharge of waste from mammals and birds, from agricultural and storm runoff, and from untreated human sewage.

Large quantities of fecal coliform bacteria in water may indicate a higher risk of pathogens being present in the water. Because Long Indian Creek has a designated use of "Fishing", the City of Alpharetta and the City of Johns Creek value the protection of humans as well as the environment and therefore would like to see it monitored to reduce fecal coliform loadings, with this data used in future listing decisions.

During the year 2015, eighty grab samples were taken in accordance with the SQAP by City of Alpharetta. Additional samples were taken to establish ambient water quality and to isolate and identify concentrated sources of fecal pollution. The geometric means for the grab samples is listed in **Table 1**. Fulton County also samples water quality on Long Indian Creek at Waters Road as part of the County Watershed Protection Plan.

Table 1 shows the geometric mean values collected in 2015 by the City of Alpharetta and by Fulton County. The majority of the geometric mean values meet the Georgia Water Use Classification and Water Quality Criteria with the exception of one geometric mean valued collected in July at Willow Meadow Road and all the geometric mean values collected in October except High Hampton Chase.

Table 1 - Long Indian Creek Fecal Coliform, MPN/100 ml

Date	SITE 1 State Bridge Road	SITE 2 Buice Road	SITE 3 Willow Meadow Road	SITE 4 Waters Road	SITE 5 High Hampton Chase
January 2015	58	140	91	96	23
April 2015	35	185	76	76	78
July 2015	62	188	**391**	88	186
October 2015	**285**	**231**	**406**	200	152
Fulton County Data					
June 2015				**225**	
August 2015				**796**	
November 2015				515	

*Values in bold exceed the Georgia 391-3-6 Water Use Classification and Water Quality Criteria Rule

Table 2 identifies the Georgia Water Use Classification and Water Quality Criteria for freshwater streams, lakes and reservoirs. The table shows the geometric mean value for freshwater streams from May to October is 200 MPN/100 mL or 500 MPN/100 mL for single sample. The geometric mean criteria is 1000 MPN/100 mL which is much higher during low exposure cold weather period from November to April.

Table 2 – Georgia Water Quality Criteria Rule

Season	Criteria[1]	Water body
May – October	200 MPN / 100 mL	Stream/River
	300[2] MPN / 100 mL	Lakes and Reservoirs
	500[2] MPN / 100 mL	Flowing Freshwater Streams
Nov – April	1000 MPN / 100 mL, and	Stream/River
	> 4000 MPN / 100 mL for any one sample	

Notes:
1. Not to exceed value of 300 col/100mL for Lakes and Reservoirs and 500 col/100 mL for streams
2. Not to exceed value of 4,000 col/100mL

Table 3 shows the total rainfall per month for the study period. Heavy rainfall events or extended wet weather can contribute to elevated levels of bacteria within samples from stormwater runoff contributions. Typically samples collected during dry periods tend to have lower levels of bacteria. The year 2015 can be described as a wet year with nearly 50 inches of rainfall total in the area to date. Three of the six sampling months have rainfall totals over 5.0 inches.

Table 3 - Rainfall Totals from USGS Gage at Big Creek near Alpharetta

Date	Monthly Summary in Inches
January 2015	4.58
April 2015	6.70
June 2015	1.58
August 2015	3.36
October 2015	5.60
November 2015	6.10

Delisting Evaluation

The Georgia EPD Georgia's 2014 305(b)/303(d) Listing Assessment Methodology document identifies the following delisting criteria:

- Waters were eligible for delisting for fecal coliform if 10% or less of the geometric means exceeded the water quality criteria. If fewer than 4 geometric means were available for assessment, GA EPD may have considered a water eligible for delisting if there were at least two summer geometric means available for assessment and they complied with the water quality criteria.

With multiple consecutive years of available data:

- Waters were eligible for delisting for fecal coliform bacteria if 10% or fewer of the geometric means exceeded water quality criteria.

A total of 23 geometric means were collected in the Long Indian Creek watershed in 2015. Of the 23 geometric means, 16 were within the water quality criteria from bacteria and 7 of the geometric means were higher than the water quality criteria. A total of 30% of the geometric means were above the water quality criteria while, 7 of the 12 geometric means collected during the May to October criteria period were above the 200 MPN/ 100 mL criteria (58%).

The City of Alpharetta should continue monitoring in coordination with the City of Johns Creek and Fulton County prior to submitting the results of the monitoring for the 2015 calendar year to Georgia EPD for stream delisting. Critical sampling months range from May to October. Continued monitoring of bacteria levels and analysis of the Bacteria

Source Tracking (BST) will lead to targeted best management practices (BMPs). This will assist the City in reducing bacteria levels below the summer criteria threshold to meet the delisting goal. Once the bacteria levels are below both the winter and summer criteria the City will be able to submit the water quality data to EPD for delisting.

APPENDIX G: LONG INDIAN CREEK BACTERIA SOURCE TRACKING TECHNICAL MEMORANDUM

a reservoir of expertise.

Technical Memorandum

To: Mr. Sam Fleming P.E. – Dewberry

From: Amanda Lester P.E. - R2T, Inc.

Date: June 10, 2016

Re: Draft – Long Indian Creek Bacteria Source Tracking Final Draft

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Background

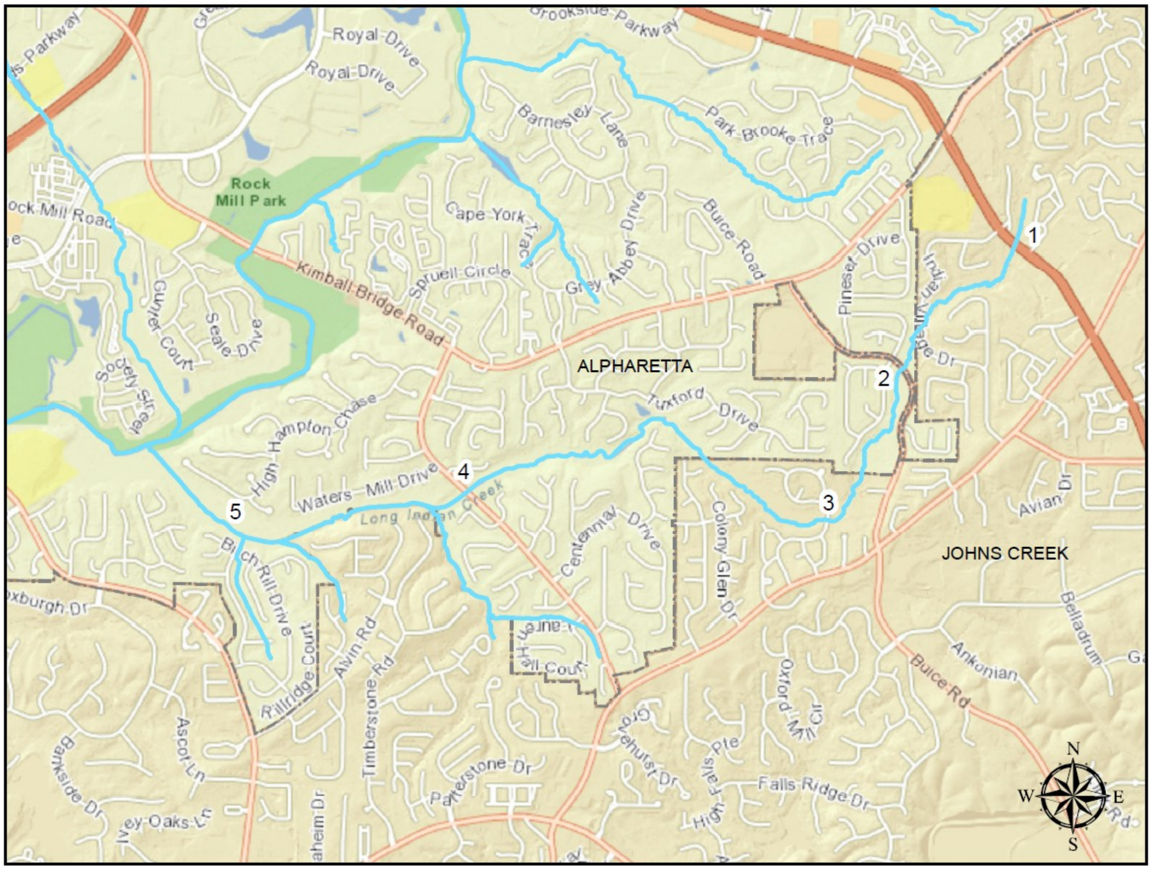
The City of Alpharetta (City) is committed to improving water quality within the City watersheds. The City is preparing a Watershed Improvement Plan (WIP) for the Long Indian Creek subwatershed. The WIP will outline several management measures for identifying water quality pollution prevention and best management practices for improving water quality within the watershed.

Bacteria Source Tracking (BST) was included in the WIP to quantify the sources of bacteria pollution within the watershed. BST is a new methodology used to determine the source(s) of pathogen contamination in environmental water samples. BST techniques attempt to provide the best method to determine the origins of bacterial contamination in water bodies. BST uses DNA evaluation of the *E. Coli* bacteria found in a water sample and compares it with an existing DNA library to identify the *E. Coli* source is human, dog, geese, or other wildlife. Once the source of bacteria is identified, the City will employ specific best management practices (BMP)s to reduce the amount of fecal contamination in Long Indian Creek.

BST sampling was conducted during dry weather conditions defined as 72 hours of less than 0.1 inches of precipitation on November 12, 2015 at five locations sampled as part of the City's Sampling Quality Assurance Plan (SQAP) (Map 1).

BST sampling was also conducted during the following three wet weather condition events defined by the number of inches of rain greater than 0.30 inches within 24 hours as measured by the USGS gage 02335700 Big Creek near Alpharetta, Georgia.

- December 3, 2015 - 0.35 inches of rain.
- April 12, 2016 - 0.38 inches of rain.
- May 17, 2016 - 1.02 inches of rain.



Map 1 – Bacteria Source Tracking Locations

Site 1: Long Indian Creek near State Bridge Road – Johns Creek
GPS Coordinates: 34.050859 N, -84.227183 W

Site 2: Long Indian Creek near Buice Road - Alpharetta
GPS Coordinates: 34.044721 N, -84.233267 W

Site 3: Long Indian Creek near Willow Creek Circle – Johns Creek
GPS Coordinates: 34.038129 N, -84.237667 W

Site 4: Long Indian Creek near Waters Road - Alpharetta
GPS Coordinates: 34.039325 N, -84.257503 W

Site 5: Long Indian Creek near Big Creek at Hampton Hall - Alpharetta
GPS Coordinates: 34.038031 N, -84.27144 W

The goal of the BST sampling is to identify if the bacteria contamination noted in Long Indian Creek originates from human sources as septic leak or sanitary sewer overflow or animal sources. The samples were collected from Long Indian Creek to determine baseline conditions for bacteria in Long Indian Creek. The BST samples were sent to an accredited laboratory (Source Molecular Corporation) for evaluation. Samples were also collected during a stormwater event to identify and quantify the level of bacteria contributed during stormwater events. These samples were sent to the same accredited laboratory.

Laboratory Method/Analysis

To determine the contaminate source, the laboratory detected and quantified the fecal *bacteroidetes* human gene biomarker for human fecal contamination. The presence of the biomarkers are determined by quantitative polymerase chain reaction (qPCR) DNA analytical technology. Researchers use this method to distinguish certain genomes such as the human gene biomarker from the *Bacteroides* and *Prevotella* genus. For a thorough discussion of the method, please refer to the Appendix.

Positive laboratory results indicate the Total Fecal *Bacteroidetes* and Human Fecal *Bacteroidetes* were detected. The results were quantified, where possible, and, as applicable, interpreted as “negative”, “trace”, “low concentration”, “moderate concentration”, or “high concentration.” Results from analysis coupled with the geographic locations of the samples will allow the City of Alpharetta to determine most likely sources of bacteria within the watershed.

Laboratory Results

<u>Dry Weather Conditions</u>

The results of the laboratory analysis of the dry weather sampling conducted on November 12, 2015 showed minor contribution of dog bacteria marker in the water samples collected from Long Indian Creek at Waters Road location. Other results included:

- Traces of dog marker were also noted at the States Bridge Road and Hampton Hall sampling locations.

- Traces of human bacteria marker were identified at Buice Road and Waters Road sampling locations, and

- Traces of bird bacteria marker were identified at State Bridge Road and Waters Road.

- Goose and Ruminant biomarkers were not detected in the water samples collected.

In general, results identified dog fecal sources of contamination to be a minor component of the positive samples. The human bacteroidetes identified at Buice Road and Waters Road were identified as Dorei species. However levels of the Dorei species were below the quantification limits. A summary of the laboratory results are included in **Table 1**.

Table 1
City of Alpharetta Department of Public Works
Long Indian Creek Bacteria Source Tracking (BST)
Results Summary from November 12, 2015 Dry Weather Event

Location	Human	Bird	Dog	Goose	Ruminant
Site 1 Long Indian at States Bridge Road	ND	Trace	Trace	ND	
Site 2 Long Indian at Buice Road	Trace	ND	ND		ND
Site 3 Long Indian at Willow Creek Circle	ND	ND	ND		ND
Site 4 Long Indian at Waters Road	Trace	Trace	**Low Concentration 356 (copy#/100mL)**	ND	
Site 5 Long Indian at Hampton Hall	ND	ND	Trace		ND

*Trace - Below limit of quantification. ND – None Detected.

Wet Weather Conditions

The results of the laboratory analysis of the wet weather sampling conducted on December 03, 2015 showed no contribution of bird or goose bacteria markers in the water samples collected. Other results included:

- Traces of dog bacteria markers were noted at moderate levels for all sites except Long Indian at Willow Creek Circle (Site 3) which had low levels.
- Traces of human bacteria marker were identified at low concentrations at all sites.
- Ruminant bacteria markers were detected at trace levels in the water for samples collected at Long Indian at Buice Rd (Site 2), and Long Indian at Hampton Hall (Site 5).

In general, results identified dog fecal sources of contamination to be a moderate component of the positive samples. The human bacteroidetes identified at low concentrations at all sites were identified as Dorei species with trace levels of EPA human bacteroidetes at the Waters Rd and Hampton Hall sites. A summary of the laboratory results are included in **Table 2.**

The results of the laboratory analysis of the wet weather sampling conducted on April 12, 2016 showed no contribution of goose bacteria markers in the water samples collected. Other results included:

- The presents of dog bacteria markers were noted at moderate levels for all sites except Long Indian Creek at States Bridge Road (Site 1) which had low levels.
- Traces of human bacteria marker were identified at low concentrations at all sites except Long Indian Creek at Willow Creek Circle (Site 3) which had moderate levels.
- Traces of bird bacteria marker were identified at samples collected at Long Indian Creek at States Bridge Road (Site 1), Buice Road (Site 2), and Willow Creek Circle (Site 3). However, bacteria marker levels were below the level of quantification.
- Ruminant bacteria markers were detected at trace levels in the water for samples collected at Long Indian at Buice Rd (Site 2), and Long Indian at Hampton Hall (Site 5). However, bacteria marker levels were below the level of quantification.

In general, results identified dog fecal sources of contamination to be a moderate component of the positive samples. The human bacteroidetes identified at low concentrations at all sites were identified as Dorei species. A summary of the laboratory results are included in **Table 2.**

Table 2
City of Alpharetta Department of Public Works
Long Indian Creek Bacteria Source Tracking (BST)
Results Summary

Wet Weather Event 12/3/2015				**Human:**		
Presence or Absence	**Bird**	**Dog**	**Goose**	**Dorei**	**EPA**	**Ruminant**
Site 1 Long Indian at States Bridge Road	ND	Moderate	ND	LC	ND	
Site 2 Long Indian at Buice Road	ND	Moderate		LC	ND	Trace
Site 3 Long Indian at Willow Creek Circle	ND	Low		LC	ND	ND
Site 4 Long Indian at Waters Road	ND	Moderate	ND	LC	Trace	
Site 5 Long Indian at Hampton Hall	ND	Moderate		LC	Trace	Trace
Wet Weather Event 12/3/2015				**Human:**		
Quantification	**Bird**	**Dog**	**Goose**	**Dorei**	**EPA**	**Bird**
Site 1 Long Indian at States Bridge Road	ND	1.43E+04	ND	3.87E+02	ND	
Site 2 Long Indian at Buice Road	ND	1.66E+04		3.77E+02	ND	<LOQ
Site 3 Long Indian at Willow Creek Circle	ND	8.56E+03		2.51E+02	ND	ND
Site 4 Long Indian at Waters Road	ND	1.23E+04	ND	2.94E+02	<LOQ	
Site 5 Long Indian at Hampton Hall	ND	1.93E+04		3.30E+02	<LOQ	<LOQ
Wet Weather Event 4/12/2016				**Human:**		
Presence or Absence	**Bird**	**Dog**	**Goose**	**Dorei**	**EPA**	**Ruminant**
Site 1 Long Indian at States Bridge Road	Trace	Low	ND	Trace	ND	
Site 2 Long Indian at Buice Road	Trace	Moderate		Trace	ND	Trace
Site 3 Long Indian at Willow Creek Circle	Trace	Moderate		Present	ND	ND
Site 4 Long Indian at Waters Road	ND	Moderate	ND	Trace	ND	
Site 5 Long Indian at Hampton Hall	ND	Moderate		Trace	ND	Trace
Wet Weather Event 4/12/2016				**Human:**		
Quantification	**Bird**	**Dog**	**Goose**	**Dorei**	**EPA**	**Ruminant**
Site 1 Long Indian at States Bridge Road	<LOQ	2.60E+03	ND	<LOQ	ND	
Site 2 Long Indian at Buice Road	<LOQ	2.96E+04		<LOQ	ND	ND
Site 3 Long Indian at Willow Creek Circle	<LOQ	1.22E+04		2.94E+02	ND	ND
Site 4 Long Indian at Waters Road	ND	1.72E+04	ND	<LOQ	ND	
Site 5 Long Indian at Hampton Hall	ND	2.49E+04		<LOQ	ND	ND

Table 2
City of Alpharetta Department of Public Works
Long Indian Creek Bacteria Source Tracking (BST)
Results Summary (Continued)

Wet Weather Event 5/17/2016				Human:		
Presence or Absence	**Bird**	**Dog**	**Goose**	**Dorei**	**EPA**	**Ruminant**
Site 1 Long Indian at States Bridge Road	Trace	Low	ND	LC	LC	
Site 2 Long Indian at Buice Road	Trace	Low		LC	LC	Trace
Site 3 Long Indian at Willow Creek Circle	Trace	Low		LC	LC	ND
Site 4 Long Indian at Waters Road	Trace	Low	ND	LC	LC	
Site 5 Long Indian at Hampton Hall	Trace	Moderate		LC	LC	Trace
Wet Weather Event 5/17/2016				**Human:**		
Quantification	**Bird**	**Dog**	**Goose**	**Dorei**	**EPA**	**Ruminant**
Site 1 Long Indian at States Bridge Road	<LOQ	4.61E+03	ND	5.99E+02	<LOQ	
Site 2 Long Indian at Buice Road	<LOQ	5.03E+03		7.58E+02	<LOQ	<LOQ
Site 3 Long Indian at Willow Creek Circle	<LOQ	7.68E+03		7.39E+02	<LOQ	ND
Site 4 Long Indian at Waters Road	<LOQ	7.69E+03	ND	6.93E+02	3.20E+02	
Site 5 Long Indian at Hampton Hall	<LOQ	1.53E+04		1.15E+02	3.71E+02	<LOQ

*Trace - <LOQ Below limit of quantification. ND – None Detected.

The results of the laboratory analysis of the wet weather sampling conducted on May 17, 2016 showed no contribution of goose bacteria markers in the water samples collected. Other results included:

- The presents of dog bacteria markers were noted at low levels for all sites except Long Indian Creek at Hampton Hall (Site 5) which had moderate levels.

- Low concentrations of human bacteria marker were identified at all sites. Both the Dorei and EPA human bacteria marker were identified at all sites. Concentrations of bacteria marker were quantifiable for the Dorei biomarker at all sites. The EPA bacteria marker was quantifiable at sites Long Indian Creek at Waters Road (Site 4) and Hampton Hall (Site 5). Long Indian Creek at Buice Road (Site 2) had the largest quantification of Dorei bacteria biomarker. Long Indian Creek at Hampton Hall (Site 5) had the highest quantification of EPA biomarker.

- Traces of bird bacteria marker were identified at samples collected at all sites sampled on Long Indian Creek. However, bacteria marker levels were below the level of quantification at all of the sites tested.

- Ruminant bacteria markers were detected at trace levels in the water for samples collected at Long Indian at Buice Rd (Site 2), and Long Indian at Hampton Hall (Site 5). However, bacteria marker levels were below the level of quantification. Ruminant bacteria marker was not detected at Long Indian Creek Willow Creek Circle (Site 3).

In general, results identified dog fecal sources of contamination to be a low to moderate component of the positive samples. The human bacteroidetes identified at low concentrations at all sites were identified as Dorei species. The EPA bacteria marker was identified at two sites (Site 4 and Site 5). A summary of the laboratory results are included in **Table 2.**

Results Analysis – Dry Weather Conditions

The results of the data analysis indicate low concentrations of dog bacteroidetes with trace amounts of human, and bird bacteroidetes to the overall bacteroidetes totals identified within Long Indian Creek during dry weather conditions. Separate bacteria analysis for quantification was completed at Long Indian Creek at Waters Road. Total Fecal Coliform count was measured to be 170 colonies/100 mL and the *E.coli* total was measured to be 160 MPN/100mL. Direct comparison between the total quantification and the quantification of the bacteroidetes results can't be made because the bacteroidetes represents copies of the bacteria sources.

Although human sources were not identified as the main source of bacteria measured within Long Indian Creek, human bacteria are present in dry weather conditions at both States Bridge Road and Waters Road sampling locations. This could indicate septic tank leakage, sanitary sewer leaks, or other human sources within the watershed. The results of the dry weather conditions laboratory analysis are provided in **Appendix A** of this report.

Results Analysis – Wet Weather Conditions

The analysis of the data set indicate that the most prevalent form of bacteroidetes at all sites monitored during the project are dog bacteroidetes at moderate to low levels. Moderate concentrations were measured multiple times at Buice Road (Site 2), Waters Road (Site 4), and Hampton Hall (Site 5). Dog bacteroidetes levels were the most prevalent of the bacteroidetes types tested during this project. A summary of all dog bacteroidetes levels is identified in **Table 3**.

All sites had human Dorei bacteroidetes at low concentrations. Waters Road (Site 4) and Hampton Hill (Site 5) had human EPA bacteria markers at trace levels below the level of quantification for the first wet weather event collected on December 3, 2015. The second wet weather event collected on April 12, 2016 identified trace levels of Dorei bacteroidetes at all sites with the exception of Willow Creek Circle (Site 3) which had low concentrations. The human EPA bacteria marker was not identified at any of the sites during this sampling event. The last wet weather event collected on May 17, 2016 identified low to moderate concentrations of Dorei bacteroidetes at all sampling locations. Low concentrations of the EPA bacteroidetes were also identified at all sampling locations. A summary of all human bacteroidetes levels is identified in **Table 4**.

Other bacteroidetes tests were completed for bird bacteroidetes at all sites. Two sites were tested for goose bacteroidetes (States Bridge Road –Site 1, and Waters Road – Site 4), while the remaining sites were tested for ruminant bacteroidetes. Only trace amounts of bird bacteroidetes were identified below quantifiable levels at States Bridge Road (Site 1), Buice Road (Site 2), and Willow Creek Circle (Site 3). Trace amounts of ruminant bacteroidetes were identified below quantifiable levels at Buice Road (Site 2) and Hampton Hall (Site 5). The results of the wet weather conditions laboratory analysis are provided in **Appendix B** of this report.

Table 3
City of Alpharetta Department of Public Works
Long Indian Creek Bacteria Source Tracking (BST)
Dog Bacteroidetes Results Summary

Dog Bacteroidetes Quantification Summary	11/12/2016	12/3/2015	4/12/2016	5/17/2016
Site 1 Long Indian at States Bridge Road	<LOQ	14,300	2,600	4,610
Site 2 Long Indian at Buice Road	ND	16,600	29,600	5,030
Site 3 Long Indian at Willow Creek Circle	ND	8,560	12,200	7,680
Site 4 Long Indian at Waters Road	356	12,300	17,200	7,690
Site 5 Long Indian at Hampton Hall	<LOQ	19,300	24,900	15,300

Table 4
City of Alpharetta Department of Public Works
Long Indian Creek Bacteria Source Tracking (BST)
Human Dorei Bacteroidetes Results Summary

Human Dorei Bacteroidetes Quantification Summary	11/12/2016	12/3/2015	4/12/2016	5/17/2016
Site 1 Long Indian at States Bridge Road	ND	387	<LOQ	599
Site 2 Long Indian at Buice Road	<LOQ	377	<LOQ	758
Site 3 Long Indian at Willow Creek Circle	ND	251	294	739
Site 4 Long Indian at Waters Road	<LOQ	294	<LOQ	693
Site 5 Long Indian at Hampton Hall	ND	330	<LOQ	115

Results Analysis – Summary

The results of the data analysis indicate low concentrations of human Dorei bacteria with trace amounts of the human EPA bacteria, and low to moderate concentrations of dog bacteria. The main source of fecal input is identified to be dogs. These results indicate that, while not directly of human origin, the source is likely considered anthropogenic as described below.

The analyses detected mainly Dorei in quantifiable amounts with EPA biomarker concentration at quantifiable levels at Waters Road and Hampton Hall Sites. The detection of human bacteria in low concentrations indicates the likelihood that human bacteria are present in the watershed and could possibly identify leaking sewer, or septic systems. The low concentrations of human biomarker could also be sourced through dogs' fecal matter. This is a common finding since dogs and humans live in close proximity and dogs likely share some measure of human bacteria. Dog fecal samples were collected on May 17, 2016 along with the water samples collected to determine if any human biomarkers could be identified directly from the dog fecal sample. Sample results did not indicate any human biomarkers within the dog fecal sample.

Fecal coliform concentrations sourced from dogs as pets can be significantly reduced through a combination of social marketing, education, and low-cost structural best management practices (BST) identified in the recommendations section of this report. Fecal coliforms of human origin through sewage spills or leaks or the discharge of partially treated effluent through septic drain fields can require years-long planning and construction to remedy.

Recommendations

The results of the laboratory analysis indicate significant dog contributions to bacteria in Long Indian Creek at Waters Road during dry weather conditions and significantly during wet weather conditions at Hampton Hall. The moderate to low level concentrations identified at all sites during wet weather confirms the need for stormwater management solutions to address dog pollution.

The trace levels of human pollution identified during dry weather could indicate leaking sanitary sewer or leaking septic systems. Low concentrations of human bacteria sources identified during wet weather conditions could indicate the presence of leaking sanitary sewer or leaking septic systems. Elevated levels of human bacteria during wet weather could also be a result of elevated sediment levels if bacteria are attached to the sediment. The interaction of sediment-bacteria fate and transport are beyond the scope of this task.

Additional Bacteria Monitoring

It is recommended that the City of Alpharetta continue to monitor bacteria sources using the BST method in the spring and summer of 2016 when human and animal activity in the watershed are high. Additional BST sampling during wet weather conditions is recommended to further develop the bacteria source profile. Current BST sampling results provide support for the development of stormwater management Best Management Practices (BMPs) focused on reducing dog and human bacteria sources.

Strategic Placement of Pet Waste Stations

It is recommended that the City of Alpharetta invest in the strategic placement of pet waste stations to reduce the amount of dog bacteria polluting Long Indian Creek. Pet waste stations average in cost between $200 and $500 dollars to purchase and install[1]. Priority areas should be near parks, walking trails, apartment complexes, and area neighborhoods. The development of the watershed model will provide additional information to determine the best placement for BMPs. Possible areas for installation include the following locations:

- Ocee Park
- Long Indian Creek Community Area
- Pine Hollow Community Area
- Willow Run Community Area
- The Pines at Kimball Bridge Community Area
- Kimball Bridge Crossing Community Area
- Tuxford Community Area
- Birkdale Community Area
- Dunmoor Community Area
- Waters Landing Community Area
- Hampton Hall Community Area

[1] http://www.zerowasteusa.com/Complete-Dog-Waste-Stations-Prodlist.html

Bacteria Reduction Education

The biggest impact for reducing bacteria pollution from dog waste is to educate dog owners on the importance of proper waste disposal. Several educational tools and materials are available to help the City of Alpharetta educate dog owners. The City may want to partner with veterinary clinics and pet boarding businesses to help reach pet owners and provide them with the proper tools for pet waste disposal. Educational resources are provided by the United States Environmental Protection Agency (EPA), the Atlanta Regional Commission's Clean Water Campaign.

Pet Waste Ordinances

The City of Alpharetta may consider developing ordinances to reduce pet waste. The City of Seattle has developed the following ordinances to protect the Puget Sound[2]:

- Allowing the accumulation of feces (civil infraction, $109.00 fine)
- Not removing feces from another's property (civil infraction, $54.00 fine)
- Not having equipment to remove feces (civil infraction $54.00 fine)
- Keeping an animal in unsanitary conditions (criminal – animal cruelty, maximum $1,000 fine)
- In Parks: Failure to carry equipment for removing feces OR failure to place feces in appropriate receptacle. (civil infraction, maximum $54 fine)

[2] http://www.seattle.gov/util/EnvironmentConservation/MyHome/PreventPollution/PetWaste/index.htm

Appendix A – BST Dry Weather Conditions Results 11/12/15

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Preliminary Interpretation of Bird Fecal ID™ Quantification Results

Detection and quantification of Bird-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: November 13, 2015
Date Reported: November 25, 2015

SM #	Client #	Approximate Contribution of Bird Fecal Pollution in Water Sample	Comment
SM-5K13020	site 1	**Trace**	Trace levels of bird fecal biomarker
SM-5K13021	site 2	Not Detected	Bird fecal biomarker not detected
SM-5K13022	site 3	Not Detected	Bird fecal biomarker not detected
SM-5K13023	site 4	**Trace**	Trace levels of bird fecal biomarker
SM-5K13024	site 5	Not Detected	Bird fecal biomarker not detected

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Source Molecular
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Tel: (1) 786-220-0379, Fax: (1) 786-513-2733, Email:

Bird Fecal ID™ Quantification

Detection and quantification of Bird-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: November 13, 2015
Date Reported: November 25, 2015

SM #	Client #	Analysis Requested	Bird Specific Marker Quantified*	DNA Analytical Results
SM-5K13020	site 1	Bird Fecal ID	<LOQ**	**Present (Trace)**
SM-5K13021	site 2	Bird Fecal ID	ND***	Absent
SM-5K13022	site 3	Bird Fecal ID	ND***	Absent
SM-5K13023	site 4	Bird Fecal ID	<LOQ**	**Present (Trace)**
SM-5K13024	site 5	Bird Fecal ID	ND***	Absent

*Numbers reported as copy numbers per 100 mL of water
**Below level of quantification
***Non-detect

Laboratory Comments

Submitter: R2T, Inc.

Report Date: November 25, 2015

Negative Results

In sample(s) classified as negative, the bird-associated fecal gene biomarker(s) was either not detected in test replicates, one replicate was detected at a cycle threshold greater than 35 and the other was not, or one replicate was detected at a cycle threshold less than 35 and the other was not after repeated analysis. It is important to note that a negative result does not mean that the sample does not definitely have bird fecal contamination. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Trace Results

In sample(s) classified as trace, the bird-associated fecal biomarker was detected in both test replicates but in quantities below the limit of quantification. This result indicates that fecal indicators associated with bird were present in the sample(s) but in low concentrations.

Bird Fecal Reference Samples

The client is encouraged to submit fecal samples from suspected sources in the surrounding area in order to gain a better understanding of the concentration of the bird-associated fecal genetic in the geographic region of interest. A more precise interpretation would be available to the client with the submittal of such baseline samples.

Result Interpretations

Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing

A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to perform additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **sourcemolecular.com/tests**

DNA Analytical Method Explanation

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications to detect the target gene biomarker were run on an Applied Biosystems StepOnePlus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul containing sample extract, forward primer, reverse primer and an optimized buffer. All assays were run in duplicate. Absolute quantification was achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of known gene copy numbers.

For quality control purposes, a positive control consisting of bird fecal DNA or plasmid containing the target and a negative control consisting of PCR-grade water, were run alongside the sample(s) to ensure a properly functioning reaction and to reveal any false negatives or false positives. The accumulation of PCR product was detected and graphed in an amplification plot. If the target gene biomarker was absent in the sample, this accumulation was not detected and the sample was considered negative. If accumulation of PCR product was detected, the sample was considered positive.

Theory Explanation of Bird Fecal ID™ Quantification

The genus *Helicobacter* is a group of gram-negative, microaerophilic bacteria that were initially classified under the *Campylobacter* genus prior to 1989. Since then, they have been reclassified into the genus *Helicobacter* after 16S rRNA sequencing differentiated them from other *Campylobacter* species. This group of bacteria typically have a spiral, curved or fusiform morphology with multiple flagella allowing them to rapidly maneuver in the intestinal mucous lining of their hosts. *Helicobacter* species colonize the gastrointestinal tract of mammals and birds and are shed in feces. There are approximately 20 strains of *Helicobacter*[1]. Certain strains, such as *Helicobacter pylori,* are pathogenic to humans causing chronic gastritis, peptic ulcers and stomach cancer.

The Bird Fecal Quantification ID™ service is designed around the principle that certain DNA sequences contained within strains of the *Helicobacter* genus are specific to wild birds. These *Helicobacter* sequences can be used as indicators of bird fecal contamination. Several species have been isolated from specific animal hosts such as *H. fennelliae* from humans, *H. hepaticus* from mice and *H. felis* from cats and dogs.[1] The Bird Fecal Quantification ID™ service targets a bird-associated gene biomarker in *Helicobacter pametensis.*[2] The biomarker is present at different degrees in the feces of various birds including but not limited to gull, goose, chicken, pigeon and duck.

One of the advantages of the Bird Fecal Quantification ID™ service is that the entire population of *Helicobacter* of the selected portion of the water sample is screened. As such, this method avoids the randomness effect of selecting isolates off a petri dish.

Accuracy of the results is possible because the method uses qPCR DNA technology. qPCR simulataneously confirms and quantifies the bird-associated gene biomarker. This is accomplished with small pieces of DNA called primers that are complementary and specific to the genome to be detected. This qPCR technology avoids the cumbersome process of distinguishing DNA bands on a gel electrophoresis apparatus.

Through a heating process called thermal cycling, the double stranded DNA is denatured and inserted with complementary primers to create exact copies of the DNA fragment desired. This process is repeated rapidly many times ensuring an exponential progression in the number of copied DNA. If the primers are successful in finding a site on the DNA fragment that is specific to the genome to be studied, then billions of copies of the DNA fragment will be available and detected in real-time. The accumulation of DNA product is plotted as an amplification curve. The absence of an amplification curve indicates that the bird-associated *Helicobacter* gene biomarker is not present.

References

[1] Goldman, E. and Green, L. H. (2009). *Practical Handbook of Microbiology* (2nd ed) . Boca Raton, FL: CRC Press.
[2] Seymour, C., Lewis, R.G., Kim, M., Gagnon, D.F., Fox, J.G., Dewhirst, F.E., and Paster, B.J. Isolation of *Helicobacter* Strains from Wild Bird and Swine Feces. Appl. Environ. Microbiol. (1994) 60:3, 1025-1028.

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Preliminary Interpretation of Dog "Quantification" ID™ Results

Detection and quantification of the fecal Dog gene biomarker for Dog fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: November 13, 2015
Date Reported: November 25, 2015

SM #	Client #	Approximate Contribution of Dog Fecal Pollution in Water Sample	Comment
SM-5K13015	site 1	**Trace**	Trace levels of dog fecal biomarker
SM-5K13016	site 2	Not Detected	Dog fecal biomarker not detected
SM-5K13017	site 3	Not Detected	Dog fecal biomarker not detected
SM-5K13018	site 4	**Low Concentration**	Low levels of dog fecal biomarker
SM-5K13019	site 5	**Trace**	Trace levels of dog fecal biomarker

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Dog Bacteroidetes Quantification ID™

Detection and quantification of the fecal Dog gene biomarker for Dog fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA

Submitter: R2T, Inc.
Date Received: November 13, 2015
Date Reported: November 25, 2015

SM #	Client #	Analysis Requested	Dog Specific Marker Quantified*	DNA Analytical Results
SM-5K13015	site 1	Dog Bacteroidetes ID	<LOQ**	**Present (Trace)**
SM-5K13016	site 2	Dog Bacteroidetes ID	ND***	Absent
SM-5K13017	site 3	Dog Bacteroidetes ID	ND***	Absent
SM-5K13018	site 4	Dog Bacteroidetes ID	3.56E+02	**Present**
SM-5K13019	site 5	Dog Bacteroidetes ID	<LOQ**	**Present (Trace)**

*Numbers reported as copy numbers per 100 mL of water
**Below level of quantification
***Non-detect

Laboratory Comments

Submitter: R2T, Inc.

Report Date: November 25, 2015

Negative Results
In sample(s) classified as negative, the dog-associated fecal gene biomarker(s) was either not detected in test replicates, one replicate was detected at a cycle threshold greater than 35 and the other was not, or one replicate was detected at a cycle threshold less than 35 and the other was not after repeated analysis. It is important to note that a negative result does not mean that the sample does not definitely have dog fecal contamination. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Positive Results
In sample(s) classified as positive, the dog-associated fecal gene biomarker(s) was detected in both test replicates suggesting that dog fecal contamination is present in the water sample(s). The biomarker(s) serve as an indicator of the targeted fecal pollution, but the presence of the biomarker does not signify conclusively the presence of that form of fecal pollution. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Trace Results
In sample(s) classified as trace, the dog-associated fecal biomarker was detected in both test replicates but in quantities below the limit of quantification. This result indicates that fecal indicators associated with dog were present in the sample(s) but in low concentrations.

Dog Fecal Reference Samples
The client is encouraged to submit fecal samples from suspected sources in the surrounding area in order to gain a better understanding of the concentration of the dog-associated fecal genetic marker in the geographic region of interest. A more precise interpretation would be available to the client with the submittal of such baseline samples.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to perform additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **sourcemolecular.com/tests**

DNA Analytical Method Explanation

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications to detect the target gene biomarker were run on an Applied Biosystems StepOnePlus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul containing sample extract, forward primer, reverse primer, probe and an optimized buffer. The following thermal cycling parameters were used: 95°C for 10 min and 40 cycles of 95°C for 15 s and 60°C for 1 min. All assays were run in duplicate. Absolute quantification was achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of known gene copy numbers.

For quality control purposes, a positive control consisting of Dog fecal DNA and a negative control consisting of PCR-grade water, were run alongside the sample(s) to ensure a properly functioning reaction and reveal any false negatives or false positives. The accumulation of PCR product is detected and graphed in an amplification plot. If the fecal indicator organism is absent in the sample, this accumulation is not detected and the sample is considered negative. If accumulation of PCR product is detected, the sample is considered positive.

Theory Explanation of Dog Bacteroidetes "Quantification" ID™

The phylum *Bacteroidetes* is composed of three large groups of bacteria with the best-known category being *Bacteroidaceae*. This family of gram-negative bacteria is found primarily in the intestinal tracts and mucous membranes of warm-blooded animals and is sometimes considered pathogenic.

Comprising *Bacteroidaceae* are the genus *Bacteroides* and *Prevotella*. The latter genus was originally classified within the former (i.e. *Bacteroides*), but since the 1990's it has been classified in a separate genus because of new chemical and biochemical findings. *Bacteroides* and *Prevotella* are gram-negative, anaerobic, rod-shaped bacteria that inhabitant of the oral, respiratory, intestinal, and urogenital cavities of humans, animals, and insects. They are sometimes pathogenic.

Fecal *Bacteroidetes* are considered for several reasons an interesting alternative to more traditional indicator organisms such as *E. coli* and *Enterococci*.[1] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems. This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*. Furthermore, these latter two organisms are facultative anaerobes and as such they can be problematic for monitoring purposes since it has been shown that they are able to proliferate in soil, sand and sediments.

The Dog Bacteroidetes ID™ service is designed around the principle that fecal *Bacteroidetes* are found in large quantities in feces of warm-blooded animals.[2,3,4,5,6] Furthermore, certain categories of *Bacteroidetes* have been shown to be predominately detected in dog. Within these *Bacteroidetes*, certain strains of the *Bacteroides* and *Prevotella* genus have been found in dog.[2,3,5,6] As such, these bacterial strains can be used as indicators of dog fecal contamination.

One of the advantages of the Dog Bacteroidetes ID™ service is that the entire water is sampled and filtered for fecal *Bacteroidetes*. As such, this method avoids the randomness effect of culturing and selecting bacterial isolates off a petri dish. This is a particular advantage for highly contaminated water systems with potential multiple sources of fecal contamination.

Accuracy of the results is possible because the method uses PCR DNA technology. PCR allows quantities of DNA to be amplified into large number of small copies of DNA sequences. This is accomplished with small pieces of DNA called primers that are complementary and specific to the genomes to be detected.

Through a heating process called thermal cycling, the double stranded DNA is denatured and inserted with complementary primers to create exact copies of the DNA fragment desired. This process is repeated rapidly many times ensuring an exponential progression in the number of copied DNA. If the primers are successful in finding a site on the DNA fragment that is specific to the genome to be studied, then billions of copies of the DNA fragment will be available and detected in real-time. The accumulation of DNA product is plotted as an amplification curve. The absence of an amplification curve would indicate that the dog *Bacteroidetes* gene biomarker is not present.

References

[1] Scott, Troy M., Rose, Joan B., Jenkins, Tracie M., Farrah, Samuel R., Lukasik, Jerzy **Microbial Source Tracking: Current Methodology and Future Directions.** Appl. Environ. Microbiol. (2002) 68: 5796-5803.

[2] Bernhard, A.E., and K.G. Field (2000a). **Identification of nonpoint sources of fecal pollution in coastal waters by using host-specific 16S ribosomal DNA genetic markers from fecal anaerobes.** Applied and Environmental Microbiology, 66: 1,587-1,594.

[3] Bernhard, A.E., and K.G. Field (2000b). **A PCR assay to discriminate human and ruminant feces on the basis of host differences in Bacteroides-Prevotella genes encoding 16S rRNA.** Applied and Environmental Microbiology, 66: 4,571-4,574.

[4] Kreader, C.A. (1995). **Design and evaluation of Bacteroides DNA probes for the specific detection of human fecal pollution.** Applied and Environmental Microbiology, 61: 1,171-1,179.

[5] Fogarty, Lisa R., Voytek, Mary **A.Comparison of Bacteroides-Prevotella 16S rRNA Genetic Markers for Fecal Samples from Different Animal Species** Appl. Environ. Microbiol. 2005 71: 5999-6007.

[6] Dick, Linda K., Bernhard, Anne E., Brodeur, Timothy J., Santo Domingo, Jorge W., Simpson, Joyce M., Walters, Sarah P., Field, Katharine G. **Host**

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Preliminary Interpretation of Canada Goose "Quantification" ID™ Results

Detection and quantification of the fecal Canada Goose gene biomarker for Canada Goose fecal contamination by quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: November 13, 2015
Date Reported: November 25, 2015

SM #	Client #	Approximate Contribution of Canada Goose Fecal Pollution in Water Sample	Comment
SM-5K13025	site 1	Not Detected	Goose fecal biomarker not detected
SM-5K13026	site 4	Not Detected	Goose fecal biomarker not detected

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Canada Goose Bacteroidetes Quantification ID™

Detection and quantification of the fecal Canada Goose gene biomarker for Canada Goose fecal contamination by quantitative Polymerase Chain Reaction (qPCR) DNA analytical

Submitter: R2T, Inc.
Date Received: November 13, 2015
Date Reported: November 25, 2015

SM #	Client #	Analysis Requested	Canada Goose Specific Marker Quantified*	DNA Analytical Results
SM-5K13025	site 1	Goose Bacteroidetes ID	ND**	Absent
SM-5K13026	site 4	Goose Bacteroidetes ID	ND**	Absent

*Numbers reported as copy numbers per 100 mL of water
**Non-detect

Laboratory Comments

Submitter: R2T, Inc.

Report Date: November 25, 2015

Negative Results
In sample(s) classified as negative, the goose-associated fecal gene biomarker(s) was either not detected in test replicates, one replicate was detected at a cycle threshold greater than 35 and the other was not, or one replicate was detected at a cycle threshold less than 35 and the other was not after repeated analysis. It is important to note that a negative result does not mean that the sample does not definitely have goose fecal contamination. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Goose Fecal Reference Samples
The client is encouraged to submit fecal samples from suspected sources in the surrounding area in order to gain a better understanding of the concentration of the goose-associated fecal genetic marker in the geographic region of interest. A more precise interpretation would be available to the client if baseline samples are provided.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", "trace", "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to arrange for additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **sourcemolecular.com/tests**

DNA Analytical Method Explanation

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications to detect the target gene biomarker were run on an Applied Biosystems StepOne Plus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul sample extract, forward primer, reverse primer and an optimized buffer. The following thermal cycling parameters were used: 95°C for 10 min and 40 cycles of 95°C for 15 s and 60°C for 1 min. All assays were run in duplicate. Absolute quantification was achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of known gene copy numbers.

For quality control purposes, a positive control consisting of bird fecal DNA and a negative control consisting of PCR-grade water, were run alongside the sample(s) to ensure a properly functioning reaction and reveal any false negatives or false positives. The accumulation of PCR product is detected and graphed in an amplification plot. If the fecal indicator organism is absent in the sample, this accumulation is not detected and the sample is considered negative. If accumulation of PCR product is detected, the sample is considered positive.

Theory Explanation of Canada Goose Bacteroidetes "Quantification" ID™

The phylum *Bacteroidetes* is composed of three large groups of bacteria with the best-known category being *Bacteroidaceae*. This family of gram-negative bacteria is found primarily in the intestinal tracts and mucous membranes of warm-blooded animals and is sometimes considered pathogenic.

Comprising *Bacteroidaceae* are the genus *Bacteroides* and *Prevotella*. The latter genus was originally classified within the former (i.e. *Bacteroides*), but since the 1990's it has been classified in a separate genus because of new chemical and biochemical findings. *Bacteroides* and *Prevotella* are gram-negative, anaerobic, rod-shaped bacteria that inhabitant of the oral, respiratory, intestinal, and urogenital cavities of humans, animals, and insects. They are sometimes pathogenic.

Fecal *Bacteroidetes* are considered for several reasons an interesting alternative to more traditional indicator organisms such as *E. coli* and *Enterococci*.[1] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems. This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*. Furthermore, these latter two organisms are facultative anaerobes and as such they can be problematic for monitoring purposes since it has been shown that they are able to proliferate in soil, sand and sediments.

The Canada Goose Bacteroidetes ID™ service is designed around the principle that fecal *Bacteroidetes* are found in large quantities in feces of warm-blooded animals.[2,3,4,5,6] Furthermore, certain categories of *Bacteroidetes* have been shown to be predominately detected in Canada geese.[7] Within these *Bacteroidetes*, certain strains of the *Bacteroides* and *Prevotella* genus have been found in Canada geese.[7] As such, these bacterial strains can be used as indicators of Canada geese fecal contamination.

One of the advantages of the Canada Goose Bacteroidetes ID™ service is that the entire water is sampled and filtered for fecal *Bacteroidetes*. As such, this method avoids the randomness effect of culturing and selecting bacterial isolates off a petri dish. This is a particular advantage for highly contaminated water systems with potential multiple sources of fecal contamination.
Accuracy of the results is possible because the method uses PCR DNA technology. PCR allows quantities of DNA to be amplified into large number of small copies of DNA sequences. This is accomplished with small pieces of DNA called primers that are complementary and specific to the genomes to be detected.

Through a heating process called thermal cycling, the double stranded DNA is denatured and inserted with complementary primers to create exact copies of the DNA fragment desired. This process is repeated rapidly many times ensuring an exponential progression in the number of copied DNA. If the primers are successful in finding a site on the DNA fragment that is specific to the genome to be studied, then billions of copies of the DNA fragment will be available for detection in real-time.

References

[1] Scott, Troy M., Rose, Joan B., Jenkins, Tracie M., Farrah, Samuel R., Lukasik, Jerzy **Microbial Source Tracking: Current Methodology and Future Directions.** Appl. Environ. Microbiol. (2002) 68: 5796-5803.

[2] Bernhard, A.E., and K.G. Field (2000a). **Identification of nonpoint sources of fecal pollution in coastal waters by using host-specific 16S ribosomal DNA genetic markers from fecal anaerobes.** Applied and Environmental Microbiology, 66: 1,587-1,594.

[3] Bernhard, A.E., and K.G. Field (2000b). **A PCR assay to discriminate human and ruminant feces on the basis of host differences in Bacteroides-Prevotella genes encoding 16S rRNA.** Applied and Environmental Microbiology, 66: 4,571-4,574.

[4] Kreader, C.A. (1995). **Design and evaluation of Bacteroides DNA probes for the specific detection of human fecal pollution.** Applied and Environmental Microbiology, 61: 1,171-1,179.

[5] Fogarty, Lisa R., Voytek, Mary **A.Comparison of Bacteroides-Prevotella 16S rRNA Genetic Markers for Fecal Samples from Different Animal Species** Appl. Environ. Microbiol. 2005 71: 5999-6007.

[6] Dick, Linda K., Bernhard, Anne E., Brodeur, Timothy J., Santo Domingo, Jorge W., Simpson, Joyce M., Walters, Sarah P., Field, Katharine G. **Host distributions of uncultivated fecal Bacteroidales bacteria reveal genetic markers for fecal source identification** Appl. Environ. Microbiol. 2005 71: 3184-3191.

[7] Fremaux, B., Boa, T., Yost, C. K. **Quantitative Real-Time PCR Asays for Sensitive Detection of Canada Goose-Specific Fecal Pollution in Water Sources.** Appl. Environ. Microbiol. 2010 76: 4886-4889.

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Preliminary Interpretation of Human Fecal Pollution ID™ Results

Detection and quantification of the fecal Human gene biomarker for Human fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: November 13, 2015
Date Reported: November 25, 2015

SM #	Client #	Approximate Contribution of Human Fecal Pollution in Water Sample	Comment
SM-5K13005	site 1	Not Detected	2 Human fecal biomarkers not detected
SM-5K13006	site 2	**Trace**	Trace levels of 1 human fecal biomarker
SM-5K13007	site 3	Not Detected	2 Human fecal biomarkers not detected
SM-5K13008	site 4	**Trace**	Trace levels of 1 human fecal biomarker
SM-5K13009	site 5	Not Detected	2 Human fecal biomarkers not detected

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Source Molecular
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Human Fecal Pollution ID™ Quantification

Detection and quantification of the fecal Human gene biomarker for Human fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: November 13, 2015
Date Reported: November 25, 2015

SM #	Client #	Analysis Requested	Target	Human Specific Marker Quantified*	DNA Analytical Results
SM-5K13005	site 1	Human Bacteroidetes ID 1	Dorei	ND**	Absent
SM-5K13006	site 2	Human Bacteroidetes ID 1	Dorei	<LOQ***	**Present (Trace)**
SM-5K13007	site 3	Human Bacteroidetes ID 1	Dorei	ND**	Absent
SM-5K13008	site 4	Human Bacteroidetes ID 1	Dorei	<LOQ***	**Present (Trace)**
SM-5K13009	site 5	Human Bacteroidetes ID 1	Dorei	ND**	Absent
SM-5K13010	site 1	Human Bacteroidetes ID 2	EPA	ND**	Absent
SM-5K13011	site 2	Human Bacteroidetes ID 2	EPA	ND**	Absent
SM-5K13012	site 3	Human Bacteroidetes ID 2	EPA	ND**	Absent
SM-5K13013	site 4	Human Bacteroidetes ID 2	EPA	ND**	Absent
SM-5K13014	site 5	Human Bacteroidetes ID 2	EPA	ND**	Absent

*Numbers reported as copy numbers per 100 mL of water
**Non-detect
***Below level of quantification

Laboratory Comments

Submitter: R2T, Inc.

Report Date: November 25, 2015

Negative Results
In sample(s) classified as negative, the human-associated Bacteroidetes gene biomarker(s) was either not detected in test replicates, one replicate was detected at a cycle threshold greater than 35 and the other was not, or one replicate was detected at a cycle threshold less than 35 and the other was not after repeated analysis. It is important to note that a negative result does not mean that the sample does not definitely have human fecal contamination. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.
In order to strengthen the result, a negative sample should be analyzed further for human fecal contamination with other DNA analytical tests. A list of human fecal ID tests can be found at **www.sourcemolecular.com/human**.

Trace Results
In sample(s) classified as trace, the human-associated Bacteroidetes biomarker was detected in both test replicates but in quantities below the limit of quantification. This result indicates that fecal indicators associated with human were present in the sample(s) but in low concentrations.

Human Fecal Reference Samples
The client is encouraged to submit samples from the surrounding wastewater facilities and/or septic systems in order to gain a better understanding of the concentration of the human-associated fecal Bacteroidetes genetic marker as well as the concentration of the general fecal Bacteroidetes genetic marker in the geographic region of interest. A more precise interpretation would be available to the client with the submittal of such baseline samples.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to perform additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **www.sourcemolecular.com/tests**

DNA Analytical Method Explanation

All reagents, chemicals and apparatuses were verified and inspected beforehand to ensure that no false negatives or positives could be generated. In that regard, positive and negative controls were run to attest the integrity of the analysis. All inspections and controls tested negative for possible extraneous contaminates, including PCR inhibitors.

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications were run on an Applied Biosystems StepOnePlus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul containing sample extract, forward primer, reverse primer, probe and an optimized buffer. The following thermal cycling parameters were used: 50°C for 2 min, 95°C for 10 min and 40 cycles of 95°C for 15 s and 60°C for 1 min. All assays were run in duplicate. Absolute quantification was achieved by extrapolating genome copy numbers from standard curves generated from serial dilutions of Human specific and generic genomic DNA.

For quality control purposes, a positive control consisting of appropriate genomic DNA and a negative control consisting of PCR-grade water were run alongside the sample(s) to ensure a properly functioning reaction and reveal any false negatives or false positives.

Human Bacteroidetes ID™ Species: *B. dorei*

The **Human Bacteroidetes ID™ Species*: B. dorei*** service targets the species *Bacteroides dorei*. *B. dorei* is an anaerobe that is frequently shed from the gastrointestinal tract and isolated from human feces worldwide. It is a newly discovered species that is widely distributed in the USA.[1,2] The human-associated marker DNA sequence is located on the 16S rRNA gene of *B. dorei*.[3] The marker is the microbial source tracking (MST) marker of choice for detecting human fecal pollution due to its exceptional sensitivity and specificity. Internal validations have been conducted on hundreds of sewage, septage, human and animal host fecal samples collected from throughout the U.S and archived in the Source Molecular fecal bank. The marker has also been evaluated in both inland and coastal waters. A recent, comprehensive, multi-laboratory MST method evaluation study, exploring the performance of current MST methods, concluded the *B. dorei* qPCR assay to be the top performing human-associated assay amongst those tested. The success and consistency of this marker in numerous studies around the world[1,3,4] makes the **Human Bacteroidetes ID™ Species*: B. dorei*** service the primary service for identifying human fecal pollution at Source Molecular.

Fecal *Bacteroidetes* are considered for several reasons an interesting alternative to more traditional indicator organisms such as *E. coli* and *Enterococci*.[5] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems. This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*.

The Human Bacteroidetes ID™ service is designed around the principle that fecal *Bacteroidetes* are found in large quantities in feces of warm-blooded animals.[3,5,6,7,8] Furthermore, certain strains of *Bacteroidetes* have been found to be associated with humans.[3,6] As such, these bacterial strains can be used as indicators of human fecal contamination.

Accuracy of the results is possible because the method amplifies DNA into a large number of small copies of the gene biomarker of interest. This is accomplished with small pieces of DNA called primers that are complementary and specific to the unique *B. dorei* DNA sequence. Through a heating process called thermal cycling, the double stranded DNA is denatured, hybridized to the complementary primers and amplified to create many copies of the DNA fragment desired. If the primers are successful in finding a site on the DNA fragment that is specific to the *B. dorei* DNA sequence, then billions of copies of the DNA fragment will be available and detected in real-time. The accumulation of DNA product is plotted as an amplification curve by the qPCR software. The absence of an amplification curve indicates that the *B. dorei* gene biomarker is not detected in the water sample because it is either not present or present at concentrations below the analytical detection limit.

To strengthen the validity of the results, additional tests targeting other high-ranking, human-associated *Bacteroidetes* species should be performed, such as
Human Bacteroidetes ID™ Species*: B. stercoris*,
Human Bacteroidetes ID™ Species*: B. fragilis,* and
Human Bacteroidetes ID™ Species*: B. thetaiotaomicron*.

[1]Boehm, A., Fuhrman, J., Mrse, R., Grant, S. **Tiered approach for identification of a human fecal pollution source at a recreational beach: case study at Avalon Bay, Catalina Island, California**. Environ Sci Technol. 2003 37**:** 673–680.
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[3] Bernhard, A., Field, K. **A PCR assay to discriminate human and ruminant feces on the basis of host differences in Bacteroides-Prevotella genes encoding 16S rRNA.** Appl. Environ. Microbiol. 2000b 66: 4571-4574.
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[5] Scott, T., Rose, J., Jenkins, T., Farrah, S., Lukasik, J. **Microbial Source Tracking: Current Methodology and Future Directions.** Appl. Environ. Microbiol. 2002 68: 5796-5803.
[6] Bernhard, A., Field, K. **Identification of nonpoint sources of fecal pollution in coastal waters by using host-specific 16S ribosomal DNA genetic markers from fecal anaerobes.** Appl. Environ. Microbiol. 2000a 66: 1587-1594.
[7] Fogarty, L., Voytek, M. **A Comparison of Bacteroides-Prevotella 16S rRNA Genetic Markers for Fecal Samples from Different Animal Species.** Appl. Environ. Microbiol. 2005 71: 5999-6007.
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Human Bacteroidetes ID™: EPA Developed Assay

The **Human Bacteroidetes ID™: EPA Developed Assay** service targets a functional gene biomarker in *Bacteroidales*-like anaerobic bacteria that is present in high concentrations in the human gut. The U.S Environmental Protection Agency (U.S. EPA) was the first to target the biomarker using quantitative Polymerase Chain Reaction (qPCR) technology in order to detect ground and surface waters impacted by human fecal pollution.[1] Since it's development, the assay has been used succesfully around the U.S to identify fecal pollution originating from human sources, such as sewage and septage wastewaters.

The U.S. EPA Developed assay has been shown to be highly associated with human fecal pollution. It has successfully been validated in multiple nationwide studies using at least 300 individual reference fecal material from 22 different animal species known to commonly contaminate environmental waters.[1,2] A reported 99.2% specificity to human fecal material makes this one of the leading assays to confirm the presence of fecal contamination that is of human origin.[1] The *Bacteroidales*-like bacteria is widely distributed. It was detected in 100% of hundreds of sewage and human reference fecal samples collected from more than 20 human populations, making it highly sensitive. Internal validations have also been conducted on hundreds of wastewater, human and animal host fecal samples archived in the Source Molecular fecal bank.

Fecal anaerobic bacteria are considered for several reasons an interesting alternative to more traditional fecal indicator organisms such as *E. coli* and *Enterococci*.[3] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems.[3] This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*.

The **Human Bacteroidetes ID™: EPA Developed Assay** service is designed around the principle that fecal *Bacteroidales*-like bacteria are found in large quantities in feces of warm-blooded animals.[4,5] Furthermore, certain strains have been shown to be associated with humans.[4,5] As such, these bacterial strains can be used as indicators of human fecal contamination. An advantage of the Human Bacteroidetes ID™ service is that the entire portion of water sampled is filtered to concentrate bacteria. As such, this method avoids the randomness effect of culturing and selecting bacterial isolates. This is an advantage for highly contaminated water systems with potential multiple sources of fecal contamination.

Accuracy of the results is possible because the method amplifies DNA into a large number of copies of the gene biomarker of interest. This is accomplished with small pieces of DNA called primers that are complementary and specific to the gene biomarker. Through a heating process called thermal cycling, the double stranded DNA is denatured, hybridized to the complementary primers and amplified to create many copies of the DNA fragment. If the primers are successful in finding a site on the DNA fragment that is specific to the human-associated biomarker, billions of copies of the DNA fragment will be available and detected in real-time. The accumulation of DNA product is plotted as an amplification curve by qPCR software. The absence of an amplification curve indicates that the gene biomarker is not detectable in the water sample either because it is not present or present at concentrations below the analytical detection limit.

To strengthen the validity of the results, additional tests targeting other high-ranking, human-associated *Bacteroidetes* species should be performed, such as
Human Bacteroidetes ID™ Species*: B. dorei*,
Human Bacteroidetes ID™ Species*: B. fragilis,* and
Human Bacteroidetes ID™ Species*: B. stercoris*

[1] Shanks, O., Kelty, C., Sivaganesan, M., Varma, M. and Haugland, R. **Quantitative PCR for Genetic Markers of Human Fecal Pollution**. Appl. Environ. Microbiol. 2009 75: 5507-5513.
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[3] Scott, T., Rose, J., Jenkins, T., Farrah, S. and Lukasik, J. **Microbial Source Tracking: Current Methodology and Future Directions.** Appl. Environ. Microbiol. 2002 68: 5796-5803.
[4] Bernhard, A., Field, K. **Identification of nonpoint sources of fecal pollution in coastal waters by using host-specific 16S ribosomal DNA genetic markers from fecal anaerobes.** Appl. Environ. Microbiol. 2000a 66: 1587-1594.
[5] Bernhard, A., Field, K. **A PCR assay to discriminate human and ruminant feces on the basis of host differences in Bacteroides-Prevotella genes encoding 16S rRNA.** Appl. Environ. Microbiol. 2000b 66: 4571-4574.

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Preliminary Interpretation of Ruminant Fecal ID™ "Quantification" Results

Detection and quantification of Ruminant-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: November 13, 2015
Date Reported: November 25, 2015

SM #	Client #	Approximate Contribution of Ruminant Fecal Pollution in Water Sample	Comment
SM-5K13027	site 2	Not Detected	Ruminant fecal biomarker not detected
SM-5K13028	site 3	Not Detected	Ruminant fecal biomarker not detected
SM-5K13029	site 5	Not Detected	Ruminant fecal biomarker not detected

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Ruminant Fecal ID™ Quantification

Detection and quantification of Ruminant-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: November 13, 2015
Date Reported: November 25, 2015

SM #	Client #	Analysis Requested	Ruminant Specific Marker Quantified*	DNA Analytical Results
SM-5K13027	site 2	Ruminant Fecal ID	ND**	Absent
SM-5K13028	site 3	Ruminant Fecal ID	ND**	Absent
SM-5K13029	site 5	Ruminant Fecal ID	ND**	Absent

*Numbers reported as copy numbers per 100 mL of water
**Non-detect

Laboratory Comments

Submitter: R2T, Inc.

Report Date: November 25, 2015

Negative Results
In sample(s) classified as negative, the ruminant-associated fecal gene biomarker(s) was either not detected in test replicates, one replicate was detected at a cycle threshold greater than 35 and the other was not, or one replicate was detected at a cycle threshold less than 35 and the other was not after repeated analysis. It is important to note that a negative result does not mean that the sample does not definitely have ruminant fecal contamination. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Ruminant Fecal Reference Samples
The client is encouraged to submit fecal samples from suspected sources in the surrounding area in order to gain a better understanding of the concentration of the ruminant-associated fecal genetic marker in the geographic region of interest. A more precise interpretation would be available to the client if baseline samples are provided.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to arrange for additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **sourcemolecular.com/tests**

DNA Analytical Method Explanation

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications to detect the target gene biomarker were run on an Applied Biosystems StepOnePlus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul containing sample extract, forward primer, reverse primer, probe and an optimized buffer. All assays were run in duplicate. Absolute quantification was achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of known gene copy numbers.

For quality control purposes, a positive control consisting of ruminant fecal DNA and a negative control consisting of PCR-grade water, were run alongside the sample(s) to ensure a properly functioning reaction and to reveal any false negatives or false positives. The accumulation of PCR product was detected and graphed in an amplification plot. If the fecal indicator organism was absent in the sample, this accumulation was not detected and the sample was considered negative. If accumulation of PCR product was detected, the sample was considered positive.

Theory Explanation of Ruminant Fecal ID™ Quantification

The phylum *Bacteroidetes* is composed of three large groups of bacteria with the best-known category being *Bacteroidaceae* . This family of gram-negative bacteria is found primarily in the intestinal tracts and mucous membranes of warm-blooded animals and is sometimes considered pathogenic.

Comprising *Bacteroidaceae* are the genus *Bacteroides* and *Prevotella*. The latter genus was originally classified within the former (*i.e.Bacteroides*), but since the 1990's findings. *Bacteroides* and *Prevotella* are gram-negative, anaerobic, rod-shaped bacteria that inhabitant of the oral, respiratory, intestinal, and urogenital cavities of humans, animals and insects. They are sometimes pathogenic.

Fecal *Bacteroidetes* are considered for several reasons an interesting alternative to more traditional indicator organisms such as *E. coli* and *Enterococci*.[1] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems. This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*. Furthermore, these latter two organisms are facultative anaerobes and as such they can be problematic for monitoring purposes since it has been shown that they are able to proliferate in soil, sand and sediments.

The Ruminant Fecal Quantification ID™ service is designed around the principle that fecal *Bacteroidetes* are found in large quantities in feces of warm-blooded animals.[2,3,4,5,6] Furthermore, certain categories of *Bacteroidetes* have been shown to be predominately detected in ruminants. Within these *Bacteroidetes*, certain genetic sequences in the *Bacteroides* and *Prevotella* genus have been found in ruminants.[7] As such, these bacterial strains can be used as indicators of ruminant fecal contamination.

One of the advantages of the Ruminant Fecal Quantification ID™ service is that the entire water is sampled and filtered for fecal *Bacteroidetes*. As such, this method avoids the randomness effect of culturing and selecting bacterial isolates off a petri dish. This is a particular advantage for highly contaminated water systems with potential multiple sources of fecal contamination.

Accuracy of the results is possible because the method uses PCR DNA technology. PCR allows quantities of DNA to be amplified into large number of small copies of DNA sequences. This is accomplished with small pieces of DNA called primers that are complementary and specific to the genomes to be detected. Through a heating process called thermal cycling, the double stranded DNA is denatured and inserted with complementary primers to create exact copies of the DNA fragment desired. This process is repeated rapidly many times ensuring an exponential progression in the number of copied DNA. If the primers are successful in finding a site on the DNA fragment that is specific to the genome to be studied, then billions of copies of the DNA fragment will be available and detected in real-time. Quantitative PCR (qPCR) adds a variant to the PCR process by inserting of a fluorescent probe within the primer set. This fluorescent probe serves as a molecular beacon for the quantification step. During each PCR cycle, quantitative PCR monitors the fluorescence emitted during the reaction. This is done in real-time during the first PCR cycles as a way to quantify the targeted gene. Absolute quantification is achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of plasmid DNA containing a known amount of the ruminant-specific biomarker. The Ruminant Fecal Quantification ID™ service uses qPCR to simultaneously confirm and quantify the ruminant- specific fecal *Bacteroidetes* genetic biomarker. This PCR technology avoids the cumbersome process of distinguishing DNA bands on a gel electrophoresis apparatus.

References

[1] Scott, Troy M., Rose, Joan B., Jenkins, Tracie M., Farrah, Samuel R., Lukasik, Jerzy **Microbial Source Tracking: Current Methodology and Future Directions.** Appl. Environ. Microbiol. (2002) 68: 5796-5803.

[2] Bernhard, A.E., and Field, K.G. **Identification of nonpoint sources of fecal pollution in coastal waters by using host-specific 16S ribosomal DNA genetic markers from fecal anaerobes.** Appl. Environ. Microbiol. (2000a) 66: 1,587-1,594.

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[6] Dick, Linda K., Bernhard, Anne E., Brodeur, Timothy J., Santo Domingo, Jorge W., Simpson, Joyce M., Walters, Sarah P., Field, Katharine G. **Host Distributions of Uncultivated Fecal Bacteroidales Bacteria Reveal Genetic Markers for Fecal Source Identification** Appl. Environ. Microbiol. (2005) 71: 3184-3191.

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Appendix B – BST Wet Weather Conditions Results

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Preliminary Interpretation of Bird Fecal ID™ Quantification Results

Detection and quantification of Bird-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: December 3, 2015
Date Reported: December 11, 2015

SM #	Client #	Approximate Contribution of Bird Fecal Pollution in Water Sample	Comment
SM-5L03041	site 1	Not Detected	Bird fecal biomarker not detected
SM-5L03042	site 2	Not Detected	Bird fecal biomarker not detected
SM-5L03043	site 3	Not Detected	Bird fecal biomarker not detected
SM-5L03044	site 4	Not Detected	Bird fecal biomarker not detected
SM-5L03045	site 5	Not Detected	Bird fecal biomarker not detected

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Bird Fecal ID™ Quantification

Detection and quantification of Bird-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: December 3, 2015
Date Reported: December 11, 2015

SM #	Client #	Analysis Requested	Marker Quantified (copies/100 ml)	DNA Analytical Results
SM-5L03041	site 1	Bird Fecal ID	ND	Absent
SM-5L03042	site 2	Bird Fecal ID	ND	Absent
SM-5L03043	site 3	Bird Fecal ID	ND	Absent
SM-5L03044	site 4	Bird Fecal ID	ND	Absent
SM-5L03045	site 5	Bird Fecal ID	ND	Absent

ND: Not Detected

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Preliminary Interpretation of Dog "Quantification" ID™ Results

Detection and quantification of the fecal Dog gene biomarker for Dog fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: December 3, 2015
Date Reported: December 11, 2015

SM #	Client #	Approximate Contribution of Dog Fecal Pollution in Water Sample	Comment
SM-5L03036	site 1	**Moderate Concentration**	Moderate levels of dog fecal biomarker
SM-5L03037	site 2	**Moderate Concentration**	Moderate levels of dog fecal biomarker
SM-5L03038	site 3	**Low Concentration**	Low levels of dog fecal biomarker
SM-5L03039	site 4	**Moderate Concentration**	Moderate levels of dog fecal biomarker
SM-5L03040	site 5	**Moderate Concentration**	Moderate levels of dog fecal biomarker

Limitation of Damages – Repayment of Service Price
It is agreed that in the event of breach of any warranty or breach of contract, or negligence of Source Molecular Corporation, as well as its agents or representatives, the liability of the company shall be limited to the repayment, to the purchaser (submitter), of the individual analysis price paid by him/her to Source Molecular Corp. The company shall not be liable for any damages, either direct or consequential. Source Molecular Corp. provides analytical services on a PRIME CONTRACT BASIS ONLY. Terms are available upon request. The sample(s) cited in this report may be used for research purposes after an archiving period of 3 months from the date of this report. Research includes, but is not limited to internal validation studies and peer-reviewed research publications. Anonymity of the sample(s), including the exact geographic location will be maintained by assigning an arbitrary internal reference. These anonymous samples will only be grouped by state / province of origin for research purposes. The client must contact Source Molecular in writing within 10 days from the date of this report if he/she does not wish for their submitted sample(s) to be used for any type of future research.

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Dog Bacteroidetes Quantification ID™

Detection and quantification of the fecal Dog gene biomarker for Dog fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA

Submitter: R2T, Inc.
Date Received: December 3, 2015
Date Reported: December 11, 2015

SM #	Client #	Analysis Requested	Marker Quantified (copies/100 ml)	DNA Analytical Results
SM-5L03036	site 1	Dog Bacteroidetes ID	1.43E+04	**Present**
SM-5L03037	site 2	Dog Bacteroidetes ID	1.66E+04	**Present**
SM-5L03038	site 3	Dog Bacteroidetes ID	8.56E+03	**Present**
SM-5L03039	site 4	Dog Bacteroidetes ID	1.23E+04	**Present**
SM-5L03040	site 5	Dog Bacteroidetes ID	1.93E+04	**Present**

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Preliminary Interpretation of Canada Goose “Quantification” ID™ Results

Detection and quantification of the fecal Canada Goose gene biomarker for Canada Goose fecal contamination by quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: December 3, 2015
Date Reported: December 11, 2015

SM #	Client #	Approximate Contribution of Canada Goose Fecal Pollution in Water Sample	Comment
SM-5L03046	site 1	Not Detected	Goose fecal biomarker not detected
SM-5L03047	site 4	Not Detected	Goose fecal biomarker not detected

Limitation of Damages – Repayment of Service Price
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Canada Goose Bacteroidetes Quantification ID™

Detection and quantification of the fecal Canada Goose gene biomarker for Canada Goose fecal contamination by quantitative Polymerase Chain Reaction (qPCR) DNA analytical

Submitter: R2T, Inc.
Date Received: December 3, 2015
Date Reported: December 11, 2015

SM #	Client #	Analysis Requested	Marker Quantified (copies/100 ml)	DNA Analytical Results
SM-5L03046	site 1	Goose Bacteroidetes ID	ND	Absent
SM-5L03047	site 4	Goose Bacteroidetes ID	ND	Absent

ND: Not Detected

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Preliminary Interpretation of Human Fecal Pollution ID™ Results

Detection and quantification of the fecal Human gene biomarker for Human fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: December 3, 2015
Date Reported: December 11, 2015

SM #	Client #	Approximate Contribution of Human Fecal Pollution in Water Sample	Comment
SM-5L03026	site 1	**Low Concentration**	Low levels of 1 human fecal biomarker
SM-5L03027	site 2	**Low Concentration**	Low levels of 1 human fecal biomarker
SM-5L03028	site 3	**Low Concentration**	Low levels of 1 human fecal biomarker
SM-5L03029	site 4	**Low Concentration**	Low levels of 2 human fecal biomarkers
SM-5L03030	site 5	**Low Concentration**	Low levels of 2 human fecal biomarkers

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Human Fecal Pollution ID™ Quantification

Detection and quantification of the fecal Human gene biomarker for Human fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: December 3, 2015
Date Reported: December 11, 2015

SM #	Client #	Analysis Requested	Target	Human Specific Marker Quantified*	DNA Analytical Results
SM-5L03026	site 1	Human Bacteroidetes ID 1	Dorei	3.87E+02	**Present**
SM-5L03027	site 2	Human Bacteroidetes ID 1	Dorei	3.77E+02	**Present**
SM-5L03028	site 3	Human Bacteroidetes ID 1	Dorei	2.51E+02	**Present**
SM-5L03029	site 4	Human Bacteroidetes ID 1	Dorei	2.94E+02	**Present**
SM-5L03030	site 5	Human Bacteroidetes ID 1	Dorei	3.30E+02	**Present**
SM-5L03031	site 1	Human Bacteroidetes ID 2	EPA	ND	Absent
SM-5L03032	site 2	Human Bacteroidetes ID 2	EPA	ND	Absent
SM-5L03033	site 3	Human Bacteroidetes ID 2	EPA	ND	Absent
SM-5L03034	site 4	Human Bacteroidetes ID 2	EPA	<LOQ	**Present (Trace)**
SM-5L03035	site 5	Human Bacteroidetes ID 2	EPA	<LOQ	**Present (Trace)**

ND: Not Detected
<LOQ: Below level of quantification

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Preliminary Interpretation of Ruminant Fecal ID™ "Quantification" Results

Detection and quantification of Ruminant-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: December 3, 2015
Date Reported: December 11, 2015

SM #	Client #	Approximate Contribution of Ruminant Fecal Pollution in Water Sample	Comment
SM-5L03048	site 2	**Trace**	Trace levels of ruminant fecal biomarker
SM-5L03049	site 3	Not Detected	Ruminant fecal biomarker not detected
SM-5L03050	site 5	**Trace**	Trace levels of ruminant fecal biomarker

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Ruminant Fecal ID™ Quantification

Detection and quantification of Ruminant-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: December 3, 2015
Date Reported: December 11, 2015

SM #	Client #	Analysis Requested	Marker Quantified (copies/100 ml)	DNA Analytical Results
SM-5L03048	site 2	Ruminant Fecal ID	<LOQ	**Present (Trace)**
SM-5L03049	site 3	Ruminant Fecal ID	ND	Absent
SM-5L03050	site 5	Ruminant Fecal ID	<LOQ	**Present (Trace)**

ND: Not Detected
<LOQ: Below level of quantification

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Preliminary Interpretation of Bird Fecal ID™ Quantification Results

Detection and quantification of Bird-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: April 13, 2016
Date Reported: April 25, 2016

SM #	Client #	Approximate Contribution of Bird Fecal Pollution in Water Sample	Comment
SM-6D13026	Site 1	**Trace**	Trace levels of bird fecal biomarker
SM-6D13027	Site 2	**Trace**	Trace levels of bird fecal biomarker
SM-6D13028	Site 3	**Trace**	Trace levels of bird fecal biomarker
SM-6D13029	Site 4	Not Detected	Bird fecal biomarker not detected
SM-6D13030	Site 5	Not Detected	Bird fecal biomarker not detected

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Bird Fecal ID™ Quantification

Detection and quantification of Bird-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: April 13, 2016
Date Reported: April 25, 2016

SM #	Client #	Analysis Requested	Bird Specific Marker Quantified*	DNA Analytical Results
SM-6D13026	Site 1	Bird Fecal ID	<LOQ	**Present (Trace)**
SM-6D13027	Site 2	Bird Fecal ID	<LOQ	**Present (Trace)**
SM-6D13028	Site 3	Bird Fecal ID	<LOQ	**Present (Trace)**
SM-6D13029	Site 4	Bird Fecal ID	ND	Absent
SM-6D13030	Site 5	Bird Fecal ID	ND	Absent

<LOQ: Below level of quantification
ND: Not Detected

Negative Results
In sample(s) classified as negative, the bird-associated fecal gene biomarker(s) was either not detected in test replicates, one replicate was detected at a cycle threshold greater than 35 and the other was not, or one replicate was detected at a cycle threshold less than 35 and the other was not after repeated analysis. It is important to note that a negative result does not mean that the sample does not definitely have bird fecal contamination. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Trace Results
In sample(s) classified as trace, the bird-associated fecal biomarker was detected in both test replicates but in quantities below the limit of quantification. This result indicates that fecal indicators associated with bird were present in the sample(s) but in low concentrations.

Bird Fecal Reference Samples
The client is encouraged to submit fecal samples from suspected sources in the surrounding area in order to gain a better understanding of the concentration of the bird-associated fecal genetic in the geographic region of interest. A more precise interpretation would be available to the client with the submittal of such baseline samples.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to perform additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **sourcemolecular.com/tests**

DNA Analytical Method Explanation

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications to detect the target gene biomarker were run on an Applied Biosystems StepOnePlus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul containing sample extract, forward primer, reverse primer and an optimized buffer. All assays were run in duplicate. Absolute quantification was achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of known gene copy numbers.

For quality control purposes, a positive control consisting of bird fecal DNA or plasmid containing the target and a negative control consisting of PCR-grade water, were run alongside the sample(s) to ensure a properly functioning reaction and to reveal any false negatives or false positives. The accumulation of PCR product was detected and graphed in an amplification plot. If the target gene biomarker was absent in the sample, this accumulation was not detected and the sample was considered negative. If accumulation of PCR product was detected, the sample was considered positive.

Theory Explanation of Bird Fecal ID™ Quantification

The genus *Helicobacter* is a group of gram-negative, microaerophilic bacteria that were initially classified under the *Campylobacter* genus prior to 1989. Since then, they have been reclassified into the genus *Helicobacter* after 16S rRNA sequencing differentiated them from other *Campylobacter* species. This group of bacteria typically have a spiral, curved or fusiform morphology with multiple flagella allowing them to rapidly maneuver in the intestinal mucous lining of their hosts. *Helicobacter* species colonize the gastrointestinal tract of mammals and birds and are shed in feces. There are approximately 20 strains of *Helicobacter*[1]. Certain strains, such as *Helicobacter pylori,* are pathogenic to humans causing chronic gastritis, peptic ulcers and stomach cancer.

The Bird Fecal Quantification ID™ service is designed around the principle that certain DNA sequences contained within strains of the *Helicobacter* genus are specific to wild birds. These *Helicobacter* sequences can be used as indicators of bird fecal contamination. Several species have been isolated from specific animal hosts such as *H. fennelliae* from humans, *H. hepaticus* from mice and *H. felis* from cats and dogs.[1] The Bird Fecal Quantification ID™ service targets a bird-associated gene biomarker in *Helicobacter pametensis.*[2] The biomarker is present at different degrees in the feces of various birds including but not limited to gull, goose, chicken, pigeon and duck.

One of the advantages of the Bird Fecal Quantification ID™ service is that the entire population of *Helicobacter* of the selected portion of the water sample is screened. As such, this method avoids the randomness effect of selecting isolates off a petri dish.

Accuracy of the results is possible because the method uses qPCR DNA technology. qPCR simulataneously confirms and quantifies the bird-associated gene biomarker. This is accomplished with small pieces of DNA called primers that are complementary and specific to the genome to be detected. This qPCR technology avoids the cumbersome process of distinguishing DNA bands on a gel electrophoresis apparatus.

Through a heating process called thermal cycling, the double stranded DNA is denatured and inserted with complementary primers to create exact copies of the DNA fragment desired. This process is repeated rapidly many times ensuring an exponential progression in the number of copied DNA. If the primers are successful in finding a site on the DNA fragment that is specific to the genome to be studied, then billions of copies of the DNA fragment will be available and detected in real-time. The accumulation of DNA product is plotted as an amplification curve. The absence of an amplification curve indicates that the bird-associated *Helicobacter* gene biomarker is not present.

References

[1] Goldman, E. and Green, L. H. (2009). *Practical Handbook of Microbiology* (2nd ed) . Boca Raton, FL: CRC Press.
[2] Seymour, C., Lewis, R.G., Kim, M., Gagnon, D.F., Fox, J.G., Dewhirst, F.E., and Paster, B.J. Isolation of *Helicobacter* Strains from Wild Bird and Swine Feces. Appl. Environ. Microbiol. (1994) 60:3, 1025-1028.

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Preliminary Interpretation of Dog "Quantification" ID™ Results

Detection and quantification of the fecal Dog gene biomarker for Dog fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: April 13, 2016
Date Reported: April 25, 2016

SM #	Client #	Approximate Contribution of Dog Fecal Pollution in Water Sample	Comment
SM-6D13021	Site 1	**Low Concentration**	Low levels of dog fecal biomarker
SM-6D13022	Site 2	**Moderate Concentration**	Moderate levels of dog fecal biomarker
SM-6D13023	Site 3	**Moderate Concentration**	Moderate levels of dog fecal biomarker
SM-6D13024	Site 4	**Moderate Concentration**	Moderate levels of dog fecal biomarker
SM-6D13025	Site 5	**Moderate Concentration**	Moderate levels of dog fecal biomarker

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Dog Bacteroidetes Quantification ID™

Detection and quantification of the fecal Dog gene biomarker for Dog fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA

Submitter: R2T, Inc.
Date Received: April 13, 2016
Date Reported: April 25, 2016

SM #	Client #	Analysis Requested	Marker Quantified (copies/100 ml)	DNA Analytical Results
SM-6D13021	Site 1	Dog Bacteroidetes ID	2.60E+03	**Present**
SM-6D13022	Site 2	Dog Bacteroidetes ID	2.96E+04	**Present**
SM-6D13023	Site 3	Dog Bacteroidetes ID	1.22E+04	**Present**
SM-6D13024	Site 4	Dog Bacteroidetes ID	1.72E+04	**Present**
SM-6D13025	Site 5	Dog Bacteroidetes ID	2.49E+04	**Present**

Laboratory Comments

Submitter: R2T, Inc.

Report Date: April 25, 2016

Positive Results
In sample(s) classified as positive, the dog-associated fecal gene biomarker(s) was detected in both test replicates suggesting that dog fecal contamination is present in the water sample(s). The biomarker(s) serve as an indicator of the targeted fecal pollution, but the presence of the biomarker does not signify conclusively the presence of that form of fecal pollution. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Dog Fecal Reference Samples
The client is encouraged to submit fecal samples from suspected sources in the surrounding area in order to gain a better understanding of the concentration of the dog-associated fecal genetic marker in the geographic region of interest. A more precise interpretation would be available to the client with the submittal of such baseline samples.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to perform additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **sourcemolecular.com/tests**

DNA Analytical Method Explanation

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications to detect the target gene biomarker were run on an Applied Biosystems StepOnePlus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul containing sample extract, forward primer, reverse primer, probe and an optimized buffer. The following thermal cycling parameters were used: 95°C for 10 min and 40 cycles of 95°C for 15 s and 60°C for 1 min. All assays were run in duplicate. Absolute quantification was achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of known gene copy numbers.

For quality control purposes, a positive control consisting of Dog fecal DNA and a negative control consisting of PCR-grade water, were run alongside the sample(s) to ensure a properly functioning reaction and reveal any false negatives or false positives. The accumulation of PCR product is detected and graphed in an amplification plot. If the fecal indicator organism is absent in the sample, this accumulation is not detected and the sample is considered negative. If accumulation of PCR product is detected, the sample is considered positive.

Theory Explanation of Dog Bacteroidetes "Quantification" ID™

The phylum *Bacteroidetes* is composed of three large groups of bacteria with the best-known category being *Bacteroidaceae*. This family of gram-negative bacteria is found primarily in the intestinal tracts and mucous membranes of warm-blooded animals and is sometimes considered pathogenic.

Comprising *Bacteroidaceae* are the genus *Bacteroides* and *Prevotella*. The latter genus was originally classified within the former (i.e. *Bacteroides*), but since the 1990's it has been classified in a separate genus because of new chemical and biochemical findings. *Bacteroides* and *Prevotella* are gram-negative, anaerobic, rod-shaped bacteria that inhabitant of the oral, respiratory, intestinal, and urogenital cavities of humans, animals, and insects. They are sometimes pathogenic.

Fecal *Bacteroidetes* are considered for several reasons an interesting alternative to more traditional indicator organisms such as *E. coli* and *Enterococci*.[1] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems. This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*. Furthermore, these latter two organisms are facultative anaerobes and as such they can be problematic for monitoring purposes since it has been shown that they are able to proliferate in soil, sand and sediments.

The Dog Bacteroidetes ID™ service is designed around the principle that fecal *Bacteroidetes* are found in large quantities in feces of warm-blooded animals.[2,3,4,5,6] Furthermore, certain categories of *Bacteroidetes* have been shown to be predominately detected in dog. Within these *Bacteroidetes*, certain strains of the *Bacteroides* and *Prevotella* genus have been found in dog.[2,3,5,6] As such, these bacterial strains can be used as indicators of dog fecal contamination.

One of the advantages of the Dog Bacteroidetes ID™ service is that the entire water is sampled and filtered for fecal *Bacteroidetes*. As such, this method avoids the randomness effect of culturing and selecting bacterial isolates off a petri dish. This is a particular advantage for highly contaminated water systems with potential multiple sources of fecal contamination.

Accuracy of the results is possible because the method uses PCR DNA technology. PCR allows quantities of DNA to be amplified into large number of small copies of DNA sequences. This is accomplished with small pieces of DNA called primers that are complementary and specific to the genomes to be detected.

Through a heating process called thermal cycling, the double stranded DNA is denatured and inserted with complementary primers to create exact copies of the DNA fragment desired. This process is repeated rapidly many times ensuring an exponential progression in the number of copied DNA. If the primers are successful in finding a site on the DNA fragment that is specific to the genome to be studied, then billions of copies of the DNA fragment will be available and detected in real-time. The accumulation of DNA product is plotted as an amplification curve. The absence of an amplification curve would indicate that the dog *Bacteroidetes* gene biomarker is not present.

References

[1] Scott, Troy M., Rose, Joan B., Jenkins, Tracie M., Farrah, Samuel R., Lukasik, Jerzy **Microbial Source Tracking: Current Methodology and Future Directions.** Appl. Environ. Microbiol. (2002) 68: 5796-5803.

[2] Bernhard, A.E., and K.G. Field (2000a). **Identification of nonpoint sources of fecal pollution in coastal waters by using host-specific 16S ribosomal DNA genetic markers from fecal anaerobes.** Applied and Environmental Microbiology, 66: 1,587-1,594.

[3] Bernhard, A.E., and K.G. Field (2000b). **A PCR assay to discriminate human and ruminant feces on the basis of host differences in Bacteroides-Prevotella genes encoding 16S rRNA.** Applied and Environmental Microbiology, 66: 4,571-4,574.

[4] Kreader, C.A. (1995). **Design and evaluation of Bacteroides DNA probes for the specific detection of human fecal pollution.** Applied and Environmental Microbiology, 61: 1,171-1,179.

[5] Fogarty, Lisa R., Voytek, Mary **A.Comparison of Bacteroides-Prevotella 16S rRNA Genetic Markers for Fecal Samples from Different Animal Species** Appl. Environ. Microbiol. 2005 71: 5999-6007.

[6] Dick, Linda K., Bernhard, Anne E., Brodeur, Timothy J., Santo Domingo, Jorge W., Simpson, Joyce M., Walters, Sarah P., Field, Katharine G. **Host**

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Preliminary Interpretation of Canada Goose "Quantification" ID™ Results

Detection and quantification of the fecal Canada Goose gene biomarker for Canada Goose fecal contamination by quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: April 13, 2016
Date Reported: April 25, 2016

SM #	Client #	Approximate Contribution of Canada Goose Fecal Pollution in Water Sample	Comment
SM-6D13031	Site 1	Not Detected	Goose fecal biomarker not detected
SM-6D13032	Site 4	Not Detected	Goose fecal biomarker not detected

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Canada Goose Bacteroidetes Quantification ID™

Detection and quantification of the fecal Canada Goose gene biomarker for Canada Goose fecal contamination by quantitative Polymerase Chain Reaction (qPCR) DNA analytical

Submitter: R2T, Inc.
Date Received: April 13, 2016
Date Reported: April 25, 2016

SM #	Client #	Analysis Requested	Canada Goose Specific Marker Quantified*	DNA Analytical Results
SM-6D13031	Site 1	Goose Bacteroidetes ID	ND	Absent
SM-6D13032	Site 4	Goose Bacteroidetes ID	ND	Absent

ND: Not Detected

Laboratory Comments

Submitter: R2T, Inc.

Report Date: April 25, 2016

Negative Results
In sample(s) classified as negative, the goose-associated fecal gene biomarker(s) was either not detected in test replicates, one replicate was detected at a cycle threshold greater than 35 and the other was not, or one replicate was detected at a cycle threshold less than 35 and the other was not after repeated analysis. It is important to note that a negative result does not mean that the sample does not definitely have goose fecal contamination. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Goose Fecal Reference Samples
The client is encouraged to submit fecal samples from suspected sources in the surrounding area in order to gain a better understanding of the concentration of the goose-associated fecal genetic marker in the geographic region of interest. A more precise interpretation would be available to the client if baseline samples are provided.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to arrange for additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **sourcemolecular.com/tests**

DNA Analytical Method Explanation

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications to detect the target gene biomarker were run on an Applied Biosystems StepOne Plus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul sample extract, forward primer, reverse primer and an optimized buffer. The following thermal cycling parameters were used: 95°C for 10 min and 40 cycles of 95°C for 15 s and 60°C for 1 min. All assays were run in duplicate. Absolute quantification was achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of known gene copy numbers.

For quality control purposes, a positive control consisting of bird fecal DNA and a negative control consisting of PCR-grade water, were run alongside the sample(s) to ensure a properly functioning reaction and reveal any false negatives or false positives. The accumulation of PCR product is detected and graphed in an amplification plot. If the fecal indicator organism is absent in the sample, this accumulation is not detected and the sample is considered

Theory Explanation of Canada Goose Bacteroidetes "Quantification" ID™

The phylum *Bacteroidetes* is composed of three large groups of bacteria with the best-known category being *Bacteroidaceae*. This family of gram-negative bacteria is found primarily in the intestinal tracts and mucous membranes of warm-blooded animals and is sometimes considered pathogenic.

Comprising *Bacteroidaceae* are the genus *Bacteroides* and *Prevotella*. The latter genus was originally classified within the former (i.e. *Bacteroides*), but since the 1990's it has been classified in a separate genus because of new chemical and biochemical findings. *Bacteroides* and *Prevotella* are gram-negative, anaerobic, rod-shaped bacteria that inhabitant of the oral, respiratory, intestinal, and urogenital cavities of humans, animals, and insects. They are sometimes pathogenic.

Fecal *Bacteroidetes* are considered for several reasons an interesting alternative to more traditional indicator organisms such as *E. coli* and *Enterococci*.[1] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems. This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*. Furthermore, these latter two organisms are facultative anaerobes and as such they can be problematic for monitoring purposes since it has been shown that they are able to proliferate in soil, sand and sediments.

The Canada Goose Bacteroidetes ID™ service is designed around the principle that fecal *Bacteroidetes* are found in large quantities in feces of warm-blooded animals.[2,3,4,5,6] Furthermore, certain categories of *Bacteroidetes* have been shown to be predominately detected in Canada geese.[7] Within these *Bacteroidetes*, certain strains of the *Bacteroides* and *Prevotella* genus have been found in Canada geese.[7] As such, these bacterial strains can be used as indicators of Canada geese fecal contamination.

One of the advantages of the Canada Goose Bacteroidetes ID™ service is that the entire water is sampled and filtered for fecal *Bacteroidetes*. As such, this method avoids the randomness effect of culturing and selecting bacterial isolates off a petri dish. This is a particular advantage for highly contaminated water systems with potential multiple sources of fecal contamination.
Accuracy of the results is possible because the method uses PCR DNA technology. PCR allows quantities of DNA to be amplified into large number of small copies of DNA sequences. This is accomplished with small pieces of DNA called primers that are complementary and specific to the genomes to be detected.

Through a heating process called thermal cycling, the double stranded DNA is denatured and inserted with complementary primers to create exact copies of the DNA fragment desired. This process is repeated rapidly many times ensuring an exponential progression in the number of copied DNA. If the primers are successful in finding a site on the DNA fragment that is specific to the genome to be studied, then billions of copies of the DNA fragment will be available for detection in real-time.

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[1] Scott, Troy M., Rose, Joan B., Jenkins, Tracie M., Farrah, Samuel R., Lukasik, Jerzy **Microbial Source Tracking: Current Methodology and Future Directions.** Appl. Environ. Microbiol. (2002) 68: 5796-5803.

[2] Bernhard, A.E., and K.G. Field (2000a). **Identification of nonpoint sources of fecal pollution in coastal waters by using host-specific 16S ribosomal DNA genetic markers from fecal anaerobes.** Applied and Environmental Microbiology, 66: 1,587-1,594.

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[7] Fremaux, B., Boa, T., Yost, C. K. **Quantitative Real-Time PCR Asays for Sensitive Detection of Canada Goose-Specific Fecal Pollution in Water Sources.** Appl. Environ. Microbiol. 2010 76: 4886-4889.

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Preliminary Interpretation of Human Fecal Pollution ID™ Results

Detection and quantification of the fecal Human gene biomarker for Human fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: April 13, 2016
Date Reported: April 25, 2016

SM #	Client #	Approximate Contribution of Human Fecal Pollution in Water Sample	Comment
SM-6D13011	Site 1	**Trace**	Trace levels of 1 human fecal biomarker
SM-6D13012	Site 2	**Trace**	Trace levels of 1 human fecal biomarker
SM-6D13013	Site 3	**Low Concentration**	Low levels of 1 human fecal biomarker
SM-6D13014	Site 4	**Trace**	Trace levels of 1 human fecal biomarker
SM-6D13015	Site 5	**Trace**	Trace levels of 1 human fecal biomarker

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Human Fecal Pollution ID™ Quantification

Detection and quantification of the fecal Human gene biomarker for Human fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: April 13, 2016
Date Reported: April 25, 2016

SM #	Client #	Analysis Requested	Target	Marker Quantified (copies/100 ml)	DNA Analytical Results
SM-6D13011	Site 1	Human Bacteroidetes ID 1	Dorei	<LOQ	**Present (Trace)**
SM-6D13012	Site 2	Human Bacteroidetes ID 1	Dorei	<LOQ	**Present (Trace)**
SM-6D13013	Site 3	Human Bacteroidetes ID 1	Dorei	2.94E+02	**Present**
SM-6D13014	Site 4	Human Bacteroidetes ID 1	Dorei	<LOQ	**Present (Trace)**
SM-6D13015	Site 5	Human Bacteroidetes ID 1	Dorei	<LOQ	**Present (Trace)**
SM-6D13016	Site 1	Human Bacteroidetes ID 2	EPA	ND	Absent
SM-6D13017	Site 2	Human Bacteroidetes ID 2	EPA	ND	Absent
SM-6D13018	Site 3	Human Bacteroidetes ID 2	EPA	ND	Absent
SM-6D13019	Site 4	Human Bacteroidetes ID 2	EPA	ND	Absent
SM-6D13020	Site 5	Human Bacteroidetes ID 2	EPA	ND	Absent

<LOQ: Below level of quantification
ND: Not Detected

Laboratory Comments

Submitter: R2T, Inc.

Report Date: April 25, 2016

Negative Results
In sample(s) classified as negative, the human-associated Bacteroidetes gene biomarker(s) was either not detected in test replicates, one replicate was detected at a cycle threshold greater than 35 and the other was not, or one replicate was detected at a cycle threshold less than 35 and the other was not after repeated analysis. It is important to note that a negative result does not mean that the sample does not definitely have human fecal contamination. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.
In order to strengthen the result, a negative sample should be analyzed further for human fecal contamination with other DNA analytical tests. A list of human fecal ID tests can be found at **www.sourcemolecular.com/human**.

Positive Results
In sample(s) classified as positive, the human-associated Bacteroidetes gene biomarker(s) was detected in both test replicates suggesting that human fecal contamination is present in the water sample(s). The biomarker(s) serve as an indicator of the targeted fecal pollution, but the presence of the biomarker does not signify conclusively the presence of that form of fecal pollution. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Trace Results
In sample(s) classified as trace, the human-associated Bacteroidetes biomarker was detected in both test replicates but in quantities below the limit of quantification. This result indicates that fecal indicators associated with human were present in the sample(s) but in low concentrations.

Human Fecal Reference Samples
The client is encouraged to submit samples from the surrounding wastewater facilities and/or septic systems in order to gain a better understanding of the concentration of the human-associated fecal Bacteroidetes genetic marker as well as the concentration of the general fecal Bacteroidetes genetic marker in the geographic region of interest. A more precise interpretation would be available to the client with the submittal of such baseline samples.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to perform additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **www.sourcemolecular.com/tests**

DNA Analytical Method Explanation

All reagents, chemicals and apparatuses were verified and inspected beforehand to ensure that no false negatives or positives could be generated. In that regard, positive and negative controls were run to attest the integrity of the analysis. All inspections and controls tested negative for possible extraneous contaminates, including PCR inhibitors.

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications were run on an Applied Biosystems StepOnePlus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul containing sample extract, forward primer, reverse primer, probe and an optimized buffer. The following thermal cycling parameters were used: 50°C for 2 min, 95°C for 10 min and 40 cycles of 95°C for 15 s and 60°C for 1 min. All assays were run in duplicate. Absolute quantification was achieved by extrapolating genome copy numbers from standard curves generated from serial dilutions of Human specific and generic genomic DNA.

For quality control purposes, a positive control consisting of appropriate genomic DNA and a negative control consisting of PCR-grade water were run alongside the sample(s) to ensure a properly functioning reaction and reveal any false negatives or false positives.

Human Bacteroidetes ID™ Species*: B. dorei*

The **Human Bacteroidetes ID™ Species*: B. dorei*** service targets the species *Bacteroides dorei*. *B. dorei* is an anaerobe that is frequently shed from the gastrointestinal tract and isolated from human feces worldwide. It is a newly discovered species that is widely distributed in the USA.[1,2] The human-associated marker DNA sequence is located on the 16S rRNA gene of *B. dorei*.[3] The marker is the microbial source tracking (MST) marker of choice for detecting human fecal pollution due to its exceptional sensitivity and specificity. Internal validations have been conducted on hundreds of sewage, septage, human and animal host fecal samples collected from throughout the U.S and archived in the Source Molecular fecal bank. The marker has also been evaluated in both inland and coastal waters. A recent, comprehensive, multi-laboratory MST method evaluation study, exploring the performance of current MST methods, concluded the *B. dorei* qPCR assay to be the top performing human-associated assay amongst those tested. The success and consistency of this marker in numerous studies around the world[1,3,4] makes the **Human Bacteroidetes ID™ Species*: B. dorei*** service the primary service for identifying human fecal pollution at Source Molecular.

Fecal *Bacteroidetes* are considered for several reasons an interesting alternative to more traditional indicator organisms such as *E. coli* and *Enterococci*.[5] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems. This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*.

The Human Bacteroidetes ID™ service is designed around the principle that fecal *Bacteroidetes* are found in large quantities in feces of warm-blooded animals.[3,5,6,7,8] Furthermore, certain strains of *Bacteroidetes* have been found to be associated with humans.[3,6] As such, these bacterial strains can be used as indicators of human fecal contamination.

Accuracy of the results is possible because the method amplifies DNA into a large number of small copies of the gene biomarker of interest. This is accomplished with small pieces of DNA called primers that are complementary and specific to the unique *B. dorei* DNA sequence. Through a heating process called thermal cycling, the double stranded DNA is denatured, hybridized to the complementary primers and amplified to create many copies of the DNA fragment desired. If the primers are successful in finding a site on the DNA fragment that is specific to the *B. dorei* DNA sequence, then billions of copies of the DNA fragment will be available and detected in real-time. The accumulation of DNA product is plotted as an amplification curve by the qPCR software. The absence of an amplification curve indicates that the *B. dorei* gene biomarker is not detected in the water sample because it is either not present or present at concentrations below the analytical detection limit.

To strengthen the validity of the results, additional tests targeting other high-ranking, human-associated *Bacteroidetes* species should be performed, such as
Human Bacteroidetes ID™ Species*: B. stercoris*,
Human Bacteroidetes ID™ Species*: B. fragilis,* and
Human Bacteroidetes ID™ Species*: B. thetaiotaomicron*.

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Human Bacteroidetes ID™: EPA Developed Assay

The **Human Bacteroidetes ID™: EPA Developed Assay** service targets a functional gene biomarker in *Bacteroidales*-like anaerobic bacteria that is present in high concentrations in the human gut. The U.S Environmental Protection Agency (U.S. EPA) was the first to target the biomarker using quantitative Polymerase Chain Reaction (qPCR) technology in order to detect ground and surface waters impacted by human fecal pollution.[1] Since it's development, the assay has been used succesfully around the U.S to identify fecal pollution originating from human sources, such as sewage and septage wastewaters.

The U.S. EPA Developed assay has been shown to be highly associated with human fecal pollution. It has successfully been validated in multiple nationwide studies using at least 300 individual reference fecal material from 22 different animal species known to commonly contaminate environmental waters.[1,2] A reported 99.2% specificity to human fecal material makes this one of the leading assays to confirm the presence of fecal contamination that is of human origin.[1] The *Bacteroidales*-like bacteria is widely distributed. It was detected in 100% of hundreds of sewage and human reference fecal samples collected from more than 20 human populations, making it highly sensitive. Internal validations have also been conducted on hundreds of wastewater, human and animal host fecal samples archived in the Source Molecular fecal bank.

Fecal anaerobic bacteria are considered for several reasons an interesting alternative to more traditional fecal indicator organisms such as *E. coli* and *Enterococci*.[3] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems.[3] This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*.

The **Human Bacteroidetes ID™: EPA Developed Assay** service is designed around the principle that fecal *Bacteroidales*-like bacteria are found in large quantities in feces of warm-blooded animals.[4,5] Furthermore, certain strains have been shown to be associated with humans.[4,5] As such, these bacterial strains can be used as indicators of human fecal contamination. An advantage of the Human Bacteroidetes ID™ service is that the entire portion of water sampled is filtered to concentrate bacteria. As such, this method avoids the randomness effect of culturing and selecting bacterial isolates. This is an advantage for highly contaminated water systems with potential multiple sources of fecal contamination.

Accuracy of the results is possible because the method amplifies DNA into a large number of copies of the gene biomarker of interest. This is accomplished with small pieces of DNA called primers that are complementary and specific to the gene biomarker. Through a heating process called thermal cycling, the double stranded DNA is denatured, hybridized to the complementary primers and amplified to create many copies of the DNA fragment. If the primers are successful in finding a site on the DNA fragment that is specific to the human-associated biomarker, billions of copies of the DNA fragment will be available and detected in real-time. The accumulation of DNA product is plotted as an amplification curve by qPCR software. The absence of an amplification curve indicates that the gene biomarker is not detectable in the water sample either because it is not present or present at concentrations below the analytical detection limit.

To strengthen the validity of the results, additional tests targeting other high-ranking, human-associated *Bacteroidetes* species should be performed, such as
Human Bacteroidetes ID™ Species*: B. dorei*,
Human Bacteroidetes ID™ Species*: B. fragilis,* and
Human Bacteroidetes ID™ Species*: B. stercoris*

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Preliminary Interpretation of Ruminant Fecal ID™ "Quantification" Results

Detection and quantification of Ruminant-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: April 13, 2016
Date Reported: April 25, 2016

SM #	Client #	Approximate Contribution of Ruminant Fecal Pollution in Water Sample	Comment
SM-6D13033	Site 2	Not Detected	Ruminant fecal biomarker not detected
SM-6D13034	Site 3	Not Detected	Ruminant fecal biomarker not detected
SM-6D13035	Site 5	Not Detected	Ruminant fecal biomarker not detected

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Ruminant Fecal ID™ Quantification

Detection and quantification of Ruminant-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: April 13, 2016
Date Reported: April 25, 2016

SM #	Client #	Analysis Requested	Marker Quantified (copies/100 ml)	DNA Analytical Results
SM-6D13033	Site 2	Ruminant Fecal ID	ND	Absent
SM-6D13034	Site 3	Ruminant Fecal ID	ND	Absent
SM-6D13035	Site 5	Ruminant Fecal ID	ND	Absent

ND: Not Detected

Laboratory Comments

Submitter: R2T, Inc.

Report Date: April 25, 2016

Negative Results
In sample(s) classified as negative, the ruminant-associated fecal gene biomarker(s) was either not detected in test replicates, one replicate was detected at a cycle threshold greater than 35 and the other was not, or one replicate was detected at a cycle threshold less than 35 and the other was not after repeated analysis. It is important to note that a negative result does not mean that the sample does not definitely have ruminant fecal contamination. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Ruminant Fecal Reference Samples
The client is encouraged to submit fecal samples from suspected sources in the surrounding area in order to gain a better understanding of the concentration of the ruminant-associated fecal genetic marker in the geographic region of interest. A more precise interpretation would be available to the client if baseline samples are provided.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to arrange for additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **sourcemolecular.com/tests**

DNA Analytical Method Explanation

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications to detect the target gene biomarker were run on an Applied Biosystems StepOnePlus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul containing sample extract, forward primer, reverse primer, probe and an optimized buffer. All assays were run in duplicate. Absolute quantification was achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of known gene copy numbers.

For quality control purposes, a positive control consisting of ruminant fecal DNA and a negative control consisting of PCR-grade water, were run alongside the sample(s) to ensure a properly functioning reaction and to reveal any false negatives or false positives. The accumulation of PCR product was detected and graphed in an amplification plot. If the fecal indicator organism was absent in the sample, this accumulation was not detected and the sample was considered negative. If accumulation of PCR product was detected, the sample was considered positive.

Theory Explanation of Ruminant Fecal ID™ Quantification

The phylum *Bacteroidetes* is composed of three large groups of bacteria with the best-known category being *Bacteroidaceae* . This family of gram-negative bacteria is found primarily in the intestinal tracts and mucous membranes of warm-blooded animals and is sometimes considered pathogenic.

Comprising *Bacteroidaceae* are the genus *Bacteroides* and *Prevotella*. The latter genus was originally classified within the former (*i.e.Bacteroides*), but since the 1990's findings. *Bacteroides* and *Prevotella* are gram-negative, anaerobic, rod-shaped bacteria that inhabitant of the oral, respiratory, intestinal, and urogenital cavities of humans, animals and insects. They are sometimes pathogenic.

Fecal *Bacteroidetes* are considered for several reasons an interesting alternative to more traditional indicator organisms such as *E. coli* and *Enterococci*.[1] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems. This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*. Furthermore, these latter two organisms are facultative anaerobes and as such they can be problematic for monitoring purposes since it has been shown that they are able to proliferate in soil, sand and sediments.

The Ruminant Fecal Quantification ID™ service is designed around the principle that fecal *Bacteroidetes* are found in large quantities in feces of warm-blooded animals.[2,3,4,5,6] Furthermore, certain categories of *Bacteroidetes* have been shown to be predominately detected in ruminants. Within these *Bacteroidetes*, certain genetic sequences in the *Bacteroides* and *Prevotella* genus have been found in ruminants.[7] As such, these bacterial strains can be used as indicators of ruminant fecal contamination.

One of the advantages of the Ruminant Fecal Quantification ID™ service is that the entire water is sampled and filtered for fecal *Bacteroidetes*. As such, this method avoids the randomness effect of culturing and selecting bacterial isolates off a petri dish. This is a particular advantage for highly contaminated water systems with potential multiple sources of fecal contamination.

Accuracy of the results is possible because the method uses PCR DNA technology. PCR allows quantities of DNA to be amplified into large number of small copies of DNA sequences. This is accomplished with small pieces of DNA called primers that are complementary and specific to the genomes to be detected. Through a heating process called thermal cycling, the double stranded DNA is denatured and inserted with complementary primers to create exact copies of the DNA fragment desired. This process is repeated rapidly many times ensuring an exponential progression in the number of copied DNA. If the primers are successful in finding a site on the DNA fragment that is specific to the genome to be studied, then billions of copies of the DNA fragment will be available and detected in real-time. Quantitative PCR (qPCR) adds a variant to the PCR process by inserting of a fluorescent probe within the primer set. This fluorescent probe serves as a molecular beacon for the quantification step. During each PCR cycle, quantitative PCR monitors the fluorescence emitted during the reaction. This is done in real-time during the first PCR cycles as a way to quantify the targeted gene. Absolute quantification is achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of plasmid DNA containing a known amount of the ruminant-specific biomarker. The Ruminant Fecal Quantification ID™ service uses qPCR to simultaneously confirm and quantify the ruminant- specific fecal *Bacteroidetes* genetic biomarker. This PCR technology avoids the cumbersome process of distinguishing DNA bands on a gel electrophoresis apparatus.

References

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Preliminary Interpretation of Bird Fecal ID™ Quantification Results

Detection and quantification of Bird-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: May 18, 2016
Date Reported: June 2, 2016

SM #	Client #	Approximate Contribution of Bird Fecal Pollution in Water Sample	Comment
SM-6E18032	Site 1	**Trace**	Trace levels of bird fecal biomarker
SM-6E18033	Site 2	**Trace**	Trace levels of bird fecal biomarker
SM-6E18034	Site 3	**Trace**	Trace levels of bird fecal biomarker
SM-6E18035	Site 4	**Trace**	Trace levels of bird fecal biomarker
SM-6E18036	Site 5	**Trace**	Trace levels of bird fecal biomarker

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Bird Fecal ID™ Quantification

Detection and quantification of Bird-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: May 18, 2016
Date Reported: June 2, 2016

SM #	Client #	Analysis Requested	Bird Specific Marker Quantified*	DNA Analytical Results
SM-6E18032	Site 1	Bird Fecal ID	<LOQ	**Present (Trace)**
SM-6E18033	Site 2	Bird Fecal ID	<LOQ	**Present (Trace)**
SM-6E18034	Site 3	Bird Fecal ID	<LOQ	**Present (Trace)**
SM-6E18035	Site 4	Bird Fecal ID	<LOQ	**Present (Trace)**
SM-6E18036	Site 5	Bird Fecal ID	<LOQ	**Present (Trace)**

<LOQ: Below level of quantification

Trace Results
In sample(s) classified as trace, the bird-associated fecal biomarker was detected in both test replicates but in quantities below the limit of quantification. This result indicates that fecal indicators associated with bird were present in the sample(s) but in low concentrations.

Bird Fecal Reference Samples
The client is encouraged to submit fecal samples from suspected sources in the surrounding area in order to gain a better understanding of the concentration of the bird-associated fecal genetic in the geographic region of interest. A more precise interpretation would be available to the client with the submittal of such baseline samples.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to perform additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **sourcemolecular.com/tests**

DNA Analytical Method Explanation

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications to detect the target gene biomarker were run on an Applied Biosystems StepOnePlus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul containing sample extract, forward primer, reverse primer and an optimized buffer. All assays were run in duplicate. Absolute quantification was achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of known gene copy numbers.

For quality control purposes, a positive control consisting of bird fecal DNA or plasmid containing the target and a negative control consisting of PCR-grade water, were run alongside the sample(s) to ensure a properly functioning reaction and to reveal any false negatives or false positives. The accumulation of PCR product was detected and graphed in an amplification plot. If the target gene biomarker was absent in the sample, this accumulation was not detected and the sample was considered negative. If accumulation of PCR product was detected, the sample was considered positive.

Theory Explanation of Bird Fecal ID™ Quantification

The genus *Helicobacter* is a group of gram-negative, microaerophilic bacteria that were initially classified under the *Campylobacter* genus prior to 1989. Since then, they have been reclassified into the genus *Helicobacter* after 16S rRNA sequencing differentiated them from other *Campylobacter* species. This group of bacteria typically have a spiral, curved or fusiform morphology with multiple flagella allowing them to rapidly maneuver in the intestinal mucous lining of their hosts. *Helicobacter* species colonize the gastrointestinal tract of mammals and birds and are shed in feces. There are approximately 20 strains of *Helicobacter*[1]. Certain strains, such as *Helicobacter pylori,* are pathogenic to humans causing chronic gastritis, peptic ulcers and stomach cancer.

The Bird Fecal Quantification ID™ service is designed around the principle that certain DNA sequences contained within strains of the *Helicobacter* genus are specific to wild birds. These *Helicobacter* sequences can be used as indicators of bird fecal contamination. Several species have been isolated from specific animal hosts such as *H. fennelliae* from humans, *H. hepaticus* from mice and *H. felis* from cats and dogs.[1] The Bird Fecal Quantification ID™ service targets a bird-associated gene biomarker in *Helicobacter pametensis.*[2] The biomarker is present at different degrees in the feces of various birds including but not limited to gull, goose, chicken, pigeon and duck.

One of the advantages of the Bird Fecal Quantification ID™ service is that the entire population of *Helicobacter* of the selected portion of the water sample is screened. As such, this method avoids the randomness effect of selecting isolates off a petri dish.

Accuracy of the results is possible because the method uses qPCR DNA technology. qPCR simulataneously confirms and quantifies the bird-associated gene biomarker. This is accomplished with small pieces of DNA called primers that are complementary and specific to the genome to be detected. This qPCR technology avoids the cumbersome process of distinguishing DNA bands on a gel electrophoresis apparatus.

Through a heating process called thermal cycling, the double stranded DNA is denatured and inserted with complementary primers to create exact copies of the DNA fragment desired. This process is repeated rapidly many times ensuring an exponential progression in the number of copied DNA. If the primers are successful in finding a site on the DNA fragment that is specific to the genome to be studied, then billions of copies of the DNA fragment will be available and detected in real-time. The accumulation of DNA product is plotted as an amplification curve. The absence of an amplification curve indicates that the bird-associated *Helicobacter* gene biomarker is not present.

References

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Preliminary Interpretation of Dog "Quantification" ID™ Results

Detection and quantification of the fecal Dog gene biomarker for Dog fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: May 18, 2016
Date Reported: June 2, 2016

SM #	Client #	Approximate Contribution of Dog Fecal Pollution in Water Sample	Comment
SM-6E18027	Site 1	**Low Concentration**	Low levels of dog fecal biomarker
SM-6E18028	Site 2	**Low Concentration**	Low levels of dog fecal biomarker
SM-6E18029	Site 3	**Low Concentration**	Low levels of dog fecal biomarker
SM-6E18030	Site 4	**Low Concentration**	Low levels of dog fecal biomarker
SM-6E18031	Site 5	**Moderate Concentration**	Moderate levels of dog fecal biomarker

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Dog Bacteroidetes Quantification ID™

Detection and quantification of the fecal Dog gene biomarker for Dog fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA

Submitter: R2T, Inc.
Date Received: May 18, 2016
Date Reported: June 2, 2016

SM #	Client #	Analysis Requested	Marker Quantified (copies/100 ml)	DNA Analytical Results
SM-6E18027	Site 1	Dog Bacteroidetes ID	4.61E+03	Present
SM-6E18028	Site 2	Dog Bacteroidetes ID	5.03E+03	Present
SM-6E18029	Site 3	Dog Bacteroidetes ID	7.68E+03	Present
SM-6E18030	Site 4	Dog Bacteroidetes ID	7.69E+03	Present
SM-6E18031	Site 5	Dog Bacteroidetes ID	1.53E+04	Present

Laboratory Comments

Submitter: R2T, Inc.

Report Date: June 2, 2016

Positive Results
In sample(s) classified as positive, the dog-associated fecal gene biomarker(s) was detected in both test replicates suggesting that dog fecal contamination is present in the water sample(s). The biomarker(s) serve as an indicator of the targeted fecal pollution, but the presence of the biomarker does not signify conclusively the presence of that form of fecal pollution. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Dog Fecal Reference Samples
The client is encouraged to submit fecal samples from suspected sources in the surrounding area in order to gain a better understanding of the concentration of the dog-associated fecal genetic marker in the geographic region of interest. A more precise interpretation would be available to the client with the submittal of such baseline samples.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to perform additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **sourcemolecular.com/tests**

DNA Analytical Method Explanation

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications to detect the target gene biomarker were run on an Applied Biosystems StepOnePlus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul containing sample extract, forward primer, reverse primer, probe and an optimized buffer. The following thermal cycling parameters were used: 95°C for 10 min and 40 cycles of 95°C for 15 s and 60°C for 1 min. All assays were run in duplicate. Absolute quantification was achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of known gene copy numbers.

For quality control purposes, a positive control consisting of Dog fecal DNA and a negative control consisting of PCR-grade water, were run alongside the sample(s) to ensure a properly functioning reaction and reveal any false negatives or false positives. The accumulation of PCR product is detected and graphed in an amplification plot. If the fecal indicator organism is absent in the sample, this accumulation is not detected and the sample is considered negative. If accumulation of PCR product is detected, the sample is considered positive.

Theory Explanation of Dog Bacteroidetes "Quantification" ID^{TM}

The phylum *Bacteroidetes* is composed of three large groups of bacteria with the best-known category being *Bacteroidaceae*. This family of gram-negative bacteria is found primarily in the intestinal tracts and mucous membranes of warm-blooded animals and is sometimes considered pathogenic.

Comprising *Bacteroidaceae* are the genus *Bacteroides* and *Prevotella*. The latter genus was originally classified within the former (i.e. *Bacteroides*), but since the 1990's it has been classified in a separate genus because of new chemical and biochemical findings. *Bacteroides* and *Prevotella* are gram-negative, anaerobic, rod-shaped bacteria that inhabitant of the oral, respiratory, intestinal, and urogenital cavities of humans, animals, and insects. They are sometimes pathogenic.

Fecal *Bacteroidetes* are considered for several reasons an interesting alternative to more traditional indicator organisms such as *E. coli* and *Enterococci*.[1] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems. This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*. Furthermore, these latter two organisms are facultative anaerobes and as such they can be problematic for monitoring purposes since it has been shown that they are able to proliferate in soil, sand and sediments.

The Dog Bacteroidetes ID^{TM} service is designed around the principle that fecal *Bacteroidetes* are found in large quantities in feces of warm-blooded animals.[2,3,4,5,6] Furthermore, certain categories of *Bacteroidetes* have been shown to be predominately detected in dog. Within these *Bacteroidetes*, certain strains of the *Bacteroides* and *Prevotella* genus have been found in dog.[2,3,5,6] As such, these bacterial strains can be used as indicators of dog fecal contamination.

One of the advantages of the Dog Bacteroidetes ID^{TM} service is that the entire water is sampled and filtered for fecal *Bacteroidetes*. As such, this method avoids the randomness effect of culturing and selecting bacterial isolates off a petri dish. This is a particular advantage for highly contaminated water systems with potential multiple sources of fecal contamination.

Accuracy of the results is possible because the method uses PCR DNA technology. PCR allows quantities of DNA to be amplified into large number of small copies of DNA sequences. This is accomplished with small pieces of DNA called primers that are complementary and specific to the genomes to be detected.

Through a heating process called thermal cycling, the double stranded DNA is denatured and inserted with complementary primers to create exact copies of the DNA fragment desired. This process is repeated rapidly many times ensuring an exponential progression in the number of copied DNA. If the primers are successful in finding a site on the DNA fragment that is specific to the genome to be studied, then billions of copies of the DNA fragment will be available and detected in real-time. The accumulation of DNA product is plotted as an amplification curve. The absence of an amplification curve would indicate that the dog *Bacteroidetes* gene biomarker is not present.

References

[1] Scott, Troy M., Rose, Joan B., Jenkins, Tracie M., Farrah, Samuel R., Lukasik, Jerzy **Microbial Source Tracking: Current Methodology and Future Directions.** Appl. Environ. Microbiol. (2002) 68: 5796-5803.

[2] Bernhard, A.E., and K.G. Field (2000a). **Identification of nonpoint sources of fecal pollution in coastal waters by using host-specific 16S ribosomal DNA genetic markers from fecal anaerobes.** Applied and Environmental Microbiology, 66: 1,587-1,594.

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[4] Kreader, C.A. (1995). **Design and evaluation of Bacteroides DNA probes for the specific detection of human fecal pollution.** Applied and Environmental Microbiology, 61: 1,171-1,179.

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[6] Dick, Linda K., Bernhard, Anne E., Brodeur, Timothy J., Santo Domingo, Jorge W., Simpson, Joyce M., Walters, Sarah P., Field, Katharine G. **Host**

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Preliminary Interpretation of Canada Goose "Quantification" ID™ Results

Detection and quantification of the fecal Canada Goose gene biomarker for Canada Goose fecal contamination by quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: May 18, 2016
Date Reported: June 2, 2016

SM #	Client #	Approximate Contribution of Canada Goose Fecal Pollution in Water Sample	Comment
SM-6E18037	Site 1	Not Detected	Goose fecal biomarker not detected
SM-6E18038	Site 4	Not Detected	Goose fecal biomarker not detected

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Canada Goose Bacteroidetes Quantification ID™

Detection and quantification of the fecal Canada Goose gene biomarker for Canada Goose fecal contamination by quantitative Polymerase Chain Reaction (qPCR) DNA analytical

Submitter: R2T, Inc.
Date Received: May 18, 2016
Date Reported: June 2, 2016

SM #	Client #	Analysis Requested	Canada Goose Specific Marker Quantified*	DNA Analytical Results
SM-6E18037	Site 1	Goose Bacteroidetes ID	ND	Absent
SM-6E18038	Site 4	Goose Bacteroidetes ID	ND	Absent

ND: Not Detected

Laboratory Comments

Submitter: R2T, Inc.

Report Date: June 2, 2016

Negative Results
In sample(s) classified as negative, the goose-associated fecal gene biomarker(s) was either not detected in test replicates, one replicate was detected at a cycle threshold greater than 35 and the other was not, or one replicate was detected at a cycle threshold less than 35 and the other was not after repeated analysis. It is important to note that a negative result does not mean that the sample does not definitely have goose fecal contamination. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Goose Fecal Reference Samples
The client is encouraged to submit fecal samples from suspected sources in the surrounding area in order to gain a better understanding of the concentration of the goose-associated fecal genetic marker in the geographic region of interest. A more precise interpretation would be available to the client if baseline samples are provided.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to arrange for additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **sourcemolecular.com/tests**

DNA Analytical Method Explanation

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications to detect the target gene biomarker were run on an Applied Biosystems StepOne Plus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul sample extract, forward primer, reverse primer and an optimized buffer. The following thermal cycling parameters were used: 95°C for 10 min and 40 cycles of 95°C for 15 s and 60°C for 1 min. All assays were run in duplicate. Absolute quantification was achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of known gene copy numbers.

For quality control purposes, a positive control consisting of bird fecal DNA and a negative control consisting of PCR-grade water, were run alongside the sample(s) to ensure a properly functioning reaction and reveal any false negatives or false positives. The accumulation of PCR product is detected and graphed in an amplification plot. If the fecal indicator organism is absent in the sample, this accumulation is not detected and the sample is considered

Theory Explanation of Canada Goose Bacteroidetes "Quantification" ID™

The phylum *Bacteroidetes* is composed of three large groups of bacteria with the best-known category being *Bacteroidaceae*. This family of gram-negative bacteria is found primarily in the intestinal tracts and mucous membranes of warm-blooded animals and is sometimes considered pathogenic.

Comprising *Bacteroidaceae* are the genus *Bacteroides* and *Prevotella*. The latter genus was originally classified within the former (i.e. *Bacteroides*), but since the 1990's it has been classified in a separate genus because of new chemical and biochemical findings. *Bacteroides* and *Prevotella* are gram-negative, anaerobic, rod-shaped bacteria that inhabitant of the oral, respiratory, intestinal, and urogenital cavities of humans, animals, and insects. They are sometimes pathogenic.

Fecal *Bacteroidetes* are considered for several reasons an interesting alternative to more traditional indicator organisms such as *E. coli* and *Enterococci*.[1] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems. This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*. Furthermore, these latter two organisms are facultative anaerobes and as such they can be problematic for monitoring purposes since it has been shown that they are able to proliferate in soil, sand and sediments.

The Canada Goose Bacteroidetes ID™ service is designed around the principle that fecal *Bacteroidetes* are found in large quantities in feces of warm-blooded animals.[2,3,4,5,6] Furthermore, certain categories of *Bacteroidetes* have been shown to be predominately detected in Canada geese.[7] Within these *Bacteroidetes*, certain strains of the *Bacteroides* and *Prevotella* genus have been found in Canada geese.[7] As such, these bacterial strains can be used as indicators of Canada geese fecal contamination.

One of the advantages of the Canada Goose Bacteroidetes ID™ service is that the entire water is sampled and filtered for fecal *Bacteroidetes*. As such, this method avoids the randomness effect of culturing and selecting bacterial isolates off a petri dish. This is a particular advantage for highly contaminated water systems with potential multiple sources of fecal contamination.
Accuracy of the results is possible because the method uses PCR DNA technology. PCR allows quantities of DNA to be amplified into large number of small copies of DNA sequences. This is accomplished with small pieces of DNA called primers that are complementary and specific to the genomes to be detected.

Through a heating process called thermal cycling, the double stranded DNA is denatured and inserted with complementary primers to create exact copies of the DNA fragment desired. This process is repeated rapidly many times ensuring an exponential progression in the number of copied DNA. If the primers are successful in finding a site on the DNA fragment that is specific to the genome to be studied, then billions of copies of the DNA fragment will be available for detection in real-time.

References

[1] Scott, Troy M., Rose, Joan B., Jenkins, Tracie M., Farrah, Samuel R., Lukasik, Jerzy **Microbial Source Tracking: Current Methodology and Future Directions.** Appl. Environ. Microbiol. (2002) 68: 5796-5803.

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[4] Kreader, C.A. (1995). **Design and evaluation of Bacteroides DNA probes for the specific detection of human fecal pollution.** Applied and Environmental Microbiology, 61: 1,171-1,179.

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[7] Fremaux, B., Boa, T., Yost, C. K. **Quantitative Real-Time PCR Asays for Sensitive Detection of Canada Goose-Specific Fecal Pollution in Water Sources.** Appl. Environ. Microbiol. 2010 76: 4886-4889.

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Preliminary Interpretation of Human Fecal Pollution ID™ Results

Detection and quantification of the fecal Human gene biomarker for Human fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: May 18, 2016
Date Reported: June 2, 2016

SM #	Client #	Approximate Contribution of Human Fecal Pollution in Water Sample	Comment
SM-6E18017	Site 1	**Low Concentration**	Low/Trace levels of 2 human fecal biomarkers
SM-6E18018	Site 2	**Low Concentration**	Low/Trace levels of 2 human fecal biomarkers
SM-6E18019	Site 3	**Low Concentration**	Low/Trace levels of 2 human fecal biomarkers
SM-6E18020	Site 4	**Low Concentration**	Low levels of 2 human fecal biomarkers
SM-6E18021	Site 5	**Low Concentration**	Low levels of 2 human fecal biomarkers

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Human Fecal Pollution ID™ Quantification

Detection and quantification of the fecal Human gene biomarker for Human fecal contamination by real-time quantitative Polymerase Chain Reaction (qPCR) DNA analytical technology

Submitter: R2T, Inc.
Date Received: May 18, 2016
Date Reported: June 2, 2016

SM #	Client #	Analysis Requested	Target	Marker Quantified (copies/100 ml)	DNA Analytical Results
SM-6E18017	Site 1	Human Bacteroidetes ID 1	Dorei	5.99E+02	**Present**
SM-6E18018	Site 2	Human Bacteroidetes ID 1	Dorei	7.58E+02	**Present**
SM-6E18019	Site 3	Human Bacteroidetes ID 1	Dorei	7.39E+02	**Present**
SM-6E18020	Site 4	Human Bacteroidetes ID 1	Dorei	6.93E+02	**Present**
SM-6E18021	Site 5	Human Bacteroidetes ID 1	Dorei	1.15E+03	**Present**
SM-6E18022	Site 1	Human Bacteroidetes ID 2	EPA	<LOQ	**Present (Trace)**
SM-6E18023	Site 2	Human Bacteroidetes ID 2	EPA	<LOQ	**Present (Trace)**
SM-6E18024	Site 3	Human Bacteroidetes ID 2	EPA	<LOQ	**Present (Trace)**
SM-6E18025	Site 4	Human Bacteroidetes ID 2	EPA	3.20E+02	**Present**
SM-6E18026	Site 5	Human Bacteroidetes ID 2	EPA	3.71E+02	**Present**

<LOQ: Below level of quantification

Laboratory Comments

Submitter: R2T, Inc.

Report Date: June 2, 2016

Positive Results
In sample(s) classified as positive, the human-associated Bacteroidetes gene biomarker(s) (were) detected in both test replicates suggesting that human fecal contamination is present in the water sample(s). The biomarker(s) serve as an indicator of the targeted fecal pollution, but the presence of the biomarker does not signify conclusively the presence of that form of fecal pollution. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Trace Results
In sample(s) classified as trace, the human-associated Bacteroidetes biomarker was detected in both test replicates but in quantities below the limit of quantification. This result indicates that fecal indicators associated with human were present in the sample(s) but in low concentrations.

Human Fecal Reference Samples
The client is encouraged to submit samples from the surrounding wastewater facilities and/or septic systems in order to gain a better understanding of the concentration of the human-associated fecal Bacteroidetes genetic marker as well as the concentration of the general fecal Bacteroidetes genetic marker in the geographic region of interest. A more precise interpretation would be available to the client with the submittal of such baseline samples.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to perform additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **www.sourcemolecular.com/tests**

DNA Analytical Method Explanation

All reagents, chemicals and apparatuses were verified and inspected beforehand to ensure that no false negatives or positives could be generated. In that regard, positive and negative controls were run to attest the integrity of the analysis. All inspections and controls tested negative for possible extraneous contaminates, including PCR inhibitors.

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications were run on an Applied Biosystems StepOnePlus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul containing sample extract, forward primer, reverse primer, probe and an optimized buffer. The following thermal cycling parameters were used: 50°C for 2 min, 95°C for 10 min and 40 cycles of 95°C for 15 s and 60°C for 1 min. All assays were run in duplicate. Absolute quantification was achieved by extrapolating genome copy numbers from standard curves generated from serial dilutions of Human specific and generic genomic DNA.

For quality control purposes, a positive control consisting of appropriate genomic DNA and a negative control consisting of PCR-grade water were run alongside the sample(s) to ensure a properly functioning reaction and reveal any false negatives or false positives.

Human Bacteroidetes ID™ Species*: B. dorei*

The **Human Bacteroidetes ID™ Species*: B. dorei*** service targets the species *Bacteroides dorei*. *B. dorei* is an anaerobe that is frequently shed from the gastrointestinal tract and isolated from human feces worldwide. It is a newly discovered species that is widely distributed in the USA.[1,2] The human-associated marker DNA sequence is located on the 16S rRNA gene of *B. dorei*.[3] The marker is the microbial source tracking (MST) marker of choice for detecting human fecal pollution due to its exceptional sensitivity and specificity. Internal validations have been conducted on hundreds of sewage, septage, human and animal host fecal samples collected from throughout the U.S and archived in the Source Molecular fecal bank. The marker has also been evaluated in both inland and coastal waters. A recent, comprehensive, multi-laboratory MST method evaluation study, exploring the performance of current MST methods, concluded the *B. dorei* qPCR assay to be the top performing human-associated assay amongst those tested. The success and consistency of this marker in numerous studies around the world[1,3,4] makes the **Human Bacteroidetes ID™ Species*: B. dorei*** service the primary service for identifying human fecal pollution at Source Molecular.

Fecal *Bacteroidetes* are considered for several reasons an interesting alternative to more traditional indicator organisms such as *E. coli* and *Enterococci*.[5] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems. This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*.

The Human Bacteroidetes ID™ service is designed around the principle that fecal *Bacteroidetes* are found in large quantities in feces of warm-blooded animals.[3,5,6,7,8] Furthermore, certain strains of *Bacteroidetes* have been found to be associated with humans.[3,6] As such, these bacterial strains can be used as indicators of human fecal contamination.

Accuracy of the results is possible because the method amplifies DNA into a large number of small copies of the gene biomarker of interest. This is accomplished with small pieces of DNA called primers that are complementary and specific to the unique *B. dorei* DNA sequence. Through a heating process called thermal cycling, the double stranded DNA is denatured, hybridized to the complementary primers and amplified to create many copies of the DNA fragment desired. If the primers are successful in finding a site on the DNA fragment that is specific to the *B. dorei* DNA sequence, then billions of copies of the DNA fragment will be available and detected in real-time. The accumulation of DNA product is plotted as an amplification curve by the qPCR software. The absence of an amplification curve indicates that the *B. dorei* gene biomarker is not detected in the water sample because it is either not present or present at concentrations below the analytical detection limit.

To strengthen the validity of the results, additional tests targeting other high-ranking, human-associated *Bacteroidetes* species should be performed, such as
Human Bacteroidetes ID™ Species*: B. stercoris*,
Human Bacteroidetes ID™ Species*: B. fragilis,* and
Human Bacteroidetes ID™ Species*: B. thetaiotaomicron*.

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[7] Fogarty, L., Voytek, M. **A Comparison of Bacteroides-Prevotella 16S rRNA Genetic Markers for Fecal Samples from Different Animal Species.** Appl. Environ. Microbiol. 2005 71: 5999-6007.
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Human Bacteroidetes ID™: EPA Developed Assay

The **Human Bacteroidetes ID™: EPA Developed Assay** service targets a functional gene biomarker in *Bacteroidales*-like anaerobic bacteria that is present in high concentrations in the human gut. The U.S Environmental Protection Agency (U.S. EPA) was the first to target the biomarker using quantitative Polymerase Chain Reaction (qPCR) technology in order to detect ground and surface waters impacted by human fecal pollution.[1] Since it's development, the assay has been used succesfully around the U.S to identify fecal pollution originating from human sources, such as sewage and septage wastewaters.

The U.S. EPA Developed assay has been shown to be highly associated with human fecal pollution. It has successfully been validated in multiple nationwide studies using at least 300 individual reference fecal material from 22 different animal species known to commonly contaminate environmental waters.[1,2] A reported 99.2% specificity to human fecal material makes this one of the leading assays to confirm the presence of fecal contamination that is of human origin.[1] The *Bacteroidales*-like bacteria is widely distributed. It was detected in 100% of hundreds of sewage and human reference fecal samples collected from more than 20 human populations, making it highly sensitive. Internal validations have also been conducted on hundreds of wastewater, human and animal host fecal samples archived in the Source Molecular fecal bank.

Fecal anaerobic bacteria are considered for several reasons an interesting alternative to more traditional fecal indicator organisms such as *E. coli* and *Enterococci*.[3] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems.[3] This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*.

The **Human Bacteroidetes ID™: EPA Developed Assay** service is designed around the principle that fecal *Bacteroidales*-like bacteria are found in large quantities in feces of warm-blooded animals.[4,5] Furthermore, certain strains have been shown to be associated with humans.[4,5] As such, these bacterial strains can be used as indicators of human fecal contamination. An advantage of the Human Bacteroidetes ID™ service is that the entire portion of water sampled is filtered to concentrate bacteria. As such, this method avoids the randomness effect of culturing and selecting bacterial isolates. This is an advantage for highly contaminated water systems with potential multiple sources of fecal contamination.

Accuracy of the results is possible because the method amplifies DNA into a large number of copies of the gene biomarker of interest. This is accomplished with small pieces of DNA called primers that are complementary and specific to the gene biomarker. Through a heating process called thermal cycling, the double stranded DNA is denatured, hybridized to the complementary primers and amplified to create many copies of the DNA fragment. If the primers are successful in finding a site on the DNA fragment that is specific to the human-associated biomarker, billions of copies of the DNA fragment will be available and detected in real-time. The accumulation of DNA product is plotted as an amplification curve by qPCR software. The absence of an amplification curve indicates that the gene biomarker is not detectable in the water sample either because it is not present or present at concentrations below the analytical detection limit.

To strengthen the validity of the results, additional tests targeting other high-ranking, human-associated *Bacteroidetes* species should be performed, such as
Human Bacteroidetes ID™ Species*: B. dorei*,
Human Bacteroidetes ID™ Species*: B. fragilis,* and
Human Bacteroidetes ID™ Species*: B. stercoris*

[1] Shanks, O., Kelty, C., Sivaganesan, M., Varma, M. and Haugland, R. **Quantitative PCR for Genetic Markers of Human Fecal Pollution**. Appl. Environ. Microbiol. 2009 75: 5507-5513.
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[4] Bernhard, A., Field, K. **Identification of nonpoint sources of fecal pollution in coastal waters by using host-specific 16S ribosomal DNA genetic markers from fecal anaerobes.** Appl. Environ. Microbiol. 2000a 66: 1587-1594.
[5] Bernhard, A., Field, K. **A PCR assay to discriminate human and ruminant feces on the basis of host differences in Bacteroides-Prevotella genes encoding 16S rRNA.** Appl. Environ. Microbiol. 2000b 66: 4571-4574.

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Preliminary Interpretation of Ruminant Fecal ID™ "Quantification" Results

Detection and quantification of Ruminant-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: May 18, 2016
Date Reported: June 2, 2016

SM #	Client #	Approximate Contribution of Ruminant Fecal Pollution in Water Sample	Comment
SM-6E18039	Site 2	**Trace**	Trace levels of ruminant fecal biomarker
SM-6E18040	Site 3	Not Detected	Ruminant fecal biomarker not detected
SM-6E18041	Site 5	**Trace**	Trace levels of ruminant fecal biomarker

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It is agreed that in the event of breach of any warranty or breach of contract, or negligence of Source Molecular Corporation, as well as its agents or representatives, the liability of the company shall be limited to the repayment, to the purchaser (submitter), of the individual analysis price paid by him/her to Source Molecular Corp. The company shall not be liable for any damages, either direct or consequential. Source Molecular Corp. provides analytical services on a PRIME CONTRACT BASIS ONLY. Terms are available upon request. The sample(s) cited in this report may be used for research purposes after an archiving period of 3 months from the date of this report. Research includes, but is not limited to internal validation studies and peer-reviewed research publications. Anonymity of the sample(s), including the exact geographic location will be maintained by assigning an arbitrary internal reference. These anonymous samples will only be grouped by state / province of origin for research purposes. The client must contact Source Molecular in writing within 10 days from the date of this report if he/she does not wish for their submitted sample(s) to be used for any type of future research.

Source Molecular
Leader in Microbial Source Tracking
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Ruminant Fecal ID™ Quantification

Detection and quantification of Ruminant-associated fecal indicator bacteria by real-time quantitative Polymerase Chain Reaction (qPCR)

Submitter: R2T, Inc.
Date Received: May 18, 2016
Date Reported: June 2, 2016

SM #	Client #	Analysis Requested	Marker Quantified (copies/100 ml)	DNA Analytical Results
SM-6E18039	Site 2	Ruminant Fecal ID	<LOQ	**Present (Trace)**
SM-6E18040	Site 3	Ruminant Fecal ID	ND	Absent
SM-6E18041	Site 5	Ruminant Fecal ID	<LOQ	**Present (Trace)**

<LOQ: Below level of quantification
ND: Not Detected

Negative Results
In sample(s) classified as negative, the ruminant-associated fecal gene biomarker(s) was either not detected in test replicates, one replicate was detected at a cycle threshold greater than 35 and the other was not, or one replicate was detected at a cycle threshold less than 35 and the other was not after repeated analysis. It is important to note that a negative result does not mean that the sample does not definitely have ruminant fecal contamination. Only repeated sampling (both during wet and dry sampling events) will enable you to draw more definitive conclusions as to the contributor(s) of fecal pollution.

Trace Results
In sample(s) classified as trace, the ruminant-associated fecal biomarker was detected in both test replicates but in quantities below the limit of quantification. This result indicates that fecal indicators associated with ruminant were present in the sample(s) but in low concentrations.

Ruminant Fecal Reference Samples
The client is encouraged to submit fecal samples from suspected sources in the surrounding area in order to gain a better understanding of the concentration of the ruminant-associated fecal genetic marker in the geographic region of interest. A more precise interpretation would be available to the client if baseline samples are provided.

Result Interpretations
Quantitative results are reported along with interpretations. Interpretations are given as "negative", “trace”, "low concentration", "moderate concentration", or "high concentration" based on the concentration of the genetic markers found in the water samples.

Additional Testing
A portion of all samples has been frozen and will be archived for 3 months. The client is encouraged to arrange for additional tests on the sample(s) for other hosts suspected of contributing to the fecal contamination. A list of available tests can be found at **sourcemolecular.com/tests**

DNA Analytical Method Explanation

Each submitted water sample was filtered through 0.45 micron membrane filters. Each filter was placed in a separate, sterile 2ml disposable tube containing a unique mix of beads and lysis buffer. The sample was homogenized for 1min and the DNA extracted using the Generite DNA-EZ ST1 extraction kit (GeneRite, NJ), as per manufacturer's protocol.

Amplifications to detect the target gene biomarker were run on an Applied Biosystems StepOnePlus real-time thermal cycler (Applied Biosystems, Foster City, CA) in a final reaction volume of 20ul containing sample extract, forward primer, reverse primer, probe and an optimized buffer. All assays were run in duplicate. Absolute quantification was achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of known gene copy numbers.

For quality control purposes, a positive control consisting of ruminant fecal DNA and a negative control consisting of PCR-grade water, were run alongside the sample(s) to ensure a properly functioning reaction and to reveal any false negatives or false positives. The accumulation of PCR product was detected and graphed in an amplification plot. If the fecal indicator organism was absent in the sample, this accumulation was not detected and the sample was considered negative. If accumulation of PCR product was detected, the sample was considered positive.

Theory Explanation of Ruminant Fecal IDTM Quantification

The phylum *Bacteroidetes* is composed of three large groups of bacteria with the best-known category being *Bacteroidaceae* . This family of gram-negative bacteria is found primarily in the intestinal tracts and mucous membranes of warm-blooded animals and is sometimes considered pathogenic.

Comprising *Bacteroidaceae* are the genus *Bacteroides* and *Prevotella*. The latter genus was originally classified within the former (*i.e.Bacteroides*), but since the 1990's findings. *Bacteroides* and *Prevotella* are gram-negative, anaerobic, rod-shaped bacteria that inhabitant of the oral, respiratory, intestinal, and urogenital cavities of humans, animals and insects. They are sometimes pathogenic.

Fecal *Bacteroidetes* are considered for several reasons an interesting alternative to more traditional indicator organisms such as *E. coli* and *Enterococci*.[1] Since they are strict anaerobes, they are indicative of recent fecal contamination when found in water systems. This is a particularly strong reference point when trying to determine recent outbreaks in fecal pollution. They are also more abundant in feces of warm-blooded animals than *E. coli* and *Enterococci*. Furthermore, these latter two organisms are facultative anaerobes and as such they can be problematic for monitoring purposes since it has been shown that they are able to proliferate in soil, sand and sediments.

The Ruminant Fecal Quantification IDTM service is designed around the principle that fecal *Bacteroidetes* are found in large quantities in feces of warm-blooded animals.[2,3,4,5,6] Furthermore, certain categories of *Bacteroidetes* have been shown to be predominately detected in ruminants. Within these *Bacteroidetes*, certain genetic sequences in the *Bacteroides* and *Prevotella* genus have been found in ruminants.[7] As such, these bacterial strains can be used as indicators of ruminant fecal contamination.

One of the advantages of the Ruminant Fecal Quantification IDTM service is that the entire water is sampled and filtered for fecal *Bacteroidetes*. As such, this method avoids the randomness effect of culturing and selecting bacterial isolates off a petri dish. This is a particular advantage for highly contaminated water systems with potential multiple sources of fecal contamination.

Accuracy of the results is possible because the method uses PCR DNA technology. PCR allows quantities of DNA to be amplified into large number of small copies of DNA sequences. This is accomplished with small pieces of DNA called primers that are complementary and specific to the genomes to be detected. Through a heating process called thermal cycling, the double stranded DNA is denatured and inserted with complementary primers to create exact copies of the DNA fragment desired. This process is repeated rapidly many times ensuring an exponential progression in the number of copied DNA. If the primers are successful in finding a site on the DNA fragment that is specific to the genome to be studied, then billions of copies of the DNA fragment will be available and detected in real-time. Quantitative PCR (qPCR) adds a variant to the PCR process by inserting of a fluorescent probe within the primer set. This fluorescent probe serves as a molecular beacon for the quantification step. During each PCR cycle, quantitative PCR monitors the fluorescence emitted during the reaction. This is done in real-time during the first PCR cycles as a way to quantify the targeted gene. Absolute quantification is achieved by extrapolating target gene copy numbers from a standard curve generated from serial dilutions of plasmid DNA containing a known amount of the ruminant-specific biomarker. The Ruminant Fecal Quantification IDTM service uses qPCR to simultaneously confirm and quantify the ruminant- specific fecal *Bacteroidetes* genetic biomarker. This PCR technology avoids the cumbersome process of distinguishing DNA bands on a gel electrophoresis apparatus.

References

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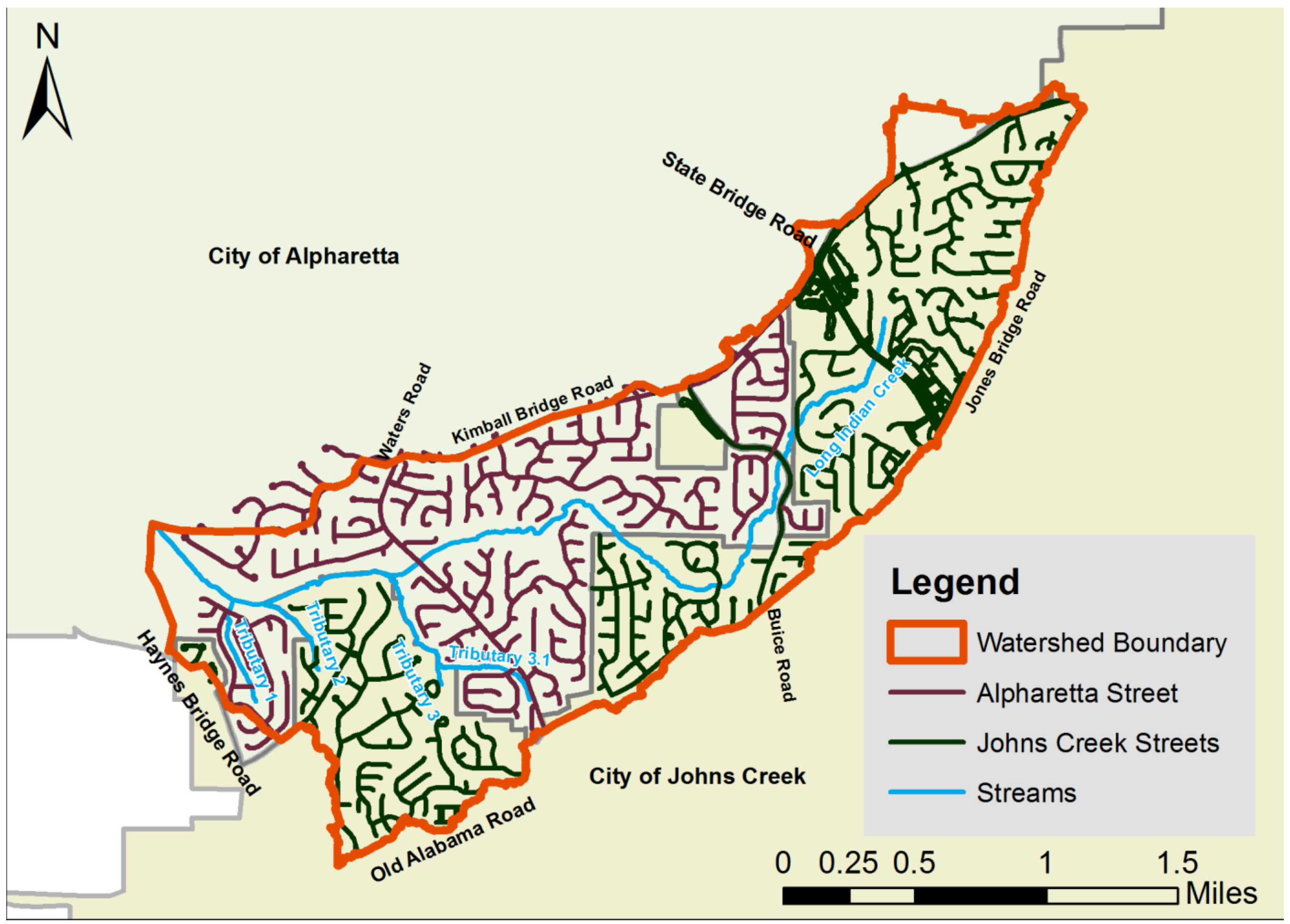
Project Overview

The installation of dog waste stations partnered with robust community education provides the best and most cost-effective opportunity to reduce fecal coliform loads in the watershed. The most successful results are modeled when dog waste stations are installed throughout the entire watershed, including in the City of Johns Creek. It is recommended that dog waste stations are installed every ½ mile along all city streets, especially in neighborhoods where residents are most likely to walk their dogs.



City	Street Miles	No. Waste Stations
City of Alpharetta	25 Miles	50
City of Johns Creek	55 Miles	110

Cost

Costs are based on an initial cost of $500 per waste station with a predicted weekly maintenance cost of $15. Homeowner Associations provide potential partnering vehicles for the Cities to help defray the maintenance costs of dog waste stations located in neighborhoods.

Item	Alpharetta	Johns Creek
Initial Capital Cost	$25,000	$55,000
Annual Maintenance Cost	$39,000	$85,800
Annual Public Education Cost	$5,000	$5,000

Educational image from the City of Alpharetta and the Clean Water Campaign.

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #1 – Dog Waste Stations & Public Education

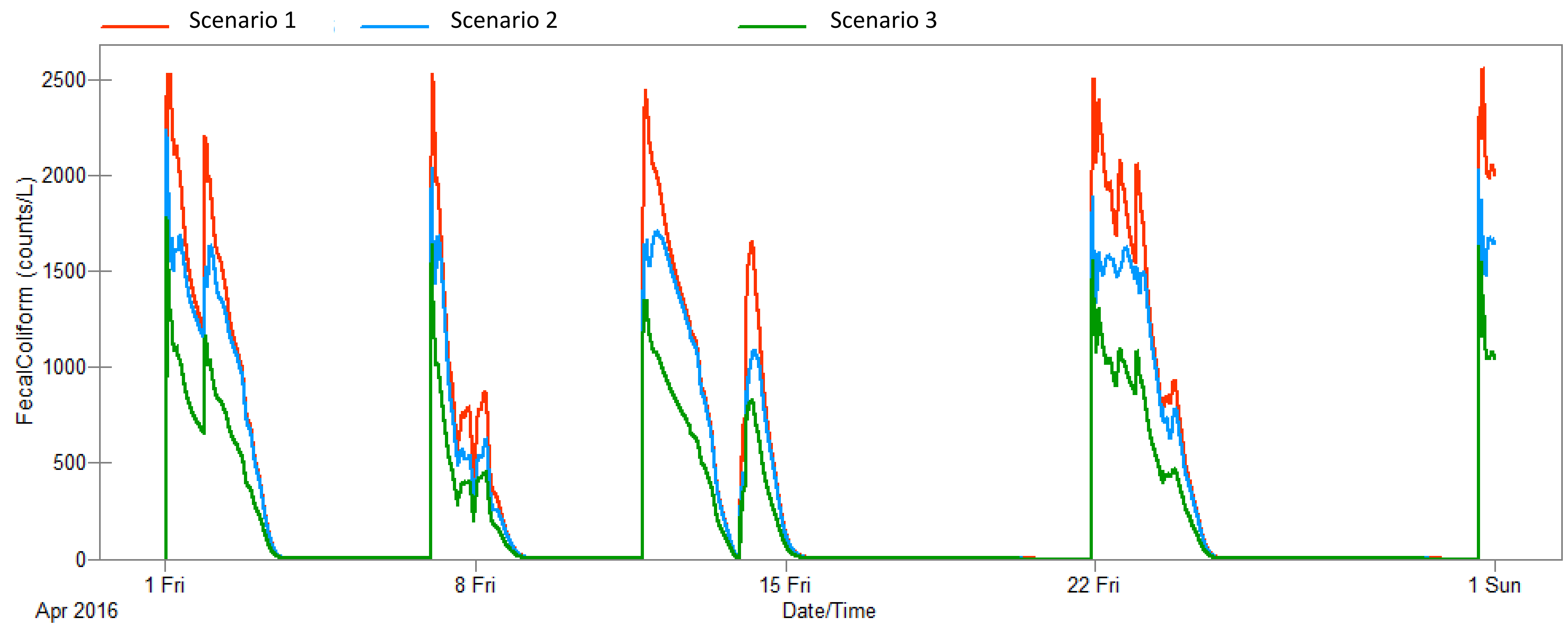
THE CITY OF ALPHARETTA
Dewberry

SHEET C.1

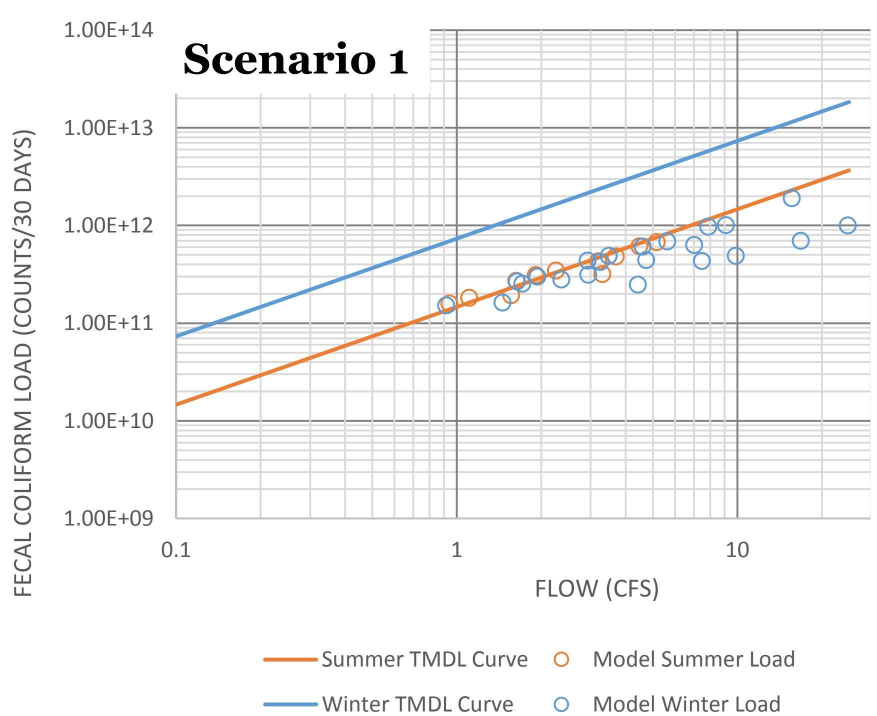
Benefits

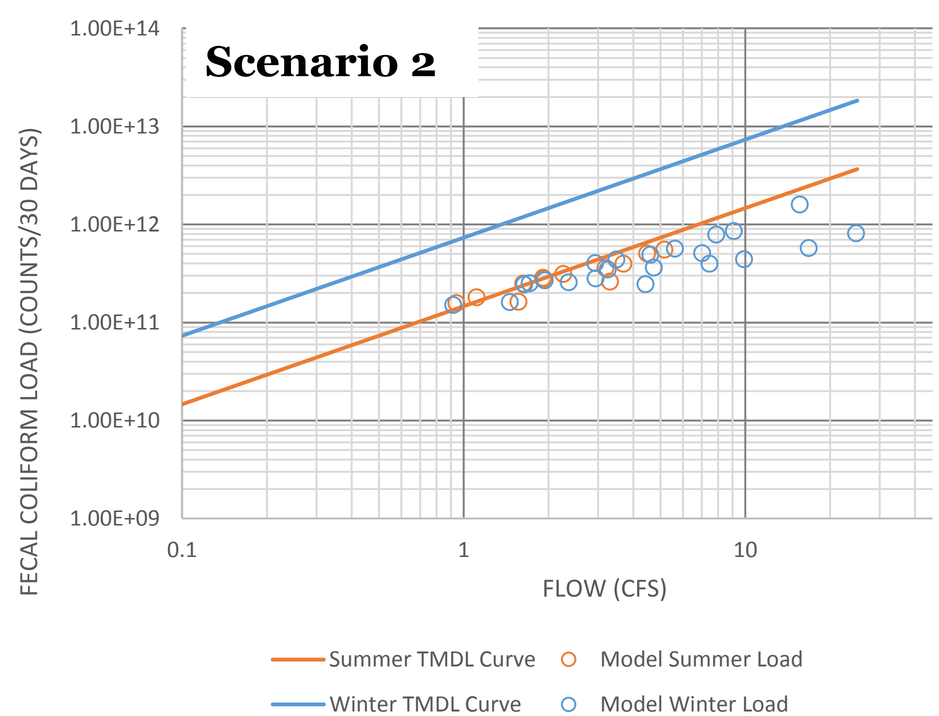
To demonstrate the expected benefits from installation of dog waste stations in the City of Alpharetta and Johns Creek, the following scenarios were compared :

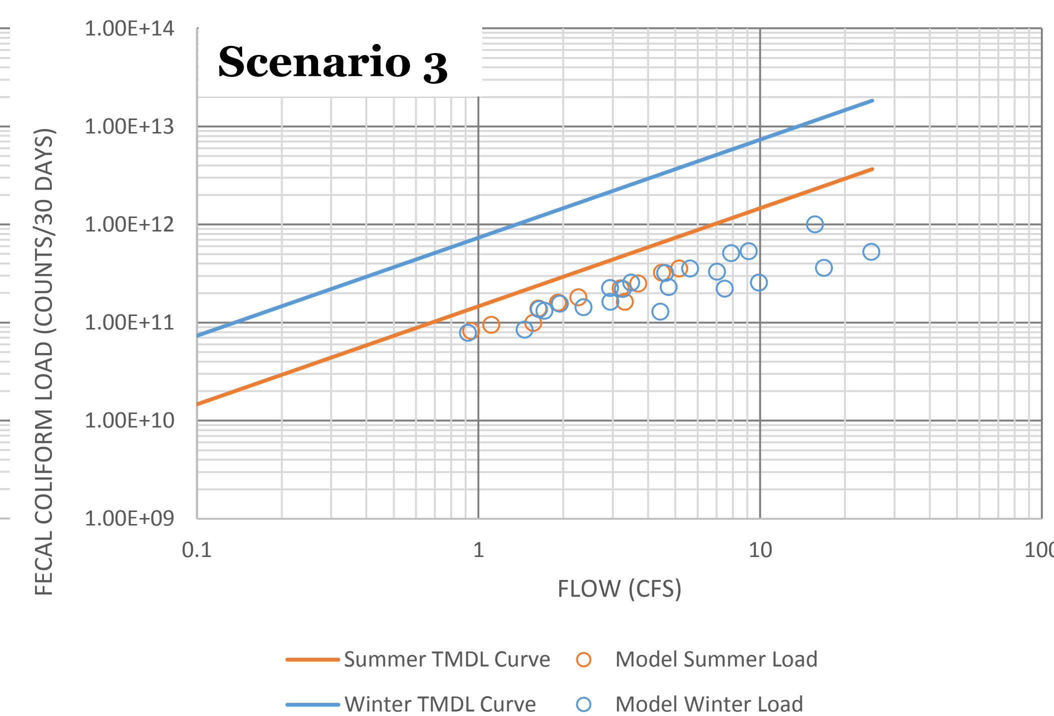
- **Scenario 1:** Existing conditions model
- **Scenario 2:** Dog waste stations and community education are implemented in all areas of the watershed that are part of the City of Alpharetta and two 'hotspot' areas within Johns Creek
- **Scenario 3:** Dog waste stations and community education are implemented throughout the entire watershed including the City of Johns Creek



Comparison of expected fecal coliform loads for Scenarios 1, 2, and 3 at the furthest downstream sampling site based on sampling results from April 2016. For April 2016, Scenario 2 is expected to reduce fecal loading by 19% and Scenario 3 is expected to reduce fecal loading by 47% at the most downstream site.







CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #1 – Dog Waste Stations & Public Education

THE CITY OF ALPHARETTA

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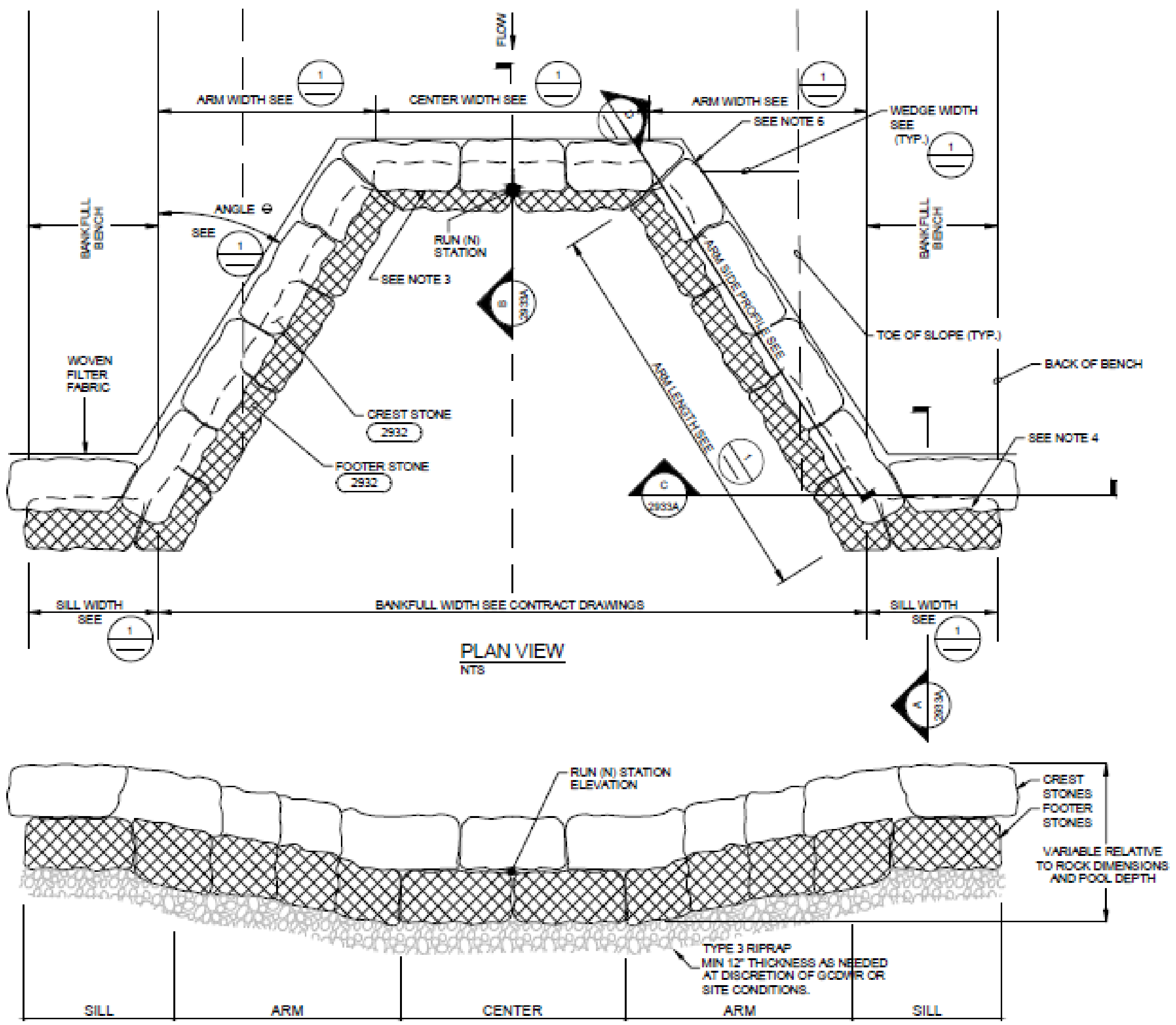
SHEET C.2

Project Overview

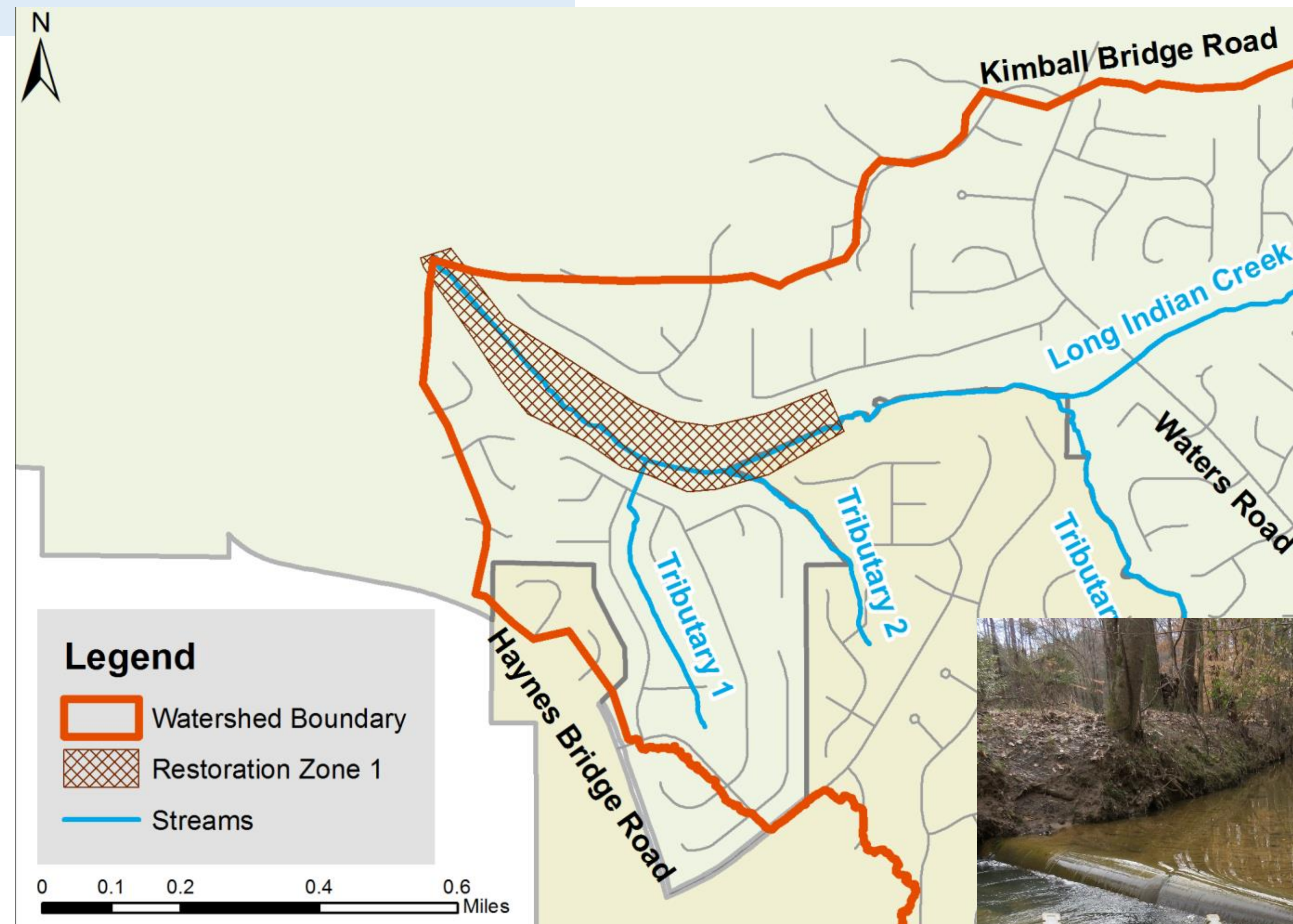
Project 1 of the Stream Restoration and Sanitary Sewer Protection Plan extends 3800 feet upstream from the confluence of Long Indian Creek with Big Creek (labeled Zone 1 in the map). The stream can be accessed from a park located on High Hampton Chase and via a sewer easement that traverses alongside the stream. Based on conditions observed during the stream walk, a Priority 3 Stream Restoration Project using natural channel design techniques is recommended to create a more stable plan form and profile and to reconnect the stream to the historic floodplain. Further, there are two exposed sanitary sewer pipes along this section of stream where cross vanes are recommended to be placed immediately downstream to raise the streambed and bury the pipes, protecting them against debris jams which could break the pipes.

Benefits

- Reduce TSS load by approximately 575 tons/year
- Reduce stream velocity
- Protect existing sanitary sewer infrastructure and prevent future fecal coliform contamination from damaged pipes
- Improve stream habitat
- Improve aesthetics of stream



A typical cross vane detail that would be installed to protect sanitary sewer infrastructure



Exposed pipe located at 600 feet upstream of the confluence.

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #2 – Stream Restoration and Sanitary Sewer Protection Project 1

THE CITY OF ALPHARETTA

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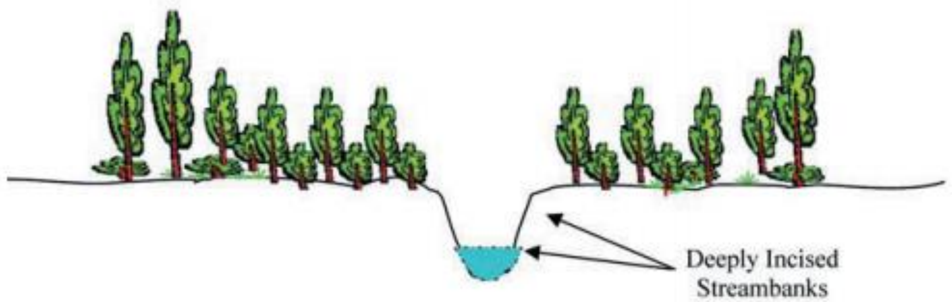
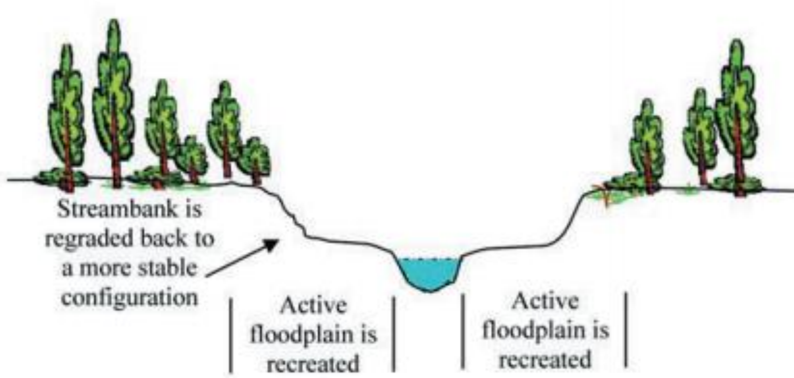
SHEET C.3

Item	Unit	Quantity	Unit Price	Total Price
Clearing & Grubbing	AC	7	$50,000	$350,000
Erosion Control	LF	3,800	$25	$95,000
Earthwork	CY	5,700	$15	$85,500
Riparian Buffer Plantings	LF	3,800	$35	$133,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Large	EA	2	$35,000	$70,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Medium	EA	0	$25,000	$0
Stream Structures (Cross-Vane, J-Hook, etc.) – Small	EA	0	$15,000	$0
			Construction Sub-Total	$733,500
			Engineering and Permitting (25%)	$183,375
			Contingency (20%)	$183,375
			Capital Cost	**$1,100,250**
			Annual Maintenance Cost	**$250**

A severely incised bank typical of the lower section of Long Indian Creek.





Graphic showing incised banks and ideal banks after regarding (Santa Clara Valley Water District, 2016).

9/19/2016 Damaged pipe send sewage into Chattahoochee tributary | News

Nearly 1,500 gallons of sewage spilled into a tributary of the Chattahoochee River in the [illegible] area on Labor Day because of a damaged pipe, a [illegible] official announced on Tuesday.

The water department said the spill occurred on a gravity sanitary sewer line at [illegible] Director of Permitting and Regulatory Services [illegible] did not specify what type of damage the pipe had, but he said in a statement that it was caused a build up of logs and debris.

A debris jam below an incised bank. Debris jams have the potential to cause flooding and damage infrastructure.

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #2 – Stream Restoration and Sanitary Sewer Protection Project

THE CITY OF ALPHARETTA
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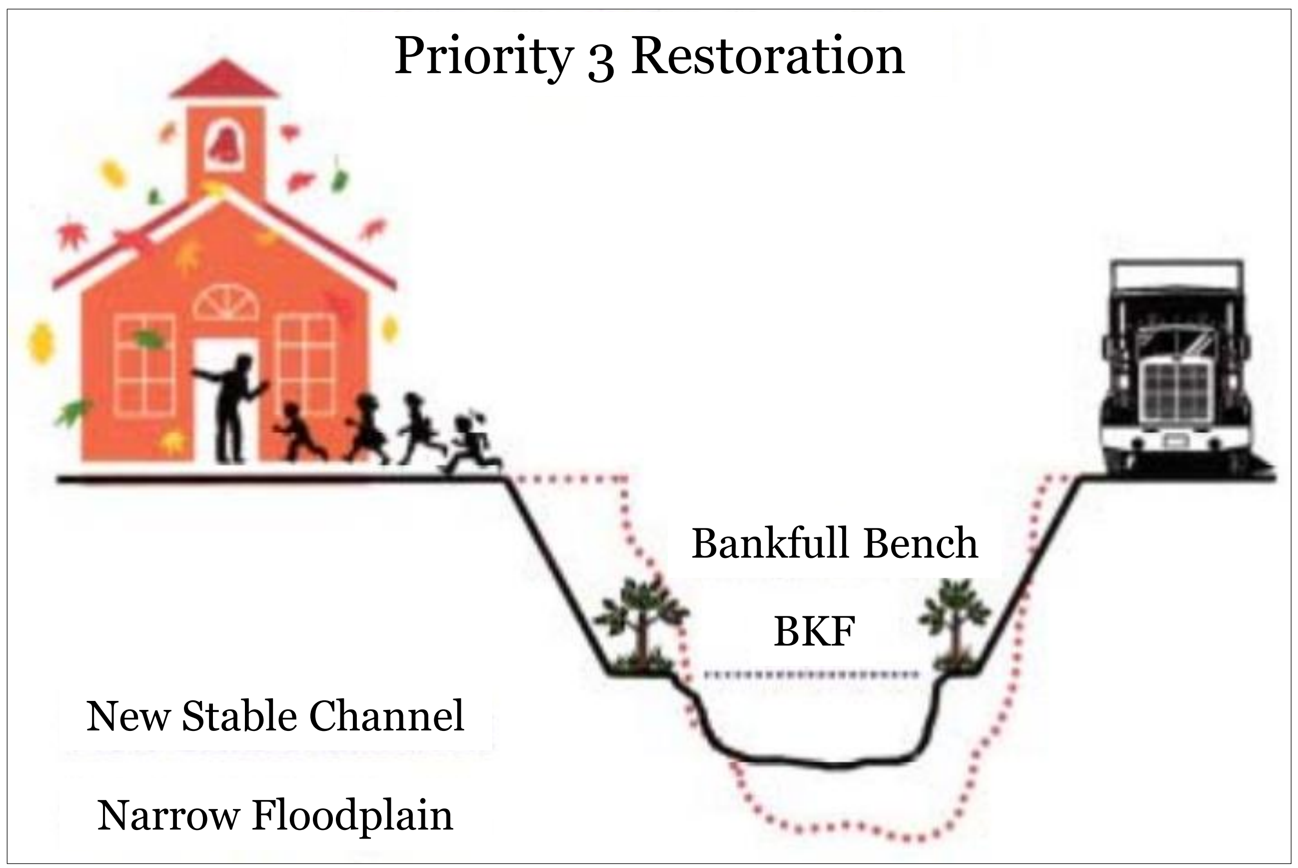
SHEET C.4

Project Overview

Project 2 of the Stream Restoration and Sanitary Sewer Protection Plan extends 2500 feet upstream along Long Indian Creek Tributary 3 from the confluence with Long Indian Creek (labeled Zone 2 in the map). Since there are no community open spaces near Tributary 3, the stream must be accessed through private property. The best entry point is off of New Heritage Drive where the lot sizes are larger and a sewer easement that runs parallel to the tributary can be easily reached. Based on conditions observed during the stream walk, a Priority 3 Stream Restoration Project using natural channel design techniques is recommended to create a more stable plan form and profile and to reconnect the stream to the historic floodplain. Further, there are two exposed sanitary sewer pipes along this section of stream where cross vanes are recommended to be placed immediately downstream to raise the streambed and bury the pipes, protecting them against debris jams which could break the pipes.



Graphic showing the construction of stabilized banks to help reconnect the stream with its historic floodplain (FWS, 2016).

An incised stream bank that has migrated laterally towards sanitary sewer running parallel to the stream. Further, migration could compromise the infrastructure.

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #3 – Stream Restoration and Sanitary Sewer Protection Project 2

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SHEET C.5

Item	Unit	Quantity	Unit Price	Total Price
Clearing & Grubbing	AC	4	$50,000	$200,000
Erosion Control	LF	2,500	$25	$62,500
Earthwork	CY	3,750	$15	$56,250
Riparian Buffer Plantings	LF	2,500	$35	$87,500
Stream Structures (Cross-Vane, J-Hook, etc.) – Large	EA	0	$35,000	$0
Stream Structures (Cross-Vane, J-Hook, etc.) – Medium	EA	1	$25,000	$25,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Small	EA	1	$15,000	$15,000
			Construction Sub-Total	$446,250
			Engineering and Permitting (25%)	$111,563
			Contingency (20%)	$111,563
			Capital Cost	**$669,375**
			Annual Maintenance	**$250**

Exposed pipe in the upper part of the stream restoration zone. The stream is sufficiently degraded to expose the push-on joint.

Exposed pipe in the lower part of the stream restoration zone. The stream is sufficiently degraded to expose the push-on joint.

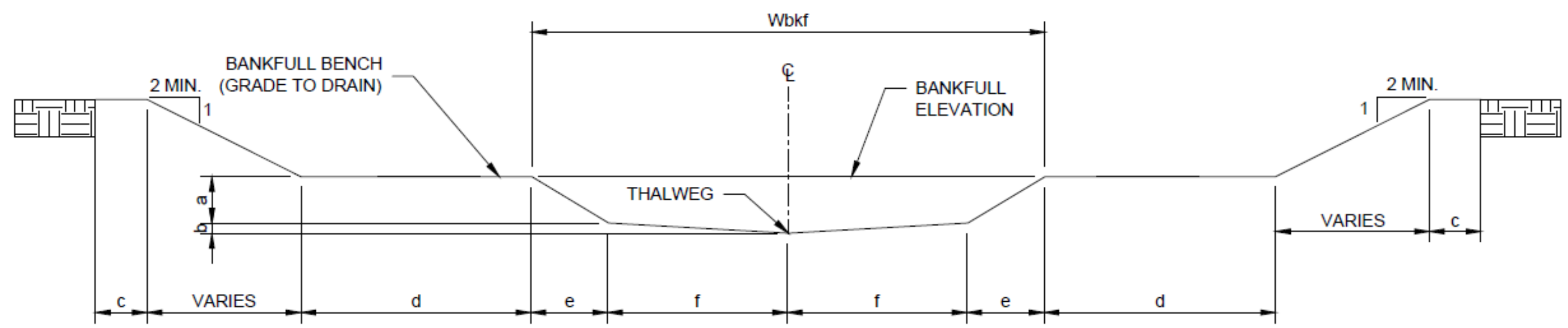
Benefits

- Reduce TSS load by approximately 220 tons/year
- Reduce stream velocity
- Provide grade control along the stream
- Protect existing sanitary sewer infrastructure and prevent future fecal coliform contamination from damaged pipes
- Improve stream habitat
- Improve aesthetics of stream

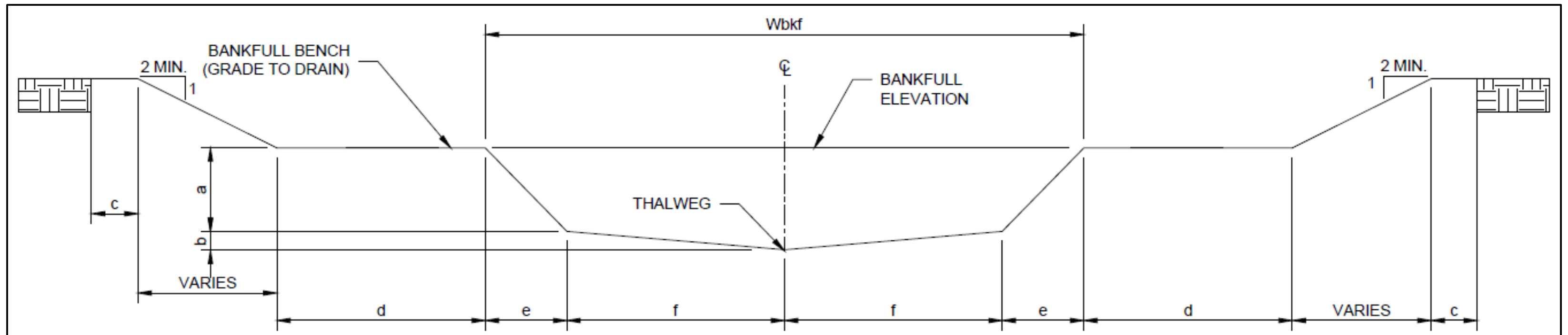
A sample cross vane from a completed project. The cross vane would be placed just downstream of the exposed sanitary sewer pipe. This would provide grade control for the stream, and protect the sanitary sewer pipe from future damage during flooding events.

Project Overview

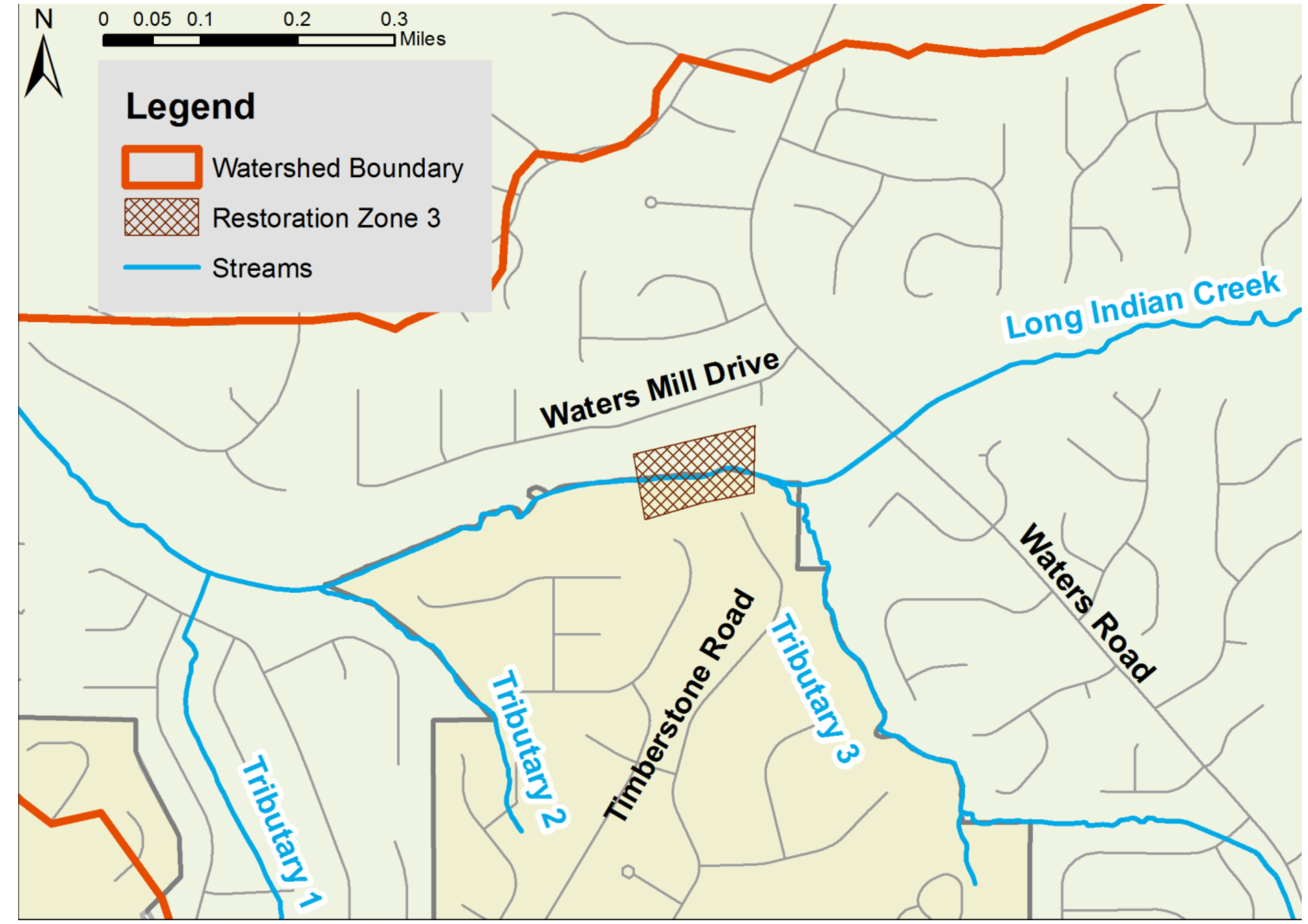
Project 3 of the Stream Restoration and Sanitary Sewer Protection Plan extends 500 feet downstream along Long Indian Creek from the confluence of Long Indian Creek with Tributary 3 (labeled Zone 3 in the map). The stream can be accessed from a park located on Waters Mill Drive and via a sewer easement that traverses parallel the stream. Based on the stream walk, the restoration measures called for include bank stabilization measures which involve using tree stumps, geotextile fabrics, plants, stone, and other materials to reduce erosion on banks that have been regarded to better connect the stream to its historic floodplain. Further, there is one exposed sanitary sewer pipe which requires protection with a cross vane.



1 TYPICAL RIFFLE CROSS SECTION
NTS



3 TYPICAL CENTER POOL CROSS SECTION
NTS

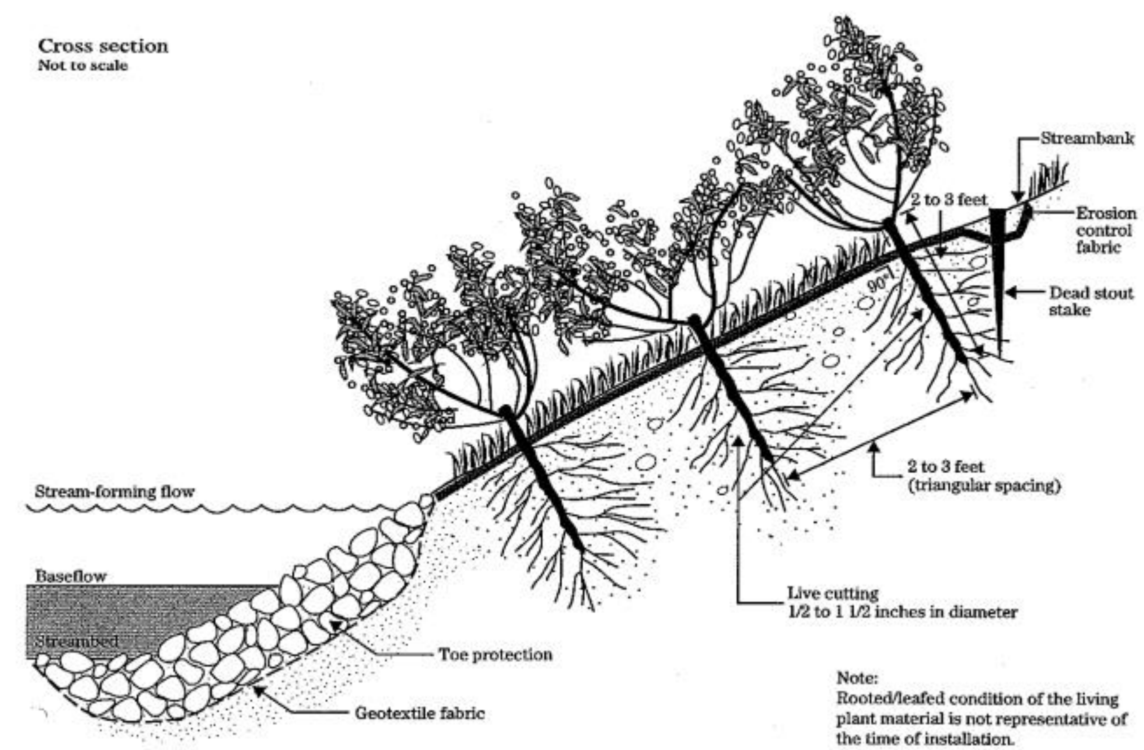


Benefits

- Reduce TSS load by approximately 55 tons/year
- Reduce stream velocity
- Provide grade control along the stream
- Protect existing sanitary sewer infrastructure
- Prevent future fecal coliform contamination from damaged pipes
- Improve stream habitat
- Remove of invasive plant species
- Improve aesthetics of stream

The two drawings to the left provide typical riffle and pool cross sections for regraded stream banks.

Item	Unit	Quantity	Unit Price	Total Price
Clearing & Grubbing	AC	1	$50,000	$50,000
Erosion Control	LF	500	$25	$12,500
Earthwork	CY	750	$15	$11,250
Riparian Buffer Plantings	LF	500	$35	$17,500
Stream Structures (Cross-Vane, J-Hook, etc.) – Large	EA	1	$35,000	$35,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Medium	EA	0	$25,000	$0
Stream Structures (Cross-Vane, J-Hook, etc.) – Small	EA	0	$15,000	$0
			Construction Sub-Total	$126,250
			Engineering and Permitting (25%)	$31,563
			Contingency (20%)	$31,563
			Capital Cost	**$189,375**
			Annual Maintenance Cost	**$250**



Live staking detail. Live staking is an effective bioengineering method to stabilize banks (GA DNR, 2011).

Exposed sanitary sewer pipe. A grade-control structure such as a cross vane can be installed to protect the pipe.

Severely eroded stream bank in section of Long Indian Creek recommended for stream restoration.

Live staking along stream bank (Kingsport, 2016).

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #4 – Stream Restoration and Sanitary Sewer Protection Project 3

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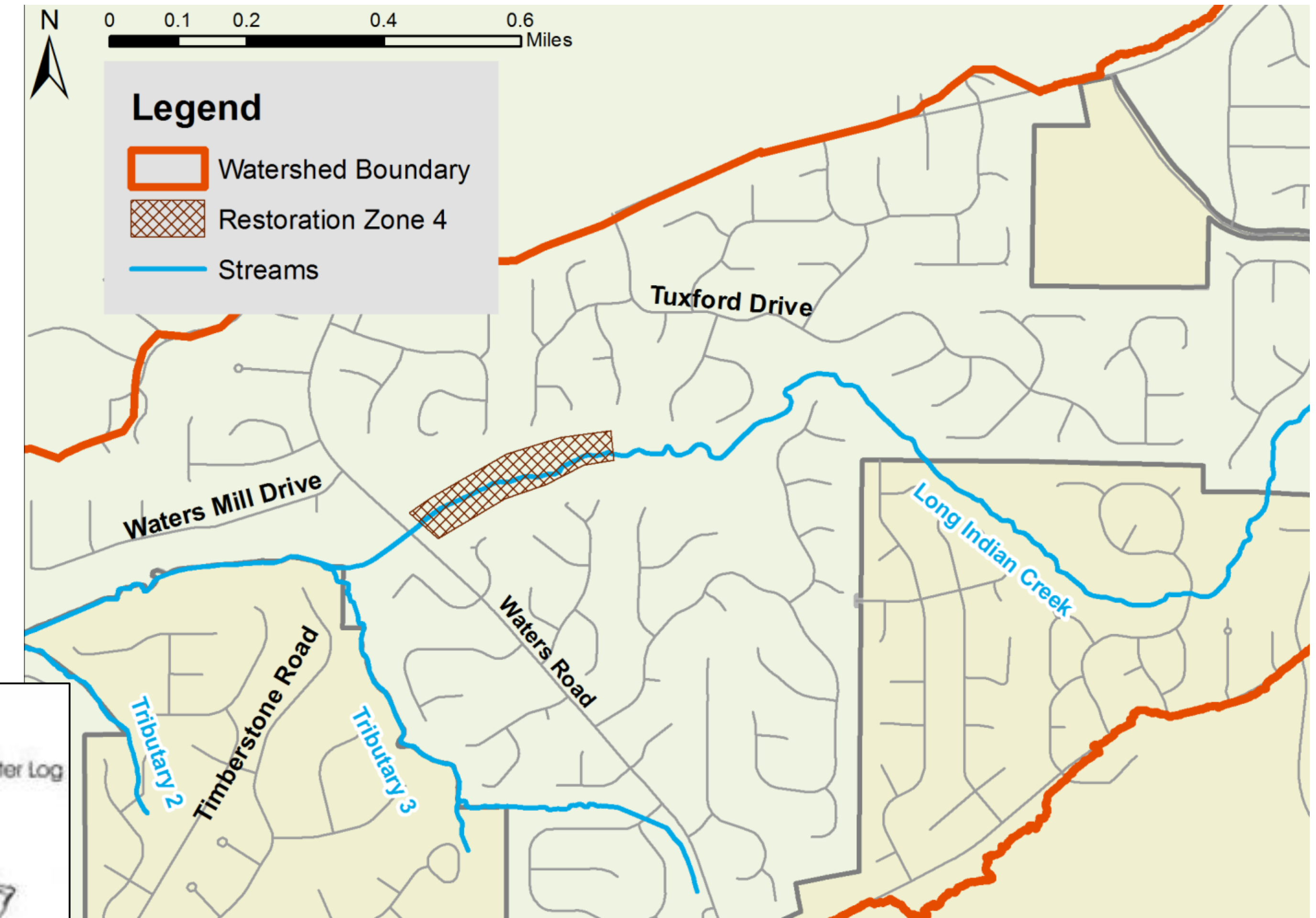
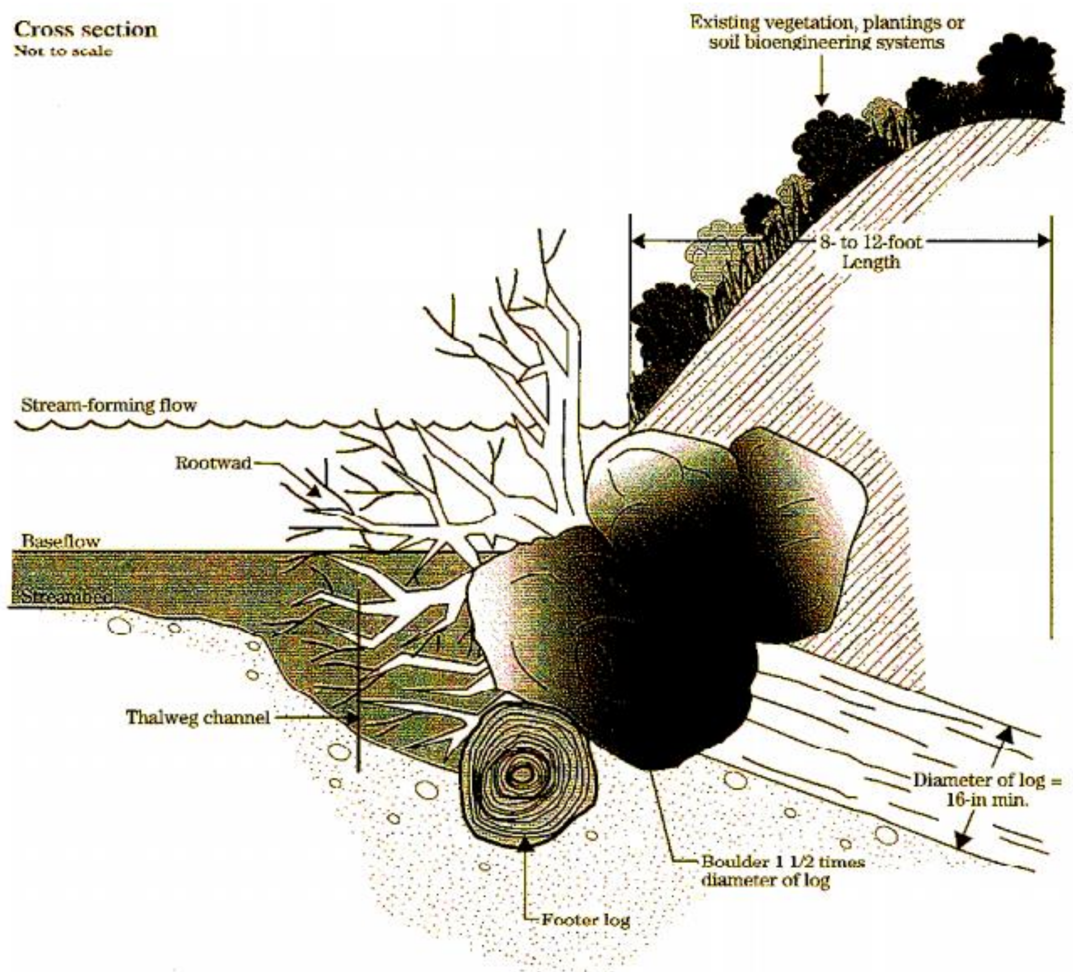
SHEET C.8

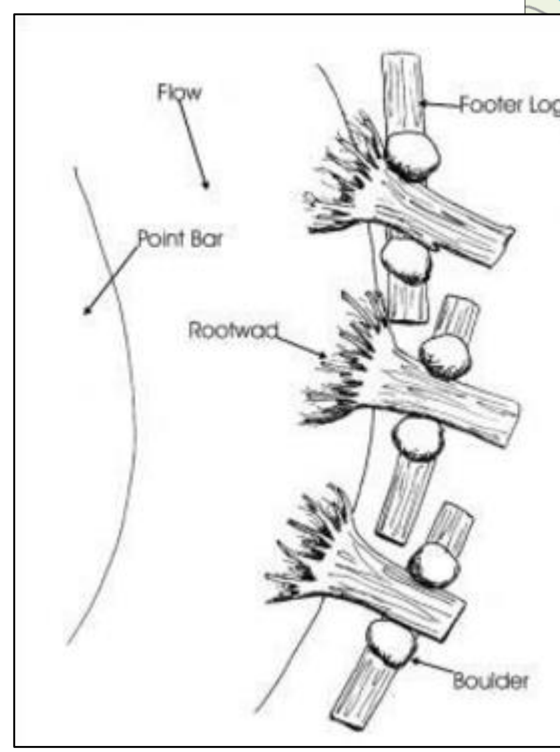
Project Overview

Project 4 of the Stream Restoration and Sanitary Sewer Protection Plan extends 2000 feet upstream along Long Indian Creek from Waters Road (labeled Zone 4 in the map). The site can be accessed from Waters Road, and then a sanitary sewer easement can be used to traverse the stream length. Based on the stream walk, the restoration measures called for are a mixture of Rosgen Priority 3 Channel Restoration, bank stabilization, and bank protection groups. Bank protection groups differ from bank stabilization because bank protection groups utilize structural methods to protect banks while bank stabilization employs non-structural techniques to resist bank erosion. Further, there are three exposed sanitary sewer pipes along this section of stream which require protection with cross vanes.

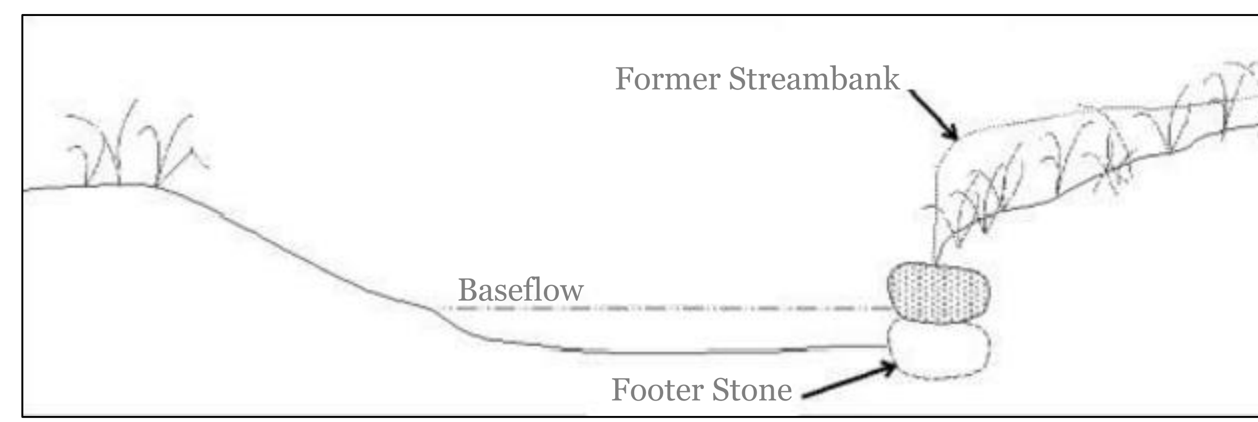




Log, rootwad, and boulder revetment. Example of a bank protection group (GA DNR, 2011).



Plan view of rootwad revetment. Rootwad revetments prevent bank erosion and provide excellent habitats (SMRC, 2016).



Profile view of single boulder revetment. Although boulder revetments do prevent erosion, they offer limited potential for improving in-stream habitats (SMRC, 2016).

Exposed sanitary sewer pipe near the downstream end of the project.

Benefits

- Reduce TSS load by approximately 220 tons/year
- Reduce stream velocity
- Provide grade control along the stream
- Protect existing sanitary sewer infrastructure
- Prevent future fecal coliform contamination from damaged pipes
- Improve stream habitat
- Remove of invasive plant species
- Improve aesthetics of stream

Item	Unit	Quantity	Unit Price	Total Price
Clearing & Grubbing	AC	3	$50,000	$150,000
Erosion Control	LF	2,000	$25	$50,000
Earthwork	CY	3,000	$15	$45,000
Riparian Buffer Plantings	LF	2,000	$35	$70,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Large	EA	3	$35,000	$105,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Medium	EA	0	$25,000	$0
Stream Structures (Cross-Vane, J-Hook, etc.) – Small	EA	0	$15,000	$0
			Construction Sub-Total	$420,000
			Engineering and Permitting (25%)	$105,000
			Contingency (20%)	$105,000
			Capital Cost	**$630,000**
			Annual Maintenance Cost	**$250**

Exposed sanitary sewer pipe near the center of the restoration project. The pipes are attached with a flange joint, and therefore not as susceptible to damage during flood events.

Exposed sanitary sewer pipe near the upstream end of the project. A large debris jam is located just upstream of the pipe which could damage the pipe during a flood event.

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #5 – Stream Restoration and Sanitary Sewer Protection Project 4

THE CITY OF ALPHARETTA
Dewberry

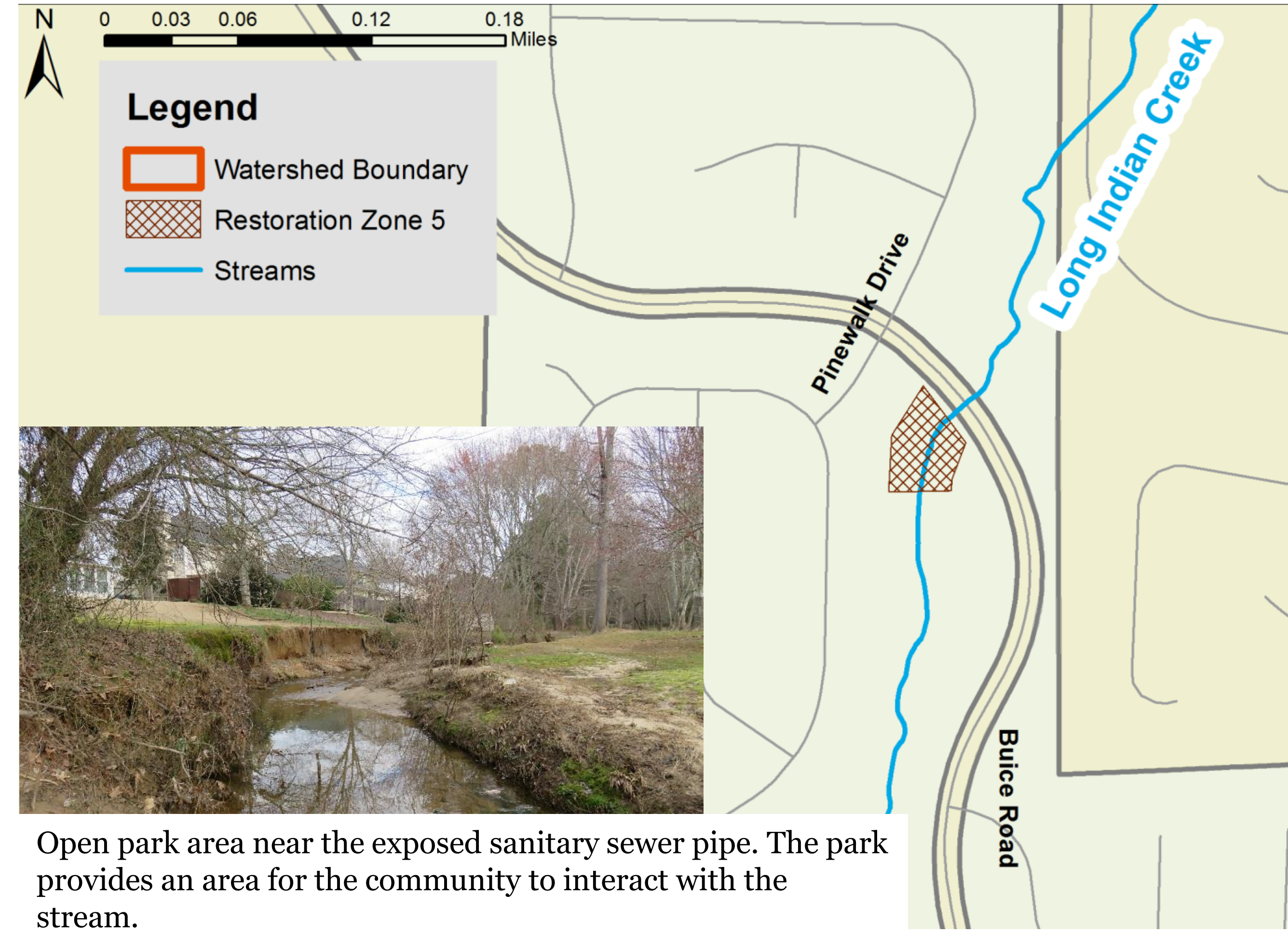
SHEET C.10

Project Overview

Project 5 of the Stream Restoration and Sanitary Sewer Protection Plan only incorporates the couple hundred feet of Long Indian Creek directly downstream of Buice Road (labeled Zone 5 in the map). Access to the site can be gained from a park off of Buice Road. The stream is in relatively good condition in this reach. Therefore, only a minor amount of grade control is suggested just downstream of the exposed sanitary sewer pipe to protect it from future damage and further reduce stream velocities in the affected area.

Item	Unit	Quantity	Unit Price	Total Price
Clearing & Grubbing	AC	0.5	$50,000	$22,957
Erosion Control	LF	200	$25	$5,000
Earthwork	CY	300	$15	$4,500
Riparian Buffer Plantings	LF	200	$35	$7,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Large	EA	0	$35,000	$0
Stream Structures (Cross-Vane, J-Hook, etc.) – Medium	EA	1	$25,000	$25,000
Stream Structures (Cross-Vane, J-Hook, etc.) – Small	EA	0	$15,000	$0
			Construction Sub-Total	$64,457
			Engineering and Permitting (25%)	$16,114
			Contingency (20%)	$16,114
			Capital Cost	**$96,685**
			Annual Maintenance Cost	**$250**

Exposed sanitary sewer pipe. A cross vane can be installed downstream of the pipe to protect it from future damage and improve the aesthetics of the surrounding park.



Open park area near the exposed sanitary sewer pipe. The park provides an area for the community to interact with the stream.

Benefits

- Reduce TSS load by approximately 15 tons/year
- Reduce stream velocity
- Provide grade control along the stream
- Protect existing sanitary sewer infrastructure
- Prevent future fecal coliform contamination from damaged pipes
- Improve stream habitat
- Improve aesthetics of stream
- Provide an opportunity for the community to interact with the stream
- Educate the public about the Long Indian Creek stream restoration in a highly visible location

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #6 – Stream Restoration and Sanitary Sewer Protection Project 5

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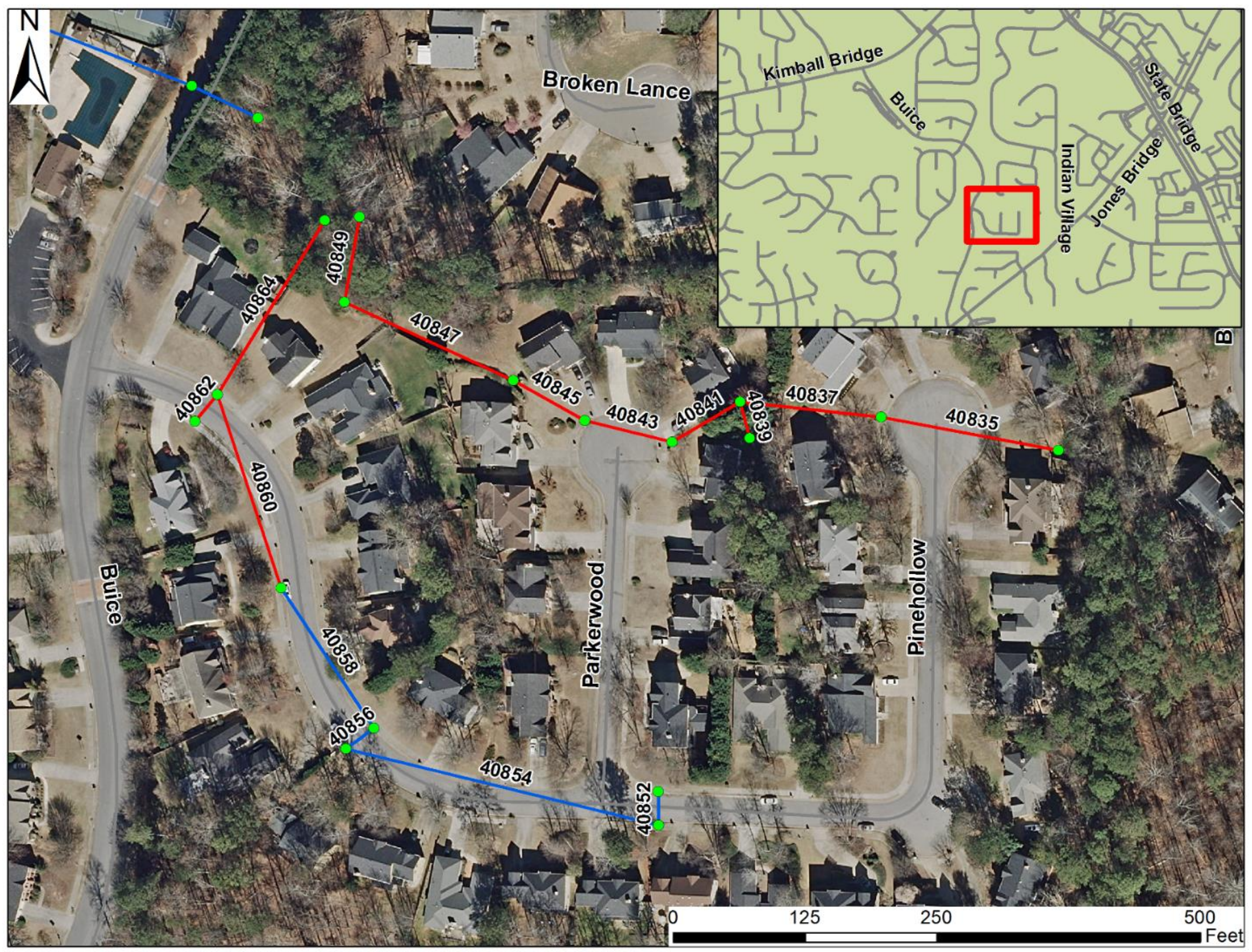
Project Overview

Pinehollow Court is a neighborhood, composed of two streets, located off of Buice Road. There are no drainage complaints within the neighborhood, and the Dewberry field team was not approached with system flooding complaints by any residents. However, the existing model indicates that 11 of the 15 pipes within the neighborhood are undersized. In the most severe case, an 18-inch pipe at the outlet of the system requires on upgrade to a 48-inch pipe to meet the 25-year level of service. Therefore despite the lack of City or resident complaints, the Dewberry team has identified the Pinehollow Court neighborhood as a candidate for system improvements based on model-indicated, neighborhood-wide flooding.



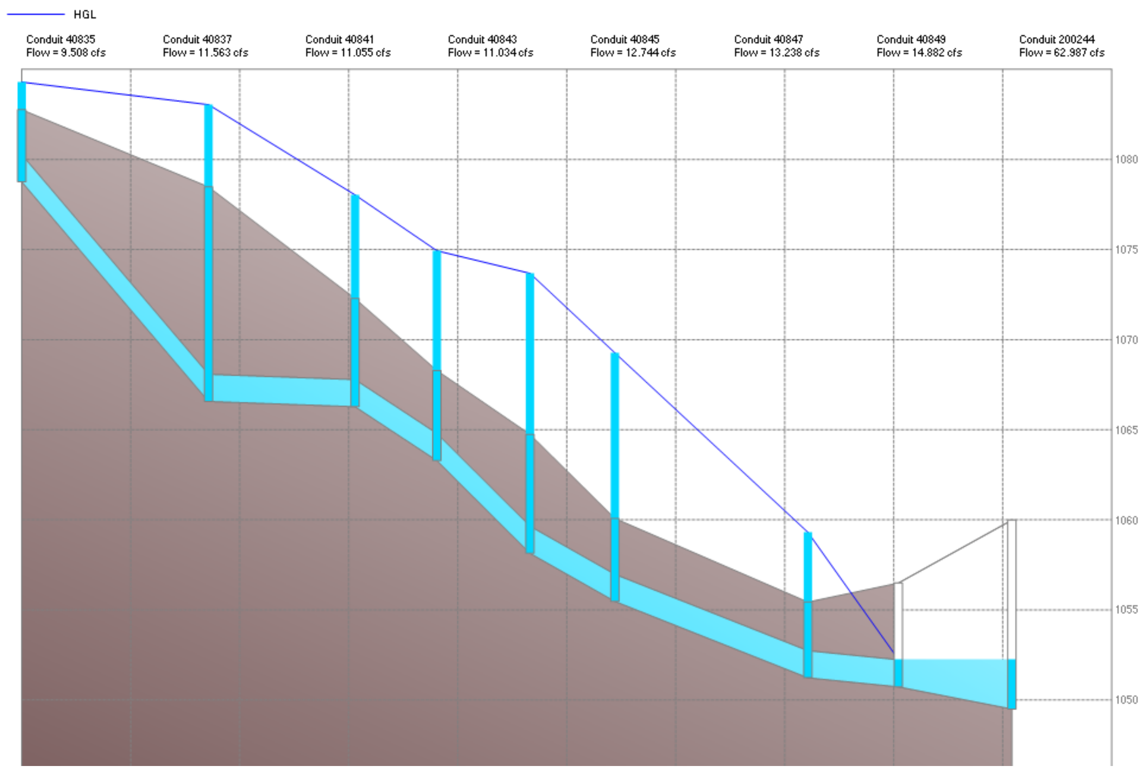
Location of the Pinehollow Court Neighborhood and its existing stormwater system. Red pipes do not meet the 25-year level of service, and blue pipes do meet the 25-year level of service. Pipe Facility ID Numbers are displayed next to each pipe and can be related to the upgrade scenario tables and the system analysis database.

Cost

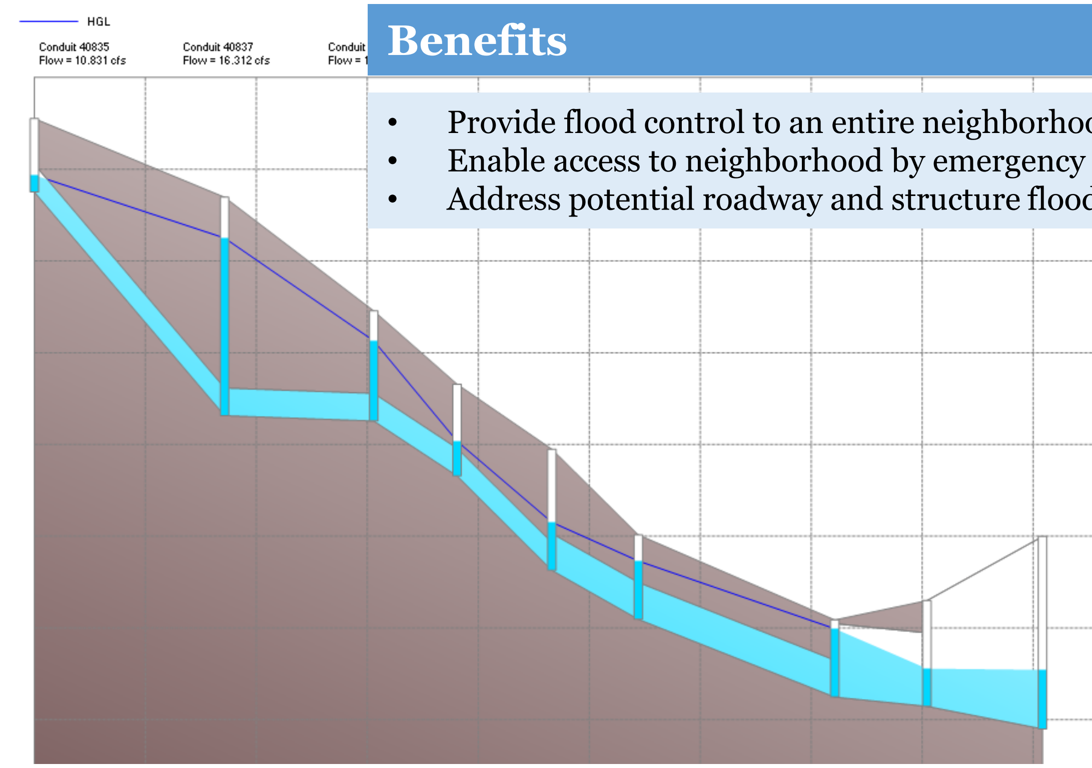
Construction related items are populated in the database to serve as input data for the Stormwater System Cost Estimation Tool. These items include the following:

- CIPP rehabilitation, inversion setup, and pipe cleaning
- Pipe removal and replacement
- Depth to top of the pipe for depths over 8'
- Structure removal and replacement
- Unsuitable haul-off allowances
- Driveway, sidewalk, and street cut replacement
- Silt Fence and Sod

Description	Quantity	Unit Cost	Total Cost
18" RCP Pipe (L.F.)	36	$60.0	$2,149.8
24" RCP Pipe (L.F.)	451	$65.0	$29,318.8
48" RCP Pipe (L.F.)	83	$150.0	$12,454.1
Catch Basin Complete, Group 1 or 2 (V.F.)	13	$500.0	$6,400.0
Headwall for 24" Pipe (Each)	1	$600.0	$600.0
Headwall for 48" Pipe (Each)	1	$1,400.0	$1,400.0
Manhole Complete, Type 1 or 2 (V.F.)	6	$500.0	$3,000.0
Yard Inlet All Types Complete, Group 1 or 2 (V.F.)	12	$600.0	$7,080.0
Depth to Top of Pipe (< 8.1') (L.F.)	570	$0.0	$0.0
Driveway (6" Concrete) (S.Y.)	1	$60.0	$68.1
Haul Off Unsuitables and Classified Stone Backfill (C.Y.)	397	$60.0	$23,816.2
Removal of Existing Drainage Structures (Each)	8	$500.0	$4,000.0
Remove Existing Pipe, All Types and Sizes (L.F.)	570	$25.0	$14,247.9
Silt Fence Type C, Complete (L.F.)	1615	$4.0	$6,458.4
Sodding Complete (S.Y.)	1418	$7.0	$9,928.3
Street Cut (Detail C) (S.Y.)	82	$75.0	$6,129.8
CIPP 18" (L.F.)	210	$102.0	$21,371.4
18" Pipe - Cleaning less than 25% full (L.F.)	210	$4.0	$838.1
Inversion Setup Charge 15"-36" CIPP (Each)	2	$1,740.0	$3,480.0
		Construction Sub-Total	$152,741
		Engineering and Permitting (20%)	$30,550
		Contingency (20%)	$36,658
		Capital Cost	**$219,950**
		Annual Maintenance Cost	**$500**



Maximum Hydraulic Grade Line (HGL) for an existing portion of the Pinehollow Court neighborhood stormwater system. Currently, all nodes flood in the 25-year storm event.



Maximum Hydraulic Grade Line (HGL) for an upgraded portion of the Pinehollow Court neighborhood stormwater system. In the upgrade scenario, none of the nodes flood during a 25-year storm event.

Benefits

- Provide flood control to an entire neighborhood
- Enable access to neighborhood by emergency vehicles during storm events
- Address potential roadway and structure flooding within neighborhood

The database presents upgrade scenarios, detailing pipe size and pipe material, for the following five options:

Scenario 1: Cured-in-Place Pipe (CIPP)
Scenario 2: Replace like size with HDPE
Return "Not Applicable" where limitations exists
Scenario 3: Replace like size with RCP
Scenario 4: Replace pipe to meet desired Level of Service HDPE
Return "Not Applicable" where limitations exists
Scenario 5: Replace pipe to meet desired Level of Service RCP

	Existing Conditions				Scenario 1			Scenario 2			Scenario 3			Scenario 4			Scenario 5		
Facility ID	Shape	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)
40835	Circular	RC	18	5	RL	18	10	RC	18	10	RC	18	10	RC	18	25	RC	18	25
40837	Circular	CO	18	5	RL	18	10	PT	18	10	RC	18	10	PT	18	25	RC	18	25
40839	Circular	PL	12	1	RL	12	2	PT	12	2	RC	12	2	PT	18	25	RC	18	25
40841	Circular	CO	18	2	RL	18	5	PT	18	5	RC	18	5	PT	18	25	RC	18	25
40843	Circular	RC	18	1	RL	18	2	PT	18	2	RC	18	2	PT	18	25	RC	18	25
40845	Circular	CO	18	<1	RL	18	1	PT	18	1	RC	18	1	PT	24	100	RC	24	100
40847	Circular	CO	18	<1	RL	18	<1	PT	18	<1	RC	18	<1	PT	24	25	RC	24	25
40849	Circular	CO	18	<1	RL	18	<1	PT	18	<1	RC	18	<1	PT	48	25	RC	48	25
40852	Circular	RC	18	100	RL	18	100	RC	18	100	RC	18	100	RC	18	100	RC	18	100
40854	Circular	RC	18	100	RL	18	100	RC	18	100	RC	18	100	RC	18	100	RC	18	100
40856	Circular	RC	18	100	RL	18	100	RC	18	100	RC	18	100	RC	18	100	RC	18	100
40858	Circular	RC	18	100	RL	18	100	RC	18	100	RC	18	100	RC	18	100	RC	18	100
40860	Circular	RC	18	5	RL	18	10	RC	18	10	RC	18	10	RC	18	25	RC	18	25
40862	Circular	RC	18	1	RL	18	5	RC	18	5	RC	18	5	RC	18	25	RC	18	25
40864	Circular	CO	18	2	RL	18	5	PT	18	5	RC	18	5	PT	24	25	RC	24	25

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #7 – Pinehollow Court Neighborhood Flooding

SHEET C.13

Project Overview

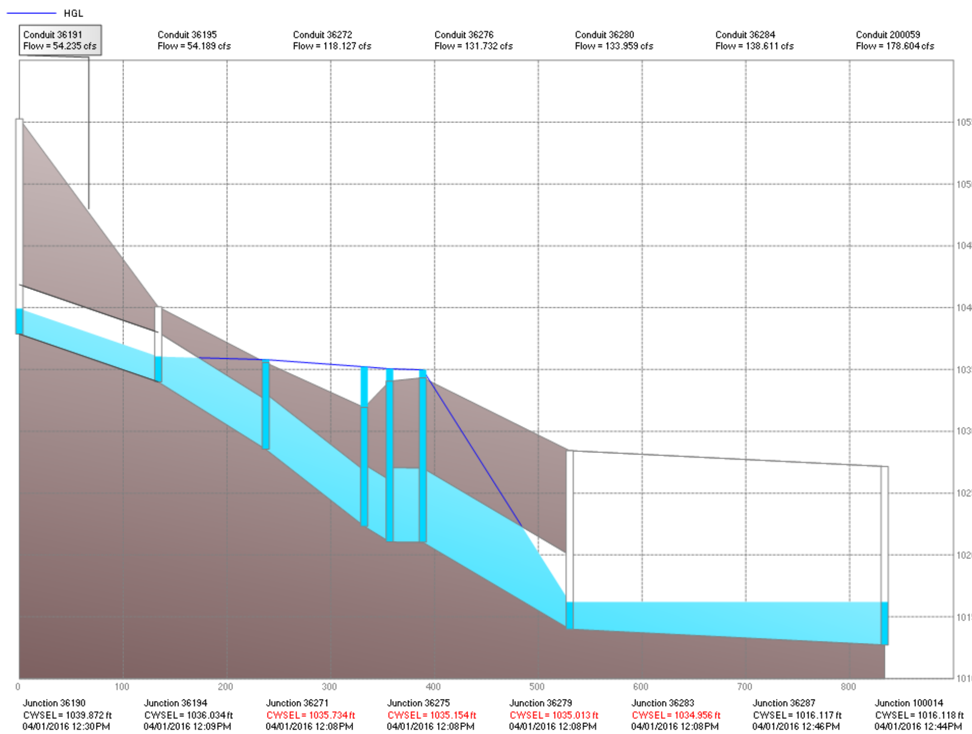
Tuxford is a neighborhood located off of Kimball Bridge Road. Stormwater runoff within the neighborhood is conveyed by a closed stormwater system. For this analysis, the focus will be on the pipes spanning Tuxford Drive between Dunoon Drive and Grenadier Lane. There are several drainage complaints in the area surrounding the pipes. Two complaints are for erosion and one complaint is for structure maintenance. Additionally, the Dewberry field team was approached by residents during their surveying. Several residents described persistent system flooding and erosion. Further, the existing model corroborates the accounts of residents and indicates flooding due to insufficient capacity in the four most downstream pipes of the system. Due to drainage complaints from the City, resident complaints, and model-verified system flooding, the Dewberry team has identified the Tuxford neighborhood as a candidate for system improvements.

Description	Quantity	Unit Cost	Total Cost
90" RCP Pipe (L.F.)	142	$490.0	$69,362.9
Catch Basin Complete, Group 1 or 2 (V.F.)	13	$500.0	$6,650.0
Headwall for 90" Pipe (Each)	1	$3,750.0	$3,750.0
Depth to Top of Pipe (8.1' - 12.0') (L.F.)	142	$50.0	$7,077.9
Haul Off Unsuitables and Classified Stone Backfill (C.Y.)	544	$60.0	$32,648.8
Removal of Existing Drainage Structures (Each)	2	$500.0	$1,000.0
Remove Existing Pipe, All Types and Sizes (L.F.)	142	$25.0	$3,538.9
Silt Fence Type C, Complete (L.F.)	414	$4.0	$1,655.0
Sodding Complete (S.Y.)	744	$7.0	$5,206.7
Street Cut (Detail C) (S.Y.)	64	$75.0	$4,765.8
CIPP 36" (L.F.)	236	$306.0	$72,067.0
CIPP 48" (L.F.)	237	$510.0	$121,007.2
CIPP 54" (L.F.)	95	$1,030.0	$97,766.6
CIPP 60" (L.F.)	25	$882.0	$21,657.5
36" Pipe - Cleaning Less Than 25% Full (L.F.)	236	$6.0	$1,413.1
48" Pipe - Cleaning Less Than 25% Full (L.F.)	237	$9.0	$2,135.4
54" Pipe - Cleaning Less Than 25% Full (L.F.)	95	$9.0	$854.3
60" Pipe - Cleaning Less Than 25% Full (L.F.)	25	$11.0	$270.1
Inversion Setup Charge 15"-36" CIPP (Each)	1	$1,740.0	$1,740.0
Inversion Setup Charge 42"-60" CIPP (Each)	4	$4,140.0	$16,560.0
		Construction Sub-Total	$471,128
		Engineering and Permitting (20%)	$94,226
		Contingency (20%)	$113,071
		Capital Cost	**$678,425**
		Annual Maintenance Cost	**$500**

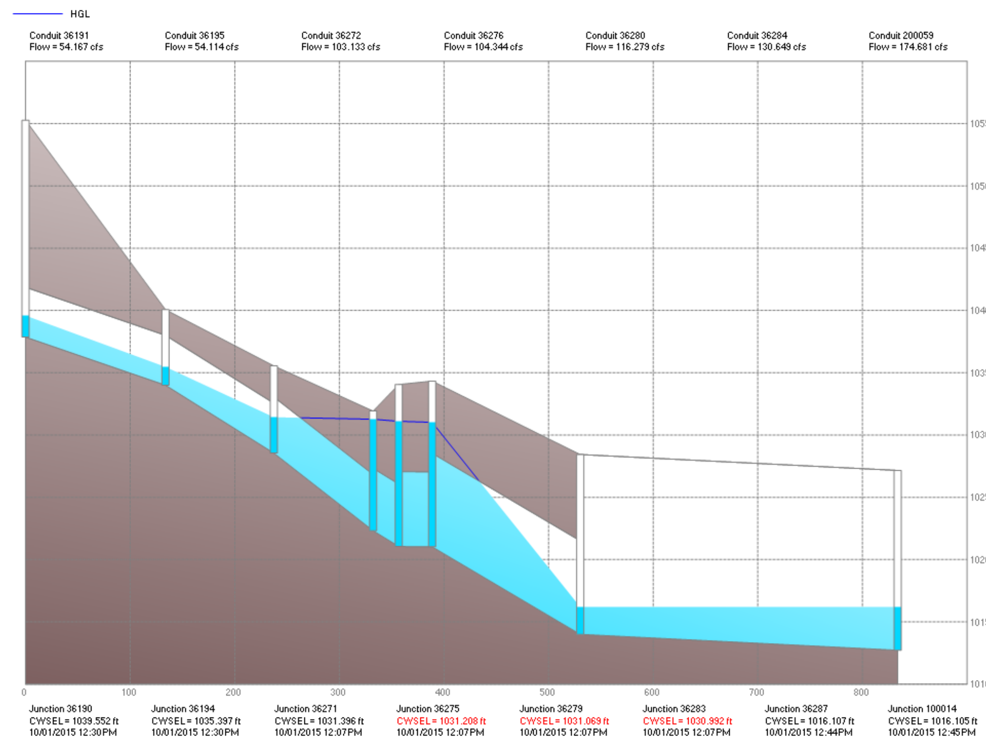
Location of the Tuxford Neighborhood and its existing stormwater system. Red pipes do not meet the 25-year level of service, and blue pipes do meet the 25-year level of service. Pipe Facility ID Numbers are displayed next to each pipe and can be related to the upgrade scenario tables and the system analysis database.

Cost

Construction related items are populated in the database to serve as input data for the Stormwater System Cost Estimation Tool. These items include: 1) CIPP rehabilitation, inversion setup, and pipe cleaning; 2) Pipe removal and replacement; 3) Depth to top of the pipe for depths over 8'; 4) Structure removal and replacement; 5) Additional excavation allowances; 6) Driveway, sidewalk, and street cut replacement; and 7) Silt Fence and Sod



Maximum Hydraulic Grade Line (HGL) for an existing portion of the Tuxford neighborhood stormwater system. Currently, the four most downstream pipes have insufficient capacity.



Maximum Hydraulic Grade Line (HGL) for an upgraded portion of the Tuxford neighborhood stormwater system. In the upgrade scenario, none of the nodes flood during a 25-year storm event.

The database presents upgrade scenarios, detailing pipe size and pipe material, for the following five options:

Scenario 1: Cured-in-Place Pipe (CIPP)
Scenario 2: Replace like size with HDPE
Return "Not Applicable" where limitations exists
Scenario 3: Replace like size with RCP
Scenario 4: Replace pipe to meet desired Level of Service HDPE
Return "Not Applicable" where limitations exists
Scenario 5: Replace pipe to meet desired Level of Service RCP

	Existing Conditions				Scenario 1			Scenario 2			Scenario 3			Scenario 4			Scenario 5		
Facility ID	Shape	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)
36191	Circular	CO	48	100	RL	48	100	PT	48	100	RC	48	100	PT	48	100	RC	48	100
36195	Circular	CO	48	100	RL	48	100	PT	48	100	RC	48	100	PT	48	100	RC	48	100
36241	Circular	RC	48	100	RL	48	100	PT	48	100	RC	48	100	PT	48	100	RC	48	100
36272	Circular	CO	54	2	RL	54	2	PT	54	2	RC	54	2	PT	54	100	RC	54	100
36276	Circular	CO	60	1	RL	60	1	PT	60	1	RC	60	1	PT	60	100	RC	60	100
36280	Circular	RC	72	2	RL	72	2	RC	72	2	RC	72	2	RC	72	100	RC	72	100
36284	Circular	CO	72	2	RL	72	2	RC	72	2	RC	72	2	RC	90	100	RC	90	100
39983	Circular	CO	18	100	RL	18	100	PT	18	100	RC	18	100	PT	18	100	RC	18	100
42107	Circular	CO	36	100	RL	36	100	PT	36	100	RC	36	100	PT	36	100	RC	36	100
100060	Circular	PT	12	25	RL	12	25	PT	12	25	RC	12	25	PT	12	25	RC	12	25

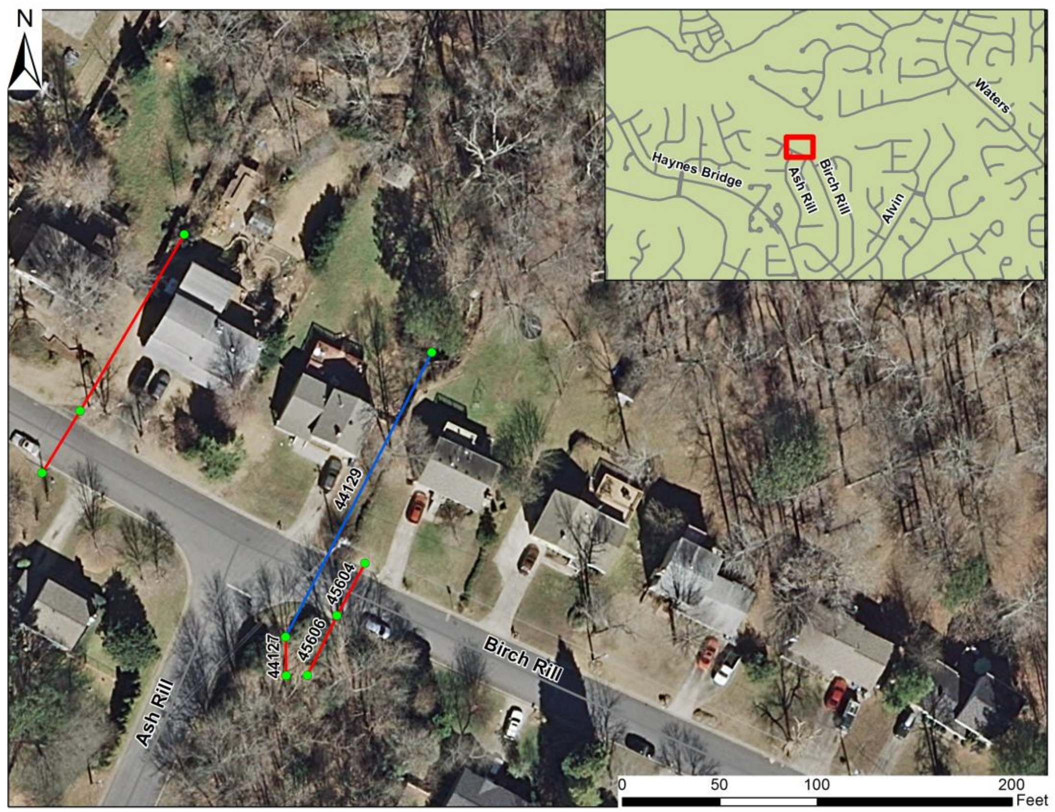
Only pipe 36284 requires an upgrade from a 72-inch diameter pipe to a 90-inch diameter pipe in order to meet a 25-year level of service. Normally, this is an ideal solution as upgrades are limited to a single pipe in order to meet the requirements of the entire system. Unfortunately, the size of the pipe and the its location between two houses could present construction site constraints. The trench cut required to install the larger pipe would overlap with existing houses, making it impossible to install the larger pipe needed to meet the 25-year level of service. Therefore, alternate solutions, such as a parallel system would need to be explored as potential solutions.

Project Overview

CIP No. LIC_0100_1 is the Birch Rill Drive Culvert that spans Long Indian Creek Tributary 1. In the December 2011 CIP Report, the HEC-RAS model indicated that the culvert overtops during the 5-year storm event. Due to this overtopping frequency, the CIP was ranked 5th. In this 2016 WIP Report, each CIP was reassessed using a SWMM model. Often the more granular, hydrodynamic SWMM model allows for improved routing and attenuation when compared to steady state HEC-RAS models. Therefore, it is not uncommon for the level of service to increase for CIPs when they are analyzed using a SWMM model. In the case of CIP No. LIC_0100_1, the SWMM model indicated an improved level of service from a 5-year overtopping frequency to a 10-year overtopping frequency. Although the SWMM model does indicate an increase of the service level for LIC_0100_1 for Birch Rill Drive, an upgrade to a 54" pipe is required to meet the 25-year level of service.

The database presents upgrade scenarios, detailing pipe size and pipe material, for the following five options:

Scenario 1: Cured-in-Place Pipe (CIPP)
Scenario 2: Replace like size with HDPE
Return "Not Applicable" where limitations exists
Scenario 3: Replace like size with RCP
Scenario 4: Replace pipe to meet desired Level of Service HDPE
Return "Not Applicable" where limitations exists
Scenario 5: Replace pipe to meet desired Level of Service RCP



Location of CIP No. LIC_0100_1. Red pipes do not meet the 100-year level of service, and blue pipes do meet the 100-year level of service. Pipe Facility ID Numbers are displayed next to each pipe.

Description	Quantity	Unit Cost	Total Cost
54" RCP PIPE (L.F.)	184	$175.0	$32,200.7
HEADWALL FOR 48" PIPE (EACH)	1	$1,400.0	$1,400.0
HEADWALL FOR 54" PIPE (EACH)	1	$1,600.0	$1,600.0
WEIR (EQUIV TO YI FOR PURPOSE OF COST) (V.F.)	10	$600.0	$6,084.0
DEPTH TO TOP OF PIPE (< 8.1') (L.F.)	184	$0.0	$0.0
DRIVEWAY (6" Concrete) (S.Y.)	39	$60.0	$2,365.8
Haul Off Unsuitables and Classified Stone Backfill (C.Y.)	938	$60.0	$56,255.6
REMOVAL OF EXISTING DRAINAGE STRUCTURES (EACH)	3	$500.0	$1,500.0
REMOVE EXISTING PIPE, ALL TYPES AND SIZES (L.F.)	184	$25.0	$4,600.1
SILT FENCE TYPE C, COMPLETE (L.F.)	479	$4.0	$1,915.1
SODDING COMPLETE (S.Y.)	567	$7.0	$3,969.4
STREET CUT (Detail C) (S.Y.)	100	$75.0	$7,533.7
CIPP 18" (L.F.)	65	$102.0	$6,589.6
18" PIPE - Cleaning less than 25% full (L.F.)	65	$4.0	$258.4
INVERSION SETUP CHARGE 15"-36" CIPP (EACH)	2	$1,740.0	$3,480.0
		Construction Sub-Total	$129,753
		Engineering and Permitting (20%)	$25,951
		Contingency (20%)	$31,141
		Capital Cost	**$186,845**
		Annual Maintenance Cost	**$500**

	Existing Conditions				Scenario 1			Scenario 2			Scenario 3			Scenario 4			Scenario 5		
Facility ID	Shape	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)	Material	Diameter (inch)	Level of Service (years)
44127	Circular	CO	36	10	RL	36	10	PT	36	10	RC	36	10	PT	54	100	RC	54	100
44129	Circular	CO	48	100	RL	48	100	PT	48	100	RC	48	100	PT	54	100	RC	54	100
45604*	Circular	CO	18	<1	RL	18	<1	PT	18	<1	RC	18	<1	PT	18	25	RC	18	25
45606*	Circular	CO	18	<1	RL	18	<1	PT	18	<1	RC	18	<1	PT	18	25	RC	18	25

*Pipe 45604 and 45606 increase their LOS without any upgrades due to improved downstream hydraulics cause by upgrades to pipe 44127 and 44129.

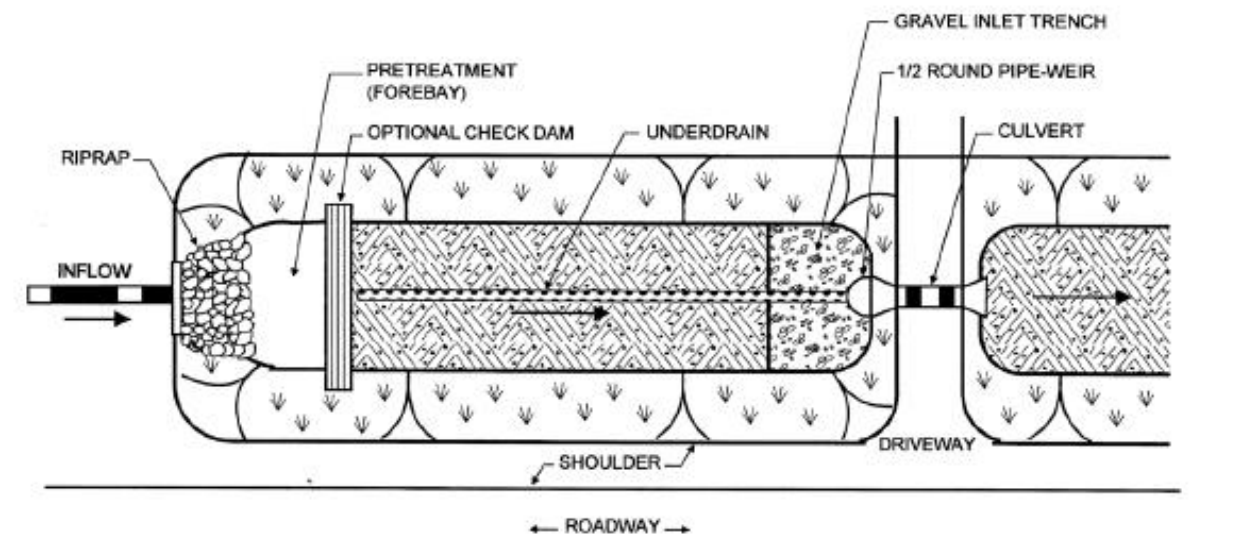
CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #9 – Birch Rill Drive Capital Improvement Project No. LIC_0100_1

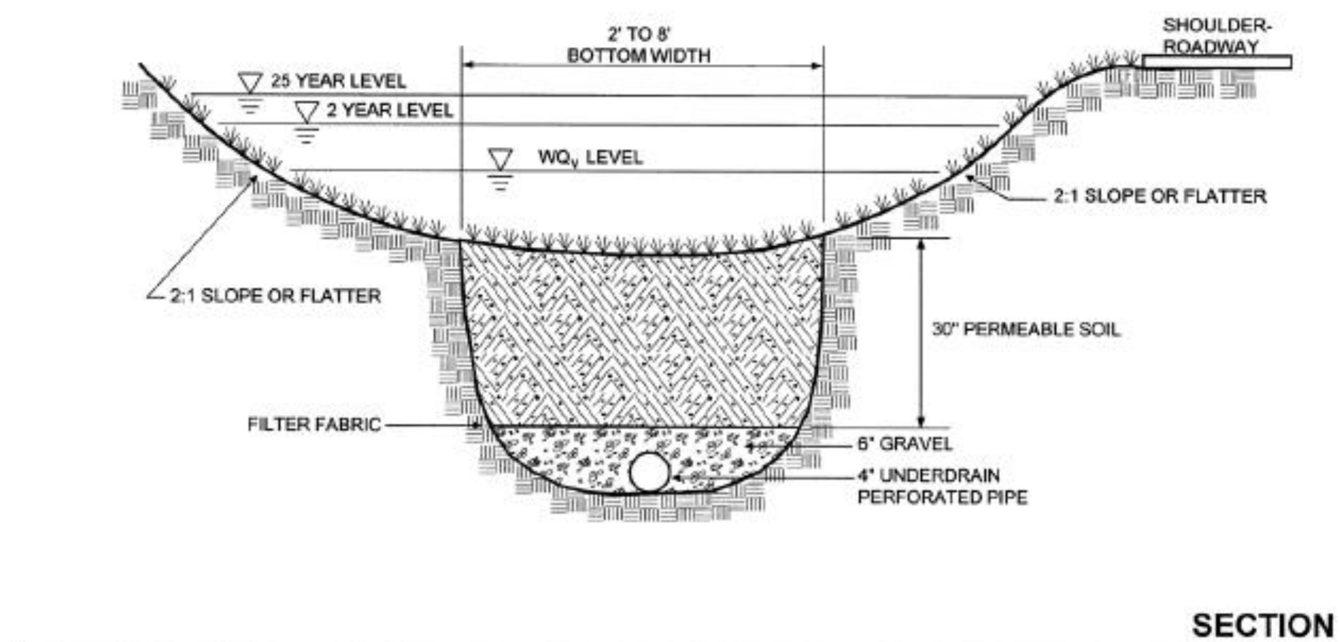
THE CITY OF ALPHARETTA
Dewberry

Project Overview

An enhanced dry swales is recommended along the west side of Waters Road just north of where Long Indian Creek crosses the road. Due to the lack of public land within the Long Indian Creek watershed, swales are recommended for reducing runoff and total suspended solids loading into Long Indian Creek because of their linear nature and lesser land requirements. Based on the available land, it is estimated that approximately 350 linear feet of swale could be installed. In total, this installation would treat 2.4 acres of land, of which 0.65 acres (27%) is impervious cover. The Stormwater Quality Site Development Review Tool, version 2.2, from the Georgia Stormwater Management Manual was used to predict a runoff reduction volume of 2,559 cubic feet and a water quality treatment volume of 3,071 cubic feet from runoff from a 1-inch storm. This storage volume would remove 80% of the TSS from the contributing drainage area.

Location of proposed enhanced dry swale along Waters Road. A runoff reduction volume of 50% and a TSS removal rate of 80% is expected for the area treated by the swale.





Typical schematic for a dry swale from the Georgia Stormwater Management Manual (ARC, 2016)

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #10 – Waters Road Enhanced Dry Swale Project 1 (North)

THE CITY OF ALPHARETTA

Dewberry

SHEET C.17

Item	Unit	Quantity	Unit Price	Total Price
Clearing and Grubbing	AC	0.2	$25,000	$5,022
Erosion Control	LF	350	$20	$7,000
Earthwork - Haul off and Engineered Soils	CY	100	$75	$7,500
Sod Complete	SY	800	$10	$8,000
Check Dam	EA	6	$2,500	$15,000
Plastic Filter Fabric	SY	400	$10	$4,000
			Construction Sub-Total	$46,522
			Engineering and Permitting (25%)	$20,000
			Contingency (20%)	$13,304
			Capital Cost	**$79,826**
			Annual Maintenance Cost	**$500**

KEY CONSIDERATIONS

DESIGN CRITERIA
- Longitudinal slopes must be less than 4%
- Bottom width of 2 to 8 feet
- Side slopes 2:1 or flatter; 4:1 recommended
- Convey the 25-year storm event with a minimum of 6 inches of freeboard

ADVANTAGES / BENEFITS
- Combines stormwater treatment with runoff conveyance system
- Less expensive than curb and gutter
- Reduces runoff velocity

DISADVANTAGES / LIMITATIONS
- Higher maintenance than curb and gutter systems
- Cannot be used on steep slopes
- Possible resuspension of sediment
- Potential for odor / mosquitoes (wet swale)

MAINTENANCE REQUIREMENTS
- Maintain grass heights of approximately 4 to 6 inches (dry swale)
- Remove sediment from forebay and channel

POLLUTANT REMOVAL (DRY SWALE)
- 80% Total Suspended Solids
- 40% Metals - Cadmium, Copper, Lead, and Zinc removal
- 50/50% Nutrients - Total Phosphorus / Total Nitrogen removal
- N/A Pathogens – Fecal Coliform

POLLUTANT REMOVAL (WET SWALE)
- 80% Total Suspended Solids
- 20% Metals - Cadmium, Copper, Lead, and Zinc removal
- 25/40% Nutrients - Total Phosphorus / Total Nitrogen removal
- N/A Pathogens – Fecal Coliform

STORMWATER MANAGEMENT SUITABILITY
- ✓ Runoff Reduction
- ✓ Water Quality
- ★ Channel Protection
- Overbank Flood Protection
- Extreme Flood Protection

✓ suitable for this practice
★ may provide partial benefits

IMPLEMENTATION CONSIDERATIONS
- M Land Requirement
- M Capital Cost
- L Maintenance Burden

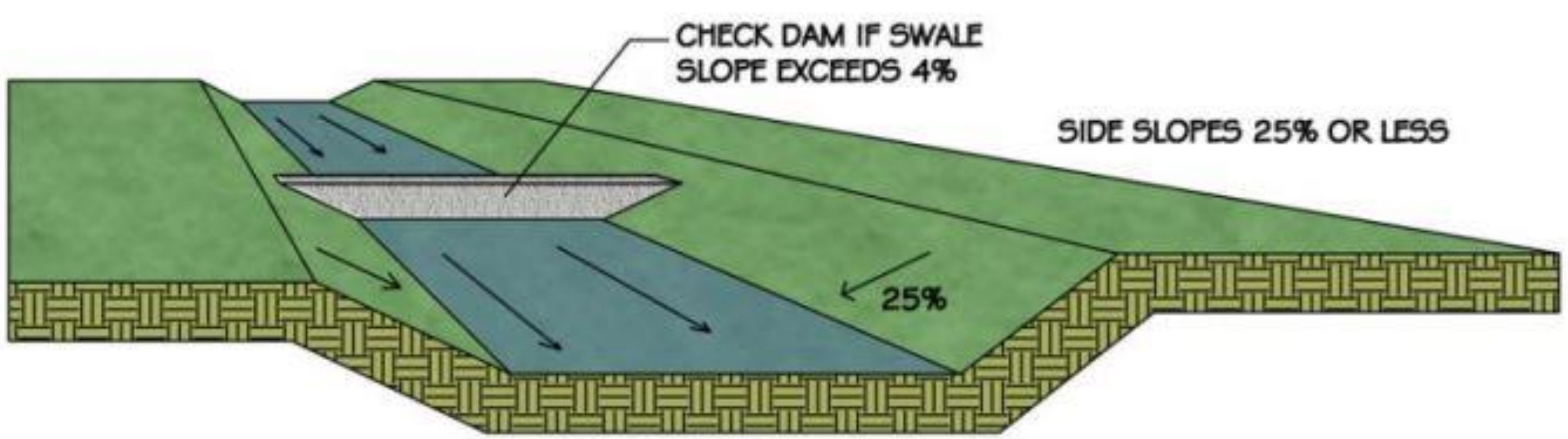
Residential Subdivision Use: *Yes*
High Density/Ultra-Urban: *No*
Drainage Area: *5 acres max*

Soils: *No restrictions*

Other Considerations:
- Permeable soil layer (dry swale)
- Wetland plants (wet swale)

L=Low M=Moderate H=High

RUNOFF REDUCTION CREDIT
- Dry Swale: 100% of the runoff reduction volume provided (no underdrain)
- Dry Swale: 50% of the runoff reduction volume provided (underdrain)
- Wet Swale: 0% of the runoff reduction volume provided



VEGETATED (grassed) SWALE

Check dams can be used for swales whose slopes exceed 4% as would be the case for this project.

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #10 – Waters Road Enhanced Dry Swale Project 1 (North)

THE CITY OF ALPHARETTA
Dewberry

SHEET C.18

Project Overview

An enhanced dry swales is recommended along the east side of Waters Road south of where Long Indian Creek crosses the road. Due to the lack of public land within the Long Indian Creek watershed, swales are recommended for reducing runoff and total suspended solids loading into Long Indian Creek because of their linear nature and lesser land requirements. Based on the available land, it is estimated that approximately 500 linear feet of swale could be installed. In total, this installation would treat 2/3 acres of land, of which 0.38 acres (56%) is impervious cover. The Stormwater Quality Site Development Review Tool, version 2.2, from the Georgia Stormwater Management Manual was used to predict a runoff reduction volume of 1,347 cubic feet and a water quality treatment volume of 1,617 cubic feet from runoff from a 1-inch storm. This storage volume would remove 80% of the TSS from the contributing drainage area.

Location of proposed enhanced dry swale along Waters Road. A runoff reduction volume of 50% and a TSS removal rate of 80% is expected for the area treated by the swale.

Example of a dry swale from the Georgia Stormwater Management Manual (ARC, 2016)

Item	Unit	Quantity	Unit Price	Total Price
Clearing and Grubbing	AC	0.3	$25,000	$7,174
Erosion Control	LF	500	$20	$10,000
Earthwork - Haul off and Engineered Soils	CY	200	$75	$15,000
Sod Complete	SY	1,200	$10	$12,000
Check Dam	EA	0	$2,500	$0
Plastic Filter Fabric	SY	500	$10	$5,000
			Construction Sub-Total	$49,174
			Engineering and Permitting (25%)	$20,000
			Contingency (20%)	$13,835
			Capital Cost	**$83,009**
			Annual Maintenance Cost	**$500**

CITY OF ALPHARETTA
Long Indian Creek Watershed Improvement Plan
WIP #11 – Waters Road Enhanced Dry Swale Project 2 (South)

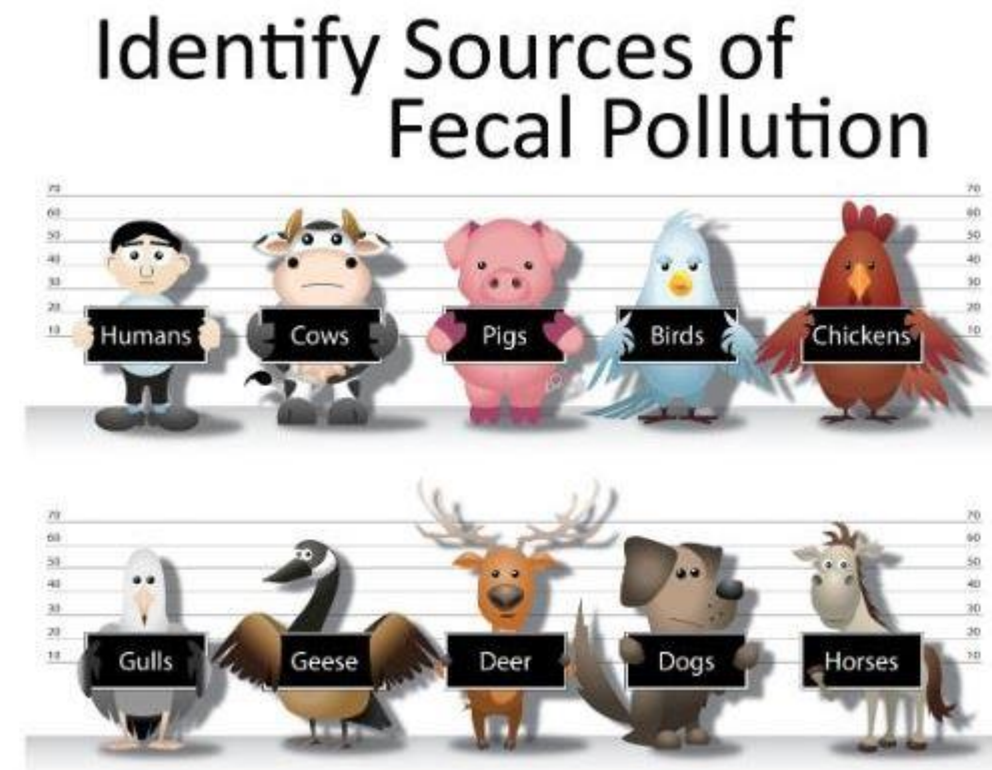
THE CITY OF ALPHARETTA

Dewberry

SHEET C.19

Project Overview

Bacterial Source Tracking, commonly referred to as BST, allows for the determination of the source(s) of fecal contamination because of variations in DNA sequences between living organisms that make it possible to distinguish one organisms from another through molecular biology techniques. This can be done through a process called Polymerase Chain Reaction (PCR) in which DNA sequences are extracted and amplified to identify and quantify the presence of microorganisms in water samples based on the unique genetic sequence of that organism (Source Molecular, 2016). This process is the preferred BST technology (Shanks , 2015), and Source Molecular is licensed by the EPA to use their patented genetic testing methods developed to identify Human, cattle, chicken, and dog fecal contamination. It is recommended that the City of Alpharetta continues to utilize BST technology to monitor the source(s) of fecal contamination in watersheds. Continued BST monitoring will ensure that the best and most targeted measures are being used to address fecal coliform contamination within the Long Indian Creek Watershed. It is anticipated that BST monitoring will cost $25,000 annually, but this cost can be customized to the City's needs by adjusting the number of samples and their sampling frequency.



Sample BST Results:

SM #	Client #	Analysis Requested	Marker Quantified (copies/100 ml)	DNA Analytical Results
SM-6D13021	Site 1	Dog Bacteroidetes ID	2.60E+03	Present
SM-6D13022	Site 2	Dog Bacteroidetes ID	2.96E+04	Present
SM-6D13023	Site 3	Dog Bacteroidetes ID	1.22E+04	Present
SM-6D13024	Site 4	Dog Bacteroidetes ID	1.72E+04	Present
SM-6D13025	Site 5	Dog Bacteroidetes ID	2.49E+04	Present