Potato Creek
Watershed Protection Plan
Update

March
2012

Produced for:

City of Griffin
StormWater Department

100 S. Hill Street

Griffin, GA 30224

Produced by:

TETRA TECH

2110 Powers Ferry Road SE

Suite 202

Atlanta, GA 30339

Contents

Tables

Figures

Appendices

1 Introduction

The City of Griffin has developed along the divide between the Upper Ocmulgee River system to the east and the Upper Flint River system to the west. Six watersheds within the City of Griffin are contained within these two river systems (see Figure 1-1). The Cabin Creek watershed eventually drains to the Ocmulgee River. The Heads Creek, Shoal Creek, Wasp Creek, Honey Bee Creek, and the Potato Creek watersheds eventually drain to the Flint River. The City of Griffin lies at the headwaters of all these watersheds.

Since 2000, the City of Griffin has implemented a monitoring program in coordination with the Georgia Environmental Protection Division (EPD) for the Potato Creek Watershed. An initial Watershed Assessment was prepared for Potato Creek by Integrated Science and Engineering (ISE) in 2001. On May 6, 2004 Georgia EPD issued Guidance for developing a watershed management plan that includes three components: a Watershed Monitoring Plan, a Watershed Assessment, and a Watershed Protection Plan. The City of Griffin, in preparation for its wastewater treatment plant National Pollutant Discharge Elimination System (NPDES) permit renewal, developed watershed plan documents that meet the Georgia EPD requirements. A Potato Creek Watershed Assessment and a Potato Creek Watershed Management Plan were completed in 2005. The Watershed Assessment, prepared by Paragon Consulting Group, updated the 2001 Assessment to comply with the 2004 Guidance, provided an analysis of data through 2005, and documented the City's past monitoring effort. The Watershed Management Plan, also prepared by Paragon Consulting Group, fulfilled the requirements of a Protection Plan. These documents have been reviewed and approved by the Georgia EPD.

This document is provided as an addendum to the 2005 Watershed Management Plan, and serves to update the Potato Creek Protection Plan based on water quality data, studies, and activities in the watershed through 2009.

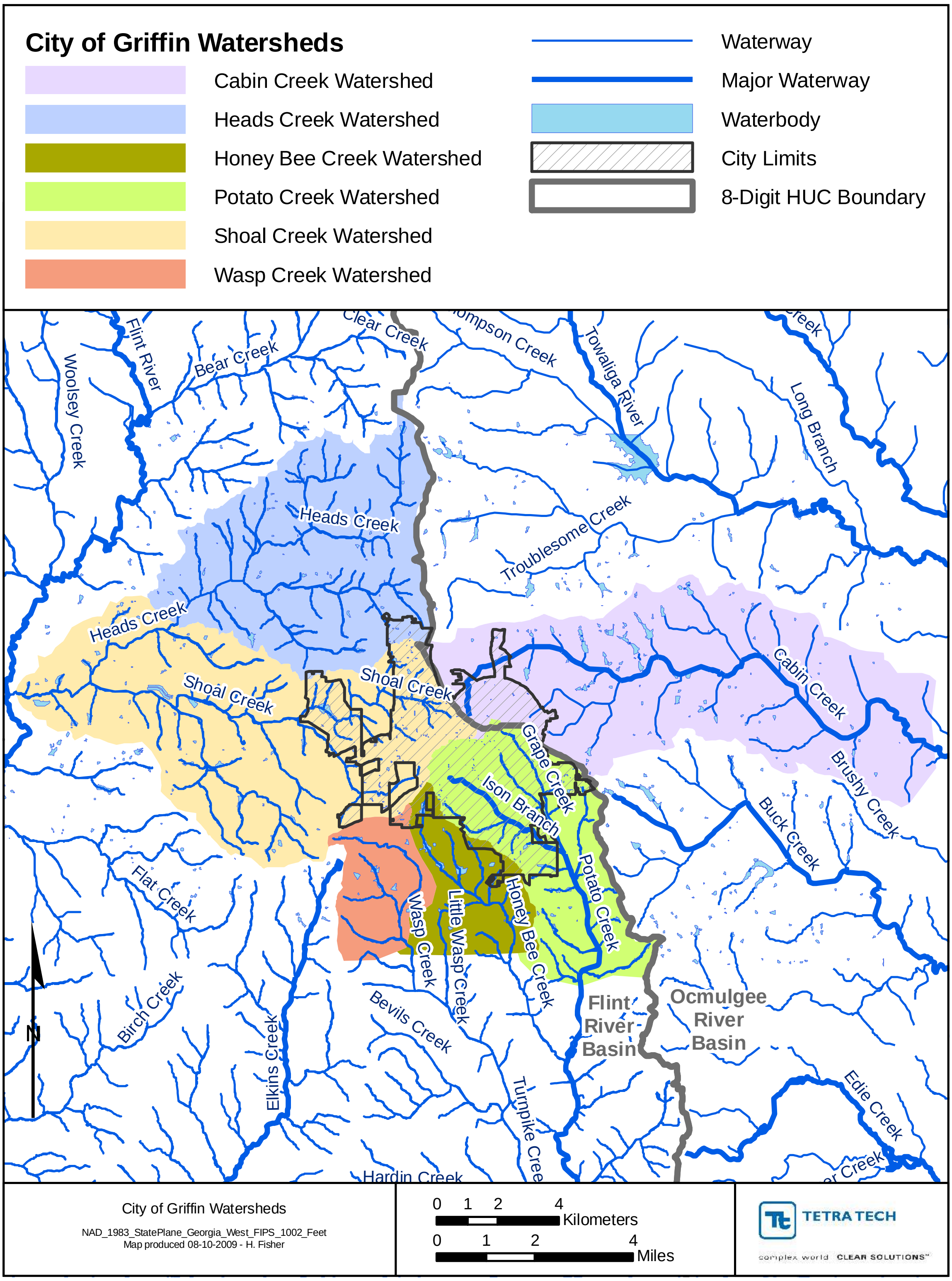

Figure 1-1 City of Griffin Watersheds

The Potato Creek Protection Plan Update includes the following components:

1) Goals, objectives, indicators and benchmarks
2) Existing conditions
3) BMP implementation summary
4) Watershed projects and research
5) Long-term monitoring plan
6) Watershed management needs
7) Watershed management opportunities

This document was prepared for the City of Griffin Public Works and Utilities and Stormwater Departments. The contact information for city staff responsible for preparation of the document is as follows:

Mr. Brant Keller, PhD, Director
City of Griffin Public Works and Utilities
100 S. Hill Street
Griffin, GA 30224
770.229.6424
bkeller@cityofgriffin.com

Mr. Chris Edelstein, Deputy Director
City of Griffin Stormwater
100 S. Hill Street
Griffin, GA 30224
770.229.6424
cedelstein@cityofgriffin.com

2 Goals, Objectives, Indicators, and Benchmarks

2.1 Goals, Objectives, and Indicators

Watershed protection plans should be built on explicitly defined goals and objectives. In the context of watershed planning, a goal is a general statement about the desired condition or outcome of the watershed protection or restoration strategies, and objectives are specific statements that define what must be true for the goals to be achieved. Essentially, chosen objectives provide the foundation for watershed restoration and protection decisions. Since objectives are often difficult to measure directly, indicators can be used as measurable surrogates.

The recommended Potato Creek watershed goals, objectives, and indicators can be used in screening management options and crafting and selecting management strategies during future planning and implementation. It is also proposed that they be used to track progress and success in implementation of the plan. If the City decides to adopt similar goals and objectives for its remaining two watershed plans for Shoal and Cabin Creek, they could provide a standardized means of assessing watersheds and prioritizing projects city-wide.

In developing the draft goals and objectives, Tetra Tech drew upon several key documents:

- City of Griffin Stormwater Utility Mission Statement.
- Potato Creek Watershed Assessment. Paragon Consulting. 2005.
- Potato Creek Watershed Management Plan. Paragon Consulting. 2005.
- Stream Channel Erosion Activity Assessment – Potato Creek. Tetra Tech. 2008.
- City of Griffin NPDES Stormwater Permit Notice of Intent. 2007.

The Stormwater Utility Mission Statement provides clear guidance in developing goals and objectives:

> *To provide a comprehensive program for watershed management which includes: seeking out alternative funding mechanisms to enhance Griffin's stormwater management system; establish programs to address infrastructure problems; cost-effective design and construction of the necessary improvements; providing leadership through the implementation of Best Management Practices that will enhance water quality throughout the region; and improving the overall quality of life for our citizens.*

Through a comprehensive watershed management program, the Potato Creek Watershed Management Plan addresses stormwater impacts from planned new development as well as impacts from uncontrolled runoff from existing development. It also addresses the City's desire to lead through example in implementing programs for construction, maintenance, and citizen engagement that reflect outstanding watershed stewardship. Watershed Goals and Objectives were developed based on the Stormwater Utility's existing program and existing conditions in the Potato Creek watershed. There are four overarching goals proposed for the protection plan:

1) Enhance water quality in the City and the region.
2) Meet or exceed state and federal water quality requirements, including removal of the City of Griffin streams from the state's list of impaired waters.
3) Implement innovative, cost-effective solutions.
4) Improve the overall quality of life for citizens in the City of Griffin.

Tetra Tech recommends eight objectives in support of these goals (see Table 2-1). All of the objectives support multiple goals, and Table 2-1 also shows these linkages.

Table 2-2 lists indicators in three categories: watershed impact, source, and programmatic. Watershed impact indicators are environmental measures such as benthic community, channel stability, and water quality. Source indicators are measures of potential stressors such as impervious area and deficient riparian area vegetation. Programmatic indicators refer to potential or actual management measures. As shown in Table 2-2 most of the indicators serve as measurable, meaningful surrogates for multiple protection objectives.

Finally, Table 2-3 provides a description of each indicator as well as the proposed assessment tool for measurement. The assessment tools are comprehensive and include monitoring, stream surveys, watershed modeling, GIS analysis, stormwater utility records, CIP program records, and program tracking.

Benchmarks have been developed for select indicators to assess status, help select among management options, and track progress in meeting objectives.

The goals, objectives, indicators, and benchmarks presented in this Plan essentially connect and enhance the tools already being used by the City in its comprehensive watershed management program, and provide standardized means to assess watersheds and prioritize projects city-wide.

Table 2-1 Objectives Linked to Goals

Watershed Improvement Program Objectives		Goals			
		G1 **Enhance Water Quality**	**G2** **Meet Requirements**	**G3** **Be Cost-Effective & Innovative**	**G4** **Improve Quality of Life**
A.	Minimize impacts of stormwater runoff and erosion on stream *hydrology* to promote stable stream morphology, protect habitat, and support biota (city-wide).	■	■		■
B.	Minimize impacts to stream *water quality* from pollutants in stormwater runoff, particularly: • Impacted biota and habitat (watershed-wide). • Low Dissolved Oxygen levels (watershed-wide). • Elevated metals concentrations (downtown). • Elevated nutrients (watershed-wide).	■			■
C.	Meet state and federal requirements such as Phase II stormwater, NPDES requirements for expansion of the Potato Creek WWTP, and 303(d) listing of the upper Potato Creek for impaired biota.	■	■		■
D.	Ensure Best Management Practices are properly maintained and functioning.	■	■		■
E.	Minimize impacts of large woody debris to promote stable stream morphology, protect habitat, and support biota (watershed-wide).	■			■
F.	Use Low Impact Development, Green Infrastructure, and innovative regional BMPs, to the extent practicable, to enhance water quality and quality of life in the community.	■		■	■
G.	Actively engage the community in adopting measures to protect and restore streams	■	■	■	■
H.	Implement cost-effective City programs that provide leadership in watershed stewardship.	■		■	■

Table 2-2 Watershed Impact, Source, and Programmatic Indicators Linked to Objectives

WATERSHED IMPACT INDICATORS	OBJECTIVES							
	A	B	C	D	E	F	G	H
Benthic Communities	■	■	■	■	■	■	■	■
Aquatic Habitat	■	■	■	■	■	■	■	■
Fish Communities	■	■	■	■	■	■	■	■
Channel Morphology	■		■	■	■	■	■	■
Channel Stability	■		■	■	■	■	■	■
Instream Sediment	■		■	■	■	■	■	■
Hydrology (frequency, magnitude, and duration of flows)	■	■	■	■	■	■	■	■
Drainage Complaints	■				■		■	■
Percent Riparian Area Deficient of Vegetation	■	■				■	■	■
Percent Connected Natural Area	■	■				■	■	■
Water Quality (Modeling of Future Conditions): Relative nutrient, upland sediment, and metals loading from 2009.		■	■					■
Water Quality (Observed/measured): Instream TP, TN, TSS, FC, Metals, Dissolved Oxygen, Turbidity		■	■					■

Table 2-2 cont'd Watershed Impact, Source, and Programmatic Indicators Linked to Objectives

SOURCE INDICATORS	OBJECTIVES							
	A	B	C	D	E	F	G	H
Impervious Area	■	■	■	■		■	■	■
Stormwater Outfalls	■	■						■
Property Loss Due to Erosion	■	■	■	■	■	■	■	■
Percent of Development With Uncontrolled Stormwater	■	■	■	■		■	■	■
Percent Highways With Uncontrolled Stormwater	■	■	■			■		■
Sanitary Sewer Crossings and Sewer Spills		■						■
Deficient Riparian Area Vegetation	■	■				■	■	■
TP, TN, TSS, Metals Loading (modeled)		■						

Table 2-2 cont'd **Watershed Impact, Source, and Programmatic Indicators Linked to Objectives**

PROGRAMMATIC INDICATORS	OBJECTIVES							
	A	B	C	D	E	F	G	H
# Cisterns Installed	■	■				■	■	■
# Disconnected Downspouts		■				■	■	■
# Retrofits of Existing Flood Control Structures for Water Quality/Hydrology	■	■		■		■	■	■
Length Stream Restoration	■	■					■	■
Acres Buffer Restoration Using Native Vegetation	■	■				■	■	■
Percent Development Using LID and Green Infrastructure (since 2009)	■	■		■		■	■	■
# BMPs Providing Neighborhood or Community Amenity (e.g. open space, garden, water features)	■	■				■	■	■
# Regional BMPs Constructed	■	■		■		■	■	■
Percent Development With Stormwater BMPs Functioning as Designed	■	■	■	■		■	■	■
Percent City Projects With LID or Green Infrastructure	■	■				■		■
Percent City Projects With Stormwater BMPs Functioning as Designed	■	■		■				■
Mitigation Cost-effectiveness ($/load reduced)								■
Leveraged Funding Sources								■

Table 2-3 Description of Watershed Impact, Source, and Programmatic Indicators

Watershed Impact Indicators	Description	Assessment Tool
Benthic Communities	Georgia DNR Standard Operating Procedures for Macroinvertebrate Biological Assessment.	Monitoring
Aquatic Habitat	Georgia DNR Standard Operating Procedures for Macroinvertebrate Biological Assessment.	Stream Survey
Fish Communities	Standard Operation Procedure for Conducting Biomonitoring on Fish Communities in Wadeable Streams in Georgia (GA DNR, 2005).	Monitoring
Channel Morphology	Visual based physical habitat assessment per Georgia DNR Standard Operating Procedures for Macroinvertebrate Biological Assessment.; other options include the Incised Channel Evolution Model (ICEM) which defines the stages of channel evolution following land development, urbanization, and restoration.	Stream Survey
Channel Stability	Visual based physical habitat assessment per Georgia DNR Standard Operating Procedures for Macroinvertebrate Biological Assessment; other options include a comparison of specific stream power and velocity to critical threshold values relevant to channel stability.	Stream Survey Watershed Model
Instream Sediment	Visual based physical habitat assessment per Georgia DNR Standard Operating Procedures for Macroinvertebrate Biological Assessment.; other options include qualitative or quantitative estimate of sediment load generated by channel erosion (specify load if quantitative).	Qualitative Assessment, Literature Review, or Permanent Cross Section Data
Hydrology (frequency, magnitude, and duration of flows)	A measure or index that uses storm event simulations to provide information on hydrologic alteration and potential impacts to stream morphology, habitat, and biota.	Monitoring and Storm Event Simulation
Drainage Complaints	Records Number of drainage complaints per square mile of developed area.	Public Works Records
Percent Riparian Area Deficient of Vegetation	Percent of land within the riparian buffer lacking sufficient natural, vegetative cover. (If using the Multi-Resolution Land Characteristics Consortium (MRLC) Landscape Fire and Resource Management (LANDFIRE) 2001 data, less than 30 percent coverage within any vegetative layer could be used as an indicator of deficiency.)	Stream Survey GIS Analysis
Percent Connected Natural Area	Percent of land within a subwatershed that supports natural areas with significant connectivity.	GIS Analysis
Water Quality Future Conditions	Relative nutrient, metals, and upland sediment, loading as measured from 2009.	Watershed Model
Water Quality Observed/Measured	Instream TP, TN, TSS, FC, Metals, Dissolved Oxygen, Turbidity.	Monitoring

Table 2-3 cont'd Description of Watershed Impact, Source, and Programmatic Indicators

Source Indicators	Description	Assessment Tool
Percent Impervious Area	Percent of land in subwatershed with impervious surface.	GIS Analysis of Land Use/ Land Cover Data
Stormwater Outfalls	Number and location of stormwater outfalls per mile of stream.	Stream Surveys and GIS Analysis
Property Loss Due to Erosion	Widening of stream channels resulting in property loss.	Stream Surveys; Aerial Photographs
Percent of Development With Uncontrolled Stormwater	Areas of development prior to stormwater control requirements.	Stormwater Utility Records
Percent Highways With Uncontrolled Stormwater	Highways built prior to stormwater control requirements.	Stormwater Utility Records
Sanitary Sewer Crossings and Sewer Spills	Number of locations where sanitary sewers cross streams per mile of stream. Number of sanitary sewer spills or overflows per square mile of subwatershed.	Stream Surveys; Record of Spill Notices
Percent Riparian Area Deficient of Vegetation	Percent of land within the riparian buffer lacking sufficient natural, vegetative cover.	Stream Surveys and GIS Model
TP, TN, TSS, Metals Loading (modeled)	Estimated and predicted loading of nutrient, upland sediment, metals, and bacteria.	Watershed Model

Table 2-3 cont'd Description of Watershed Impact, Source, and Programmatic Indicators

Programmatic Indicators	Description	Assessment Tool
# Cisterns Installed	Self explanatory	Program Tracking
# Disconnected Downspouts	Self explanatory	Program tracking
# Retrofits of Existing Flood Control Structures for water quality/hydrology	Self explanatory	CIP Program Records
Length Stream Restoration	Self explanatory	Program Tracking
Acres Buffer Restoration	Self explanatory	Program Tracking
Percent development using LID and Green Infrastructure (since 2009)	Self explanatory	Land Development Records
# Regional BMPs Constructed	Self explanatory	CIP Program Records
Percent development with stormwater BMPs functioning as designed	Self explanatory	Inspections Records
Percent City projects with LID or green infrastructure	Self explanatory	Program Tracking
# BMPs providing neighborhood or community amenity (e.g. open space, garden, water features)	Rain gardens, constructed wetlands, greenways, ponds, tree planters, or BMPs that provide amenities in neighborhoods, parks, streetscapes, city courtyards/plazas, etc.	Program Tracking
Percent City Projects with stormwater BMPs functioning as designed	Self explanatory	Inspection Records
Mitigation Cost-Effectiveness	Cost per ton of TSS reduced, cost per pound of nutrients and metals reduced, cost per detention volume, etc.	Program Tracking; cost analysis.
Leveraged Funding Sources	Grants received, cost-share dollars from other agencies, and in-kind contributions.	Program Tracking

2.2 BENCHMARKS

Tetra Tech has developed benchmarks as a means of tracking progress towards the recommended goals and objectives for City of Griffin watersheds. Benchmarks are indicator values that represent conditions at which a particular environmental objective has been achieved. The water quality benchmarks presented here are recommended for use in interpreting dry weather or long-term average concentration data. Benchmarks are also recommended for benthic communities, aquatic habitat, and impervious area. Tetra Tech recommends that the benchmarks be used to flag potential impacts during observed and simulated data review and evaluation. These values are not recommended as standards for regulation or as absolute targets to denote unimpacted conditions.

Water Quality Benchmarks

The water quality benchmarks were developed primarily for use in evaluating baseflow, or dry weather, water quality monitoring data in streams. They are not directly applicable to measurements obtained from individual storms, which often may be much higher, but are applicable to interpreting long-term averages of concentration data obtained from a mix of dry weather and wet weather monitoring. The benchmarks would be appropriate to apply to the City of Griffin dry weather sample data, which may be influenced by some wet weather events. The benchmarks should not be applied to data measured exclusively during wet weather events.

To develop the benchmarks, Tetra Tech reviewed the State of Georgia water quality regulations for any relevant standards (State of Georgia, 2010). For constituents that did not have numeric state standards, Tetra Tech reviewed literature values for reference conditions within the Georgia piedmont. The literature review focused on instream, baseflow measurements.

A benchmark range is recommended for each parameter for which targets are not directly established by a published state water quality criterion. If a parameter is observed above this range, this would indicate that there is a potential for significant impacts, and the stream reach should be investigated further. If the parameter is within the range, some moderate impacts due to water quality are likely but to a lesser extent. Reaches within the benchmark range would be considered a lower priority for investigation. Below the range, the parameter is not considered a concern for that steam reach, and further investigation is likely unnecessary.

The City of Griffin dry weather monitoring data were used to develop the benchmarks. Tetra Tech used the data collected in 2005 through 2009 for the currently sampled Potato Creek watershed stations: 1p (WQ1), 3ib (WQ3), 4g (WQ4), 16hb (WQ14), 13ib (WQ34), 7gtg (WQ35), and 5g (WQ36).

For the upper bound Total Phosphorous (TP) benchmark range, a regression equation from Dodds et al (2002, 2006) was used to estimate the concentration at which benthic algal density would likely reach nuisance levels in the absence of other limiting factors such as grazing or insufficient light. The coefficient of variation from the dry weather monitoring data was applied to the regression equation, and a Redfield ratio for TN:TP (molecular ratio of nutrients in phytoplankton) of 7.2 (by mass) was assumed to develop a unique TP benchmark. From these relationships, Tetra Tech calculated the upper 95 percent confidence interval for TP at which excessive algal growth would be expected. This value (0.20 mg/L) was used as the upper bound of the benchmark range. When calculating the coefficient of variation, samples below the detection limit were included as half of the detection limit.

A Total Nitrogen (TN) concentration of 2.9 mg/L also was estimated using regression equations from Dodds et al (2002, 2006), but this value was not used as a benchmark because it exceeded the majority of the TN measured values and is unlikely to represent an achievable objective in Potato Creek. The 25th percentile of the distribution of all observed concentrations was used as the TN upper bound concentration. The rationale for using the 25^{th} percentile is explained below.

For the lower bounds of the TN and TP benchmark range, EPA nutrient criteria guidance for streams was used, and Tetra Tech consulted the specific guidance for Nutrient Subecoregion 45, which coincides with the City of Griffin. According to this guidance, if reference data are available, the 75th percentile of reference data is recommended as a criterion. If reference data are not available, then the 25th percentile of the distribution of all observed concentrations is recommended as a reasonable approximation of reference conditions. The USEPA guidance states that these recommended criteria should be used as guidance, but that states and other agencies should conduct further research to determine the most appropriate criteria for their location (USEPA, 2000). Consistent with the EPA guidance, the 75th percentile of concentrations from least-disturbed EPA Wadeable Stream Assessment reference-sites were used for the lower bounds of the TN and TP benchmark range (Herlihy and Sifneos, 2008).

For most of the remaining constituents, the upper and lower bounds were based on two types of reference values: 1) the highest reference values within the literature and 2) the 25th percentile of dry weather water quality data (consistent with EPA guidance discussed above). The highest literature reference values were chosen because all information sources reflected relatively unimpacted conditions within the Georgia piedmont physiographic region, and the highest values among these sources should represent a potential threshold between natural, or background, conditions and impacted conditions. When calculating the 25th percentile of the dry weather data, samples below the detection limit were included as half the detection limit. Collectively, these values provided a reasonable range, below which a parameter is not considered a concern and represents achievement of objectives. For most constituents, the literature values represented the upper bound, and the 25th percentile of dry weather data represented the lower bound of the range. For NO_3-NO_2, the benchmarks were reversed because the literature value method produced a lower benchmark than the 25th percentile method. The TKN literature reference value (2 mg/L) exceeded the TN upper bound (1.2 mg/L), so 1.2 mg/L was used as the TKN upper bound.

The benchmark for turbidity is especially uncertain, and this uncertainty should be accounted for when evaluating watershed conditions. Instead of using the maximum reference value, Tetra Tech is recommending 30 NTU as the upper bound benchmark, which represents the average reference conditions found in the literature search.

As noted above, the current set of benchmarks are established primarily for dry weather conditions and are not necessarily applicable during storms, when runoff or channel erosion processes may cause elevated concentrations. For those constituents for which Georgia has adopted numeric water quality criteria, the differences between wet and dry weather concentrations are addressed through the use of two-number criteria. These criteria consist of an average or chronic value and an acute or instantaneous value. The acute (instantaneous) criterion is applicable to all individual observations, except as otherwise exempted, and is thus applicable to both wet and dry weather benchmarks. The more stringent average or chronic values provide benchmarks that are relevant to dry weather or average conditions, while the acute or instantaneous values provide benchmarks for all individual observations, including wet weather data.

For constituents for which numeric criteria are not established in regulations, benchmarks for wet weather samples are more difficult to derive. As wet weather data are collected, the City of Griffin could consider wet weather benchmarks in addition to the dry weather benchmarks recommended in this report. Reference information on wet weather benchmarks was not readily available during this phase of the project. When reference data are available, wet weather benchmarks can vary considerably by local conditions. Benchmarks for TSS and turbidity, for example, are most relevant under dry weather conditions since these constituents can vary widely by channel condition under wet weather. Given these limitations, the best approach for assessing wet weather data for constituents without acute numeric criteria would be to evaluate the watershed data based on conditions within the watershed and note concentrations that are likely indicators of impacts. If load limits are developed in the future, these limits could be used to develop wet weather benchmarks to ensure that load limits are met.

The recommended benchmarks are provided in Table 2-4 and Table 2-5. Table 2-4 lists the benchmarks based on water quality standards. Table 2-5 lists the benchmarks that were based on literature values and EPA criteria guidance. As noted above, the benchmarks were derived for use in evaluating average and baseflow (dry weather) water quality monitoring data in streams.

The benchmark ranges in Table 2-5 should be used to flag conditions in the watershed for further consideration and analysis. These values are not recommended as standards for regulation or as absolute targets to denote unimpacted conditions. It is important to note that biological monitoring may indicate that impacts are occurring even when water quality data are within the ranges specified by the benchmarks. As additional water quality data are collected and compared to the benchmarks, further refinement may be warranted.

Table 2-4 Benchmarks Derived from Georgia Numeric Water Quality Criteria

Parameter	Benchmark[1]	Reference	Typical Nonpoint Sources
pH	Between 6.0 and 8.5	State of Georgia (2010) Standards	Decaying organic matter, groundwater
Dissolved Copper (µg/L)[2]	7 µg/L at 50 mg/L CaCO3 (acute criterion, hardness dependent) 5 µg/L at 50 mg/L CaCO3 (chronic criterion, hardness dependent)	State of Georgia (2010) Standards	Road runoff (brakepads, automotive flaking), parking areas in urban and industrial sites (from vehicular traffic), roofing and storage building materials, copper gutters
Dissolved Zinc (µg/L)	65 µg/L at 50 mg/L hardness (acute and chronic criterion hardness dependent)	State of Georgia (2010) Standards	Road runoff (brakepads, automotive flaking), parking areas in urban and industrial sites (from vehicular traffic), corrugated metal roofing and siding, native soils
Dissolved Cadmium (µg/L)[2]	1.0 µg/L at 50 mg/L CaCO3 (acute criterion, hardness dependent) 0.15 µg/L at 50 mg/L CaCO3 (chronic criterion, hardness dependent)	State of Georgia (2010) Standards	Car exhaust
Dissolved Lead (µg/L) [2]	30 µg/L at 50 mg/L CaCO3 (acute criterion, hardness dependent) 1.2 µg/L at 50 mg/L CaCO3 (chronic criterion, hardness dependent)	State of Georgia (2010) Standards	Urban runoff, soil near roads containing legacy contamination from leaded gasoline, and soil near factories that use lead
Fecal Coliform (# /100 mL)	May – October: 200 # /100mL 30-day geomean November – April: 4000 # /100mL instantaneous; 1000 # /100mL 30-day geomean	State of Georgia (2010) Standards	Wildlife, birds, pets, cattle, malfunctioning septic systems, sewer system leaks and spills, illicit connections
DO (mg/L)	>4 mg/L instantaneous; >5 mg/L daily average	State of Georgia (2010) Standards	Affected by BOD load, groundwater and activity of algae, heterotrophic bacteria and fungi

[1]Note: Acute or instantaneous criteria are applicable benchmarks for both wet and dry weather conditions; chronic, average or geomean criteria are applicable benchmarks for dry weather sampling.

[2]The copper, cadmium, and lead standards will need to be recalculated based on observed hardness and converted to total copper, total cadmium, and total lead to compare to monitoring data.

Table 2-5 Additional Water Quality Benchmarks for Dry Weather Monitoring Data

Parameter	Benchmark Range[1]	References for Lower Bound Benchmarks	References for Upper Bound Benchmarks	Typical Nonpoint Sources
TSS (mg/L)	1 to 13 mg/L	25th percentile of 2005-2009 dry weather observed data	Paul et al (2006), Roy et al (2003), Schoonover et al (2005) , Tetra Tech (2006)	Channel erosion, upland erosion, roads, agricultural tillage, construction/land disturbance
Turbidity (NTU)	4 to 30 NTU	25th percentile of 2005-2009 dry weather observed data	GA EPD (2007a), GA EPD (2007b), Tetra Tech (2006), Roy et al (2003), Pitt (2000), USEPA (2000)	Primarily driven by TSS; color and dissolved organic matter from humus
BOD (mg/L)[2]	1 to 3 mg/L	25th percentile of 2005-2009 dry weather observed data	Fox and Absher (2002)	Manure, plant material, algal blooms, septic systems
TP (mg/L)	0.06 to 0.20 mg/L	Herlihy and Sifneos (2008)	Dodds et al (2006), Dodds et al (2002)	Agricultural and landscaping runoff (fertilizers and organic matter), regeneration from stream sediment
TN (mg/L)	0.7 to 1.2 mg/L	Herlihy and Sifneos (2008)	25th percentile of 2005-2009 dry weather observed data	Agricultural and landscaping runoff (fertilizers and organic matter), atmospheric deposition, septic systems
NO_3-NO_2 as N (mg/L)	0.4 to 0.6 mg/L	GA EPD (2007a), Gore et al (2005), Roy et al (2003), USEPA (2000)	25th percentile of 2005-2009 dry weather observed data	Same as TN
NH_3 as N (mg/L)[2]	0.02 to 1 mg/L	25th percentile of 2005-2009 dry weather observed data	GA EPD (2007a), Gore et al (2005), Meyer et al (2005), Roy et al (2003), Schoonover et al (2005)	Septic systems, agricultural groundwater, fertilizers, instream production from decaying organic matter, regeneration from stream sediment
TKN (mg/L)	0.5 to 1.2 mg/L	25th percentile of 2005-2009 dry weather observed data	TN Upper Bound	Same as NO_3-NO_2 as N
PO_4 as P(mg/L)[2]	0.01 to 0.1 mg/L	25th percentile of 2005-2009 dry weather observed data	Pitt (2000), Tetra Tech (2006)	Same as TP

TBD = To Be Determined; NA = Not Available
[1]Sampling and analysis methods could not be verified for all references.
[2]Lower bound represents detection limit.

Other Benchmarks

Where information was available, Tetra Tech developed the following recommended benchmarks for indicators other than the water quality constituents. These benchmarks represent conditions at which the relevant goals and objectives may be met.

- Benthic Communities: Good or excellent rating.
- Aquatic Habitat – A score of 113 or higher (using the 2009 scoring methods), which indicates optimal or suboptimal habitat conditions.
- Impervious Area – Percent imperviousness of 25 or less considered a desirable condition. Above this value, severe degradation is expected to occur and indicators of stream quality consistently shift to a poor condition (CWP, 2003). Most stream quality indicators begin to decline at 10 percent impervious, which could be used as a more conservative benchmark.

3 Existing Conditions

3.1 LAND USE

Figure 1-1depicts the Potato Creek Watershed in relation to Griffin City limits. The Watershed originates in downtown Griffin, and is heavily developed, especially in the downtown area. Percent impervious cover, derived from University of Georgia's Georgia Land Use Trends (GLUT) GIS data, was calculated for the subwatersheds (drainage areas) of each of the current water quality monitoring stations, and is presented in Table 3-1, below. Subwatershed boundaries are depicted in Figure 7-2, in the Management Needs section. Impervious cover in the Potato Creek subwatersheds range from 15.86% to 35.19%. Urban development, particularly the conversion of pervious land cover to impervious land cover, negatively affects the hydrology of a stream system by increasing the peak runoff rate and volume, most notably from the smaller more frequent storm events. Urban development also increases pollutant concentrations and loadings to water bodies. Much of the Potato Creek Watershed was developed prior to the implementation of the current stormwater performance standards; therefore, many detention facilities currently located within the City of Griffin are under sized and have suboptimal designs for removing pollutants. New development is required to comply with stormwater performance standards and design policies outlined in the City's Stormwater Design Manual.

Table 3-1 Impervious surface coverage of subwatersheds

Subwatershed	Area (acres)	Impervious Area (acres)	Percent Impervious
1p	6120	1001	16.35%
3ib	2252	470	20.86%
4g	1707	408	23.88%
16hb	197	69	35.19%
5g	930	303	32.64%
7gtg	373	59	15.86%
13ib	1110	296	26.68%

Existing land use in the Potato Creek Watershed is shown in Figure 3-1, and summarized in Table 3-2. The watershed is primarily residential, with appreciable areas of institutional, commercial, and industrial land uses. Future land use, projected for 2024, is shown in Figure 3-2.

Land uses categories on the Future Land Use map are quite different than the categories on the Existing Land Use map, which makes a direct comparison difficult. However, future land use predictions for Griffin are detailed in the City of Griffin Comprehensive Plan (City of Griffin, 2004). Based on population projections, it is expected that Residential land use will increase by approximately 4% by the year 2024. Industrial, Commercial, and Public/Institutional land uses are also expected to increase to maintain the per capita rate. Transportation/ Communication/ Utility land use will increase at a slower rate than other land uses due to the fact that existing facilities can service increased densities. The parks/ recreation/ conservation land use category is projected to increase in order to maintain the City's core system of park lands. The future land use plan calls for the expansion of the parks and recreation system primarily through a network of trails and greenways. Based on projections of the additional acreage needed to support anticipated population growth, the remaining undeveloped land in Griffin in 2025 would total 834 acres. In 2004, there was an estimated 1,712 acres of undeveloped land. The City of Griffin has numerous opportunities for infill and redevelopment. The Future Land Use Plan outlined in the City's Comprehensive Plan encourages mixed-use redevelopment of corridors where public services are currently available.

Spalding County, which had a population of 54,117 in 2000, is expected to grow to between 75,900 (low projection) and 103,000 (high projection) residents by 2025 (Spalding County, 2004). It can be expected that some of this growth will occur in unincorporated Spalding County, on the outskirts of Griffin. The Future Land Use map, however, does not indicate any land use changes that would dramatically affect impervious surface coverage or water quality.

Although there may be some growth and development in the Potato Creek watershed between now and 2024, the increase in land required for additional residences, businesses, and public/institutional facilities is not great, and can be accomplished to a large degree through infill and redevelopment, particularly within the City of Griffin. All new development will be required to use stormwater Best Management Practices (BMPs), and comply with regulations concerning development within wetlands and stream buffers. Flows may increase slightly through the addition of some impervious area, but will likely be mitigated through stormwater detention ponds and other BMPs. There are no projected land use changes that would be expected to significantly affect sediment, nutrients, fecal coliform, dissolved oxygen, or temperature within the stream systems. Given the scenario presented here, it is expected that land use changes in the Potato Creek service area will maintain current water quality.

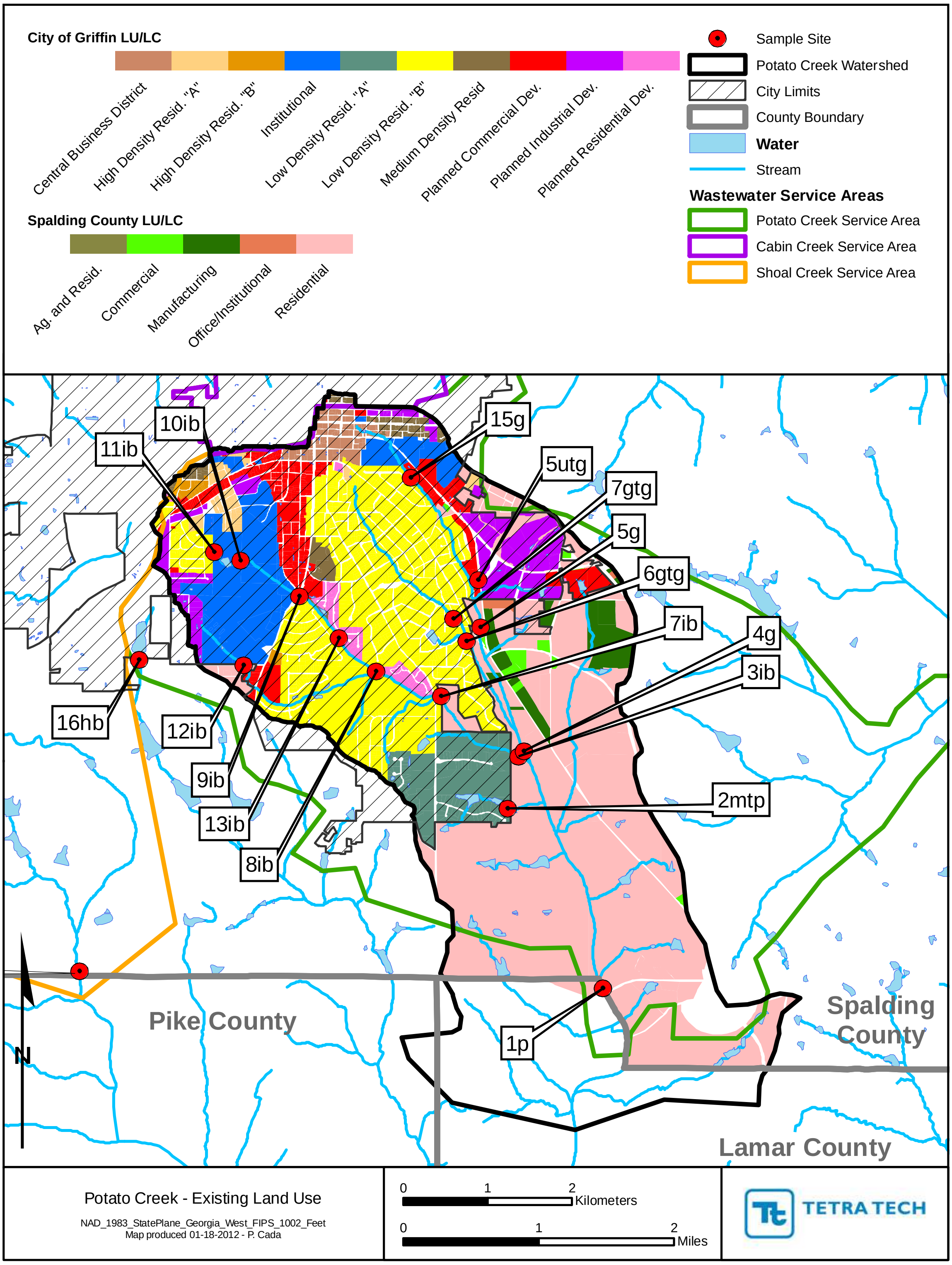

Figure 3-1 Existing Land Use in the Potato Creek Watershed

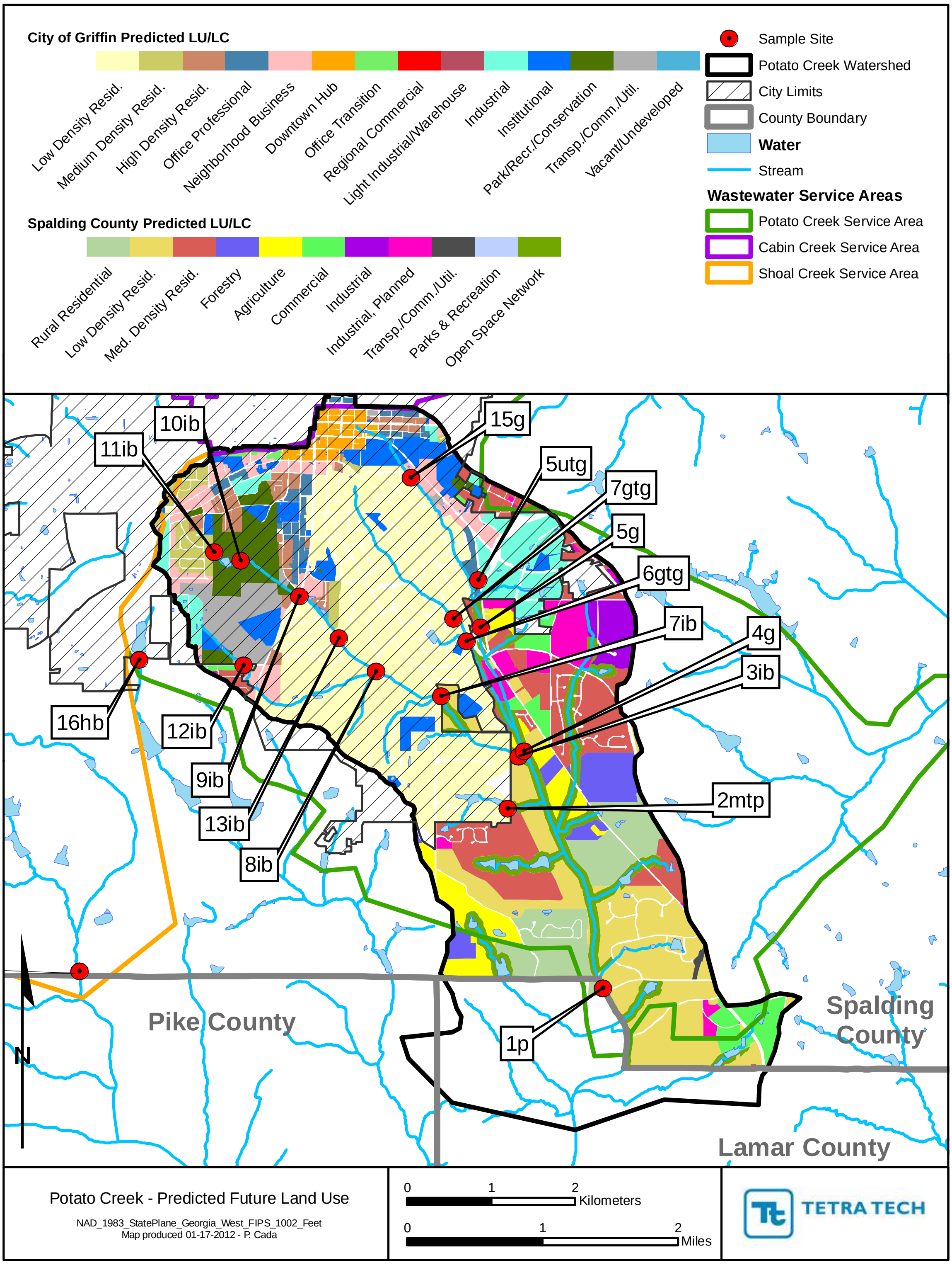

Figure 3-2 Future Land Use in the Potato Creek Watershed

Table 3-2 Existing and Future Land Use Summaries

Existing Land Use		
City	**Acres**	**Percent (City)**
Central Business District	81.4	2.52%
High Density Residential-A	64.4	1.99%
High Density Residential-B	20.1	0.62%
Institutional	524.1	16.20%
Low Density Residential-A	324.5	10.03%
Low Density Residential-B	1374.0	42.48%
Medium Density Residential	82.9	2.56%
Planned Commercial Dev.	353.1	10.91%
Planned Industrial Dev.	311.3	9.62%
Planned Residential Dev.	80.9	2.50%
County	**Acres**	**Percent (County)**
Commercial	35.0	1.18%
Manufacturing	151.0	5.09%
Office/Institutional	10.7	0.36%
Residential	2770.6	93.37%

Future Land Use		
City	**Acres**	**Percent (City)**
Downtown Hub	74.8	2.33%
High Density Residential	114.4	3.56%
Industrial	272.2	8.48%
Institutional	284.9	8.88%
Low Density Residential	1641.4	51.13%
Light Industrial/Warehouse	0.7	0.02%
Medium Density Residential	110.4	3.44%
Neighborhood Business	219.2	6.83%
Office Transition	15.8	0.49%
Office Professional	104.7	3.26%
Park/Rec./Conservation	208.0	6.48%
Transp./Comm./Util.	158.9	4.95%
Vacant/Undeveloped	5.0	0.16%
County	**Acres**	**Percent (County)**
Commercial	158.0	5.46%
Forestry	154.9	5.35%
Industrial	93.1	3.21%
Industrial, Planned	171.4	5.92%
Low Density Resid.	768.0	26.53%
Medium Density Resid.	566.1	19.56%
Open Space Network	424.3	14.66%
Rural Residential	350.9	12.12%
Transp./Communications/Util.	6.5	0.23%

3.2 SIGNIFICANT FACILITIES

There are two NPDES permitted facilities within the Potato Creek watershed according to the EPA Envirofacts Geospatial Data: the Weyerhaeuser Company and the Potato Creek Wastewater Treatment Plant (WWTP). Other facilities in the Potato Creek Watershed that are registered with the EPA include Toxic Release Inventory (TRI), Section Seven Tracking System (SSTS), and Resource Conservation and Recovery Act (RCRA) sites. All permitted facilities are identified in Figure 3-3.

There are no reservoirs within the Potato Creek service area. However, Potato Creek is a water supply for the City of Thomaston in Upson County, approximately 24 miles south (downstream) of Griffin. The City of Thomaston has three intakes on Potato Creek: the first is just below Red River, the second is just below Drake Creek, and the third is just below Ten Mile Creek.

Onsite wastewater systems, or septic systems, that are not properly maintained are a potential source of nutrients and bacteria to surface and ground water. Although the service area is sewered, some residential properties continue to use septic systems. The Spalding County Health Department maintains records of these systems, and Figure 3-3 illustrates the locations of known septic systems in the vicinity of the watershed. About 200 septic systems are known to exist in the Potato Creek Watershed, and 10 exist within city limits.

Stormwater runoff can be a source of pollutant loading, including sediment, nutrients, bacteria, and metals. Runoff can also cause instability and erosion in streambanks and channels. The City of Griffin's stormwater drainage system extends to most of the developed areas of the Potato Creek watershed within city limits. Griffin was the first local government in the state of Georgia to set up a stormwater utility. The utility charges a fee for residences and commercial developments, which funds the treatment and control of stormwater runoff before it is discharged to surface water. The City of Griffin stormwater is permitted under the Georgia Phase II NPDES General Permit. Figure 3-3 illustrates the current locations of stormwater facilities in the city; this includes stormwater detention ponds and proprietary BMP devices.

3.3 EXISTING STREAM IMPAIRMENTS

The EPD, in compliance with the Clean Water Act, has developed a listing of water quality impaired streams in Georgia. The listing is subdivided into several categories: streams that do not support their designated use, reservoirs and lakes not fully supporting their designated use, and estuaries not fully supporting their designated use.

According to the 2008 and the draft 2010 303(d) lists, Grape Creek, a major tributary of Potato Creek, is supporting its designated use of Fishing. Potato Creek, from its headwaters to US Highway 333, is on the not supporting list for its designated use of Fishing, for violating the criteria of Biota due to sedimentation. A TMDL for sediment (biota impacted) was completed for Potato Creek in 2003.

In 1990, 1998, 1999, and 2000, the Department of Natural Resources (DNR) Wildlife Resources Division (WRD) conducted studies of fish populations at a number of monitoring sites in the Flint River Basin, including Potato Creek. WRD used the Index of Biotic Integrity (IBI) and modified Index of Well-Being (IWB) to identify affected fish populations. The IBI and IWB values were used to classify the populations as Excellent, Good, Fair, Poor, or Very Poor. Stream segments with fish populations rated as Poor or Very Poor were listed as Biota Impacted. The Biota Impacted designation indicates that studies have shown a significant modification of the biological community. The general cause of low IBI scores in Potato Creek is the lack of fish habitat due to stream sedimentation.

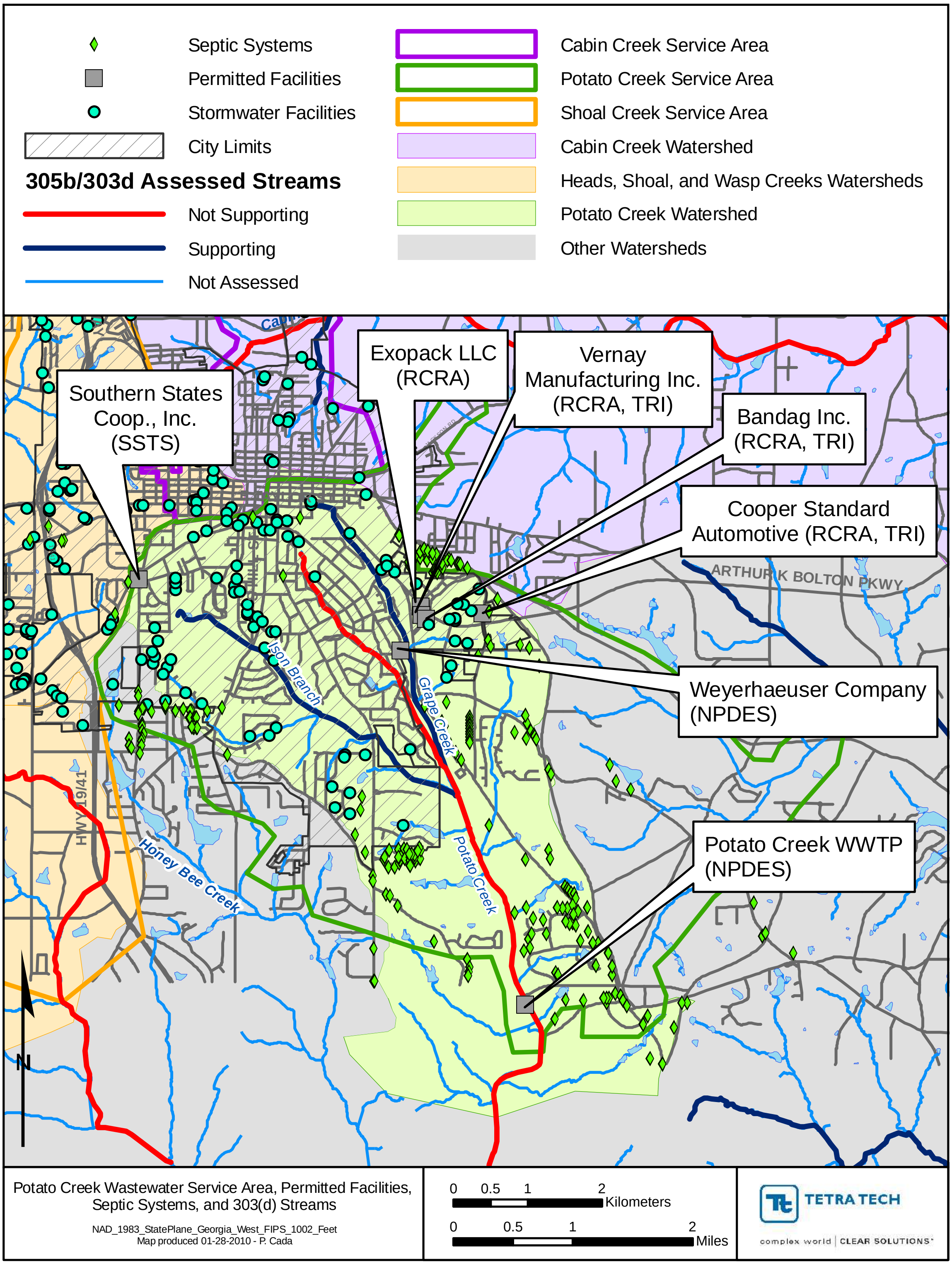

Figure 3-3 Potato Creek Wastewater Service Area, Permitted Facilities, Septic Systems, and 303(d) Streams

3.4 WATER QUALITY AND BIOLOGICAL ANALYSIS, 2005-2009

Since 2005, the City of Griffin has collected quarterly water quality data at seven sites within the Potato Creek Service Area Watershed. These sites are listed in Table 1-1 and are identified as current sample sites in Figure 6-1**Error! Reference source not found.**. A Biological Assessment was conducted in 2009 at all seven of these sites for macroinvertebrates and at three of these sites (3ib, 4g, and 1p) for fish.

Water quality data was examined for all Potato Creek sample sites to assess the current water quality of the Potato Creek Service Area Watershed and to compare current water quality concerns with those noted in the 2005 Potato Creek Watershed Assessment. Water quality data is presented in time-series graphs for the entire monitoring period, beginning in 2000 (Appendix A). This includes data from current sample locations, past sample locations, and a reference site in Meriwether County (REF-1). The water quality analysis below focuses on data from the time that sample sites were revised, from March 2005 through December 2009.

As noted in Section 3.3, Potato Creek is not supporting its designated use of fishing, having violated the criteria of Biota (due to sediment). Water quality and biological monitoring by the City of Griffin confirms that the state water quality standard is being violated in the area of Biota. State water quality standards have also been violated for dissolved oxygen (DO), pH, and fecal coliform. Water temperature measurements are all below the state maximum standard of 90° F (32°C). The following discussion provides an evaluation of monitoring data in relation to state standards:

Biota- Impaired biota is indicated by a “Poor” IBI score for fish at all three of the Potato Creek Watershed sample sites included in the 2009 Biological Assessment, 3ib, 4g, and 1p. Note that site 4g is on Grape Creek, which is listed as supporting the designated use of Fishing on the State’s 303(d) list.

DO- Median DO values are greater than 5.0 mg/L for all sites (see DO Data Summary chart in Appendix A), however standards were violated as indicated by individual measurements less than 4.0 mg/L at four sample sites:

1p: 8-8-07 (3.01 mg/L)

16hb: 5-25-05 (3.73 mg/L), 11-14-06 (3.5 mg/L), 8-8-07 (3.54 mg/L), 11-16-07 (2.85 mg/L), 8-21-08 (3.45 mg/L), and 8-11-09 (3.84 mg/L)

7gtg: 8-8-07 (1.93)

5g: 8-22-06 (3.51) and 8-8-07 (1.96)

There is a strong inverse relationship between DO and water temperature, with low DO levels during summer months, particularly in low-flow conditions (see the DO vs. Water Temperature graph and DO vs. Area-weighted Discharge graph in Appendix A).

pH- Standards for pH were violated as indicated by individual measurements less than 6.0 at two sample sites. These measurements fall just outside of state standards and do not appear to be a major concern:

1p: 2-8-06 (5.56)

16hb: 8-21-08 (5.93)

Fecal Coliform- State fecal coliform standards were violated based on one individual measurement greater than 4,000 colonies/100 mL (from November through April) at site 5g on 11-16-07 (4520/100mL). Fecal coliform has not yet been sampled in such a way that the geometric mean can be calculated according to Georgia EPD methodology. Beginning in fiscal year 2010-2011, the City will begin sampling fecal coliform between May and October in order to determine the geometric mean of bacteria in the watershed. However, fecal coliform data has been collected for several years, so summer averages and winter averages can be compared to state standards. Fecal coliform measurements were averaged for all samples collected May through October and those collected November through April (see Average Fecal Coliform chart in Appendix A). Average fecal coliform counts for the months of May through October exceeded 200 colonies/100 mL at all sites except 16hb. These sites would likely have geometric means that exceed the state standard of 200 colonies/100 mL for the months of May through October. Median fecal coliform counts (for all months) are also greater than 200 colonies/100 mL at all sites except 16hb, indicating that high fecal coliform levels at these sites are common, and the averages are not skewed from just one or two severe events.

Also of concern with regards to water quality are elevated levels of nutrients. High phosphorus concentrations are seen throughout the watershed. The EPA recommends that total phosphorus should not exceed 0.1 mg/L in streams that do not discharge directly into lakes or reservoirs (Muller and Helsel, 1996). In the Potato Creek watershed, most sites have numerous individual measurements greater than 0.1 mg/L and several that are greater than 0.2 mg/L (the upper bound benchmark presented in section 2). Sites 7gtg, 3ib, and 13ib have median concentrations of total phosphorous greater than 0.06 mg/L (the lower bound benchmark). Nitrogen concentrations are also a concern throughout the watershed. All sample sites have median concentrations of total nitrogen that are greater than 0.7 mg/L (the lower bound benchmark), and five sites have median concentrations of total nitrogen that are greater than 1.2 mg/L (the upper bound benchmark). Nutrient data is presented in time-series graphs, a Data Summary (2005-2009) table, and data summary charts in Appendix A.

Occasional spikes in Total Kjeldahl nitrogen (TKN) concentrations can be seen at the Potato Creek sample sites. TKN measurements have exceeded the upper bound benchmark at all sample sites, and should continue to be monitored closely. TKN is a measure of both the ammonia and organic forms of nitrogen. High measurements of TKN can result from sewage and manure discharges to water bodies.

The presence of zinc and copper in the watershed is a potential concern. The 2005 Watershed Assessment noted elevated metals in the downtown area (subwatershed 5g). Copper and zinc are toxic to aquatic organisms when they are present at high enough concentrations. The Georgia EPD has set for freshwater ecosystems an acute and chronic maximum standard of 65 µg/L (0.065 mg/L) for the dissolved fraction of zinc. Since 2005, the total concentrations of zinc have been below 0.065 mg/L, meaning the dissolved fractions are also below this concentration. This indicates some improvement from zinc concentrations prior to 2005, perhaps, in part, due to the TEA-21 project BMPs that ware installed in downtown Griffin in May 2002. The Georgia EPD has set for freshwater ecosystems an acute maximum standard of 7.0 µg/L (0.007 mg/L) and a chronic maximum standard of 5.0 µg/L (0.005 mg/L) for the dissolved fraction of copper. The current water quality data gives the total concentration of copper, but this cannot be directly related to the state toxicity standards. The City will begin sampling hardness, as calcium carbonate ($CaCO_3$), in fiscal year 2010-2011. This sampling will allow the City to calculate dissolved metal concentrations based on measured total metal concentrations, and to determine if state standards are being met.

A pollutant loading analysis was done to identify which areas in the Potato Creek watershed were contributing the greatest annual sediment and nutrient loads. The analysis was done by hand-calculation using the City of Griffin's quarterly monitoring data. Constituents examined include Total Suspended Solids (TSS), Phosphorous (P), Ammonia, Nitrate, and Nitrite. Subwatersheds are defined by the drainage area of each monitoring station and are referred to by the monitoring station site IDs. For example, the land that drains to station 1p is named "subwatershed 1p". Monitoring station 1p is the most downstream station in the watershed; therefore, subwatershed 1p includes all other subwatersheds. For each constituent, there is a chart that depicts pollutant loading in lbs/yr, a chart that depicts pollutant loading in lbs/ac/yr, and a chart that depicts the five-year mean and median pollutant loads by total subwatershed area and per acre. These charts are included in Appendix A.

TSS loads were low for all stations in 2005 through 2007. Very high TSS loadings occurred in 2008 and 2009. Both of these years had sampling events that occurred at times when discharge rates were extremely high. In these years, TSS loads were greatest in the subwatersheds draining to monitoring stations 1p, 3ib, and 4g. These three subwatersheds contributed a great deal more sediment load by total subwatershed area and per acre than the other monitoring stations. Annual TSS loading appears to be greatly affected by extreme (heavy storm) events. In looking at five-year TSS loadings, mean values are much higher than median values. Median values are also very similar between stations; mean values vary considerably from station to station, highlighting the differences in how each subwatershed responds to extreme events. Nutrient loads are generally greatest in the subwatersheds draining to monitoring stations 3ib, and 13ib. Monitoring station 13ib is upstream of 3ib. From 2005 to 2009 the average annual nutrient loads in lb/ac/yr (including phosphorous, ammonia, nitrate and nitrite) were all higher in basins 13ib and 3ib than the other stations. The median annual nutrient loads in (lbs/ac/yr) over this time period were relatively similar across all monitoring stations, and they were all very low compared to mean loads. This indicates that the high nutrient loadings in basins 3ib and 13ib are particularly influenced by extreme (heavy storm) events. The source of the nutrients is unknown, but may be due to fertilizers used at the municipal golf course in subwatershed 13ib.

Sediment is known to be a problem in Potato Creek because the creek is included on the 303(d) list for impaired Biota due to sediment. Median TSS values at all Potato Creek monitoring sites fall within the benchmark range, as defined in Section 2.2, indicating that sediment loading is likely to be elevated above natural reference conditions and may be causing moderate impacts to water quality watershed-wide. The TSS loading analysis confirms that sediment is a problem in the Potato Creek Watershed. The dramatic increase in sediment concentrations following storm events is evident from the time-series graphs for TSS. Turbidity also appears to be reflective of sediment concentrations, as the Turbidity and TSS graphs generally peak at the same times. As with the fish community, the macroinvertebrate community has likely been impacted due to sediment. The 2009 Biological Assessment found that the condition of the benthic macroinvertebrate community was fair at two of the sample locations (3ib and 16hb) and poor at all other stations. Habitat scores from the 2009 Habitat Assessment, conducted as part of the biological assessment, indicated conditions ranging from marginal (16hb and 1p) to marginal-suboptimal (all other stations) in the watershed. Moderate deposition of new sediment was observed at many of the Potato Creek sites during the habitat assessment.

The analysis presented here provides a basis for identifying management needs in the Potato Creek Watershed which can then be addressed through current and proposed BMPs and continued long-term monitoring in the watershed.

4 BMP Implementation

The City of Griffin is proactive in its implementation and maintenance of stormwater Best Management Practices (BMPs). The City's Stormwater Department prides itself on going above and beyond what is expected, continually developing innovative programs and pushing forward with numerous measures aimed at protecting the City's waters from pollutants and educating its citizens about stormwater issues. Progress reports have been provided to the EPD in 2008 and 2009 detailing the status of BMPs that have been implemented in the Potato Creek Watershed (Appendix B). Additionally, the Stormwater Department posts Annual Reports on its website: http://www.cityofgriffin.com/Departments/PublicWorks/Stormwater/Education.aspx

Griffin's BMP commitments are described in detail in the City's MS4 permit Notice of Intent (NOI), included as Appendix C.

4.1 BMP Implementation Summary

Table 4-1 lists BMPs implemented or proposed for the Potato Creek Watershed and identifies the implementation status of each measure. The BMPs are arranged in four categories: items identified as current BMPs in the 2005 Watershed Management Plan, BMPs recommended in the 2005 Watershed Management Plan, MS4 Notice of Intent (NOI) commitments, and additional BMPs implemented since 2005.

Table 4-1 BMP Implementation Status

Best Management Practice (BMP)	Implementation Status*	Comments
CURRENT BMPS FROM 2005 MANAGEMENT PLAN		
Sewage Collection and Treatment System	●	Ongoing
Flood Control and Stormwater Management		
GIS Mapping / Inventory Collection	●	Continues to be updated/maintained
Stormwater Design Manual	●	Complete
Floodplain Mapping	●	Complete
Stormwater Infrastructure Maintenance	●	Ongoing
City of Griffin Ordinances		
Stormwater Utility Ordinances	●	Complete
Development Ordinance	●	Complete
Tree Preservation Ordinance	●	Complete
Soil Erosion and Sedimentation Control Ordinance	●	Complete
Illicit Discharge and Connections Ordinance	●	Complete
Spalding County Ordinances		
Illicit Discharge and Connections Ordinance	●	Complete

*● Fully Implemented
○ Partially Implemented or Initiated/Underway
— Not implemented or initiated

Table 4-1 cont'd BMP Implementation Status

Best Management Practice (BMP)	Implementation Status*	Comments
Soil Erosion and Sedimentation Control Ordinance	●	Complete
Sedimentation and Erosion Controls for New Developments		
New Development Process	●	Built into the permitting process
Inspection and Enforcement	●	Ongoing
Public Education and Outreach Programs		
Classroom Education	●	Ongoing use of Enviroscape models
Web Page	●	Maintained regularly
Flyers and Brochures	●	Ongoing
Media Notifications	●	Ongoing
Stormwater Newsletter	●	Issued in 1999 and 2000, then replaced by annual reports
Complaint Database	●	Maintained continually
Road Signage Program	●	Complete
Erosion and Sediment Control at Construction Sites	●	Pamphlets provided during permitting process
Hazardous Material (HAZMAT)/Recycling Programs	●	Ongoing
TEA-21 project BMPs		
SMI- Storm Filter	●	Maintained regularly

*● Fully Implemented
○ Partially Implemented or Initiated/Underway
▬ Not implemented or initiated

Table 4-1 cont'd BMP Implementation Status

Best Management Practice (BMP)	Implementation Status*	Comments
Baysaver 10k	●	Maintained regularly
PBM CrystalStream	●	Maintained regularly
BMPS RECOMMENDED IN 2005 MANAGEMENT PLAN		
Site-Specific BMP Design	○	A site-specific BMP tool is currently being developed
Floodplain Management/Flood Damage Prevention Ordinance	●	Complete
New Urbanized Flood Zone Policy	○	The floodplain identified in Griffin's floodplain study has been incorporated as Zone A in FEMA FIRMs. The city is currently working to get Base Flood Elevations incorporated.
Ordinance for Post-Development Stormwater Management For New Development and Redevelopment	●	Complete
Stream and Wetlands Buffer Ordinance	—	The City is relying on the State's regulation of a 25 ft buffer from State waters
Illicit Discharge and Illegal Connection Ordinance	●	Complete
Litter Ordinance	●	Complete
Other Model Ordinances	○	Impervious surface limitations have been incorporated into zoning regulations of the City's Municipal Code
New Development Requirements	○	A Floodplain Ordinance has been created which addresses some of the recommended changes.

*● Fully Implemented
○ Partially Implemented or Initiated/Underway
— Not implemented or initiated

Table 4-1 cont'd BMP Implementation Status

Best Management Practice (BMP)	Implementation Status*	Comments
Classroom Education	○	The county has put in a learning trail and outdoor classroom. An educational partnership with Caterpillar was not developed. Initially, the WaterWise program was implemented in schools. This program has been replaced by curriculum provided through a Watershed Assistant. A Watershed Assistant has been provided for the Griffin/Spalding school system (funded jointly by the City, County and UGA Extension office). The Watershed Assistant presents watershed, water quality, water conservation and stormwater issues to the 4H Cloverleaf students which includes all 5th grade students in the Griffin-Spalding County School System, private schools within the County and home school groups.
Georgia Adopt-A-Stream Program	●	This program has been implemented in Griffin, and is supported by the City. City of Griffin Stormwater Department hosts an annual Stream clean-up event.
Stenciling Program	●	The City now installs 500 metal disk stormdrain markers per year and will soon be updating stenciled drains with the metal disks.
ACOE Partnership	—	The City is no longer pursuing this action item.
Stream Mitigation Bank	—	The City is no longer pursuing this action item.
Study of Nutrients in City Golf Course Area	—	This study has not been pursued.
Fecal Coliform Source Tracking	●	A report on Bacterial Source Tracking in the Potato Creek Watershed is included as Appendix A of the 2005 Potato Creek Management Plan.
Downtown Area BMPs for Elevated Metals	●	Three TEA-21 BMPs recommended in 2005 plan have been implemented and are being monitored.

*● Fully Implemented
○ Partially Implemented or Initiated/Underway
— Not implemented or initiated

Table 4-1 cont'd BMP Implementation Status

Best Management Practice (BMP)	Implementation Status*	Comments
MS4 NOTICE OF INTENT (NOI) COMMITMENTS		
Public Education and Outreach on Stormwater Impacts		
1. Presentation of Stormwater Projects at Commission meetings	●	Presented once a year
2A. Water Sourcebook Program	●	An ongoing WaterWise program
2B. Water Education Poster	●	Distributed annually to elementary schools
2C. Classroom Education	●	Stormwater Dept. staff educates school and civic association children on stormwater, water quality, soil, erosion and sedimentation, and on Fats, Oils and Grease (FOG) issues.
2D. Career Day Activities	●	Stomwater Dept. staff participate in at least one Career Day annually
3. Web Site	●	Maintained regularly
4. Flyers	●	Distributed in utility bills annually
5. Annual Reports	●	Published on website and in local newspaper each year
6. Brochures and Bookmarks	●	Distributed at public buildings, events, and festivals
7. Large Display Stand	●	Periodically updated with new material and moved to a new public location
8. Ecomasters CD	●	500 copies distributed annually to 3rd and 4th graders
9. BMP training site and annual training	●	Training is held each October

*● Fully Implemented
○ Partially Implemented or Initiated/Underway
▬ Not implemented or initiated

Table 4-1 cont'd BMP Implementation Status

Best Management Practice (BMP)	Implementation Status*	Comments
10. Annual Stormwater Workshop	●	A workshop is held each February
Public Participation and Involvement		
1. Curb marker program	●	500 markers are installed each year
2. Development of Watershed Advisory Council	●	Council meetings are held quarterly
3. Consumer satisfaction surveys	●	Mailed twice during permit period
4. Stream/Lake clean-up event	●	Annual clean-up held each April
Illicit Discharge Detection and Elimination		
1. Brochure mailings to Restaurants and Businesses	●	At least 100 brochures mailed each year
2. Citizen complaints/ reporting of problems	●	Available through website and Environmental Hotline
3. Storm sewer outfall inspection	●	20% of City outfalls are inspected each year and the City attempts to identify and eliminate any free flowing illicit discharges.
4. Curb marker Program	●	500 markers are installed each year
5. Inspection of road culvert pipes	●	Level 1&2 culverts inspected annually, level 3 semi-annually, and level 4 quarterly
6. SWPPP Site Inspections	●	Quarterly visual Inspections and annual site inspections at the six sites owned by the city
Construction Site Stormwater Runoff Control		
1. Enforcement of Litter Ordinance	●	During site inspections

*● Fully Implemented
○ Partially Implemented or Initiated/Underway
▬ Not implemented or initiated

Table 4-1 cont'd BMP Implementation Status

Best Management Practice (BMP)	Implementation Status*	Comments
2. Review of Erosion Control Plans	●	Ongoing for development that disturbs over 1 acre of land
3. BMP Inspection at Construction Sites	●	Ongoing
4. Citizen complaints/ reporting of problems	●	Available through website and Environmental Hotline
5. Pre-construction meetings	●	Prior to issuance of land disturbing permits for commercial projects
6. BMP training site and annual training	●	Training is held each October
Post Construction Storm Water Management in New Development and Redevelopment		
1. Inspection of ponds and stormwater facilities	●	Inspected annually, and deficiencies are corrected
2. Structural BMP evaluation	●	A structural BMP is evaluated annually
3. LSPC model distribution	●	Annual distribution to Planning Dept.
Pollution Prevention/Good Housekeeping for Municipal Operations		
1. Street Sweeping	●	The City sweeps roughly 700 miles of street every year
2. Vacuum and jet out storm drains	●	The City cleans approximately 2,500 storm drains and jets 10,000 feet of storm drain each year
3. Training program for city workers	●	Annual training for all Pubic Works departments
4. Review of flood control capital improvement projects	●	Every new project is evaluated for BMP opportunities
4A. Retrofit of existing structures	●	Review of one existing project each year

*● Fully Implemented
○ Partially Implemented or Initiated/Underway
▬ Not implemented or initiated

Table 4-1 cont'd BMP Implementation Status

Best Management Practice (BMP)	Implementation Status*	Comments
5. Use of City Pollution Prevention Plans	●	All six of the City's industrial sites are inspected each year
6. Maintain a system of benchmarks	●	All 85 benchmarks are inspected and maintained annually. An inventory is maintained on the website.
7. Paperless tracking of storm system Operation and Maintenance	●	Storm system O&M activities are tracked using CityWorks
8. Tree inventory	●	Tree planting and removal is tracked through CityWorks
9. Basin assessment	●	One basin will be assessed each year for potential stormwater quality ponds
ADDITIONAL BMPS IMPLEMENTED SINCE 2005		
Only Rain in the Drain – Illicit Discharge Video	●	Distributed at events and available on the Public Works and utilities website
Rehabilitation of sewer system	●	Old and undersized sewer lines in the Potato Creek Sewer Basin have been replaced and improved.
Inflow and Infiltration (I/I) study	●	Conducted as part of the City's rehabilitation of the sewer system in the Potato Creek Sewer Basin

*● Fully Implemented
○ Partially Implemented or Initiated/Underway
▬ Not implemented or initiated

4.2 PROGRESS ON NONSTRUCTURAL BMPS

The 2005 Watershed Management Plan discussed a number of existing City of Griffin efforts, including infrastructure maintenance programs, the development of the stormwater design manual, floodplain mapping, ordinances to improve water quality protection, and public education and outreach efforts. The watershed management plan also provided recommendations for enhancing these efforts, including a number of new policies, regulations, and other nonstructural practices to address watershed needs. The following progress has been achieved since the 2005 plan. Each bullet below refers to a subsection under Section 7.5 New Policies and Regulations in the 2005 plan.

- **Site-Specific Stormwater BMP Design:** The city is working with Tetra Tech to develop a tool that developers can use to quantify the pollutant reduction in their project developments.
- **Floodplain Management/Flood Damage Prevention Ordinance /New Urbanized Flood Zone Policy:** The City's flood management ordinance was updated in January 2010. The City has been conducting surveys and modeling to develop floodplain delineations and base flood elevations (BFEs). New FEMA DFIRM maps based on the City's floodplain mapping efforts were released in May 2010. The BFEs have not been approved, and the City is currently working with EPD to get funding for additional surveys and modeling needed to refine the BFEs.
- **Ordinance for Post-Development Stormwater Management for New Development and Redevelopment:** The City of Griffin's post-development stormwater ordinance was adopted in 2007. The ordinance requires developers to prepare a stormwater management plan and specifies stormwater management plan requirements. It also addresses post-development stormwater runoff quality and quantity impacts by requiring the use of BMPs, structural and nonstructural, to achieve technical performance criteria. The ordinance itself establishes the major requirements, and the stormwater design manual outlines the more detailed requirements, including design specifications. The City does not require that a developer use nonstructural practices, but a developer can reduce the required water quality treatment volume by using the following BMPs:
  - Natural area conservation
  - Stream buffers
  - Vegetated channels
  - Overland flow filtration/infiltration zones
  - Environmentally sensitive large lot subdivisions

  The above practices are defined in the stormwater design manual. The City of Griffin encourages the use of Low Impact Development (LID) and provides guidelines for the application of LID, including site analysis methods, hydrology considerations, and maintenance needs.

  The 2005 plan also recommends specific requirements for managing stormwater on new development. The City has addressed most of these recommendations in the recent stormwater ordinances, either by adopting the recommendation or a similar policy. Some of the City's practices are more protective than the recommendations. For example, bi-weekly inspections of construction sites were recommended, and the City is currently inspecting active construction sites on a weekly basis. The one recommendation for new development that has not been fully addressed involves mitigation for floodway encroachments, which cannot be addressed until the floodplain mapping, as noted above, is complete.

  The City of Griffin also requires the long-term maintenance of structural BMPs. Owners of existing stormwater BMPs are required to perform maintenance, and these BMPs are inspected by the city once per year at a minimum. Maintenance agreements must be established for all new development, and new BMP sites must be designed with adequate maintenance access.

- **Stream and Wetlands Buffer Ordinance:** Under the sediment and erosion control ordinance, the City of Griffin currently prohibits land disturbing activities within 25-feet of streams per the Georgia Erosion and Sediment Control Act. Under the current stormwater program, developers receive credit for protecting or restoring stream or wetland buffers beyond the required 25 feet. The 2005 plan recommends that no disturbance should be allowed within the first 50 feet of streams and wetlands except under special circumstances, and that no structures or impervious surface should be allowed within 100 feet of streams. The City has not implemented this, and is relying on the State's regulation of a 25 ft buffer from State waters at this time.
- **Illicit Discharge and Illegal Connection Ordinance:** This ordinance was updated in 2007 to give the City the authority and enforcement power to eliminate illicit discharges. As part of its illicit discharge detection and elimination program under the MS4 permit, the City is inspecting 20 percent of its storm sewer system outfalls per year for illicit discharges. The program also includes outreach to businesses, citizen reporting methods, volunteer curb marker placement, the inspection of road culvert pipes, and the inspection of wastewater treatment and industrial sites for compliance with stormwater pollution prevention plans (SWPPPs).
- **Litter Ordinance:** The City's litter ordinance was last updated in 2002, which prohibits any littering on public or private property. The City's MS4 permit also contains a provision to control discarded building materials, concrete truck washout, chemicals, and other illegal dumping on both private and public property during construction site inspections. The City of Griffin also conducts annual volunteer stream cleanups citywide. The most recent clean-up in 2010 removed 4000 pounds of litter and debris from city streams.
- **Other Model Ordinances:** The 2005 plan recommended a number of ordinances for consideration. The City has promulgated policies that address the majority of these recommendations. The credits for nonstructural BMPs in the stormwater manual address the 2005 recommendations for Conservation Subdivision/Open Space Development. Impervious surface limitations and parking ratios are addressed within the City's zoning regulations, and clearing and grading limitations are addressed in the soil and erosion control requirements for construction sites. Roadway width minimums are set by the fire and solid waste departments. One consideration relating to these policies is that no new construction has occurred since the City released its stormwater design manual. The current requirements should be evaluated first for successful water quality and quantity protection. Once the recent requirements have been tested on new development, other requirements could be examined to further protect water resources.

  The City has an extensive grease management program that has been in operation since 2004 (http://www.cityofgriffin.com/Departments/PublicWorks/FatsOilsGreaseFOG.aspx). The program includes inspection and enforcement of grease management for food facilities. Under this program, the city also provides public education to reduce improper disposal of oils, grease, and fats.
- **Enhanced Public Education and Outreach Activities:** As part of its MS4 stormwater program, the City of Griffin conducts a number of education and outreach activities that thoroughly address the recommendations in the 2005 plan. The educational programs reach out to a variety of stakeholder groups, including school-age children, builders/developers, city staff, business owners, home owners, commercial employees, and all taxpayers/ratepayers. The city also provides opportunities for the public to participate in watershed improvement activities through an advisory council, mail surveys, stream/lake clean-ups and the curb marker program. In addition to these programs, volunteers with the Spalding County 4-H Adopt-a-Stream program monitor water quality, invertebrates, and stream bank conditions and perform stream clean-ups.

The above review of nonstructural practices demonstrated that many of the 2005 plan recommendations have been accomplished to date. Several opportunities for nonstructural practices are available that would help address the Potato Creek watershed management needs, and these opportunities are discussed in Section 8.

The City of Griffin maintains records of pollutant reductions achieved through non-structural BMPs. Below are recent data on street sweeping and stream clean-up efforts:

- **Street Sweeper data (June 2008 – October 2009):**

  The City removed an average of 66 tons of debris from 227 miles of streets per month for a yearly total of 792 tons removed from 2725 miles of streets.

- **Steam Clean-Up data (2006 – 2009):**

  The following data includes all efforts in the City of Griffin. In the Potato Creek Watershed, Grape Creek was cleaned all years and Ison Branch was cleaned in 2007 and 2008.

  2006 – 800 pounds of garbage and 440 pounds of tires
  2007 – 2800 pounds of garbage, 820 pounds of recyclable metal and 400 pounds of tires
  2008 – 2180 pounds of garbage, 200 pounds of recyclable metal and 1000 pounds of tires
  2009 – 3000 pounds of garbage, 460 pounds of recyclable metal and 1000 pounds of tires

The City of Griffin also uses best management practices on some of their large municipal properties, though the practices are not included within the City's expressly stated BMP commitments. At the City Park and Golf course, the City uses slow release fertilizer, and leaves a 25 foot creek buffer that is mowed once a year. At the cemetery, no fertilizers are used.

5 Watershed Projects and Research

5.1 TEA-21 Project

The goal of this project was to provide quantitative data regarding the effectiveness of various quality improvement BMPs for stormwater runoff that originates along highly developed and urbanized highway corridors. Three BMP devices, including the SMI- Storm Filter, the Baysaver 10k, and the PBM CrystalStream, were installed in highly developed subwatersheds along the State Route 16 corridor in Griffin. The final report on the TEA-21 project was completed in 2004, and is available on the Griffin Stormwater Department website:

http://www.cityofgriffin.com/Departments/PublicWorks/Stormwater/Projects.aspx

The report details the maintenance needs, pollutant removal efficiencies, and cost effectiveness of each device.

Pollutant removal efficiencies were calculated by comparing mean estimated baseline (pre-construction) pollutant loading to mean estimated post-construction pollutant loading. Pollutant removal efficiencies of the three devices for Total Copper and Total Zinc are presented in Table 5-1.

Table 5-1 TEA-21 Pollutant Removal Efficiencies for Copper and Zinc

	Removal Efficiency	
BMP Device	**Total Cu**	**Total Zn**
SMI- Storm Filter	66.7%	42.9%
Baysaver	66.7%	11.1%
PBM CrystalStream	33.3%	-6.7%

Since completion of the project, the devices have been maintained regularly, but no further water quality data has been collected.

5.2 Bacterial Source Tracking

Peter G. Hartel PhD., an associate professor at the University of Georgia, published a report on Bacterial Source Tracking (BST) in the Potato Creek Watershed. This report is included as Appendix A of the 2005 Potato Creek Management Plan. The study found that the Griffin reach was persistently contaminated with high numbers of *E. coli* bacteria during both base and stormflow conditions. The report concluded that human fecal contamination in the Griffin reach during baseflow conditions was unlikely, and the most likely source of fecal contamination was from pets and urban wildlife. The report also states that fecal contamination in the lower branches of Potato Creek is more than likely caused by dairy cattle and a set of dog kennels.

5.3 Fecal Coliform Reduction

The City of Griffin and the McIntosh Trail Regional Development Center have been awarded a Section 319 grant aimed at reducing fecal coliform in the Potato Creek Watershed. The City will be installing 10 to 15 pet waste pick up stations within the Potato Creek Watershed. Additional BMPs will be installed within the watershed, but outside of City limits. Griffin collected one wet weather and one dry weather water quality sample in January 2010, prior to installation. The City will take another set of wet and dry weather intermediate samples as the BMPs are being installed over the summer, and a final set of samples after everything is installed in the fall.

5.4 Paragon Sub-basin Study

Paragon Consulting Group, Inc. has conducted a sub-basin study on the Potato Creek Watershed to identify potential measures for improving water quality in the watershed. Within the limits of the City of Griffin, 56 basins in the Potato Creek watershed were characterized based on information derived from field visits. The dominant land use was noted, current drainage features were described, and recommendations were made on what type of treatment measures, if any, could be implemented in each basin. The treatment options considered for this project include new stormwater detention ponds, retrofits to existing detention ponds, and proprietary BMP devices capable of treating eight to ten acres (such as the Stormceptor STC 11000). Existing outfall structures were identified in the study area and the drainage basins were divided into 362 sub-basins, sized approximately eight to ten acres such that each sub-basin could potentially be treated by one BMP device. Each sub-basin was assessed to identify if treatment was already included as part of the existing stormwater management system. In addition, each sub-basin was field assessed to identify if it was a candidate for structural BMP retrofit (available space for BMP). Sub-basins for which treatment was already in place and for which no space for BMP retrofit was available were screened out. The project identified 159 locations that may be suitable for proprietary BMPs and 38 locations where new ponds could be built or existing ponds modified/retrofit.

5.5 2008 Stream Channel Erosion Activity Assessment

A Stream Channel Erosion Activity Assessment was conducted to assess the geomorphic state of streams in the Potato Creek watershed from the Southern Spalding County Line (County Line Road) to its headwaters. During March and April of 2008, the assessment was carried out by a fluvial geomorphologist walking either on the stream bed or along the stream bank while conducting Rapid Geomorphic Assessments (RGAs). Stream reaches were rated in terms of erosion potential and descriptions were provided via a written report, maps, and photographs. The assessment found that the main stem of Potato Creek, downstream of the Ison Branch tributary, is responding to a high sediment load. The entire reach is bedded with sand. Much of Potato Creek and its two largest tributaries have been historically channelized, which serves to speed flood flows through the watershed. The maps produced as part of the geomorphic assessment identify many areas of moderate and high channel erosion activity along Potato Creek and its tributaries.

5.6 Sand Filters

The City received a 319(h) grant to install and sample influent and effluent water quality from eight modified Delaware Sand Filters. The objective of this project is to evaluate the effectiveness of the modified version of the Delaware Sand Filter to address non-point source pollutants present in stormwater runoff using various media readily available in the State of Georgia. All eight of the sand filters have been installed within the Potato Creek watershed and will be receiving stormwater runoff from residential areas and a City maintenance yard for Public Works. The first monitoring event has occurred but data is not yet available.

5.7 Hydrology and Water Quality Modeling

In March 2008, Tetra Tech updated the Watershed Hydrology and Water Quality Report for the City of Griffin Watersheds. The Watershed Hydrology Modeling Report presents the results for the model calibration and validation of the Cabin Creek (HUC8 No. 03070103, Upper Ocmulgee), Shoal Creek, Potato Creek, Heads Creek, and Honeybee Creek (HUC8 No. 03130005, Upper Flint) Watersheds. The Water Quality Report presents the results of the preliminary water quality calibration and validation of the same watersheds. The Loading Simulation Program C++ (LSPC) was used to represent the hydrological conditions. The LSPC model is capable of representing loading, both flow and water quality, from nonpoint and point sources. The watershed model represented the variability of nonpoint source contributions through dynamic representation of hydrology and land practices. The model included all point and nonpoint source contributions.

In 2010, Tetra Tech amended the LSPC Watershed model to include data through the December 2009. This model is for the whole city of Griffin. The 2010 Watershed Hydrology and Water Quality Modeling Report is included in Appendix D.

Improvements in 2010 include the addition of monitored water quality data and USGS flow records through December 2009. With this additional data, the model simulation time was extended, thereby improving the diversity of precipitation and response conditions for the modeled watersheds. In addition, the 2008 model represented water quality loading through accumulation and wash-off rates only. In this release, the water quality loading simulations were improved through the inclusion of biochemical processes.

Overall, the 2010 model hydrology calibration looks reasonable. However, in 2005 there is a large July storm event followed by several smaller storms which causes a slightly elevated recession in the simulated results. The large storms in July and August followed by a period of dry weather in September and the first part of October 2005 appear to be causing a slight over prediction of the simulated flow. In 2006, there is good agreement between the simulated and observed flow. The only exception is a couple of storm flows observed in the measured data in September which are not seen in the precipitation data, thus are under estimated in the simulated flows. In 2007 there was a significant deficit in rainfall. As such, the simulations are reasonably good, but are slightly low for this year. In general, simulated flows during 2007 and a portion of 2008 follow the observed pattern and are within an acceptable margin of error given that much of the year flows were less than 5 cfs and commonly drop to as low as 1 cfs. The 2009 simulations have good agreement.

At each of the calibration stations, the total volume error for the 6-year simulation was less than 10%. Similarly, the seasonal volumes for each of the gages were all less than 30%. The metric for both gages that was most difficult to calibrate was the error in 50% lowest flows. This problem is not uncommon when low flow conditions drop below 10 cfs. For the calibration stations, the flow is frequently less than 10 cfs and further exasperated by the drought conditions of 2006, 2007, and parts of 2008. During these extended dry periods, the observed flow could often drop to a range as low as 3 to 1 cfs, thereby causing large percentage variations detected in the low flow calibration metrics.

Like the hydrology calibration, the water quality calibration looks reasonable at the four water quality stations used for calibration (WQ-1 and WQ-28) and validation (WQ-15 and WQ-3). Water temperature simulation at each of the calibration and validation locations is very good. However, for isolated winter dates in 2007 and 2008, the temperature drops to 0°C. The reason the simulated temperature is dropping to the freezing point in these isolated instances is because the simulated water depth is less than 2-inches. When the simulated water depth drops below 2-inches, the model applies the ambient air temperature as the water temperature. Overall, the water temperature simulation shows the seasonal trends well at all of the water quality stations.

Dissolved Oxygen is simulated well at three of the four water quality stations. The one exception is station WQ-15 which is at a location downstream of the point sources. At WQ-15, the dissolved oxygen simulation is high from 2003 to 2008. Investigations into the high simulation suggest that one or both of the point source inputs are influencing the less than ideal dissolved oxygen response. Much like the temperature calibration, the dissolved oxygen simulation shows the seasonal trends well at all of the water quality stations.

BOD is simulated fairly well at each of the stations, but with notable caveats. At station WQ-15, the simulation misses several of the peak observed concentrations. This station is downstream of the point sources and the peak concentrations might be an artifact of the point source discharges. At water quality stations WQ-1 and WQ-3, the simulation appears to be slightly elevated. At these stations, the simulation is hovering around the detection limit data sets. At WQ-28, the simulated BOD concentrations are slightly less than the simulated concentrations at WQ-1 and WQ-3. At this station, the simulated results are within a very agreeable range.

Total Nitrogen, Ammonia, Nitrate, and Nitrite were generally simulated well at each of the stations. However, one anomaly was observed in the measured data set that wasn't picked up in the simulations. During 2005, there appears to be an increase in Total Nitrogen of about 2 mg/l at water quality stations WQ-1 and WQ-3, as well as an increase in the range of 1 to 2 mg/l at station WQ-28. WQ-15 doesn't reveal this trend as noticeably because both the simulated and measured results are heavily influenced by the upstream point sources.

Total Phosphorus was simulated well at each of the stations, however, at station WQ-3, the simulation appears to be slightly low. There is a golf course just upstream of WQ-3 which is the likely cause of the higher measured total phosphorus concentrations at this station. Unfortunately, the land use descriptions used in the model do not include golf courses, thereby making it difficult to improve the total phosphorus agreement at this station. Ortho Phosphorus was difficult to analyze at each of the stations. In several locations the measured Ortho Phosphorus concentrations are greater than the measured Total Phosphorus concentrations. Overall, the Ortho Phosphorus simulations follow an agreeable pattern and the concentrations are within an acceptable range.

6 Long Term Monitoring Plan

6.1 WATER QUALITY MONITORING

The City has conducted a comprehensive program of water quality sampling in the Potato Creek Watershed since late 2000. There were originally 14 sample sites where in-situ and grab samples were taken. Following review with the Georgia EPD in August 2004, the number of sample sites was reduced from 14 to 7. These seven sites include four of the original sample sites and three new sample sites. The Potato Creek monitoring stations are listed in Table 6-1 and depicted in Figure 6-1. One reference site in Meriwether County is also monitored (Figure 6-2). Since 2005, the sample sites have been monitored quarterly for water quality. A USGS stream gage is located on Potato Creek, near the downstream portion of the service area watershed, which records gage height and discharge. Precipitation is measured at a Georgia Automated Environmental Monitoring Network (GAEMN) Georgia Experiment Station in Griffin.

The long term monitoring plan for the Potato Creek Watershed includes continued quarterly water quality monitoring, with two wet and two dry weather samples collected each year. Some parameters will be measured at site (in-situ) and others will be measured in a laboratory from samples collected at the sites (laboratory grab). The sampling schedule, as well as targets for wet and dry sample collection, is described in the City of Griffin QAPP (Appendix E). All water quality measurements will be taken using standard operating procedures approved or similar to those listed in 40 CFR part 136, excluding the fecal coliform method, which uses a standard operating procedure published in Standard Methods but not listed in the CFR.

The Potato Creek Monitoring Plan is detailed in the 2005 Potato Creek Watershed Assessment prepared by Paragon Consulting Group in 2005. The monitoring protocol will continue to be the same as it has been since 2005, with the addition of a few new parameters. In fiscal year 2010-2011, one composite sample will be performed at one of the monitoring stations that will cover the complete hydrograph during a wet weather event. Beginning in fiscal year 2010-2011, the City will also begin sampling fecal coliform between May and October in order to determine the geometric mean of bacteria in the watershed. E. coli will be sampled once per year beginning in fiscal year 2010-2011. The City will begin sampling hardness, as calcium carbonate ($CaCO_3$), in fiscal year 2010-2011. This sampling will allow the City to calculate dissolved metals concentrations based on the total metal concentrations sampled for cadmium, copper, lead, and zinc. When possible, the City should measure or estimate stream flow during each sampling event at each monitoring site. If the stream is dry or there is no flow at a monitoring site, this will be noted in the field notes and the Annual Report. The City has conducted priority pollutant scans and sediment sampling in the past and may continue to do these analyses periodically at their discretion. Table 6-2 displays the parameters measured by the City, as well as the referenced standard operating procedure and accompanying detection limit.

Table 6-1 Current Monitoring Stations

Site ID (Griffin ID)	Description
1p (WQ 1)	Potato Creek @ County Line Road
3ib (WQ3)	Ison Branch Just Prior to Confluence With Potato Creek
4g (WQ 4)	Grape Creek Just Prior to Confluence with Potato Creek
5g (WQ 36)	Grape Creek @ Hudson Road.
7gtg (WQ 35)	Grandview Tributary to Grape Creek @ Glenwood Avenue
13ib (WQ 34)	Ison Branch Close to Ashford Place
16hb (WQ 14)	Honey Bee Creek @ Airport Road
REF-1 (WQ 40)	Brittens Creek, Meriwether County

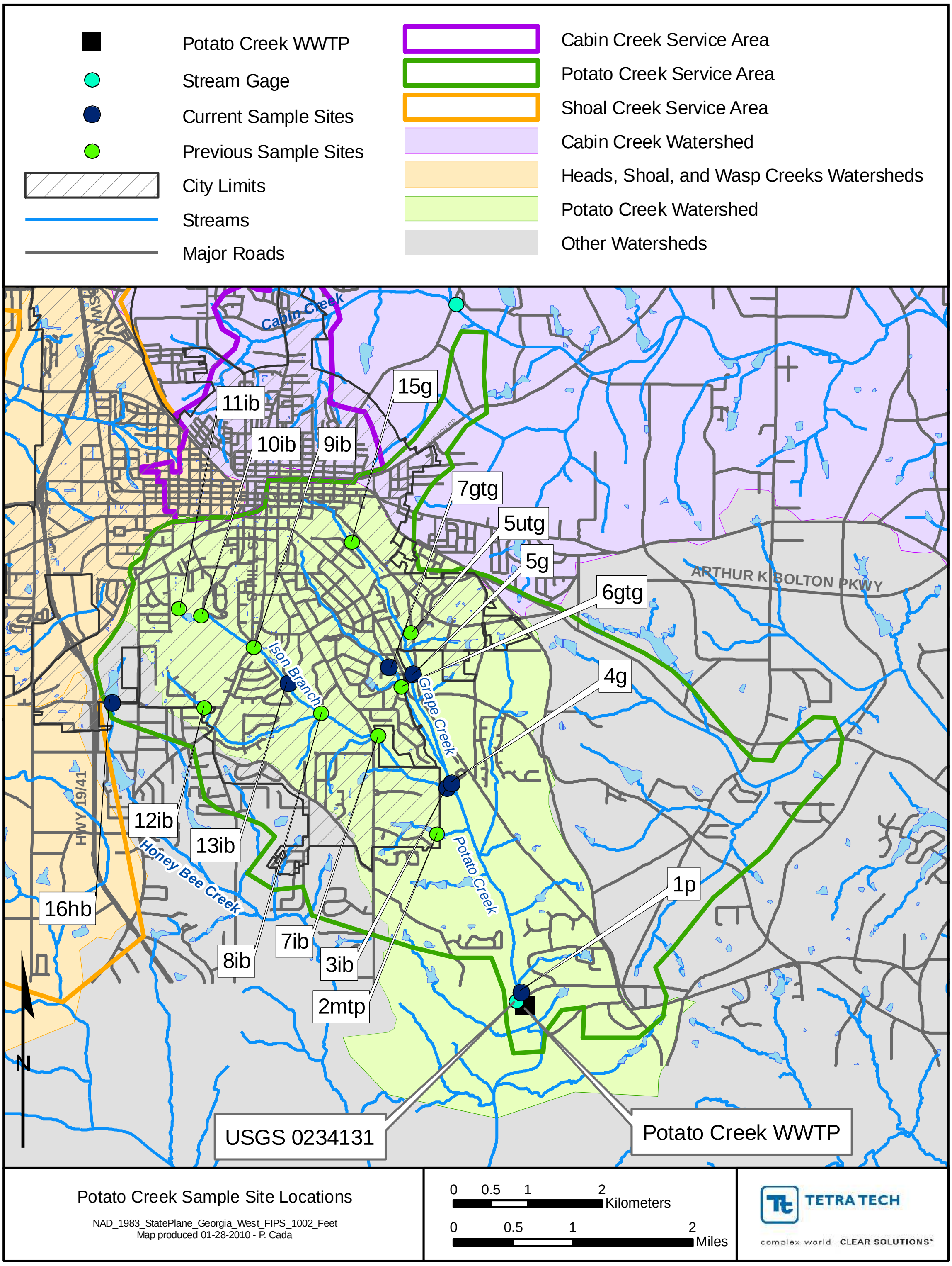

Figure 6-1 Potato Creek Monitoring Stations

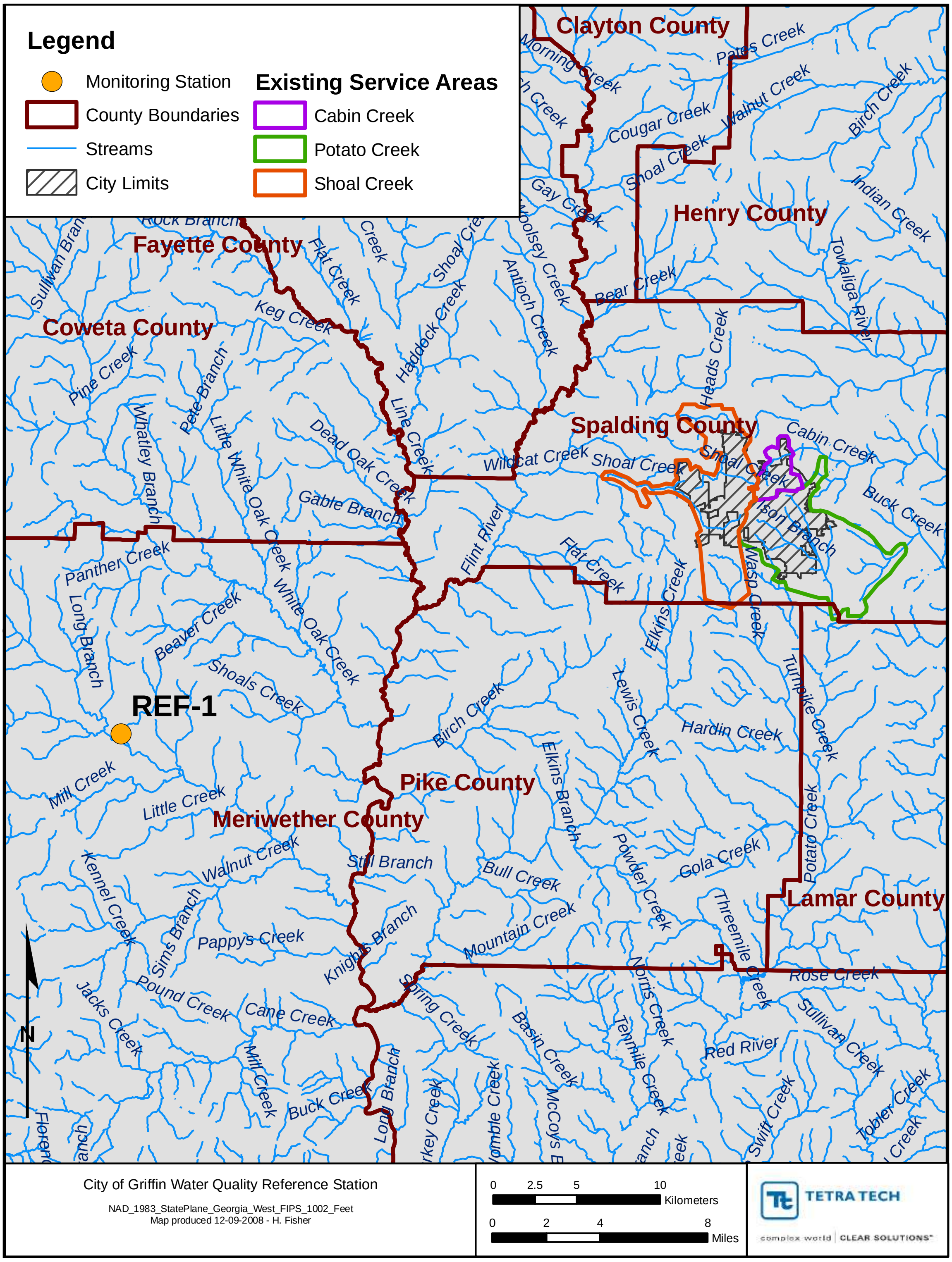

Figure 6-2 City of Griffin Water Quality Reference Monitoring Station

Table 6-2 Water Quality Parameters Measured by the City of Griffin

Parameter	Sample Type	Method(s)	Detection Limit
Temperature			
Air	In-situ	Troll 9500	N/A
Water	In-situ	Troll 9500	N/A
Oxygen demand			
DO	In-situ	Troll 9500	N/A
Carbonaceous biochemical oxygen demand (5-day) (CBOD5)	Laboratory grab	SM 5210B	2.0 mg/L
Chemical oxygen demand (COD)	Laboratory grab	Hach Method 8000	2.0 mg/L
Sediment Load			
TSS	Laboratory grab	SM 2540D	1.0 mg/L
Turbidity	In-situ	Horiba U-10 Checker	N/A
Nutrients			
TP	Laboratory grab	Hach Method 8190	0.01 mg/L
Orthophosphate	Laboratory grab	SM 4500-P E	0.02 mg/L
Nitrates (NO_3)	Laboratory grab	Hach Method 8039	0.3 mg/L
Nitrites (NO_2)	Laboratory grab	Hach Method 8507	0.002 mg/L
Ammonia nitrogen	Laboratory grab	SM 4500-NH3 F	0.01 mg/L
TKN	Laboratory grab	SM 4500-Norg B/NH3 D	0.4 mg/L
Flow	In-situ	Visual estimate	N/A
Metals			
Specific conductivity (SpC)	In-situ	Troll 9500	N/A
pH	In-situ	Troll 9500	N/A
Total cadmium (Cd)	Laboratory grab	EPA 200.7	0.0005 mg/L
Total copper (Cu)	Laboratory grab	EPA 200.7	0.004 mg/L
Total lead (Pb)	Laboratory grab	EPA 200.7	0.005 mg/L
Total zinc (Zn)	Laboratory grab	EPA 200.7	0.004 mg/L

Table 6-2 cont'd Water Quality Parameters Measured by the City of Griffin

Parameter	Sample Type	Method(s)	Detection Limit
Dissolved Cd [1]	Calculated	Calculated	Calculated
Dissolved Cu [1]	Calculated	Calculated	Calculated
Dissolved Pb [1]	Calculated	Calculated	Calculated
Dissolved Zn [1]	Calculated	Calculated	Calculated
Hardness as $CaCO_3$[1]	Laboratory grab	Hach 8226	0.3 mg/L
Priority pollutants			
Priority pollutant scan	Laboratory grab	Multiple methods	Parameter dependent
Sediments			
Metals, pesticides, polychlorinated biphenyls (PCBs), polynuclear aromatic hydrocarbons (PAHs)	Laboratory grab	Multiple methods	Parameter dependent
Fecal Indicator Bacteria			
Fecal coliform	Laboratory grab	SM 9222 D	1 colony/100 mL
E. coli[1]	Laboratory grab	SM 9223 B	1 colony/100 mL

[1] Sampling required to measure these parameters will begin in fiscal year 2010-2011.

A regular assessment of water quality data will be conducted to compare measured data to established benchmarks and to characterize trends in each of the measured parameters. Annual progress reports to the Georgia EPD will relate pollutant concentrations to the water quality benchmarks established in this Protection Plan Update. These reports should include a statistical analysis of recent data, as well as figures similar to those in Appendix A of this report to observe trends over time for constituents of concern.

6.2 Biological Monitoring

The City of Griffin has conducted three Biological Assessments to date (2000, 2004/2005, and 2008/2009).

The City of Griffin will continue to conduct regular biological assessments as part of the long term monitoring plan. Macroinvertebrate and habitat sampling will be conducted twice every five years at all Potato Creek sites. Fish community sampling will occur twice every five years at sites 3ib, 4g, and 1p. Monitoring will be conducted using the most recent edition of GA DNR's Standard Operating Procedures for Macroinvertebrate Biological Assessment of Wadeable Streams in Georgia and Standard Operating Procedures for Conducting Biomonitoring on Fish Communities in Wadeable Streams in Georgia. In-situ measurements and samples for alkalinity and nutrients (total phosphorous, orthophosphate, total Kjeldahl nitrogen, ammonia, nitrite/nitrate) will be taken immediately before habitat data and biological samples are collected. The nutrient data can also be used for one of the dry-weather water quality monitoring events. Sampling for the macroinvertebrate and fish assessments will be performed at least two weeks apart.

7 Watershed Management Needs

The 2005 management plan provided a foundation for implementing strategies that would address the multiple concerns within the Potato Creek watershed. As an update to the plan, Tetra Tech considered recent data and information and developed a framework to prioritize management needs based on spatial variation in the watershed. Previous assessment results were reviewed along with the updated monitoring data and loading analysis. Information sources include the 2005 Potato Creek Management Plan, the 2005-2009 Water Quality and Biological Analysis (Section 3), and the 2008 Stream Channel Erosion Activity Assessment.

Through this review, management needs were identified on a subwatershed basis (defining subwatersheds as the land draining to each monitoring station). The watershed impact indicators (described in Section 2.1) were used to prioritize the subwatersheds for particular management needs relating to each indicator. Indicators considered for this evaluation were selected based on their relevance in the Potato Creek Watershed and whether information or data were readily available.

Where a subwatershed is identified as a priority for a particular indicator, management within that subwatershed is expected to provide improvement within the subwatershed and at downstream locations. Therefore, some subwatersheds are selected as priorities for management because they can address a downstream management need. The strategies for identifying priority subwatersheds differed by indicator and are explained in more detail below.

Sediment, Channel Stability, and Channel Morphology

As discussed in Sections 3.3 and 3.4, sediment loading to streams is a major stressor in the Potato Creek watershed. The loading analysis identified subwatersheds 1p, 3ib, and 4g as having the greatest TSS loads. Sediment loads at station 1p, however, appear to be originating in subwatersheds upstream.

Sources of instream sediment include erosion from upland areas and erosion occurring along the banks of the stream channels. Although most of the sediment loading is likely attributed to bank and channel erosion, upland sediment is another potential source, particularly stormwater runoff from construction sites and other areas where bare soil is exposed. Since the greatest loading appears to originate within subwatersheds 3ib and 4g, these areas are considered priorities for managing instream sediment. The extent that upland sediment contributes to TSS and turbidity cannot be estimated without a model simulation. Until the upland and instream sources of sediment can be more closely studied, management measures that address both upland and stream channel sources should be considered.

Bank and channel erosion upstream of subwatershed 1p likely contributes a large portion of the sediment loading in the Potato Creek Watershed. The Channel Stability and Channel Morphology indicators can be used to prioritize subwatersheds where stream restoration can reduce instream sediment loading. Two information sources are available relating to these indicators. As noted in Section 5.5, the 2008 Geomorphic Assessment assessed the geomorphic state of streams and rated stream reaches as having a low, moderate, or high erosion activity (Figure 7-1). Through an earlier assessment, the 2005 Potato Creek Watershed Management plan recommended three levels of restoration for streams within the Potato Creek watershed. The high level of stream restoration would involve extensive excavation and construction activities that could include reconnecting a stream to its floodplain, creating a new channel, and restoring meanders and other features to a channel. The medium level of stream restoration would involve less extensive measures such as spot repairs for bank or channel erosion, levee removal, and instream grade control structures. The low level of stream restoration would include vegetation management, buffer restoration/enhancement, and preservation. The figure on page 83 of the

Management Plan illustrates which reaches were recommended for each type of restoration. The 2005 and 2008 studies contrast somewhat in the type of information provided. The 2005 plan recommended the type of restoration appropriate and designates these types at a relatively coarse scale. The 2008 assessment provided details on the conditions along stream segments at a finer scale than the 2005 plan. The differences between the study results may also be due to changes in stream geomorphology between 2005 and 2008.

The 2008 Geomorphic Assessment confirms that the reach in subwatershed 1p is responding to a high sediment load, but it categorized this reach as having low to moderate channel erosion activity. Reaches within subwatersheds 3ib and 4g, immediately upstream of subwatershed 1p, have high channel erosion activity (i.e. poor channel stability), indicating that these are likely sources of sediment. The geomorphic assessment identified extensive channelization in the reaches within subwatersheds 3ib, 4g, and 13ib. Channelization is a major contributing factor of the channel instability in the 3ib and 4g subwatersheds. In contrast, the channelized reach identified through the golf course in subwatershed 13ib appears stable.

The 2005 plan recommends medium level restoration for the reaches within subwatersheds 3ib and 4g. The 2008 findings suggest that these reaches may present opportunities for high level as well as medium level restoration. For subwatershed 13ib, the 2005 plan recommends locations for high level restoration that are different than the reaches rated as having high erosion rates in the 2008 study. This discrepancy may be due to changes, both natural and anthropomorphic, that occurred between 2005 and 2008. The 2005 plan also may have designated these reaches for high level restoration due to the urbanized nature of the channels and the presence of artificial grade controls. Despite these differences, both studies indicate that restoration needs exist within subwatershed 13ib. Since the channelized reach in 13ib identified through the golf course appears stable, subwatershed 13ib has restoration needs relating to channel morphology and not stability.

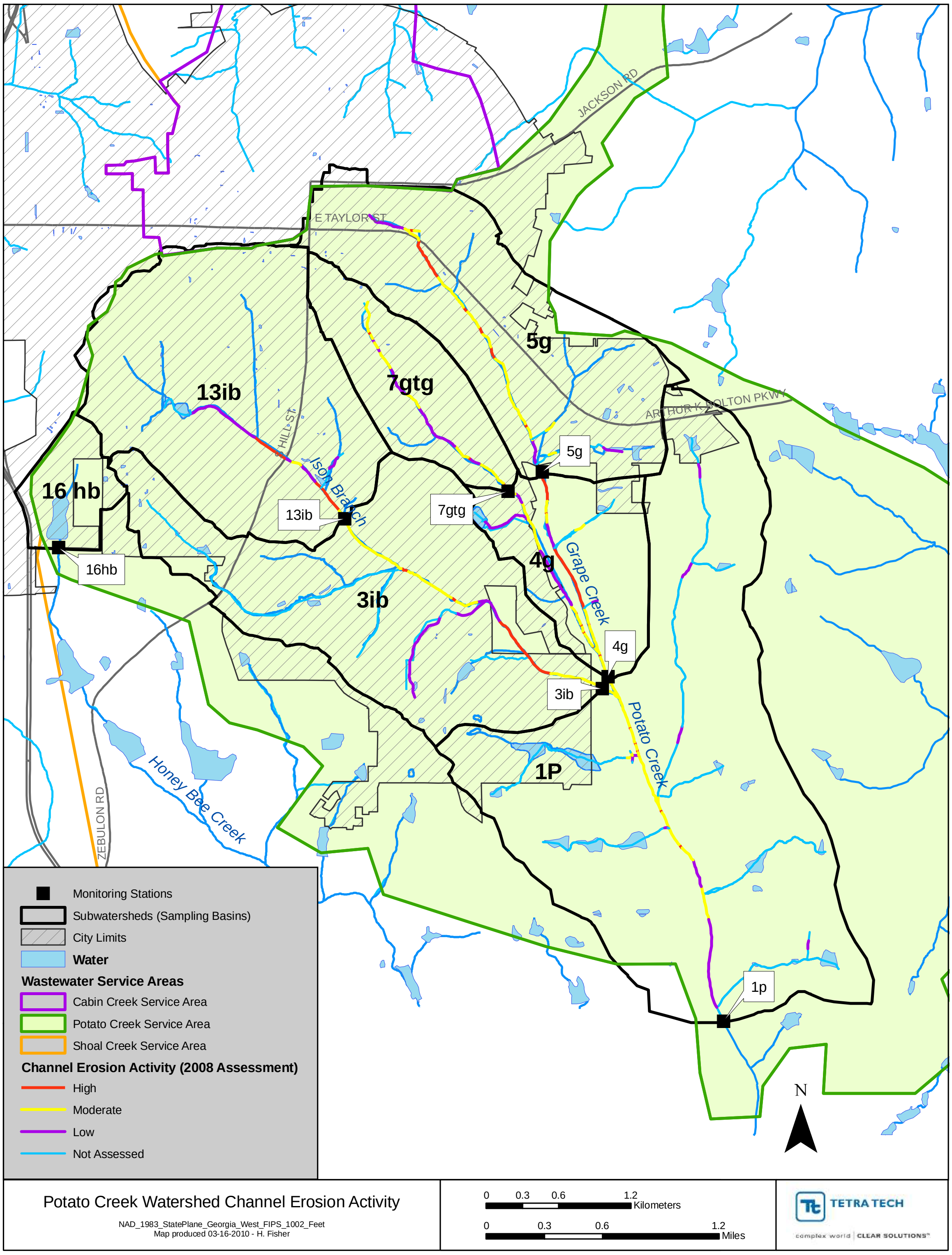

Figure 7-1 Channel Erosion Activity Ratings from 2008 Geomorphic Assessment

Hydrology

Disturbance and development in upland areas can alter the natural hydrology of a watershed and lead to lost watershed functions. These conditions can cause, among other impacts, erosion (both in stream channels and in upland areas), increased flooding, and wetland conversion due to decreases in the water table. At the present time, hydrology modeling data have not been interpreted to provide estimates of where the greatest impacts of increased peak flow and volume from urban development may be occurring. As an initial hypothesis, subwatersheds 5g, 7gtg, and 13ib should be prioritized for upland flow controls because these areas contain an extensive degree of urban development; they are also upstream of subwatersheds 4g and 3ib which exhibit severe erosion and scour, and contribute the heaviest sediment loads. BMPs implemented in subwatersheds 5g, 7gtg, and 13ib would provide flow control in heavily developed headwater areas and reduce the rate of downstream erosion.

Metals

Acute and chronic toxicity from dissolved metals in surface water can endanger human health and aquatic life. The portion of the watershed draining the downtown area (upstream of sample point 5g) was highlighted in the 2005 Management Plan as a concern for elevated metals loading, particularly zinc. As stated in Section 5.1 of the Plan, stormwater treatment devices were installed to reduce metals loading as part of the Transportation Enhancement Activities for the 21st Century (TEA-21) project. Metals management in the Potato Creek watershed should involve the calculation of the dissolved fraction of metals as part of the long term monitoring plan before additional BMPs are identified and implemented. Further investigation into metal concentrations and potential management needs should proceed with a particular focus on subwatershed 5g.

Dissolved Oxygen

Low dissolved oxygen conditions exist in several locations within the watershed and may be impacting aquatic communities. The water quality analysis indicates that dissolved oxygen standards were violated by individual measurements of less than 4.0 mg/L at four sample sites: 1p, 16hb, 7gtg, and 5g. As noted in Section 3.4, there is a strong inverse relationship between DO and water temperature, creating low DO levels during summer months, particularly in low-flow conditions. Impervious surfaces contribute to increases in stormwater temperatures, indirectly contributing to low DO concentrations. Subwatersheds 16hb and 5g, which each have two or more DO violations, also have the greatest percentage of impervious surface in their drainage areas (35.19% and 32.64% respectively). Elevated nutrient concentrations throughout the watershed could also be contributing to the low DO concentrations. To address low DO concerns in the priority subwatersheds 1p, 16hb, 7gtg, and 5g, stream restoration opportunities should include the consideration of measures to improve dissolved oxygen. This could include riparian zone enhancement to reduce water temperature and channel alteration to constrict flow and improve mixing at points along impacted reaches. BMP retrofits could be selected to reduce nutrient concentrations in runoff, reduce peak flows, increase base flow, and achieve a more natural hydrograph.

Nutrients

Nutrient concentrations in the Potato Creek watershed are a concern for water quality within the watershed and in downstream waterbodies. The 2005 Watershed Assessment noted concern over elevated nutrients in the City of Griffin Municipal Golf Course area. Monitoring at the sample sites immediately upstream and downstream of the Golf Course was discontinued at the end of 2004, so recent data is not available that is specific to the Golf Course area. However, the loading analysis does confirm that the subwatersheds containing the golf course (13ib and 3ib) are “hot spots” for nutrient loading. Elevated phosphorus and nitrogen concentrations are a concern throughout the entire watershed and should be addressed on a watershed scale, but the greatest annual loading is occurring in subwatersheds 3ib and 13ib. Therefore, subwatersheds 13ib and 3ib were selected as priority subwatersheds for nutrient management. Management opportunities should include both upland (e.g., fertilizer management and BMP retrofits) and instream (e.g., stream restoration) strategies.

Bacteria (Fecal Coliform)

Fecal coliform counts provide an indicator of human health risk to pathogens in waterbodies. The 2005 Watershed Assessment noted a concern over elevated fecal levels in Grandview and upstream of the golf course. Current data indicate that fecal coliform levels are a problem throughout the watershed, and are in violation of State standards at all sample sites except for the area draining to site 16hb on Honey Bee Creek. BMP types considered throughout the watershed should include those that are effective at removing bacteria from stormwater. All subwatersheds were designated as priorities for managing bacteria loading.

Physical Habitat and Biology

Aquatic communities provide indicators of overall ecosystem health. The 2009 macroinvertebrate and fish monitoring data indicate that improvement of aquatic communities should be a watershed-wide effort. The benthic macroinvertebrate community was rated fair at two of the sample locations (3ib and 16hb) and poor at all other stations. All three sampling sites (3ib, 4g, and 1p) were rated poor for fish. Given these observations, all subwatersheds were designated a priority for overall improvement of biology.

Sedimentation, hydrology, and water quality all affect the viability of aquatic life in streams, and the subwatershed priorities for these stressors were addressed individually above. Although these stressors are indicators of habitat degradation, it is also useful to address the degradation of physical aquatic habitat directly. Habitat scores from the 2009 assessment indicated conditions ranging from marginal (16hb and 1p) to marginal-suboptimal (all other stations). These scores indicate that habitat degradation is prevalent throughout the watershed.

Where excessive sedimentation is occurring, habitat concerns are best addressed by implementing BMP measures aimed at sediment load reduction. Similarly, where low dissolved oxygen is limiting aquatic communities, BMP measures that increase dissolved oxygen concentrations must be considered. Once these and other sources of habitat degradation are addressed, then stream reaches can be evaluated for opportunities to restore physical aquatic habitat through restoration. Stream restoration activities should target the habitat parameters that are in poor condition (vegetative protection, epifaunal substrate, etc.) on a site-by-site basis. Habitat is considered a priority watershed-wide, but it must be addressed through the management of stressors, which have been identified at the subwatershed scale, and through restoration measures that directly improve physical habitat at individual sites. Restoration measures will provide an immediate improvement to habitat conditions, and the management of stressors will improve the long-term stability and health of the aquatic habitat and aquatic communities.

Summary

Table 7-1 and Figure 7-2 summarize the management needs discussed above, noting which subwatersheds are priorities for each indicator. Several parameters require focus across the whole watershed, while for others, specific subwatersheds are identified as being priority areas. As management activities are implemented in the watershed, these priorities should be reviewed to assess progress in meeting watershed goals and objectives. Periodic adjustments to the priorities may be required based on the progress of watershed improvement projects and changes in watershed conditions.

Table 7-1 Management Priorities by Subwatershed

Watershed Impact Indicator	Considered in Evaluation	Priority Subwatersheds
Benthic Communities	Yes	All
Aquatic Habitat	Yes	All
Fish Communities	Yes	All
Channel Morphology	Yes (2008 assessment)	4g, 3ib, and 13ib
Channel Stability	Yes (2008 assessment)	4g, 3ib
Instream Sediment	Yes (2008 assessment)	4g, 3ib
Hydrology (frequency, magnitude, and duration of flows)	Best professional judgment through aerial photographs and sediment load analysis	7gtg, 5g, 13ib
Drainage Complaints	No	N/A
Percent Riparian Area Deficient of Vegetation	No	N/A
Percent Connected Natural Area	No	N/A
Water Quality (Modeling of Future Conditions): Relative nutrient, upland sediment, and metals loading from 2009.	No	N/A
Water Quality (Observed/measured):		
Nutrients	Yes	13ib, 3ib
Instream Sediment (TSS)	Yes (2005-2009 loading analysis)	4g, 3ib
Bacteria (Fecal Coliform)	Yes	All
Metals	Yes	5g
Dissolved Oxygen	Yes	16hb, 7gtg, 5g, 1p

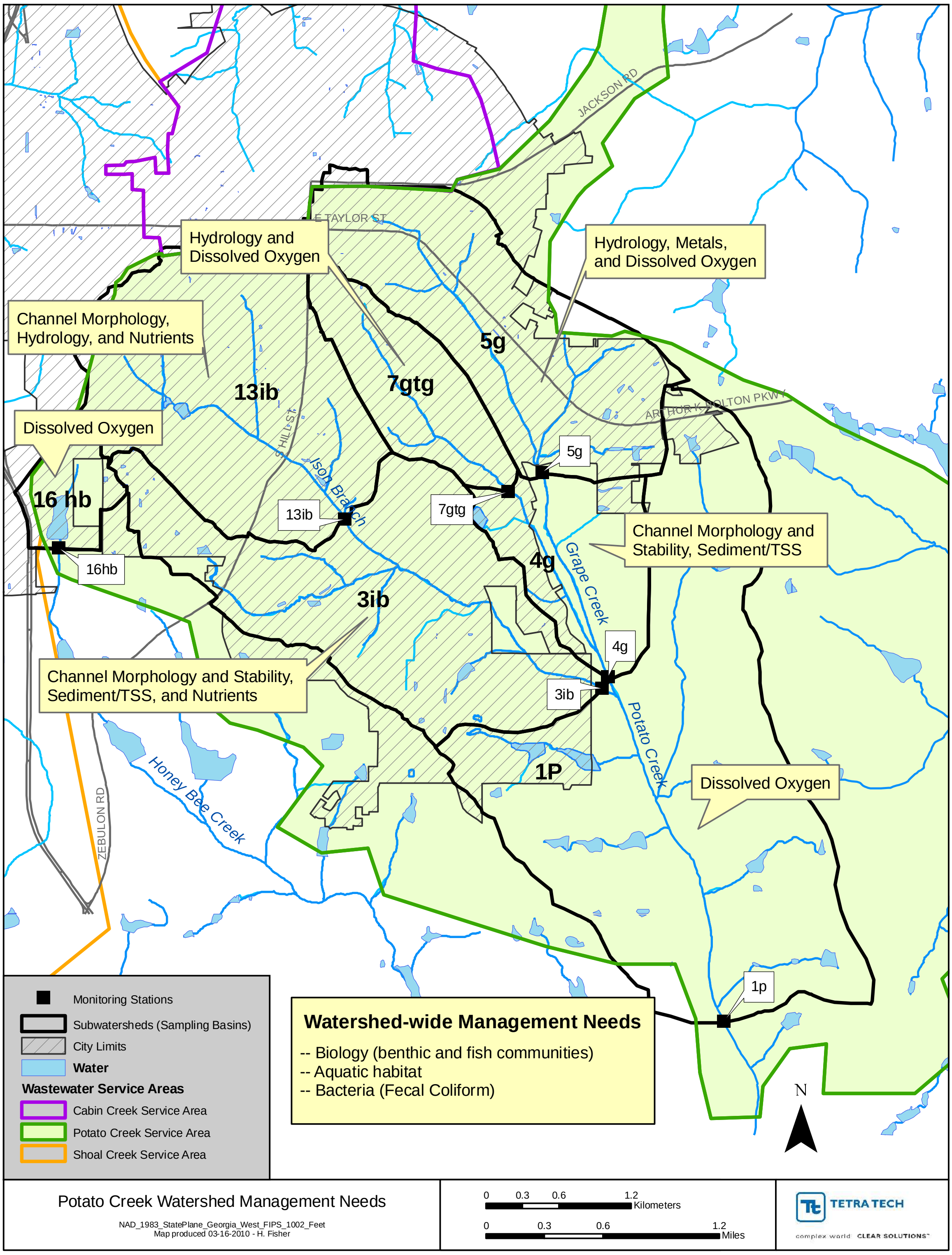

Figure 7-2 Management Needs

8 Watershed Management Opportunities

Management opportunities have been identified that will best address the management needs of the Potato Creek Watershed. The management needs identified in Section 7 are expressed in terms of watershed impact indicators. It is important to note that each watershed impact indicator addresses multiple objectives, and, therefore, management opportunities identified through these indicators will help achieve multiple objectives.

8.1 Identification of Potential Stream Restoration and BMP Sites

A desktop analysis was conducted to identify potential stream restoration and BMP sites in the Potato Creek Service Area. Screening criteria, methodologies, and results are presented below.

Preliminary Screening Guidelines

The selection of sites mainly focused on site-level characteristics. However, to ensure that a sufficient number of sites were located where the greatest needs exist, site selection did include a consideration of management priorities by subwatershed, as identified in Section 7. The evaluation also considered stream restoration ratings from the 2005 Potato Creek Watershed Management Plan and stream erosion activity ratings from the 2008 Stream Channel Erosion Activity Assessment. Tetra Tech's water quality benchmarks were also used as a factor in identifying priorities.

Methodology for Selection of Potential Stream Restoration Sites

Evidence for selecting stream restoration opportunities in the City of Griffin's Potato Creek Service Area was based on previous 2005 and 2008 stream assessments. As noted in Section 7, the 2005 study provided a measure of restoration potential, and the 2008 study evaluated stream segments in the watershed for channel morphology conditions, including erosion activity. Tetra Tech selected potential stream restoration sites based on the management needs identified in these studies. To address the greatest management needs relating to channel stability and morphology, Tetra Tech selected all reaches in subwatersheds 4g and 3ib with high channel erosion activity. Additional reaches throughout the watershed were selected based on erosion activity ratings or other restoration needs. Table 8-1 lists the potential restoration sites, as well as their justification for selection, and Figure 8-1 shows their location in the study area.

Table 8-1 Potential Stream Restoration Sites

Reach ID	Reason for Selection as Potential Restoration Sites
R01-4g	Address channel erosion and historic channelization (Note: outside of city limits)
R02-4g	Address channel erosion and historic channelization (Note: outside of city limits)
R03-4g	2008 assessment noted erosion hot-spots along this reach; only “moderate erosion” reach within city limits in subwatershed 4g
R04-7gtg	Address channel erosion; address low dissolved oxygen concerns with in-stream restoration measures; most downstream reach and the greatest contributing drainage area for the 7gtg subwatershed
R05-5g	Address channel erosion; address low dissolved oxygen concerns; has a large contributing drainage area of the 5g subwatershed
R06-3ib	Address channel erosion and historic channelization (Note: outside of city limits)
R07-3ib	Address channel erosion and historic channelization; address sediment/TSS and nutrients
R08-13ib	Address historic channelization; address nutrient and hydrology concerns
R09-13ib	Address historic channelization; address nutrient and hydrology concerns
R10-5g	Address channel erosion

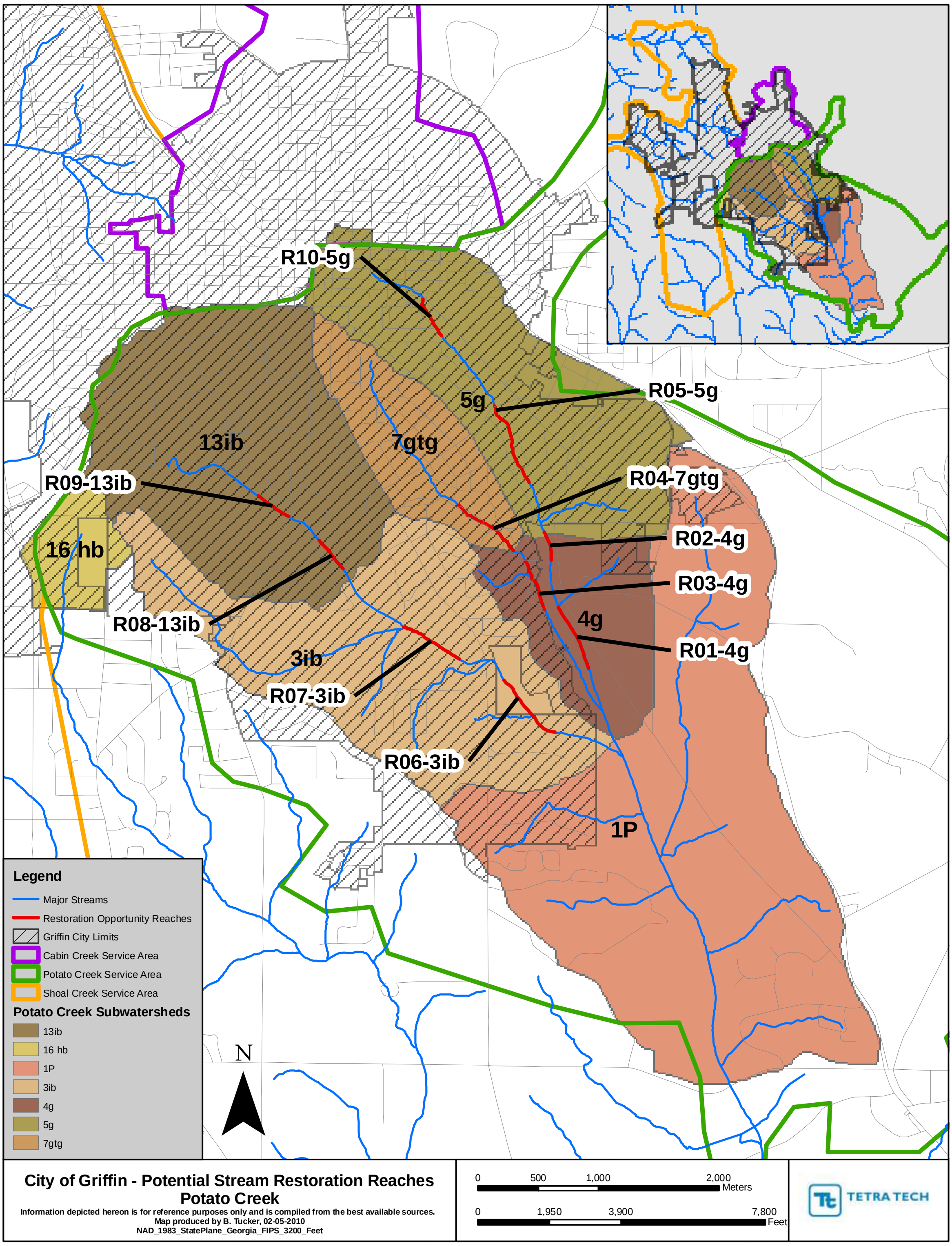

Figure 8-1 Potential Stream Restoration Sites

Methodology for Selection of Potential BMP Sites

In preparation for the field investigation of potential new BMP opportunities in the City of Griffin's Potato Creek Service Area, Tetra Tech conducted desktop screening using a variety of available data. GIS data included parcel information, aerial photography, sanitary and storm sewer locations, topographic and hydrographic data, wetland and hydric soil delineations, as well as a pond inventory and proposed BMP retrofits created by Paragon Consulting Group. The potential stream restoration opportunities identified above were also utilized to prioritize new BMP opportunities. The process of selecting Potential BMP sites involved initial site selection, and a series of screening processes described below.

1) Initial BMP Site Selection

Selecting new BMP sites within a watershed typically requires reasonable assumptions to focus the search. The City of Griffin's parcel layer includes approximately 4,200 individual parcels within the City of Griffin's Potato Creek Service Area. As a result, Tetra Tech used three site selection criteria to identify potential sites for further screening: Paragon's modified and proposed BMP pond sites, public parcels, and riparian parcels adjacent to potential stream restoration reaches.

- Paragon - Paragon Consulting Group previously performed a field investigation for the City of Griffin that involved assessing existing stormwater ponds for water quality-based retrofits, as well as identifying new sites for water quality ponds and proprietary BMPs. Paragon's pond sites within the Potato Creek Service Area were selected for further screening and prioritization.
- Public - Tetra Tech identified publicly owned parcels as opportunities since private land is potentially costly and complicated to acquire for BMP easements. Note that the parcel ownership layer provided to Tetra was incomplete and excluded several large public areas. Following the BMP screening process, Tetra Tech added several parcels to the field investigation list that were not included in the public parcel layer (e.g., airport, golf course, and the Griffin-Oak Hill Cemetery).
- Stream - Stream corridor BMP sites were identified in riparian areas located along potential stream restoration reaches. Privately-owned parcels were included in the list of potential stream corridor sites because of the sites' high potential for immediate downstream improvement and typical insuitability of riparian parcels for development by private interests.

The three site selection criteria and the number of potential sites associated with each criterion are shown in Table 8-2.

Table 8-2 BMP Site Selection Criteria with Number of Potential Sites

Site Selection Criteria	Number of Sites
Proposed Paragon Sites (PGN)	New (26), Modified (8)
Public Parcels (PUB)	27
Stream Corridor BMP Sites (STRM)	98
Total	159

2) Initial Constructability Analysis

Tetra Tech performed an initial constructability analysis for each site/parcel identified in the initial BMP site selection above to remove infeasible sites from further BMP screening. Three main criteria were used to determine if a site is unfeasible for BMP construction:

1. insufficient upland runoff
2. lack of available BMP area
3. wetland or stream impacts

BMP sites must receive considerable drainage from upland areas to be cost effective. The City's storm sewer network and topography data were used to assess a site's potential to collect and treat significant runoff volumes. For large public sites like schools, Tetra Tech used professional judgment to determine if treatment could be limited to onsite runoff due to the large impervious area.

Tetra Tech also assumed that a minimum of 0.5 acres of open land would be needed on each site to feasibly construct a stormwater BMP. This criterion was neglected for highly impervious sites in the downtown area where LID BMPs like permeable pavement and rainwater harvesting might be implemented using a 1:1 drainage to treatment area ratio.

Current federal and state regulatory interpretation of Section 404/401 compliance requirements limits the use of instream stormwater facilities such as regional ponds or wetlands where impacts to perennial and intermittent streams are necessary. The existence of perennial wetlands (according to National Wetlands Inventory) also limits the use of infiltrative-type BMPs and requires an extensive permitting process to meet U.S. Army Corp of Engineer's Section 404 compliance. As a result, Tetra Tech removed potential sites from further screening if they required an impact to natural wetlands or instream construction for implementation of a BMP.

After eliminating potential sites due to constructability limitations (e.g., no offsite drainage, insufficient area for BMP, wetland impacts), the number of potential BMP sites was reduced to 58 sites.

3) Prioritization - Step 1

Following the initial BMP site selection and constructability analysis using the aforementioned criteria, screening attributes were developed to score and prioritize the remaining 58 potential sites. The attributes were devised to use "0" and "1" scoring, where "1" represents a positive attribute for BMP constructability and "0" represents a negative attribute.

Tetra Tech used a manual, GIS-based approach to screen the potential sites for these attributes since automatic processes would not yield accurate results. The five screening criteria are described below:

1. Redundant Treatment – The locations of potential BMP sites were evaluated relative to the City of Griffins BMP geodatabase coverage to reduce redundant treatment. Existing BMPs included dry detention ponds and several proprietary BMPs. Sites without adjacent BMPs in their drainage area were scored a "1".
2. Adjacent Streams – Zero scoring was assigned to sites where BMP construction would impact a stream or wetland, which requires additional permitting to meet U.S. Army Corp of Engineer's Section 404 compliance. The data source for the stream layer is the National Hydrography Dataset.
3. Utility Conflicts – Sanitary sewers and water supply lines were the only utility layers available for the site screening. Conflicts were determined if the utility line intersected the site in the general vicinity of where a BMP could be located. Utility conflicts do not eliminate a BMP from being constructed within their easement, but it could increase long-

term maintenance cost (if sewer maintenance has to impact a BMP structure) and require additional permitting issues.

4. Publicly-Owned Parcel – Although this attribute was used as site selection criteria, publicly-owned parcels were also assigned a “1” score in the screening process due to their appeal for BMP retrofits.
5. High-Loading Land Use – Potential BMPs were credited with a “1” for this attribute if their drainage area included significant areas of land use with greater pollutant export rates. These types of land use include parking lots, industrial areas, high traffic roadways, golf courses, etc.

These five BMP screening criteria were applied to each site, and sites were subsequently ranked by their total screening score. Once sites were scored, potential BMP sites were removed from further consideration if a site:

a) exhibited a stream impact
b) had a total screening score of 2 of less
c) had a total screening score of 3 or less and was located in subwatershed 13ib since this watershed contained, by far, the largest number of potential BMP sites

Thirty-six potential BMP sites remained following the first prioritization process.

4) Prioritization - Step 2

For the second prioritization step, an additional (sixth) attribute, “Downstream Condition”, was scored for each of the thirty-six sites remaining from the first prioritization process. This attribute is described below.

6. Downstream Condition – The erosion condition (based on 2008 Tetra Tech assessment) of the downstream channel was considered for each potential BMP site. BMPs were assigned the following scores depending on the channel condition immediately downstream.

Condition	Score
Not Assessed	0
Low	0
Moderate	1
High	2

Sites were then scored for all six screening criteria and re-ranked accordingly by total score. Table 8-3 shows an example of the BMP attribute scoring for the second prioritization process.

Table 8-3 Example of BMP Site Scoring for Three BMP Sites

Site ID	Subwatershed	Adjacent BMPs	Adjacent Streams	Utility Conflicts	Publicly-Owned	High-Loading Land Use	Downstream Condition	Total Score
PGN6-5g	5g	0	1	1	1	1	1	5
PUB15-5g	5g	1	1	1	0	1	1	5
PUB26-5g	5g	1	1	1	1	1	0	5

5) Management Needs Adjustment

The preliminary management needs (Figure 7-2) were compared to the site locations that resulted from the above screening processes. Generally, the number of restoration and BMP sites supported the management needs prioritized for each subwatershed with one exception. The subwatershed 7gtg was prioritized for hydrology but only one potential BMP location had been selected in the subwatershed. To address this, an additional BMP opportunity with the next highest screening score (PGN19-7gtg) was added to the list within subwatershed 7gtg.

BMP Screening Results

Following the second prioritization process and management needs adjustment, Tetra Tech selected the 20 highest ranking sites as the final potential BMP sites for the field investigation. Table 8-4 shows the final list of sites and Figure 8-2 shows the locations of the sites within the watershed.

Table 8-4 Final BMP Screening Site List

Rank #	BMP ID	Subwatershed	Parcel Owner	Total Score
1	PUB20-13ib	13ib	City of Griffin	7
7	PGN1-13ib	13ib	City of Griffin	6
7	PUB13-5g	5g	Griffin-Spalding Co. Development Authority	6
7	PUB24-5g	5g	Griffin-Spalding Co. Public School System	6
7	STRM6-4g	4g	Grace Fellowship Church, Inc.	6
7	STRM96-5g	5g	Spalding County	6
18	STRM98-5g	5g	City of Griffin	5
18	PGN2-13ib	13ib	Halpern Enterprises, Inc.	5
18	PGN28-5g	5g	Leila Barnes Cheatham	5
18	PGN6-5g	5g	Griffin-Spalding Co. Development Authority	5
18	PUB15-5g	5g	Griffin-Spalding Co. Development Authority	5
18	PUB26-5g	5g	City of Griffin	5
18	PUB28-7gtg	7gtg	City of Griffin Board of Education	5
18	STRM26-13ib	13ib	James S. Murray Jr.	5
18	STRM7-3ib	3ib	The Dairy Community Assoc., Inc.	5
18	STRM9-3ib	3ib	The Dairy, Inc.	5
18	STRM91-5g	5g	Markland Management LLC.	5
20	PGN19-7gtg	7gtg	John Henry Cheatham III	4
20	PGN21-13ib	13ib	City of Griffin	4
20	STRM8-3ib	13ib	Gladys H. Harden	4

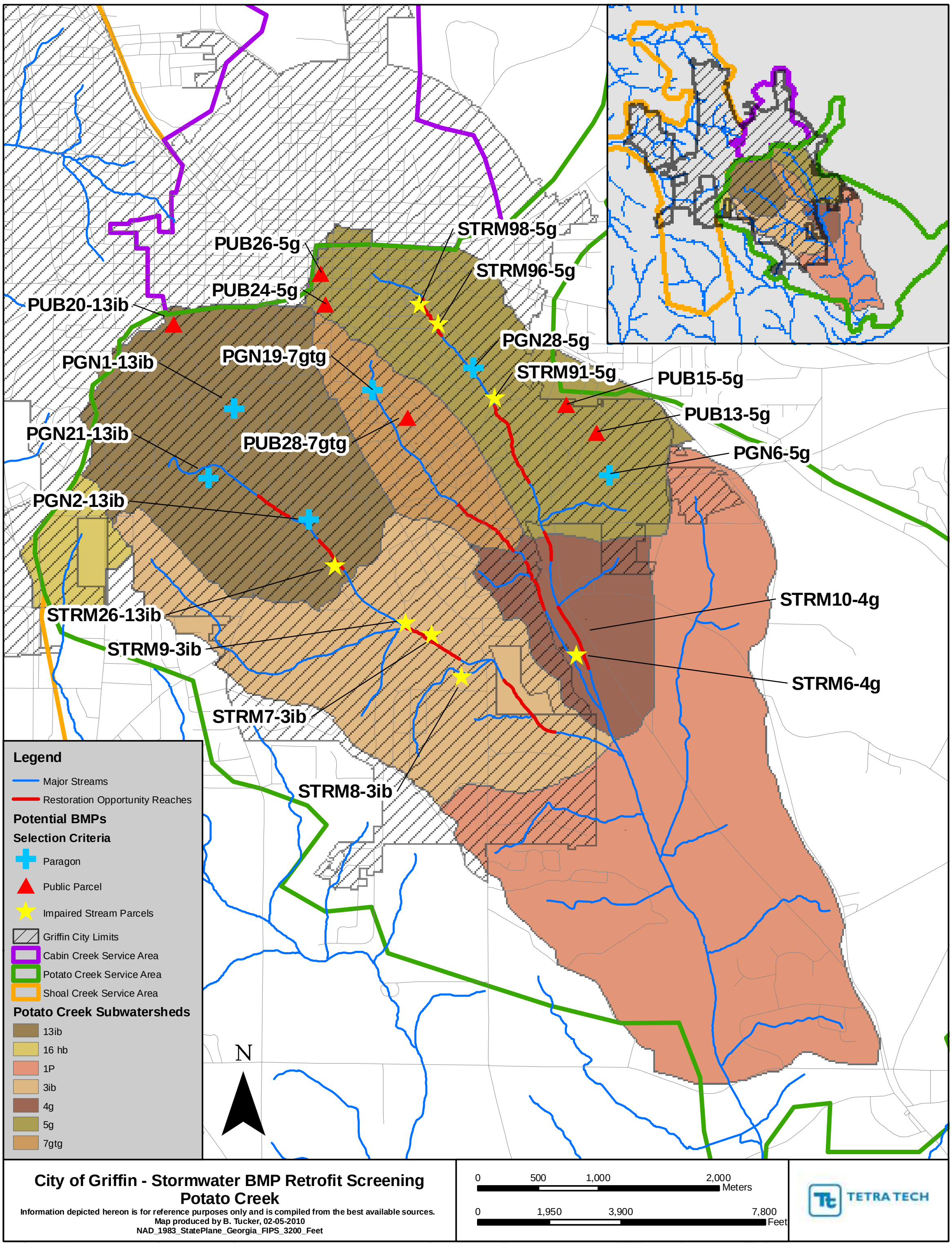

Figure 8-2 Final Screened BMP Sites

8.2 FIELD ASSESSMENT

Field crews consisting of 2-3 Tetra Tech employees and one additional City of Griffin staff member field located and assessed each of the 20 BMP sites identified during the screening and site selection process, as well as two additional public sites (Spalding-Griffin airport and Crescent Elementary School) that did not get included in the screening process due to the incomplete parcel-owner information. During the field visit, the BMP team evaluated the potential site to determine if construction is feasible. For each site, the field crew created site sketches along with notes for potential BMP options or sites constraints, and collected photographic documentation. For the feasible sites, the field crew also assigned an engineering cost factor that reflects the extent that sites constraints will influence the overall project cost (further described in Section 8.3)

Many of the BMP sites were deemed unfeasible as a retrofit opportunity upon the detailed field assessment due to various site constraints, which included utility conflicts, insufficient BMP area, steep slopes, inadequate elevation grade between stormwater outfalls and BMP area, etc. Out of the final 20 sites selected during the screening process and the additional sites noted above, only five sites were recommended as potential retrofit sites and included in rating and prioritization evaluation (discussed below). During the field assessment, Tetra Tech also identified six additional sites that are suitable for BMP construction and meet the BMP implementation goals. These sites were identified during the field activities as exhibiting high retrofit potential and field assessments were conducted on these sites. These six sites were added to the list of potential retrofit sites. The resulting 11 recommended BMP sites are listed in Table 8-5 along with the parcel owner, parcel ID, and the proposed BMP type. The BMP types (wetland, bioretention, and detention basin) are described in the City's stormwater design manual. Figure 8-3 shows the site locations within the Potato Creek Watershed. Data sheets for each of these sites are included in Appendix F. Note that five of the six field-selected BMP sites are located on public property although the map symbols do not reflect this.

Table 8-5 Final Selected BMP Sites

BMP ID	Proposed BMP Type	Parcel Owner	Parcel ID
PGN3-13ib	Wetland	Glynn E. Daniels (Ashton Place)	032 01002
PGN6-5g	Detention Basin	Griffin-Spalding Co. Development Auth.	039 01030
PUB12-13ib	Bioretention	Griffin-Spalding Co. Board of Education	031 04001
STRM6-4g	Wetland	Grace Fellowship Church, Inc.	229 02003C
STRM7-3ib	Wetland	The Dairy Community Assoc., Inc.	040 02030
FSEL1-5g	Wetland	City of Griffin (Griffin - Oak Hill Cemetery)	020 02001
FSEL2-5g	Bioretention	Spalding County	039 01028
FSEL3-5g	Wetland	Bandag, Inc.	039 01003
FSEL4-13ib	Detention Basin	City of Griffin	047A01003
FSEL5-13ib	Detention Basin	City of Griffin and Spalding Co.	047A01002
FSEL6-13ib	Bioretention	City of Griffin	047 01022

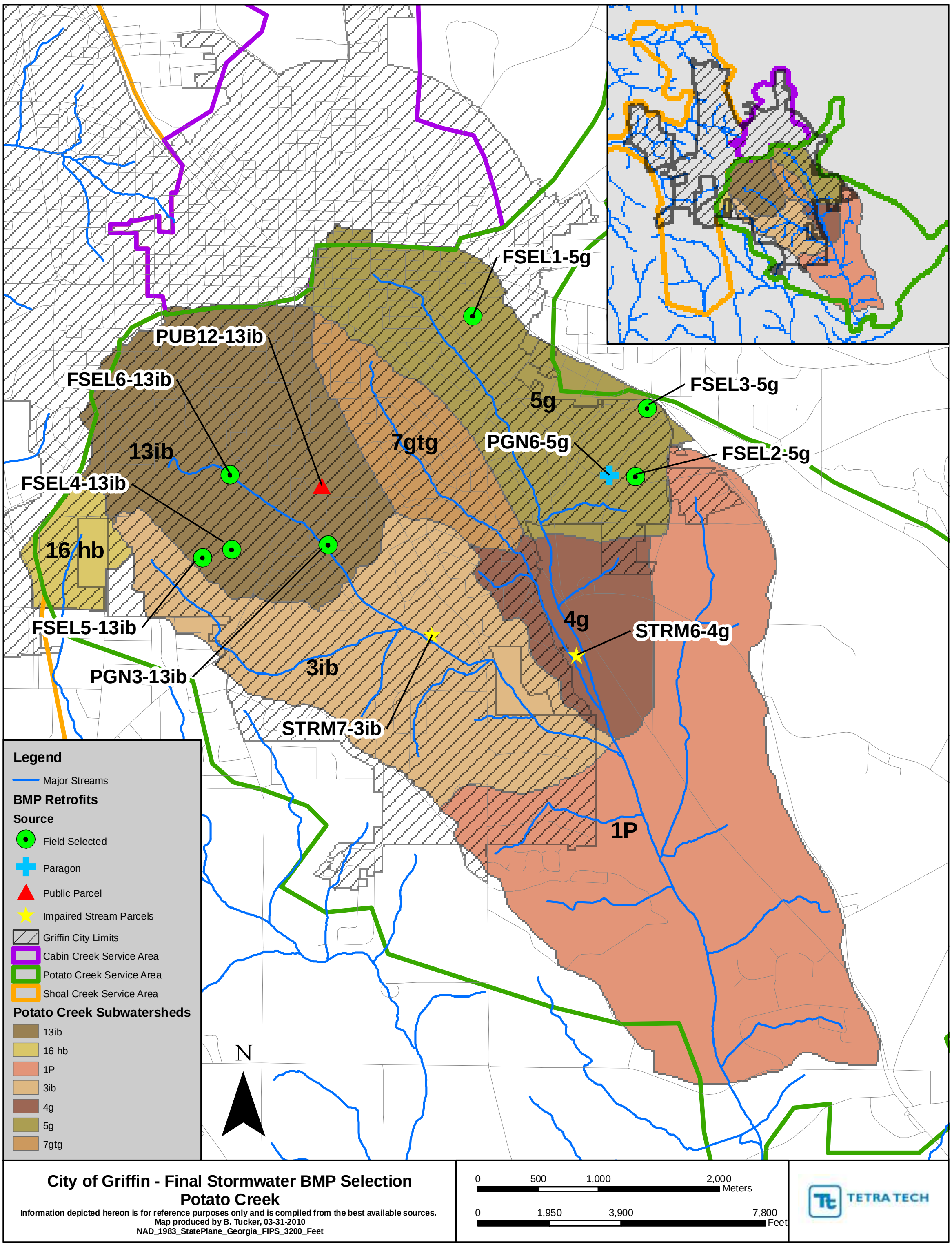

Figure 8-3 Final Selected BMP Sites

8.3 Rating System and Results

Evaluation and Rating of Potential BMP Sites

Prioritization and evaluation of the 11 recommended retrofit sites consisted of scoring and ranking the sites according to eight BMP attributes. Some of these attributes, like "Education Potential," are qualitative and thus involve only a "yes" and "no" scoring criteria while attributes like runoff volume and pollutant reduction potential are quantitative and required additional hydrologic and BMP sizing calculations. Watershed size and characteristics were determined for each of the 11 recommended sites as well as determinations of target and available footprint and storage volume. Target water quality and stream protection volumes were calculated according the City of Griffin Stormwater Design Manual. Available site footprint was determined using GIS imagery and sketches made of each site during field assessment. Available water quality volume and stream protection volume were based on available site footprint and the field reviewers estimate of available storage depths of the proposed BMP.

Scoring BMP sites for the quantitative attributes also required threshold criteria (ranges of values) developed from all the site attribute values. Thresholds were selected to assign scores to ranges of attribute values, either based on the distribution of the attribute values or by using a ranking of the attribute values. BMP scoring was based on a total maximum score of 100 points with each attribute receiving a possible score between 0 and 10. Since there are only eight prioritization attributes and some attributes have more importance for BMP implementation than others, Tetra Tech applied weighting factors to each attribute to ensure that the maximum possible score equals 100. The weightings were based on the relative importance of the attribute to overall achievement of the goals and objectives. Each BMP prioritization attribute and its associated scoring criteria are described below, and the weighting assumptions are discussed in the next section.

1. *Drainage Area Treated* – The amount of treated drainage area helps represent the combined water quality and quantity improvement attained from the BMP. The loading attributes described below differentiate how much load and flow are addressed depending on the type of BMP, whereas this attribute measures how much land in general is treated. The scoring criteria for the drainage area attribute are shown in Table 8-6. The treated drainage area represents the fraction of the total site drainage area that the BMP is capable of treating to equally score the undersized BMPs. The drainage area thresholds were chosen based on natural breaks in the data. For example, there was a large range between the BMP with the largest treatment area (200 acres) and the next four largest drainage areas (all around 11 acres), so the two highest threshold scores were set to "5" and "10." The one, five and 20 acre threshold values were selected to group the 200 acre site, the four 11-acre sites, the three 6-9 acre sites, the one 3-acre site, and the two sites with less than a 1-acre drainage area into separate scoring categories.

Table 8-6 Treated Drainage Area Scoring Criteria

Drainage Area Threshold	Score
<1 acre	0
1 – 5 acres	2.5
5 – 20 acres	5
20+ acres	10

2. *Ownership* – Publicly owned parcels were given priority over privately owned parcels since easements and land acquisition will be easier and less expensive to acquire on public land. Public parcels received a score of “10” while private parcels were scored “0.”

3. *Education Potential* – A benefit of retrofit sites located on publicly exposed parcels is to provide opportunity for community education regarding stormwater management and watershed ecology. Examples of sites with good education potential include schools, high-trafficked public properties, churches, parks, etc. BMP sites that provide educational opportunities were scored a “10” while those that do not received a “0.”

4. *Maintenance Needs* – Regular BMP maintenance is required to ensure that BMPs perform as intended. Just as each type of BMP is different, so is the intensity and frequency of the necessary maintenance activities. BMP maintenance needs were considered either “frequent or intensive,” “moderate,” or “infrequent or minimal,” and assigned scores of “0,” “5,” and “10,” respectively. These levels of maintenance needs are based on the frequency of inspection, sediment cleanout, vegetation management, as well as the level of effort required for the various maintenance activities.

5. *Potential for Controlling Storm Flows* – This attribute categorizes the extent that a proposed BMP controls the stream protection runoff volume within its specific drainage area. Performance standards in the City of Griffin’s Stormwater Design Manual define the stream channel protection volume as the 1-year frequency storm event depth distributed over a 24-hour rainfall period. The scoring criterion for this attribute is the percentage of drainage area runoff from the 1-year, 24-hour storm event that can be stored within each BMP. This “storm control” volume includes both the water quality storage volume (i.e., 1.2” rainfall event) and any additional detention volume (when available) sized for the 1-year event. Runoff volumes were estimated using the Simple Method as defined in the City of Griffin’s Stormwater Design Manual (Paragon, 2007). Tetra Tech used NOAA’s Precipitation-Frequency Data Server (http://hdsc.nws.noaa.gov/hdsc/pfds) to determine a 1-year, 24-hour rainfall depth of 3.25 inches for the City of Griffin. Table 8-7 shows the scoring regime for the percent reduction in runoff volume provided by each potential BMP retrofit.

Table 8-7 Scoring Criteria for Storm Flow Reduction

Percent of Stream Protection Volume	Score
0-25%	0
25-50%	2.5
50%-75%	5
75-90%	7.5
90-100%	10

6. *Potential for Reducing Pollutant Loads* – The existing LSPC model constructed by Tetra Tech for the Potato Creek Watershed was used to estimate the annual pollutant loads of TSS, TP, and TN delivered to each BMP site from its contributing drainage area. Typical removal efficiencies for the three recommended BMP types were obtained from the GA and NC BMP Manuals (see Table 8-8) and applied to the annual runoff loads. Many of the potential BMP measures will be undersized because the sites do not provide enough land area to treat the entire water quality volume. To estimate the relative load reduction for undersized BMPs, Tetra Tech scaled the removal efficiency

by the fraction of the water quality volume that is available for treatment. The assumed scaling factors are shown in Table 8-9. Thus, the total annual pollutant load removed by each potential BMP site equals the annual runoff load estimated by the LSPC model multiplied by both the recommended BMP removal efficiency and the undersized scaling factor (if necessary). The calculated pollutant load reductions are reported in Table 8-10.

Table 8-8 BMP Removal Efficiencies

BMP Type	Source	TSS	TP	TN
Dry Extended Detention	NC BMP Manual (NCDENR, 2007)	50%	10%	10%
Wetland	GA BMP Manual (ARC, 2001)	80%	40%	30%
Bioretention	GA BMP Manual (ARC, 2001)	80%	60%	50%

Table 8-9 Scaling Factors for Undersized BMPs

Percent of Water Quality Volume Treated	Percent of Full Removal Credit
25-49%	50%
50-74%	67%
75-99%	83%
100%	100%

Table 8-10 Pollutant Load Reductions

BMP ID	TSS Removal (lbs/yr)	TN Removal (lbs/yr)	TP Removal (lbs/yr)	Attribute Score
PGN3-13ib	4677	24.6	0.52	5
PGN6-5g	15,657	42.4	0.64	9
PUB12-13ib	969	7.7	0.13	2
STRM6-4g	162,177	911.8	20.53	10
STRM7-3ib	2158	17.9	0.54	3
FSEL1-5g	13,991	72.1	1.49	8
FSEL2-5g	350	2.8	0.05	0
FSEL3-5g	6,080	31.9	0.66	6
FSEL4-13ib	3,523	10.4	0.18	4
FSEL5-13ib	11,402	28.9	0.40	7
FSEL6-13ib	872	9.3	0.22	1

7. Scoring for this attribute was based on a ranking of the load reduction values. The load reductions for each pollutant were ranked separately and averaged to determine a total rank value (1-11) for each BMP. Since high load reductions receive higher priority, attribute scores were then assigned by subtracting one from the rank score to yield a score range from “0” and “10.” *LID, Green, and Innovative BMPs* – One objective of the watershed protection plan is to implement LID, green infrastructure, or regional innovative BMPs. Of the three types of BMPs recommended for the Potato Creek Watershed, both bioretention and constructed wetlands fit this category and were scored a “10” while detention basins received a “0” score.
8. *Removal Efficiency Cost* – Cost estimates were developed for each BMP, comprising land acquisition, scaled construction, design and engineering, and operation and maintenance over a 20-year life-cycle. For private properties, land acquisition costs were based on the recent tax value (land portion only) for each parcel reported by the Spalding County Tax Assessor’s Office (http://qpublic3.qpublic.net/ga_search.php?county=ga_spalding) and prorated to the amount of area need to construct the proposed BMP. It was assumed that an easement would be purchased from the landowner, and the acquisition costs was assumed to be 80 percent of the land value to account for the lesser cost of an easement. The acquisition cost for public properties was assumed to be zero.

   The construction costs were estimated from the unit cost equations reported in Schueler et al. (2007) and were adjusted from 2006 to 2010 dollars using an annual inflation rate of 3 percent. The construction cost assumptions are displayed in Table 8-11. Note that for construction cost of undersized bioretention cells, which is estimated based on the contributing drainage area (CDA), the CDA was adjusted to reflect the percentage of water quality volume that the specific BMP is capable of treating.

To more accurately reflect each BMP's construction costs given the site constraints, the general construction cost estimates were adjusted by a designer's cost factor (1-10) that was assigned during the field assessment. Higher numbers reflect more site constraints that would require greater construction costs, such as significant earthwork and utility alterations. A designer's cost factor of "5" represents the average construction cost estimated by the unit cost equations, so the construction cost was adjusted by 5 percent for each incremental deviation in the cost factor from "5." For example, construction cost for projects with cost factors of "3" and "7" would be adjusted by (-)10 percent and 10 percent, respectively. Design and engineering costs were assumed to be 25 percent of the scaled construction cost.

Table 8-11 Construction Cost Assumptions, 2010 dollars (Scheueler et al., 2007)

BMP Type	Sites	Cost Assumption
Bioretention	FSEL2-5g FSEL6-13ib PUB12-13ib	$10.50 per CF treatment volume (Scheueler et. al, 2007, Table E.4; larger bioretention retrofit median unit cost)
Detention Basin	FSEL4-13ib FSEL5-13ib PGN6-5g	$11.54*Vs^{0.780}$, Vs= Treatment Volume (Scheueler et. al, 2007, CC equation for extended detention)
Wetland	FSEL1-5g FSEL3-5g PGN3-13ib STRM6-4g STRM7-3ib	$9600 per impervious acre treated (Scheueler et. al, 2007, Table E.2; high range of new wetland unit cost)

Operation and maintenance (O&M) cost assumptions were based on information collected for a recent Tetra Tech publication on a green BMP O&M study (Tetra Tech, 2009). The study provided unit area annual O&M costs for multiple BMPs, including the three shown in Table 8-12.

Table 8-12 O&M Annual Cost Assumptions, 2010 dollars (Tetra Tech, 2009)

BMP ID	Cost Equation
Constructed Wetland	0.28*A
Dry Detention Basin	0.56*A
Bioretention	1.47*A

A = BMP surface area (sq. ft.)

The construction and O&M cost components were summed to calculate a total 20-year cost estimate. Final BMP Cost Estimates are shown in Table 8-13.

Table 8-13 Final BMP Cost Estimates

BMP ID	Raw Const. Cost Estimate	Const. Cost Adjusted to Cost Factor	Inflation Adjusted Const. Cost	Design and Eng.	20-Yr O&M	Property Acquisition	Total 20-Yr Cost
PGN3-13ib	$35,569	$28,455	$32,027	$8,007	$55,228	$1,676	$96,937
PGN6-5g	$32,202	$32,202	$36,243	$9,061	$181,282	$0	$226,587
PUB12-13ib	$24,745	$19,796	$22,280	$5,570	$57,676	$0	$85,527
STRM6-4g	$342,112	$307,901	$346,545	$86,636	$635,900	$64,860	$1,133,941
STRM7-3ib	$22,237	$20,014	$22,526	$5,631	$40,172	$309	$68,638
FSEL1-5g	$39,100	$46,920	$52,809	$13,202	$62,316	$0	$128,328
FSEL2-5g	$10,812	$7,569	$8,519	$2,130	$25,202	$0	$35,851
FSEL3-5g	$41,124	$37,012	$41,657	$10,414	$63,408	$82,658	$198,138
FSEL4-13ib	$57,631	$63,395	$71,351	$17,838	$55,611	$0	$144,800
FSEL5-13ib	$84,432	$67,546	$76,023	$19,006	$90,738	$0	$185,767
FSEL6-13ib	$53,207	$42,566	$47,908	$11,977	$124,019	$0	$183,904

The total 20-year cost for each BMP was divided by the 20-year load reductions provided by the BMP to obtain cost-effectiveness ratios for TSS, TN, and TP. The cost-effectiveness ratios for each BMP are shown in Table 8-14. Scoring of removal efficiency costs was performed similarly to the pollutant load reduction attribute where the ranking for each pollutant was averaged and adjusted to a 0 to 10 scale. However, for this attribute, the score was inverted from the rank value since higher costs are a negative ranking attribute.

Table 8-14 Pollutant Removal Cost Estimates

BMP ID	TSS Removal Cost ($/lb/yr)	TN Removal Cost ($/lb/yr)	TP Removal Cost ($/lb/yr)	Attribute Score
PGN3-13ib	$1.04	$197	$9,403	7
PGN6-5g	$0.72	$267	$17,800	6
PUB12-13ib	$4.41	$558	$33,699	3
STRM6-4g	$0.35	$62	$2,762	10
STRM7-3ib	$1.59	$192	$6,357	7

Table 8-14 cont'd Pollutant Removal Cost Estimates

BMP ID	TSS Removal Cost ($/lb/yr)	TN Removal Cost ($/lb/yr)	TP Removal Cost ($/lb/yr)	Attribute Score
FSEL1-5g	$0.46	$89	$4,315	9
FSEL2-5g	$5.13	$633	$37,108	2
FSEL3-5g	$1.63	$310	$15,039	5
FSEL4-13ib	$2.06	$695	$40,786	2
FSEL5-13ib	$0.81	$322	$23,288	5
FSEL6-13ib	$10.55	$985	$41,834	0

Final BMP Scoring and Ranking

Following the evaluation and scoring of each recommended BMP site according to each prioritization attribute, all of the scores for each attribute were adjusted by a weighting factor. The selected BMP attributes cover a range of BMP selection criteria, including the magnitude and cost efficiency of pollutant load reduction, feasibility of land acquisition and construction, overall project costs, as well as several other indirect benefits. The weighting factors help emphasize BMP prioritization with respect to the project goals and balance the importance and skew that some attributes impose on the total prioritization score. For example, most of the quantitative attributes, like storm flow, pollutant load reduction, and cost-effectiveness, were considered the most importance factors for BMP prioritization because they directly target the watershed protection goals 1-3 specified in Section 2. Education potential and LID/green BMP classification (which have large scoring margins between the "yes" and "no" criteria) were weighted to have less influence on the total score. Although these qualities also address the goals and objectives, they are less critical to achieving the overall water quality and quantity goals. Table 8-15 shows the assigned weighting factor for each attribute, all the individual attribute scores for each BMP, and the final prioritization ranking based on the total BMP scores.

The high ranking opportunities provide multiple benefits, including strong water quality and hydrology benefits. The two potential BMP sites with the highest prioritization for implementation are the proposed wetland at the Griffin-Oak Hill Cemetery (FSEL1-5g) and the proposed detention basin at the Spalding-Griffin Airport (FSEL5-13ib). Both of these sites are publicly owned, treat relatively large drainage areas, and can control at least 80 percent of the channel-protection storm flow. The lowest scoring sites (FSEL2-5g and FSEL6-13ib) are both proposed bioretention areas that require more frequent and intensive maintenance compared to the other recommended BMP types, treat small drainage areas, and provide minimal peak flow reduction from the channel protection storm. These two BMPs may be ranked higher if the implementation of LID BMPs and green infrastructure is awarded a greater weighting factor.

Table 8-15 BMP Attribute Scores and Final Ranking

BMP Ranking Attribute	Weighting Factor	PGN3-13ib	FSEL1-5g	STRM6-4g	PGN6-5g	STRM7-3ib	PUB12-13ib	FSEL2-5g	FSEL3-5g	FSEL6-13ib	FSEL4-13ib	FSEL5-13ib
Drainage area treated	1	5	5	10	5	5	0	0	5	2.5	5	5
Ownership	1	0	10	0	10	0	10	10	0	10	10	10
Education potential	0.5	0	5	0	0	0	5	0	0	5	0	0
Maintenance needs	1	0	0	0	5	0	0	0	0	0	5	5
Storm flow control	2	5	15	0	0	5	5	5	20	5	20	20
Pollutant reduction	2	10	16	20	18	6	4	0	12	2	8	14
LID, green, or innovative BMP	0.5	5	5	5	0	5	5	5	5	5	0	0
Removal efficiency cost	2	14	18	20	12	14	6	4	10	0	4	10
Total Score		**39**	**74**	**55**	**50**	**35**	**35**	**24**	**52**	**30**	**52**	**64**
Rank		7	1	3	6	8	8	11	4	10	4	2

Evaluation and Rating of Stream Restoration Reaches

The ten sites identified in Figure 8-1 as potential restoration reaches were characterized and evaluated in order to rate the sites. The sites were characterized and evaluated based on information from the 2008 Geomorphic Assessment, Spalding County parcel data, and aerial photographs. It was not necessary to visit sites in the field; however, most sites were visited because many of the reaches were adjacent to potential BMP sites that were assessed in the field. Reach R03-4g was divided into two separate reaches due to the very different nature of the reach north (upstream) of Grandview Drive from the reach south (downstream) of Grandview Drive. This resulted in 11 sites that were rated. Six attributes were selected for the rating process, which relate to constructability and public benefit. Higher scores were given to sites with public land ownership, good education potential, public amenity potential, good design potential and minimal earthwork needs, no utility conflicts, and a riparian zone that is less than 50% forested. An evaluation of the sites, with respect to the rating criteria is presented in Table 8-16.

The rating results are presented in Table 8-17. The highest possible score is 12. Four sites scored $\geq$ 7. The remainder of the sites scored $\leq$ 4. The sites are listed in order of their ranking in Table 8-18. The top four ranking sites are recommended for ongoing consideration. All of these reaches are best suited for high level restoration, and would have similar restoration concepts. Activities would include laying back the bank slopes and contouring the channel to a stable profile. The design could incorporate meanders in the stream channel where space permits. The banks and riparian areas would be planted with native vegetation. It is recommended that a more detailed site evaluation be conducted on any reaches that are favorable to the City as potential restoration sites. A Bank Erosion Hazard Index (BEHI) could be calculated for reaches that are potential stream restoration sites to quantify environmental benefits with respect to TSS reduction. A description of the four highest ranking sites is presented below. The information in parentheses after the reach name refers to the corresponding stream or tributary name and the Site IDs from the 2008 Geomorphic Assessment. Data sheets for each of these sites are included in Appendix F.

Highest Ranking Stream Restoration Sites:

- **R10-5g** (Grape Creek, 117-118)**:** This reach is in the headwaters of Grape Creek; it is all publicly owned. The stream is bordered by the City Cemetery on the right bank and by the County library on the left bank. The northern portion of this reach is already being restored by the City of Griffin through a Clean Water Act, Section 319 grant. Therefore, only the reach south of the Section 319 restoration project was evaluated. The length of the reach is approximately 290 ft. The channel type is pool-riffle and the bed consists of bedrock, cobbles, and gravel. The CEM class is ambiguous. This reach was categorized as having high erosion activity in the 2008 Geomorphic Assessment. The banks are 2-3 meters high. The stream has incised through partially weathered rock to bedrock. Bank vegetation is primarily Chinese privet and kudzu, with a few trees. There is a large field on the south side of the library that is unused. It is a sloped, mowed grass lawn with a drainage ditch. There is a large elevation drop where the drainage ditch flows into the creek. There is potential for future erosion here, but there is currently no headcut migration. Restoration activities at this site could be dovetailed into the upstream restoration project. Restoration may be constrained by close proximity of graves on the right bank.
- **R01-4g** (Grape Creek, 700-712)**:** This reach of Grape Creek is owned by two private entities; the northern portion of the reach is owned by Dan P. Slade and the southern portion is owned by Grace Fellowship Church. The reach is approximately 1800 ft. long, with a pool-riffle channel type. The northernmost end of the reach is a CEM Class V; the remainder of the reach is class IV to V. The bed contains stable embedded gravel. There are a few large woody debris jams along the reach. This reach was categorized as having high erosion activity in the 2008 Geomorphic Assessment. Banks are 2-2.5 meters high. There is a narrow strip of trees and Chinese privet along each bank, then open field or lawn beyond the trees. The site is outside of, but adjacent to City limits. If the city purchases this land, it would be conducive to being a public park/ recreation area. This area is also on the list of potential BMP site locations. Stream restoration could be done in conjunction with stormwater BMP measures.
- **R03-4gS** (Trib H, 26-29)**:** This reach is along a tributary of Grape Creek; it is owned by GA DOT. It extends approximately 970 feet south from Grandview Drive. The channel type is pool-riffle and the bed contains sand embedded gravel. The CEM class is ambiguous. Bank vegetation and riparian zone consist of mixed brush/shrubs. Banks are stable, but approximately 50% are eroded by scour. This reach was categorized as having moderate erosion activity in the 2008 Geomorphic Assessment. Banks are 1.2-1.5 m. high. One large woody debris jam was noted in 2008. Overhead utility lines cross the southern portion of the reach, but do not appear to be a constraint to potential restoration activities. This site would have little potential to be a public amenity or educational resource due to limited access and space constraints.
- **R09-13ib** (Trib G, 68-76): This reach of the Ison Branch tributary is located entirely on City of Griffin Property. It is a forested reach just downstream of the City golf course. The reach is approximately 1,140 long, with a pool-riffle channel type. The bed appears to be natural with bedrock outcroppings, cobble and gravel riffles, aggrading sand pools, and alternating sand and gravel bars. The reach is a CEM class V. This reach was categorized as having high erosion activity in the 2008 Geomorphic Assessment. Bank heights are 1.3 to 1.7 m. high. The reach has moderate scour and mass wasting. The left bank has a strip of 40' tall bamboo that is approximately 2.5 m. wide, then a cleared sewer easement, then deciduous forest. The right bank

has a strip of 40’ tall bamboo that is up to 2.5 m. wide, then deciduous forest. The sewer easement along the left bank may prohibit bank shaping. As an alternative to restoring this reach, it could also be left to return to a stable form through natural processes. This site has potential as a public green space due to its proximity to the golf course, although access may be an issue due to space constraints and the forested nature of the site.

Table 8-16 Stream Restoration Site Evaluation

Restoration Site Attribute	R10-5g	R05-5g	R02-4g	R01-4g	R03-4gN	R03-4gS
Ownership	All publicly owned. The City cemetery is along the west side of this reach. The County library is along the east side.	All privately owned. About 15 land owners. Residential area.	Two private land owners.	Two private land owners. Majority is owned by Grace Fellowship Church.	Residential area. Four private land owners.	Owned by GA DOT
Education Potential	Good. Public property right beside the County library	Poor. Residential location does not facilitate public access.	Poor. Location does not facilitate public access.	Good, presuming the site is purchased by the City and made a public amenity.	Poor. Residential location does not facilitate public access.	Poor. Location does not facilitate public access.
Public amenity potential	Yes. Public property adjacent to City cemetery and County library.	No. Residential location does not facilitate public access.	No. Privately owned, small area, and heavily forested. Not a good location for a public park.	Yes. The plan for this site would include having the City purchase the site. Site size and location would be good for a public park.	No. Residential location does not facilitate public access.	No. Limited space and access for public use.
Earthwork/Design Potential	Moderate alterations would be required due to proximity to graves on right Bank. Banks are 2-3 m. high.	Poor design potential due to close proximity to residential lawns.	Minimal earthwork/good design potential. No infrastructure conflicts. Banks are 1.6-2.4 m. high.	Minimal earthwork/good design potential. No infrastructure conflicts. Banks are 2.0-2.5 m. high.	Poor design potential due to close proximity to residential lawns.	Minimal earthwork/good design potential. Overhead utility line crossing does not appear to be a conflict. Banks are 2.0-2.5 m. high.
Utility conflicts	No conflicts	Sewer easement parallel to Left Bank.	No conflicts	No conflicts	No conflicts	No conflicts
Forested/Clear riparian zone	>50% clear. Left bank: commercial/yards. Right Bank: grass/cemetery	>50% clear. Left bank: sewage easement in northern half, residential yards in southern half. Right bank: residential lawns with occasional trees and privet on banks.	Heavily forested. Forested riparian zone except for one house on north end of reach.	>50% clear. Generally open field beyond a 2-3 meter strip of trees and privet on each bank.	>50% clear. Banks are adjacent to residential lawns.	>50% clear. Riparian zone is mixed brush and shrubs.

Table 8-16 cont'd Stream Restoration Site Evaluation

Restoration Site Attribute	R04-7gtg	R06-3ib	R07-3ib	R08-13ib	R09-13ib
Ownership	Residential area. Approximately 15 different private land owners.	Two private land owners.	Three private land owners. The largest being The Dairy Community Association.	Five private land owners, including Hillandale Homeowners Inc.	City of Griffin Property.
Education Potential	Poor. Residential location does not facilitate public access.	Poor. Location does not facilitate public access.	Poor. Residential location does not facilitate public access.	Poor. Residential location does not facilitate public access.	Good. City property adjacent to City golf course. The area could be accessible to the public.
Public amenity potential	No. Residential location does not facilitate public access.	No. Private ownership. Isolated, heavily forested site does not facilitate public access.	No. Residential location does not facilitate public access.	No. Residential location does not facilitate public access.	Yes. City property adjacent to City golf course. The area could be accessible to the public.
Earthwork/Design Potential	Poor design potential due to close proximity to residential lawns.	Moderate alterations required. Restoration would require construction access rd. through woods.	Minimal earthwork/good design potential. One sewer line crossing that will pose minimal conflict.	Steep, forested banks extending from stream channel up to residential area would require extensive earthwork. Little opportunity/ area to lay back banks.	Moderate alterations required. Sewer line constraints and restoration could potentially require construction access road through woods
Utility conflicts	One pipeline crossing south of Tupelo St.	No conflicts	Sewer Easement crosses the stream and extends along a portion of Left Bank.	No conflicts	Sewer easement parallel to Left Bank.
Forested/Clear riparian zone	>50% clear. North of Tupelo St., riparian zone is primarily grasses with a few large trees. South of Tupelo St., LB is adjacent to lawns. RB is adjacent to lawns at north end and heavily wooded at south end.	Heavily forested. Northern portion of left bank is 5m. woods, then residential. Remainder of reach is heavily forested.	Heavily forested. Forested riparian zone on right bank and 25-30 ft forested riparian area on left bank which opens up into open field and walking path	Heavily forested. Left bank is 10 m. of forest, then residential. RB is 50 m. of forest then residential.	Heavily forested. Left bank has approximately 2.5 m. of bamboo, then cleared sewer easement, then deciduous forest. RB has 0-2.5 m. of bamboo, then deciduous forest.

Table 8-17 Stream Restoration Rating Results

Restoration Site Attribute	Rating	R10-5g	R05-5g	R02-4g	R01-4g	R03-4gN	R03-4gS	R04-7gtg	R06-3ib	R07-3ib	R08-13ib	R09-13ib
Ownership												
Private	0		0	0	0	0		0	0	0	0	
Public	2	2					2					2
Education Potential												
poor	0		0	0		0	0	0	0	0	0	
good	2	2			2							2
Public amenity potential												
no	0		0	0		0	0	0	0	0	0	
yes	2	2			2							2
Earthwork/Design Potential (assume priority 2 restoration)												
major alterations required/ poor design potential	0		0			0		0			0	
moderate alterations required / fair design potential	1	1							1			1
minimal alterations required/ good design potential	2			2	2		2			2		
Utility conflicts												
Yes	0		0					0		0		0
No	2	2		2	2	2	2		2		2	
Forested/clear riparian zone												
Heavily forested	0			0					0	0	0	0
>50% clear	2	2	2		2	2	2	2				
Total		11	2	4	10	4	8	2	3	2	2	7

Table 8-18 Restoration Site Rankings

Reach ID	Rating score	Ranking
R10-5g*	11	1
R01-4g*	10	2
R03-4gS*	8	3
R09-13ib*	7	4
R03-4gN	4	5
R02-4g	4	5
R06-3ib	3	6
R05-5g	2	7
R04-7gtg	2	7
R07-3ib	2	7
R08-13ib	2	7

*recommended stream restoration sites

8.4 MANAGEMENT RECOMMENDATIONS

In this section, management actions are recommended that will help the City of Griffin meet its objectives for the Potato Creek Watershed and achieve the overarching goals of this Protection Plan.

Structural BMPs

Significant protection can be provided to the Potato Creek Watershed through the construction of structural BMPs that reduce storm flows and filter pollutants. These measures can include detention basins, bioretention areas, and wetland creation areas. In Section 8.3, eleven BMP sites are identified as opportunities for implementing projects that will achieve multiple objectives. Tetra Tech is currently developing a BMP model that will evaluate the BMPs' effectiveness at reducing pollutant loads and optimize the BMPs to identify the best size and combination of BMP measures to achieve the greatest benefit for the least cost. Once the BMP model is complete and has been run for the BMPs measures under consideration, the City can use the results of the modeling to develop an Implementation Plan that works with the Stormwater Department's priorities, budget, and funding sources. Estimated costs for structural BMP measures are detailed in Table 8-13.

Stream Restoration

In Section 8.3, four high level stream restoration sites were identified that would improve water quality and be public amenities. Restoration projects that the City deems feasible should be incorporated into an Implementation Plan. Ideally, the selected stream restoration projects should not be initiated until selected BMP projects upstream of the restoration reaches are complete. This will give the restoration projects a better chance of success due to better management of storm flows. Stream restoration costs can vary widely depending on many situational factors. Estimated costs for high level restoration are presented in Table 8-19. The restoration sites identified in the Potato Creek Watershed will vary considerably in the width of riparian zone restoration.

In addition to the high level restoration areas identified by Tetra Tech, numerous medium level restoration opportunities exist throughout the watershed. These are small, isolated areas of erosion along streambanks, around storm drain outfalls, or at headcuts (where there is an abrupt change in stream gradient over an erodible surface). The cumulative contribution of TSS loads from these numerous erosional areas can be significant. Stormwater Department personnel should identify such "erosion hot spots" during their routine inspections, and spot repairs should be done using bank stabilization measures.

Low level restoration opportunities exist wherever stream banks are generally stable, but bank vegetation and riparian vegetation are lacking or are poor quality. Low level restoration opportunities on city property include the City of Griffin Municipal Golf Course, and Oak Hill Cemetery on the northeast side of Memorial Drive. Both of these properties contain stream segments that are mowed to the banks, or lack vegetative protection on the banks and in the riparian zone. Low level restoration on private property can be facilitated through educational workshops discussed under Non-structural BMPs, below.

Table 8-19 Stream Restoration Unit Cost Estimates

Restoration Level*	Unit	Approx. Unit Fee**
High: Complete channel reconstruction, bank stabilization, buffer restoration, instream structures, etc. They would all be riffle-pool channel design and have an average of 60 ft of riparian restoration on either side of the stream.	Linear Foot	$150 - $350
Medium: Spot repairs to stabilize streambanks, headcuts, and erosion around culverts.	Linear Foot	$75 - $200
Low: Minor bank shaping and vegetation enhancement, including a 2-meter strip of complete vegetation plantings on each bank.	Linear Foot	$50 - $100

* Restoration level categories were provided by Tetra Tech.

** Approximate Unit Fees are for preliminary planning purposes only and may change considerably based on the nature of a particular project characteristics and/or goals.

Note: Restoration costs can vary widely based on a number of factors including stream width, amount of earthwork required, size of the project (as the size of the project increases, the cost per unit will typically decline), etc. Restoration projects that include stormwater BMP's, wooded riparian zones, access and property constraints, flashy urban settings, or topographic/substrate issues can expect significant cost adjustments (for both design and construction). Design costs can be generally assumed to be approximately 30 percent for High Level restoration, 15 percent for Medium Level restoration, and 10 percent for Low Level restoration of the costs provided. External cost considerations may include costs for formal bid document preparation, federal, state or local permitting (USACE, State Stream Buffer Variance, Land Disturbance Permitting, etc.), and extensive hydraulic/hydrologic modeling.

Source: Ecological Consultants, 2010, personal communication

Non-structural BMPs

The structural BMPs and restoration measures recommended above represent an important step towards addressing management needs in the Potato Creek watershed. However, stormwater BMP retrofits and stream restoration, in isolation, will not meet the Protection Plan goals and objectives. Some land with high impervious surface coverage or high contributing pollutant loads will remain untreated or continue to have uncontrolled runoff, either due to lack of landowner interest or a feasible structural BMP opportunity. Some pollutant sources, like fertilizers and pet waste, cannot be addressed by a limited number of structural BMPs; therefore, public policies, education, and outreach are necessary to encourage further pollutant load reduction. The City is currently operating a number of programs that address these management needs. As outlined in Section 4, ordinances have been updated or adopted since the 2005 plan to regulate how land is used and to minimize pollutant discharges. The City's MS4 stormwater program contains a diversity of strategies that target the multiple pollutant sources and stressors within the Potato Creek watershed and citywide.

Since much has been accomplished to-date, recommendations for future nonstructural practices are limited to several key strategies that are likely to provide measurable improvements. As sediment and nutrient loading are important concerns in the watershed, strategies to preserve and restore riparian areas would fill a management gap not provided by currently programs or recommended structural projects. To accomplish this, a phased-approach could be used that begins with citizen education and transitions to requiring wider riparian buffer protection. The city could conduct citizen education on maintaining and restoring vegetation along streams. The efforts could involve riparian management events in which volunteers help to remove invasive species and restore riparian vegetation. As education events are implemented, the city could work on policy to increase undisturbed buffer requirements. As recommended in the 2005 plan, the undisturbed buffer requirements could be increased from 25 feet to 50 feet from streams, with an additional 50 feet beyond this buffer where certain land uses are allowed but structures and other impervious surfaces are prohibited.

Fertilizer is another pollutant source for which nonstructural practices can be successful in contributing to watershed improvement. The City of Griffin Municipal Golf Course provides an opportunity to assess fertilizer application and develop strategies to reduce the nutrient loading. Strategy development for the golf course should involve a review of existing soil testing and fertilizer application methods and how those methods can be modified to minimize nutrient loading while maintaining healthy turf.

Additional efforts could be directed towards encouraging or requiring the reduction of fertilizer use on private property. Landscaping workshops can be provided for the public to educate them how to select the proper fertilizer and application rate. The workshops could also provide instruction on other landscaping techniques as an incentive for the public to participate. Educational efforts that provide direct and detailed instruction can be more effective than more indirect methods (mailings, public service announcements, etc.) because the attendees already have an interest and time investment in the techniques.

Fertilizer ordinances have been used in some local communities to reduce nutrient loading, and these ordinances can have multiple purposes. Some regulations prevent the application of fertilizer where it is not necessary (driveways, sidewalks, and other impervious surfaces) or where it has more significant impacts (near streams, wetlands, and other waterbodies). Fertilizer ordinances can also regulate application techniques, including how the timing and areal application rates are chosen for each property. These ordinances can be written to provide flexibility for individual landowners.

Tree boxes were considered as a distributed BMP opportunity during the BMP field assessment but were removed from consideration due to the mature trees along many of the city streets. Other program opportunities may be available to implement distributed BMPs in the future.

In summary, the nonstructural techniques that appear to be most beneficial for future consideration are policies and programs that:

1. Promote riparian buffer preservation and restoration
2. Encourage the reduction of fertilizer application
3. Plan future landscape and infrastructure improvement efforts to allow for implementation of distributed BMPs

The extensive nonstructural BMPs that the City is currently operating provide important benefits to the watershed. These additional nonstructural BMPs are recommended for integration into the City's existing efforts to further address the Potato Creek watershed goals and objectives.

Implementation Schedule

The City of Griffin will implement new watershed management actions over the next few years, in addition to continuing their current management practices and stormwater programs. In an effort to meet the goals and objectives presented in this Protection Plan, the City will actively work to maintain and improve conditions in the Potato Creek Watershed. Table 8-20 proposes a schedule for implementing new management actions over the next five fiscal years. Sources of funding will include the city's Stormwater Utility, Section 319 grants, and Water and Wastewater Department funds.

The City of Griffin will submit the following information to Georgia EPD by June 30th of each year:

a. Annual certification of Watershed Protection Plan implementation
b. Electronic submittal that includes:
    - Long-term trend water quality monitoring data using EPD's Excel template, available on GAEPD's website at: http://www.gaepd.org/Documents/techguide wpb.html#wappg;
    - Long-term habitat and biological monitoring data;
    - Copies of all field data sheets, laboratory taxa lists, macroinvertebrate multimetric spreadsheets and fish IBI and Iwb metric calculations; and
    - GIS coverages of the City's jurisdictional limits, service area and subwatershed delineations, unless already submitted.
c. Progress Report that includes:
    - Discussion of the monitoring data and results;
    - An evaluation of what the data shows in terms of water quality, the health of the biological communities, and any trends that are being shown by the data;
    - Specific actions or BMPs that have been implemented; and,
    - Summary of any changes and/or revisions to the Watershed Protection Plan, if necessary.

Table 8-20 Implementation Schedule

Fiscal Year (July 1-June 30)	Management Action	Estimated Cost Range
2010-2011	Select one BMP project based on BMP modeling results and City resources for implementation in fiscal year 2012-2013.	
	Initiate coordination between city departments to allow for stormwater BMP planning as part of infrastructure improvement projects.	
2011-2012	Identify areas in need of spot repairs (medium level restoration) through routine stormwater inspections. Schedule priority repairs for the upcoming 1-2 years.	
	Assess fertilizer application practices at the City of Griffin Municipal Golf Course and develop strategies for reduction of nutrients.	
	Select a low level restoration project on city property (such as the Municipal Golf Course or Oak Hill Cemetery). Plan a workshop that allows citizens to participate in the restoration project and learn about riparian zone protection and restoration, fertilizer use, etc.	
2012-2013	Conduct spot repairs on small, actively eroding areas identified through stomwater inspections.	
	Acquire property for the selected BMP project site.	$0 - $83,000
	Conduct design and engineering for the BMP measure.	$2,000 - $87,000
	Construct the BMP measure.	$8,500 - $346,500
	Select a stream restoration site (high level restoration) based on Protection Plan recommendations and begin detailed site investigation to determine scope of work and costs.	
2013-2014	Continue with spot repairs on small, actively eroding areas identified through stormwater inspections.	
2014-2015	Design and construct the selected stream restoration project	$10,500 - $433,500

9 References

City of Griffin. 2004. City of Griffin 2024 Comprehensive Plan.

CWP. 2003. Impacts of Impervious Cover on Aquatic Systems. Center for Watershed Protection. Watershed Protection Research Monograph No. 1. Ellicott City, MD.

Dodds, W.K., V.H. Smith, and K. Lohman. 2006. Erratum: Nitrogen and phosphorus relationships to benthic algal biomass in temperate streams. Canadian Journal of Fisheries and Aquatic Sciences, 63: 1190–1191.

Dodds, W.K., V.H. Smith, and K. Lohman. 2002. Nitrogen and phosphorus relationships to benthic algal biomass in temperate streams. Canadian Journal of Fisheries and Aquatic Sciences, 59: 865–874.

Fox and Absher. 2002. The ABCs of Water-Quality Assessment in Georgia. Stormwater, March-April 2002. Accessed April 2009. http://www.stormh2o.com/march-april-2002/water-quality-assessment.aspx

GA EPD. 2007a. Macroinvertebrate Reference Data Piedmont Ecoregion (45), Southern Outer Piedmont -- 45b Data. GA Department of Natural Resources, Environmental Protection Division. Accessed May 2009. http://www.gaepd.org/Documents/WPB_Macroinvertebrate_SOP.html

GA EPD. 2007b. Total Maximum Daily Load Evaluation for Two Stream Segments in the Oconee River Basin for Sediment (Biota Impacted). Submitted to the U.S. Environmental Protection Agency, Region 4, Atlanta, GA. Submitted by the GA Department of Natural Resources Environmental Protection Division, Atlanta, GA. Accessed March 2009. http://www.gaepd.org/Files_PDF/techguide/wpb/TMDL/Oconee/EPD_Final_Oconee_Sediment_TMDL_2007.pdf

Gore, J.A., J.R. Olsen, D.L. Hughes, and P.M. Brossett. 2005. Reference conditions for wadeable stream in Georgia with a multimetric index for the bioassessment and discrimination of reference and impaired streams. Phase II. Final Report. Columbus State University, Columbus, GA.

Herlihy, A.T., and J.T. Sifneos. 2008. Developing nutrient criteria and classification schemes for wadeable streams in the conterminous US. Journal of the North American Benthological Society. 27(4):932–948.

Meyer, J. L., M. J. Paul, and W. K. Taulbee. 2005. Stream ecosystem function in urbanizing landscapes. Journal of the North American Benthological Society. Vol. 24(3):602-612.

Mueller, D.K., and Helsel, D.R., 1996, Nutrients in the Nation's waters- Too much of a good thing?: U.S. Geological Survey Circular 1136, 24 p.

Paragon Consulting Group. 2007. City of Griffin Stormwater Design Manual.

Paul, M. J., J. L. Meyer, C. A. Couch. 2006. Leaf Breakdown in Streams Differing in Catchment Land Use. Freshwater Biology. Vol. 51:1684-1695. Blackwell Publishing Ltd.

Pitt, R. E. 2000. Water Quality Conditions in the Cahaba River and Likely Pollutant Sources. University of Alabama at Birmingham Department of Civil and Environmental Engineering. Accessed March 2009. http://unix.eng.ua.edu/~rpitt/Publications/MonitoringandStormwater/Cahaba%20problems%20and%20sources.PDF

Roy, A.H., A. D. Rosemond, M. J. Paul, D. S. Leigh, and J. B. Wallace. 2003. Stream Macroinvertebrate Response to Catchment Urbanization. Freshwater Biology 48:329-346. Blackwell Publishing Ltd.

Scheueler, T., D.h. Hirschman, M. Novotney, and J. Zielinkski. 2007. Urban Stormwater Retrofit Practices V 1.0, Appendices. Prepared for US Environmental Protection Agency, Office of Wastewater

Management. Prepared by Center for Watershed Protection. Accessed March 2010. http://www.cwp.org/Resource_Library/Center_Docs/USRM/ELC_USRM3app.pdf

Schoonover, J. E., B. G. Lockaby, S. Pan. 2005. Changes in chemical and physical properties of stream water across and urban-rural gradient in western Georgia. Urban Ecosystems. Vol. 8:107-124. Springer Science + Business Media, Inc.

Spalding County. 2004. Spalding County 2024 Comprehensive Plan.

State of Georgia. 2010. 391-3-6-.03 Water Use Classifications and Water Quality Standards. State of Georgia, Office of the Secretary of State. Accessed February 2010. http://rules.sos.state.ga.us/cgi-bin/page.cgi?g=GEORGIA_DEPARTMENT_OF_NATURAL_RESOURCES/ENVIRONMENTAL_PROTECTION/WATER_QUALITY_CONTROL/index.html&d=1

Tetra Tech. 2006. Baseline Biological and Water Quality Conditions for Selected Streams in Dekalb and Fulton Counties, Georgia. Prepared by Tetra Tech, Inc. Prepared for US Army Corps of Engineers, Mobile District.

Tetra Tech. 2009. Green Best Management Practice (BMP) Operation and Maintenance Study. Prepared by Tetra Tech, Inc. Prepared for the City of Columbus, Ohio Public Utilities Department. Columbus, OH.

USEPA. 2000. Ambient Water Quality Criteria Recommendations: Rivers and Streams in Nutrient Ecoregion IX. US Environmental Protection Agency, Office of Water. EPA 822-B-00-019. Accessed April 2009. http://www.epa.gov/waterscience/criteria/nutrient/ecoregions/rivers/rivers_9.pdf