FARM CREEK AND MARUMSCO CREEK WATERSHED MANAGEMENT PLAN

PREPARED FOR:
PRINCE WILLIAM COUNTY DEPARTMENT
OF PUBLIC WORKS
ENVIRONMENTAL SERVICES DIVISION
WATERSHED MANAGEMENT BRANCH
5 COUNTY COMPLEX COURT
PRINCE WILLIAM, VIRGINIA

PREPARED BY:
PARSONS BRINCKERHOFF
HERNDON, VIRGINIA

DECEMBER 2009

Table of Contents

List of Figures

List of Tables

EXECUTIVE SUMMARY

This study presents a watershed-based analysis of the Marumsco and Farm Creeks that involves assessment of the conditions and resources within the watersheds. The primary objective of this study is to assess stream corridor and stormwater management (SWM) best management practice (BMP) conditions to develop conceptual plans that can be used to prioritize and plan Capital Improvement Projects (CIPs) within the Marumsco Creek and Farm Creek watersheds. This study was limited to include only identification of capital improvement projects based upon current conditions and analysis of flooding issues without performing detailed flooding studies. The study also did not include a comprehensive investigation of upland areas for identification of specific pollutant sources and investigation of county maintenance practices (street sweeping, BMP maintenance, etc). Previous studies and existing water quality data within the watersheds were referenced and supplemented with data collected during field assessments to develop conceptual restoration strategies that address watershed degradation. Four primary assessment components of this study include:

- Stream stability assessment;
- Stormwater facility assessment;
- Opportunities for trash reduction and/or abatement; and
- Tidal area assessment and retrofit potential.

The watershed assessment conducted include both review of existing studies and field investigations. Review of existing studies was focused on a detailed analysis data relevant to flooding issues within the study area. Field investigations included two major components: 1) rapid corridor stream assessments of all perennial streams and 2) detailed inspection of 12 of the 29 SWM facilities within the watersheds.

A total of 289 potential water quality problems were identified along the wadeable, perennial streams walked within the Marumsco Creek and Farm Creek watersheds. The table below summarizes the number of potential problems observed for each type of impact assessed.

Type of Impact	No. of Sites
Outfalls	88
Severe Erosion	48
Impacted Buffers	29
Utilities	12
Trash and Debris	40
Stream Crossings	24
Channel Modifications	20
Miscellaneous	28
Total	***289***

Excluding pipe outfalls, the most frequently observed water quality problem was related to erosion. Trash and debris and inadequate buffers were also were also observed in several

locations throughout the stream network surveyed. Impacts related to utilities within the stream corridors were the least observed. A summary of the lengths of erosion, impacted stream buffers, and channel modifications is presented in the table below.

Type of Impact	Length of Impact (ft)
Severe Erosion	11,445
Impacted Buffers	39,960
Channel Modifications	8,960
Total	***60,365***

Based upon the results of the field assessments, twelve (12) Stream Corridor Improvement Projects (SCIPs) and four (4) Coastal Zone Improvement Projects (CZIPs) have been identified. The projects were identified in consideration of both the assessment results and from reviewing existing data and studies to address watershed degradation in the Marumsco Creek and Farm Creek watersheds. In addition, six (6) water quality retrofit and nine (9) maintenance opportunities were identified during stormwater management (SWM) facility inspections. The conceptual project recommendations were developed considering each of the primary assessment components. Each concept plan includes the following components: site location, problem description, proposed water quality benefits, and cost estimates. The conceptual recommendations and plans can be found in the appendices of this report. The total cost of the stream corridor projects, coastal zone improvement projects, and SWM facility retrofit and maintenance projects is estimated at $5.8 million. The cost estimates were developed based on PB's regional experience with design and construction of similar projects.

This watershed study also included an evaluation of flooding problem areas within the subsheds. The evaluation resulted in identification of ten (10) flooding problem areas. Some of the problem areas warrant additional study by the County including: the Route 1 corridor upstream of the CSX crossing of Marumsco Creek; the Tributary A of Marumsco Creek culverts below the Woodbridge Neighborhoods Mobile Home Park; the Horner Road culvert crossing; and the mainstem of Marumsco Creek in the Botts subdivision. Detailed studying of these areas will assist the County in developing strategies for reduction of the flooding and protection of infrastructure and private property. Conceptual recommendations for improvement of the CSX railroad crossing and reduction of flooding along the US Route 1 corridor developed in this study have estimated project costs of $1 to $2 million. Conceptual treatments and costs were not developed for the other flooding problem areas.

The projects discussed above are recommended capital improvements to be implemented by Prince William County for improving the quality of the Marumsco and Farm Creek streams and watershed. Aside from these capital improvement projects, the watershed assessment identified many stream impacts that may be more effectively implemented by County maintenance programs and community outreach efforts. The assessments estimated that a total of 163 pick-up truck loads would be required to remove trash and debris from the streams and dumping sites. The significant and widespread amount of the trash and dumping observed suggest larger issues with community perception that the County will need to address. Prince William County should consider implementing proactive and focused community outreach programs directed at educating the community of the value and importance of the streams and

the adverse impacts of littering and dumping. The outreach program will be most effective through support and collaboration with local watershed associations, organized stream clean-up activities, and a visible posting of stream protection areas.

Street sweeping and trash rack maintenance activities are maintenance programs that the County should re-evaluate. The County maintains several trash racks at culvert crossings along Marumsco Creek, Farm Creek and their tributaries. During the watershed assessments, it was noted that at many of these locations, the debris cleaned from the racks was dumped in the floodplain adjacent to the racks. The County should consider developing guidelines for maintenance personnel responsible for these racks that include requirements for removal of all trash and debris from the stream and disposal off-site in an appropriate manner. The street sweeping program currently implemented by the County was not reviewed as part of this study. However, the large amounts of street litter present in the streams indicate that the County should review the program and evaluate the focus, frequency and coverage of the program. Additionally, the County should consider developing a database system for tracking of trash / debris removal volumes for use in supporting the County's NPDES / MS4 program and future TMDL requirements.

This study also provides a limited evaluation of the existing land uses within the Marumsco and Farm Creek watersheds and the stormwater management practices within each neighborhood. The results of the analysis show that large portions of the watershed are developed and directly connected to the streams, yet have no stormwater management practices in place. Construction of stormwater management BMPs for these older developments is a very costly and difficult undertaking using standard retention pond (in-line or off-line) designs. In these areas the County should consider development of low impact development (LID) retrofit projects within the communities. Types of LID retrofits that can be implemented within the existing developments include downspout disconnections via rain barrels or rain gardens, conversion of roadside ditches into bioswales, installation of bioretention areas, and removal of paved surfaces / impervious areas (Jefferson Plaza) that are seldom used. The majority of these types of projects will inherently be located on privately owned lands and will require close coordination between the County, local watershed organizations, and the community. Outreach programs focused on environmental stewardship education throughout the community will help provide the County with the means of executing this type of program. This study does not provide a comprehensive evaluation of the upland conditions within the watershed and cannot provide specific recommendations for development of a LID retrofit program or outreach program for the community. The County should consider supplementing the current watershed study which focuses on the stream corridors with an upland study that is focused on the existing development practices and opportunities for environmental stewardship projects.

CHAPTER 1: INTRODUCTION

1.1 Background

The Marumsco and Farm Creeks are located in the vicinity of Woodbridge, Virginia in Prince William County and drain to the Occoquan Bay. Marumsco Creek begins slightly less than 1 mile west of I-95 and flows southeast to the Occoquan Bay. It forms the southwestern boundary of the Occoquan Bay National Wildlife Refuge (NWR) near its outlet. Farm Creek is located south of Marumsco Creek, beginning about 1,000 feet east of US Route 1 and also flows southeast to the Occoquan Bay. This study presents a watershed-based analysis of the Marumsco and Farm Creeks that involves investigation into the conditions and resources within the watersheds.

In recent years, there has been a shift toward using a watershed-based approach for managing natural resources and restoring impaired water bodies. A watershed approach involves assessing and prioritizing water quality issues according to specified drainage areas (i.e., watersheds) to develop and implement restoration strategies. Many watershed organizations, federal and state agencies, and localities are adopting this approach to manage water quality and to meet new regulatory requirements including stormwater provisions of the federal Clean Water Act. Watershed management plans developed locally also help the state meet commitments related to the Chesapeake 2000 Agreement intended to steer restoration activities throughout the Chesapeake Bay Watershed through 2010. Prince William County has conducted multiple studies in recent years to better understand the nature and conditions of watersheds throughout the County. One key study among these is the Prince William County Stream Protection Strategy (CH2M HILL 2004) which involved a county-wide assessment of stream conditions. The results of the stream assessments were compiled into a database. The database in conjunction with Geographic Information System (GIS) data provides a tool which the County can use to update and monitor the status of stream and watershed health.

Like other areas in Prince William County, the Marumsco Creek and Farm Creek watersheds have experienced steady development in recent years, contributing to watershed degradation and encroachment on receiving waters. This Watershed Management Plan presents restorative action recommendations intended to address watershed degradation and improve water quality to receiving waters including Marumsco Creek, Farm Creek, Occoquan Bay, the Potomac River, and ultimately, the Chesapeake Bay.

1.2 Purpose

The primary objective of this study is to investigate stream corridor and stormwater management (SWM) best management practice (BMP) conditions to create conceptual plans that can be used to prioritize and plan Capital Improvement Projects (CIPs) within the Marumsco Creek and Farm Creek watersheds. Previous studies and existing water quality data within the watershed were referenced and supplemented with data collected during field assessments to develop conceptual restoration strategies that address watershed degradation. To minimize costs and issues associated with easement and land acquisition, efforts were concentrated on publicly-owned lands or those owned by homeowner associations. Four primary assessment components of this study include:

- Stream stability assessment;
- Stormwater facility assessment;
- Opportunities for trash reduction and/or abatement; and
- Tidal area assessment and retrofit potential.

Conceptual project recommendations that have the potential to improve overall watershed function and health are presented at the end of this report. Each concept plan includes the following components: site location, problem description, proposed water quality benefits, and cost estimates.

1.3 Report Organization

This report is organized into the following four major chapters:

Chapter 1 explains the background and purpose of this report.

Chapter 2 summarizes current watershed conditions related to various factors that may affect natural resources and water quality. This chapter also contains a summary of existing data and previous studies relevant to the watershed.

Chapter 3 describes the field investigation protocols and findings for the stream corridor assessments and stormwater management facility inspections.

Chapter 4 presents watershed management strategies and recommended actions appropriate for addressing watershed degradation.

Chapter 5 lists the references used to develop this report.

CHAPTER 2: WATERSHED CHARACTERIZATION

2.1 General Watershed Characteristics

This section describes the condition of the Marumsco Creek and Farm Creek watersheds including natural land surface characteristics and development activities. These types of parameters affect the quantity and quality of watershed runoff. Land use characteristics, for instance, influence the type and extent of pollutants carried by stormwater. For example, residential or agricultural areas may contribute fertilizers and pesticides to stormwater runoff. Developed areas may transmit various types of pollutants directly to receiving water bodies such as trash, bacteria (livestock and pet waste), and chemicals depending on land use activities since there is often inadequate buffer or vegetation to filter pollutants. The information presented in this section provides an overview of the physical setting and background necessary to evaluate other watershed components including water quality, natural resources, restoration, and management.

2.1.1 Location and Scale

A watershed-based approach for evaluating water quality conditions and improvement potential involves determining the drainage area that contributes runoff and groundwater to a specific water body. Together, the Marumsco Creek and Farm Creek watersheds encompass approximately 3,780 acres (5.9 square miles) in the northeastern corner of Prince William County. The majority of this area is located east of I-95. Both watersheds drain to the Occoquan Bay along the northeastern coastline of the County, between the Occoquan River and Neabsco Creek. The Marumsco Creek watershed comprises approximately 2,742 acres (4.3 square miles), including many of the older sections of Woodbridge, Virginia. The Farm Creek watershed covers approximately 1,038 acres (1.6 square miles) along the coastline of Occoquan Bay. The Marumsco Creek and Farm Creek watersheds were subdivided into five subwatersheds to refine drainage area influences and to focus restoration efforts (see Figure 2-1). Subwatershed delineations are based on the County's GIS data layer. Three of these subwatersheds comprise the Marumsco Creek watershed and two represent the Farm Creek watershed. Subwatersheds are the most commonly used and practical hydrologic units for management and restoration purposes. Also, success of projects can be more easily monitored and measured on this smaller scale. Subwatersheds and corresponding acreages are listed below in Table 2-1.

Table 2-1: Subwatershed Acreages

Subshed ID	Watershed	Area (Acres)	Area (Sq Miles)
905	Marumsco Creek	764	1.2
910	Marumsco Creek	912	1.4
915	Marumsco Creek	1,066	1.7
10	Farm Creek	671	1.0
20	Farm Creek	367	0.6
	Totals	***3,780***	***5.9***

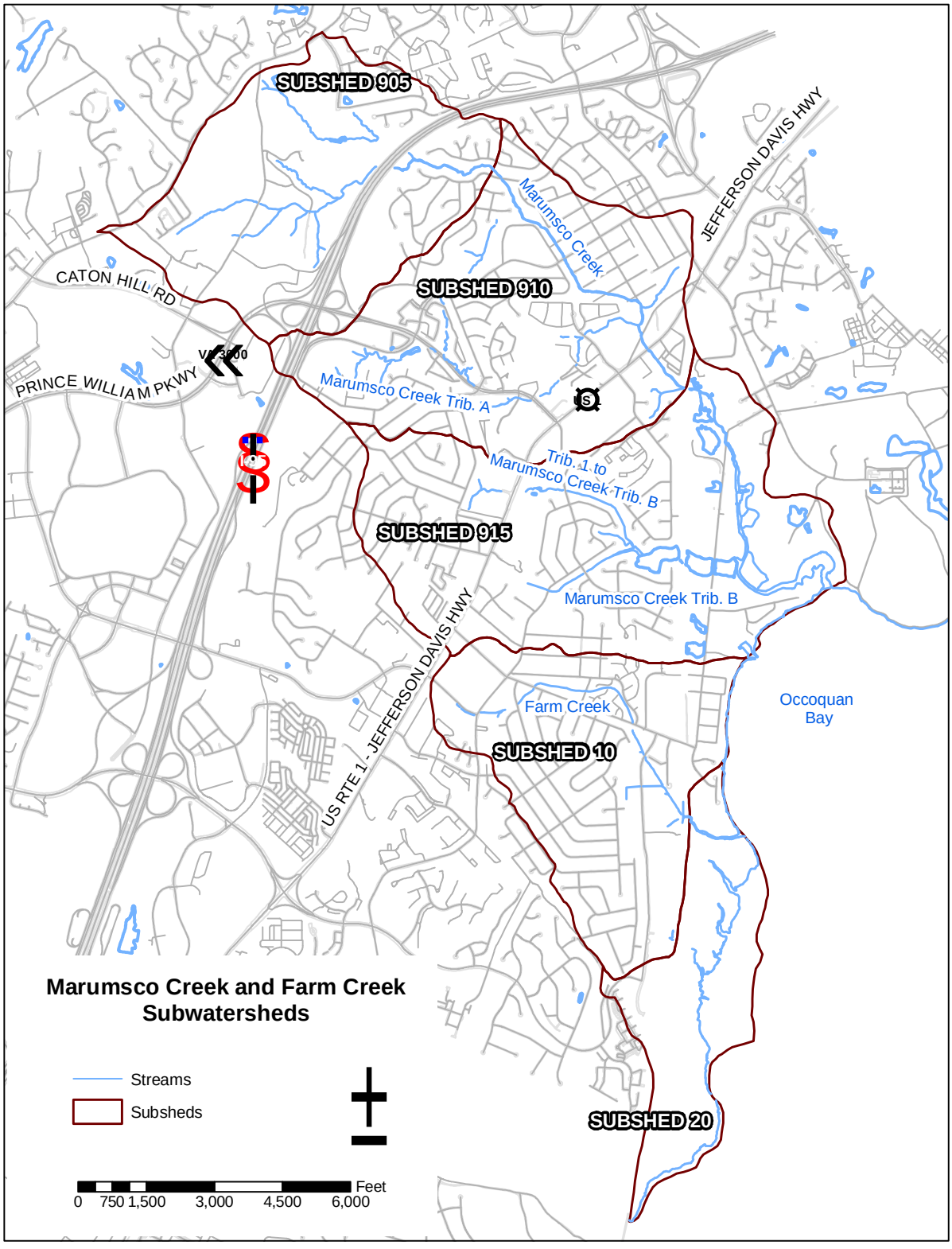

Figure 2-1: Marumsco Creek and Farm Creek Subwatersheds

2.1.2 Geomorphology

The Marumsco and Farm Creek watersheds primarily fall within the Coastal Plain physiographic province with minor portions in the Piedmont province. The Coastal Plain physiographic province is generally characterized by low gradient streams with high sinuosity and wide floodplains. The Coastal Plain is formed in sedimentary deposits between the Piedmont region and the Atlantic Ocean. Sedimentary deposits that historically formed the Coastal Plain consist largely of sand, silt and clay. Farm Creek is located entirely within the Coastal Plain, while the headwaters of Marumsco Creek are located in the Piedmont before the stream crosses the fall line into the Coastal Plain. Each of the streams has portions located within the upland and lowland subprovince of the Coastal Plain. The headwaters of Marumsco Creek are located in the Outer Piedmont subprovince.

Geologic maps and soils maps were collected to describe the morphologic properties of the watersheds. The geologic maps describe the underlying rock within the watershed, including bedrock in the upland areas and sedimentary deposits in the coastal zone. The soils maps are used to describe the overlying soils throughout the watersheds. Each of the data sets are described in this section. The relevance of the geologic and soil formations to the hydrologic and water quality aspects of the watersheds is also discussed in this report.

2.1.2.1 Geology

Geologic mapping for Prince William County was obtained from the U.S. Geological Survey (USGS). The mapping was compiled by the USGS as part of the Virginia geologic map data set originally published in 1993. The mapping shows the following formations across the Marumsco and Farm Creek watersheds, listed by formation age. Geology mapping for the watersheds is illustrated in Figure 2-2.

<u>Paleozoic Era</u>

The oldest rock formations within the Marumsco Creek watershed are dated from the Paleozoic Era, with formations from the Cambrian and Ordovician periods. The rock formations from this era pre-date the separation of the continents, development of the Appalachian Mountains, and formation of the Atlantic Ocean.

- Chopawamsic Formation: The oldest rock formation within the Marumsco Creek watershed. The formation was developed from volcanic flows and is classified as metavolcanic rock. Rock formations are composed of volcanoclastic rocks with interlayered quartzite, quartzose greywacke, schist, and phyllite. This rock formation contains varying concentrations of iron pyrite.

- Occoquan Granite: The granite formation consists of hard light-gray, muscovite-biotite monzogranite and lesser granodiorite and tonalite and is limited to the center of Subwatershed 905. The granite formations can be interspersed with iron pyrite veins. A few limited granite bedrock outcrops can be found along the headwater streams tributary to Marumsco Creek. The bedrock outcrops form a hardened inerodible control for the stream bed and valley wall in locations where they have been exposed.

- Quantico Formation: The Quantico Formation consists of slate and porphyroblastic shist rock formations. The formation is characterized by gray to black, graphitic, pyritic phyllite and slate. The formation is found along upper portions of Marumsco Creek, primarily upstream of I-95. The rock outcrops found along the stream are generally oriented with vertical fissures in the rock. The rock outcrops found along the stream are generally soft and erodible. The outcrops are less erodible than surrounding soils, but do not provide a long-term grade or lateral control to the stream. This rock formation contains varying concentrations of iron pyrite.

Mesozoic Era

The Mesozoic Era covers the geologic period of time when the continents were separating to form the modern formations. The Appalachian Mountains formed at the beginning of this period and the Atlantic Ocean formed during this period.

- Potomac Formation: The Potomac Formation is a sedimentary formation consisting of feldspathic sand interbedded with sandy clay and silt. The formation was deposited in the Inner Coastal Plain mainly in fluvial-deltaic environments. The Potomac Formation likely contains interspersed iron precipitates.

Cenozoic Era

The Cenozoic Era is the current geologic era that covers from 65.5 million years ago to present. The continents settled into their current positions at the beginning of the era. The only geologic formations developed within the Marumsco subwatersheds during the current period have occurred due to erosional and depositional processes.

- Windsor Formation: Sedimentary deposit consisting of sand, gravel, silt and clay. Deposits are found in the Coastal Plain along fluvial-estuarine terraces. Formations are up to 40 feet thick.

- Tabb Formation: Sedimentary deposits of sand, silt and peat. Deposits are found in the Coastal Plain along fluvial-estuarine terraces.

- Alluvium: Coastal Plain sedimentary deposits of sand, silt and clay. Deposits occur mainly along channels, point-bar and flood-plain environments. Deposits can be up to 80 feet thick along major streams.

Geologic data analyses show two types of natural deposits that could contribute to water quality degradation within Marumsco and Farm Creeks. The natural deposits are veins of Iron Pyrite associated with the Chopawamsic, Occoquan Granite and Quantico Formations and iron precipitates found in the Potomac Formation. The generalized discussion of Iron Pyrite and Iron deposits presented herein is not based on physical sampling of these minerals from the subwatersheds; rather, it is based on qualitative observations from similar areas, observations of water quality impacts from the field inspections and typical occurrences within given geologic formations. The discussion of these minerals is not intended to exclude the presence of other types of toxic minerals that may exist in the subwatersheds and should not be construed as a definitive analysis of all mineral types and potential toxic mineral impacts to water quality within the subwatersheds. Further discussion of the pyrite and iron deposits and their potential impact

on the water quality within Marumsco Creek can be found in Chapter 4 under Geologic Impacts to Water Quality.

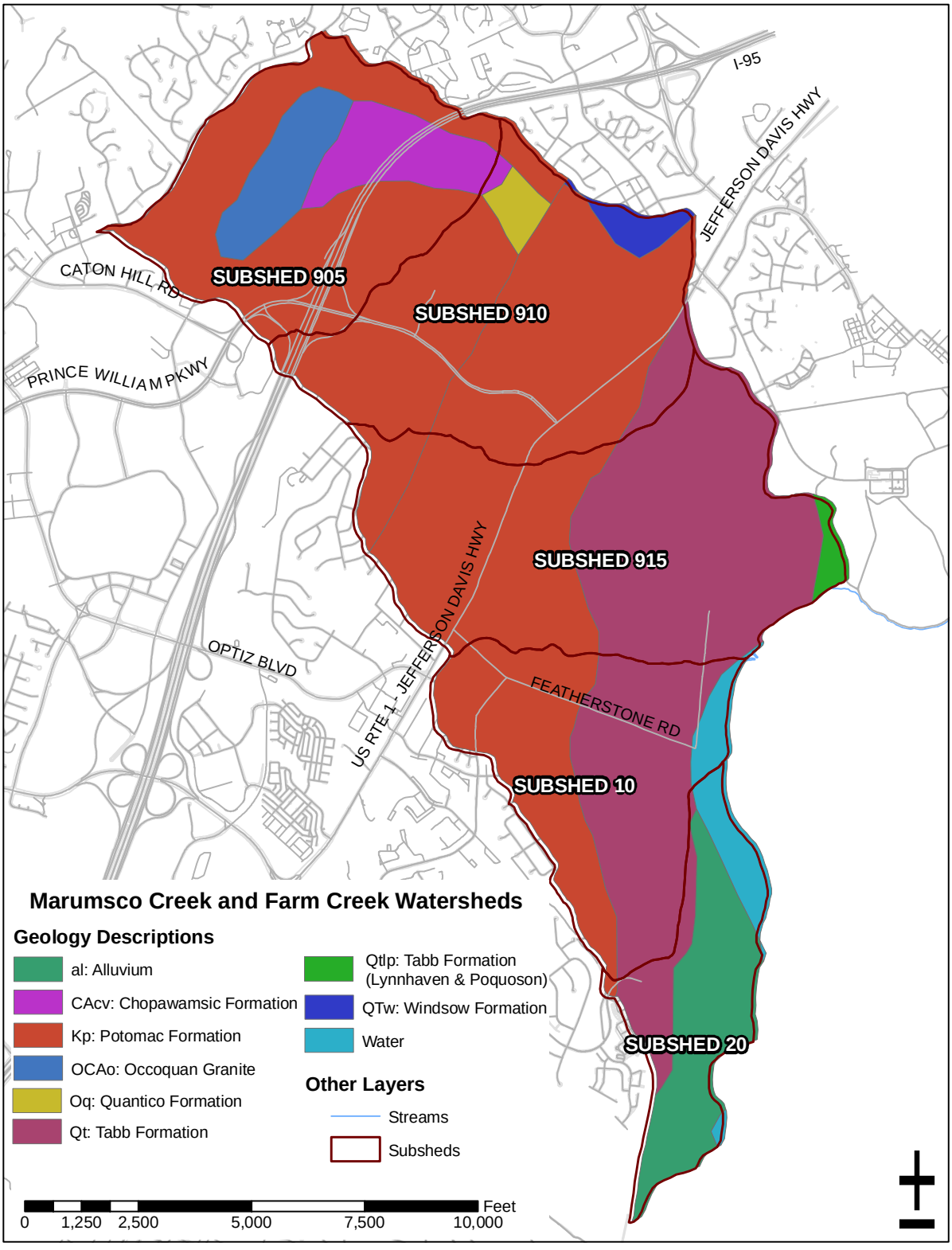

Figure 2-2: Geology within the Marumsco Creek and Farm Creek Watersheds

2.1.2.2 Soils

Soils maps for Prince William County were acquired form the Natural Resources Conservation Service (NRCS) Soil Data Mart. The soils maps collection for the Marumsco Creek and Farm Creek watersheds are shown in Figure 2-3. The primary soil type along with acreages and hydrologic soils types within the watershed are listed in the table below.

Table 2-2: Summary of Primary Soil Types in Marumsco Creek and Farm Creek Watersheds

Soil Unit Name	Area (Acres)	Percentage of Total Area	Hydrologic Soil Type	Hydric Soil
Aden Silt Loam	0.4	0.1%	C	Yes
Delanco fine sandy loam	5.3	1.5%	C	Yes
Dumfries sandy loam	17.1	4.9%	B	No
Elsinboro sandy loam	6.7	1.9%	B	Yes
Featherstone mucky silt loam	27.8	8.0%	D	Yes
Hatboro-Codorus complex	5.4	1.6%	D	Yes
Lunt loam	12.1	3.5%	C	No
Marr very fine sandy loam	0.4	0.1%	B	No
Marumsco loam	11.6	3.4%	C	No
eadowville loam	0.7	0.2%	B	Yes
Neabsco-Quantico complex	12.5	3.6%	C	No
Quantico sandy loam	43.9	12.7%	B	No
Sycoline-Kelly complex	0.8	0.2%	D	No
Urban land-Udorthents complex	186.9	54.1%	A/B/C/D	No
Watt channery silt loam	7.7	2.2%	D	No
Unclassified Areas	6.2	1.8%	-	-

The soil survey data for Marumsco and Farm Creeks shows that the percentage of urban land with disturbed soils greatly dominates the coverage of the watersheds. Unfortunately, this type of soils coverage is generally a mixture of different soil types and specific engineering properties of the soils are difficult to document on a large scale. The predominance of urban land soils means that little information can be inferred about runoff, infiltration and hydric soils in these areas.

NRCS classifies soils into four hydrologic soil types based on runoff potential (A, B, C, D). Soils with high infiltration (ability to absorb precipitation) will have low runoff potential and vice versa. Infiltration capacity is highly variable among soil types and is also affected by land development activities. For example, urbanization in watersheds with high infiltration rates (e.g., sands and gravels) will impact runoff more than in watersheds consisting mostly of silts and clays which have low infiltration rates. Brief descriptions of each hydrologic soil type are provided below. Further explanation can be found in the U.S. Department of Agriculture (USDA)/NRCS publication, *Urban Hydrology for Small Watersheds*, also called Technical Release 55 (USDA 1986):

- **Type A** soils include sand, loamy sand, or sandy loam types. These soils have a high infiltration rate and low runoff potential even when thoroughly wet. These consist mainly of deep, well to excessively drained sands or gravel. These soils have a high rate of water transmission.

- **Type B** soils include silt loam or loam types. They have a moderate infiltration rate when thoroughly wet. These soils mainly consist of somewhat deep to deep, moderately well to well drained soils with moderately fine texture to moderately coarse texture. These soils have a moderate rate of water transmission.

- **Type C** soils are sandy clay loam. These soils have a low infiltration rate when thoroughly wet. These types of soils typically have a layer that hinders downward movement of water and soils with moderately fine texture or fine texture. These soils have a low rate of water transmission.

- **Type D** soils include clay loam, silty clay loam, sandy clay, silty clay, or clay types. These soils have a very low infiltration rate and high runoff potential when thoroughly wet. These consist mainly of clays with high swell potential, soils with a permanent high water table, soils with a claypan or clay layer at or near the surface, and shallow soils over nearly impervious material. These soils have a very low rate of water transmission.

Analysis of the undisturbed soil types within the Farm Creek and Marumsco Creek watersheds shows a distribution of mainly B, C and D hydrologic soil types, with each type roughly representing 12 to 20 percent of the total watershed (B: 20%, C: 12%, D: 12%). These soils correspond to low to medium infiltration rates or relatively high runoff potential. The watersheds also contain several soil types that are potential hydric soils (soils that are frequently wet and conducive to the development of wetland environments) with the total watershed containing potentially up to fifteen (15) percent hydric soils.

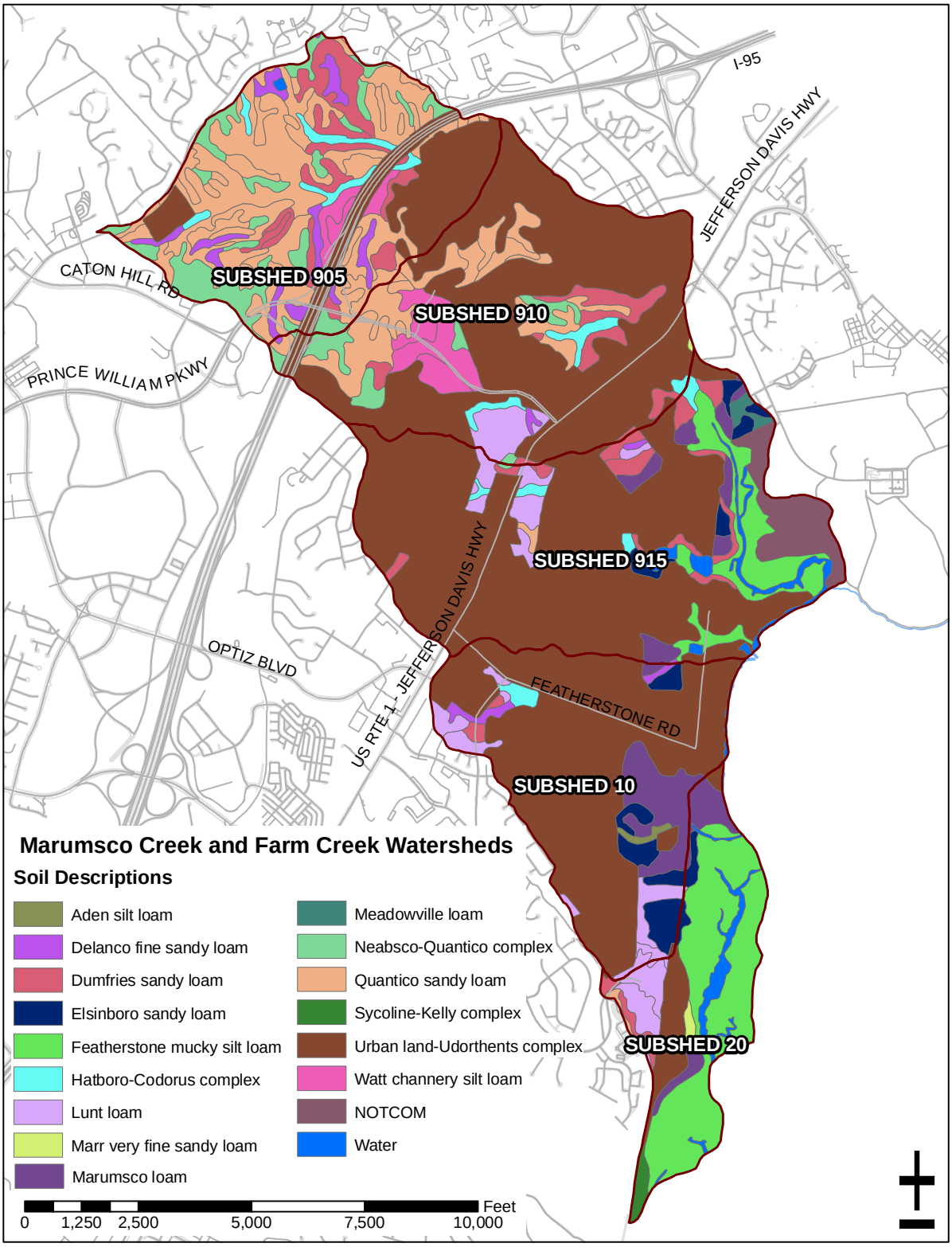

Figure 2-3: Soil Types within the Marumsco Creek and Farm Creek Watersheds

2.1.3 Watershed History and Development

According to the *Prince William County 2008 Comprehensive Plan* (PWC 2008), Prince William County is the third most populous jurisdiction in Virginia. Between 2000 and 2006, the population increased nearly 35%, from about 280,813 to 378,455. The County predicts an additional 47% growth by 2030, which corresponds to a population of about 555,012 (PWC 2008). The County's eastern waterfront along the Potomac River has been the strongest influence on its development for most of its history. The County's proximity to Washington D.C. has influenced development in more recent years.

The eastern shore of the County including Marumsco Creek and Farm Creek watersheds were inhabited by one of the Algonquin tribes by 1500 A.D. During this time, there were very deep creeks that cut across wide portions of this area which were hilly and wooded peninsulas and drained to the Potomac River. The earliest European settlement is not well documented, but some reports claim that Catholic missionaries from Spain visited this area in the late 1500s, who were mostly killed by Indians. Captain John Smith first sailed up the Potomac and Occoquan Rivers in 1608 and led several explorations through the entire area, publishing a map by 1612. This prompted exploration and settlement of the region by other Europeans. One of the first land grants was issued in 1653 for 3,000 acres extending from Neabsco Creek to the Occoquan River, including the Marumsco Creek and Farm Creek watersheds. Significant settlement along the waterfront, however, did not occur in the area until 1722 after the rise of the local government and protection from Indian raids. Large plantations for tobacco cultivation were well established in the tidal area by this time. Tobacco production largely influenced the growth of the County waterfront area including how roads and towns were established and served as the main currency. The main transportation route along the waterfront was the Potomac Path which approximately parallels today's US Route 1. Eventually, tobacco cultivation took its toll on the land eroding topsoil off of steep slopes and clogging waterways with silt. Consequently, other industries began forming and by the mid-1800s transportation improvements in highways and railroads eliminated the dependence on the shipping trade. Growth slowed along the waterfront during and after the Civil War. By 1900, the economy had rebounded and development of the waterfront increased. Agriculture remained as the primary industry and a railroad connection between Richmond and Washington D.C. was completed for linking markets, passing through the Marumsco Creek and Farm Creek watersheds. In the early 1900s, a 440-acre dairy farm was established on the Featherstone area (in the present day Farm Creek watershed). Other waterfront areas were used for commercial fishing, recreational, and industrial purposes. After World War II, dairy farms operations slowly stopped as a result of new government regulations that made milk production less profitable. Several areas were developed into residential subdivisions including Featherstone to support workers commuting to Washington D.C. By this time, industrial development was impacting natural resources in the area. For example, birds began to migrate east away from the pollution. (Karnes 1998)

Today, the County waterfront including the Marumsco Creek and Farm Creek watersheds consists of mixed communities with residential, office, and commercial uses. Water quality improvement efforts have contributed to wildlife benefits such as an increase in numbers of fish and bald eagles. For example, the Occoquan Bay NWR was established near the site where John Smith first landed, part of which encompasses the outlet of Marumsco Creek. As discussed in the previous section, the Marumsco Creek and Farm Creek watersheds largely consist of residential areas with some commercial and light industrial uses and various public lands including parks and open spaces. The *Prince William County 2008 Comprehensive Plan*

was developed with the intent to preserve existing public lands and support varying types of development through transitions and capitalization of transportation infrastructure.

2.1.4 Existing and Long Range Land Uses

Land use has a pronounced impact on watershed health, particularly water quality and habitat. Different land uses generate different types and amounts of pollutants. An undeveloped (i.e., forested) watershed has the capacity to absorb pollutants such as sediment and nutrients and reduce the flow rate of water into streams. Developed areas with impervious surfaces such as roads, parking lots, and roofs block the natural seepage of precipitation into the ground. Consequently, developed areas tend to concentrate stormwater runoff, accelerate flow rates, and direct stormwater to the nearest stream which can contribute to stream erosion, in-stream and riparian habitat destruction and higher pollutant loads. Undeveloped watersheds and those with small amounts of impervious surfaces, however, tend to have better water quality in local streams than developed watersheds with large amounts of impervious surfaces. Increased importance of water quality and water resource protection has led to incorporation of stormwater management practices for new and redevelopment and a general shift toward adopting practices that mimic natural hydrologic processes, are low impact, and achieve pre-development conditions. Sustainable site design and stormwater management practices can be incorporated to offset adverse impacts from urbanization, including Best Management Practices (BMPs) that are designed for controlling stormwater runoff quantity and quality from developed areas before it enters stream systems.

The majority of the Marumsco Creek and Farm Creek watersheds is occupied by low and high density residential land uses. Commercial development is mostly concentrated in the central portion of the Marumsco Creek watershed along US Route 1. There are some light industrial uses in the Farm Creek watershed along the western side of the railroad. The watersheds also encompass important natural resources and open spaces including Featherstone National Wildlife Refuge, Veterans Memorial Park, Marumsco Acre Lake Park, and the western portion of the Occoquan Bay National Wildlife Refuge. For the most part, stormwater management practices are limited in existing developed areas throughout the watersheds. While there are some existing BMPs such as ponds, many are designed for water quantity control only and provide little or no water quality improvement benefits. There is, however, potential for retrofitting existing BMPs to provide water quality improvement benefits (see Chapter 2.1.4 for further discussion on existing stormwater management facilities).

The *Prince William County 2008 Comprehensive Plan* presents long range land uses planned to meet public demands based on projected growth while also preserving important natural features such as public lands, parks and open spaces. This plan reflects land uses intended for at least the next five years as Section 15.2-2223 of the Virginia Code requires that comprehensive plans be reviewed every five years to verify that the goals are still relevant and being supported. In general, the County has designated established residential, commercial, and industrial areas and some undeveloped or underdeveloped lands based on the projected growth for the County. Re-development and revitalization of existing, older areas of the County is preferred over new development designations. Long range land uses planned for many portions of the Marumsco Creek and Farm Creek watersheds are consistent with existing land uses, where current residential, industrial and commercial areas will remain as such, perhaps with re-development of established areas. Significant natural features within the watersheds such as the two wildlife refuges and other parks and open spaces are to be preserved according

to the Comprehensive Plan. Some undeveloped areas in the watersheds, particularly in the northernmost portion, are planned for new development to provide a better transition between uses of varying intensities. New and re-development projects offer a great opportunity to address existing watershed degradation and to minimize adverse impacts of increased impervious surfaces by implementing stormwater management practices that provide both water quantity and quality control. Existing and long range land uses are described below for each subwatershed. Long range land use designations and descriptions that are relevant to the Marumsco Creek and Farm Creek watersheds based on the Comprehensive Plan are summarized in Table 2-2 at the end of this section.

Subwatershed 905

Subwatershed 905 covers the headwaters of Marumsco Creek and is bounded at the upstream limit by Minnieville Road with the subwatershed covering portions of Marumsco Creek downstream through the I-95 corridor ending near the stream crossing at Hylton Avenue. Existing landuse conditions with Subwatershed 905 consist primarily of the following areas:

- Undeveloped wooded areas: Comprise the largest percentage of the subwatershed including the corridor surrounding I-95 and Telegraph Road. Wooded/undeveloped areas encompass approximately fifty-one (51) percent of the total subwatershed.

- Low Density Residential (SRL): Low density residential neighborhoods can be found in two portions of Subwatershed 905, north of I-95 off of Summit School Road (Brooke Farm and Park Center subdivisions) and south of I-95 off of Hylton Avenue and Forest Glen Road (Marumsco Village Subdivision). The Brooke Farm and Park Center subdivisions are newer developments that include modern stormwater treatment techniques through three wet ponds and one dry pond that provide treatment for stormwater quantity and quality for the entire development. The Marumsco Village subdivision located off Hylton Avenue and Forest Glen Road does not contain any stormwater management facilities and has several uncontrolled stormwater discharges into Marumsco Creek. Low density residential areas comprise approximately twenty (20) percent of the total subwatershed. Additionally, the Woodbridge Mobile Home Park is located in the western portion of the subwatershed off of Minnieville Road. The mobile home park comprises about three (3) percent of the total watershed area and contains a privately-owned treatment works (POTW) for treatment of sanitary sewage from the dwellings. The POTW outfalls into the headwaters of Marumsco Creek.

- High Density Residential (SHR): A single, newly developed high density residential neighborhood (Caton's Ridge) can be found in the western portion of the subwatershed near the Mobile home park off of Minnieville Road near Caton Hill Road. Caton's Ridge comprises approximately two (2) percent of the total watershed area.

- Commercial Areas: The 905 subwatershed contains a few independent commercial parcels that are not part of a larger commercial development. These limited commercial areas include an office building, an auto repair/storage/salvage lot and a contractor storage lot. The commercial parcels amount to about two (2) percent of the total subwatershed area.

- Agricultural Areas: A single agricultural area is located in the 905 subwatershed off of Minnieville Road near Summit School Road. The agricultural operations on this land plot

appear to be aimed at hay and straw production, but detailed investigations into the type of agriculture have not been undertaken. Runoff from this plot of land is uncontrolled and flows into a small tributary in the headwaters of Marumsco Creek. The agricultural area encompasses approximately four (4) percent of the subwatershed area.

- Utility Right-of-Way: A series of high-tension electrical transmission lines cross the 905 subwatershed. The right-of-way surrounding each of these lines has been clear cut of all woody vegetation and is currently in a state of overgrowth from native brush and several varieties of invasive species. The utility right-of-way currently has poorly controlled access and appears to be a common area for illegal dumping activities. The utility right-of-way comprises approximately three (3) percent of the total subwatershed area.

- Interstate-95 Corridor and Commuter Lot: The final dominate land use across the 905 subwatershed is the I-95 corridor and the large commuter park and ride lot associated with it. These transportation elements account for sixteen (16) percent of the total subwatershed area. Each of these components is primarily impervious paved surfaces (highway and parking lots) and each has provided stormwater management facilities within the 905 subwatershed.

Future trends in the use of the lands within each subwatershed were investigated based upon documentation in the 2008 Comprehensive Plan developed by Prince William County. Based on the comprehensive plan the documented low density residential areas are to remain as low density. A small tract of wooded/undeveloped land south of the I-95 interchange with Prince William Parkway is planned for development into a high density residential neighborhood. The largest tract of undeveloped/wooded areas is included in the development plan for the Parkway Employment Center according to the 2008 Comprehensive Plan. Utility right-of-way areas, the small commercial parcels, the mobile home park and the agricultural area are all included in the tract of land designated for the Parkway Employment Center. The Parkway Employment Center sector area plan is intended to provide a transition between the existing low density residential areas, dense commercial areas (Potomac Mills Mall) and the I-95 corridor. The sector area plan includes both Regional Employment Center and Environmental Resource long range land use designations. Regional Employment Center designations are intended for large-scale, non-retail employment developments such as office buildings, lodging, and mixed-use development. The Environmental Resource land areas are not intended for development. Rather these land areas are part of action strategies that have also been incorporated in the area environmental plan to preserve and enhance natural features and open space. Some of the key environmental action strategies are listed below:

- Preserve existing forested areas on 15% or greater slopes adjacent to streams to reduce flooding, minimize sediments, and enhance aesthetics of the area.

- Encourage preservation of existing tree stands within open space areas through rezoning commitments or special use permits requiring that wooded open space areas remain undisturbed.

- Implement stormwater pre-treatment devices in parking areas that involve handling of petroleum products, outside motor vehicle storage, and motor vehicle repair.

- Require all developments in the watershed to participate in the regional stormwater management (SWM) program. Seek commitments to reduce peak runoff rates by a minimum of 25% to mitigate flooding problems along Marumsco Creek.

Subwatershed 910

Subwatershed 910 covers the portions of Marumsco Creek from the Hylton Avenue crossing downstream to the CSX railroad (formerly RF&P Railroad) crossing of Marumsco Creek. The subwatershed includes a major tributary to Marumsco Creek that runs along the Prince William Parkway corridor from I-95 through to US Route 1. Existing land use conditions within Subwatershed 910 consist primarily of the following areas:

- Low Density Residential Areas (SRL): Comprise the largest percentage of the land uses within the 910 subwatershed. Low density residential areas are found through out the subshed with particularly large concentrations found along the mainstem of Marumsco Creek at the northern portion of the subshed and a separate neighborhood south of Prince William Parkway between I-95 and Route 1. Low density residential areas cover approximately forty-six (46) percent of the total watershed area. Additionally, Subwatershed 910 contains two small mobile home park areas (Holly Acres Mobile Home Park and Marumsco Neighborhoods Mobile Home Park); both of these areas are located off the US Route 1 corridor and portions of each appear to be located within the 100-year floodplain. The mobile home parks comprise about one (1) percent of the total subwatershed area.

- High Density Residential Areas (SRH): High density residential areas encompass fifteen (15) percent of the subwatershed area. The high density residential areas are mostly new developments located off the recent Prince William Parkway extension between I-95 and US Route 1. The new high desity residential areas include Summerhouse Condo, Summerland, Dawson's Ridge, and The Commons on William Square Condo subdivisions. The new high density residential areas each have implemented quantity and quality control stormwater BMPs. The sole older high density development without a stormwater BMP is located south of the US Route 1 corridor (Marumsco Acres S4 Subdivision).

- Wooded/Undeveloped Areas: Wooded and undeveloped areas are scattered throughout the 910 subwatershed. These areas consist of thirteen (13) percent of the total subwatershed area. Some of the existing wooded areas are located along the mainstem of Marumsco Creek and its tributaries and currently provide a limited buffer between the stream and the surrounding developments.

- Commercial Areas: Commercial areas within the 910 subwatershed are principally located along the old US Route 1 corridor (Jefferson Plaza). The bulk of the commercial properties along this corridor are older developments in deteriorating condition or in disuse. These older properties do not have any stormwater BMPs and mostly have uncontrolled stormwater discharges into Marumsco Creek or its tributaries. The commercial areas encompass twelve (12) percent of the total subwatershed area.

- Institutional Areas: Institutional areas within Subwatershed 910 consist of schools, religious facilities, and recreational parks. The institutional areas are dispersed throughout

the southern portion of the subshed and constitute about nine (9) percent of the total subshed area.

- I-95 Corridor: The I-95 corridor crosses a small portion of Subwatershed 910 along its western boundary. The I-95 corridor covers two (2) percent of the subwatershed area.

- Medium Density Residential (SRM): A small medium density residential area is located in Subwatershed 910 near the intersection of Prince William Parkway and US Route 1. This neighborhood covers less than one (1) percent of the subwatershed area. The medium density residential neighborhood does contain quantity control BMP stormwater ponds which may also provide limited water quality control as well.

Long range land uses within Subwatershed 910 do not project any significant changes from the existing land uses with the exception of potential development of wooded areas. Consistent with existing usage, the long range land uses shown in the Comprehensive Plan consist mainly of suburban high and low density residential (SRH, SRL) uses. The Comprehensive Plan specifies that existing public lands, parks and open spaces are intended to be preserved as well as environmental resource areas surrounding Marumsco Creek. The northeastern corner of Subwatershed 910 includes a small portion of the North Woodbridge Potomac Community (sector plan area 7A), which is also part of the 2008 Comprehensive Plan. Sector plan area 7A is intended to take advantage of the improved transportation access planned for this area between US Route 1 and Occoquan Road. This community is planned for a mix of high intensity uses, using existing properties that have been in transition for many years to create a more cohesive development. The long range land uses within Subwatershed 910 that are included in the revitalization plan for sector plan area 7A are general commercial (GC), urban residential medium (URM), and urban mixed uses (UMU). Some existing commercial uses will be redeveloped into the higher density residential uses (URM) in this subwatershed along Occoquan Road to facilitate a better transition to the lower density residential area to the south. General commercial uses will remain between Horner Road and US Route 1. The largest long-term development trend that can seemingly be anticipated within Subwatershed 910 would be re-development of under utilized commercial properties along the US Route 1 corridor.

Subwatershed 915

Subwatershed 915 covers Marumsco Creek from the CSX Railroad crossing downstream to the confluence with the Occoquan Bay and the Potomac River. The subwatershed contains a system of tributaries that stretch from the US Route 1 corridor at their headwaters to the confluence with the mainstem of Marumsco in Veterans Memorial Park. Existing land use conditions within Subwatershed 915 consist primarily of the following areas:

- Low Density Residential Areas (SRL): Comprise about half of the land area within the 915 subwatershed. Low density residential areas are found primarily in the middle of the subwatershed between US Route 1 and the CSX railroad (Marumsco Acres subdivision). Low density residential areas cover approximately forty (40) percent of the total watershed area.

- Wooded/Marshland/Wildlife Refuges: Undeveloped areas dedicated to preservation of natural resources encompass approximately thirty-one (31) percent of the 915 subwatershed. Among these areas are portions of the Occoquan Bay National Wildlife Refuge and tidal marshlands along Marumsco Creek downstream of the CSX Railroad

crossing. Additional small pockets of woods among the more developed portions of the watershed are also present.

- Commercial Areas: Commercial areas within the 910 subwatershed are principally located along the US Route 1 corridor. The commercial properties in this portion of the corridor are in better condition and use than those in the 910 subwatershed. A portion of the commercial properties in the 915 subwatershed have stormwater BMP controls. The commercial areas encompass ten (10) percent of the total subwatershed area.

- High Density Residential Areas (SRH): High density residential areas encompass five (5) percent of the subwatershed area (Marumsco Acres S4 subdivision). The high density residential areas are older developments located Longview Road east of US Route 1. These older high density developments do not have stormwater BMP controls.

- Industrial: Three industrial developments fall within the 915 subwatershed. These developments comprise a total of five (5) percent of the total subwatershed area. The industrial developments are older and do not have stormwater BMP controls and each discharge uncontrolled surface runoff to Marumsco Creek or Occoquan Bay.

- Veterans Memorial Park: Veterans Memorial Park encompasses seven (7) percent of the 915 subwatershed area. The park consists of several recreation complexes, a community garden and other open areas

As with Subwatershed 910, the majority of the existing Subwatershed 915 land uses are similar to planned long range land uses. Consistent with existing uses, the western portion of the subwatershed is planned for mostly single residential low (SRL) and general commercial (GC) uses with some suburban residential low and medium (SLR, SLM) areas. The southwest corner of this subwatershed includes a portion of the Neabsco Mills Potomac Community (sector plan area 7B) in the 2008 Comprehensive Plan. Sector Plan Area 7B is intended to strengthen existing commercial nodes and to integrate commercial and residential areas. The portion of sector plan area 7B within Subwatershed 915 is planned for urban mixed uses (UMU) including office, high density residential, and recreation and retail uses. The overall intensity, however, is intended to be lower than that of the North Woodbridge Potomac Community (sector plan area 7A). As noted, a percentage of Subwatershed 915 is currently occupied by the Occoquan Bay National Wildlife Refuge (NWF) and various parks and open spaces along the right bank of Marumsco Creek including Veterans Memorial Park and Marumsco Acre Lake Park (right and left banks are defined looking downstream). The Occoquan Bay NWF was originally a military research site and was established as a refuge in 1998 (USFWS 2009). It includes wetlands, forest, and native grasslands that provide habitats for various wildlife species. These public lands, parks, and open spaces are intended to be preserved per the 2008 Comprehensive Plan in addition to environmental resource areas (ER) identified along the creek. The northeast corner of the subwatershed includes a portion of land designated as flexible employment center (FEC) or light industrial uses.

Subwatershed 10

Subwatershed 10 covers the majority of Farm Creek from its headwaters at US Route 1 downstream to the CSX Railroad crossing. Existing land use conditions within Subwatershed 10 consist primarily of the following areas:

- Low Density Residential Areas (SRL): Comprises the majority of the land area within the 10 subwatershed. Low density residential areas are found through out the center of the subwatershed and along the shoreline at the Occoquan Bay. Low density residential areas cover approximately sixty (60) percent of the total watershed area. The majority of the residential areas do not contain any stormwater control BMPs.

- Industrial (FEC): The second largest land use within subwatershed 10 is industrial areas within the Featherstone Industrial area. The industrial area covers about twenty-five (25) percent of Subwatershed 10. The Featherstone Industrial Area is located west of the CSX Railroad tracks on the eastern portion of Subwatershed 10. The developments within the industrial area have a variety of stormwater BMPs, with the majority of the BMPs only providing stormwater quantity control.

- Medium Density Residential (SRM): A small medium density residential area is located in Subwatershed 10 along Featherstone Road. This neighborhood covers about six (6) percent of the subwatershed area. The medium density residential neighborhood does not have any stormwater BMP controls.

- Commercial Areas: The only commercial areas within the Subwatershed 10 are located at the stream headwaters along the US Route 1 corridor. The commercial properties in this portion of the corridor are in better condition and use than those in the 910 subwatershed. The commercial areas cover less than four (4) percent of the total subwatershed area.

- Institutional: Institutional areas cover a small portion of Subwatershed 10 along Reddy Drive. The institutional areas consist of a religious facility and a school and cover less than two (2) percent of the subwatershed area.

As with the lower subwatersheds along Marumsco Creek, the majority of Subwatershed 10 land uses are generally consistent with proposed long range land uses including suburban residential low and medium (SRL, SRM) and flexible employment center (FEC) designations. The northwestern corner of Subwatershed 10 encompasses a portion of the Neabsco Mills Potomac Community (sector plan area 7B) discussed for Subwatershed 915. The sector plan area within this subwatershed preserves existing public lands and general commercial areas. The remaining portion is designated as urban mixed uses (UMU) with a lower intensity than sector plan area 7A.

Subwatershed 20

Subwatershed 20 encompasses the confluence of Farm Creek with the Occoquan Bay and the Potomac River. Existing land use conditions within Subwatershed 20 consist primarily of the following areas:

- Wooded/Marshland/Wildlife Refuges: Undeveloped areas dedicated to preservation of natural resources encompass approximately eighty-eight (88) percent of Subwatershed 20. This area is the Featherstone National Wildlife Refuge. It is bordered by the CSX Railroad crossing to the west, the Occoquan Bay shoreline to the east, a residential development to the north and the confluence of Neabsco Creek and the Potomac River to the south.

- Mass Transit Node (MTN): The second largest land use within Subwatershed 20 is a mass transit node in the western corner of the subwatershed, located off of Farm Creek Drive. This area covers about six (6) percent of Subwatershed 20 and is the Rippon Station on the Fredericksburg Line of the Virginia Railway Express (VRE). The station is located on the western side of the railroad and largely consists of surface parking area. There is some open space and wooded areas scattered among the parking areas, railroad crossing, Farm Creek Drive and Rippon Boulevard.

- Industrial (FEC): A small portion of the Featherstone Industrial area is located in the western portion of Subwatershed 20. The industrial area covers about two (2) percent of Subwatershed 20. The Featherstone Industrial Area is located west of the CSX Railroad tracks and immediately north of the Rippon VRE Station. The developments within the industrial area have a variety of stormwater BMPs, with the majority of the BMPs only providing stormwater quantity control. :

- High Density Residential (SRH): A small high density residential area is located in the western corner of Subwatershed 20, along Rippon Boulevard. It covers approximately two (2) percent of the subwatershed and is located immediately west of the Rippon VRE Station. The high density residential area includes a stormwater wet pond with wetland plantings located at the intersection of Farm Creek Drive and Rippon Boulevard.

- Low Density Residential (SRL): A small low density residential area is located in the northern corner of the subwatershed. It covers approximately two (2) percent of the subwatershed and is located immediately north of the Featherstone National Wildlife Refuge. The development is at the end of Featherstone Road off of Marseille Lane. The low density residential neighborhood does not have any stormwater BMP controls.

The majority of the existing Subwatershed 20 land uses are similar to planned long range land uses. Consistent with existing uses, the western portion of the subwatershed is planned for suburban residential high (SRL), mass transit node (MTN), and industrial (FEC) uses. The northern corner of the watershed is planned to accommodate a suburban residential low (SLR) area. As noted, the majority of Subwatershed 20 is currently occupied by the Featherstone National Wildlife Refuge (NWF). It is comprised of tidal marsh, riparian wetlands, and a forest of oaks, tulip poplars and red maples (USFWS 2009). There is currently no public access to the site; however, the County and refuge staff are working to provide public access and possibly a route for the Potomac Heritage Natural Scenic Trail. The refuge includes the outlet of Farm Creek and provides habitat for various species of birds including bald eagles. This are is intended to be preserved as public land according to the 2008 Comprehensive Plan.

Summary

Analysis of the long range land uses as compared to existing conditions shows that little change is expected through the Marumsco Creek and Farm Creek watersheds, with the exception of Subwatershed 905 in the Marumsco Creek watershed. Planned changes in Subwatershed 905 include substantial development and build-out of currently undeveloped areas. Traditionally, this scenario would contribute to already high stormwater discharge rates as well as increases in sediment and nutrient loadings to receiving waters. However, by using state-of-the-art SWM quantity and quality control BMPs in conjunction with environmentally sensitive design and low impact development (LID) strategies, these adverse impacts can be minimized or even potentially reduced to pre-development conditions.

Summation of the existing development within the watersheds shows that while a high percentage of the area has been developed, the entire watershed does not have stormwater management/ water quality BMP treatment. Portions of both watersheds include various types of developed properties and impervious surfaces that send uncontrolled stormwater into local streams. Uncontrolled stormwater discharges into Farm and Marumsco Creeks are causing increases in flood volumes beyond natural (i.e., pre-development) conditions and in common stormwater pollutant loading which stresses natural aquatic habitat. Construction of stormwater management BMPs to trat the increased discharges and pollutants loadings from the untreated developments is a very costly and difficult undertaking using standard retention pond (in-line or off-line) designs. In these areas the County should consider development of LID retrofit projects. Types of LID retrofits that can be implemented within the existing developments include downspout disconnections with rain barrels or rain gardens, conversion of roadside ditches into bioswales, installation of bioretention areas, and removal of paved surfaces / impervious areas (Jefferson Plaza) that are seldom used. The majority of these types of projects will inherently be located on privately owned lands and will require close coordination between the County, local watershed organizations, and the community. Outreach programs focused on environmental stewardship education throughout the community will help provide the County with the means of executing this type of program.

This study does not provide a comprehensive evaluation of the upland conditions within the watershed and cannot provide specific recommendations for development of a LID retrofit program or outreach program for the community. The County should consider supplementing the current watershed study which focuses on the stream corridors with an upland study that is focused on the existing development practices and opportunities for environmental stewardship projects.

Table 2-3: Long Range Land Uses in Marumsco Creek and Farm Creek Watersheds

Land Use Designation		Description
Urban Areas		
Mass Transit Node	MTN	Provides for higher density, mixed-use development near existing and future rail and Metrorail stations.
Regional Employment Center	REC	For sites close to or with good access from major interstate highways. Allows 75% employment use and 25% retail and/or residential with 16-30 dwellings/acre.
General Commercial	GC	Provides for infill of existing commercial strips.
Suburban Areas		
Flexible Employment Center	FEC	Provides for light manufacturing, start-up business, and offices.
Suburban Residential High	SRH	Multi-family housing, allows 10-15 dwellings/acre.
Suburban Residential Medium	SRM	Allows 4-6 dwellings/acre. Single family detached is preferred with single family attached limited to 25% of total land area.
Suburban Residential Low	SRL	Allows 1-4 single-family detached dwellings/acre.
County-wide		
Environmental Resource	ER	100-year floodplains, Resource Protection Areas, areas with 25% or greater slopes, areas with 15% or greater slopes and with soils that have severe limitations, soils with a predominance of marine clays, public water supply sources, wetlands, and critically erodible shorelines and stream banks.
Parks and Open Space	P&OS	Existing parks and recreation areas of the County.
Public Land	PL	Identifies public land within the County to provide an indication of existing and planned public facilities, institutions, or other government installations.
Potomac Communities		
Urban Mixed Use	UMU	For a coordinated project or integrated group of projects, consisting of at least 3 components – residential, office, or regional employment, and recreation – combined to take full advantage properties with excellent transportation.
Urban Residential Medium	URM	For attached residential development at a density up to 20 dwellings/acre and attendant community facilities such as schools, churches, and public safety stations.

2.1.5 Storm Drain Infrastructure and Stormwater Management

Stormwater is water generated during and immediately after storm events. Stormwater that does not seep into the ground becomes stormwater runoff and goes directly to receiving waters. Stormwater management (SWM) is a significant consideration for new and redevelopment to reduce erosion, sedimentation, pollution and flooding. The complexity and extent of storm drain infrastructure and SWM is directly related to the density of development. Intensely developed areas are likely to have significant impervious cover, which means less infiltration capacity and more stormwater runoff. Therefore, developed areas require a greater capacity for SWM (i.e., a more extensive storm drain network and/or SWM facilities) than undeveloped areas to manage the higher volumes of runoff generated.

Storm drain infrastructure refers to the network of inlets, piping, and outfalls intended to prevent flooding by removing stormwater from impervious surfaces such as roadways and conveying it to the stream system. While stormwater is removed quickly from impervious surfaces, storm

drain infrastructure often delivers increased runoff volumes and untreated pollutants to receiving waters. Visual inspection of the County's 'Storm_Points' and 'Storm_Segments' GIS data layers showed the highest concentration of outfalls along roadways in the more developed areas of the watersheds. The most storm drain outfalls were observed along roadways in Subwatersheds 910 and 915 in the Marumsco Creek watershed and Subwatershed 10 in the Farm Creek watershed, which are the areas with the highest densities of existing residential, industrial and commercial development. Storm drain outfalls were also apparent along the roadway networks in Subwatershed 905, particularly in the northern portion of the subwatershed where existing residential development is clustered and in the vicinity of the Park and Ride (Exit 158 off of I-95 South). Storm drain infrastructure becomes scarce in the western portion of Subwatershed 915 in the Occoquan Bay NWF, where Marumsco Creek discharges to the Occoquan Bay. Only a few outfalls are documented along Veterans Drive within this subwatershed. Because Subwatershed 20 largely consists of the Featherstone NWR, storm drain infrastructure is the least apparent in this area. The storm drain network in this subwatershed is limited to the area bordering the western side of the railroad where there is existing residential and transportation-related development (parking areas) along Rippon Boulevard and Farm Creek Drive.

SWM facilities refer to Best Management Practices (BMPs) that are designed to manage stormwater runoff and also provide stormwater quality treatment. There are various types of BMPs available for managing stormwater. SWM facilities target specific objectives depending on BMP type such as stormwater quality, soil stabilization, stormwater flow control, and stream restoration. Pollutant removal capabilities also depend on facility type. For example, SWM dry ponds generally have low pollutant removal efficiency compared to practices that filter stormwater or allow it to infiltrate into the ground or through plant roots. Several considerations are taken into account when selecting appropriate stormwater treatment measures such as space requirements, maintenance, cost and community acceptance. There are a total of 29 SWM facilities throughout the Marumsco Creek and Farm Creek watersheds based on the County's 'SWM_Facilities' GIS data layer, including dry and wet ponds, underground storage facilities, and infiltration trenches. Table 2-3 provides a summary of the different SWM facilities located within the Marumsco Creek and Farm Creek watersheds by subwatershed.

Table 2-4: Stormwater Management Facilities

	NO. OF SWM FACILITIES BY TYPE				
Subshed ID	Dry Pond	Wet Pond	Underground Storage	Trench	Total
905	4	3	-	-	***7***
910	3	-	3	-	***6***
915	3	1	3	-	***7***
10	6	-	-	2	***8***
20	1	-	-	-	***1***
Totals	***17***	***4***	***6***	***2***	***29***

Table 2-3 shows that the most common type of SWM within the watersheds are dry ponds. Each subwatershed has six or more SWM facilities, with the exception of Subwatershed 20. Subwatershed 20 only has one SWM facility (dry pond for the existing transportation facility) which is reasonable since it is the least developed subwatershed. The dry pond facilities represent the best opportunity for conversion to BMPs with higher pollutant removal capabilities.

2.2 Summary of Reference Data and Reports

Several types of studies have been performed to better understand the water quality conditions in the Marumsco Creek and Farm Creek watersheds. The following sections describe studies relevant to the Marumsco and Farm Creek watersheds from Prince William County records and other available sources.

2.2.1 Prince William County Stream Protection Strategy

The Prince William County Stream Protection Strategy was prepared by CH2M HILL, Williamsburg Environmental Group, and Michael Baker Jr and submitted to Prince William County in 2004. The Stream Protection Strategy study focuses specifically on the streams within Prince William County and included assessments for nearly all of the streams within the county. The purpose of the assessments was to collect information on the following stream conditions:

- Habitat Conditions
- Erosion, Buffer and Infrastructure Impacts
- General Stream Characteristics

The data from the 2004 study were analyzed as part of the current watershed study. Results of the study were obtained through the Prince William County Stream Assessment Viewer. The results of the Stream Protection Strategy assessments and a brief comparison to the field observations from the present study are as follows:

- Five obstruction sites were noted in various reaches of Marumsco Creek. The obstruction sites included concrete rubble/ waste, beaver dams, and debris jams. In the current study, two of the five documented obstruction sites were noted including both of the concrete rubble / waste locations. However, the noted debris jams, beaver dams, and apparent temporary construction crossing had been removed prior to the current study.
- Two streambank erosion sites were noted. Each of the noted erosion sites are along Marumsco Creek Tributary B. The recent field investigations confirmed the erosion and location of the site near the confluence of Tributary B and Marumsco Creek; however, the second site near Charles Court was not observed.
- Six impaired buffer sites were noted. Each impaired buffer site falls along the mainstem of Marumsco Creek and were observed, investigated and noted by the current study.
- One impaired utility site was noted along the mainstem of Marumsco Creek just downstream of the Easy Street crossing. The impaired utility was documented as a sanitary manhole and sewer line within the stream. The concrete encasement for the sewer line had broken apart and failure of the line would have been considered as a high potential. The impacted utility at this location appears to have been repaired / relocated prior to the present study.

All of the documented sites from the Stream Protection Strategy study fall within Marumsco Creek Subwatershed 910. In addition to the 15 problem sites noted above, the study documented an additional 8 road crossings over Marumsco Creek.

2.2.2 Marumsco Acres Lake Litter Study

The Marumsco Acres Lake Litter Study Report was prepared by Prince William County personnel in response to resident and staff complaints about floatable trash in the lake and along the shoreline (PWC 2006). As part of the litter study, PWC personnel performed a field investigation of the streams and tributaries to Marumsco Acres Lake and the surrounding watersheds. The results of the field investigation indicated that the littler problem is not attributable to a single point source or problem area, but rather is the result of widespread littering typical of most developed areas. Tributaries to Marumsco Acres Lake were also inspected for the purposes of this study; findings from this study are consistent with the observations provided by the PWC personnel and confirm the results of the litter study (see Chapter 3). The recommendations provided in the litter study include public outreach and education, increased trash removal/waste pick-up from non-residential properties, improved street sweeping when possible, and regularly scheduled trash removal from the lake and shorelines by PWC Park Authority personnel. Each of these recommendations is valid and effective.

2.2.3 303(d) Listings and Total Maximum Daily Loads (TMDLs)

Section 303(d) of the 1972 Clean Water Act requires states to develop (and periodically update) a list of impaired waters that fail to meet applicable state water quality standards which are defined by their designated uses. States must also establish priority rankings and develop Total Maximum Daily Loads (TMDLs) for waters on the 303(d) list. According to USEPA, a TMDL is a calculation of the maximum amount of a pollutant that a water body can receive and still safely meet state water quality standards. TMDLs can be developed for a single pollutant or group of pollutants of concern which generally include sediment, metals, bacteria, nutrients, and pesticides.

The Virginia Department of Environmental Quality (DEQ) monitors over 130 different pollutants on an annual basis to determine whether receiving waters meet state water quality standards established for swimming, fishing, and drinking. DEQ has been developing 303(d) lists of impaired waters since 1992. The most recent list is included their 2008 Integrated Report which is a summary of water quality conditions in Virginia from January 1, 2001 to December 31, 2006 (VADEQ 2008). This report is submitted to USEPA by DEQ every even-numbered year.

In DEQ's 2008 Integrated List, Marumsco Creek was placed in the fully supporting category, meaning that the creek is supporting one or more designated uses. Specifically it is classified as Category 2A, which means that the creek is attaining all of the uses for which is monitored but there is insufficient data to document attainment of all uses. Marumsco Creek was previously listed as impaired by Ammonia in 1998 but was de-listed in 2000. The 1998 sampling occurred at a location downstream of the Woodbridge Mobile Home Park privately owned waste water treatment facility (POTW) in the stream headwaters above I-95. The subsequent de-listing of Marumsco Creek is seemingly due to upgrades and ammonia-specific treatment at the POTW. Occoquan Bay, on the other hand, was placed in the impaired category. It was classified as Category 5A which denotes that the water quality standard is not attained and a TMDL is

required since one or more designated uses is threatened. Occoquan Bay impairments are related to aquatic life and fish consumption and include aquatic plants (macrophytes), polychlorinated biphenyls (PCBs) in fish tissue, and pH. PCBs and pH were initially listed as impairments to Occoquan Bay in 2002. Occoquan Bay was also designated as nutrient enriched waters in the 2002 listing. Aquatic plants were first listed in 2006. Note, however, that Occoquan Bay was partially delisted for SAV since the 2008 assessment demonstrated that the goal has been met. TMDLs are scheduled for completion by 2010 for pH and by 2014 for PCBs in fish tissue.

CHAPTER 3: WATERSHED ASSESSMENT

3.1 Introduction

This chapter describes the investigations conducted to assess the current conditions of the Marumsco Creek and Farm Creek watersheds. The investigations conducted include both review of existing studies and field investigations. Review of existing studies was focused on a detailed analysis of data relevant to flooding issues within the study area. Field investigations included two major components: 1) rapid corridor stream assessments of all perennial streams and 2) detailed inspection of 13 of the 29 SWM facilities within the watersheds. For each field component, the assessment protocol, summary of sites investigated, and general findings are described in the sections below.

3.2 Existing Flood Studies

Some areas within the Farm Creek and Marumsco Creek watersheds are susceptible to flooding. Therefore, previous studies relevant to flooding issues within the study area were carefully reviewed.

FEMA Flood Insurance Study (January 1995)

The Marumsco Creek and Farm Creek watersheds fall within the Federal Emergency Management Administration (FEMA) Flood Insurance Study (FIS) for Prince William County Unincorporated Areas (Community Number 510119). The initial countywide effective date for the FIS is January 5, 1995; no revisions are currently available from FEMA for the Unincorporated Areas encompassing Marumsco or Farm Creeks. Farm Creek and Marumsco Creek were both included as detailed study areas for the FEMA analysis of Prince William County. Flood Insurance Rate Maps (FIRM) that cover both streams are included on panels 217, 219, and 238 (Map Nos. 51153C0217, 51153C0219 and 51153C0238) for Prince William County. FIRMETTE copies of the Flood Insurance Rate Maps are included in Appendix D of this report. Farm Creek was modeled as a single stream in the FEMA study with the upper limit of the study occurring at the outlet of the culvert crossing under Featherstone Drive. Marumsco Creek was modeled by FEMA using a more complex model with the stream mainstem and four major tributaries. The modeled branches of Marumsco Creek and model limits include:

- The mainstem of Marumsco Creek from the Occoquan Bay to immediately downstream of the I-95 culvert crossings. The model covers stream segments in Subwatersheds 905, 910 and 915. The FEMA models refer to this reach as Marumsco Creek.

- The major tributary to Marumsco Creek contained within Subwatershed 910. This tributary is located along the extended portion of Prince William Parkway between I-95 and US Route 1. The FEMA mapping for this stream pre-dates the Prince William Parkway extension project. The upper limit of the FEMA detailed study for this tributary is near the intersection of Prince William Parkway and West Longview Drive. The FEMA study refers to this reach as Marumsco Creek Tributary A.

- The northern tributary to Marumsco Acres Lake that confluences with Marumsco Creek in Veterans Memorial Park. This tributary is wholly located in Subwatershed 915. The

upstream limit of the FEMA study is the downstream end of the tributary crossing of US Route 1. The FEMA study refers to this reach as Tributary No. 1 to Marumsco Creek Tributary B.

- The final branch of the FEMA model is the southern tributary to Marumsco Acres Lake. Modeling of this tributary includes Marumsco Acres Lake to the confluence with Marumsco Creek in Veterans Memorial Park. The upstream limit of the FEMA study of this tributary falls at a point between the Blackburn Road crossing and the US Route 1 crossing of the stream. The FEMA study refers to this reach as Marumsco Creek Tributary B.

Analysis of the FEMA flood insurance maps for Marumsco Creek show that several improved properties within the watershed are subject to flooding during storm events. The analysis and determination that a property is at risk for flooding is based solely on mapping limits developed by FEMA and comparison of the mapping to recent aerial photography for the County. Detailed hydrologic and hydraulic computations were not performed as part of the current study, nor were surveys of specific properties suspected of being within the flood hazard areas performed. Suspected causes of property flooding discussed in this section are based on qualitative observations and interpretation of the FEMA results. The results of the analysis comparing the FEMA flood hazard areas to the county aerial photography yielded the following observations:

- Approximately sixteen (16) homes within the Botts subdivision along Baxter Street fall inside the FEMA 100-year floodplain. Each of these homes is located along the left stream bank of Marumsco Creek (right and left banks are defined looking downstream). The primary source of flooding is floodplain flows from Marumsco Creek.

- One home at the intersection of Millwood Drive and Horner Road. The home is located along the right stream bank of Marumsco Creek. The suspected source of flooding is backwater due to the Horner Road stream crossing.

- Five (5) homes at the ends of D Street and Congress Street. Each of these homes is located along the left stream bank of Marumsco Creek. The primary source of flooding is floodplain flows from Marumsco Creek.

- The Marumsco Neighborhoods mobile home park along Griffin Drive, variable number of homes due to the non-permanence of mobile homes. The mobile home park is located across the floodplain of the Marumsco Creel Tributary A, with the tributary confined to culverts that travel below the mobile home park. The suspected source of flooding include undersized culverts under the mobile home park, potential debris build-up at the trash racks on the upstream end of the culverts, and the development fill not rising above the natural floodplain elevation.

- Multiple businesses along Easy Street and US Route 1 at the Marumsco Creek crossings for each road. Flooding occurs along both the right and left banks of Marumsco Creek at this location. Flooding source is cited by other reports as being under sized culverts at the CSX railroad crossing, the US Route 1 crossing and the Easy Street crossing; however, analysis of FEMA mapping shows that the primary cause of the backwater is the CSX railroad crossing. US Route 1 and Easy Street may have undersized crossings at this location, but replacement of these structures without

increasing the capacity of the railroad crossing may only provide minor flood mitigation benefits.

- Holly Acres Mobile Home Park located off of US Route 1, variable number of homes due to the non-permanence of mobile homes. Approximately seventy (70) percent of the Holly Acres Mobile Home Park is located within the FEMA 100-year floodplain along the left bank of Marumsco Creek (right and left banks are defined looking downstream). The primary source of flooding to the mobile home park is floodplain flows increased by backwater effects from the undersized culvert crossing at the CSX railroad crossing.

- One business located along Industry Court. The business is located at the end of Industry Court near the CSX railroad embankment. The suspected cause of flooding at this location is backwater from the undersized CSX railroad crossing over Marumsco Creek Tributary A at the outlet of Marumsco Acres Lake.

- Thirteen (13) homes along Bay Street and Bay Circle fall within the FEMA 100-year floodplain. These homes are located along the waterfronts off the Occoquan Bay and Marumsco Creek near the confluence of Marumsco Creek with Occoquan Bay. Flooding at these locations is driven by coastal storm surges driven up the Potomac River.

- One business at the end of Tyrrell Lane falls within the 100-year floodplain. The business is located along the waterfront of the Occoquan Bay. Flooding of the property is caused by coastal storm surge conditions.

- Multiple homes and businesses are located within the 500-year FEMA floodplain within Subwatershed 20. The homes are located off of Featherstone Road and the businesses fall within the Featherstone Industrial Area. The flooding in this area is controlled by coastal storm surge conditions.

The flooding of properties is further discussed in Chapter 4, including conceptual methods for reduction of flooding where possible.

Study of Marumsco Creek Storm Drainage (October 1977)

The *Study of Marumsco Creek Storm Drainage* report was prepared for Prince William County by Bengtson, DeBell & Elkin, Inc. (Bengston 1977). The report was submitted in October of 1977 and specifically focuses on drainage issues between the CSX (formerly Richmond Fredericksburg & Potomac Railroad) railroad culvert and Easy Street.

The study identifies the following two major flooding areas:

- From US Route 1 to just upstream of Easy Street

- From CSX Railroad crossing upstream to US Route 1

Hydrologic computations were performed in the storm drainage study using the Anderson method. Hydraulic capacities of the limiting stream crossings were presented. Results of a comparative analysis showed that many of the stream crossings are undersized. The results of the study supported the conclusion of major flooding areas along US Route 1 and Easy Street.

The results of this 1977 storm drainage study are consistent with the observations from the FEMA studies previously discussed.

The primary goal of the storm drainage study was to identify improvements for reduction of flooding in the major flood areas. Recommendations included:

- Straightening, lining and vegetation removal along the mainstem of Marumsco Creek to reduce flooding in the Botts subdivision. The study concluded that this option, while reducing flooding in the Botts subdivision, may increase flooding to the US Route 1 corridor.

- Structure sizing to improve conveyance. Principle sources of flooding identified were the CSX railroad, US Route 1 and Easy Street culverts. Analyses showed that each culvert is undersized and contributes to flooding conditions in the stream corridor.

- Options for siting and sizing of regional SWM ponds to reduce flood peaks. The report presents six locations for construction of in-line regional SWM ponds. The locations include the mainstem of Marumsco Creek upstream of Easy Street, the mainstem of Marumsco Creek along Hylton Avenue near Greenacre Drive, the headwaters of Marumsco Creek upstream of I-95 (two separate locations proposed), Marumsco Creek Tributary B upstream of the confluence with Marumsco Creek and Easy Street, and Marumsco Creek Tributary B near the current location of Prince William Parkway.

- Options for PWC acquiring land within floodplain through eminent domain, removal of properties within the floodplain and preservation of the floodplain as a natural resource area.

A combination of the above noted treatments were presented as the preferred option for reduction of flooding in the major flooding area. Of the four provided concepts, only the concepts for replacement of existing undersized stream crossings is feasible given the current development level of the watershed, permitting regulations within the state and county, and socioeconomic climate of the country. Chapter 4 provides additional discussion of the flooding issues and preferable concepts for mitigation of flooding due to culvert sizing.

The concept involving acquisition of land for preservation of the floodplain and removal of development within the floodplain remains a desirable long-term change to land usage along the stream corridor; however, this may not be a currently viable concept. The developments cited for acquisition and removal within the floodplain appear to be largely low income housing alternatives within the County. Attempts to acquire this land may involve complex environmental justice issues and require costly replacement and relocation costs to offset the loss of low income housing alternatives. The concept that included the concrete lining and straightening of Marumsco Creek is not likely to be permitted, given the current environmental movement that emphasizes restoration of ecological habitat within streams over concrete lining for improved flood control and conveyance. Finally, the in-line regional SWM pond concept provides many issues with regard to permitting and current development within the watershed. Many of the sites located in the 1977 study are no longer feasible due to development within the watershed that has eliminated the opportunity for construction of a pond. The use of smaller off-line ponds or site-specific low impact development (LID) BMPs are preferable to the construction of large regional SWM ponds.

Prince William County Comprehensive Storm Drainage Study #15 (June 1981)

The *Prince William County Comprehensive Storm Drainage Study* was prepared for the county by Gannett Fleming Engineers (Gannett Fleming 1981). The study focuses on 9 storm drainage problem areas across Prince William County. Of the 9 problem areas, 5 are located within the Marumsco Creek watershed. The five problem areas described within the Marumsco Creek watershed include:

- Flooding of the Holly Acres Mobile Home Park: The 1981 study concludes that the flooding is due to backwater effects from the undersized culvert crossing at the RF&P Railroad. Based on the analysis presented in the FEMA section, this problem area is still a valid concern within the watershed.

- Erosion along the tributaries to Marumsco Acres Lake and sedimentation within Marumsco Acres Lake: Erosion areas and channel stabilization projects have been thoroughly mapped and documented as part of the present study and provide an update to all erosional discussions presented in the 1981 report. However, the present study did not evaluate sedimentation rates within Marumsco Acres Lake. Based on observed erosion within the tributaries to the lake it assumed that some degree of sedimentation and filling of the lake continues to occur.

- Flooding of properties along Marumsco Creek upstream of the Horner Road crossing: The 1981 study concluded that flooding at this location was no longer a problem due to upgrades to the Horner Road culvert system. However, analysis of the FEMA studies refutes this conclusion and seemingly indicates that flooding is still of concern in this area.

- Flooding of properties along Forest Drive and Meridan Drive: The 1981 study described flooding issues occurring in this area as a result of an insufficient and undersized storm drain system. The current study does not provide a detailed analysis of the hydrologic properties or hydraulic capacities of the storm drain networks and cannot verify or refute the 1981 analysis.

- Flooding at the Illinois Road outfall and storm drain system: The 1981 study described flooding issues occurring in this area as a result of an insufficient storm drain system and inefficient swales downstream of the storm drain system. The current study does not provide a detailed analysis of the hydrologic properties or hydraulic capacities of the storm drain networks and cannot verify or refute the 1981 analysis.

Marumsco Creek Regional SWM Ponds Technical Report (April 1989)

The *Marumsco Creek Regional SWM Ponds Technical Report* was prepared for Prince William County by Bernard Johnson Inc. and is dated April 1989 (Bernard Johnson 1989). The technical report specifically focuses on the design of two large regional SWM ponds along the headwater streams of Marumsco Creek upstream of the I-95 crossings. The design report follows the project recommendations from the 1988 *Marumsco Creek Regional Stormwater Management Drainage Study*. The 1988 study was not available for review as part of this current watershed study.

The two proposed regional SWM ponds were seemingly designed in anticipation of the large parcel of land along Marumsco Creek upstream of Interstate 95. Land use mapping from 1989 show this parcel as largely wooded with some limited medium density residential areas and meadow land. The planning mapping presented as part of the pond design show anticipated complete development of this area into industrial, commercial and high density residential areas. The nature of the development proposed would certainly increase peak runoff rates and the ponds as designed would provide an effective means for mitigating these flow increases. However, the regional SWM program as designed in the 1989 report is an outdated methodology that does not fit well with current trends in stormwater management or with the new Prince William County Comprehensive Plan. As discussed in the previous section, the use of smaller, off-line ponds or site-specific low impact development (LID) BMPs is preferable to the construction of large regional stormwater management ponds.

3.3 Stream Corridor Assessments

Stream corridor assessments were conducted for all of the wadeable, perennial streams within the Marumsco Creek and Farm Creek watersheds to identify water quality problems and potential project locations. These were conducted based on the Center for Watershed Protection's (CWP) *Unified Stream Assessment* protocols (CWP 2005) which is a continuous stream walk method designed to rapidly collect basic information needed to develop a manageable list of restoration projects. Assessments were used to document channel instabilities, outfall retrofit potentials, utility conflicts, and trash reduction opportunities within the Marumsco Creek and Farm Creek watersheds. The protocol employed, stream corridors investigated, and results for Marumsco Creek and Farm Creek are described in the following sections.

3.3.1 Assessment Protocol

The Unified Stream Assessment (USA) method is used to quickly assess the range of water quality and habitat impacts and restoration opportunities along a stream corridor. Potential restoration practices include stormwater retrofits, stream repair, riparian management, and discharge prevention. The USA method includes eight types of impact assessments. Two person field crews walked all of the wadeable, perennial streams within the Marumsco Creek and Farm Creek watersheds and identified the following environmental problems (impacts) based on the USA method:

- Outfalls
- Severe Erosion
- Impacted Buffers
- Utilities in the Stream Corridor
- Trash and Debris
- Stream Crossings
- Channel Modifications

- Miscellaneous Impacts

Coastal zone assessments were also conducted to evaluate physical shoreline conditions and identify potential restoration opportunities within tidal areas. The field survey team walked along selected stream corridors and shorelines noting the location of problem and coastal zone assessment sites on field maps and filling out appropriate data sheets for each site. Each site was assigned a unique identification (ID) number according to map ID number and then numbered sequentially in the order it was encountered. At least one photograph was taken at each site to document the conditions observed.

All sites were rated by the field survey team on a scale of one to five for severity, access, and/or restoration potential depending on the site being evaluated (i.e., impact type, overall reach conditions, or coastal zone assessment). The scores are intended to help prioritize potential restoration opportunities where generally, a score of 5 denotes severe impacts or good restoration potential and a score of 1 would be minor impacts or sites with limited restoration potential. In addition to these ratings, site descriptions and measurements were also collected depending on site assessment type. Information collected and guidelines used to assess specific impacts and conditions are discussed further in the next section.

3.3.2 General Findings

A total of 289 potential water quality problems were identified along the wadeable, perennial streams walked within the Marumsco Creek and Farm Creek watersheds. The table below summarizes the number of potential problems observed for each type of impact assessed.

Table 3-1: Number of Impact Assessment Sites

Type of Impact	No. of Sites
Outfalls	88
Severe Erosion	48
Impacted Buffers	29
Utilities	12
Trash and Debris	40
Stream Crossings	24
Channel Modifications	20
Miscellaneous	28
Total	***289***

Excluding pipe outfalls, the most frequently observed water quality problem was related to erosion. Trash and debris and inadequate buffers were also were also observed in several locations throughout the stream network surveyed. Impacts related to utilities within the stream corridors were the least observed. A summary of the lengths of erosion, impacted stream buffers, and channel modifications is presented in Table 3-2 below.

Table 3-2: Observed Water Quality Impact Lengths

Type of Impact	Length of Impact (ft)
Severe Erosion	11,445
Impacted Buffers	39,960
Channel Modifications	8,960
Total	***60,365***

The field team also estimated that a total of 163 pick-up truck loads would be required to remove trash and debris from dumping sites. A total 12 coastal zone assessments were also conducted. Each assessment category (water quality problems and coastal zone assessments) and corresponding results are discussed in the following sections.

3.3.2.1 Outfalls

Outfalls include all pipes or small manmade channels that discharge stormwater runoff into the stream corridor. These are considered a potential water quality problem since they can carry untreated runoff and pollutants such as oil, heavy metals, and nutrients to a stream system. In addition, large stormwater volumes can cause flooding, erosion, and habitat degradation. Of particular interest were suspected illicit discharges and local opportunities to stabilize or repair streams and outfalls.

During the stream corridor assessments, general outfall information was collected including type (enclosed or open channel), material, size and shape. Also documented were signs of physical deterioration (e.g., corrosion, cracking, etc.), odor, deposits/stains, and benthic growth. If an outfall was flowing at the time of the survey, the color, turbidity, and physical content of the flow were noted. Any other water quality concerns were also noted such as excessive trash or heavy sedimentation. Outfall severity was rated on a scale of 1 (minor) to 5 (very severe). The severity rating was primarily based on the discharge including whether discharge was present, color, odor, amount, and downstream impacts. Each outfall assessed was assigned one of the following severity ratings:

- ***5 (very severe)***: Heavy discharge with a distinct color and/or strong smell. The amount of discharge is significant compared to the amount of normal flow in receiving stream; discharge appears to be having a significant impact downstream.

- ***4 (severe)***: Moderate discharge with some color and/or odor. Discharge appears to be having a noticeable impact on the stream.

- ***3 (moderate):*** Small discharge; flow may have a slight color or odor. If the discharge has a color and/or odor, the amount of discharge is very small compared to the stream's base flow and any impact appears to be minor / localized.

- ***2 (low):*** Small discharge; flow mostly clear and odorless. If the discharge has a color and/or odor, the amount of discharge is very small compared to the stream's base flow and any impact appears to be minor / localized.

- ***1 (minor):*** Outfall does not have dry weather discharge; staining; or appearance of causing any erosion problems.

Finally, potential restoration actions were also noted for each outfall including discharge investigation, local stream repair/outfall stabilization, stormwater retrofit, and/or none.

A total of 88 outfalls were identified during the stream corridor assessments. The table below summarizes the number of pipe outfalls associated with each severity rating (1, 2, 3, 4, or 5).

Table 3-3: Outfall Severity Ratings

Severity Rating	No. of Outfalls	Percentage
5 (Very Severe)	7	8%
4 (Severe)	6	7%
3 (Moderate)	23	26%
2 (Low)	34	39%
1 (Minor)	18	20%
Total	***88***	***100%***

Of the 88 outfalls documented during the stream corridor assessments, 7 were considered as very severe problems (rating = 5), 6 were severe (rating = 4), and 23 were moderately severe due to the nature of the discharge. These outfalls represent opportunities for for either stormwater retrofit or local stream repair/outfall stabilization. Over half of the outfalls assessed (52 out of 88) were considered as low severity or minor issues and most of these outfalls (87%) were not considered potential candidates for restoration. Figure 3-1 shows the location of outfalls that were rated as in the very severe, severe or moderate water quality problems.

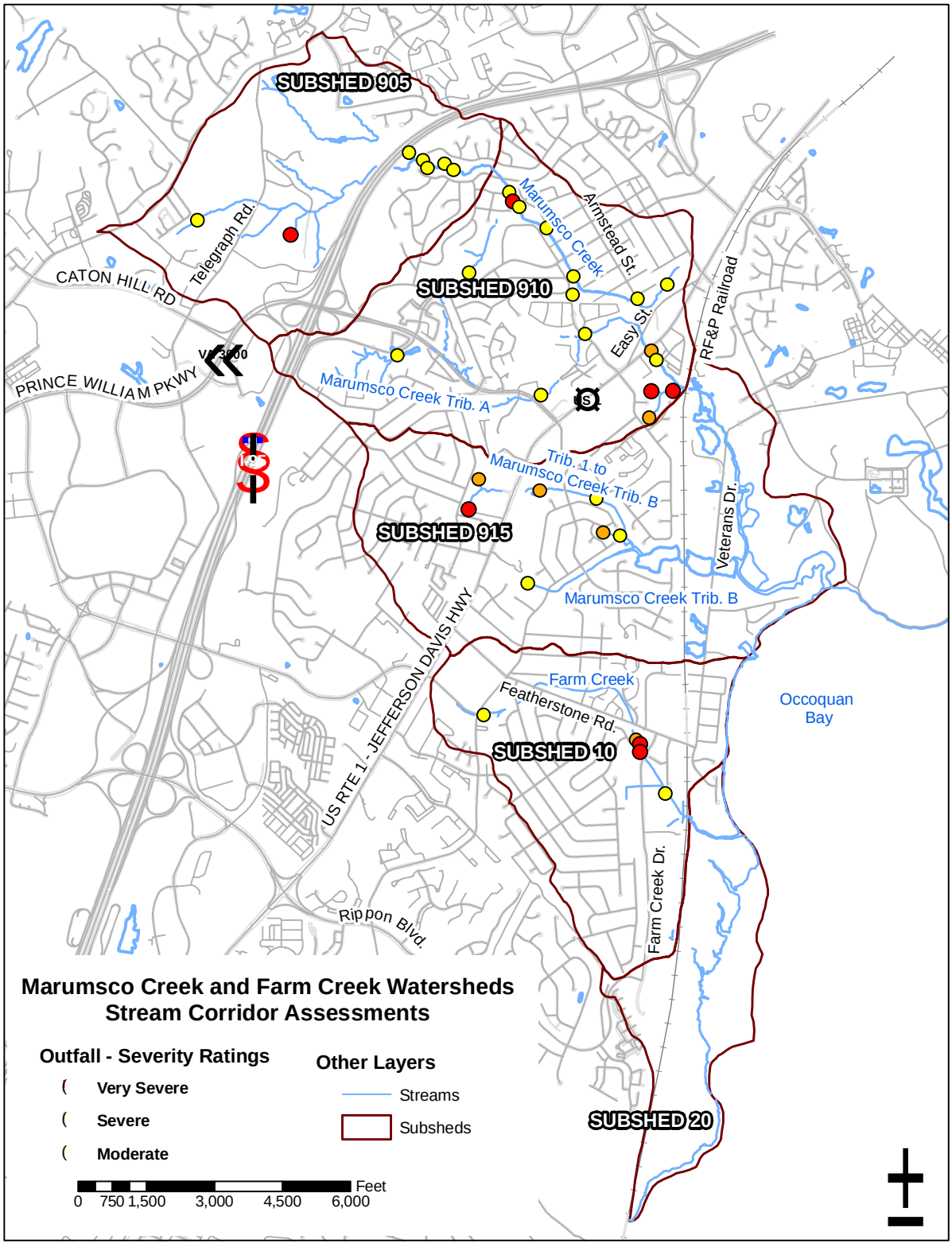

Figure 3-1: Very Severe to Moderately Severe Rated Outfall Locations with Restoration Potential

3.3.2.2 Stream Erosion

Erosion can destabilize stream banks, destroy habitat, and cause sediment pollution problems downstream. Significant erosion problems are often a result of changes to stream hydrology or sediment supply which is often attributed to land use changes in a watershed (e.g., urbanization). Since erosion is also a natural process, every occurrence of erosion was not identified. Rather, the focus of the stream corridor assessments was to identify the most severe eroding banks within the watersheds, particularly where infrastructure is threatened, and the areas with potential for stream repair or restoration opportunities.

Field teams noted the dominant channel erosion processes, the location and dimensions of the eroding area, existing riparian width, and the ownership and land cover of the adjacent stream corridor. It was also noted whether the bank erosion was a threat to property/infrastructure. Potential restoration actions were recorded for each erosion site including bank stabilization, grade control, and bioengineering. Erosion severity was rated on a scale of 1 (minor) to 5 (very severe) based on the extent of the eroding bank (i.e., length and height). Each erosion site assessed was assigned one of the following severity ratings:

- ***5 (very severe):*** Active downcutting; tall banks on both sides of the stream eroding at a fast rate; erosion contributing significant amount of sediment to stream; obvious threat to property or infrastructure.

- ***4 (severe):*** Active downcutting, moderate tall banks on one side of the stream eroding at a fast rate; long-term threat to property or infrastructure.

- ***3 (moderate):*** Downcutting evident, active stream widening, banks actively eroding at a moderate rate; no threat to property or infrastructure

- ***2 (low):*** Evidence of active or historic bank erosion, banks eroding at a low rate. No threat to property or infrastructure.

- ***1 (minor):*** Grade and width stable; isolated areas of bank failure/erosion; likely caused by a pipe outfall, local scour, impaired riparian vegetation or adjacent use.

Access to the site for restoration purposes was also rated on a scale of 1 (difficult) to 5 (good). Good access (rating = 5) was assigned to open, publicly-owned areas with easy access for heavy equipment and room for a staging area. Difficult access (rating = 1) was assigned to sites where it would require crossing a wetland, steep slope, or other sensitive areas requiring specialized equipment and where minimal space was available for stockpile materials.

A total of 48 erosion sites were identified during the stream corridor assessments. The table below summarizes the number of erosion sites associated with each severity rating (1, 2, 3, 4, or 5).

Table 3-4: Erosion Severity Ratings

Severity Rating	No. of Erosion Sites	Percentage
5 (Very Severe)	8	17%
4 (Severe)	8	17%
3 (Moderate)	15	31%
2 (Low)	14	29%
1 (Minor)	3	6%
Total	***48***	***100%***

Erosion sites observed total 11,445 feet (2.2 miles) of stream bank with bank heights ranging from 1 to 20 feet. Most erosion sites were documented as moderately severe (rating = 3) and low severity (rating = 2) problems. Location of erosion sites including severity ratings are shown in Figure 3-2.

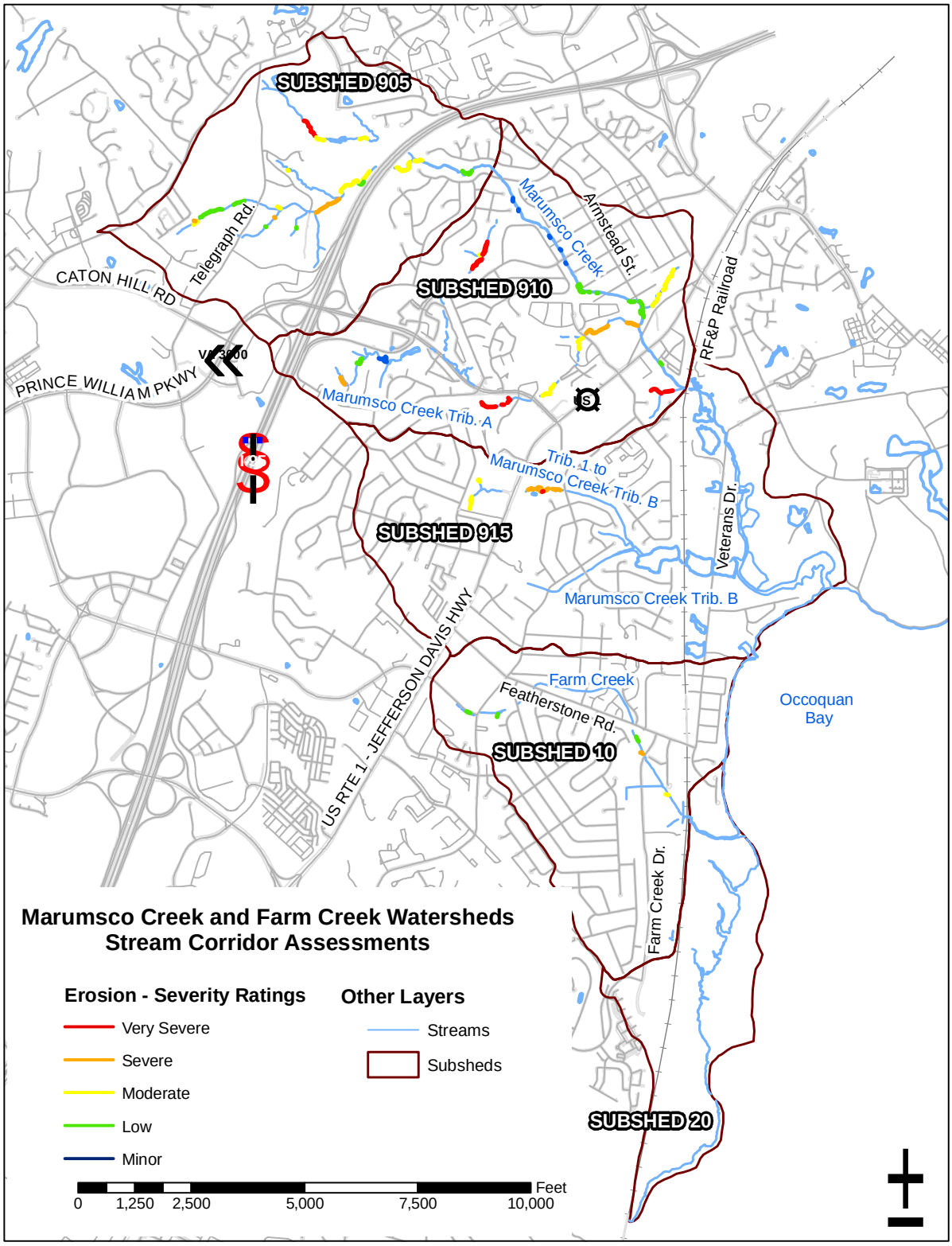

Figure 3-2: Erosion Site Locations

3.3.2.3 Impacted Buffers

Riparian buffers refer to the vegetated areas adjacent to streams that protect receiving waters from pollutant loads while also providing bank stabilization and habitat. Vegetated buffer areas along streams are important for improving water quality and flood mitigation since they can reduce surface runoff, stabilize stream banks, trap sediment and provide habitat for various types of terrestrial and aquatic life. Tree roots, for example, can capture and remove pollutants such as nutrients and sediment from shallow flowing water while also slowing down erosion and flow. This reduces pollutant loads and the risk of flooding. Tree canopy provides shade which is important for maintaining cooler water temperatures required by various species. Plant material falling into the stream such as leaves also provides a food source for aquatic life. When stream riparian buffers are replaced by development, many of these benefits are lost and stream health declines. Riparian buffer zones can be re-established or preserved as a BMP to reduce land use impacts by intercepting and controlling pollutants entering a water body.

For the stream corridor assessments, impacted buffers were flagged for stream corridor lengths greater than 100 feet long that lacked a minimum 25-foot wide, naturally vegetated riparian buffer on one or both sides of the stream. The information collected at these sites included the reason buffer was determined to be inadequate, land cover and adjacent land uses, extent of invasive plants, stream shade conditions, and potential restoration action, area, and conflicts. Potential restoration actions included active reforestation, natural regeneration, invasives removal, or bank planting. Impacted buffer severity was rated on a scale of 1 (minor) to 5 (very severe) based on the extent of the existing buffer. Each impacted site assessed was assigned one of the following severity ratings:

- ***5 (very severe):*** No trees or vegetation on either side of the stream corridor. Encroachment up to stream channel from development activities.

- ***4 (severe):*** No trees or vegetation on one side of the stream corridor for a significant length.

- ***3 (moderate):*** A minimum 25-foot wide forested buffer on one side of the stream corridor and inadequate buffer on the other; 10-foot wide vegetated or forested buffer on both sides of stream corridor.

- ***2 (low):*** A minimum 25-foot wide forested buffer on one side of the stream and slightly impaired buffer on the other (less than 25 feet but more than 10 feet).

- ***1 (minor):*** A minimum 25-foot wide, forested buffer on both sides of stream corridor.

The field team identified a total of 29 impacted buffer sites within the study area. The table below summarizes the number of impacted buffer sites associated with each severity rating (1, 2, 3, 4, or 5).

Table 3-5: Impacted Buffer Severity Ratings

Severity Rating	No. of Impacted Buffer Sites	Percentage
5 (Very Severe)	12	41%
4 (Severe)	12	41%
3 (Moderate)	4	14%
2 (Low)	1	4%
1 (Minor)	-	0%
Total	***29***	***100%***

Impacted buffer sites observed add up to 39,960 feet (7.6 miles). Both sides of the stream corridor were lacking adequate buffers for all but four of these sites. Most of the impacted buffer sites (20 out of 29 sites) were flagged because they were too narrow (i.e., less than 25-feet wide). The remaining sites were identified as impacted buffers due to a lack of vegetation or widespread invasive plants. Most of the sites assessed (24 out of 29) were considered as very severe or severe stream buffer problems. Location of impacted buffer sites including severity ratings are shown in Figure 3-3.

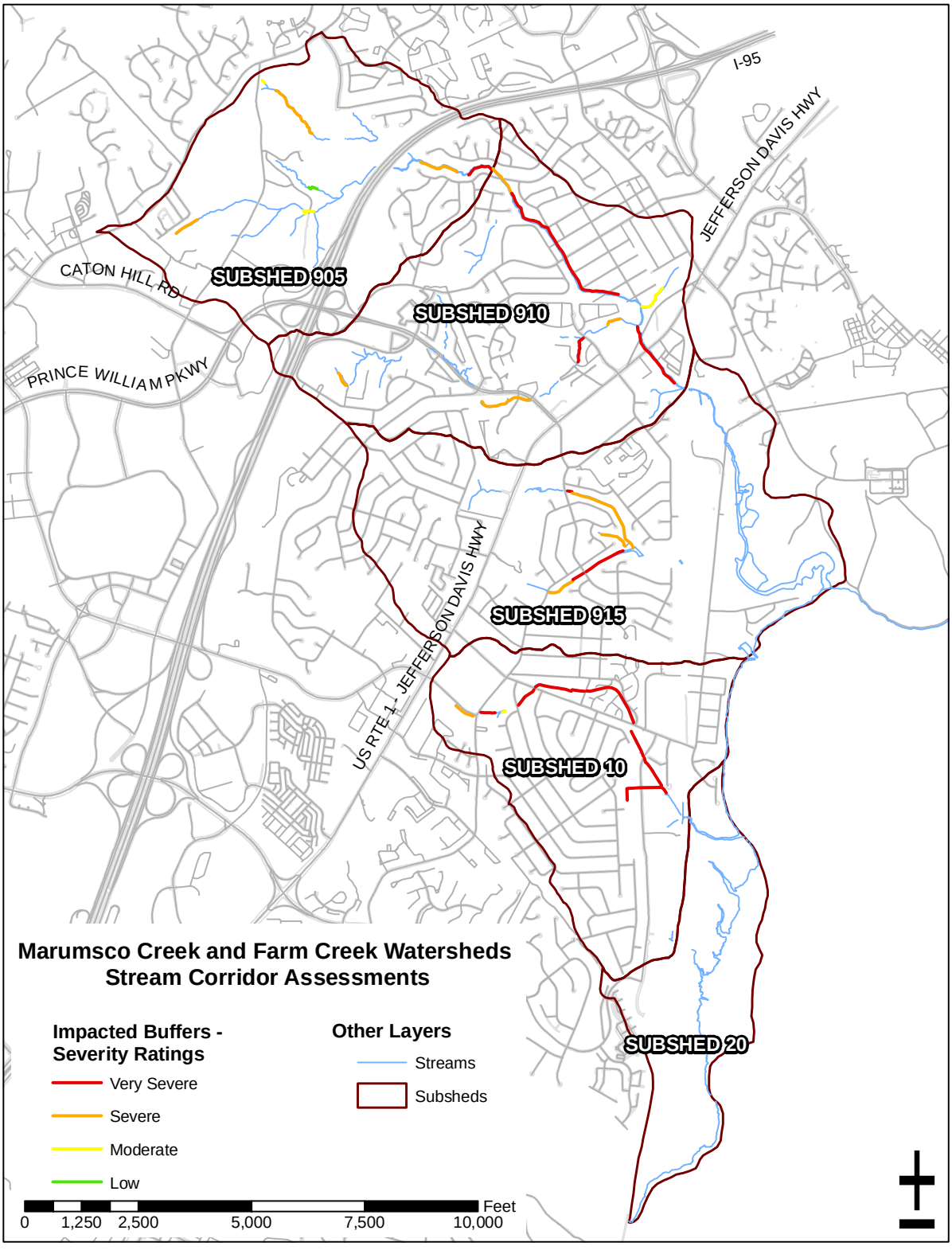

Figure 3-3: Impacted Buffer Site Locations

3.3.2.4 Utility Impacts

All locations where utilities cross the stream corridor and could potentially cause water quality, stream habitat, or channel stability problems were assessed during the stream assessments. Utilities include leaking or exposed sewer pipes, manhole stacks (sewer overflows), and overhead power line crossings. This is important because leaking or overflowing sewer pipes can discharge raw sewage into the stream system. Leaking water and sewer pipes can also increase dry weather stream flows. In some cases, pipe infrastructure can lead to physical stream impacts such as fish barriers, bank instability, and scour. There is also a chance for exposed pipes to be damaged during large storm events. Field teams paid particular attention to locations where stream repairs or discharge investigations are needed.

During the stream corridor assessments, the type, material, location, condition, pipe dimensions, and fish barrier drop height were noted at utility crossings within the streams. Field teams noted the color, odor, and deposit characteristics of discharge, if any. Potential restoration actions included structural repairs, fish barrier removal, stream stabilization, or investigation. Utility impact severity was rated on a scale of 1 (minor) to 5 (very severe) based on the extent of the impact. Each utility crossing site assessed was assigned one of the following severity ratings:

- ***5 (very severe):*** Section of pipe undermined by erosion and could collapse in the near future; a pipe running across the bed or suspended above the stream; a long section along the edge of the stream where nearly the entire side of the pipe is exposed; or a manhole stack that is located in the center of the stream channel and there is evidence of stack failure. The utility is showing evidence of discharge into the stream.

- ***4 (severe):*** Section of pipe undermined by erosion and could collapse in the near future; a pipe running across the bed or suspended above the stream; a long section along the edge of the stream where nearly the entire side of the pipe is exposed. The utility is not showing evidence of discharge into the stream.

- ***3 (moderate):*** A moderately long section of pipe is partially exposed but there is no immediate threat that the pipe will be undermined and break in the immediate future. The primary concern is that the pipe may be punctured by large debris during a large storm event.

- ***2 (low):*** A section of pipe is exposed or a manhole stack is exposed along a streambank. Pipe or stack are currently protected from sheltered from immediate danger due to flows and debris in the stream.

- ***1 (minor):*** Small section of exposed pipe, stream bank near the pipe is stable; the pipe is across the bottom of the stream but only a small portion of the top of the pipe exposed; the pipe is exposed but is reinforced with concrete and it is not causing a blockage to upstream fish movement; a manhole stack that is at the edge of the stream and does not extend very far out into the active stream channel.

The field team identified a total of 12 utility crossings during the stream corridor assessments. The table below summarizes the number of utility impact sites associated with each severity rating (1, 2, 3, 4, or 5) and potential restoration project recommendations.

Table 3-6: Utility Crossing Severity Ratings

Severity Rating	No. of Utility Crossings	Percentage
5 (Very Severe)	1	8%
4 (Severe)	1	8%
3 (Moderate)	4	33%
2 (Low)	2	17%
1 (Minor)	4	33%
Total	***12***	***100%***

Half of the utility crossing sites (6 out of 12) were rated as very severe to moderately severe water quality problems. Location of utility impact sites including severity ratings are shown in Figure 3-4.

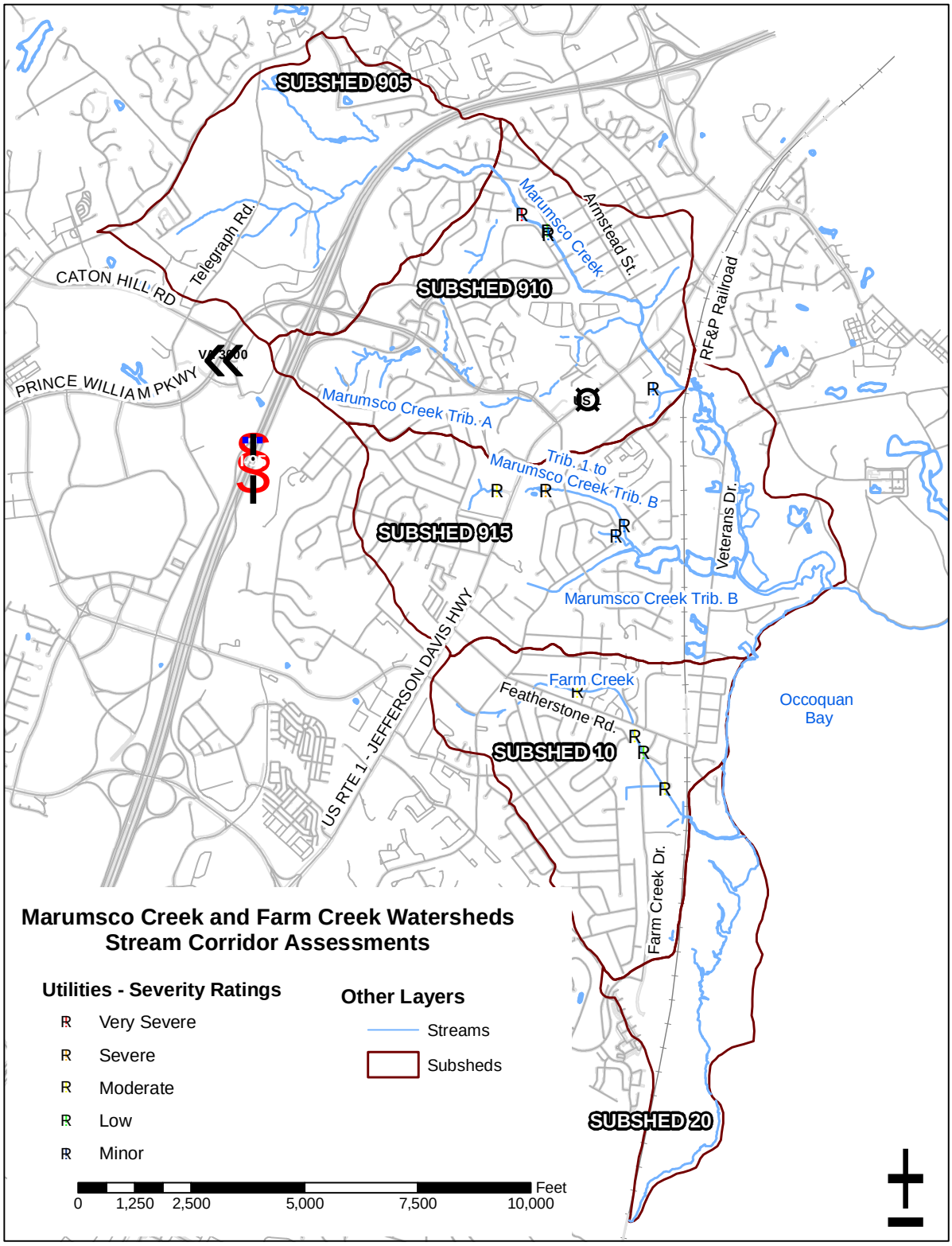

Figure 3-4: Utility Impact Site Locations

3.3.2.5 Trash and Debris

Trash and debris sites are places where large amounts of trash have been dumped or have accumulated inside the stream corridor. Trash and debris can contribute pollutants, create blockages at outfalls or within the stream channel, and degrade public perception about stream quality. Identifying these sites helps target stream reaches for routine cleanups, adoption, major removal of dumped materials, or limited access.

At trash and debris sites, the field team document the waste type and materials, source (if known), location (in-stream or riparian area), and land ownership. The field team also estimated the number of pick-up truck loads required to remove the trash and debris from the site and whether there was a dumpster within 100 feet of the site. The type of equipment (trash bags or heavy equipment) and personnel (volunteers, local government, or hazmat team) required for removal was also noted. Potential restoration actions included stream cleanup, stream adoption segment, and/or removal/prevention of dumping. Severity of trash and debris sites were rated on a scale of 1 (minor) to 5 (very severe) based on the extent of the dumping (amount and type of waste materials) and access considerations. Each trash and debris site assessed was assigned one of the following severity ratings:

- ***5 (very severe):*** A large amount of trash or debris scattered over a large area, where access is very difficult. Or presence of drums or indications of hazardous materials

- ***4 (severe):*** A large amount of trash or debris scattered over a large area, where access is difficult.

- ***3 (moderate):*** A large amount of trash, or bulk items, in a small area with easy access. Trash may have been dumped over a long period of time but it could be cleaned up in a few days, possibly with a small backhoe.

- ***2 (low):*** A moderate amount of trash with reasonable access.

- ***1 (minor):*** A small amount of trash (i.e., less than two pickup truck loads) located inside a park with easy access.

Cleanup potential was rated on a scale of 1 (high) to 5 (low). High potential (rating = 1) was assigned to trash and debris sites with small amount of trash with easy access. Low potential (rating = 5) was assigned to a large amount of trash scatter over a large area with difficult access or sites with hazardous materials.

The field team identified a total of 40 trash and debris sites within the study area. The table below summarizes the number of trash and debris sites associated with each severity rating (1, 2, 3, 4, or 5).

Table 3-7: Trash and Debris Severity Ratings

Severity Rating	No. of Trash and Debris Sites	Percentage
5 (Very Severe)	2	5%
4 (Severe)	7	18%
3 (Moderate)	9	22%
2 (Low)	16	40%
1 (Minor)	6	15%
Total	***40***	***100%***

The field team estimated that a total of 163 pick-up truck loads would be necessary to clean up all 29 trash and debris sites. Volunteers or local government were identified as the potential cleanup team for all of the sites identified. Most trash and debris sites were considered as moderate to low severity issues. Location of trash and debris sites including severity ratings and possible volunteer projects (see Chapter 4) are shown in Figure 3-5.

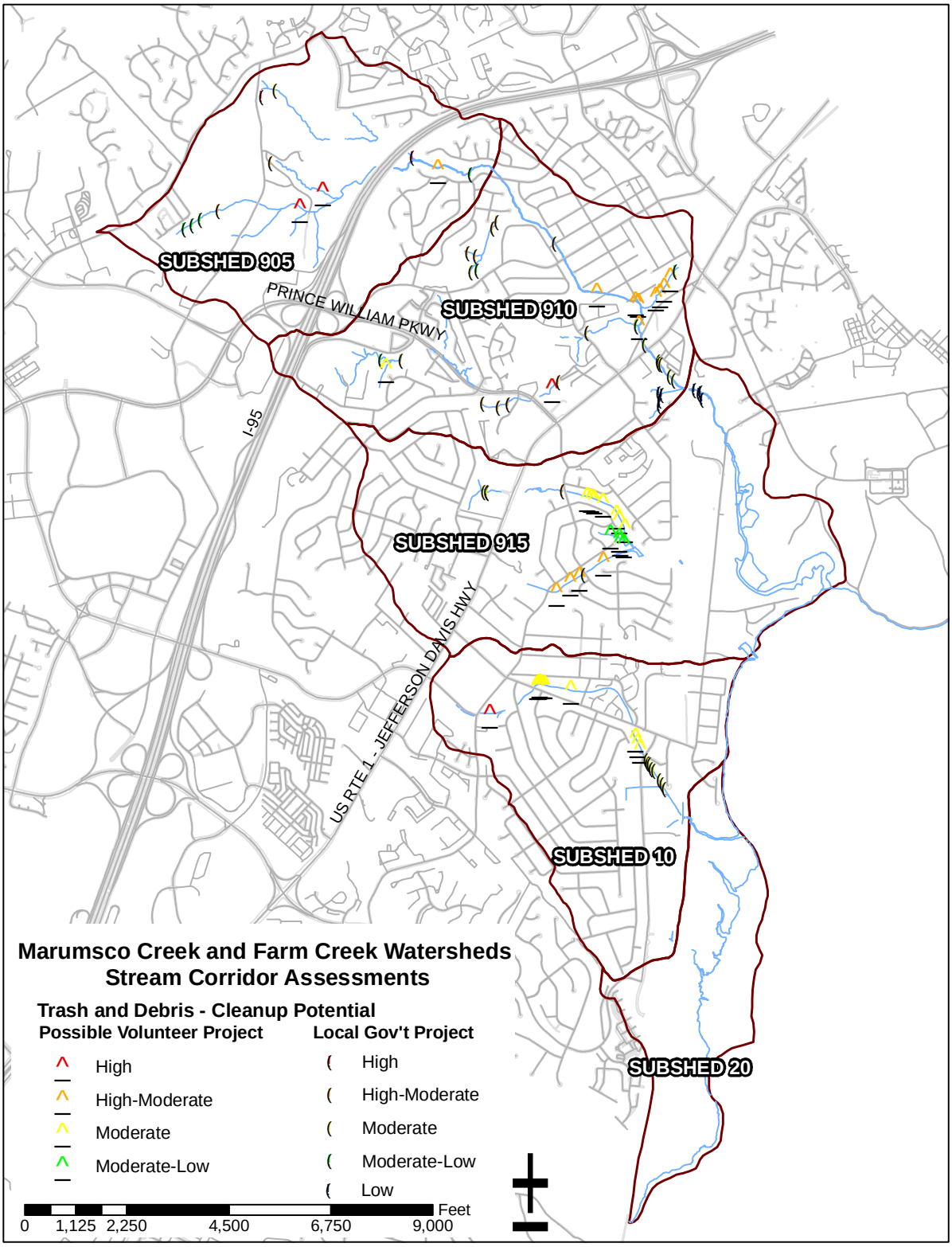

Figure 3-5: Trash and Debris Site Locations

3.3.2.6 Stream Crossings

Structural crossings that occurred across the stream corridors were assessed and included road crossings and culverts under developments. Stream crossings increase as watersheds become more developed and transportation infrastructure expands. These can alter local hydrology, cause stream bank instability, and hinder fish migration when located inappropriately.

At stream crossings, the field team noted the type, size and shape, material, alignment, condition, and slope. If a stream crossing was identified as a fish barrier, the extent of the blockage, cause, water depth, and drop height were also recorded. The field team also noted opportunities for potential fish barrier removal, culvert repair/replacement, stormwater retrofit, local stream repair, and debris removal. Blockage severity was rated on a scale of 1 (minor) to 5 (very severe) based on the extent of the impact. Each stream crossing site assessed was assigned one of the following severity ratings:

- ***5 (very severe):*** A structure such as a dam or road culvert on a 3rd order or greater stream blocking the upstream movement of anadromous fish; no fish passage device present.

- ***4 (severe):*** A road culvert on a 2nd order stream blocking the upstream movement of anadromous fish; no fish passage device present.

- ***3 (moderate):*** A total fish blockage on a tributary that would isolate a significant reach of stream, or partial blockage that may interfere with the migration of anadromous fish.

- ***2 (low):*** A temporary barrier such as a beaver dam or a blockage along a tributary stream.

- ***1 (minor):*** A temporary barrier such as a beaver dam or a blockage at the very head of a stream with very little viable fish habitat above it; natural barriers such as waterfalls.

The field team identified a total of 24 stream crossings during the stream corridor assessments. The table below summarizes the number of stream crossing sites associated with each severity rating (1, 2, 3, 4, or 5).

Table 3-8: Stream Crossing Severity Ratings

Severity Rating	No. of Stream Crossings	Percentage
5 (Very Severe)	1	4%
4 (Severe)	2	8%
3 (Moderate)	9	38%
2 (Low)	7	29%
1 (Minor)	5	21%
Total	***24***	

Half of the stream crossing sites (12 out of 24) were rated as very severe to moderately severe water quality problems. Restoration opportunities were limited for most of these sites. Location of stream crossing sites including severity ratings are shown in Figure 3-6.

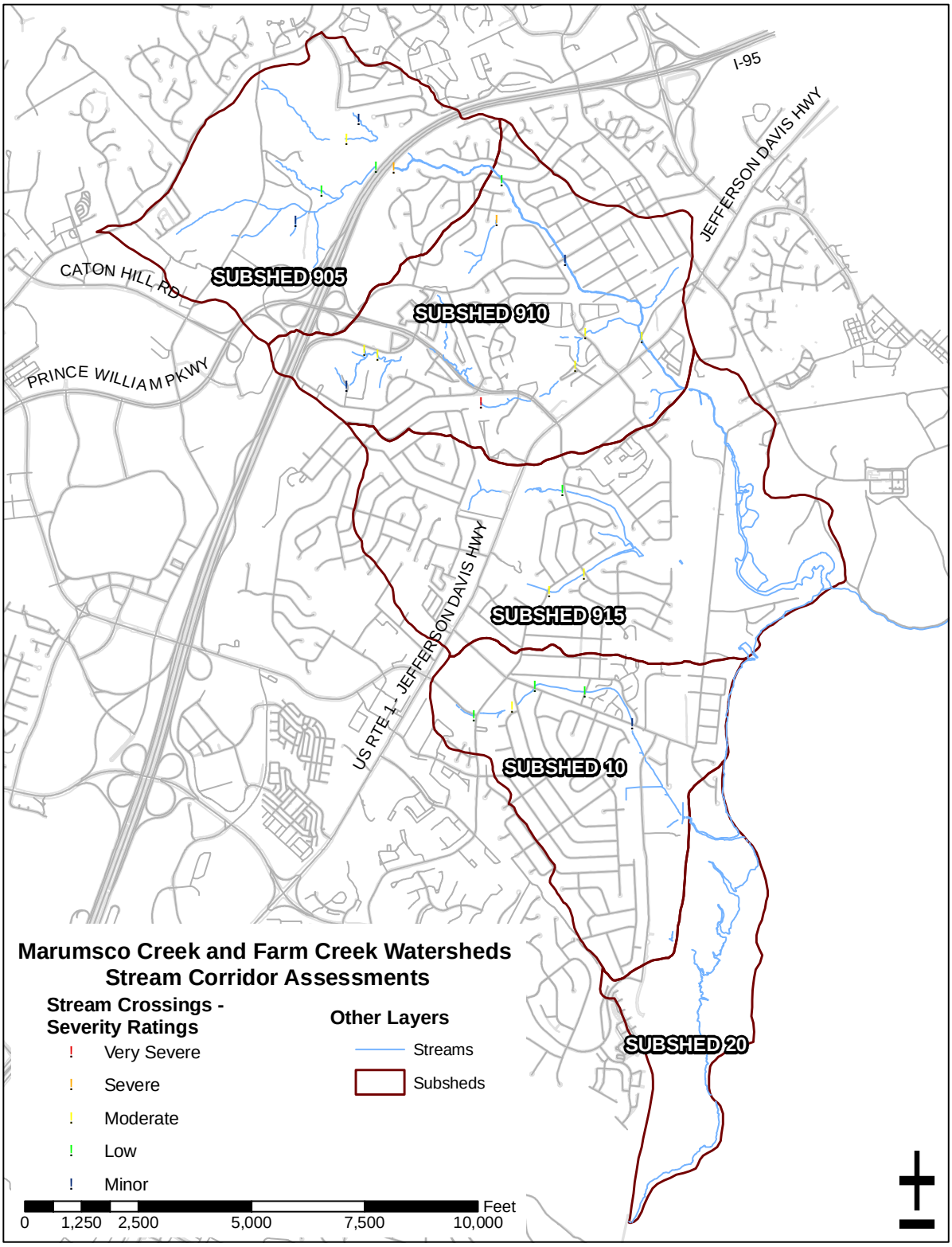

Figure 3-6: Stream Crossing Site Locations

3.3.2.7 Channel Modifications

Channel modification refers to stream sections where the banks or channel have been significantly modified from their naturally occurring condition. This includes channelization, bank armoring, channel lining, and floodplain encroachment. Modified channels are typically intended to convey more water and to prevent flooding but these types of alterations often create adverse environmental impacts such as impairing habitat and increasing water temperature. The field team focused on channel segments that needed structural repair or had opportunities for a more natural stream channel design.

For modified channel segments, the field team noted the type of modification, material and dimensions. They also documented evidence of perennial flow, sediment deposition, vegetation growth, and floodplain connection. Potential restoration recommendations included structural repair, base flow channel creation, natural channel design (bioengineering) or fish barrier removal. Channelization severity was rated on a scale of 1 (minor) to 5 (very severe) based on the extent of the impact. Each channel modification site assessed was assigned one of the following severity ratings:

- ***5 (very severe):*** A long section of concrete stream (>500') channel where water is very shallow (<1" deep) with no natural sediments present in the channel.

- ***4 (severe):*** A moderate length (>200') of channel where water is very shallow (<1" deep) with no natural sediments present in the channel.

- ***3 (moderate):*** A moderate length (>200'), but channel has stabilized and is beginning to function as a natural stream channel. Vegetated bars may have formed in channel.

- ***2 (low):*** A moderate length (>200'), Modifications are limited to armoring of channel banks and have had little impact on the natural channel function.

- ***1 (minor):*** An earthen channel less than 100 ft with good water depth, a natural sediment bottom, and size and shape similar to the unchannelized stream reaches above and below impacted area.

The field team identified a total of 20 channel modification segments during the stream corridor assessments. The table below summarizes the number of channel modification sites associated with each severity rating (1, 2, 3, 4, or 5).

Table 3-9: Stream Crossing Severity Ratings

Severity Rating	No. of Channel Modification Sites	Percentage
5 (Very Severe)	5	25%
4 (Severe)	4	20%
3 (Moderate)	6	30%
2 (Low)	0	0%
1 (Minor)	5	30%
Total	***20***	***100%***

Most of the channel modification sites (15 out of 20) were rated as very severe to moderately severe water quality problems. Location of channel modification sites including severity ratings are shown in Figure 3-7.

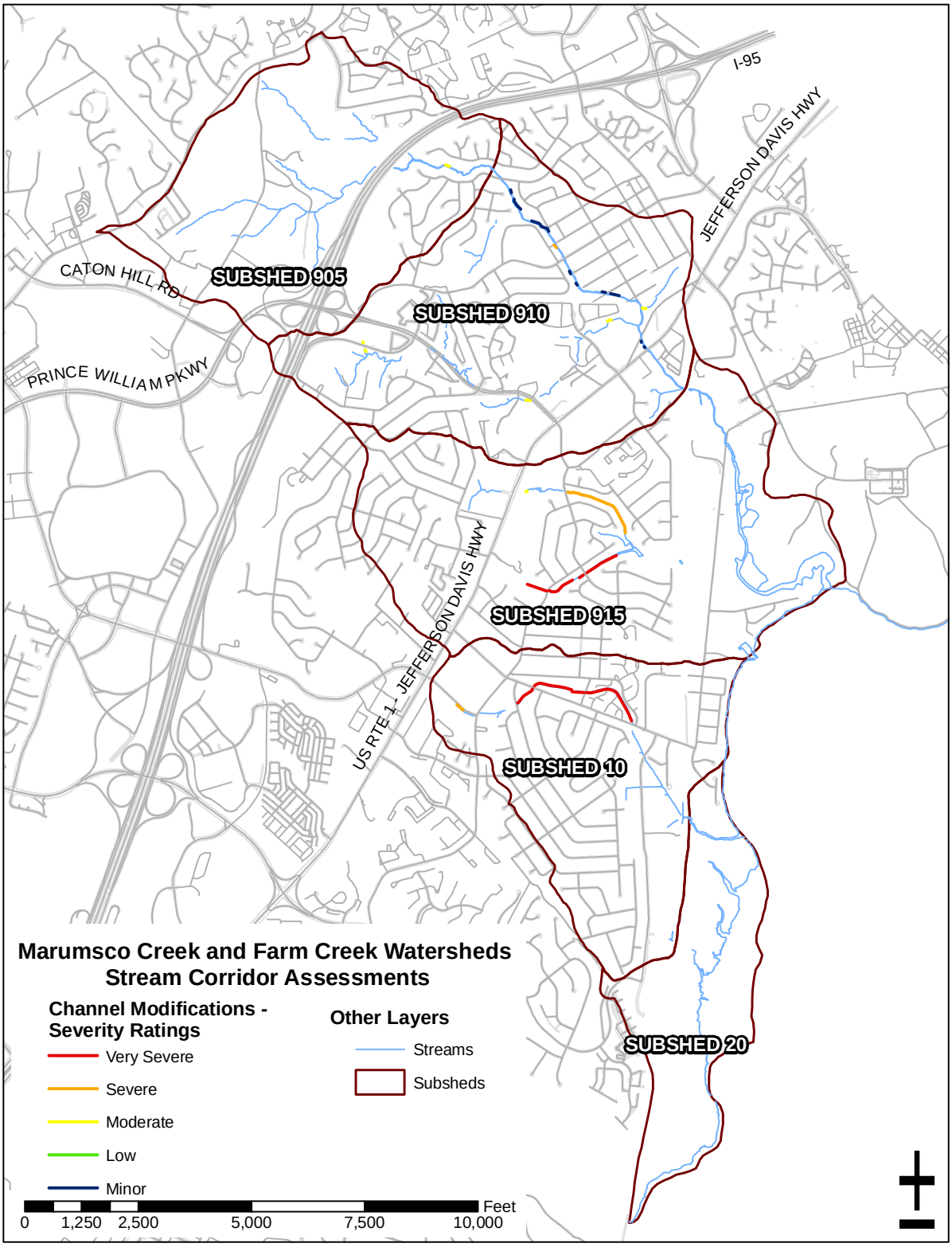

Figure 3-7: Channel Modification Site Locations

3.3.2.8 Miscellaneous Impacts

Miscellaneous impacts were used to document the location of any out of the ordinary or notable features observed during the stream assessments that did not fall within the other impact categories. A total of 28 miscellaneous impact sites were identified within the study area that could be potential water quality issues. The most common unusual conditions encountered were the presence of orange leachate and sometimes sheen (16 sites), stream bank destruction/channel blockage as a result of all terrain vehicle (ATV) crossings (3 sites), and beaver dams (2 sites). Some of the other unusual conditions encountered included invasive bamboo plants, a retaining wall failure, a complete fish blockage by a vertical drop in concrete channel, a septic tank in the stream channel, and a possible sanitary sewer overflow location. At these sites, the field team noted the location, described the condition, and recommended potential restoration actions. Potential restoration recommendations included stream restoration, prevention of ATV crossing, invasive removal or investigation. The presence of orange leachate was investigated and is discussed further in Chapter 4 – Geologic Water Quality Impacts.

3.3.2.9 Coastal Zone Assessments

The Marumsco Creek and Farm Creek watersheds include a considerable portion of the northern coastline of the County. Therefore, coastal zone assessments were also conducted to evaluate physical shoreline conditions and identify potential restoration opportunities within tidal areas. At each site, the field team recorded location, dimensions of the area surveyed, adjacent land cover, and land ownership. The physical shoreline conditions were also documented including structural conditions, if applicable. The field team also noted the presence of SAV and the width of the existing riparian buffer zone. Potential restoration recommendations included structural revetment, SAV plantings, marsh plantings, bioengineering, shoreline creation, beach nourishment, and/or none. Shoreline condition severity was rated on a scale of 1 (minor) to 5 (very severe) based on the extent of the impact. Each coastal zone site assessed was assigned one of the following severity ratings:

- ***5 (very severe):*** Large stretches of impaired shoreline with issues such as active erosion, little to no SAV near the shoreline, and tall eroding banks.
- ***4 (severe):*** Moderate stretches of impaired shoreline with issues such as active erosion, little to no SAV near the shoreline, and eroding banks.
- ***3 (moderate):*** Stable stretches of shoreline with little to no SAV and impaired habitat.
- ***2 (low):*** Short stable stretches of shoreline with little to no SAV and impaired habitat.
- ***1 (minor):*** Stable coastal zones impaired only by structural features in good condition.

Access to the site for restoration purposes was also rated on a scale of 1 (difficult) to 5 (good). Good access (rating = 5) was assigned to open, publicly-owned areas with easy access for heavy equipment and room for a staging area. Difficult access (rating = 1) was assigned to sites where it would require crossing a wetland, steep slope, or other sensitive areas requiring specialized equipment and where minimal space was available for stockpile materials.

A total of 12 coastal zone assessments were completed within the tidal portions of the study area. The table below summarizes the number of coastal zone assessment sites associated with each severity rating (1, 2, 3, 4, or 5).

Table 3-10: Coastal Zone Severity Ratings

Severity Rating	No. of Coastal Zone Assessments	Percentage
5 (Very Severe)	0	0%
4 (Severe)	1	8%
3 (Moderate)	2	17%
2 (Low)	2	17%
1 (Minor)	7	58%
Total	***12***	***100%***

Most of the coastal zone assessment sites (7 out of 12) were rated as minor water quality problems.

3.4 Stormwater Management Facilities

Existing SWM facilities within the Marumsco Creek and Farm Creek watersheds were investigated for their water quality treatment function and retrofit potential, if found lacking. As discussed in Chapter 2.1.4, there are a total of 29 SWM facilities throughout the Marumsco Creek and Farm Creek watersheds based on the County's database. These include dry and wet ponds, underground storage facilities, and infiltration trenches. Filtration/infiltration practices and extended detention facilities are considered to have higher pollutant removal capabilities since stormwater has a chance to infiltrate into the ground or through plant roots compared to SWM facilities, such as dry detention ponds, which are primarily designed for quantity control only.

Of the 29 existing SWM facilities, there are 17 dry and 4 wet detention ponds. These types of facilities have the potential for water quality retrofit which may include conversion to an extended detention facility, structural repair/improvement, re-vegetation or enhancement, and/or maintenance. The field team inspected a total of 12 existing SWM facilities (ponds) to identify water quality retrofit opportunities. Facilities were identified for investigation by a GIS-based, pre-screening analysis. The pre-screening was used to identify BMPs in older developments that would have a higher potential for maintenance or retrofit opportunities. The pre-screening identified 13 BMP sites for inspection of which the field team was only able to adequately access 12 of the site for a detailed investigation. For each facility, the field team documented the type of stormwater pond and pretreatment facility. The team also rated the condition of various components of the facilities on a scale of 0 (good) to 3 (serious), where 0 denotes a well maintained facility with no action required and 3 denotes an immediate need for repair or replacement. The components evaluated for pretreatment included maintenance access, trash/debris accumulation, sediment accumulation, clogging, dead vegetation/exposed soil, and erosion. Facility elements evaluated included maintenance access, sediment accumulation, water levels, pollution/hotspot runoff, vegetation and the condition of berms/embankments, risers/outlets, and low flow orifice. Outlet components assessed included stable conveyance, trash/debris/sediment accumulation, and erosion. The team also identified retrofit opportunities and noted any other considerations necessary. Most of the SWM facilities inspected (10 out of 12) were considered to have retrofit potential. Locations of surveyed SWM facilities are shown in Figure 3-8. Further discussion of SWM facility inspections, maintenance needs, and retrofit opportunities is included in Chapter 4.

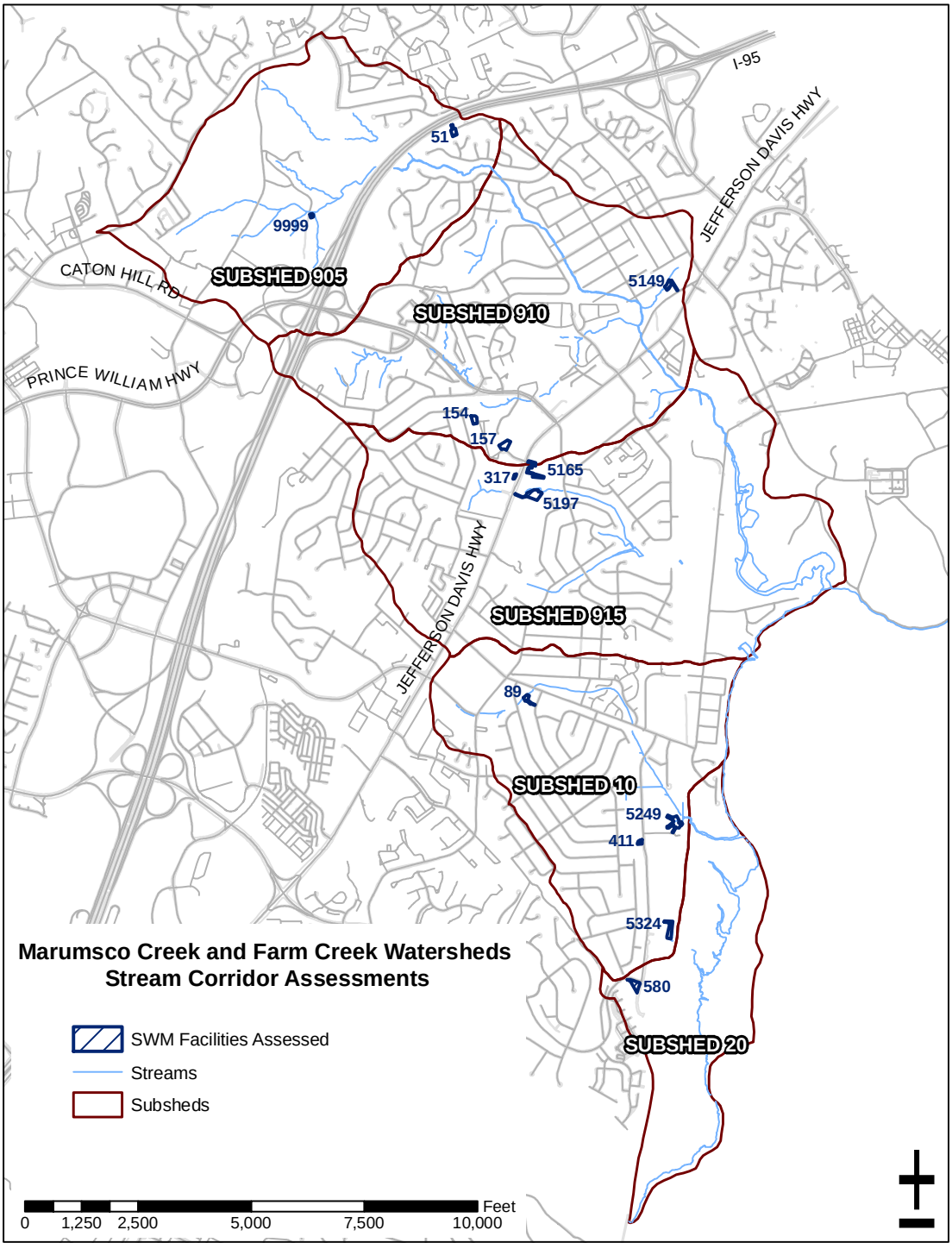

Figure 3-8: SWM Facility Survey Locations

CHAPTER 4: WATERSHED ACTION PLAN

4.1 Initial Watershed Management Strategies

Based on coordination with the County and the scope of this study, the following list of initial watershed management strategies were developed with the intent of incorporating them into final project concept plans as applicable.

1. Stream Corridor Improvement: Stream corridor assessments conducted throughout the watersheds revealed potential water quality and instability issues ranging from severe to minor problems. These included channel instabilities (e.g., erosion, channel modifications), utility and stream crossing conflicts, inadequate buffer zones, outfall impacts, and other miscellaneous issues discussed in Chapter 3. Potential stream corridor improvement techniques include stream stabilization (e.g., bioengineering, in-stream structures, grading), wetland restoration, outfall stabilization/retrofit, trash removal/prevention, and utility stabilization (e.g., removal, protective covering).

2. BMP Maintenance & Retrofit: Detailed inspections of several existing stormwater management facilities throughout the watersheds were completed. Potential water quality improvement opportunities were identified including maintenance and retrofit techniques. Maintenance may involve removal of sediment, invasive species, or other vegetation. Retrofits may include techniques such as conversion of older quantity control structures to quality control facilities, structural repair/improvement, and re-vegetation.

3. Trash Reduction and/or Abatement: During the stream corridor assessments, areas with significant trash issues were identified. The trash areas were divided into volunteer and local government projects. The identified projects should be incorporated into stream corridor improvement projects. Institution of community wide education and stream clean-up projects should be considered by the county outside of the Capital Improvement Projects discussed in the appendices.

4. Coastal Zone Improvements: During the stream corridor assessment, the tidal areas of the Marumsco Creek, Farm Creek and localized portions of the Occoquan Bay were investigated to find potential environmental enhancement projects. Three types of coastal zone improvement projects were identified during the investigations, with each type of project targeted at improving or enhancing aquatic habitat. The different enhancement techniques involve bank stabilization, submerged aquatic plantings and beach nourishment.

5. Flood Mitigation: Hydrologic and hydraulic studies of Marumsco and Farm Creeks previously prepared by regulatory agencies or other consultants were reviewed as part of the comprehensive watershed assessment. The results of the previous studies were analyzed and commented on based upon observations from the stream corridor field assessments, modern storm water management practices and modern stream corridor management practices. Conceptual alternatives for flood mitigation in certain areas are discussed in this chapter.

4.2 Recommendations

A total of 16 project concept plans have been developed based on the information collected during field assessments and from reviewing existing data and studies to address watershed degradation in the Marumsco Creek and Farm Creek watersheds. This includes 12 stream corridor improvement/flood mitigation projects and 4 coastal zone improvement projects. Water quality retrofit and maintenance opportunities were also identified during SWM facility inspections. Key watershed management strategies incorporated in the proposed projects are discussed in the subsequent sections. Appendix A includes conceptual plans for proposed Stream Corridor Improvement Projects (SCIPs). Appendix B includes summaries of the BMP maintenance inspections and conceptual retrofit opportunities. Appendix C includes conceptual plans for proposed Coastal Zone Improvement Projects (CZIPs). The project recommendations in appendices A and C are organized by watershed with the project titles including the subshed id, the type of project (SCIP or CZIP) and a numeric identifier. The BMP summaries in Appendix B are organized by the assigned PWC facility identification number. Each conceptual plan includes a problem description, discussion of concepts and benefits, an estimated cost, photos taken during field assessments, and a conceptual plan figure.

4.2.1 Stream Corridor Improvement

Stream corridor improvement practices are used to enhance the appearance, stability, and aquatic function on urban stream corridors. These projects are intended to provide water quality, aquatic habitat conservation, infrastructure maintenance and protection and natural resource conservation benefits throughout the Marumsco Creek and Farm Creek watersheds. Stream stabilization practices incorporated in the project concept plans range from simple, localized bank stabilization such as bank plantings to comprehensive repair such as constructed in-stream, rock toe and soil lift structures or bioengineering and natural channel design. Stream buffer restoration has also been incorporated into some project plans to address impacted buffer areas and reduce the runoff and pollutant loadings from developed areas from entering the stream system. Trash dumping was a recurring issue observed during stream assessments. Therefore, several projects also involve trash reduction and/or abatement measures such as stream cleanups and illegal dumping prevent programs. Outfall and utility stabilization has also been incorporated into several of the stream corridor improvement projects. For example, this may include removing and repairing abandoned outfalls or exposed pipes or using grade stabilization to protect endwalls from undermining.

A summary of proposed stream corridor improvement projects and cost estimates is provided in the table below. The provided cost estimates are planning level cost estimates and were developed based upon PB's experience with similar projects located in Maryland, Virginia and North Carolina. The cost estimates were developed by considering the size of the proposed project, design and construction complexities, and general material cost expectations. Conceptual plans for stream corridor improvement projects are included in Appendix A.

4.2.2 Flood Mitigation

Chapter 2 documented 10 locations within Marumsco Creek that are subjected to flooding based on FEMA flood hazard mapping. The primary causes of flooding to these locations include the following: backwater from undersized stream crossings, floodplain encroachment from developments and coastal storm surge flooding. The causes, locations, and potential conceptual improvements to mitigate the flooding concerns are described below. The descriptions, causes and improvement recommendations documented below are based upon qualitative analysis of FEMA mapping and are not supported by detailed hydrologic and hydraulic modeling performed for the purposes of this study.

Flooding at the Easy Street crossing, the Route 1 crossing, and the CSX Railroad crossings of Marumsco Creek are being caused by undersized culvert crossings at each of these locations. Included in the flooding at these locations are the Holly Acres Trailer Park and multiple commercial properties along Route 1 and Easy Street. However, analysis of the flood profiles prepared as part of the FEMA study show that the backwater effect caused by the CSX Railroad crossing dominates the hydraulics of Marumsco Creek up through the Route 1 and Easy Street crossings. As such, improvements to flood conveyance at the CSX Railroad crossing will improve the flooding conditions at Route 1 and Easy Street, whereas improvements to the Route 1 or Easy Street crossings without improvements to the railroad will have minimal beneficial effects to flooding. Prior reports recommended either replacement of the culvert crossing below the railroad or acquisition and removal of a portion of the improved properties (Holly Acres) within the backwater area. However, the use of pipe jacking or micro-tunneling for the installation of supplemental floodplain culverts may be a more cost effective method for increasing the hydraulic capacity of the railroad crossing. Prior experience has shown that railroad companies are amenable to these types of improvements as they generally can be performed with minimal disruption to regular operational schedules. Since hydraulic computations have not been performed specific commentary on the size and number of supplemental floodplain culverts have not been determined, but it is assumed that multiple pipes will be required. Anticipated costs for installation of the floodplain culverts are in the range of $1 million to $2 million. Replacement or improvement options for the Easy Street and Route 1 crossings may be effectively revisited after improvements to the railroad crossing have been implemented. The County should consider developing detailed hydrologic and hydraulic studies to analyze the potential of this project, the required pipe sizes, and estimated costs for mitigation of flooding along the Route 1 corridor.

Similar to the previous conceptual discussion, flooding to the commercial / industrial property off of Industry Court is also an effect of backwater from undersized culvert crossings through the CSX Railroad embankment. The flooding source at this location is Marumsco Creek Tributary A at the outlet of Marumsco Acres Lake. As with the other CSX railroad crossing, pipe jacking or micro-tunneling for installation of supplemental floodplain culverts would be an effective method for mitigation of backwater related flooding at this location.

The flooding of residential properties within the Bott's subdivision along Baxter Street, D Street and Congress Street are the result of either improper construction and confinement of the natural floodplain or increased 100-year storm discharges due to development of the watershed without adequate stormwater quantity control. Mitigation of flooding volumes at these locations could be attained through retrofitting existing storm drain systems with storm water management BMP's such as underground vaults, small localized ponds, infiltration trenches, or

other localized low impact management methods. Flood levels could potentially be reduced through these areas through stream reconstruction / restoration using a tiered channel approach that focuses on creation of lower floodplain areas while maintaining a natural, stable channel geometry.

The property at the intersection of Horner Road and Millwood Drive along Marumsco Creek is potentially flooded by backwater effects from the Horner Road culverts. The size and alignment of the Horner Road crossings may not allow for use of supplemental floodplain culverts to increase the hydraulic capacity of the opening. Options for reducing flooding at this location include reduction of flood volumes using the aforementioned storm water management BMP retrofits or improvement of flood capacity through replacement of the crossing.

The Marumsco Neighborhoods mobile home park along Griffin Drive is potentially flooded due to insufficient hydraulic capacity of the culverts that pass below the park and insufficient fill placement that may not have risen to above the original floodplain level. The flooding at this location is caused by Marumsco Creek Tributary B. Detailed hydrologic and hydraulic studies of Tributary B may provide additional insight and options for mitigation of flooding in this area, but the data review provided herein does not show any potential for mitigation of flooding in this area.

The final flooding problem areas noted in the analysis of the FEMA mapping include properties off of Bay Street, Bay Circle, Tyrell Lane, and Featherstone Road. The properties are subject to coastal storm surge flooding. Since coastal storm surge flood stages are driven by barometric pressure levels and wind forces, mitigation of the flood levels is not possible. The only methods available for protection of these properties include the costly construction, management, maintenance and regulation of protective levee systems or reconstruction of properties on fill raised above the coastal storm surge levels.

4.2.3 BMP Retrofits & Maintenance

Detailed inspections of the existing SWM facilities revealed potential retrofit opportunities to address stormwater runoff and reduce pollutant loads from adjacent residential, commercial, and industrial areas. Several of the existing SWM facilities surveyed also had opportunities for maintenance to improve water quality function. A summary of the 13 SWM facilities surveyed including initial recommendations is provided in the table below.

Table 4-2: SWM Facility Survey Summary

Facility ID	Subshed	Type	Extended Detention	Pre-treatment	Retrofit Potential	Initial Recommendation
51	905	Dry	-	-	Y	Outfall conversion, Micropool Creation
89	10	Dry	-	-	Y	Outfall conversion, Micropool Creation
154	910	Dry	Y	-	-	-
157	910	Dry	Y	-	Y	Wetland creation
317	915	Dry	Y	-	-	-
411	10	Dry	Unknown	-	Y	Wetland plantings
580	20	Dry	-	-	Y	Maintenance
5149	910	Unknown	Unknown	Unknown	Y	Extended detention & micropool retrofit
5165	915	Dry	Unknown	-	Y	Extended detention, Reinforcement planting
5197	910	Dry	Unknown	Unknown	Unknown	No access
5249	10	In-line	-	-	Y	Outfall conversion
5324	10	Dry	-	Y	Y	Outfall conversion, Micropool Creation, Extended detention
9999	915	Dry	Y	-	Y	Maintenance

Detailed inspection findings including proposed BMP retrofit/maintenance projects are included in Appendix B. Most of the proposed SWM retrofit projects involve conversion of old quantity control structures to quality control facilities. Recommendations include outfall conversions and extended detention. Some project concepts also include wetlands and micropool creation which are intended to remove sediment and enhance SWM effectiveness. Maintenance recommendations include removal of woody vegetation, invasive species, and/or sediment in some ponds and along embankments and access roads. In some cases, this is combined with replanting of appropriate vegetation to achieve water quality benefits. Other facilities are recommended for regular trash maintenance and/or debris removal to restore water quality function and in some cases, to prevent flooding. A summary of proposed BMP maintenance/retrofit projects and cost estimates is provided in the table below. The provided cost estimates are planning level cost estimates and were developed based upon PB's experience with similar projects located in Maryland, Virginia and North Carolina. The cost estimates were developed by considering the size of the proposed project, design and construction complexities, and general material cost expectations.

Table 4-3: SWM Facility Project Recommendations and Costs

SWM ID	PROJECT TYPE	CONSTRUCTION COST	DESIGN COST	TOTAL COST
51	Conversion to Extended Detention, Micropool Creation	$150,000.00	$40,000.00	***$190,000.00***
89	Conversion to Extended Detention, Micropool Creation, Maintenance	$100,000.00	$40,000.00	***$140,000.00***
154	Maintenance	$5,000.00	$ -	***$5,000.00***
157	Wetland creation, maintenance	$60,000.00	$10,000.00	***$70,000.00***
317	None	$-	$ -	***$-***
411	Wetland creation	$60,000.00	$10,000.00	***$70,000.00***
580	None	$-	$ -	***$-***
5149	Maintenance	$5,000.00	$ -	***$5,000.00***
5165	Maintenance	$5,000.00	$ -	***$5,000.00***
5197	No access	$-	$ -	***$-***
5249	Coversion to Extended Detention	$100,000.00	$30,000.00	***$130,000.00***
5324	Conversion to Extended Detention, Micropool Creation	$150,000.00	$40,000.00	***$190,000.00***
9999	Maintenance	$5,000.00	$ -	***$5,000.00***
	Totals:	***$640,000***	***$170,000***	***$810,000***

4.2.4 Geologic Water Quality Impacts

Field inspection of Farm Creek, Marumsco Creek and their tributaries have show several widespread areas where orange leachate is seeping out of the stream banks and entering the stream channel. The orange leachate is commonly present in the water as an orange precipitate with an associated sheen on the water surface. Investigation into the geology of the region (discussed in Chapter 2) has shown that there are two type of toxic minerals / heavy metals present within the local soils that are commonly associated with orange staining of streams: ferrous iron and iron pyrite.

Iron pyrite (FeS_2) is a common mineral that may be found in the Chopawamsic, Occoquan Granite and Quantico Formations around Marumsco Creek. Iron pyrite will dissolve into groundwater flows in an anaerobic state. Groundwater with the dissolved FeS_2 will be generally clear and flow freely as groundwater; however, when the groundwater leaches from the ground (e.g., into the stream banks) the oxidation reaction of the dissolved pyrite produces acid rock drainage (ARD). Acid rock drainage (commonly referred to as acid mine drainage) can be a naturally occurring environmental condition, though it is most commonly associated with mining or other earth disturbances. The oxidation reaction responsible for creation of ARD converts FeS_2 to ferrous iron (Fe^2), sulfate (SO_4), and hydrogen ions (H^+). The ferrous iron manifests as the yellow-orange precipitate. This precipitate can lead to adverse water quality impacts such as clogging the respiratory systems of aquatic animals and blocking sunlight from aquatic plants. The hydrogen ions from the reaction lower the pH of the receiving waters, creating an inhospitably acidic environment. ARD is known to decrease pH levels to as low as 3. Sulfate is considered by the USEPA to be a water quality contaminant. In general, it can disturb the

health of an aquatic system, but is most commonly associated with affecting the smell of a water body.

Ferric Iron (Fe^3) is also a common mineral that may be found interspersed in the Potomac sedimentary formation in the Marumsco Creek and Farm Creek watersheds. Similar to iron pyrite, ferric iron will dissolve into groundwater flows in an anaerobic state (know as ferrous oxide), flow freely, then undergo an oxidation reaction upon leaching from the stream bank. The oxidation reaction in this case produces ferric hydroxide ($Fe(OH)_3$) and hydrogen ions (H^+). Similar to the ferrous iron, the ferric hydroxide forms an orange precipitate which similarly can have adverse impacts on water quality such as clogging the respiratory systems of aquatic animals and blocking sunlight from aquatic plants. The hydrogen ion released also acts to lower the pH of the receiving waters; however, significantly lower concentrations of the hydrogen ions are released in this reaction and the pH reduction will not be as dramatic as experienced with ARD.

Additional evidence noted during the field inspection that supports the ARD and ferric iron speculation include the presence of sheen along the waters surface at many of the noted leachate locations. The noted sheen appears to be colonies of iron metabolizing bacteria that are commonly associated with either ARD or dissolved ferric iron streams. These colonies, when naturally occurring, could consist of *Acidithiobacillus ferrooxidans* or *Acidithiobacillus thiooxidans* bacteria.

Water quality testing is the only method for determining the specific type of natural water quality contaminant that is entering the stream. However, the mild nature of the impacts caused by the leachate and the widespread nature of the problem, seemingly indicate that dissolved ferric iron and not necessarily ARD is entering the streams. The prevalence of the Potomac Formation as opposed to the formations supporting iron pyrite support this conclusion as the noted locations of the leachate covered a significant portion of the stream's watershed.

The non-point source nature of this water quality pollutant will make treatment and mitigation of the ferric oxide nearly impossible. Future water quality testing, any animal species sampling studies and stream impairment considerations (e.g. 303d) for these streams will need to consider this mineral contamination as an important component of the Marumsco Creek and Farm Creek natural conditions. The mineral and pH levels present within the stream will also be an important consideration in any habitat improvement or species integration programs under consideration for either of these stream systems.

4.2.5 Coastal Zone Improvement

The field investigations of the tidal zones within Marumsco and Farm Creeks revealed a generally healthy coastal environment with ample tidal marshes, stable shorelines and dense forested buffers. The investigations along the local portion of the Occoquan Bay showed significant human influences, with the majority of the shoreline being reconstructed and hardened using timber bulkhead. Additionally, the forested buffer has been removed and replaced by upscale residential neighborhoods and lawns. However, the timber bulkheads were predominantly determined to be in good condition during the inspections and the potential for restoration or construction of living shorelines in these areas appears to be very low.

The developed costal zone improvement projects are intended to develop new habitat, improve water quality, protect existing habitat, and protect the natural shorelines of Marumsco Creek and

Farm Creek in the tidal areas and the Occoquan Bay. The proposed improvement practices range from small scale installations of coir fiber breakwaters and SAV plantings to complex stone jetty and beach nourishment projects.

A summary of proposed coastal zone improvement projects and cost estimates is provided in the table below. The provided cost estimates are planning level cost estimates and were developed based upon PB's experience with similar projects located in Maryland, Virginia and North Carolina. The cost estimates were developed by considering the size of the proposed project, design and construction complexities, and general material cost expectations. Conceptual plans for coastal zone improvement projects are included in Appendix C.

Table 4-4: Coastal Zone Improvement Projects – Cost Estimates

PROJECT ID	PROJECT TYPE	UNIT	QTY	UNIT COST	CONSTRUCTION COST	DESIGN COST	TOTAL COST
915-CZIP-01	Coastal Marsh Enhancement	LF	183	$30.00	$5,490.00	$-	***$5,490.00***
915-CZIP-02	Coastal Marsh Enhancement	LF	1000	$30.00	$30,000.00	$8,000.00	***$38,000.00***
20-CZIP-03	Beach Nourishment	LF	290	$1,200.00	$348,000.00	$150,000.00	***$498,000.00***
20-CZIP-04	Bank Stabilization	LF	150	$1,000.00	$150,000.00	$80,000.00	***$230,000.00***
				Totals:	$533,490	$238,000	***$771,490***

4.2.6 Maintenance and Outreach Programs

The primary focus of this report is the development of capital improvement projects to be implemented by Prince William County for improving the quality of the Marumsco and Farm Creek streams and watershed. However, aside from the noted capital improvement projects, the watershed assessment identified many stream impacts that may be more effectively implemented by county maintenance programs and community outreach efforts. The assessments estimated that a total of 163 pick-up truck loads would be required to remove trash and debris from the streams and dumping sites. The significant and widespread amount of the trash and dumping observed suggest larger issues with community perception that the County will need to address. Prince William County should consider implementing proactive and focused community outreach programs directed at educating the community of the value and importance of the streams and the adverse impacts of littering and dumping. The outreach program will be most effective through support and collaboration with local watershed associations, organized stream clean-up activities, and a visible posting of stream protection areas.

Street sweeping and trash rack maintenance activities are maintenance programs that the County should re-evaluate. The County maintains several trash racks at culvert crossings along Marumsco Creek, Farm Creek and their tributaries. During the watershed assessments it was noted that at many of these locations, the debris cleaned from the racks was dumped in the floodplain adjacent to the racks. The County should consider developing guidelines for maintenance personnel responsible for these racks that include requirements for removal of all trash and debris from the stream and disposal off-site in an appropriate manner. The street sweeping program currently implemented by the county was not reviewed as part of this study. However, the large amounts of street litter present in the streams indicate that the County should review the program and evaluate the focus, frequency and coverage of the program. Additionally, the County should consider developing a database system for tracking of trash / debris removal volumes for use in supporting the County's NPDES / MS4 program and future TMDL requirements.

4.2.7 Upland Considerations

This study provides a limited evaluation of the existing landuses within the Marumsco and Farm Creek watersheds and the stormwater management practices within each development. The results of the analysis show that large portions of the watershed are developed and directly connected to the streams, yet have no stormwater management practices in place. Construction of stormwater management BMPs for these older developments is a very costly and difficult undertaking using standard retention pond (in-line or off-line) designs. In these areas the County should consider development of low impact development (LID) retrofit projects within the communities. Types of LID retrofits that can be implemented within the existing developments include downspout disconnections with rain barrels or rain gardens, conversion of roadside ditches into bioswales, installation of bioretention areas, and removal of paved surfaces / impervious areas (Jefferson Plaza) that are seldom used. The majority of these types of projects will inherently be located on privately owned lands and will require close coordination between the County, local watershed organizations, and the community. Outreach programs focused on environmental stewardship education throughout the community will help provide the County with the means of executing this type of program. This study does not provide a comprehensive evaluation of the upland conditions within the watershed and cannot provide

specific recommendations for development of a LID retrofit program or outreach program for the community. The County should consider supplementing the current watershed study which focuses on the stream corridors with an upland study that is focused on the existing development practices and opportunities for environmental stewardship projects.

CHAPTER 5: REFERENCES

Bengston, Paul E. October 1977. *Study of Marumsco Creek Storm Drainage, Prince William County Virginia.*

Bernard Johnson Incorporated. April 13, 1989. *Marumsco Creek Regional SWM Ponds.* Technical Report Submitted to Prince Williams County Department of Public Works.

CH2M HILL. July 2004. *Prince William County Stream Protection Strategy.*

Center for Watershed Protection (CWP). February 2005. *Unified Stream Assessment: A User's Manual, Version 2.0*. Urban Subwatershed Restoration Manual Series, Manual No. 10. Prepared for USEPA, Office of Water Management.

Gannett Fleming. June 10, 1981. *Prince William County, Virginia Comprehensive Storm Drainage Study #15*. Preliminary Study Report, Work Item 35, Department of Development Administration.

Karnes, Debrarae. *The History of the Prince William County Waterfront*. Division of Long-Range Planning, Prince William County Planning Office, Prince William Virginia. Website: *http://www.pwcgov.org/docLibrary/PDF/000586.pdf*

Prince William County (PWC). March 18, 2008. *2008 Comprehensive Plan Prince William County.* Office of Planning, Prince William, Virginia. Website: *http://www.pwcgov.org/planning/*

Prince William County (PWC). June 6, 2006. *Marumsco Acres Lake Litter Study Report.*

U.S. Department of Agriculture (USDA). June 1986. *Technical Release 55: Urban Hydrology for Small Watersheds.* Natural Resources Conservation Service (NRCS), Conservation Engineering Division.

U.S. Fish and Wildlife Service (USFWS). September 30, 2009 (last updated). *National Wildlife Refuge System*. Website: *http://www.fws.gov/Refuges/*

Virginia Department of Environmental Quality (VADEQ). October 2008. *Virginia 305(b)/303(d) Water Quality Integrated Report.* Submitted to Congress and USEPA Administrator for the period January 1, 2001 to December 31, 2006, Richmond, VA. Website: *http://www.deq.virginia.gov/wqa/ir2008.html*