FINAL
WATTS BRANCH
WATERSHED ASSESSMENT

September 2015

Prepared for:

City of Rockville, Maryland
Department of Public Works

Prepared by:

BayLand Consultants & Designers, Inc.

Table of Contents

List of Figures

List of Tables

Appendices

EXECUTIVE SUMMARY

Introduction

The City of Rockville (the City) understands the importance of the health of streams. The City's urban nature presents challenges to stream quality. Urban development increases the amount of impervious surface, which prevents or inhibits the infiltration of rainwater into the earth. Impervious surface, such as buildings, paved roads and parking lots, and even highly compacted soil or gravel, causes stormwater to "run off" into storm drain pipes and streams. As the water runs over land, it picks up pollutants like oil, fertilizer, pesticides, pet waste, and sediment. Without effective water quality treatment, these pollutants impact a stream's water quality. In addition to debris and other pollutants entering storm drains, the fast-flowing water causes stream banks to continually erode for decades, dumping more sediment into waterways.

The City has a comprehensive program which includes extensive watershed protection and restoration planning, enforcement of water quality protection ordinances, Capital Improvements Program projects, outreach and education, monitoring, and infrastructure inspection and maintenance. The City is not only driven by a stewardship ethic but also has strong Federal and State stormwater management regulatory requirements to follow. Most notably, both the Clean Water Act's (CWA) Total Maximum Daily Load (TMDL) program and the National Pollutant Discharge Elimination System (NPDES) permit, which are administered through U.S. Environmental Protection Agency (EPA) and Maryland Department of the Environment (MDE), are part of the City's regulatory environment.

In 2010, the EPA, in conjunction with MDE, established the Chesapeake Bay TMDL which presented a nitrogen, phosphorus and sediment pollution diet to restore clean water to the Bay and the streams that feed into the Bay. As a result, the states that surround the Bay developed Watershed Implementation Plans (WIPs) which included strategies to meet the TMDL target (MDE, 2013).

Scope of this Assessment

This study was initiated to evaluate current conditions, including habitat assessment, in the Watts Branch watershed within the City that affect stream quality and to identify future stream erosion and water quality concerns. This study compares the findings of the 2001 Watts Branch Watershed Study and Management Plan (Center for Watershed Protection, 2001) with the findings of this report to understand the current and expected future state of the watershed. This study investigated potential upstream pollution sources. This report does not recommend specific Capital Improvements Program projects nor specific programmatic solutions to water quality issues. It does provide findings that the City will consider for future project-level and programmatic TMDL reduction strategies.

Background

Watts Branch originates in the western half of the City of Rockville, then flows through Montgomery County to its confluence with the Potomac River. It enters the Potomac just upstream of the Washington Suburban Sanitary Commission's (WSSC's) Potomac Water Filtration Plant, which supplies drinking water to most of Montgomery County and some of Prince Georges County.

The City's Watts Branch watershed has a drainage area of 5.99 square miles (3,832 acres). It is an urban watershed that includes I-270 and parts of the Rte. 355 corridors, the mixed-used developments at King Farm and Fallsgrove, Montgomery College's Rockville campus, and many residential areas. The watershed has approximately 18 miles (95,000 linear feet) of stream within the City limits.

Findings/Watershed Characterization

Land Use Analysis

Land use within the Watts Branch watershed consists of 53% residential development, 26% non-residential (institutional, industrial, and commercial), 19% open space (pasture, cropland, open urban land, forests, and water), and 2% transportation. Much of Watts Branch in Rockville was developed in the 1960s-70s and therefore has little or no stormwater treatment. The impervious area in the watershed increased from 28% in 2001 to 41% in 2013 as a result of the King Farm and Thomas Farm/Fallsgrove development areas. New impervious areas were also created by infill office or residential development, a new mixed-use complex north of King Farm, and additions at Montgomery College.

Urban tree canopy provides many benefits to the urban environment. The tree canopy in Watts Branch based upon 2007 data is 39% which is close to the American Forests recommendation of 40% tree cover for urban areas. Wetlands help filter pollutants, store flood waters, and provide wildlife habitat. Only approximately 59 acres (1.5%) of the watershed is comprised of mapped wetlands. Urbanized areas developed in the 1940s through the 1970s typically have few wetland areas because policies and regulations for wetland preservation were not widespread until after the Clean Water Act was enacted in 1972.

Potential pollution sources were investigated in the watershed. As a whole, there was little observed point-source pollution found during the field assessment. The main observed non-point source pollutant was sediment from eroding stream banks. Herbicides, pesticides, and fertilizers, which are commonly used on golf courses and residential properties, were considered the next most significant non-point source pollutants because of algae blooms found in streams which is indicative of fertilizer usage.

Water Quality Impairments

Watts Branch is not specifically listed as an impaired water; however, the MDE has listed the Potomac River within Montgomery County (which Watts Branch feed into) as a 303(d) impaired water for PCB in fish tissue, chlorides, sulfates, and total suspended solids. TMDLs have been developed for some of these pollutants. In addition, Watts Branch is regulated by the Bay-wide TMDL for sediment and nutrients.

Stormwater Management

The City's stormwater management infrastructure performs an essential role in mitigating the effects of development on streams and surrounding environmentally sensitive areas. The stormwater management infrastructure is designed to collect and slow down stormwater runoff in order to allow time to separate out pollutants that are taken up as rain passes over impervious surfaces. Many of the City's stormwater management facilities were built prior to 1998 when the amount of initial runoff they were designed to treat was only 0.5" compared to 1.0" after 1998. Of the 285 private and 91 public facilities, 202 facilities provide either partial or full water quality treatment and provide some pollution removal. The remaining facilities provide water quantity treatment only. Approximately 52% of the impervious area within the watershed is being treated at least partially with at least 48% of the watershed draining to at least one water quality facility. Through the City's Capital Improvements Program (CIP), many of these older facilities are being retrofitted to meet current standards and provide better water quality treatment.

Stream Assessment

A comprehensive stream assessment was conducted on 16.6 miles of stream within Watts Branch. The field crews walked a total of 16.6 miles of stream and created geomorphic maps for each stream reach. The geomorphic maps included areas of bank erosion, deposition, invasive species, riparian vegetation, lateral and vertical instability, debris jams, condition of utility infrastructure, outfall conditions, water quality concerns, stream buffer concerns, bank and bed stabilization structures (riprap, cross vanes, etc.), downed trees, pool and riffle depths, and bed material. The collected data, as shown on the maps in this report, were used to determine the overall stability of the reach.

The health and condition of each stream segment was rated using the Overall Stream Condition Datasheet extracted from the Unified Stream Assessment (USA) methodology (Kitchell and Schueler, 2004). Each parameter is rated from optimal to poor and given a numerical value. Several other datasheets extracted from the Unified Stream Assessment (USA) method were also used in the assessment to note areas where outfalls and utilities were failing and/or needed repair and areas of extreme trash.

Overall, stream reaches within Watts Branch showed characteristics of typical urban streams: high bank erosion, widened or entrenched channels, narrow riparian buffer, poor water quality, invasive species, and piped/straightened channels. Therefore, this study recommends some stream areas be considered for future repair. Nine outfalls had stabilization issues and were highlighted as concerns. In addition 14, utilities were exposed or had other potential maintenance issues identified. Between 2001 to 2014, the City constructed 3.25 miles of stream restoration/stabilization measures in Watts Branch. Although most projects were very successful at reducing bank erosion and in-stream sediment loads, some had localized spot failures. These areas were highlighted and recommended for continued monitoring.

Geomorphic Assessment

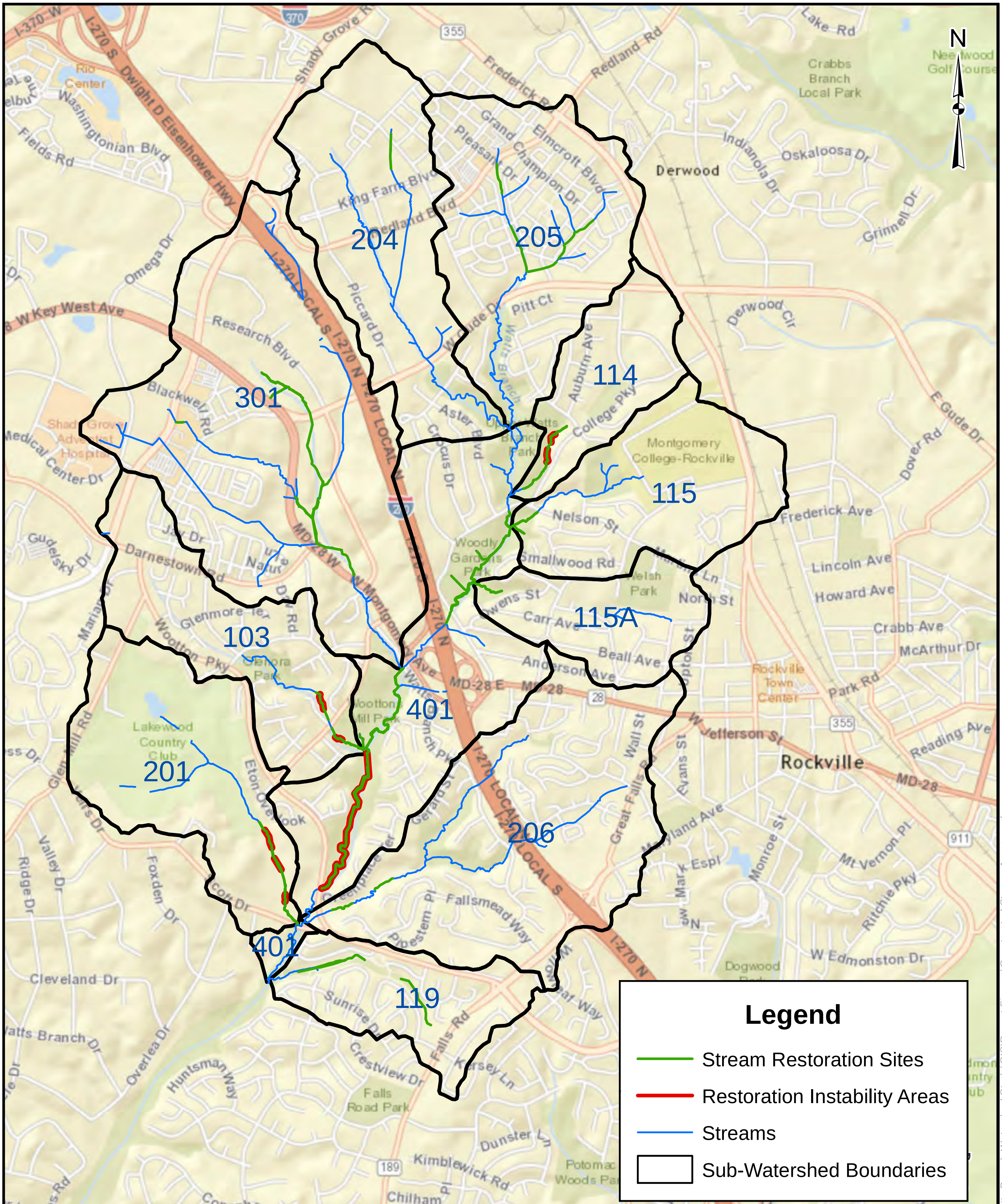
Geomorphic assessments were conducted at 10 stream cross-section sites first evaluated in the 2001 study. At each of the 10 sites, physical measurements of the channel were surveyed including a new cross-section measurement, profile, and pebble count. Each site was classified according to the Rosgen stream classification system. All the reaches assessed showed some signs of erosion, downcutting/widening and instability.

Four of the cross-sections were at locations that have not been stabilized by stream restoration projects. These sites showed signs of lateral and vertical instability (i.e., the stream channel had migrated sideways or downcut).

Six of the cross-section sites were located within reaches that had been restored/stabilized since the 2001 assessment. Where the stream banks are immobilized by the stone reinforcement of stream restoration, typical channel movement is prevented at those stone structures. However, adjacent sections of the channel may continue to change.

In general, the repaired banks at the College Gardens, Woodley Gardens Park and Woottons Mill Park stream restoration projects were still stable, although several places in the ten-year-old Woottons Mill Park project developed localized spot failures behind riprap bank protection or downstream of rock vane structures. Other instability at these six cross sections was associated with the repaired stream bank being stable, but the opposite side continuing to migrate or areas downstream of the restoration project continuing to erode. Figure 1 shows stream restoration projects across the watershed.

It is important to note that the stream restoration projects have retarded erosion and instability over the great majority of the stream lengths. Since a series of rock vanes and bank protection measures are installed along a stream reach, these tend to contain a spot failure to a single short section.



0 1,250 2,500 5,000

Feet

1 inch = 2,500 feet

BayLand Consultants & Designers, Inc.

"Integrating Engineering and Environment"

1321 Mercedes Drive, Suite A
Hanover, Maryland 21076

Phone: (410) 694-9401
Fax: (410) 694-9405

bayland@baylandinc.com

FIGURE 1
STREAM RESTORATION SITES

P:\18_19201_City of Rockville Watts Branch Watershed Study\GIS\Report Figures\Constructed Stream Areas.mxd

Conclusion

The City completed the original Watts Branch Watershed Study and Management Plan in 2001, which evaluated stream conditions and recommended a number of traditional stormwater management retrofits and stream restoration projects. To date, seven stormwater management CIP projects and seven stream restoration CIP projects have been completed.

This 2015 assessment was conducted to: compare existing conditions in the watershed with conditions in 2001, to update the previous hydrology model based upon land use changes and upgrades to stormwater management facilities, and to evaluate the success of the CIP projects.

Since 2001, two major land use changes in the watershed have occurred, the development of the King Farm and Thomas Farm/Fallsgrove areas, as well as infill in other parts of the watershed. As a result, the imperviousness in Watts Branch Watershed within the City increased from 28% in 2001 to 41% in 2013.

The stream assessment results indicated varying levels of stability within the watershed. Most of the streams display typical characteristics of urban streams: bank erosion, lack of floodplain access, lateral and vertical instability, limited riparian buffer, and straightened channel. Successful stream restoration CIP projects overall have reduced bank erosion, restored floodplain access, increased the woody riparian buffer, and provided in-stream habitat.

The geomorphic assessment results also indicated varying degrees of instability at ten cross section sites, primarily on the mainstem of Watts Branch. Six of these sites were located within stream restoration projects completed since 2001. These locations were generally stable and stream erosion was retarded. All four of the unaltered cross section locations showed signs of continued erosion and expansion and had transitioned into unstable channels.

It is the goal of the City that this current assessment will be used as a foundation for comparison for future Watts Branch watershed studies.

1 INTRODUCTION

The City of Rockville (the City) understands the importance of the health of streams. Before any development occurred, much of the rain and melting snow soaked into the soil. Water that did not soak into the soil evaporated, was absorbed by plants or traveled slowly over land to streams, wetlands, and ultimately the Chesapeake Bay.

The City's urban nature present challenges to stream quality. Urban development increases the amount of impervious surface, which prevents or inhibits the infiltration of rainwater into the earth. Impervious surface, such as buildings, paved roads and parking lots, and even highly compacted soil or gravel, causes stormwater to "run off" into storm drain pipes and streams. As the water runs over land, it picks up pollutants like oil, fertilizer, pesticides, pet waste, and sediment. Without effective water quality treatment, these pollutants impact a stream's water quality. In addition to debris and other pollutants entering storm drains, the fast-flowing water causes stream banks to continually erode for decades, dumping more sediment into waterways.

Rockville created the first stormwater management program in Maryland in 1978 to address flood control. In 1982 the State of Maryland followed suit by requiring local jurisdictions to adopt local ordinances for the control of stormwater generated by development. These early programs focused on preventing floods from larger storms but did little to protect water quality in streams. Throughout the following decades, stormwater management techniques evolved to better protect water quality, with Rockville's program frequently leading the way. Today, the City's comprehensive program includes extensive watershed protection and restoration planning, enforcement of water quality protection ordinances, Capital Improvements Program (CIP) projects, outreach and education, monitoring, and infrastructure inspection and maintenance.

The City is not only driven by a stewardship ethic but also has strong Federal and State stormwater management regulatory requirements to follow. Most notably, both the Clean Water Act's (CWA) Total Maximum Daily Load (TMDL) program and National Pollutant Discharge Elimination System (NPDES) permit, which are administered through U.S. Environmental Protection Agency (EPA) and Maryland Department of the Environment (MDE), are part of the City's regulatory environment.

When streams, lakes, and other bodies of water in Maryland are impaired, a TMDL or "pollution diet" is created by MDE. The TMDL restricts the amount of contamination that is allowed to flow into a specific water body. Specific industrial activity, including water or wastewater treatment plants, municipal maintenance yards, and certain commercial businesses like swimming pools, are directly regulated through NPDES permits issued for that property. For nonpoint-source discharges from a shared storm drain network, such as the City of Rockville, these pollution restrictions are administered through an NPDES Municipal Separate Storm Sewer System (MS4) permit.

In 2010, the EPA, in conjunction with MDE, established the Chesapeake Bay TMDL which presented a nitrogen, phosphorus and sediment pollution diet to restore clean water to the Bay and the streams that feed into the Bay. As a result, the states that surround the Bay developed

Watershed Implementation Plans (WIPs) which included strategies to meet the TMDL target (MDE, 2013).

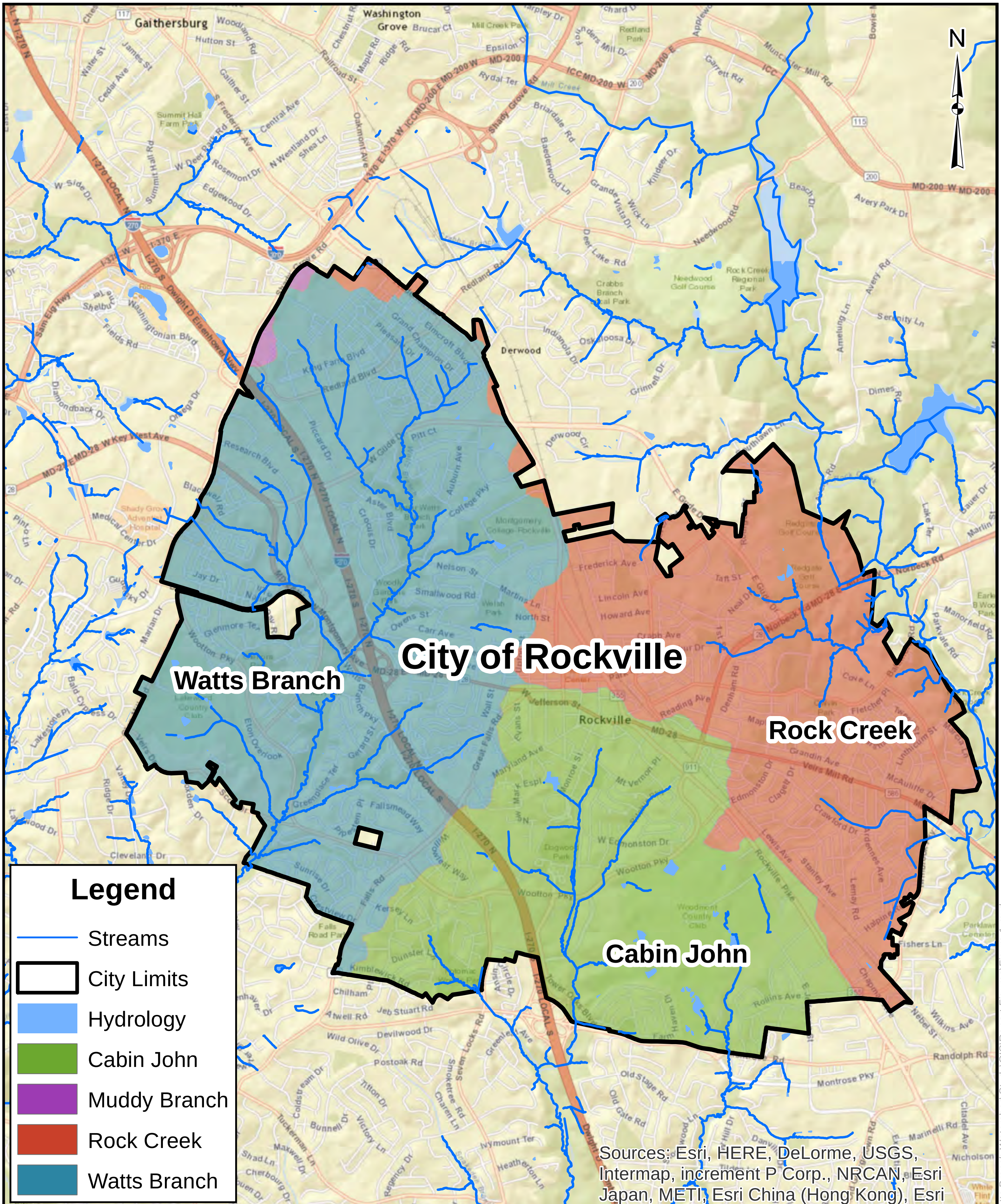
As a tributary to the Potomac River in Montgomery County, Watts Branch is included in the streams identified by the State as degraded, based on water quality sampling of benthic macroinvertebrates or fish indices of biological impairment. In response, MDE has issued a TMDL for this reach of the Potomac River and its tributaries for total suspended solids (TSS). In addition, MDE and EPA issued the Chesapeake Bay-wide TMDLs for sediments, nitrogen, and phosphorus.

Requirements to reduce these target pollutants are outlined in the City's NPDES permit. Due to its population size, Rockville is designated as a Phase II NPDES MS4 community. Under its current NPDES permit and anticipated future permits, the City is committed to carrying out activities that will reduce TMDL target contaminants. This study was initiated to understand the current conditions in the Watts Branch watershed within the City that affect stream quality and to identify future stream erosion and water quality concerns. This study compares the findings of the 2001 Watts Branch Watershed Study and Management Plan (Center for Watershed Protection, 2001) results with recent findings to understand the current and future state of the watershed. The City will also use the results of the study to aid in decision making regarding TMDL reduction strategies.

1.1 WATERSHEDS

A watershed is an area of land where all water drains to a common point. This includes water carried by pipes, streams, driveways, rooftops, roads, parking lots, and drainage ditches. There are three main watersheds within the City: Cabin John Creek, Watts Branch, and Rock Creek (see Figure 2). All three watersheds drain to the Potomac River and ultimately to the Chesapeake Bay.

Watersheds located in urban areas present several challenges. The increase in development results in a decrease in vegetation that can capture and filter rain water. The unfiltered water carries pollutants such as oil, pet waste, fertilizer, pesticide, and sediment into the streams. The large amount of impervious areas increases the amount of water and the speed of the water that is conveyed to streams. The increased speed in which water hits the stream results in bank erosion in the stream. The increased sediment from the eroding stream bank affects water quality and habitat for fish and other aquatic organisms. Some of this sediment is conveyed downstream and ultimately ends up in the Chesapeake Bay. Managing and treating storm runoff is an important factor in watershed health.



0 2,000 4,000 8,000 Feet

1 inch = 4,000 feet

BayLand Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A
Hanover, Maryland 21076
Phone: (410) 694-9401
Fax: (410) 694-9405
bayland@baylandinc.com

FIGURE 2
WATERSHED LOCATION MAP

1.2 PREVIOUS WATTS BRANCH WATERSHED STUDIES

The Watts Branch watershed in Rockville has a unique history associated with it. Dr. Luna Leopold, a well-known geomorphologist, first studied Watts Branch in 1952. During his study, the watershed changed from an agricultural land use to an urban/developed land use. His study lasted for 20 years with the conclusion that as development increased, the channel enlarged due largely to increased runoff from impervious surfaces (Leopold, 1973).

The first hydrologic study for Watts Branch for the City was completed in 1989 by Engineering Technologies Associates (ETA) and included a hydrologic analysis for Predevelopment, Existing Development with Existing Facilities and Ultimate Development with Existing Facilities. The 1989 study used Technical Release 20 (TR-20) computer model to analyze the watershed.

In 2001, The Center for Watershed Protection (CWP) submitted the Watts Branch Watershed Study and Management Plan Final Report to the City (CWP, 2001). This was the City's third and most extensive watershed study completed in the late 1990s-early 2000s. Because Watts Branch is the largest of the City's watersheds, it had many stream issues, but also many opportunities for improvement. An active group of residents formed the Watts Branch Partnership, which worked with City staff and the consultant team to evaluate and prioritize conceptual stormwater management retrofit and stream restoration projects. The Partnership weighed competing interests for water quality improvement, recreation, forest preservation, and neighborhood concerns.

The plan's goal was to develop a watershed protection strategy for the City to implement. Specific goals included:

- Minimize/control channel enlargement (e.g., stream erosion)
- Reduce pollutant loadings from nonpoint source runoff
- Develop stewardship among residents by educating and changing behaviors
- Protect existing utilities in and near streams from erosion damage
- Provide stormwater management control over a significant proportion of the watershed (or sub-watershed)
- Protect existing forest areas
- Protect existing wetlands
- Protect existing active recreational areas

The study consisted of three phases. The first phase included assessing existing conditions and identifying management measures. The second phase included developing conceptual designs and the third phase consisted of public outreach and developing a prioritization scheme.

As part of the 2001 watershed study, the hydrologic model prepared by ETA in 1989 was updated by Macris Hendricks, & Glascock (MHG). The updates included changes to the rainfall events modeled, selecting 10 historic cross section locations within the watershed and adjusting the drainage areas to these nodes, and revising previously undeveloped drainage areas to reflect current development. The model also included additional SWM facilities modeled in existing conditions and modeled potential retrofits and proposed SWM facilities.

The 2001 study broke the watershed into 10 sub-watersheds and developed a numbering convention for each reach. Results of the study concluded that Watts Branch would continue to enlarge and adjust to development for another 40-50 years after 2001 before reaching an equilibrium state. The study also identified 14 stormwater retrofit projects and 12 stream rehabilitation projects.

Since the start of the 2001 watershed study, the City has completed seven SWM retrofits and seven stream restoration projects as described in the table below.

Table 1.1
Watts Branch Watershed: Completed CIP Projects 1998-2014

Stormwater Management Projects		
Project Name	**Drainage Area (acres)**	**Year Built**
Aintree Pond	51	1998
College Gardens Low Impact Design Demonstration Projects	1	2005
Carnation Drive Pond and I-270 Industrial Park Pond (2 ponds in series)	352	2008
College Gardens Park Pond & 500 LF of stream restoration	79	2009
W. Montgomery Alley Pervious Paving (5,000 SF) & 610 LF storm drain improvements	1	2009
Lakewood Country Club Pond	45	2010
Horizon Hill Park Ponds (3 ponds in series; Ponds # 1 & 3 to be retrofitted)	186	Completion in 2015
Total Drainage Area treated by this SWM (acres)	**715**	
Stream Restoration Projects		
Project Name	**Length of Stream (linear feet)**	**Year Built**
Frost Middle School Trib.	2,000	2004
Upper and Middle Woottons Mill Park	6,700	2005
FEMA Storm Damage Repair -(stream & SD outfall damage from 2006 floods)		2007
College Gardens Trib. (500 LF of spot improvements)	900	2009
Watts Branch - Woodley Gardens Park	5,100	2010
Bouldercrest Trib. (Glenora Trib)	1,100	2014
Horizon Hills Stream Restoration	1,300	Completion in 2015
Total Stream Length Restored (linear feet)	**17,100**	

1.3 SCOPE OF 2015 WATTS BRANCH WATERSHED ASSESSMENT

This 2015 Watts Branch Watershed Assessment assesses the existing conditions of the watershed and compares them with the conditions of the watershed in 2001. This study, started in summer 2013, looks at changes in land use and imperviousness as a result of new development (Section 2.2). The 2015 assessment includes updates to the 2001 hydrologic model based upon the addition of new stormwater management ponds and changes in drainage areas and land use

(Section 4). This report also compares the current condition of each stream reach with the 2001 stream assessment results (Section 5). Finally, this report compares the results from geomorphic assessments at 10 historic cross sections surveyed in 2001 and again in 2013 (Section 6). For ease of comparison, the same numbering convention for sub-watersheds and reaches in the 2001 study was used in the 2015 assessment.

This new assessment does not include conceptual stormwater management retrofit designs. The City is still implementing the last of the Watts Branch CIP stormwater projects recommended in the 2001 plan. Stormwater management regional control methods are evolving, so future projects will be considered in the context of future NPDES MS4 permit requirements. City-wide operational measures to improve runoff quality were suggested in recent watershed assessments for Cabin John Creek and Rock Creek, and further evaluation in this Watts Branch study would be redundant.

Stream stability issues are identified in this assessment, but conceptual stream restoration projects were not developed. The City has moved to an ongoing stream restoration re-prioritization process where problem reaches are field-checked every 1-3 years, more frequently than the 15-year cycle for watershed assessments. High-priority stream projects are now implemented through the CIP based on city-wide priorities, rather than one watershed at a time.

A section of the stream reach was not assessed by BayLand as part of this 2015 study since it was under separate evaluation for a stream restoration project. The Upper Watts Branch (UWB) study, conducted between 2011-2015 by Charles P. Johnson and Associates, utilized stream assessment techniques that were also utilized in this 2015 Watts Branch Watershed Assessment. The Upper Watts Branch also had a stormwater management analysis for that portion of the watershed. The Upper Watts Branch stream findings are discussed in Section 5, Stream Assessment, of this 2015 Watts Branch Watershed Assessment. The UWB technical memoranda for stormwater analysis and stream restoration recommendations are presented in Appendix A.

1.4 OVERVIEW OF APPENDICES

Appendices are provided in a separate document or as separate files from this watershed assessment report.

Table 1.2
Overview of Appendices

Appendix	Title	Description
A	Upper Watts Branch Assessment Information	Technical memoranda for Upper Watts Branch stream stability assessment done by separate consultant. Includes SWM analysis and stream monitoring and recommendations for the sub-watershed.
B	Water Quality Monitoring Data	Summary of previous Watts Branch stream monitoring done by Montgomery County and the State of Maryland
C	Stormwater Management Facilities	Map of public and private stormwater management (SWM) facilities as of 2013
D	Water Quality Treatment Calculations	Data analysis of public and private SWM facilities to characterize acres of impervious area treated for water quality

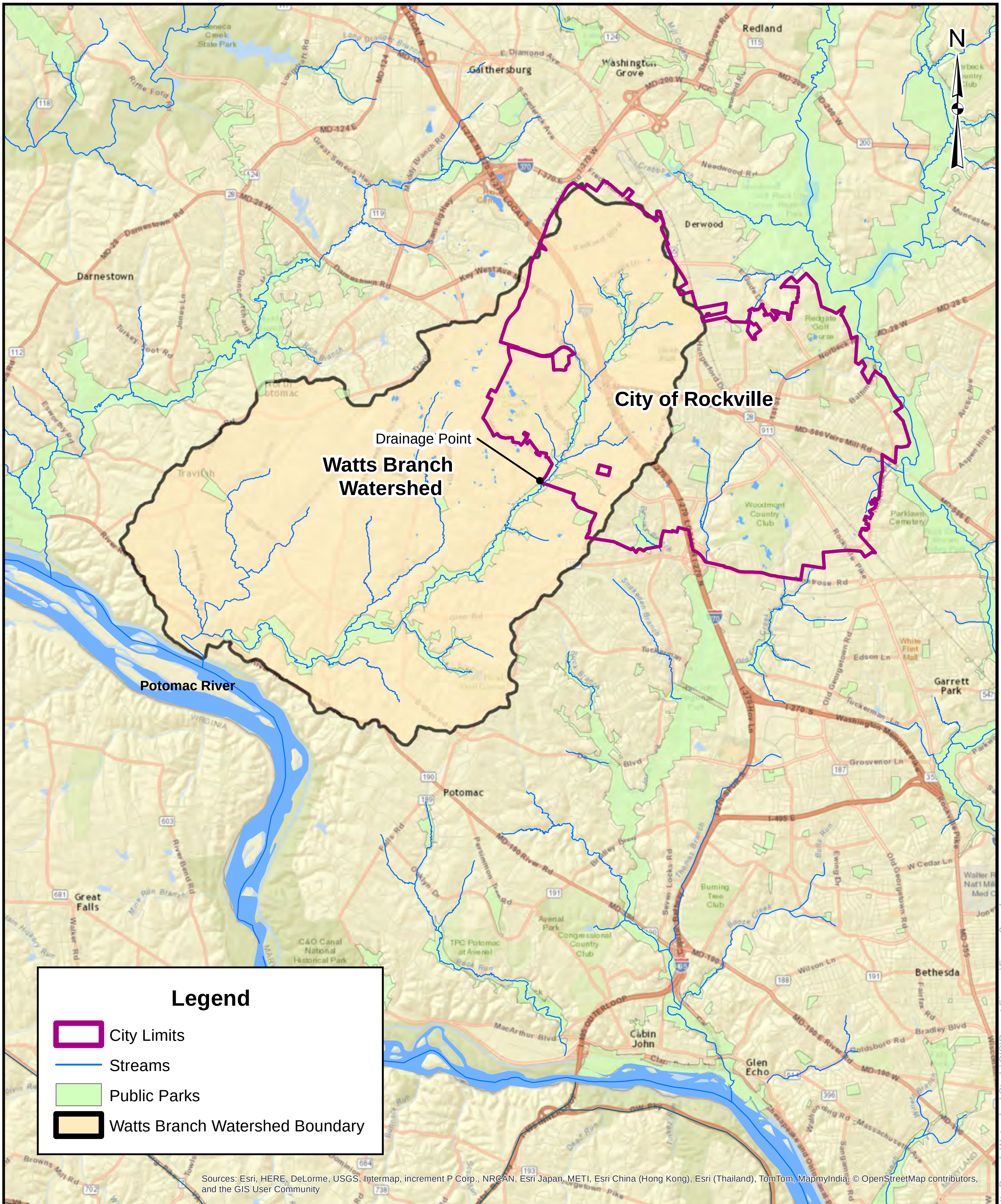
Table 1.2
Overview of Appendices

Appendix	Title	Description
E	TR-20 Model & Results	Hydrologic model for ultimate land use conditions to generate stream flow estimates for specific sized storms. Includes computer input/output files.
F	Geomorphic Maps	Detailed maps and notations of stream conditions from 2013 field work
G	Reach Wide BEHI Data	Data and summary results for Bank Erosion Hazard Index (BEHI) analysis
H	Geomorphic Assessment Data	Data sheets used for geomorphic assessment, including BEHI computations
I	USA Datasheets	Assessment data sheets for storm drain outfall conditions and stream conditions using the Unified Stream Assessment methodology
J	Stream Assessment Report	Descriptions and photos of stream conditions by sub-watershed as of 2013 field work. Includes evaluations of storm drain outfalls and utility crossings.
K	Geomorphic Assessment Report	Geomorphic assessment methodology, analysis and results. Includes profile & reach patterns, lateral and vertical stability, and cross-sectional analysis; Rosgen stream types; and photos.

2 WATERSHED CHARACTERIZATION

Watts Branch originates in the western half of the City of Rockville, then flows through Montgomery County to its confluence with the Potomac River. It enters the Potomac just upstream of the Washington Suburban Sanitary Commission's (WSSC's) Potomac Water Filtration Plant, which supplies drinking water to most of Montgomery County and some of Prince George's County. The City's portion of the Watts Branch watershed ends at the point where Watts Branch crosses the City boundary into Montgomery County (see Figure 3).

The City's Watts Branch watershed has a drainage area of 5.99 square miles (3,832 acres). It is an urban watershed that includes I-270 and parts of the Route 355 corridors, the mixed-used developments at King Farm and Fallsgrove, Montgomery College's Rockville campus, and many residential areas. The watershed has approximately 18 miles (95,000 linear feet) of stream within the City limits.



0 4,000 8,000 16,000 Feet

1 inch = 8,000 feet

BayLand Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A
Hanover, Maryland 21076
Phone: (410) 694-9401
Fax: (410) 694-9405
bayland@baylandinc.com

FIGURE 3
WATTS BRANCH WATERSHED MAP

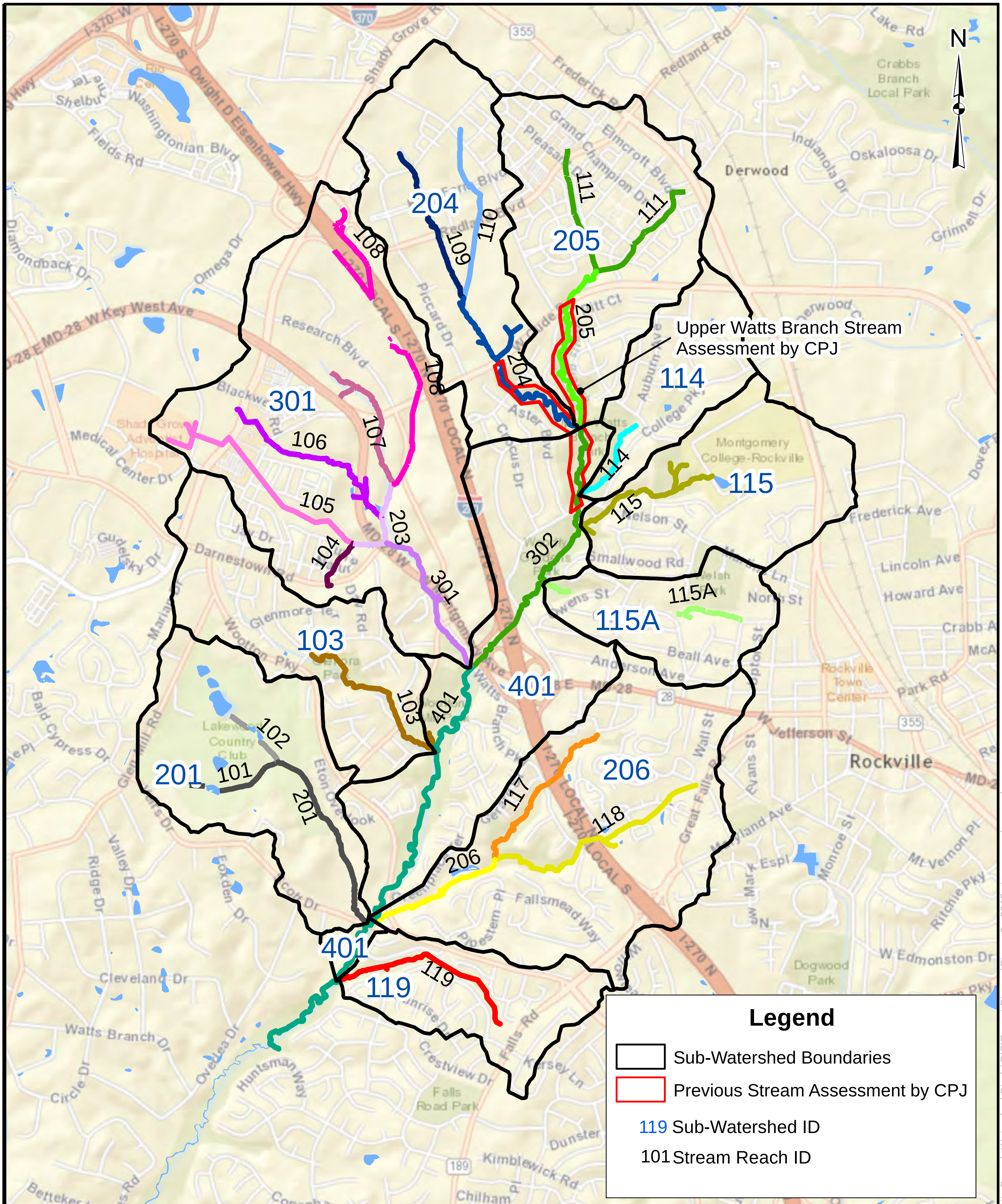
P:\18_19201_City of Rockville Watts Branch Watershed Study\GIS\Report Figures\Figure 2.mxd

2.1 SUBWATERSHEDS

Within the City, the Watts Branch Watershed is divided into 10 sub-watersheds and the mainstem (see Figure 4). The nomenclature for the sub-watersheds is based upon the highest order stream within the delineated sub-watershed. The stream nomenclature is based upon the order of the stream. Streams are numbered in a clockwise direction. This system was established by the U.S. Geological Survey and is used across the country. Stream orders are used to classify streams according to the number of tributaries associated with it. For example, first order streams are often headwater streams and have no perennial tributaries flowing into it. When two first order streams join together, it becomes a second order stream and so forth. As an example, the mainstem of Watts Branch is a 4th order stream. Each sub-watershed characteristic is listed in Table 2.1. Subwatersheds 201, 205, 301, and 401 had a reduction in stream length. This could be due to development and piping of the streams or to refinement of the City's GIS data.

Table 2.1
Sub-Watershed Characteristics

Sub-Watershed ID	Area (Acres)	2001 Stream Length (Miles)	2013 Stream Length (Miles)	Predominant Land Use
103	285	0.7	0.7	Medium Density Residential
114	159	0.4	0.4	Medium and High Density Residential
115	283	0.8	0.8	Medium Density Residential and Institutional
115A	165	0.4	0.4	Medium Density Residential
119	184	0.4	0.4	Medium Density Residential
201	336	1.4	1.2	Open Urban Land/Golf Course
204	389	2.3	2.3	Industrial and Commercial
205	407	2.5	1.9	Medium and High Density Residential
206	540	2.2	2.2	Medium Density Residential
301	735	4.1	3.1	Industrial and Commercial
401 (Mainstem)	677	3.5	3.3	Medium and High Density Residential
Total	**4,160**	**18.7**	**16.7**	



0 1,250 2,500 5,000 Feet

1 inch = 2,500 feet

BayLand Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A
Hanover, Maryland 21076
Phone: (410) 694-9401
Fax: (410) 694-9405
bayland@baylandinc.com

FIGURE 4
STREAM REACHES

P:\8_19201_City of Rockville Watts Branch Watershed Study\GIS\Report Figures\Figure 3 - 2013 stream reaches.mxd

2.2 LAND USE AND IMPERVIOUS AREA

Land use within a watershed and the amount of imperviousness (pavement, rooftops, etc.) plays an important role in water quality and stream health. A watershed with primarily forested land use produces less pollutants than a developed watershed. This is because forested land can absorb much more rainfall through infiltration into the ground and transpiration by plants, which reduces the amount of rain that runs off into the stream. An urbanized watershed with large amounts of impervious surfaces does not significantly retain rainfall. Instead, the rain runs off impervious areas in much greater quantities than under forested conditions. The runoff takes pollutants from roads, roofs and other hard surfaces with it, and transports them directly to the stream.

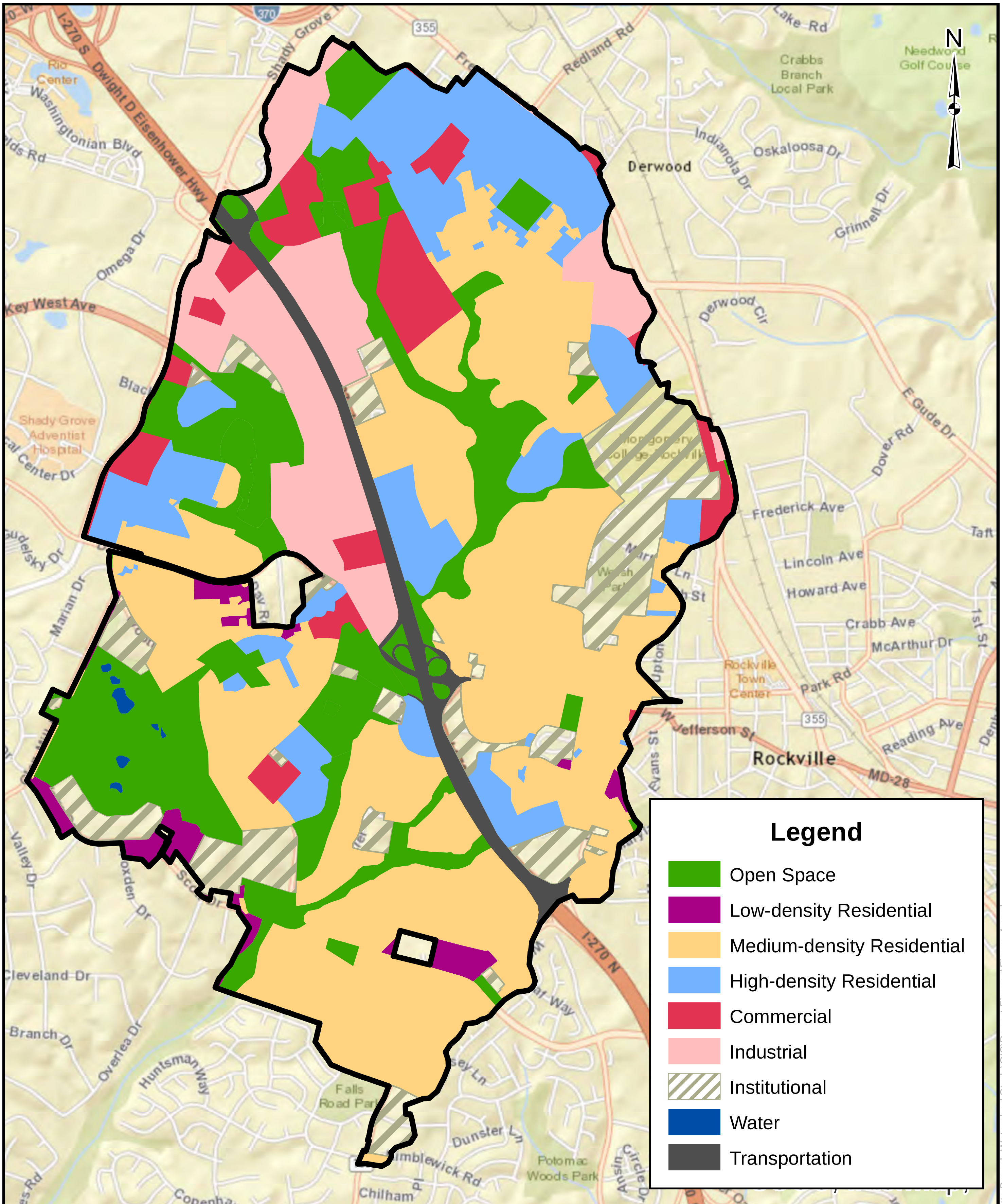
The majority of the Watts Branch watershed is dominated by residential development (53%). Residential development is broken down into low density, medium density, and high density. Low density residential development consists of detached single family/duplex homes with lot sizes less than five acres but at least ½ acre in size. Medium density residential land use consists of detached single family/duplex, or row housing with lot sizes of less than ½ acre but at least ⅛ acre. High density residential consists of attached single unit row housing, apartments, condominiums, and mobile home parks with more than eight dwellings units per acre. Residential development accounts for 19% of the imperviousness found in the watershed.

Non-residential development consisting of institutional (schools, churches, hospitals, and government offices), industrial, and commercial land use comprises 26% of the watershed and 17% of the imperviousness. Open space consisting of pasture, cropland, open urban land (golf courses, parks, cemeteries, undeveloped land, and recreation areas), forests, and water accounts for 19% of the land use and 4% of the imperviousness within Watts Branch. Figure 5 and Table 2.2 depict land use and impervious area of the Watts Branch Watershed.

Table 2.2
Current Land Use

Land Use	Acres	Percent of Watershed	Impervious Area	Percent Impervious Within the Land Use	Percent Impervious in the Watershed
Subtotal Residential	**2,011.6**	**52.56%**	**729.38**	**36.26%**	**19.06%**
Low Density Residential	75.0	1.96%	9.16	12.21%	0.24%
Medium Density Residential	1,430.8	37.39%	340.42	23.79%	8.89%
High Density Residential	505.8	13.22%	379.80	75.09%	9.92%
Subtotal Non-Residential	**978.1**	**25.56%**	**638.34**	**65.26%**	**16.68%**
Institutional	397.6	10.39%	208.11	52.34%	5.44%
Industrial	378.3	9.88%	268.67	71.02%	7.02%
Commercial	202.2	5.28%	161.56	79.90%	4.22%
Subtotal Open Space	**729.4**	**19.06%**	**144.64**	**19.83%**	**3.78%**
Pasture	74.8	1.95%	18.62	24.89%	0.49%
Cropland	124.6	3.26%	22.84	18.33%	0.60%
Open Urban Land	244.4	6.39%	22.52	9.21%	0.59%
Mixed forest	5.2	0.14%	0.42	8.08%	0.01%
Deciduous forest	266.5	6.96%	13.45	5.05%	0.35%
Brush	7.4	0.19%	0.46	6.22%	0.01%

Table 2.2 **Current Land Use**					
Land Use	**Acres**	**Percent of Watershed**	**Impervious Area**	**Percent Impervious Within the Land Use**	**Percent Impervious in the Watershed**
Water	6.3	0.16%	0.04	0.63%	<0.01
Large lot subdivision (agriculture)	0.2	<0.01	<0.01	<0.01	<0.01
Transportation	**108.1**	**2.82%**	**66.29**	**61.32%**	**1.73%**
TOTAL	**3,827.2**		**1,578.7**		**41.2%**



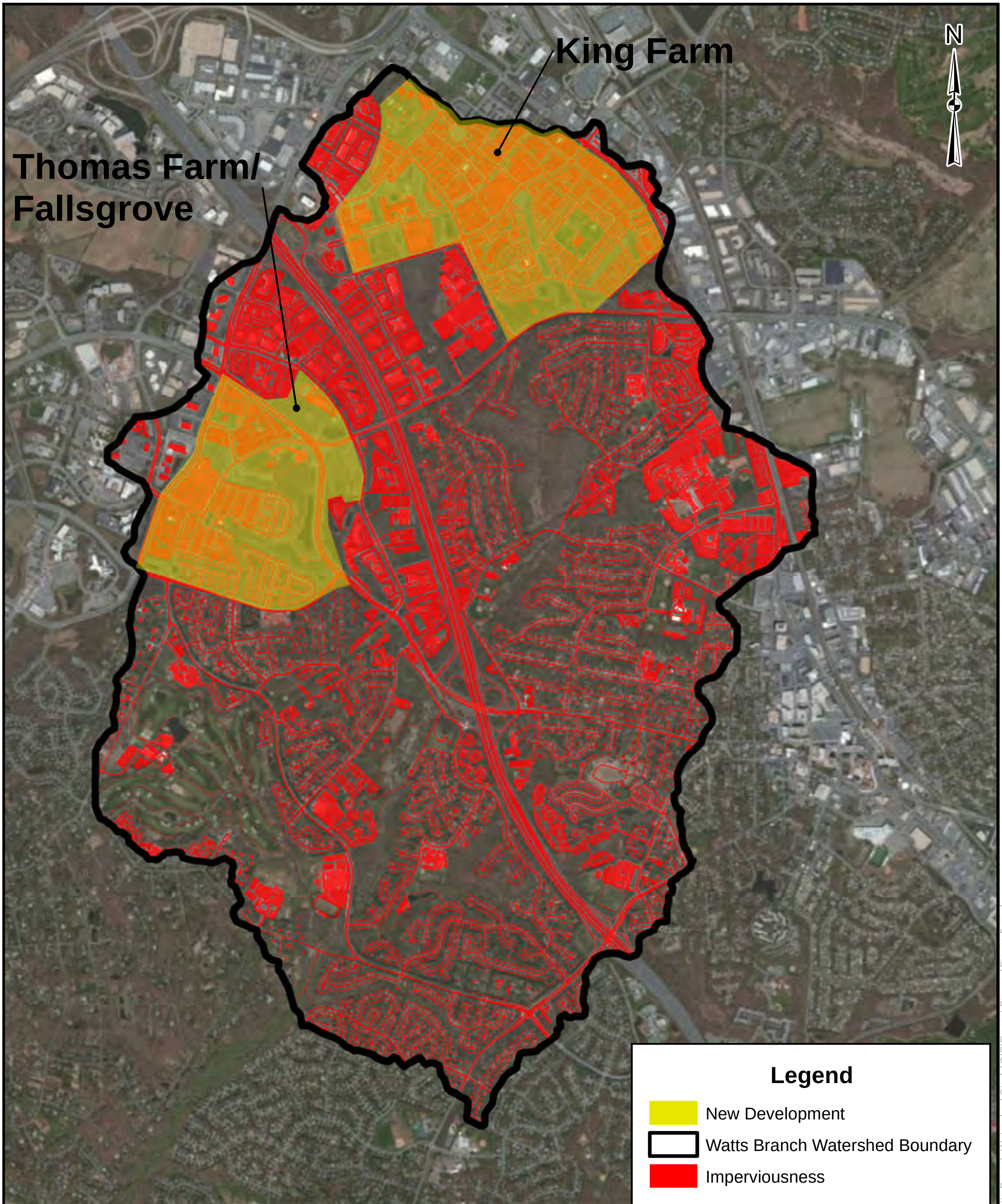
0 1,250 2,500 5,000 Feet

1 inch = 2,500 feet

BayLand Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A
Hanover, Maryland 21076
Phone: (410) 694-9401
Fax: (410) 694-9405
bayland@baylandinc.com

FIGURE 5
LAND USE MAP

The impervious area was calculated using the City's GIS database. Impervious area includes driveways, sidewalks, roads, parking lots, paths, and buildings. The Watts Branch watershed within the City is 41% impervious. High and medium density residential land use accounts for 19% of the impervious area in the City's portion of the watershed and non-residential uses (institutional, industrial, and commercial) account for another 17% of the imperviousness. This level of imperviousness is consistent with the City's other two watersheds (Cabin John 32% and Rock Creek 40%). The 2001 report indicated that the imperviousness was 28%. The increase is a result of development at King Farm in subwatersheds 204 and 205 and at Thomas Farm (Fallsgrove) in subwatershed 301 (see Figure 6). These two major subdivisions built out since the last watershed study's analysis. New impervious areas also were created by infill office or residential development, a new mixed-use complex north of King Farm, and additions at Montgomery College.



0 1,250 2,500 5,000
Feet
1 inch = 2,500 feet

BayLand
Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A
Hanover, Maryland 21076
Phone: (410) 694-9401
Fax: (410) 694-9405
bayland@baylandinc.com

FIGURE 6
IMPERVIOUS AREA MAP

P:\8_19201_City of Rockville Watts Branch Watershed Study\GIS\Report Figures\Figure 5.mxd

Research shows that, as impervious cover in a watershed increases, there is a decline in water quality and in diversity and abundance of aquatic and terrestrial life (Schueler et al., 2009). This relationship is demonstrated in the impervious cover model in Figure 7. This relationship is represented as a 'cone' that indicates a stronger relationship as impervious cover increases. At low levels of impervious cover, other watershed metrics such as forest cover, road density, and riparian buffers influence stream health. Studies used to develop the impervious cover model measured stream quality based on a variety of indicators such as the number of aquatic insect species, stream temperature, channel stability, aquatic habitat, wetland plant density, and fish communities.

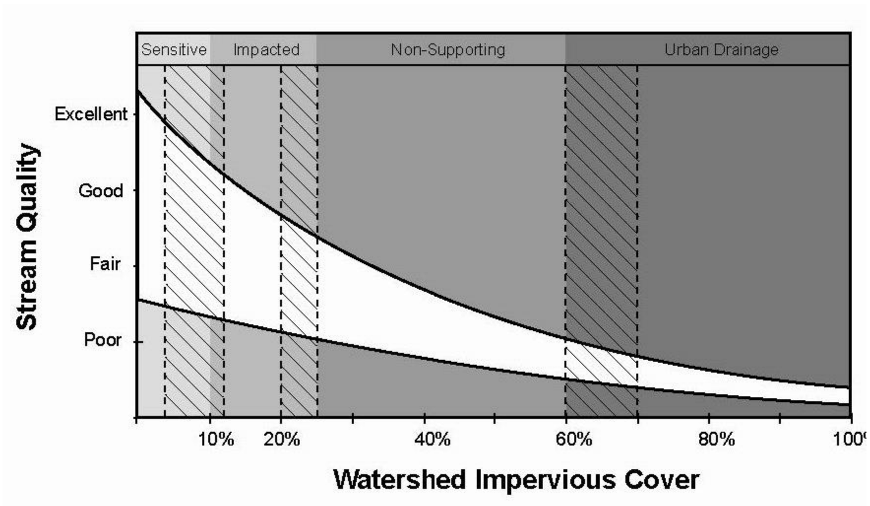


Figure 7: Impervious Cover Model (Schueler et al. 2009)

Based on the research compiled, the following general categories were developed to classify and predict stream quality in terms of impervious cover represented by bands in Figure 7:

- Sensitive – watersheds with less than 10 percent impervious cover are referred to as sensitive, and typically have high quality streams with stable channels, good habitat conditions, and good to high water quality. Sensitive watersheds are susceptible to environmental degradation with urbanization and increases in impervious cover.
- Impacted – watersheds with between 10 and 25 percent impervious cover show clear signs of degradation such as erosion, channel widening, and decline in stream habitat. Stream restoration to a somewhat natural functioning system is still possible in these watersheds.
- Non-supporting – watersheds with between 25 and 60 percent of impervious cover are characterized by fair to poor water quality, unstable channels, severe erosion, and the inability to support aquatic life and provide habitat. Many streams in this category are typically piped or channelized. This category has a wide range for impervious cover, which means that small changes in land use typically do not measurably affect water quality, either positively or negatively. Watershed interventions must occur on a comprehensive scale to lead to demonstrable improvements.

- Urban drainage – in watersheds where impervious cover exceeds 60 percent, a watershed is classified as severely damaged, which means that most of the natural open stream system has been converted to man-made concrete or riprapped channels, or moved into underground pipes.

The Watts Branch watershed at 41% percent imperviousness falls within the non-supporting category along with the other two watersheds within the City which is typical of urban watersheds. During the stream assessment, indications that many of the streams were in the non-supporting category include: bed and bank erosion, lack of riparian buffer, channelization, poor water quality, and lack of access to a floodplain.

2.3 SOILS

Soil and sedimentation has an important role in the health of streams. Sedimentation occurs when water carrying eroded soil particles slows down enough to allow the particles to settle out and cover the channel or pond bottom. Sedimentation can reduce storage volume in stormwater ponds and clog streams. Excessive sediment is considered a pollutant because it can affect physical, chemical, and biological water quality, and the overall ecology of the receiving stream. For example, sedimentation also covers stream bed spawning gravels and smothers aquatic vegetation. Smaller particles, such as clays, can stay suspended in the water for very long periods, contributing to water turbidity, reduced clarity, and impaired aquatic ecosystems. Additionally, sediment can carry organic matter such as nutrients, chemicals, pesticides, and animal wastes that may be toxic to aquatic plants and animals. Although all streams have a natural sediment load that migrates downstream, urban channels have much higher loads from unstabilized upland areas, such as construction sites, and from excessive bank erosion caused by high flow rates.

The type of soil has an effect on its ability to absorb rainfall, its rate of erosion, and its ability to filter nutrients and pollution. Soils are classified by the Natural Resource Conservation Service into four Hydrologic Soil Groups (HSG) based on the soil's runoff potential and infiltration rate (see Table 2.3). Group A soils generally are sandy with high infiltration rates and have the least runoff potential. Group D soils have high clay content with low infiltration, so they generate the most runoff. Once impervious area is created, the underlying soils are blocked from infiltration (except for porous paving systems, which are designed to pass runoff through the paving into the soils underneath).

Table 2.3
Hydrologic Soil Group

Hydrologic Soil Group	Soil Type	Infiltration Rate
A	Sandy loam to gravel	High
B	Silt loam or loam	Moderate
C	Moderately fine to fine textured	Low
D	High clay content	Very low

Along with its importance in determining runoff potential, understanding soil characteristics is also critical to managing stormwater. Some small-scale stormwater management (SWM) facility designs are dependent on high soil infiltration rates found in Group A or B soils. The Watts Branch Watershed has soils that are 85% in Group B and 15% in Group C or D (see Table 2.4), disregarding the effect of Urban Land Complex areas.

Soils disturbed during past development behave differently than the underlying original soil groups. Urban Land Complex and Urban Land soils are located in areas which have been paved over or compacted during construction, such as along I-270 or under parking lots. Regardless of the location's original soil group, these areas generally have low infiltration rates due to previous compaction. The Urban Land Complex soils found in Watts Branch are classified as B soils due to their underlying soil groups, but are poorly drained like Group D soils because they are covered by at least 30% urban development. Urban Land can also exist as its own soil type for large contiguous paved areas.

Urban Land Complex soils comprise 26% of the soils in Watts Branch watershed. Soils classified as Urban Land comprise another 3%. Combining the Group B Urban Land Complex soils with the Group C and D soil types in Table 2.4 results in 41% of the soils within the Watts Branch watershed having poor infiltration rates and a high runoff potential.

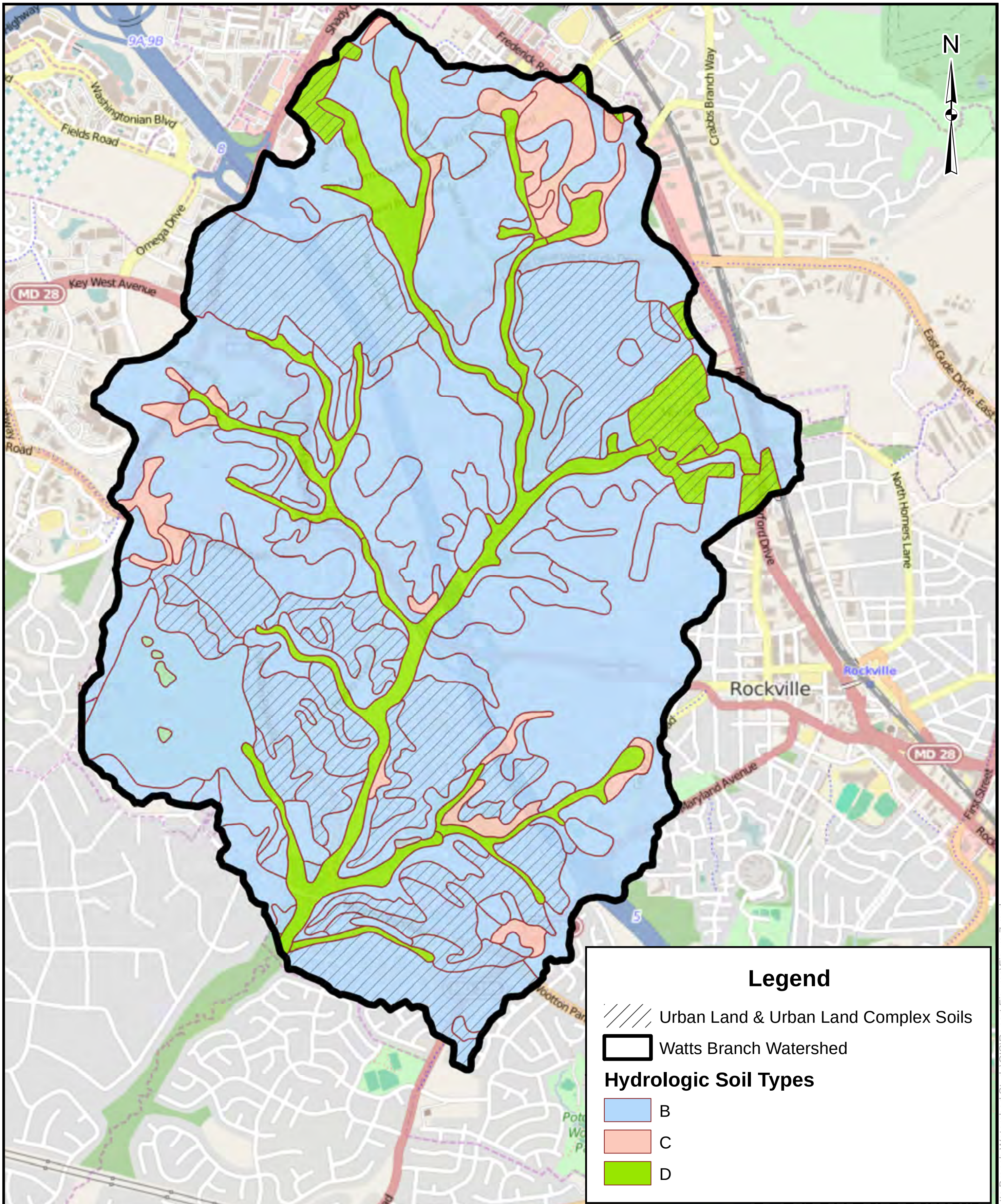
Soil erodibility is an estimate of a soil's ability to resist erosion, based on the physical characteristics of each soil type. Generally, soils with faster infiltration rates are less susceptible to erosion. Sand, sandy loam and loam-textured soils tend to be less erodible than silt, very fine sand, and certain clay-textured soils.

In general, the soils in the watershed, shown in Figure 8, tend to be well drained in the upland areas and poorly drained along the stream corridors.

Table 2.4
Hydrologic Soil Types in Watts Branch Watershed

Hydrologic Soil Type	Acres	Percent
A	0	0%
B	3,362	85% (26% Urban Land Complex soils)
C	162	4.1%
D	429	10.9% (3% Urban Land soils)

The soil survey is a broad tool for assessing infiltration rates and erodibility. A more site specific investigation is needed when determining the location of SWM facilities and accessing soil conditions. Many soils in urban watersheds have been compacted and/or altered and no longer display the original characteristics of the soils type.



0 1,250 2,500 5,000
Feet

1 inch = 2,500 feet

BayLand Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A
Hanover, Maryland 21076
Phone: (410) 694-9401
Fax: (410) 694-9405
bayland@baylandinc.com

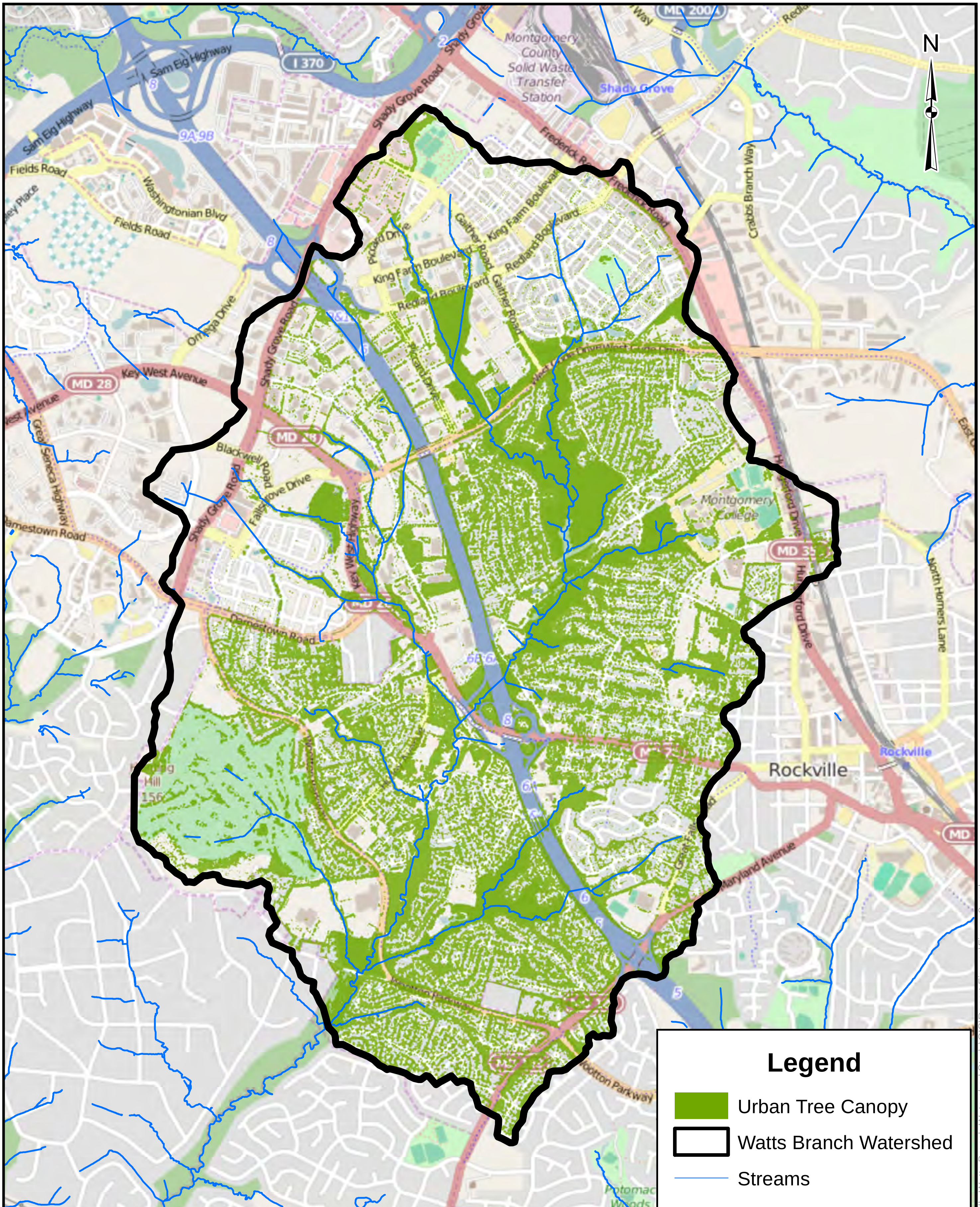
FIGURE 8
HYDROLOGIC SOIL GROUPS

2.4 TREE CANOPY

Urban tree canopy (UTC) is the layer of leaves, branches, and stems of trees that cover the ground when viewed from above (O'Neill-Dunne, 2009). The UTC provides several benefits to the urban environment including:

- Cleaning the air by producing oxygen, reducing smog, and filtering particulates
- Cooling the ambient temperatures by providing shade and removing greenhouse gases
- Conserving energy by acting as a natural air conditioner reducing cooling costs
- Reducing stormwater runoff by slowing, capturing, and storing rainfall
- Promoting the infiltration of runoff thereby filtering sediment and pollutants and replenishing groundwater supply
- Providing stream bank protection thereby reducing erosion
- Providing habitat to wildlife
- Reducing stream temperatures by shading the water and providing habitat for in-stream fish and aquatic insects
- Providing recreational opportunities and making communities more attractive

The UTC within Watts Branch based upon 2007 GIS data was 1,500 acres (39%). American Forests, a non-profit conservation organization, recommends 40% tree cover for urban areas. The entire city has approximately 3,744 acres (44%) tree canopy (O'Neil-Dunne, 2009). The tree canopy for Watts Branch accounts for approximately 40% of the entire city (see Figure 9). The average UTC within the United States is 27% in urban areas and 33% in metropolitan areas (Dwyer and Nowak, 2000). Figure 9 depicts the existing UTC within Watts Branch in the City. Contiguous forests are located along the mainstem and tributaries of Watts Branch within the County parks.



0 | 1,250 | 2,500 | 5,000 Feet

1 inch = 2,500 feet

BayLand Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A
Hanover, Maryland 21076
Phone: (410) 694-9401
Fax: (410) 694-9405
bayland@baylandinc.com

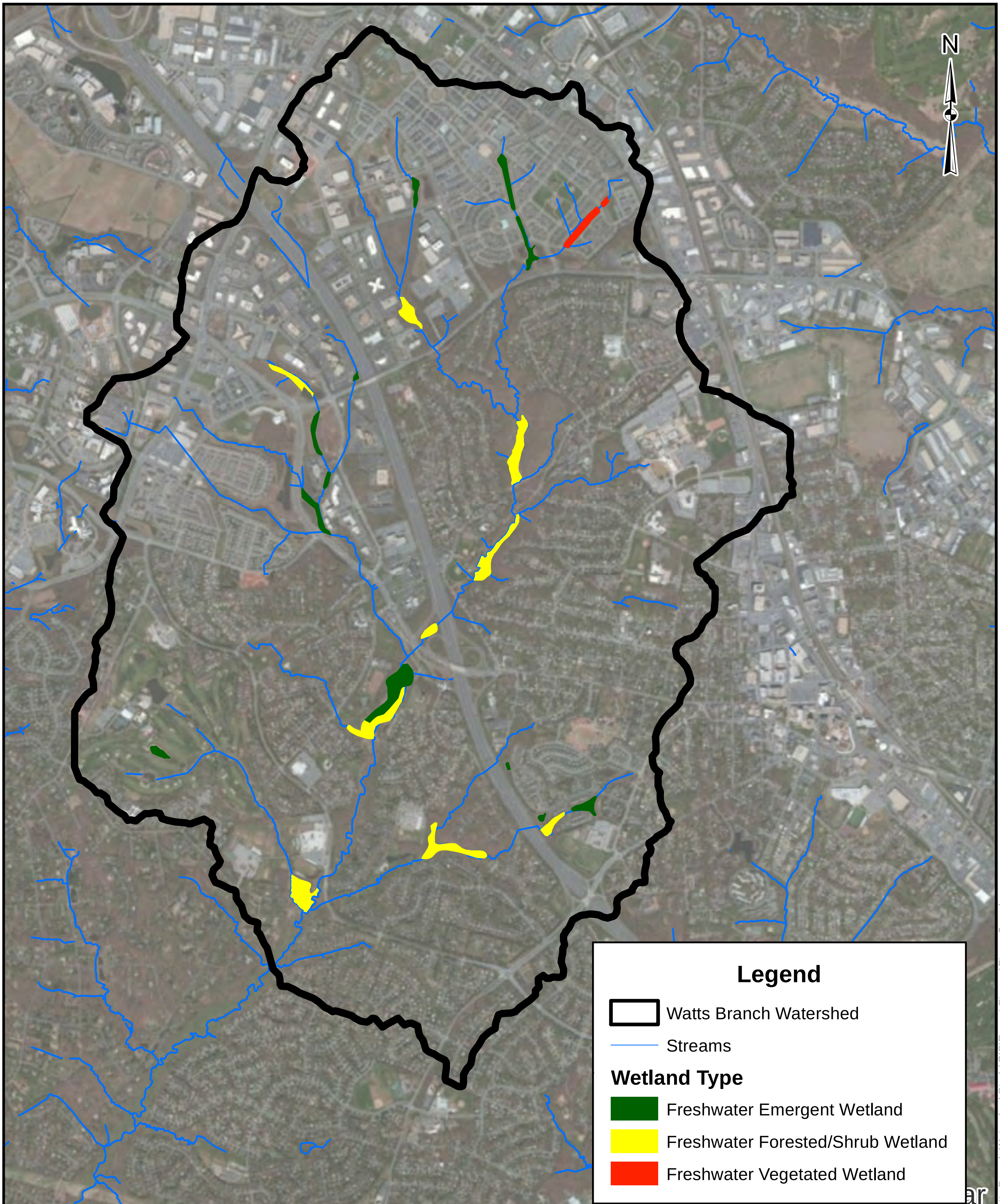
FIGURE 9
URBAN TREE CANOPY

2.5 WETLANDS

Wetland protection is critical to watershed health because wetlands filter pollutants, minimize flood damage by slowing and storing floodwaters, and provide habitat for birds and wildlife (Strommen et al., 2007). Wetlands function like sponges, storing runoff and releasing it slowly. This process slows the water's erosive potential, reduces flood depths, and allows time for groundwater recharge.

Only approximately 59 acres (1.5%) of the watershed is comprised of wetlands according to the City of Rockville's 2014 GIS layer (see Figure 10). Of these approximately 38% are emergent wetlands, 55% are forested/shrub wetlands, and 7% are vegetated wetlands. The City's GIS wetland layer was derived from combining several data sources including the National Wetlands Inventory (based on 1979 data), Maryland Department of Natural Resources, Montgomery County, and 2012 aerial photography.

Urbanized areas developed in the 1940s through the 1970s typically have few wetland areas because policies and regulations for wetland preservation were not widespread until the Clean Water Act was enacted in 1972.



0 1,250 2,500 5,000 Feet

1 inch = 2,500 feet

BayLand Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A
Hanover, Maryland 21076
Phone: (410) 694-9401
Fax: (410) 694-9405
bayland@baylandinc.com

FIGURE 10
EXISTING WETLANDS

P:\8_19201_City of Rockville Watts Branch Watershed Study\GIS\Report Figures\Figure 9.mxd

2.6 WATER QUALITY

Water quality monitoring activities identify and measure pollution within the streams and throughout the watershed. It is needed to assess the health of streams especially in urban areas where there is an increase in pollutants and a lack of riparian buffers. Water quality monitoring is essential to identifying if a water body is impaired and in need of pollutant reductions. Water quality monitoring throughout Watts Branch was performed from 1996-2007, including portions outside the City. A summary of that data can be found in Appendix B. No water quality monitoring activity was performed as part of this watershed study.

Impaired Waters

Watts Branch and its tributaries are classified according to the Code of Maryland Regulations (COMAR) Surface Water Use Designation as Use I-P. Use I-P is defined as water contact recreation, protection of nontidal warmwater aquatic life, and public water supply, meaning that streams in the watershed should be able to support these identified uses.

When water quality monitoring data suggests that a waterbody does not meet water quality standards, it is listed in Maryland's 303 (d) list of impaired waters. The listing includes the cause (pollutant) and the priority of the impairment (MDE, 2010). There are five categories of water quality:

- Category 1: Water standards are met
- Category 2: Some standards are being met
- Category 3: Insufficient information to determine if standards are being met
- Category 4: Impaired or threatened waters that do not need or have already completed TMDL
- Category 5: Impaired waters where a TMDL is required

Watts Branch is included in the 303(d) listings for the Potomac River within Montgomery County, which it feeds into (Table 2.5).

Table 2.5
Potomac River within Montgomery County Watershed 303(d) Listings

Year First Listed	Impairment	Listing Category	Designated Use	TMDL Status
2008	PCB in Fish Tissue	5 - Impaired	Fishing	Required, not completed
2012	Chlorides	5 - Impaired	Aquatic Life and Wildlife	Required, not completed
1996	Phosphorus	2-meets water quality criteria for the cause specified	Aquatic Life and Wildlife	Approved 2012
1996	Total Suspended Solids (TSS)	4a – Impaired	Aquatic Life and Wildlife	Completed, Approved 2012
2012	Sulfates	5 – Impaired	Aquatic Life and Wildlife	Required, not completed

Table 2.5 Potomac River within Montgomery County Watershed 303(d) Listings				
Year First Listed	**Impairment**	**Listing Category**	**Designated Use**	**TMDL Status**
Unknown	High pH	3 – Insufficient data for assessment	Aquatic Life and Wildlife	Additional data review needed to determine whether elevated pH is due to natural conditions or anthropogenic stressors.
Unknown	Mercury in Fish Tissue	2 – Meets water quality criteria for the cause specified	Fishing	Not required
Unknown	Fecal Coliform	2 – Meets water quality criteria for the cause specified	Water Contact Sports	Approved 2005

3 STORMWATER MANAGEMENT

Stormwater management (SWM) regulations in Maryland were enacted in the early 1980s based upon the Environmental Article of the Annotated Code of Maryland, Title 4, Subtitle 2 which states "…the management of stormwater runoff is necessary to reduce stream channel erosion, pollution, siltation and sedimentation, and local flooding, all of which have adverse impacts on the water and land resources of Maryland." Counties and municipalities are responsible for overseeing SWM programs which should "…maintain after development, as nearly as possible the predevelopment characteristics…" (MDE, 2009).

3.1 CITY'S STORMWATER MANAGEMENT OVERVIEW

The City's SWM infrastructure performs an essential role in mitigating the effects of development on streams and surrounding environmentally sensitive areas. SWM practices are required for both new development and for redevelopment projects. In addition to these private resources, the City constructs and maintains public SWM facilities and an extensive storm drain system. Rockville's stormwater system consists of more than 2,560 storm drain inlets, over 500 private and 200 public SWM facilities, and approximately 100 linear miles of public storm drain pipe.

The SWM infrastructure is designed to collect and slow down stormwater runoff in order to allow time to separate out pollutants that are taken up as rain passes over impervious surfaces. SWM facilities, such as wet ponds and sand filters, act as a repository for these pollutants as they separate from the stormwater, collecting contaminants before they enter the City's streams. The storm drain network and SWM facilities also act to reduce the velocity of runoff as it enters the streams. This reduction in stormwater's speed helps to protect receiving streams from erosion.

The City adopted a SWM ordinance in 1978, the first in the state. Since then, the law was updated to include water quality treatment, then to reflect changing standards. Most recently, City Code Chapter 19 and the City's Regulations for Stormwater Management and Erosion and

Sediment Control were updated in 2010 to adopt the State's 2009 regulations for Environmental Site Design (ESD)-based practices for SWM on new development and redevelopment. The ESD techniques focus on very small-scale treatment systems scattered throughout the developed landscape that maximize infiltration to the groundwater table in an effort to reduce the volume of stormwater as well as the pollutant concentration that reaches the stream. These laws and regulations also incorporate the latest state requirements for erosion and sediment control during construction. Finally, they include details regarding the City's SWM utility fee, an ongoing funding mechanism applicable to all property owners.

The City's SWM budget is funded to support regional stormwater facilities that treat runoff from multiple properties and public roads. These are considered public SWM facilities. The City usually takes over ownership and maintenance of SWM facilities built by developers to serve residential communities where multiple properties and City right-of-way is treated, since these facilities control runoff from public streets in the neighborhood. However, the City does not construct or maintain SWM facilities on private property that only manage that site's runoff, such as a shopping center. Private SWM facilities are built and maintained by individual owners through SWM related development regulations. Similarly, the City maintains the public storm drainage system in streets and parks, but does not manage storm drains on private property. The City has 285 private and 91 public SWM facilities in the Watts Branch watershed.

3.2 ASSESSMENT OF CURRENT STORMWATER TREATMENT

The City's existing SWM facilities database was analyzed based on the drainage area, type of facility, and date of construction. If the drainage area was not available through the City's database, the drainage area was estimated based upon the type of facility, parcel size, and other readily available information. The magnitude of runoff treated by the SWM facilities was estimated based on their date of construction and the stormwater rules and regulations at that time. The following guide, which is consistent with the MDE guidance document - *Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated, June (Draft) 2011*, was used to estimate the runoff treated:

- Partial-Quality – Water quality treatment for the first 0.5" of runoff – facilities designed prior to 1998.
- Full-Quality – Water quality treatment for the first 1.0" of runoff – facilities designed from 1998-present. Represents current State quality treatment standard as of 2014.
- Partial-Quantity – Water quantity treatment for 2-yr storms or larger – facilities designed prior to 1998.
- Full-Quantity – Water quantity treatment for 1-yr, 24-hour storm – facilities designed from 1998-present. Represents current State quantity treatment standard as of 2014.

Of the 285 private and 91 public facilities, 202 facilities provide either partial or full water quality treatment (WQ) and provide some pollution removal. Appendix C includes a map of the existing public and private facilities. While sediment separators, Stormceptor, and Oil Grit separators can provide some minimal water quality treatment, they are typically used as pre-treatment. Therefore these facilities were included in the list of partial-quality facilities. The remaining facilities and the impervious area within their drainage area provide water quantity treatment (QN) only and do not provide any WQ. Full-quantity facilities are considered effective at reducing stream erosion if the treatment covers most of the drainage area. However, in areas developed without full-quantity treatment, this benefit rapidly dwindles as the uncontrolled drainage area increases.

A summary of these public and private facilities is provided in Table 3.1. Table 3.1 also describes the function of each type of system according to the following codes:

- **"QN" systems** refer to systems designed for quantity control only. These are generally designed to reduce the peak rate of runoff (the highest rate of flow) from a developed area down to the flow that existed prior to development.
- "**WQ" systems** are generally newer, and are designed to reduce runoff pollution.
- "**WQ-QN" systems** are designed to reduce both peak flows and pollutants

Table 3.1
Stormwater Management Treatment Practices Within the Watts Branch Watershed

Stormwater Treatment Practice		Quantity/Quality	# of Public	# of Private	Total
SSP	Proprietary Sediment Separator	WQ	3	9	12
STC	Stormceptor	WQ	12	39	51
OGS	Oil Grit Separator	WQ	2	7	9
OTH	Other	-	9	17	26
UGR	Underground Recharge	-	-	8	8
BR	Bioretention	WQ	8	38	46
SF	Sandfilter	WQ	19	23	42
SFU	Underground Sand Filter	WQ	1	32	33
INF	Infiltration	WQ	2	47	49
VS	Vegetated Swale	WQ	-	2	2
PP	Pervious Pavement	WQ	2	-	2
UG	Underground	QN	-	21	21
UGP	Underground Pipe	QN	2	7	9
INFCQN	Infiltration Trench with Quantity Control	WQ-QN	-	2	2
SFQN	Sand Filter with Quantity Control	WQ-QN	-	4	4
PDQN	Pond - Quantity Only	QN	11	15	26
PDWTQNED	Pond - Wet with Quantity and Extended Detention	WQ-QN	10	4	14
PDWNED	-	QN	1	-	1
PDWTED	Pond - Wet with Extended Detention	WQ-QN	2	1	3
PDWDQN	Pond - Wetland with Quantity	WQ-QN	2	-	2
PDQNED	Pond - Quantity and Extended Detention	QN	5	6	11
PDWTQN	Pond - Wet with Quantity Control	WQ-QN	-	3	3
WATERSHED TOTAL			**91***	**285**	**376**

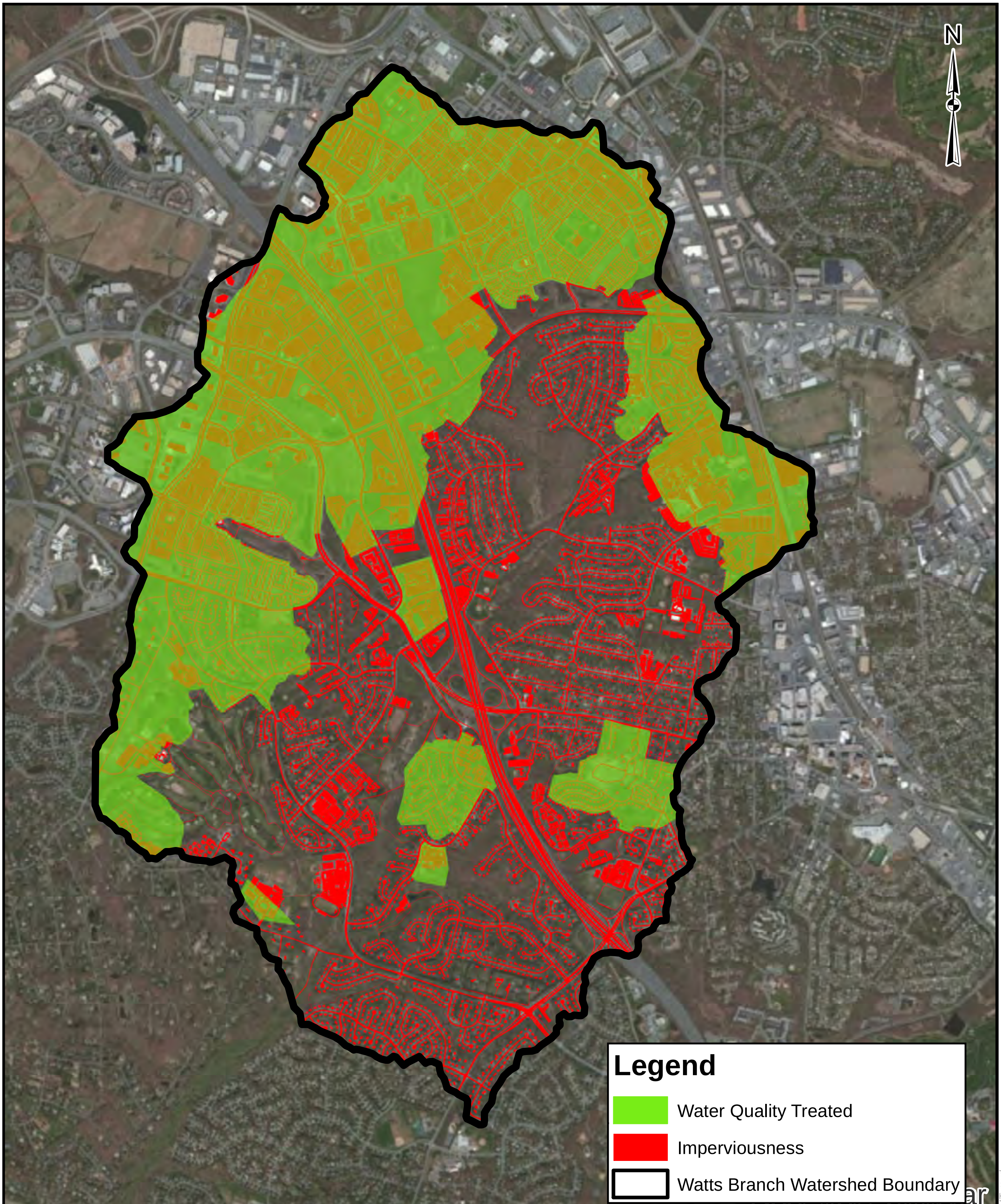
* Flow splitters are not included in the Watts Branch SWM Facilities inventory but there are 14 Private and 79 Public Flow Splitters.

Within the watershed, some form of water quality (partial quality and full quality) treatment is provided for approximately for 1,821 acres of which 819 acres is impervious. Therefore, approximately 51.8% of the 1,578.7 acres of impervious area within the watershed is being treated at least partially with at least 47.6% of the watershed draining to at least one water quality facility. This delineation of impervious area treated by the facilities identified within the City's database was derived from a visual interpretation of the outer most drainage area boundaries for the facilities within the watershed to account for which portion of the watershed drain to at least one facility. The impervious area and area draining to the facilities based on the City's database is summarized within Appendix D where the amount of area treated accounts for double counting of impervious areas treated by nested facilities.

The estimate shown in the analysis of the City's database for impervious area treated for water quality is correlated to the data provided within the database for the drainage areas of the SWM facilities. Inconsistencies and overlapping drainage areas of the facilities are referred to as 'nesting'. For example, larger drainage areas discharging to stormwater ponds that provide water quality contain smaller sub-areas that drain to infiltration practices (i.e. sand filter, bioretention, etc.) which ultimately runoff to a regional stormwater management pond. The impervious area treated is based solely on the drainage areas provided by the City's database or other readily available information and the land use within the drainage area; therefore, the impervious area treated within the smaller sub-areas is also included as impervious area treated by the stormwater pond and thus the analysis does not account for any reductions in impervious area treated by the smaller facilities that are nested in the larger facilities drainage areas.

Approximately 2,247 acres within the watershed, which includes 1,016 acres of impervious area, lacks any water quality treatment. This accounts for 48.2% of the impervious area within the watershed and 52.4% of the total watershed area. Figure 11 shows the areas within the Watts Branch watershed that provide full or partial water quality treatment. Based on the location and acreage of impervious area without effective water quality treatment, the City can evaluate specific areas and facilities most practical for retrofits, as well as consider other operational efforts to improve water quality where stormwater management facilities are not feasible.

It should be noted that the area shown on Figure 11 for the impervious area treated does not differentiate between areas treated partially or fully. The limitations of the City's GIS database and GIS layers prevented an accurate analysis to fully determine which impervious areas of the City are receiving full WQ volume and which are receiving partial treatment. Again the City is working on improving their GIS database to improve on the ability to complete this analysis.



0 1,250 2,500 5,000 Feet

1 inch = 2,500 feet

BayLand Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A Phone: (410) 694-9401
Hanover, Maryland 21076 Fax: (410) 694-9405
bayland@baylandinc.com

FIGURE 11
WATER QUALITY TREATMENT

S:\TEMPLATES\8X11_PORTRAIT.mxd

3.3 IDENTIFYING POTENTIAL POLLUTION SOURCES

Field Assessment

Stormwater pollutants can significantly influence stream health. Pollutants may not necessarily come from areas directly adjacent to the stream. Indeed, most pollutants originate in upland areas and are transported via storm drain pipes to the streams during storm events.

The City's 2007 Water Quality Protection Ordinance protects surface and groundwater by specifying prohibited discharges, such as oil or excessive sediment, to the storm drain or stream. It also establishes a duty to report and cleanup these discharges, and clarifies the City's ability to conduct inspections and enforce the ordinance. The City may use this enforcement mechanism to work with private owners to mitigate onsite activities and property management issues that may harm stream quality.

In order to identify potential pollution sources within the Watts Branch watershed, BayLand field staff reviewed drainage complaints, conducted a GIS analysis, and met with City officials to identify areas of concern. As a result of this analysis, three primary areas were assessed as potential pollutant sources: Hotspots, Sanitary Sewer Systems, and Neighborhoods.

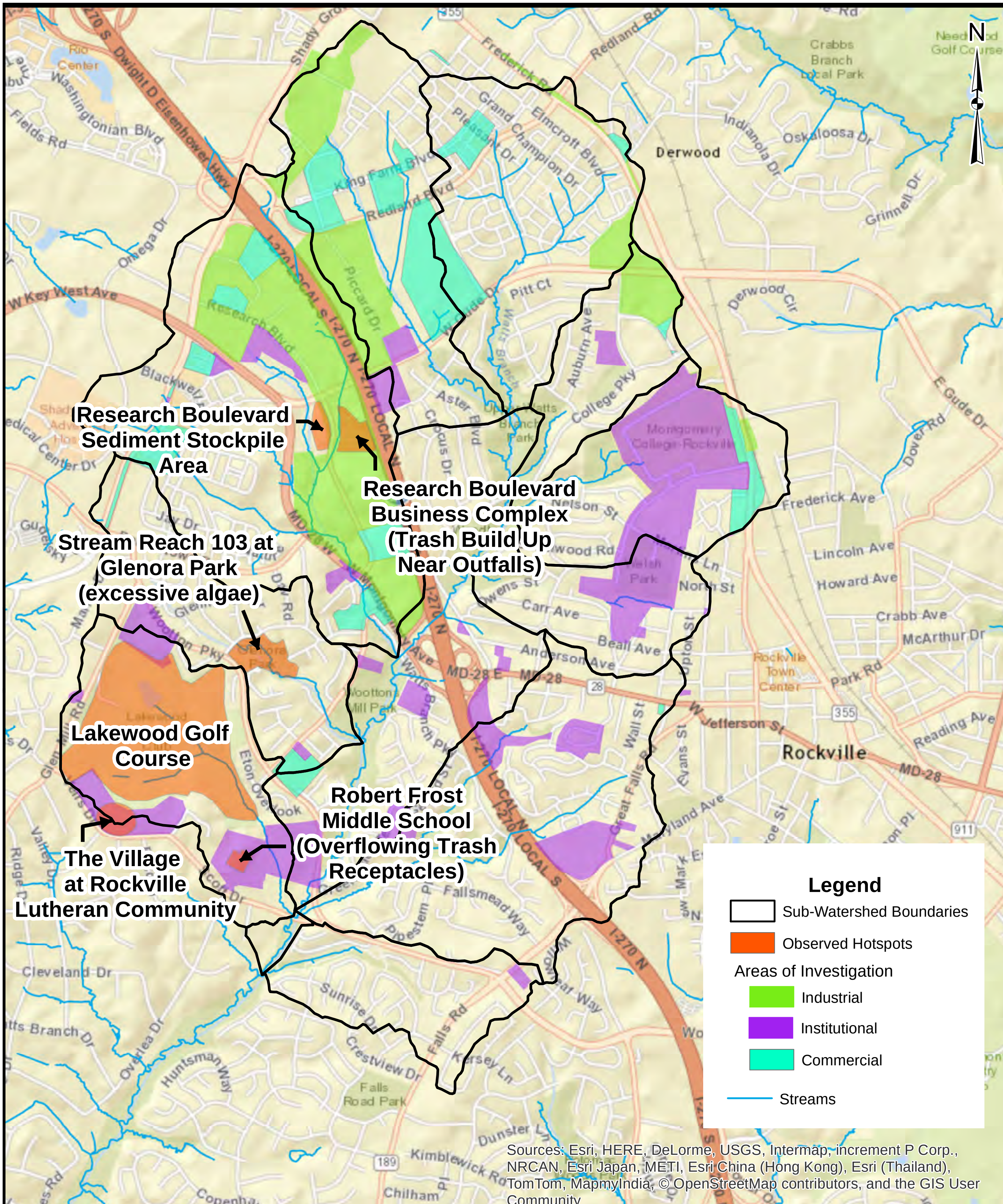
Hotspot Pollutants

For purposes of this report, hotspots consist of commercial, industrial, municipal, and transportation related sites which could contribute pollutants such as nutrients, pesticides, road salt, trace metals, sediment, fuels, and toxic chemicals to the waterways. These areas comprise 29% of the watershed. Common hotspot operations include dry cleaning and commercial laundry facilities, scrap yards, golf courses, restaurants, retail establishments, and public works yards.

The following hotspots were identified and targeted for additional field investigation (see also Figure 12):

- Lakewood Golf Course
- Research Boulevard Sediment Stockpile
- Research Boulevard Business Complex
- Institutional Sites (Montgomery College, Montgomery County Public Schools, Rockville Municipal Swim Center, National Lutheran Home, etc.)
- Office and Retail Areas
- Construction Sites

Figure 12 shows the hotspot locations identified in the City's portion of the Watts Branch watershed. Table 3.2 lists the locations of hotspots in the watershed and identifies the problems observed at these locations. At these locations, observations included: vehicle operations, outdoor storage practices, waste management, building conditions, landscaping maintenance, storm drain/stormwater infrastructure, and any other observable practice which may indicate a pollution source. It is important to note that the observations noted are based upon a single day's visit to the site and, depending on recent rain and other events, the observations may not be typical for the site.



0 1,250 2,500 5,000 Feet

1 inch = 2,500 feet

BayLand Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A
Hanover, Maryland 21076
Phone: (410) 694-9401
Fax: (410) 694-9405
bayland@baylandinc.com

FIGURE 12
POTENTIAL POLLUTION SOURCES

P:\8_19201_City of Rockville Watts Branch Watershed Study\GIS\Hot Spots Map 8x11.mxd

Table 3.2
Summary of Observed Hotspots

Site	Observed Problem(s)	Example
Stream Reach 103	• Algae (an indicator of nutrient pollution) was observed in Reach 103 near the Tennis Courts in Glenora Park	
Lakewood Golf Course	• Uncovered piles of sand; runoff from the site could potentially flow into a nearby stream • Potential overuse of fertilizers and pesticides for turf management (this type of land use generally is common, but the nutrient management plan is unknown). • Algae growth in Reach 102 and 201	
Robert Frost Middle School	• Overflowing trash receptacles; trash could runoff into a nearby stream	
Research Boulevard Sediment Stockpile Area (future development site for Fallsgrove offices)	• Uncovered piles of soil, gravel, and other materials on site; runoff from the site could potentially flow into a nearby stream	

Table 3.2 Summary of Observed Hotspots		
Site	**Observed Problem(s)**	**Example**
The Village at Rockville Lutheran Community	• Potential chemical runoff from exposed paint and other containers at Lutheran Community Center	
Research Boulevard - Westat Business Complex	• Trash and sediment built up near outfalls and along entire reach through an office area on Reach 108	

Based upon observations, BayLand field crews advised the City when immediate attention was needed and/or if the site should be evaluated further. Controlling pollution at the source is an effective strategy in pollution prevention. In some cases, regular site visits may be needed to ensure compliance.

Sanitary Sewer Systems

Leaking sewer pipes and manholes contribute fecal bacteria and nitrogen to streams and waterways impacting stream health. Nitrogen depletes oxygen levels and effects survival of aquatic wildlife. Many urban sewer systems are aging and require repairs and replacements. Since the majority of the gravity fed sewer pipes are located in stream valleys and wooded areas, these leaks may go unnoticed for long periods of time.

Four exposed sanitary sewer manholes and seven exposed pipes were identified during the stream assessment portion of the project (see Figure 13 and Table 3.3). Of the exposed infrastructure, four manholes and five pipes are owned by the City of Rockville. According to GIS mapping, two of the pipes have been abandoned so they are not active and ownership is unknown. There was no evidence of leaking sanitary sewers or spills; however, the City of Rockville and WSSC have instituted extensive efforts to prevent potential sanitary sewer leaks and spills.

The City of Rockville's ongoing Sanitary Sewer Preventive Maintenance Program is in place to prevent potential pollution spills from more than 148 miles of City-owned sanitary sewer piping.

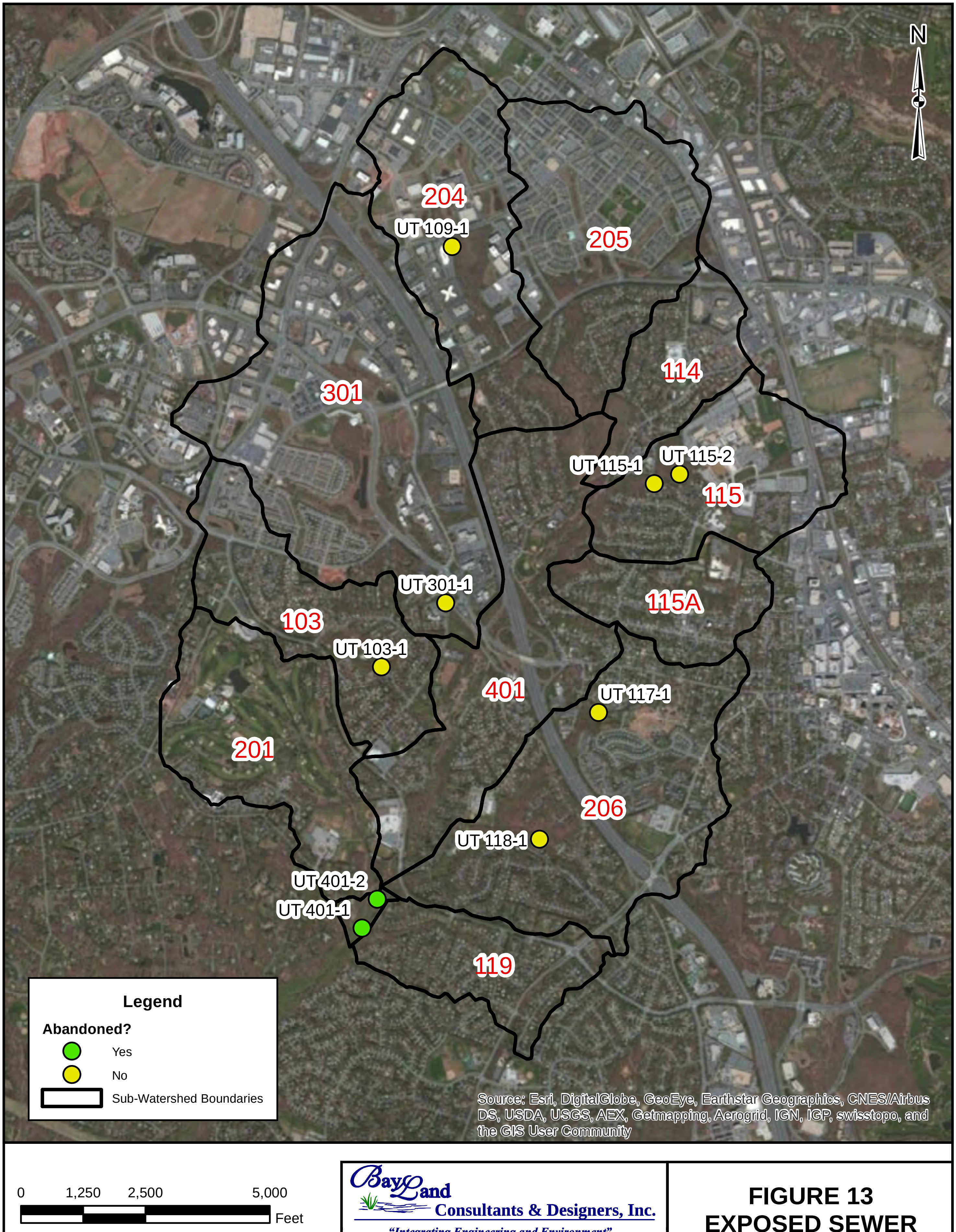
With 55 miles of piping, the Watts Branch sewershed (roughly corresponding to the watershed boundary) contains 37 percent of the City's sanitary sewer system. This multi-year initiative includes inspections of the sanitary sewer piping using closed-circuit television cameras. Sewer infrastructure with significant defects is prioritized for lining or replacement to prevent any sewage from leaking into groundwater. As of spring 2014, 16 miles of City sanitary sewer has been CCTV-inspected within the Watts Branch sewershed, and 5.1 miles of this has been rehabilitated via cured-in-place pipe liner.

Washington Suburban Sanitary Commission (WSSC) provides the sanitary sewer system for 22.5 miles of piping in the Watts Branch Watershed. WSSC is actively maintaining its sewer system. In 2005, WSSC entered into a Consent Decree with EPA, MDE, and citizens groups to require the rehabilitation of defective sewer lines or structures throughout the sewershed basin within the WSSC's sanitary sewer district. The Consent Decree requires all sewer repair, replacement, and rehabilitation projects to be completed by December 7, 2015.

Future preventive maintenance and improvements to the City-owned and WSSC sanitary sewer systems in the Watts Branch watershed are essential components of a comprehensive approach to pollution prevention.

Table 3.3
Exposed Sanitary Manhole and Pipes

Site ID	Subwatershed	Reach ID	Type	Notes	Ownership
UT 103-1	103	103	Sewer manhole and pipe	Concrete is deteriorating around pipe. Manhole is 7' high.	City of Rockville
UT 109-1	204	109	Sewer manhole	Exposed manhole is 5' high and minor deterioration of concrete is exposing bricks.	City of Rockville
UT 115-1	115	115	Sewer manhole and pipe	Concrete encasement has deteriorated and underneath the exposed pipe is undermined. Manhole is exposed on the right bank.	City of Rockville
UT 115-2	115	115	Sewer pipe	Pipe is not concrete encased.	City of Rockville
UT 117-1	206	117	Sewer pipe	Concrete encasement is mostly gone and there is undermining.	City of Rockville
UT 118-1	206	118	Sewer pipe	Pipe is being undermined and the concrete is deteriorating.	City of Rockville
UT 204-1	204	204	Sewer manhole	Manhole is exposed along left bank and is 3.5' high.	City of Rockville
UT 401-1	401	401	Abandoned sewer pipe	Appears to be inactive; pipes are exposed in three locations with lengths of 15', 10' and 93'. They are not aligned with existing manholes.	Unknown
UT 401-2	401	401	Abandoned sewer pipe	Two exposed pipes running parallel to each other. It is unclear if the pipes are active and flow is going under the pipes.	Unknown



1 inch = 2,500 feet

BayLand Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A
Hanover, Maryland 21076
Phone: (410) 694-9401
Fax: (410) 694-9405
bayland@baylandinc.com

FIGURE 13
EXPOSED SEWER MANHOLES AND PIPES

P:\8_19201_City of Rockville Watts Branch Watershed Study\GIS\Report Figures\Figure 12.mxd

Neighborhoods

Residential areas comprise 53% of the watershed and thus have the potential to contribute a significant source of pollutants to the watershed. Each neighborhood was visually assessed for signs of: excess use of fertilizers, improper disposal of motor oil and other vehicle fluids, poor trash management, pet waste disposal, and use of pesticides. The neighborhoods were fairly homogeneous in stormwater management practices and potential pollution sources. At the time of inspection, there was not a lot of evidence showing potential sources.

It is worth noting that, for the most part, pollution loadings within neighborhoods are behavior driven. Even though no pollution sources were identified at the time of the inspection, it is conceivable that some pollution does initiate from the neighborhoods within the Watts Branch watershed. Common neighborhood pollution types include:

Pesticides, herbicides and fertilizers used on lawns, gardens, and landscaped areas are always potential pollution issues, especially in residential areas. These chemicals easily run off into storm drains and streams when applied in excess or just prior to a rain event. Pesticides and herbicides contain toxins, and fertilizers contain nitrogen and phosphorus, which are two of the significant nutrient pollutants to the Chesapeake Bay. Excess nutrients cause algae growth and reduce oxygen in the water which impacts aquatic wildlife. The City currently provides outreach to citizens regarding nutrient management to help reduce potential over application of lawn fertilizer and pesticides.

Trash, sediment and illicit discharges are common urban pollutants throughout Rockville. Examples of urban pollutants include: oil and other fluids from vehicles, household trash, household cleaning chemicals, and sediment. The findings represent a snapshot in time of the watershed conditions. Factors such as recent rain events, recent trash pickup, and onsite activities can vary greatly from day to day. So while a specific activity such as improper disposal of motor oil or paint was not observed during this field investigation, it is a common occurrence in both residential and non-residential settings.

Pet waste can be a significant source of pollution in urban watersheds, not only in private residential yards, but in parks and open spaces where dogs are walked. Pet waste can be washed into storm drains and streams and affects water quality by adding nitrogen and fecal bacteria to the stream systems. While specific pet waste issues were not observed during the field investigation, it is a common occurrence in residential settings. Individual pet owners are responsible for picking up after pets and inappropriate disposal of pet waste is against the city code. Public outreach and signage can help alleviate the problem.

4 TR-20 MODEL

The United States Department of Agriculture Soil Conservation Service (SCS) Technical Release 20 (TR-20) is a computer model that utilizes selected storm events with the computed sub-basins drainage area characteristics and existing SWM facilities hydraulics to develop peak discharges for the selected study points. The model is designed to operate on a time varying rainfall to produce a hydrograph that simulates the role of the watershed area; land cover; hydrologic soil types; antecedent runoff conditions; topography; storage basins; characteristics of the overland, shallow confined, and channel flow paths; and, storage attenuation such as that created by flood plains, wetlands, structures, and ponds. A TR-20 analysis was performed as part of this study (see Appendix E). The City can utilize this updated hydrologic model to inform project designs within the watershed.

5 STREAM ASSESSMENT

5.1 METHODOLOGY

2001 Methodology

Environmental Systems Analysis, Inc. (ESA), in cooperation with the Center for Watershed Protection and the City of Rockville Department of Public Works, evaluated and characterized the physical characteristics of approximately 12.5 miles of perennial streams (streams which flow year round) within the City of Rockville which are part of the Watts Branch watershed. This assessment was performed using a field method known as the Rapid Stream Assessment Technique (RSAT) (Galli, 1996). This technique was modified to ensure compatibility with project objectives and resources for the study area. The modified RSAT was used to evaluate more than 30 physical stream conditions at stations located at 400-foot intervals (between 12 and 13 observation points per mile), or wherever unique conditions or potential problems were apparent. Evaluation categories included channel stability, channel scouring and deposition, physical in-stream habitat, water quality, riparian habitat condition, aesthetics and remoteness (CWP, 2001).

2013 Methodology

From July – October 2013, BayLand conducted a stream assessment along each of the 25 stream reaches. These reaches were numbered based upon the 2001 Watts Branch Watershed Study and are shown in Figure 4. A portion of stream reaches 204, 205, and 302 were not accessed since they had recently been evaluated as part of the Upper Watts Branch restoration design project by Charles P. Johnson and Associates (CPJ). BayLand summarized CPJ's assessment and incorporated it into this section where appropriate.

Geomorphic Mapping

BayLand field crews walked a total of 87,606 linear feet or 16.6 miles of stream and created geomorphic maps for each stream reach. The geomorphic maps included areas of bank erosion, deposition, invasive species, riparian vegetation, lateral and vertical instability, debris jams, condition of utility infrastructure, outfall conditions, water quality concerns, stream buffer concerns, bank and bed stabilization structures (riprap, cross vanes, etc.), downed trees, pool and riffle depths, and bed material. The collected data, as shown on the maps, are used to determine the overall stability of the reach. The geomorphic maps are presented in Appendix F.

Channel Dynamics & Erosion

Stream erosion is part of natural channel migration, where streams meander, widen, and narrow in order to reach a stable equilibrium. Urbanization changes stream flows, increasing the amount of water and creating flashier flows. Changes such as this can cause a stream to be unstable, as it tries to adjust its banks to the change in flows. Channel dynamics, or changes in stream channels, are described by these five terms:

- Stable: the channel is in balance between erosion and deposition
- Aggrading: the streambed is raised up by deposits of sediment carried from upstream
- Bed erosion: the streambed erodes and the channel becomes deeper, or incised
- Bank erosion: the stream banks erode and the channel becomes wider
- Head cutting: bed erosion moves upstream at nick points (waterfalls)

Stream erosion is likely to occur at confluences with other tributaries, and near a debris blockage or manmade features like culverts, bridges, and outfalls. Bank erosion is common along the outside of meander bends and is usually associated with channel deposition or bar formation along the inside of the bends. Bank erosion causes trees to fall which in turn cause channel blockages. Fallen trees and other debris dams in the stream create blockages which cause downcutting or widening of the stream channel. Erosion may be localized or reach-wide. Since channels change over time, erosion issues may become more or less pronounced at specific locations.

Monitoring active erosion sites every few years will show the rate of erosion progression, and can identify sudden failures caused by large storm events or other unusual circumstances. Areas of erosion were noted on the geomorphic maps and can be used as a basis for future stream assessments and monitoring activities.

Bank Erosion Hazard Index

In addition to noting bank erosion on the geomorphic maps, a Bank Erosion Hazard Index (BEHI) was performed at areas with high or extreme bank erosion. The BEHI is a rating system developed by Rosgen that measures the ability of stream banks to resist erosion (Rosgen, 2001). The BEHI methodology uses five parameters to calculate the channel stability hazard index, which is assigned one of six descriptive ratings – very low, low, moderate, high, very high, or extreme. The BEHI evaluates the potential for stream bank erosion by assessing the height of the bank relative to the bankfull height, the rooting depth of the trees and other vegetation on the stream banks, the density of the roots, the angle of the bank, and whether any protection such as rock or large woody material is present at the toe of the bank. BEHI rating sheets and summary results are included in Appendix G. The BEHI computations are found in Appendix H.

Overall Stream Condition

The health and condition of the physical habitat structure, or all those structural attributes that influence or sustain organisms within the stream for each stream segment was rated using the Overall Stream Condition Datasheet extracted from the Unified Stream Assessment (USA) methodology (Kitchell and Schueler, 2004). Each parameter is rated from optimal to poor and given a numerical value. Each parameter is summed and each reach is given an overall numerical value with a maximum score of 160. The following parameters are included in the assessment:

- In-stream habitat
- Vegetative protection
- Bank Erosion

- Floodplain connectivity
- Vegetated buffer width
- Floodplain vegetation
- Floodplain habitat
- Floodplain encroachment

Several other datasheets extracted from the Unified Stream Assessment (USA) method were also used in the assessment. They included outfalls, trash, and utilities. All USA datasheets are presented in Appendix I.

5.2 RESULTS

Results of the stream assessment are broken down into subwatersheds starting with the westernmost watershed and continuing in a clockwise direction and ending with the mainstem (Subwatershed 401). Results include comparisons of the condition of the reaches during the 2001 assessment with the current condition of the channels. Appendix J, the Stream Assessment Report, contains detailed descriptions and photos of each stream reach, grouped into their subwatersheds.

5.2.1 SUBWATERSHED 201

The majority of Subwatershed 201 is located within the Lakewood Country Club community and golf course and consists of stream reaches 101, 102, and 201. The headwaters of the subwatershed come from stormwater management ponds. The majority of the land use is open urban land (53%) and consists of mowed/managed grass within the golf course (see Table 5.1). Reaches 101 and 102 are located entirely within the Lakewood Country Club and a portion of Reach 201 is located within the country club property.

Table 5.1
Subwatershed 201 Land Use and Impervious Area

Land Use	Drainage Area (acres)	Percent of the Subwatershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Subwatershed
Low-Density Residential	38.48	11.45%	2.98	7.77%	0.89%
Medium Density Residential	48.33	14.38%	5.21	10.79%	1.55%
High Density Residential	0.01	>0.01%	>0.01	2.66%	>0.01%
Commercial	0.46	0.14%	0.11	24.27%	0.03%
Institutional	58.47	17.39%	19.53	33.42%	5.81%
Open Urban Land	177.29	52.73%	13.38	7.55%	3.98%
Deciduous Forest	6.83	2.03%	0.12	1.81%	0.04%
Water	6.32	1.88%	0.04	0.67%	0.01%

Reach 101

Major stream problems during the 2001 assessment for Reach 101 included *fair* water quality and lack of adequate or quality riparian buffer. The overall RSAT rating was *good* due to high scores for channel stability, channel scouring/sediment deposition, and physical in-stream habitat. The reach was ranked as a high priority site needing buffer enhancement because of an existing mowed grass riparian area.

Many of the same problems were found during the 2013 assessment. Approximately 60% of the riparian area was still mowed grass and water quality issues included the presence of iron flocculent and grass debris in the channel. An unknown exposed 6” pipe was found near the downstream end which was not identified in 2001. The channel was relatively stable, but had an overall decline in stream condition. The reach could benefit from planting a wooded riparian buffer.

Reach 102

In 2001, Reach 102 had an overall RSAT score of *fair* and was *low* for channel stability, water quality, and riparian habitat. Scores were *high* for scouring & deposition and in-stream habitat. The reach was ranked as a high priority site needing buffer enhancement because of an existing mowed grass riparian area.

Many of the same problems were found during the 2013 assessment. The riparian buffer was still limited both in width and the amount of woody vegetation. Water quality issues included dark grey water in pools and algae. An exposed gas line was found in the channel and appeared to be in good condition but needs protection. The channel also had instability issues and invasive species were found throughout most of the reach. The reach could benefit from planting a wooded riparian buffer and invasive species management.

Reach 201

In 2001, Reach 102 had an overall RSAT score of *good* with *fair* to *good* scores in scouring and deposition, in-stream habitat, and water quality. The reach rated low for riparian habitat and channel stability. The reach was ranked as a priority site needing buffer enhancement because of a narrow buffer width and the need for invasive species management.

Approximately 75% of Reach 201 is located within the golf course property with the remaining 25% located in a wooded area of Wootton Mill Park. The channel’s characteristics change significantly between these two areas. Water quality issues including iron flocculent and algae were observed within the golf course property. This section also had large amounts of invasive species and a mowed grass riparian area which was also noted in 2001.

Downstream of the golf course, stream restoration/stabilization structures had been installed in the channel with varying degrees of success. This section had large amounts of bank erosion, significant bar development, and a headcut. Overall, this section of stream was highly unstable. This reach is the most unstable reach in the watershed and has experienced an overall decline in stream condition. City staff visited this reach in 2014 and found the stream restoration between Frost Middle School and Scott Drive to be in good condition, except for one 30’ section of bank.

5.2.2 SUBWATERSHED 103

Subwatershed 103 consists of stream reach 103. The majority of the land use is residential (81%) (see Table 5.2). Reach 103 is located within a wooded riparian buffer and crosses through Glenora Park and Woottons Mill Park. The reach originates at an outfall.

Table 5.2
Subwatershed 103 Land Use and Impervious Area

Land Use	Drainage Area (acres)	Percent of the Subwatershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Subwatershed
Low-Density Residential	28	9.86%	2.01	7.16%	0.71%
Medium Density Residential	155	54.58%	18.77	12.11%	6.61%
High Density Residential	46	16.20%	23.80	51.74%	8.38%
Commercial	16	5.63%	5.94	37.13%	2.09%
Institutional	10	3.52%	4.28	42.83%	1.51%
Open Urban Land	16	5.63%	1.82	11.43%	0.64%
Cropland	8	2.82%	1.13	14.09%	0.40%
Deciduous Forest	5	1.76%	1.30	26.08%	0.46%

Reach 103

In 2001, the overall RSAT rating for Reach 103 was *fair*. The only ranking of *good* was for water quality. The reach was ranked as a high priority site needing buffer enhancement because of sparse or absent woody riparian cover. An exposed gas line was observed and the community pool deck for Carter Hill Homeowners Association downstream of Glenora Park was at risk due to bank erosion.

The 2013 assessment of Reach 103 found an unstable reach with high bank erosion. The reach was over-widened and had significant bar formation indicative of a high sediment supply. Stream restoration/stabilization was completed after the 2001 assessment but does not appear to be increasing the overall stability of the channel. The riparian habitat has improved as the majority of the reach is now located within a wooded buffer. Thick algae was observed in a portion of the reach indicating the water quality has declined.

In 2013, two utility structures were noted as needing repair or causing fish barriers and an exposed sanitary sewer manhole was observed. The gas pipe line was no longer exposed and the bank near the pool had been stabilized with riprap. One outfall was noted as being undermined.

In the summer of 2014, the City constructed stream restoration and utility protection between the pool parking lot to Hurley Avenue. This project had been recommended in the 2001 Watts Branch Watershed Management Plan.

5.2.3 SUBWATERSHED 301

The majority of Subwatershed 301 is located in industrial (office) parks between I-270 and Route 28. This subwatershed has had land use changes since the 2001 watershed study from agricultural to high density residential/commercial/office due to the new Fallsgrove (Thomas Farm) mixed-use development. Subwatershed 301 consists of stream reaches 104, 105, 106, 107, 108, 203, and 301. The most downstream reach (reach 301) leads into the mainstem of Watts Branch (reach 401). The majority of the land use is industrial (32%) and consists of mostly industrial parks and parking areas (see Table 5.3). Reach 104 is piped and Reach 105 is piped in the upstream half of the reach. A portion of Reach 106 near the Shady Grove Adventist Hospital has been redirected to Reach 105.

Table 5.3
Subwatershed 301 Land Use and Impervious Area

Land Use	Drainage Area (acres)	Percent of the Subwatershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Subwatershed
Low-Density Residential	22.16	3.02	1.97	8.88	0.27
Medium Density Residential	60.91	8.30	10.02	16.45	1.36
High Density Residential	61.37	8.36	34.53	56.27	4.70
Commercial	118.89	16.19	49.36	41.51	6.72
Industrial	231.66	31.55	135.35	58.43	18.43
Institutional	50.16	6.83	13.45	26.82	1.83
Open Urban Land	5.53	0.75	>0.01	0.02	>0.01
Cropland	87.28	11.89	18.89	21.65	2.57
Pasture	20.19	2.75	2.79	13.84	0.38
Deciduous Forest	23.54	3.21	2.77	11.78	0.38
Mixed Forest	5.16	0.70	0.42	8.22	0.06
Transportation	47.42	6.46	30.12	63.51	4.10

Reach 104

There was no RSAT assessment for Reach 104 in 2001. This reach was located in an agricultural use area in 2001. In 2013, no channel was evident at the time of investigation. The reach has been piped to a stormwater management pond and no longer exists due to the Fallsgrove development.

Reach 105

In 2001, the overall RSAT rating for Reach 105 was *fair*. There were no scores above *fair* except for remoteness. The reach was ranked as a priority site needing buffer enhancement because of a narrow buffer and invasive species.

In 2013 Reach 105 was found to be a relatively stable channel with low bank erosion. Debris jams and downed trees are becoming increasingly prevalent as the channel continues downstream and one headcut was found. Generally, there was an overall improvement in stream condition. An old culvert was found underneath an abandoned road and would be a good candidate for removal. The reach no longer rates high for remoteness since land use has changed and it is now located in a City stream valley park sandwiched between residential lots. The 125-150’ stream buffer on either side of the channel ends at the residential back yards. There is some encroachment or yard trim dumping in the buffer from adjacent neighbors.

Reach 106

In 2001, the overall RSAT rating for Reach 106 was *good* indicating it was stable. The only ranking of *fair* was for water quality. The reach was ranked as a priority site needing buffer enhancement because of sparse or absent woody riparian cover and invasive species.

During the 2013 assessment, the majority of Reach 106 was stable with moderate bank erosion. Only the last 550 feet of stream (13%) was laterally unstable and entrenched. An old collapsed culvert was found underneath an abandoned road and would be a good candidate for removal but it was not affecting the stability of the channel. Poor water quality was noted at an upstream outfall where water was black in the plunge pool indicating that water quality has not improved.

Reach 107

In 2001, the overall RSAT rating for Reach 107 was *fair* indicating an unstable channel. The only ranking of *good* was for water quality. The reach was ranked as a priority site needing invasive species management.

The 2013 assessment of Reach 107 found a stable reach with low bank erosion. Reach 107 had evidence of previous restoration/stabilization activities and they appeared to be improving the stability of the channel. There was also an improvement in riparian & in-stream habitat.

Reach 108

There was no RSAT assessment for Reach 108 in 2001.

In 2013, the majority of the reach was dry. This was the only reach with noticeable trash accumulation. Perennial flow started after the West Gude Drive culvert. The banks were eroded and there was significant deposition in this section. The channel in this area was also incised with minimal access to a floodplain. An undermined outfall was also found in Reach 108. Overall stream condition was *marginal* indicating an unstable channel.

Reach 203

In 2001, the overall RSAT rating for Reach 203 was *good*. The reach rated *fair* for in-stream habitat and riparian habitat but was found to have one of the highest ratings for channel stability.

There was improvement in riparian and in-stream habitat in 2013. Heavy vegetation was noted throughout the reach. The channel has spot treatment structures throughout the reach including imbricated riprap walls, riprap bank and bed protection, and gabion baskets. The channel has limited access to its floodplain and is incised throughout 65% of the reach indicating a decline in channel stability since 2001.

Reach 301

In 2001, the overall RSAT rating for Reach 301 was *good*. The reach scored *fair* for water quality and riparian habitat. The reach was ranked as a high priority site needing buffer enhancement because of sparse or absent woody riparian cover. Two utilities, an exposed gas line and two parallel sewer pipes were found in 2001. An exposed pipe was found in 2013 in vicinity of the 2001 exposed gas line but the exposed sewer pipes were not located. A debris jam was also noted in 2001 but was absent during the 2013 investigation.

The 2013 assessment of Reach 301 had an overall improvement in stream condition. Channel stability varied from an over-widened entrenched channel with excess sediment to a stable channel with floodplain access. Gabion baskets were found in the reach creating several fish barriers. Downed trees were common in the reach and several outfalls were failing. The majority of the riparian area in Reach 301 improved and consisted of forest, however, several patches of invasive bamboo were found north of Crofton Hill Lane.

5.2.4 SUBWATERSHED 204

The majority of Subwatershed 204 is located in industrial and residential areas including some of the reach in the new King Farm development. Subwatershed 204 consists of stream reaches 109, 110 and 204. The majority of land use is industrial (27%) and consists of mostly industrial parks and parking areas (see Table 5.4). Residential land use is a close second to industrial with 23% and consists of mostly single-family/duplex housing, high-rise apartments/condominiums and townhouses. A portion of the subwatershed in the lower quarter of Reach 204 was not assessed as it was part of a previous assessment by CPJ.

Table 5.4 Subwatershed 204 Land Use and Impervious Area					
Land Use	**Drainage Area (acres)**	**Percent of the Subwatershed**	**Impervious Area (acres)**	**Percent Impervious Within the Land Use**	**Percent Impervious of the Subwatershed**
Medium Density Residential	42.35	10.92%	4.49	10.59%	1.16%
High Density Residential	47.29	12.19%	27.63	58.42%	7.12%
Commercial	73.18	18.86%	43.68	59.69%	11.26%
Industrial	103.00	26.55%	67.38	65.42%	17.37%
Institutional	11.47	2.96%	5.31	46.30%	1.37%
Cropland	3.6	0.93%	0.22	6.02%	0.06%
Pasture	54.56	14.06%	12.66	23.20%	3.26%
Deciduous Forest	45.13	11.63%	1.40	3.09%	0.36%
Brush	7.39	1.91%	0.46	6.27%	0.12%

Reach 109

In 2001, the overall RSAT rating for Reach 109 was *fair* indicating a stream with instability and in poor condition. The reach scored *poor* for water quality and in-stream habitat and *fair* for the remaining parameters. A portion of the reach was ranked as a high priority site needing buffer enhancement because of sparse or absent woody riparian cover.

The 2013 assessment of Reach 109 had an improvement in in-stream habitat. An exposed sanitary sewer manhole was found in fair condition along the bank and a severely undermined outfall was located at the start of the reach. A two foot headcut was also located in the channel caused by fallen branches and debris and may be the result of beaver activity. Generally, the reach is incised with eroded banks with minimal access to its floodplain. This reach has not improved since the 2001 assessment.

Reach 110

In 2001, the overall RSAT rating for Reach 110 was *fair*. The reach scored *fair* for all parameters except water quality which was rated as *good*. The reach was ranked as a high priority site needing buffer enhancement because of sparse or absent woody riparian cover.

The 2013 assessment of Reach 110 had a decline in channel stability and an improvement in in-stream habitat. During the 2001 assessment, the upper half, located in the King Farm area, was in the process of being developed. This upper half has few meander bends and appears to have been straightened as part of the development. An unmapped culvert was located in this section and is likely an old farm road crossing. This section is more stable with floodplain benches. The lower half outside the King Farm development is less stable with eroded banks and an entrenched channel. The majority of the reach is now contained within a wooded riparian buffer consisting of mostly shrubs and small trees indicating an improvement since the 2001 assessment.

Reach 204

In 2001, the overall RSAT rating for Reach 204 was *good*. The reach scored *fair* for in-stream habitat. Portions of the reach were ranked as a high priority site needing buffer enhancement because of sparse or absent woody riparian cover and/or invasive species. One significant debris jam was identified at an in-stream weir. An eroded sewer crossing was observed in the CPJ area but was not investigated during the 2013 assessment.

In 2011, 27% of the reach was assessed by CPJ at the downstream end. This assessment found an unstable, slightly incised channel with generally low bank heights. It was unclear if the sewer crossing was still evident.

The remaining assessment of Reach 204 (73%) had an improvement in in-stream habitat based upon the 2013 assessment. The debris jam found in 2001 was still present during the assessment and was clogging an outfall associated with the weir causing water to back up. An exposed sanitary sewer manhole was found along the left bank. This section was entrenched with several debris jams and entirely contained with a wooded riparian buffer. This reach has declined in stability since 2001.

5.2.5 SUBWATERSHED 205

The majority of Subwatershed 205 is located in residential areas including much of King Farm's new development and consists of stream reaches 111 and 205. The majority of land use is residential (76%) and consists of mostly single-family/duplex housing, high-rise apartments/condominiums and townhouses (see Table 5.5). The confluence of reach 111 and 205 goes into SWM ponds. The majority of Reach 205 was not assessed (76%) as it was part of a previous assessment completed by CPJ.

Table 5.5
Subwatershed 205 Land Use and Impervious Area

Land Use	Drainage Area (acres)	Percent of the Subwatershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Subwatershed
Medium Density Residential	149.67	36.84%	21.25	14.20%	5.23%
High Density Residential	161.07	39.64%	90.22	56.01%	22.21%
Commercial	35.52	8.82%	23.96	66.90%	5.90%
Industrial	23.27	5.73%	6.75	28.99%	1.66%
Open Urban Land	12.68	3.12%	1.71	13.51%	0.42%
Deciduous Forest	23.77	5.85%	1.11	4.65%	0.27%

Reach 111

Reach 111 consists of two main reaches that come to a confluence at Reach 205. Reach 111 had several minor tributaries associated with it according to 2001 mapping. These tributaries have been piped or graded over and are no longer present.

In 2001, the overall RSAT rating for Reach 111 was *fair*. The reach scored *fair* for all parameters except channel stability and water quality which were rated as *good*. The reach was ranked as a high priority site needing buffer enhancement because of sparse or absent woody riparian cover. This reach is entirely contained within the King Farm development area which was under construction during the 2001 assessment. It is likely that this reach was located in an agricultural area before the development. Riparian buffers are generally absent to minimal in agricultural areas to allow maximum crop growth.

The 2013 assessment of Reach 111 had a decline in in-stream habitat. The reach was predominantly dry, stable, and had a wide floodplain. The majority of the reach appears to have been straightened to accommodate the King Farm development. One significant jam was found in the reach caused by a berm across the channel causing upstream ponding. The majority of the reach is now contained within a wooded riparian buffer consisting of mostly shrubs and small trees indicating an improvement since the 2001 assessment. This reach appears to have shifted from a perennial stream to an intermittent channel.

Reach 205

In 2001, the overall RSAT rating for Reach 205 was *good*; however there were several *fair* ratings including scouring and deposition, in-stream habitat, and water quality. A portion of the reach was ranked as a high priority site needing buffer enhancement because of sparse or absent woody riparian cover and/or a narrow buffer. In 2001, an outfall was noted as “existing plunge pool requires investigation.” This outfall is located in the CPJ “area of study” and was not investigated as part of the 2013 assessment. One significant debris jam was also located in the reach caused by fallen trees.

In 2011, 76% of the reach was assessed by CPJ at the downstream end. This assessment found a laterally unstable, moderately incised channel with 40% of the banks eroding.

The 2013 assessment of Reach 205 had no change in overall stream condition. This reach had the highest amount of eroded banks measured (32%) out of all the reaches. Flow was intermittent to dry at the time of the investigation. This section of the reach is unstable with lateral and vertical instability. The majority of this reach has access to its floodplain during bankfull events. The riparian area consisted of mostly grasses with sporadic trees and shrubs. This lack of dense roots likely contributes to the bank erosion.

5.2.6 SUBWATERSHED 114

The majority of Subwatershed 114 is located in residential neighborhoods and consists of stream reach 114. The majority of land use is residential (65%) and consists of mostly single-family/duplex housing, apartments, and townhouses (Table 5.6).

Table 5.6
Subwatershed 114 Land Use and Impervious Area

Land Use	Drainage Area (acres)	Percent of the Subwatershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Subwatershed
Medium Density Residential	60.05	37.78%	7.11	11.84%	4.47%
High Density Residential	42.42	26.8%	21.42	50.49%	13.47%
Commercial	3.63	2.28%	3.21	88.57%	2.02%
Industrial	27.55	17.33%	17.04	61.86%	10.72%
Institutional	5.83	3.67%	3.48	59.77%	2.19%
Open Urban Land	3.54	2.23%	0.35	10.00%	0.22%
Deciduous Forest	15.95	10.04%	0.52	3.29%	0.33%

Reach 114

Reach 114 was not rated in 2001 due to lack of flow and thus no information is available on its stability and condition.

The 2013 assessment of Reach 114 was *poor* for channel stability. The stream is over widening with lateral instability and significant bar deposition. This reach originates at an outfall. The water in the pool downstream of the outfall was dark in color indicating poor water quality. The channel was dry at the time of investigation with areas of standing water in deep pools. Bedrock is found throughout this reach preventing the channel from further downcutting. The majority of this reach is located within a wooded area with patches of invasive bamboo found throughout; however a 500 foot section located within the power line right of way has mostly herbaceous vegetation along the left bank. This lack of dense roots likely contributes to the bank erosion.

5.2.7 SUBWATERSHED 115

The majority of Subwatershed 115 is located in the Montgomery College property and consists of stream Reach 115. The majority of land use is institutional (42%) and consists of mostly Montgomery College and facilities related to it (Table 5.7). The headwaters of Reach 115 comes from the Montgomery College SWM pond.

Table 5.7 Subwatershed 115 Land Use and Impervious Area					
Land Use	**Drainage Area (acres)**	**Percent of the Subwatershed**	**Impervious Area (acres)**	**Percent Impervious Within the Land Use**	**Percent Impervious of the Subwatershed**
Medium Density Residential	83.64	29.50%	9.49	11.35%	3.35%
High Density Residential	22.85	8.06%	10.66	46.65%	3.76%
Commercial	18.90	6.66%	14.14	74.82%	4.99%
Industrial	10.77	3.80%	3.78	62.96%	2.39%
Institutional	119.76	42.23%	62.22	51.95%	21.94%
Open Urban Land	1.66	0.58%	0.43	25.98%	0.15%
Deciduous Forest	25.98	9.16%	0.66	2.54%	0.23%

Reach 115

In 2001, the overall RSAT rating for Reach 115 was *good*; however, the reach scored *fair* for channel stability, scouring & deposition, and in-stream habitat.

The 2013 assessment of Reach 115 had varying degrees of stability. The upper section (84%) of the reach had large amounts of debris jams, downed trees, high bank erosion, and was entrenched. Bedrock was found in portions of this reach preventing further downcutting. Downstream of the Nelson Street culvert, 16% of the reach has had stream restoration structures installed as part of the Woodley Gardens stream restoration project. This section appears to be laterally and vertically stable and is able to access its floodplain during storm events.

Several failing or exposed utilities were identified. Two sanitary sewer pipes and one manhole were exposed. There was no evidence of discharge or leakage from either sewer pipe. An outfall had a broken apron and was being undermined. The channel associated with this outfall had high bank and bed erosion. Another outfall was in good shape however flow is being directed from the center of a concrete drainage channel to the right bank causing the concrete to become undermined. A concrete drainage ditch which conveys flow from an apartment complex has become undermined and is failing due to bank erosion/lateral migration.

5.2.8 SUBWATERSHED 115A

The majority of Subwatershed 115A is located in residential neighborhoods and consists of stream Reach 115A. The majority land use is residential (69%) and consists of mostly detached single-family/duplex housing and residential recreation areas (Table 5.8). These recreation areas include baseball fields, basketball and tennis courts, etc.

Table 5.8 Subwatershed 115A Land Use and Impervious Area					
Land Use	**Drainage Area (acres)**	**Percent of the Subwatershed**	**Impervious Area (acres)**	**Percent Impervious Within the Land Use**	**Percent Impervious of the Subwatershed**
Medium Density Residential	111.40	67.74%	11.98	10.75%	7.28%
High Density Residential	2.79	1.70%	0.99	35.41%	0.60%
Institutional	46.47	28.26%	13.86	29.83%	8.43%
Deciduous Forest	3.78	2.30%	0	0%	0%

Reach 115A

In 2001, the overall RSAT rating for Reach 115A was *fair* with a *good* score for water quality. A sewer crossing was noted in 2001 as needing investigation but was not observed in 2013.

The 2013 assessment of Reach 115A had varying degrees of stability. The channel was over-widened with no access to a floodplain upstream of Owens Street. This portion of the channel (70%) was dry during the investigation. English ivy, an invasive species is prevalent in this area.

The City performed stream restoration/stabilization repair downstream of the Owens Street outfall in the early 2000's. The stabilization structures are preventing erosion and downcutting however there are isolated areas of bank erosion where structures have not been installed and the channel is not able to access a floodplain in many locations. Two outfalls were identified in Reach 115A, one with a failing concrete aprons and undermining and the other with a severely eroded drainage channel.

5.2.9 SUBWATERSHED 206

The majority of Subwatershed 206 is located in residential neighborhoods and consists of stream reaches 117, 118, and 206. The majority of land use is residential (75%) and consists of mostly detached single-family/duplex housing and townhouses (Table 5.9). A portion of Reach 118 is wetland rather than having a defined stream channel.

Table 5.9 Subwatershed 206 Land Use and Impervious Area					
Land Use	**Drainage Area (acres)**	**Percent of the Subwatershed**	**Impervious Area (acres)**	**Percent Impervious Within the Land Use**	**Percent Impervious of the Subwatershed**
Low Density Residential	16.35	3.03%	0.57	3.52%	1.11%
Medium Density Residential	356.79	66.08%	43.79	12.27%	8.11%
High Density Residential	33.55	6.21%	12.74	37.97%	2.36%
Commercial	0.50	0.09%	0.28	37.97%	2.36%
Institutional	52.79	9.78%	14.22	26.96%	2.64%
Open Urban	5.46	1.01%	0.47	8.59%	0.09%

Table 5.9 Subwatershed 206 Land Use and Impervious Area					
Land Use	**Drainage Area (acres)**	**Percent of the Subwatershed**	**Impervious Area (acres)**	**Percent Impervious Within the Land Use**	**Percent Impervious of the Subwatershed**
Land					
Deciduous Forest	34.90	6.46%	1.50	4.31%	0.28%
Transportation	34.64	6.42%	8.97	54.76%	3.51%
Large Lot Agricultural	4.95	0.92%	0.06	1.14%	0.01%

Reach 117

In 2001, the overall RSAT rating for Reach 117 was *fair* with a *good* score for water quality and riparian habitat. Portions of the reach were identified as a high priority for riparian buffer enhancement due to a sparse or absent woody cover.

The 2013 assessment of Reach 117 had an overall improvement in stream condition. The channel was dry at the time of investigation with standing water in the deeper pools. Bedrock outcroppings were protecting the bed and banks in portions of the reach. Downstream of the I-270 culvert (67% of the reach) was over-widened with eroding banks and significant bar development indicating a high sediment supply.

An exposed sanitary sewer pipe was identified with a degrading concrete encasement and undermining. Two failing and broken outfalls have eroded drainage channels. Two significant debris jams were also found, one of which appears to be man-made with fallen trees and branches piled up in the channel.

Reach 118

In 2001, the overall RSAT rating for Reach 118 was *fair* indicating an unstable channel. In 2001, a significant debris jam was identified but in 2013 the jam was identified as minor.

The 2013 assessment of Reach 118 had an improvement in channel stability and riparian habitat, and a decline in in-stream habitat. The reach originates as an ephemeral channel, transitions into a braided channel, and becomes a single threaded channel after the I-270 culvert. The reach is stable upstream of the culvert but becomes laterally unstable after the culvert with eroded banks and bar development. Gabion baskets are located in the channel bed in this section and are creating fish barriers.

An exposed sanitary sewer pipe was identified with a degrading concrete encasement and was becoming undermined. One sunken culvert was identified likely from an old farm road crossing and should be removed.

Reach 206

In 2001, the overall RSAT rating for Reach 206 was *fair* with a *good* score for water quality. Portions of the reach were identified as a priority for riparian buffer enhancement due to a narrow buffer width.

The 2013 assessment of Reach 206 had an improvement in in-stream habitat. This reach is laterally unstable with significantly eroded banks and bar development. Gabion basket protection was placed near the pool and lake at Fallsmead Park. The channel is incised in this area with no access to a floodplain. Two culverts were found associated with pedestrian trails and appear to be undersized with steep drops and undermining. Overall, there has been no improvement in stability since the 2001 assessment.

5.2.10 SUBWATERSHED 119

The majority of Subwatershed 119 is located in residential neighborhoods and consists of stream Reach 119. The majority land use is residential (94%) and consists of mostly detached single-family/duplex housing (Table 5.10).

Table 5.10
Subwatershed 119 Land Use and Impervious Area

Land Use	Drainage Area (acres)	Percent of the Subwatershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Subwatershed
Low Density Residential	8.40	4.57%	0.80	9.54%	0.44%
Medium Density Residential	164.58	89.67%	20.99	12.75%	11.44%
Institutional	2.25	1.22%	0.76	33.65%	0.41%
Open Urban Land	7.05	3.84%	1.76	24.98%	0.96%
Deciduous Forest	1.17	0.64%	0.02	1.94%	0.01%
Large Lot Agricultural	0.10	0.05%	0.03	33.30%	0.02%

Reach 119

In 2001, the overall RSAT rating for Reach 119 was *good* with an *excellent* score for channel stability but *fair* scores for in-stream habitat and water quality. The reach was identified as a high priority for riparian buffer enhancement due to a sparse or absent woody riparian cover.

The 2013 assessment of Reach 119 had a decline in channel stability and an improvement in in-stream habitat. The reach had varying degrees of stability. The upper 40% of the reach was dry during the investigation. The upper half of the channel is stable with riprap along the banks and bed.

Bank erosion becomes more prevalent and floodplain benches become less common in the lower half. A metal outfall was found in this area with a rusted and undermined apron. Gabion baskets were common in this reach and were creating incised channels and had some failure. Two headcuts were found in drainage channels associated with outfalls. Two significant debris jams were found consisting of large fallen trees and branches. This reach had significant bank erosion with 31% of the banks being highly erodible. This reach's stability has declined since the 2001 assessment.

5.2.11 SUBWATERSHED 401

The majority of Subwatershed 401 is located in residential areas and forested areas. Subwatershed 401 consists of stream reaches 302 and 401. The majority land use is residential (56%) and consists of mostly detached single family/duplex housing, townhouses and apartments (Table 5.11). Deciduous forest is second in land use and makes up 18% of this subwatershed; which consists of forested areas in which trees lose their leaves at the end of the growing season. Subwatershed 401 has the highest percent of deciduous forest of all the other subwatersheds. Reach 401 makes up the majority of the subwatershed and is the main stem of Watts Branch.

Table 5.11
Subwatershed 401 Land Use and Impervious Area

Land Use	Drainage Area (acres)	Percent of the Subwatershed	Impervious Area (acres)	Percent Impervious Within the Land Use	Percent Impervious of the Subwatershed
Low Density Residential	6.24	1.31%	0.04	0.70%	0.01%
Medium Density Residential	186.49	39.09%	22.59	12.12%	4.74%
High Density Residential	76.21	15.98%	29.17	38.28%	6.12%
Commercial	5.43	1.14%	3.67	67.61%	0.77%
Industrial	3.35	0.70%	0.08	2.52%	0.02%
Institutional	38.39	8.05%	18.48	48.13%	3.87%
Open Urban Land	15.47	3.24%	0.35	2.27%	0.07%
Cropland	25.56	5.36%	1.75	6.84%	0.37%
Deciduous Forest	84.49	17.71%	4.07	4.81%	0.85%
Transportation	35.42	7.43%	21.70	61.25%	4.55%

Reach 302

In 2001, the overall RSAT rating for Reach 302 was *good* with a *fair* score for in-stream habitat. A portion of the reach was identified as a high priority for riparian buffer enhancement due to a sparse or absent woody riparian cover and invasive species. Several problem areas were noted during the 2001 assessment of Reach 302. A severe headcut caused by runoff from Azalea Street was identified in 2001 and noted as a safety hazard. The headcut was located in the CPJ area and thus it was not assessed in 2013. An eroded manhole was also identified in 2001 but there was no observable manhole problems near this location in 2013. An outfall in need of stabilization was also identified. In 2013, the outfall could not be located at the exact location identified in 2001, but an undermined outfall located northeast of this location was identified during the recent assessment. Finally, two significant debris jams were identified in 2001 but were not located in 2013.

In 2011, 30% of the reach located upstream of Nelson Street was assessed by CPJ. This assessment found a laterally unstable and slightly incised channel with 20% of the banks eroding. Excess deposition was also noted and approximately half of the channel has access to a floodplain.

In 2013, the reach downstream of Nelson Street was assessed. The reach in this section had an improvement in in-stream habitat since the 2001 assessment. Roughly 80% of this reach between two places it crosses Nelson Street was stabilized in the 2010 Woodley Gardens Park stream restoration project by the City. The restoration area was laterally and vertically stable with localized bank erosion. An exposed gas line was found in this area which was not concrete encased but appeared to be stable.

The remaining area downstream of the I-270 culvert (20%) has not been altered and is laterally unstable with moderate to severe bank erosion and significant depositional features. Several large debris jams were found and a severely eroded drainage channel was also located. Reach 302 appears to have improved since the 2001 assessment.

Reach 401

In 2001, the overall RSAT rating for Reach 401 was *good*. Portions of the reach were identified as a priority for riparian buffer enhancement due to a sparse or absent woody riparian cover and invasive species. During this assessment, it was noted that the footers were eroding around a pedestrian bridge. A significant debris jam was also found consisting of fallen trees. It was noted in 2013 that riprap had been placed around the footer of the pedestrian bridge and the debris jam was no longer present.

The 2013 assessment of Reach 401 had an overall improvement in stream condition. The City built stream restoration/stabilization in 2005 between Watts Branch Parkway and Wootton Parkway with varying degrees of success. This reach has moderate to severe erosion with bank erosion concentrated along the outside of meander bends and significant bar development. In some locations, the banks have eroded around the bank protection.

Downstream of Wootton Parkway, the channel had excessive bar development, debris jams and severely eroded banks. The channel was incised and lacks access to a floodplain in many locations. A significant cut off channel has formed downstream of the Scott Drive culvert with excess sediment deposition. This reach below Wootton Parkway was recommended in the 2001 watershed study for restoration. It has been deferred until completion of this 2013 study to assess the current condition. Much of the stream is in a wide section of park land, where channel meanders do not threaten nearby lots. However, roughly 400 feet of stream below Scott Drive is close to the rear lot lines of houses along Starlight Court, and that bank continues to erode.

The 2013 assessment also found two abandoned sanitary sewer pipes running parallel to each other. They were exposed in two locations and causing a debris jam and possible fish barrier at one location. Three debris jams were found in the reach creating deep pools in two locations and have caused the channel to re-route in the other location. The lower section of Reach 401 downstream of Wootton Parkway was the second most unstable reach in the watershed.

5.2.12 SUMMARY

Given the built-out nature of the watershed, feasible interventions are limited to corrective action within the stream valleys and often only in the immediate stream channel. The City has an extensive history of SWM retrofits as well as onsite SWM facilities, which have focused increasingly on water quality protection. In the future, the City's NPDES permit efforts may turn towards other measures to limit stream pollution across the City, such as further outreach and enforcement against illicit discharges, education and incentives to reduce lawn-care impacts, and operational improvements to cleanse runoff from municipal streets.

Between 2001 to 2014, the City constructed 3.25 miles of stream restoration/stabilization measures in Watts Branch (Figure 14). Some projects were very successful at reducing bank erosion and in-stream sediment loads, as seen in portions of Reaches 107, 115, 115A, and 302. The stream restoration projects in reaches 103, 114, 201, and 401 have some localized areas of failure. Three of the projects in reaches 103, 201, and 401 were completed in the early 2000's. Only one project within Reach 114 was completed recently in 2008. The areas of failure which were visually observed included:

- Reach 103 – wooden stakes in middle of channel indicating channel has migrated from original stakeout location, eroded banks, scouring underneath rock cross vanes
- Reach 114 – banks eroding around toe protection
- Reach 201 – eroded banks after riprap walls, high bank erosion, and lack of access to a floodplain
- Reach 401 – banks eroding around toe protection, high bank erosion, and lack of access to a floodplain

Nine outfalls were identified as needing repair or stabilization and 14 utilities were exposed or needed repair (Figure 15). The 14 utilities include an exposed water pipe, two unknown pipes, two gas line pipes, two abandoned sewer pipes, two manhole/pipe combination sites, two manholes, and three sewer pipes. Some of these have developed problems or exposure between the watershed studies; others were present in 2001.

Stream restoration projects often develop spot instabilities over time. The causes range from more scour/erosion than expected occurring at the base of channel banks, to trees falling across the channel and knocking stabilization out of place, to debris jams causing a shift in the stream's flowpath. However, 74% of the 3.25 miles of stabilized reaches constructed between 2001 and 2014 have stayed stable.

Based upon BEHI measurements, mapped bank erosion, deposition, head cuts, debris jams, and overall visual observations, the approximate percentage of instability was assigned to each reach and are shown in Table 5.12. Overall, based on the 2013 observations, reaches 103 and 205 are the most degraded reaches in the watershed and reaches 101 and 111 were the most stable.

Because of the dynamic nature of streams in general, and particularly of urban watersheds, Table 5.12 only represents a snapshot in time. Debris jams may be moved aside by storms or human intervention. Sediment bars can shift or conversely, may grow vegetation to become more stable, which changes the channel characteristics. Erosion problems from head cuts or deteriorating outfalls are expected to worsen over time, but erratically. The stability ratings of the Watts Branch reaches depends on numerous variables that will change over time, resulting in some reaches being more stable in the future than Table 5.12 indicates, and others less stable.

Table 5.12
Percent Unstable for Each Reach

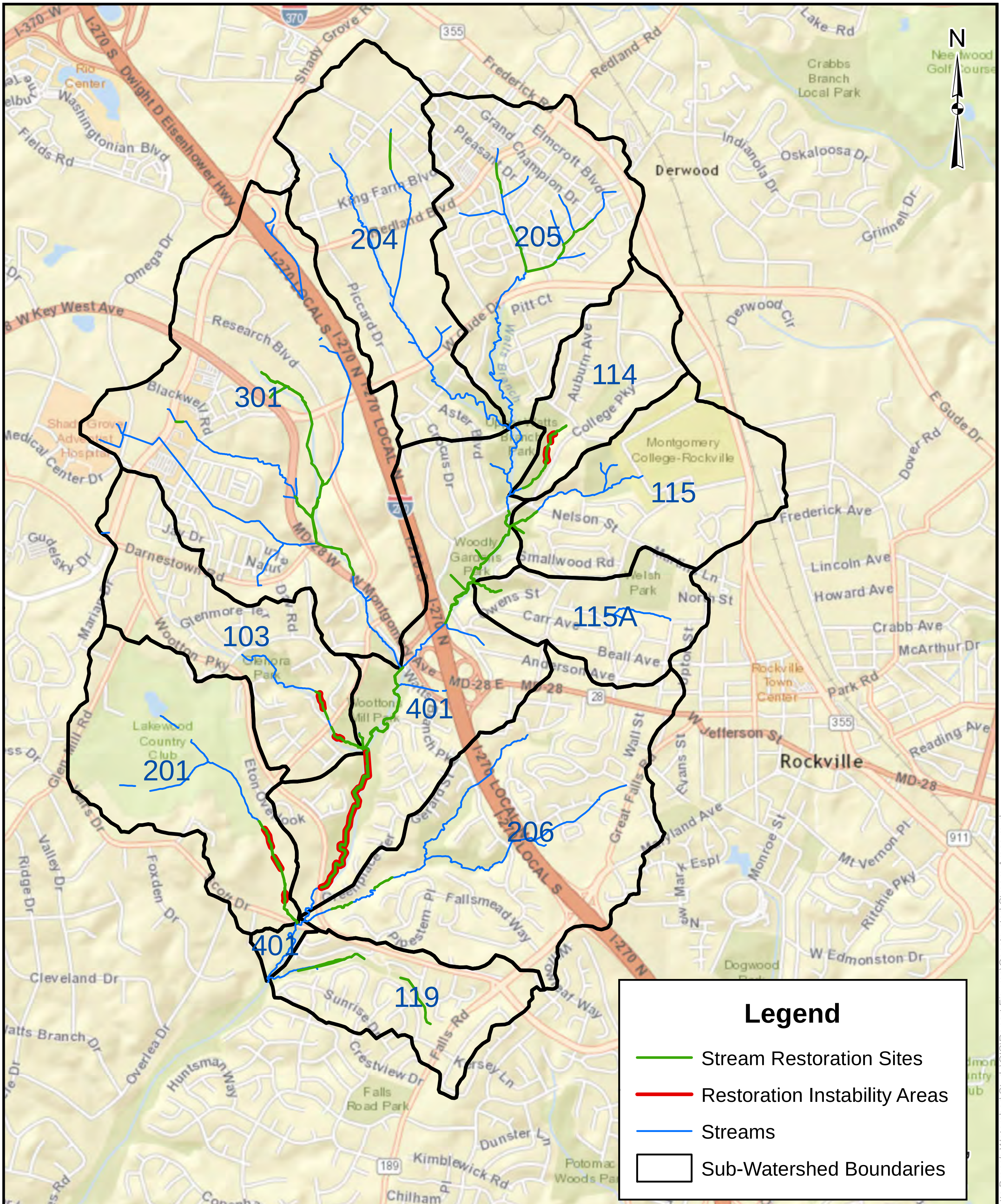
Reach	Types of Instability	Percent Unstable
111	Bank erosion and debris jams	6%
101	Bank erosion	8%
105	Bank erosion, deposition, head cuts and debris jams	10%
107	Bank erosion, deposition and debris jams	15%
203	Bank erosion	15%
110	Bank erosion, deposition, head cuts and debris jams	15%
102	Bank erosion	20%
106	Bank erosion, deposition and debris jams	20%
108	Bank erosion, deposition and debris jams	20%
118	Bank erosion, deposition and debris jams	23%
302*	Bank erosion and deposition	25%
201	Bank erosion and head cuts	25%
114	Bank erosion and deposition	25%
117	Bank erosion, deposition and debris jams	25%
115A	Bank erosion, deposition, head cuts and debris jams	25%
204*	Bank erosion, deposition and debris jams	28%
301	Bank erosion, deposition, head cuts and debris jams	30%
115	Bank erosion, deposition, head cuts and debris jams	30%
401	Bank erosion, deposition and debris jams	32%
109	Bank erosion, deposition, head cuts and debris jams	35%
206	Bank erosion, deposition and debris jams	35%
119	Bank erosion, deposition and debris jams	35%
103	Bank erosion, deposition and debris jams	50%
205*	Bank erosion, deposition and debris jams	53%

*Includes CPJ assessment areas

A USA Stream Condition datasheet was completed for all 25 reaches. The sheets are an overall average for each reach as a whole. None of the reaches had optimal stream conditions which is expected in an urban watershed. A summary is provided in the table below. Datasheets are provided in Appendix I.

Table 5.13 Stream Condition Summary Reach Stream Condition Buffer & Floodplain			
Reach	**Stream Condition**	**Buffer & Floodplain Condition**	**Overall Stream Condition**
101	Marginal	Poor	Marginal
102	Suboptimal	Poor	Suboptimal
103	Suboptimal	Suboptimal	Suboptimal
104*	N/A	N/A	N/A
105	Suboptimal	Suboptimal	Suboptimal
106	Suboptimal	Suboptimal	Suboptimal
107	Suboptimal	Suboptimal	Suboptimal
108	Marginal	Marginal	Marginal
109	Suboptimal	Marginal	Marginal
110	Suboptimal	Suboptimal	Suboptimal
111	Suboptimal	Marginal	Marginal
114	Marginal	Suboptimal	Suboptimal
115	Suboptimal	Suboptimal	Suboptimal
115 A	Suboptimal	Suboptimal	Suboptimal
117	Marginal	Suboptimal	Suboptimal
118	Marginal	Suboptimal	Suboptimal
119	Marginal	Suboptimal	Marginal
201	Marginal	poor	Marginal
203	Suboptimal	Suboptimal	Suboptimal
204	Suboptimal	Suboptimal	Suboptimal
205	Marginal	Suboptimal	Suboptimal
206	Marginal	Marginal	Marginal
301	Suboptimal	Suboptimal	Suboptimal
302	Suboptimal	Suboptimal	Suboptimal
401	Suboptimal	Suboptimal	Suboptimal

*Reach 104 has been piped and is no longer a surface water stream



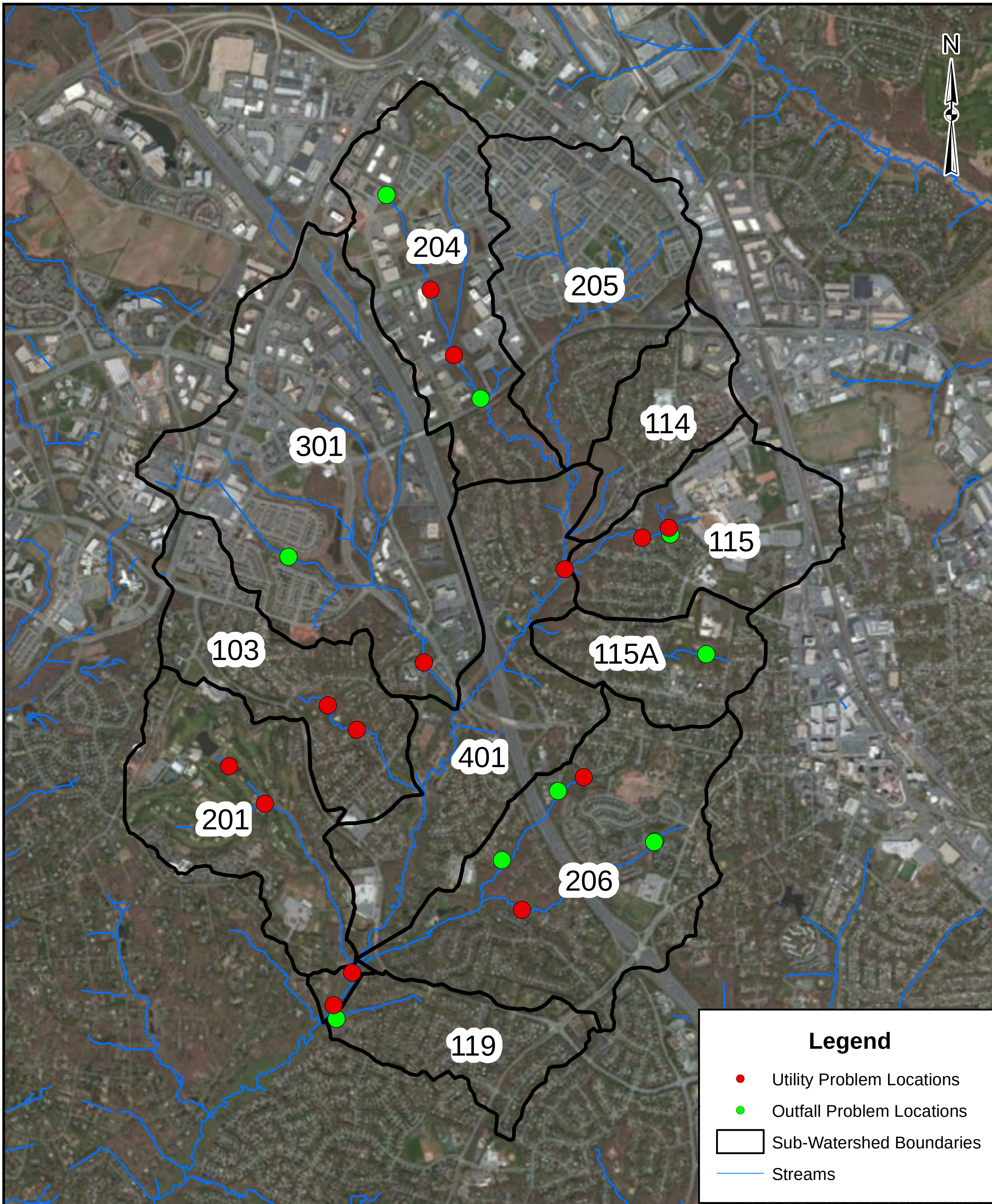
0 1,250 2,500 5,000
Feet

1 inch = 2,500 feet

BayLand Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A
Hanover, Maryland 21076
Phone: (410) 694-9401
Fax: (410) 694-9405
bayland@baylandinc.com

FIGURE 14
STREAM RESTORATION SITES

P:\8_19201_City of Rockville Watts Branch Watershed Study\GIS\Report Figures\Constructed Stream Areas.mxd



0 1,250 2,500 5,000 Feet

1 inch = 2,500 feet

BayLand Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A Phone: (410) 694-9401
Hanover, Maryland 21076 Fax: (410) 694-9405
bayland@baylandinc.com

FIGURE 15
OUTFALL AND UTILITY PROBLEM LOCATIONS

6 GEOMORPHIC ASSESSMENT

Geomorphology is the study of how landforms change and the processes that shape them. Fluvial geomorphology is the study of streams and how they interact with the land around them. Studies can be conducted at the large scale of mountain ranges and river systems, down to changes in the smallest headwater streams, such as those found in Rockville.

Geomorphic assessments of smaller urban streams are focused on determining their stability. For this more detailed assessment, physical measurements of channels in the study area were made to classify the streams by the Rosgen method (1996). The classification system is useful for assessing stream condition, predicting future changes, and developing general restoration approaches. Figure 16 shows how a stream's shape can change based on changes in flows or sediment load. The E4 and C4 channels are stable, and represent a healthy stream type. The G4 channel is one where stream bed erosion is taking place and the stream is downcutting. When it is deeply incised, the banks collapse and the stream widens to an F4 channel, which continues to be unstable. The channel is reestablished well below the adjacent floodplain, causing continued channel erosion in large storm events. The watershed also suffers from the degradation caused by decades of bank erosion. Urban streams in the Piedmont area of Maryland typically are G or F type streams in the Rosgen system. The number 4 after the stream type represents the predominant bed material, which in most cases is gravel in the City's Watts Branch streams.

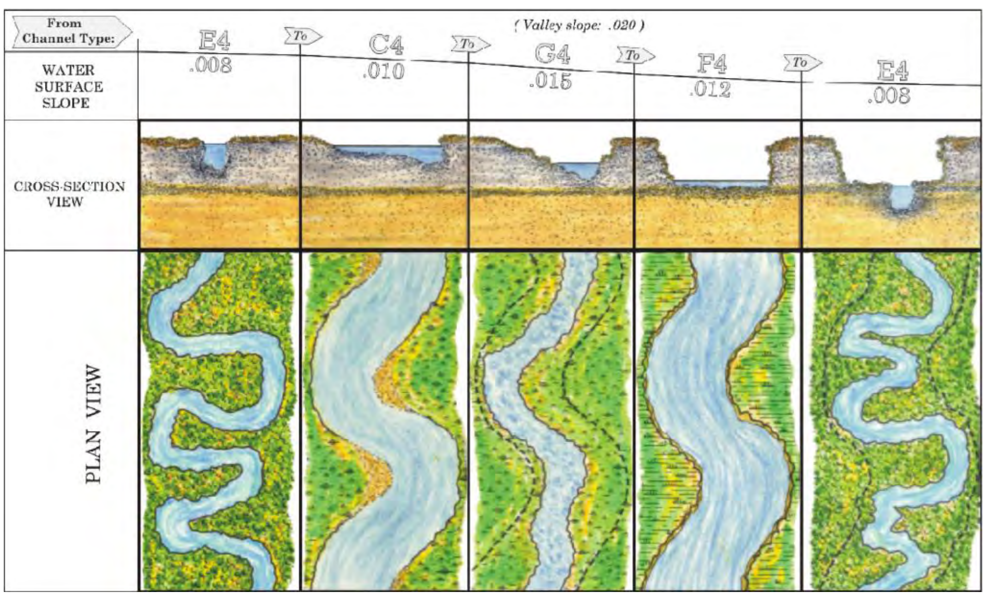


Figure 16: Geomorphic Change in Five Stages (Rosgen, 1996)

6.1 METHODOLOGY

Geomorphic assessments were conducted at 10 historic sites from the 2001 Center for Watershed Protection's (CWP's) Watts Branch Watershed Study and Management Plan. Efforts were made to locate the original rebar pins used in the 2001 cross sectional survey; however, they were unable to be located and monumented benchmarks were placed in the vicinity of the original locations (Figure 17). Sites 1, 3, 6 and 10 are located in areas which have not had any restoration or stabilization work. Site 6 is located within the I-270 interchange and sites 1 and 3 are located within the Upper Watts Branch reaches that are currently under design by CPJ. Site 10 is downstream of the Woottons Mill Park stream restoration project and just upstream of Wootton Parkway.

The remaining six sites have been altered by grading and stone stabilization structures since 2001 and therefore the geomorphic results will not directly correlate to the 2001 survey but will instead analyze whether the restoration/stabilization activity was successful. The establishment of permanent benchmarks will also allow the City to provide long term monitoring of the sites and analyze enlargement and stabilization trends over time. It will also provide long term monitoring at the stream restoration/stabilization sites.

At each of the 10 sites, physical measurements of the channel were surveyed including a cross-section, profile, and pebble count. The stream cross-sections, bed material, and stream profile were analyzed to determine a Rosgen Level II classification for each site. Rosgen channel types are dependent on a combination of factors including entrenchment, width/depth ratio, and channel slope. A Level II assessment uses field measurements to determine the stream classification. A more detailed description of methodology is provided in the Geomorphic Assessment Report in Appendix K. Field data sheets and data analysis results are provided in Appendix H.

0 750 1,500 3,000 Feet

1 inch = 1,500 feet

BayLand Consultants & Designers, Inc.
"Integrating Engineering and Environment"
1321 Mercedes Drive, Suite A
Hanover, Maryland 21076
Phone: (410) 694-9401
Fax: (410) 694-9405
bayland@baylandinc.com

FIGURE 17
GEOMORPHIC ASSESSMENT SITE LOCATIONS

P:\8_19201_City of Rockville Watts Branch Watershed Study\GIS\Report Figures\geomorphic site locations.mxd

6.2 RESULTS

Geomorphic assessments were performed in November 2013 and compared to previous data obtained from the 2001 report (CWP, 2001) and historic data. Historic data was obtained through engineering and historic stream surveys. It is important to note that the cross sections measured in 2013 were in the vicinity of the original ones but, due to missing rebar and channel alteration in the last 10 years, the original cross sections could not be located. Also some cross sections' bed features have shifted from riffles to pools which make it difficult to compare results. It is assumed that all the original cross sections were riffles. Four of the 10 sites were located in Reach 401, the mainstem of Watts Branch. More detailed results can be found in the Geomorphic Assessment Report, Appendix K.

Most of the sites' cross sectional dimensions were similar to those found in 2001. Bankfull indicators for cross section 9 were difficult to identify due to a vertical raw bank on the left and an imbricated riprap wall along the right bank and thus bankfull elevation is likely low. Anomalies in cross sectional dimensions can be a result of a misidentified bankfull elevation in either the 2001 or 2013 study or a change in hydrology. This information is presented in the table below.

Table 6.1
Channel Dimension Comparison Over Time

Site	DA	Reach	Historic*	2001			2013		
			A_{bfl}	D_{bfl}	W_{bfl}	A_{bfl}	D_{bfl}	W_{bfl}	A_{bfl}
Site 1 (pool)	0.4	204	11.7	2.1	15.3	24.6	1.6	16.9	26.5
Site 2 (riffle)	0.2	114	12.0	1.5	18.3	22.9	1.2	15.1	18.0
Site 3 (riffle)	0.7	302	18.2	2.2	22.9	35.8	1.2	22.7	28.1
Site 4 (riffle)	2.4	302	42.6	3.0	36.2	86.5	2.2	32.9	72.7
Site 5 (riffle)	2.4	302	37.1	2.6	32.9	61.8	1.8	42.9	77.0
Site 6 (pool)	2.6	302	37.7	3.1	30.4	68.5	2.6	21.3	55.0
Site 7 (riffle)	3.9	401	33.7	4.0	27.0	70.3	2.9	35.7	101.8
Site 8 (pool)	3.9	401	55.7	3.6	21.0	61.2	1.8	22.5	40.6
Site 9 (riffle)	4.4	401	85.3	3.5	31.3	98.9	3.4	33.8	113.7
Site 10 (riffle)	4.5	401	88.5	4.2	36.5	119.3	2.8	37.9	107.5

DA=Drainage Area (m^2); D_{bfl} = Bankfull channel depth (ft.); W_{bfl} = Bankfull channel width (ft.);
A_{bfl} = Bankfull channel cross-sectional area (ft^2)
*Historical bankfull width and depth data not available

Each site was classified according to the Rosgen stream classification system. Seven sites had been restored/stabilized since the 2001 assessment, therefore the stream type and stability at these sites cannot be directly compared to previous assessments. All the reaches assessed were classified as either a Rosgen type F4 or B4 and had signs of instability.

Rosgen stream type F channels are common in urbanized areas, where the flow regime has changed so that high flows become more frequent and the existing channel responds first by downcutting and then by widening. Since this type of channel is deeply incised, floodplain access is lost and stream bank erosion rates can be very high. Central and transverse bars are common as well as depositional features such as point bars.

Rosgen stream type B channels are typically moderately entrenched, have relatively stable bed and banks, and usually have a limited floodplain. This relatively stable channel type is influenced by changes in the watershed and can transform to a less stable stream type such as an F or a G if watershed conditions change.

Typically during the stream restoration design process, channels are reconstructed with dimensions of a stable Rosgen stream type, normally a C or B stream type. Out of the seven sites which were reconstructed, four of them were classified as an unstable F stream type. Identifying stream restoration sites as F channels does not necessarily indicate that the restoration efforts will fail. In many cases, imbricated riprap walls have been installed along the outside of meander bends which prevent bank erosion. Rock cross vanes and other grade control structures are installed to deflect flow away from banks thereby reducing erosion. For example, Site 2 which was identified as an F channel had the lowest bank erosion rate in 2013. Also, the Rosgen classification can be subjective and streams are dynamic by nature. It is likely that the streams were in transition in 2001 and were no longer stable B and C type channels when the restoration and/or stabilization efforts were initiated. Only one restoration site (Site 9) was identified as unsuccessful due to erosion along the left bank. A comparison of stream types and stability over time is provided in the table below.

Table 6.2
Rosgen Stream Type and Stability Comparisons

Site	2001 Stream Type	2013 Stream Type	Stream Stabilization/ Restoration
Site 1	C4	C4/B4c	No, under design
Site 2	NA*	F4	Yes
Site 3	C4	B4c	No, under design
Site 4	C4	B4c	Yes
Site 5	C4	F4	Yes
Site 6	C4	F4/B4c	No
Site 7	F4	F4	Yes
Site 8	B4	B4c	Yes
Site 9	F4	F3	Yes
Site 10	F4	B4c	No

*No data obtained in 2001 for this site

Stream bank erosion rates were calculated by combining the BEHI and Near Bank Stress (NBS) measurements using the Bank Assessment for Non-point source Consequences of Sediment (BANCS) method. The BEHI is a rating system developed by Rosgen that measures the ability of stream banks to resist erosion (Rosgen, 2001). The BEHI methodology uses five parameters to calculate the channel stability hazard index, which is assigned one of six descriptive ratings—very low, low, moderate, high, very high, or extreme. The BEHI evaluates the potential for stream bank erosion by assessing the height of the bank relative to the bankfull height, the rooting depth of the trees and other vegetation on the stream banks, the density of the roots, the angle of the bank, and whether any protection such as rock or large woody material is present at the toe of the bank. NBS is used to estimate the amount of shear stress on the banks based upon 7 methods:

1. Observations of a transverse bar or central bar creating high NBS
2. Channel pattern (ex. outside of meander bends have higher stress than inside of bends)
3. Ratio of pool slope to average water surface slope
4. Ratio of pool slope to riffle slope
5. Ratio of near-bank maximum depth to bankfull mean depth
6. Ratio of near-bank shear stress to bankfull shear stress
7. Velocity profiles/velocity gradient

NBS for this study was estimated using methods 1, 2, 5, and 6. Stream bank erosion rates were calculated using the BANCS method (Rosgen, 2001 & modified by Harman et al., 1999). This method uses NBS and BEHI data to estimate erosion rate. The rates were converted to dump truck loads per 1,000 linear foot assuming 13.5 tons/dump truck load. Bank erosion rates were highest for Sites 1 and 10. The table below lists estimated rates for each site.

Table 6.3
Bank Erosion Comparisons

Site	% Eroding Bank	Tons/foot/year	Tons/year @1000 LF	Dump Truck Loads/ 1000 LF
Site 1	70%	0.180	180	13.3
Site 2	48%	0.008	8	0.6
Site 3	83%	0.055	55	4.1
Site 4*	15%	0.010	10	0.7
Site 5*	15%	0.010	10	0.7
Site 6	58%	0.040	40	3.0
Site 7*	57%	0.100	100	7.4
Site 8*	57%	0.100	100	7.4
Site 9	27%	0.018	18	1.3
Site 10	91%	0.250	250	18.5

*BEHI and NBS measurements were grouped together for Sites 4 & 5 and Sites 7 & 8 due to their close proximity to each other.

All four of the unaltered sites (Sites 1, 3, 6 and 10) are showing signs of lateral and vertical instability and have transitioned into an unstable channel. The remaining restored or stabilized sites are also showing signs of lateral and vertical instability. Lateral stability results for Sites 5 and 10 were the most severe. Sites 1, 4, 5, 7, and 10 have widened and decreased bankfull mean depth indicating that these sites are F channels or are transitioning into F channels.

The lateral instability of Site 1 is reflected in the bank erosion results. This site has the second highest erosion rate and conveys 180 tons of sediment downstream per 1,000 linear foot. Site 3 is also highly eroded. Both Sites 1 and 3 are currently under stream restoration design in the Upper Watts Branch project.

Site 2, just downstream of the College Gardens tributary stream restoration project, had low bank erosion. This is likely due to armoring of the banks immediately upstream and because the reach does not receive perennial flow.

Stream restoration/stabilization measures appear to have succeeded the most in Sites 4 and 5, located within the Woodley Gardens Park stream restoration project limits. While the results of the lateral stability assessment indicate an unstable channel, bank erosion is low because of the imbricated riprap walls which predominant along the outside of meanders bends. It is unlikely that these sites, which are located approximately 330 feet apart, will experience significant bank erosion.

Site 6 is located within the I-270 interchange owned by the State of Maryland, and has not been altered. This channel has a high sediment supply as evidenced by significant bar formation and eroded banks. Downed and leaning trees are prevalent throughout and the lateral instability of the channel is likely to cause more debris jams and downed trees. This site's riparian area is mixed woods and herbaceous. Erosion is highest along banks where bank vegetation is mostly herbaceous.

The 10-year-old Woottons Mill Park restoration/stabilization measures in the reach at Sites 7 and 8 have experienced localized failures. Some of the banks have scoured around the riprap bank protection, causing localized erosion. There is also erosion downstream from some of the rock vane structures. It is important to note that there are also areas where rock vanes and bank protection measures are functioning correctly. Overall, stabilization efforts in this section of reach from the confluence of reaches 301 and 302 downstream to the confluence with reach 103 were successful. The majority of grade control and bank protection structures are functioning correctly and most of the channel has access to its floodplain. As a result of the localized erosion near structures and along unprotected banks between stabilization structures, these sites had the third highest bank erosion rates at 7.4 dump truck loads of sediment being carried downstream each year per 1,000 linear feet of stream.

The lateral instability of Site 9, next to the townhouses at Paulsboro Drive, is limited to the left bank as the right bank is armored with a 300-foot imbricated riprap wall to protect the backs of the nearby townhouses. This site is an F type channel and the left bank is likely to continue to erode.

Site 10, just upstream of Wootton Parkway on Watts Branch mainstem, was by far the most unstable channel with severely eroded banks, significant debris jams, and excess bar formation. Bank erosion was highest at this site was an estimated 18.5 dump truck loads of sediment eroding each year per 1,000 linear foot and 91% of the banks eroding. This channel also experienced the most significant change in stability since 2001 as the previous assessment indicated the channel was relatively stable. This site was downstream of the end of the Woottons Mills Park stream restoration efforts since there were no signs of in-stream stability structures or bank protection measures.

7 SUMMARY

The City completed the original Watts Branch Watershed Study and Management Plan in 2001, which evaluated stream conditions and recommended a number of traditional stormwater management retrofits and stream restoration Capital Improvements Program (CIP) projects. To date, seven stormwater management CIP projects and seven stream restoration CIP projects have been completed.

This 2015 assessment was conducted to: compare existing conditions in the watershed with conditions in 2001, to update the previous hydrology model based upon land use changes and upgrades to stormwater management facilities, and to evaluate the success of the CIP Projects.

Since 2001, two major land use changes in the watershed have occurred, the development of the King Farm and Thomas Farm/Fallsgrove areas, as well as infill in other parts of the watershed. As a result, the imperviousness in Watts Branch Watershed within the City increased from 28% in 2001 to 41% in 2013. Several new regional stormwater facilities were constructed, and some tributaries were modified. The TR-20 model was updated to reflect these land use changes and storm water management retrofits.

The stream assessment results indicate varying levels of stability within the watershed. Most of the streams display typical characteristics of urban streams: bank erosion, lack of floodplain access, lateral and vertical instability, limited riparian buffer, poor habitat conditions and straightened channel. There has been some success in stream restoration CIP projects which overall have reduced bank erosion, restored floodplain access, increased the woody riparian buffer, and provided in-stream habitat.

The geomorphic assessment results also indicate varying degrees of instability in the ten cross section sites. Six sites had been restored/stabilized since the 2001 assessment. All four of the unaltered sites are showing signs of lateral and vertical instability and have transitioned into an unstable channel. Stream restoration has arrested erosion at four out of six sites.

It is the goal of the City that this current assessment will be used as a foundation for comparison for future Watts Branch Watershed studies.

8 REFERENCES

Center for Watershed Protection, 2001. *Watts Branch Watershed Study and Management Plan Final Report.* Rockville, MD.

Dwyer, John F., and David. J. Nowak, 2000. "A National Assessment of the Urban Forest: An Overview", in Proceedings of the Society of American Foresters 1999 Convention, Portland, Oregon.

Galli, J. 1996. *Rapid Stream Assessment Technique (RSAT) Field Methods, Final Technical Manual.* Metropolitan Washington Council of Governments.

Harmon, Will and Jessup, Angela, 1999. Personal communication summarizing research findings on the Mitchell River stream bank erosion studies in North Carolina. North Carolina State University and Natural Resources Conservation Service, respectively.

Kitchell, A. and Schueler T., 2004. *Unified Stream Assessment: A Users Manual*. Center for Watershed Protection. Ellicott City, MD.

Leopold, L. B. 1973. "River Channel Change with Time: An Example." *Geological Society of America Bulletin* 84:1845-1860.

Maryland Department of the Environment (MDE), 2009. Maryland Stormwater Design Manual, Volumes I & II. Baltimore, MD.

MDE, 2010. Website: http://www.mde.maryland.gov/programs/researchcenter/factsheets/waterfactsheet/documents/www.mde.state.md.us/assets/document/factsheets/303dfs.pdf

MDE, 2013. Website: http://www.mde.state.md.us/programs/Water/TMDL/Integrated303dReports/Pages/303d_mapsearch.aspx?a=go&qBasinName=Potomac+River+Montgomery+County&qBasinCode=&qHUC=&qCountyName=&qWaterType=&qListingCategory=&qImpairmentCategory=&action=1&B1=Search&action2=2&action3=3

MDE, 2013. The Chesapeake Bay TMDL, Maryland's Watershed Implementation Plan and Maryland's 2012-2013 Milestone Goals http://www.mde.maryland.gov/programs/water/tmdl/chesapeakebaytmdl/pages/programs/waterprograms/tmdl/cb_tmdl/index.aspx

Naibert, Eric. July 10, 2013. Email to Lise Soukup, City of Rockville Department of Public Works regarding Montgomery County's Water Quality Monitoring Stations. Montgomery County Department of Environmental Protection, Rockville, MD.

O'Neil-Dunne, Jarlath, 2009, *A Report on the City of Rockville's Existing and Possible Urban Tree Canopy,* May 20, 2009.

Rosgen, David L., 1996. *Applied River Morphology*. Wildland Hydrology Books, Pagosa Springs, Colorado, p 6-42.

Rosgen, David L., 2001. *A Practical Method of Computing Streambank Erosion Rate*, 7th Federal Interagency Sediment Conference, March 24-29, Reno, Nevada.

Schueler, T., Fraley-McNeal, L., and K. Cappiella, 2009. *Is Impervious Cover Still Important?* Review of Recent Research. Journal of Hydrologic Engineering 14(4): 309-315.

Soil Survey Staff, Natural Resources Conservation Service, United States Department of Agriculture. Soil Survey Geographic (SSURGO) Database for Rockville, Maryland. Available online at http://websoilsurvey.nrcs.usda.gov/. Accessed August 2013.

Strommen, B., Cappiella, K., Hirschman, D., and J. Tasillo, 2007. A Local Ordinance to Protect Wetland Functions. Article 4 in the Wetlands and Watershed Article Series. Center for Watershed Protection. Ellicott City, Maryland

United States Department of Agriculture, 1992. *Computer program for project formulation-hydrology: SCS Technical Release 20,* Washington, D.C.

United States Environmental Protection Agency. 2006. *Monitoring & Assessment: 5.9 Conductivity*. *http://www.epa.gov/owow/monitoring/volunteer/stream/vms59.html*

9 GLOSSARY

Armor-in-Place: Restoration technique intended to help stream banks withstand high flows from altered hydrology. "Armor" can consist of hard elements such as concrete, rip rap, or rock, or natural materials such as fiber logs or root wads. This technique is usually used when site constraints limit other restoration options.

Baseflow: The portion of stream flow that is not from runoff, resulting from seepage of groundwater into a channel. Also called dry weather flow.

Berm: A ridge of earth formed to direct or control the flow of surface water.

Bioengineering: Stream restoration techniques which use plants and living materials in preference to rock to stabilize eroding streams or to redirect flow to improve habitat.

Bioretention: A water quality practice that uses landscaping and soils to collect and treat urban stormwater runoff. Water is collected in shallow depressions in the ground and allowed to slowly filter through a layer of filter media and soil, while plants take up water and nutrients.

Build-out: The total potential land development area based on current and future land development and zoning plans.

Buffer: A vegetated, natural area adjacent to shorelines, wetlands, or streams. See also, *Resource Protection Area* and *Riparian Buffer*.

Channel: A natural or manmade waterway.

Confluence: The point where two or more streams join to create a combined, larger stream.

Control Structure: See *Riser*

Daylighting: A stream restoration technique which involves demolition and removal of a section of storm sewer and reconstructing a natural stream channel in its place, restoring the stream flow to "daylight".

Deposition: The process in which particles (e.g., silt, sand, gravel) in the water settle to the stream bottom. Too much deposition can create a thick layer of particles on the stream bottom causing a loss of habitat and spawning areas for *aquatic* insects and fish. Stream bank erosion is a common source for the particles.

Detention: The temporary storage of stormwater runoff used to control peak runoff amounts and provide time for the gradual settling of pollutants.

Dewatering Device: A component of a stormwater pond which can be opened up to drain the pond completely dry for maintenance.

Discharge: The volume of water that passes a given location within a given period of time, usually expressed for stream flow and stormwater in cubic feet per second. In the NPDES program, a discharge is the flow from a regulated facility, or in the case of municipalities like Rockville, from public storm drain outfalls.

Disconnected Impervious Area: Impervious area which drains to a pervious area. It is considered disconnected from the storm drain system because the flow can infiltrate and evaporate. A roof where the downspouts flow on to a lawn is disconnected.

Dissolved Oxygen (DO): The amount of oxygen that is present in water**.** An adequate supply of oxygen is necessary to support life in a body of water. Measuring the amount of dissolved oxygen in water provides a means of determining the water quality.

Drainage: The flow of surface water or *groundwater* from a land area.

Drainage Area: The area of land draining to a single outlet point.

Dry Pond: See *Detention Basin*.

Detention Basin: A stormwater management pond that temporarily holds runoff and slowly releases it to a downstream stormwater system. Since a detention basin holds runoff only temporarily, it is normally dry during periods of no rainfall. (Also called a *Dry Pond*.)

Dwelling Unit: A residential building or part of a building intended for use as a complete, independent living facility.

Ecosystem: All of the organisms in an ecological community and their environment that together function as a unit.

Effluent: Water that flows from a sewage or industrial treatment plant after it has been treated.

Embankment: The structure, typically of earth or concrete, which is designed to hold back water in a stormwater pond.

Endwall: A structure at the point where a free-flowing stream enters or discharges from a pipe or culvert. The endwall protects the pipe end from erosion and guides the flow in or out.

Ephemeral: A stream with no baseflow which flows only periodically or occasionally, usually during and immediately after precipitation.

Environmental Site Design (ESD): A suite of stormwater management techniques that reduces the stormwater impacts from new development or redevelopment, which combines site design and onsite treatment techniques. Site design can include reducing the amount of *impervious surfaces* and designing the site to take advantage of the natural conditions can reduce the amount of runoff produced by a development area. Onsite treatments include techniques such as vegetated swales and *bioretention* filters or basins to reduce runoff rates and promote *infiltration*.

Erosion: The wearing away of the land surface by running water, wind, ice, or other geological agents. In streams, erosion is the removal of soil from the stream banks or streambed by rapid flows.

Eutrophication: The process of over-enrichment of water bodies by nutrients, often resulting in excess algae. Decaying algae or other organic matter reduces dissolved oxygen in streams and the Bay.

Evapotranspiration: The loss of water to the atmosphere from the earth's surface by both evaporation and by *transpiration* through plants.

Extended Detention: Additional depth in a stormwater pond (usually 2 to 3 feet) above the permanent pool or dry bottom to increase holding time and sedimentation. The additional storage is used for improving water quality or reducing flooding or peak discharges that can cause downstream channel erosion.

Fecal Coliform Bacteria: A group of bacterial organisms that live in the intestinal tracts of humans and animals. The presence of fecal coliform bacteria indicates excrement sources from humans, pets or wildlife are present in the environment.

Filter Strips: A vegetated area that treats *sheet flow* and/or interflow by removing sediment and other pollutants. The area may be grass-covered, forested or of mixed vegetative cover (e.g., wildflower meadow).

Fish Passage: Unobstructed movement of fish within the stream system. Fish require the ability to move between various habitat types and during migration.

Flashy: A description of stream flow that varies widely and rapidly between very low baseflow and significantly higher flows in wet weather.

Floatables: Trash, debris, and other large pollutants that tend to float on the surface of streams, lakes, and ponds, and which are not removed by sedimentation, filtration, or other processes in most stormwater management facilities.

Flood limit: Those land areas in and adjacent to streams subject to continuous or periodic inundation from flood events. A 100-year flood limit is an area with a 1 percent chance of inundation in any given year. Differs from a floodplain.

Floodplain: An ecosystem adjacent to a stream which undergoes fairly frequent inundation during high flows when the stream overtops its banks.

Forebay: A small storage area near the inlet of a stormwater pond to trap incoming sediment where it can be removed easily before it can accumulate in the pond.

Gabion: A wire basket or cage that is filled with rock, used to stabilize stream banks, change flow patterns, or prevent erosion.

Geographic Information System (GIS): A computer system for mapping and spatial analysis.

Geomorphology: The study of physical landforms and the processes that shape and change them. In this study, it refers to the study of fluvial (rivers and streams) geomorphology.

Grade Control (Streams): A method of stream restoration intended to halt and repair incision by adjusting the slope of the stream through a series of step pools, riffles and pools, or other constructed features.

Groundwater: Water that flows or seeps downward and saturates soil or rock, supplying springs and wells. The upper surface of the saturated zone is called the water table.

Habitat (Aquatic): A measurable description of the features of a stream which are necessary for insects, fish, and other creatures to thrive, including depth, flow, velocity, substrate, substrate size, and riparian cover.

Head Cut: A type of incision in a streambed consisting of a sudden change in elevation from upstream to downstream, similar to a waterfall. High flows erode the upstream channel at a headcut, resulting in the erosion and incision migrating upstream.

Headwater: The source of a stream or watercourse.

Hydraulics: The physical science and technology of the stationary and active behavior of fluids.

Hydrology: The science dealing with the distribution and movement of water, including the hydrologic cycle of rainfall, runoff, groundwater flow, surface water flow, and evaporation.

Illicit Discharge: To dump, spill, convey, or otherwise release pollutants to the City's waterways, storm drain system, or groundwater in violation of the City Code. Illicit discharges are regulated by the City's Water Quality Protection Ordinance.

Incised (Stream): A channel which has cut downward through its bed, becoming disconnected from its floodplain. High flows which previously overtopped the stream banks and dissipated energy in the floodplain stay within the banks of an incised channel, increasing erosion.

Impervious Surface: A surface composed of any material that impedes or prevents *infiltration* of water into the soil. Impervious surfaces include roofs, buildings, streets, and parking areas. Also called impervious cover.

Infill: A residential development that has occurred near, or within, an already established neighborhood.

Inflow: The source of flow into a stormwater pond. Usually a pipe or man-made channel.

Infiltration: The process by which water drains into the ground. Some of this water will remain in the shallow soil layer, where it will gradually move through the soil and subsurface material. Eventually, it might enter a stream by seepage out of a stream bank or it may penetrate deeper, recharging *groundwater* aquifers.

Infiltration Facility: A stormwater management facility that temporarily stores runoff so it can be absorbed into the surrounding soil. Since an infiltration facility confines runoff only temporarily, it is normally dry during periods of no rainfall. Infiltration ponds, infiltration trenches, infiltration dry wells, and porous pavement are considered infiltration facilities.

Invert: The lowest elevation of a feature in the drainage network: the bottom of a pond, the bottom of a manhole or pipe, the lowest part of a control structure,

Land Development: A man-made change to, or construction on, the land surface.

Land Use: Describes the type of activity on the land such as commercial or residential. The City zoning requirements dictates the type of land use allowed for a given area.

Low-flow Channel: In a stormwater pond, the low-flow channel guides baseflow through the pond during dry periods. Older designs used straight channels made with concrete; newer designs use meandering paths in natural soils, frequently planted with wetland vegetation.

Marsh: A wetland area, periodically inundated with water.

Meander: A stream bend or series of stream bends. Erosion is frequently found on the outer banks of meander bends because they take the force of the flow as it turns.

Median (Parking lot): A small unpaved area in the middle of a parking lot. Most designs use raised medians with curbs. LID techniques can use depressed medians for stormwater treatment.

Micropool: A small permanent pool in a larger stormwater pond system, usually at the pond outlet to provide additional settling of pollutants.

Mitigation: To make a development scenario less harmful than the original plan; or to provide a habitat in another more conducive, larger, or better-suited area, typically in a different location from the original.

Municipal Separate Storm Sewer System (MS4) Permit: An *NPDES (National Pollutant Discharge Elimination System)* permit issued to municipalities requiring the reduction in pollutants contributing to the discharges from the municipality's storm drain outfalls.

National Pollutant Discharge Elimination System (NPDES): The national program for issuing, modifying, monitoring, and enforcing permits under Sections 402 of the Clean Water Act. The NPDES permits regulate wastewater and stormwater discharges to the waters of the United States, and are administered by the Maryland Department of the Environment.

Nested Channel: A stream restoration technique for incised and over-widened streams which mimics a natural, recovered stream by constructing a small, low-flow channel with an adjacent floodplain bench, all within the existing channel.

Nitrogen: A chemical element that occurs naturally as a gas and makes up 78 percent of the atmosphere. Combined with oxygen as nitrate, it is required by plants for growth and is found in most fertilizers. Too much nitrogen in the water can cause *eutrophication* and result in excess algal blooms, reducing the amount of oxygen available to aquatic life. *Total Nitrogen* refers to all nitrogen compounds forms: nitrate, nitrite, ammonia, and organic nitrogen.

Nutrient: A substance that provides food or nourishment. In the aquatic environment, nutrients refer to compounds of phosphorus, nitrogen, and potassium that contribute to *eutrophication*.

Open Space: A portion of a development site that is permanently set aside for public or private use and will not be developed. The space may be used for recreation, or may be reserved to protect or buffer natural areas.

Outfall: Defined in the *NPDES* program as the point where discharge from a regulated system flows into waters of the United States.

Outlet: The point at which water flows from one water body to another, such as a stream or river to a lake or larger river.

Over-widened (Stream): A stream with a channel cross-section which has eroded and become wider over time. Low flows become very shallow and provide poorer habitat.

Peak Discharge: The maximum flow rate at a given location during a rainfall event. Peak discharge is a primary design factor for the design of stormwater runoff facilities such as pipe systems, storm inlets and culverts, and swales.

Perennial Streams: A body of water that normally flows year-round, supporting a variety of aquatic life.

Pervious: Any material that allows for the passage of liquid through it. Any surface area that allows *infiltration*.

Phosphorus: An element found in fertilizers and soil that can contribute to the *eutrophication* of water bodies. *Total Phosphorus* refers to all phosphorus compounds forms: orthophosphorus and both dissolved and particulate organic and inorganic phosphorus.

Plunge Pool: A small pond located at either a stormwater outfall or an inflow to a stormwater pond, designed to dissipate the energy of high-speed flows.

Pollutant: Any substance introduced to water that degrades its physical, chemical, or biological quality.

Pollutant Loading: The rate at which a pollutant enters a surface water or *groundwater* system. This is typically determined by water quality modeling and expressed in terms such as pounds per acre, per year.

Pollution Prevention: Any activity intended to reduce or eliminate stormwater pollution by reducing the amount of runoff, or by reducing the opportunity for stormwater to wash off and transport pollutants downstream.

Pool: The reach of a stream between two *riffles*; a small and relatively deep body of quiet water in a stream or river. Natural streams often consist of a succession of pools and riffles.

Post-Development: Refers to conditions that exist after completion of a land development activity on a specific site or tract of land.

Pre-Development: Refers to the conditions that exist at the time that plans for land development of a tract of land are approved by the plan approval authority.

Pre-Treatment: A component of a stormwater management facility located upstream of the main storage area. It is designed to trap trash and coarse sediment at the inflow point to increase the facility's effectiveness and maintenance life.

Quantity Control: *Stormwater management facilities* designed to reduce *post-development peak discharge* to the peak *discharge* that occurred in the *pre-development* conditions, or to reduce the amount of runoff.

Quality Controls: *Stormwater management facilities* designed to remove *pollutants* from *runoff* and improve water quality.

Rain Barrel: A storage container connected to a roof downspout, typically including a hose attachment to allow for capture and reuse of rooftop runoff.

Rain Garden: A landscaped depressed area that allows stormwater from impervious areas, typically roofs and driveways, to pond temporarily before infiltrating and being taken up by vegetation.

Reach: General term used to describe a length of stream.

Recharge: The downward movement of water through the soil into *groundwater*; for example, rainfall that seeps into a groundwater aquifer.

Redevelopment: The substantial alteration, rehabilitation, or rebuilding of a property for residential, commercial, industrial, or other purposes.

Regenerative Stream Conveyance: A stabilization technique for storm drain outfalls or small streams. A filter of large stone, sand and woodchips is installed along a downcut channel to control bank erosion and provide some water quality treatment.

Regional Ponds: Larger stormwater management facilities designed to treat the runoff from drainage areas of 100 to 300 acres.

Regrade: A stream restoration technique for incised or over-widened channels which involves excavation and fill to change the cross-section of the stream banks from an easily eroded, usually vertical, form, to a more stable, usually sloping, shape.

Retention Basin: A stormwater management pond that permanently stores water for the purpose of improving water quality. It is normally wet, even during periods without rainfall. Also called a *Wet Pond*.

Retrofit: The modification of stormwater management systems to improve water quality or to change characteristics of peak discharge control by adding storage, changing outflow characteristics, or adding water quality treatments such as pools, meanders, wetland plantings, or other features.

Riparian Buffer: Strips of grass, shrubs, and/or trees along the banks of rivers and streams that filter polluted runoff. These buffers provide a transition zone between water and human land use. Buffers are also complex ecosystems that provide habitat and improve the stream communities they shelter.

Riprap: A protective layer of large stones placed on a stream bank to prevent erosion.

Riffle: A reach of stream that is characterized by shallow, fast-moving water broken by the presence of rocks and boulders.

Riffle/Run: Streams that are generally characterized by a high slope (gradient), and a mixture of riffle and run habitat.

Riser: A pipe or structure used to control the discharge rate from a stormwater management pond.

Runoff: The portion of precipitation, snowmelt, or irrigation water that flows off the land into surface waters instead of *infiltrating*.

Run: A segment of stream length that is characterized by moderate depths, smooth flowing water at a moderate pace. A run is intermediate between a *riffle* and a *pool*.

Sand Filter: A stormwater management facility consisting of a large, flat area which collects stormwater in a shallow pond and allows it to slowly percolate through a sand bed to remove sediment and pollutants. Usually has an underdrain to collect and convey the filtered stormwater.

Sanitary Sewer: The pipe network that carries domestic and industrial wastewater to a treatment plant.

Scour: Removal of sediment from the streambed and banks caused by fast moving water. See also *Erosion*.

Sedimentation (Treatment): In a water treatment context, sedimentation refers to a pollutant removal method in which pollutants are removed by gravity as sediment settles out of the water column. An example of a *best management practice* using sedimentation is a *detention pond/wet pond*.

Sedimentation (Streams): See *Deposition*

Sheet Flow: Runoff that flows over the ground surface as a thin, even layer, not concentrated in a channel.

Sinuous: Sinuosity describes how a stream or river turns back and forth across the land as it flows downstream. A stream with many tight meanders for its length is more sinuous than one with shallow bends.

Stakeholder: Stakeholders include groups of people within the watershed (e.g., residents, businesses, industry, local government agencies, and community groups). Stakeholders may have environmental interests or other interests that affect choices for watershed management.

Storm Drain: A man-made drainage system of street or yard inlets and pipes that carries rain/snow runoff from developed areas to the stream. In Rockville and Montgomery County, storm drain pipes are completely separate from sanitary sewers that carry wastewater.

Stormwater: Surface water flow that results from rainfall.

Stormwater Management (SWM) Facility: A structure, such as a pond, that controls the quantity and quality of stormwater runoff.

Stormwater Outfall: A single location, pipe discharge, or outlet structure that releases stormwater into a stream, river, or pond.

Stormwater Ponds: A depression or dammed area with an outlet device that controls stormwater outflow. Stormwater ponds retain water from upstream areas, thereby reducing peak flows downstream. In the City of Rockville, stormwater ponds are either dry (*dry pond*) or contain a permanent pool of water (*wet pond*) and are typically designed to control the peak runoff rate for selected storm events.

Stormwater Wetlands: Areas intentionally designed to emulate the water quality improvement function of wetlands for the primary purpose of removing pollutants from stormwater.

Stream Restoration: The reestablishment of the structure and function of a stream, as closely as possible to its pre-existing condition.

Substrate: The material forming the bottom of a stream channel. Channel materials are generally broken into categories (listed smallest to largest) such as clay, silt, sand, gravel, cobble and boulder.

Sub-watershed: A smaller subsection of a larger *watershed*, often delineated to describe a particular tributary to a larger water body.

Suspended solids: Particles that are suspended in and carried by the water. The term includes sand, mud, and clay particles as well as solids in wastewater.

Swale: A natural depression or wide shallow ditch used to temporarily store, route, or filter runoff.

Toe Protection (Streams): A stream restoration technique to provide erosion protection for the bottom of the stream bank. Typically constructed of stone and tied into a regraded and re-vegetated bank.

Total Kjeldahl Nitrogen (TKN): A measure of two forms of nitrogen: ammonia and organic nitrogen. Total Nitrogen (TN) equals TKN plus nitrite plus nitrate.

Transpiration: The process by which water vapor escapes from living plants and enters the atmosphere. Studies have shown that about 10 percent of the moisture found in the atmosphere is released by plants through transpiration.

Tree Canopy Cover: The area directly beneath the crown and within the drip line of a tree.

Turbidity: Turbidity is an indicator of the amount of solid particles suspended in water. High turbidity typically is associated with runoff from construction sites, which may make water cloudy or opaque.

Underdrain: A series of perforated pipes installed under a filtration treatment system which collects filtered water and conveys it to a storm sewer or stream. May be installed in infiltration systems to divert high flows.

Waters of the United States: Lakes, rivers, streams, tidewater, wetlands, and other water bodies protected under the Clean Water Act (33 U.S.C.1252). Also see the definition set for in 40 CFR 230.3(s) and 122.2.

Watershed: An area of land that drains directly, or through tributary streams, into a particular river or water body. A watershed includes its associated groundwater. Elevated landforms, such as ridges or even roads can serve as watershed divides.

Weir: A section of a riser which limits the discharge from a stormwater pond to the level determined by the design.

Wetlands: Areas where the soil or substrate is saturated with water during at least a part of the growing season. These saturated conditions determine the types of plants and animals that live in these areas.

Wet Pond: See *Retention Basin*