MUDDY BRANCH WATERSHED STUDY

Prepared for

City of Gaithersburg, Maryland
800 Rabbitt Road
Gaithersburg, MD 20878

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URS

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BEHI	Bank Erosion Hazard Index
BMP	Best Management Practice
City	City of Gaithersburg
EPA	Environmental Protection Agency
ESD	Environmental Site Design
GIS	Geographic Information System
HOA	Homeowners' Association
MBSS	Maryland Biological Stream Survey
MDE	Maryland Department of the Environment
MEP	Maximum Extent Practicable
MS4	Municipal Separate Storm Sewer System
NPDES	National Pollutant Discharge Elimination System
SWM	Stormwater Management
TMDL	Total Maximum Daily Load
TN	Total Nitrogen
TP	Total Phosphorus
TSS	Total Suspended Solids
URS	URS Corporation
WIP	Watershed Implementation Plan

EXECUTIVE SUMMARY

The Walder Park green street on Cedar Avenue, originally constructed in Fall 2013, was monitored after construction and maintained in Fall 2014. This proactive monitoring approach will be important for the City to maintain nutrient reductions in the future.

The City of Gaithersburg (City) is proactively working toward improving stream and watershed conditions in the Muddy Branch watershed, which will help meet upcoming regulatory requirements. The Muddy Branch Watershed Study is the third of three watershed assessments that the City has initiated. The first study, the Middle Great Seneca Creek Study, completed in June 2013, provides background information on the City's stormwater management and provides additional information relative to the City's efforts. The Lower Great Seneca Creek Watershed Study, completed in August 2014, builds on the first study, and this final study provides an overview of all the City's watersheds. The City performed these studies to assess current conditions, current progress, and shed light on upcoming steps towards compliance and City goals.

The Muddy Branch watershed is the largest of the City's watersheds, with the most natural stream miles. This area has the highest percentage of open space of the watersheds, consisting primarily of riparian buffers and parks. Other unique characteristics of this watershed are higher institutional land use, large recent residential and mixed use developments, and sectors of very active environmental participation.

The Muddy Branch Watershed Study evaluated twenty nine potential stormwater sites and narrowed down the list to the top twelve:

- Casey Community Center
- Green Park Dry Pond
- Washington Woods Dry Pond
- Washington Woods Park
- Amberfield Dry Pond
- Kentlands Mid/Upper Lake District Dry Pond
- Morris Park
- Upshire Circle
- Inspiration Lane
- Stonemason Drive Playground
- West Deer Park Road
- Arts Barn

The City chose to proceed with concept designs for four stormwater management sites, which are summarized below:

Site	Drainage Area (acres)	Proposed Measure	Potential Pollutant Removal Credits	Approximate Cost
Casey Community Center	2.33	Bioretention	0.55 acre 11.35 lb TN 1.29 lb TP 810 lb TSS	$165,178
Green Park Dry Pond	26.4	Bioretention	1.7 acres 79 lb TN 5 lb TP 3036 lb TSS	$279,640
Washington Woods Dry Pond	9.8	Bioretention	1.3 acres 47 lb TN 3,8 lb TP 1880 lb TSS	$200,905
Washington Woods Park	2.8	Bioretention	1.1 acres 20 lb TN 1.7 lb TP 860 lb TSS	$157,446

TN = Total Nitrogen
TP = Total Phosphorus
TSS = Total Suspended Solids

This study also evaluated approximately eleven miles of stream for potential stream restoration sites. The City selected four sites for stream restoration concept design:

Stream Reach	Reach Length (linear feet)	Proposed Measures	Potential Pollutant Removal Credits	Approximate Cost
M2 **Future City Park**	1,720	Rock toe protection & grade control, a deflector and root wads	17.2 acres 65 lb TN 58 lb TP 110 tons TSS	$1,031,000
T 3.1 **Quince Orchard Park**	1,540	Rock toe protection & grade control	15.4 acres 58 lb TN 52 lb TP 100 tons TSS	$1,001,813
T 4.1 **Brighton Village**	970	Rock toe protection & grade control	9.7 acres 36 lb TN 33 lb TP 65 tons TSS	$701,844
T 5.2a **I-370 Outfall**	460	Rock toe protection & grade control	4.6 acres 17 lb TN 16 lb TP 30 tons TSS	$860,000

TN = Total Nitrogen
TP = Total Phosphorus
TSS = Total Suspended Solids

A combination of new, retrofit, alternative practices, and stream restoration was considered for available sites in this watershed. High private ownership in the watershed suggests a need to encourage private property owners to participate in the City's RainScapes Program to mitigate the impervious effects on their property. The City's developing Stormwater Management Program and existing Rainscapes Rewards are a start towards addressing this issue.

The City is in the process of developing a Stormwater Management Program and Stormwater Program Fee. This City fee will take the place of the Water Quality Protection Charge applied by Montgomery County and will support restoration projects. Credit for private stormwater management facilities will discount the fee; details of rates and credits have not yet been determined. The watershed studies will help the City understand the priorities within each watershed and provide direction for the City's Stormwater Management Program.

The proposed improvements identified in the Muddy Branch watershed will improve water quality by decreasing the pollutants that enter Muddy Branch and its tributaries, thereby enhancing stream habitat and stability. These recommendations will provide a step towards removing pollutants from the City's waterbodies and meeting regulatory requirements.

BACKGROUND

The City's Muddy Branch Watershed Study is a step towards addressing the City's restoration goals. This watershed study investigates these aspects of the watershed and provides suggestions to improve the watershed to meet the City goals. The City of Gaithersburg's (City's) goals are to:

- Conserve and protect healthy ecosystems
- Stabilize eroded banks and streams
- Improve degraded stream habitat
- Provide aesthetically pleasing stormwater management
- Involve the community in the process of protecting watershed health
- Meet the City's National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) permit and Chesapeake Bay requirements for pollution Total Maximum Daily Loads (TMDLs)

This watershed is one of three watersheds in the City. The streams in this watershed contribute to Muddy Branch, a tributary of the Potomac River, which discharges into the Chesapeake Bay. Approximately 3,191 acres of land in the City of Gaithersburg are part of the Muddy Branch watershed drainage area, which is the focus of this study. Residential neighborhoods make up the majority of this area, closely followed by transportation.

Muddy Branch is a highly residential area and contains large groupings of development such as:

- The Lakelands
- The Kentlands
- Rio and Washingtonian Center
- Crown Farm

Stormwater management philosophy has changed over the years and prior to 1985 land was developed without consideration of the effects of increased imperviousness on the volume and quality of water being discharged from the development. The increased imperviousness in the drainage area prevents rain from infiltrating into the ground and instead the water flows across land surfaces like driveways, roofs and patios directly to streams. As stormwater flows over land surfaces, it picks up pollutants such as sediment, trash, pesticides from lawns, nutrients from fertilizers or pet waste, and oil and grease from cars. This accumulation of stormwater and pollutants, or runoff, enters the storm drain (a.k.a. storm sewer) system which discharges to local streams, and ultimately makes its way into the Chesapeake Bay. Damage resulting from the high volumes of discharge and high pollutant loads can cause erosion, deteriorating water quality, damaging aquatic habitat, and general disruption of the natural estuarine ecosystems. Water quality regulations provide a means of enforcing corrective action to address these issues.

Runoff that accumulates nutrients from pet waste and fertilizers as it flows over land ends up in local waterbodies and can result in algae blooms.

Runoff from impervious surfaces can account for 60 percent of the stormwater volume that discharges to streams.

The City has a MS4, and is covered under the Phase II NPDES MS4 permit for stormwater discharges. The permit has been administratively extended until the Maryland Department of the Environment (MDE) releases an updated version based on Chesapeake Bay TMDL goals. The updated MS4 permit is expected to have requirements for the City to treat 20 percent of impervious surfaces that are not currently managed. This requirement is a result of the Chesapeake Bay TMDL restrictions, or "pollution diet" that sets limits on the amounts of sediment, nitrogen, and phosphorus that can enter the Bay.

New and re-development in Muddy Branch will incorporate environmental site design (ESD) to the maximum extent practicable (MEP). Existing development is the focus area for managing currently untreated areas in accordance with upcoming MS4 permit requirements. Watershed conditions and practices were analyzed to provide recommendations for updating stormwater management in existing development in the watershed. The recommendations for the Muddy Branch Watershed are a compilation of proposed improvement projects and various management strategies, and include:

- New and retrofit stormwater management facilities
- Stream restoration projects
- Conservation and enhancement of existing forested riparian buffers (reforestation)
- Public outreach and education
- Environmental site design and alternative opportunities

Concept designs for four existing stormwater facilities and four stream restoration opportunities were produced as part of this study. These concepts are designed to provide water quality improvements needed for upcoming NPDES permit requirements.

Nonstructural opportunities based on behavioral activity, existing management and regulations in the watershed were identified. These strategies focus on eliminating pollutants before they enter the storm drain system, whereas the structural suggestions are focused on removing pollutants amidst transport.

The City will need to determine the prioritization of stormwater and stream management project implementation based on available funding and need. Some suggestions can be implemented on a City-wide basis as appropriate. The next steps to meet City goals include:

- Prioritizing and implementing projects
- Enhancing public outreach and education
- Monitoring and maintaining stream and stormwater projects
- Tracking and reporting improvements

When the City receives the new MS4 Permit from the MDE, the requirements will need to be reviewed, and implementation of the watershed plans will be expected. Application of these recommendations will help the City meet its goals of improving water quality, meeting permit requirements, and improving overall watershed health.

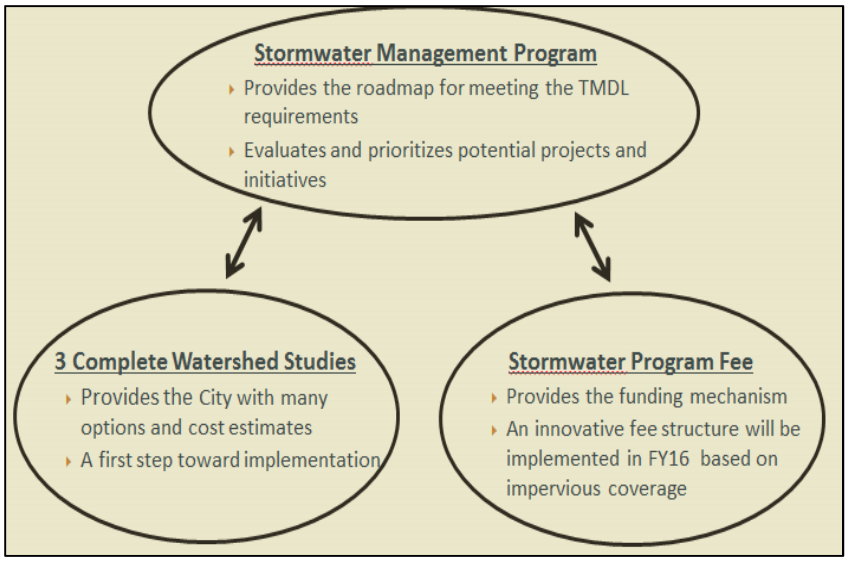
SECTION ONE: INTRODUCTION

The City of Gaithersburg (City) is actively working to understand current conditions and work to improve stormwater and stream health within its jurisdiction on a watershed basis. The Middle and Lower Great Seneca Creek watersheds in the City have been studied to determine current stormwater treatment extent and stream health and have identified restoration opportunities to improve conditions. The Muddy Branch Watershed Study is the third of the City's three watershed studies and completes the City's strategic goal of preparing watershed management plans to be used as guidance for implementation of stormwater management and stream restoration to meet state and local stormwater regulations. Each of the watershed studies provide opportunities and potential stormwater management and stream restoration projects that the City could implement in upcoming years to help meet regulatory requirements.

Sustainable funding to support the implementation of stormwater management and stream restoration projects is important to successfully improve the watershed conditions. In prior years, the County Watershed Protection Charge was a supplement fund for watershed projects, however, the City determined a need to replace this charge with one specifically developed for the City. As a result, the City is currently developing a Stormwater Program Fee, which will help fund projects to meet the City's watershed protection goals.

The funds from the Stormwater Program Fee will be managed through the concurrently developing Stormwater Management Program and will be used to implement projects to meet the City's watershed protection goals. The Stormwater Management Program regulates the total impervious surfaces and treated stormwater within the City. It also includes CIP projects, monitoring and maintaining a crediting program for parcels that implement approved stormwater management techniques. Meeting the stormwater management requirements, such as site inspections and maintenance, will result in significant increases in staff time in all areas.

This program should provide sustainable funding to support watershed protection in all of the City's watersheds in coming years, which is an important component to continuing the City's successful "Pay-as-you-go" budgeting model to



This Muddy Branch watershed study completes the trilogy of the Gaithersburg Watershed Studies and provides support for the City's development and implementation of a sustainable Stormwater Management Program and Stormwater Program Fee.

prevent the City from incurring debt.

1.1 WATERSHEDS

The Muddy Branch watershed is a highly developed with residential and commercial areas as a densely populated area, proposes many challenges to the health and management of the watershed.

1.1.1 Environmental Challenges

Hydrologic and hydraulic flows have been modified from their natural state by the construction of highly impervious development in this urban watershed. Increases in impervious surface without adequate stormwater management can accelerate stream degradation and erosion, cause flash flooding, and pollute downstream waterbodies.

1.1.2 Protecting Watersheds

The City has been working proactively to mitigate the effects of urban development in its watersheds as part of the City's goal of achieving a green and sustainable Gaithersburg. Clean, healthy watersheds protect water quality for people, wildlife, and plants and preserve the quality of open spaces.

The City has used traditional techniques in the past but is moving towards the use of ESD controls; both of which are used to reduce velocity or volume of runoff and pollutants that enter the streams.

This combination of dry pond and filter is an example of how volume and water quality can be addressed in tight spaces.

1.1.3 City of Gaithersburg Watersheds

The study watershed is part of the larger Muddy Branch watershed, whose headwaters begin in the City of Gaithersburg and discharge to the Potomac River (Figure 1.1). The entire City is divided into three watersheds: Middle Great Seneca Creek to the north, Lower Great Seneca Creek to the west and Muddy Branch to the south, all of which discharge to the Potomac River (Figure 1.2).

The City's Muddy Branch watershed:

- Is the largest of the City's watersheds
- Contains the most natural stream miles
- Has the highest acreage of residential area
- Has the highest percent of institutional area
- Contains seven high-hazard dams

There are approximately 22.4 miles of streams within the City's jurisdiction. The National Institute of Standards and Technology campus is not part of the City's jurisdiction, as shown in

Figure 1.2. The City has been updating the impervious area data in Geographic Information System (GIS) so that the data layer is more accurate, and plans to have a City-wide update when new aerial imagery is available. The City's updated GIS datasets (with improved accuracy) were used for analysis in July 2014, which has changed the comparative impervious area estimates since the Middle and Lower Great Seneca Creek Watershed Studies were developed. Table 1.1 provides an updated comparison of the three watersheds within the City based on the updated 2014 GIS data. Although the Muddy Branch watershed is the largest in both area and stream mileage, it has the highest percentage of open space area of the three watersheds.

Table 1.1: Comparison of the Watersheds within the City of Gaithersburg

Watershed	Area (acres)	Impervious Surface		Streams (miles)
		Acres	Percent	
Middle Great Seneca Creek	2,166	862	39.8%	7.71
Lower Great Seneca Creek	1,255	561	44.7%	3.71
Muddy Branch	3,191	1,176	36.8%	10.84
Upper Rock Creek Watershed*	20	15	74%	0.14

*The 20-acre Sears/Great Indoor property, annexed by the City, drains to Upper Rock Creek Watershed. Previous watershed studies assumed this area was part of Muddy Branch as GIS data for this area was not available to thwart the assumption.

Note: The City's updated GIS datasets were used for analysis in July 2014, which has changed the comparative estimates since the Lower Great Seneca Creek Watershed Study was developed. The data in this table was interpreted from the 7/1/2014 GIS data update from the City of Gaithersburg.

The City's watersheds are managed through the City's CIP. The stormwater management projects and maintenance are performed by the City's Department of Public Works staff.

1.2 REGULATORY DRIVERS

Though the City has its own internal motivations for protecting the health of the watersheds, regulatory drivers also dictate the extent of restoration needed and the restoration milestones. One objective of this watershed assessment is to proactively identify projects and programmatic solutions to manage stormwater runoff and reduce pollutants discharged to streams in the watershed. This plan will help the City comply with regulatory requirements.

1.2.1 National Pollutant Discharge Elimination System Permit

The City has a MS4, and this system is covered under the Phase II NPDES MS4 permit for stormwater discharges. The City currently practices activities to meet the minimum control measures in the current permit. The current permit has been administratively extended until MDE issues the renewed MS4 permit which at the time of this report is expected at the latest by June 15, 2015. Tentative determination of the Phase II Watershed Implementation Plan (WIP) is expected by December 31, 2014. The renewed MS4 permit will include a new requirement to

add stormwater management for 20 percent of impervious surfaces that are not currently managed. This requirement is a result of the Chesapeake Bay TMDL restrictions.

1.2.2 Chesapeake Bay Total Maximum Daily Load

The *Chesapeake Bay Total Maximum Daily Load for Nitrogen, Phosphorus and Sediment* (Chesapeake Bay TMDL) requires all states whose stormwater drains to the Chesapeake Bay to work together to reduce the amount of pollutants in their waters. The Environmental Protection Agency (EPA) has set a goal for states that contribute to the Bay to meet these reductions by 2025 and for 60 percent to be met by 2017.

The EPA's assessment of Maryland's progress in the Urban Stormwater Sector determined that:

- The urban sector is not on track for having practices in place by 2017 to achieve 60 percent of expected reductions.
- Maryland will need to finalize Phase II MS4 permits by June 15, 2015.
- Additional implementation of Best Management Practice (BMPs) in 2015 is needed (beyond what was shown in the 2013 progress).

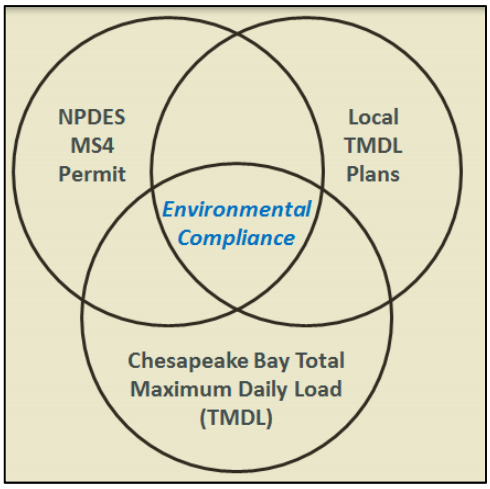
The Chesapeake Bay TMDL divides the nutrient reduction goals into individual goals for each state or jurisdiction and gives states the flexibility to delegate and enforce the pollution reduction goals in their own way.

In June 2014, the EPA evaluated Maryland's progress towards meeting the TMDL milestones that were set for 2012-2013 and to anticipate the likelihood of meeting future year's targets. The review found that Maryland achieved the target overall pollutant reductions for nitrogen, phosphorus and sediment for the 2013 milestone and that the state is on track to meet the 2017 target based on planned implementation. The EPA suggested that Maryland enhance the tracking, verification, and reporting program to be consistent with the Chesapeake Bay Partnerships framework.

Watershed Implementation Plans

In cooperation with surrounding jurisdictions (Montgomery County, the City of Rockville, the City of Takoma Park, and MNCPPC), the City contributed to the creation of the Montgomery County Phase II WIP. This Countywide Strategy describes each jurisdiction's plan of action to meet specified reduction milestones.

The City of Gaithersburg has been working closely with the County to meet the Phase II WIP goals. The City has made significant progress toward the Phase II WIP goals through the construction of Green Streets, stream restoration, stormwater management retrofits, and outreach and education programs, including the Rainscapes Rewards Program.



Environmental compliance is achieved by meeting the Chesapeake Bay and local TMDL goals and meeting MS4 permit requirements.

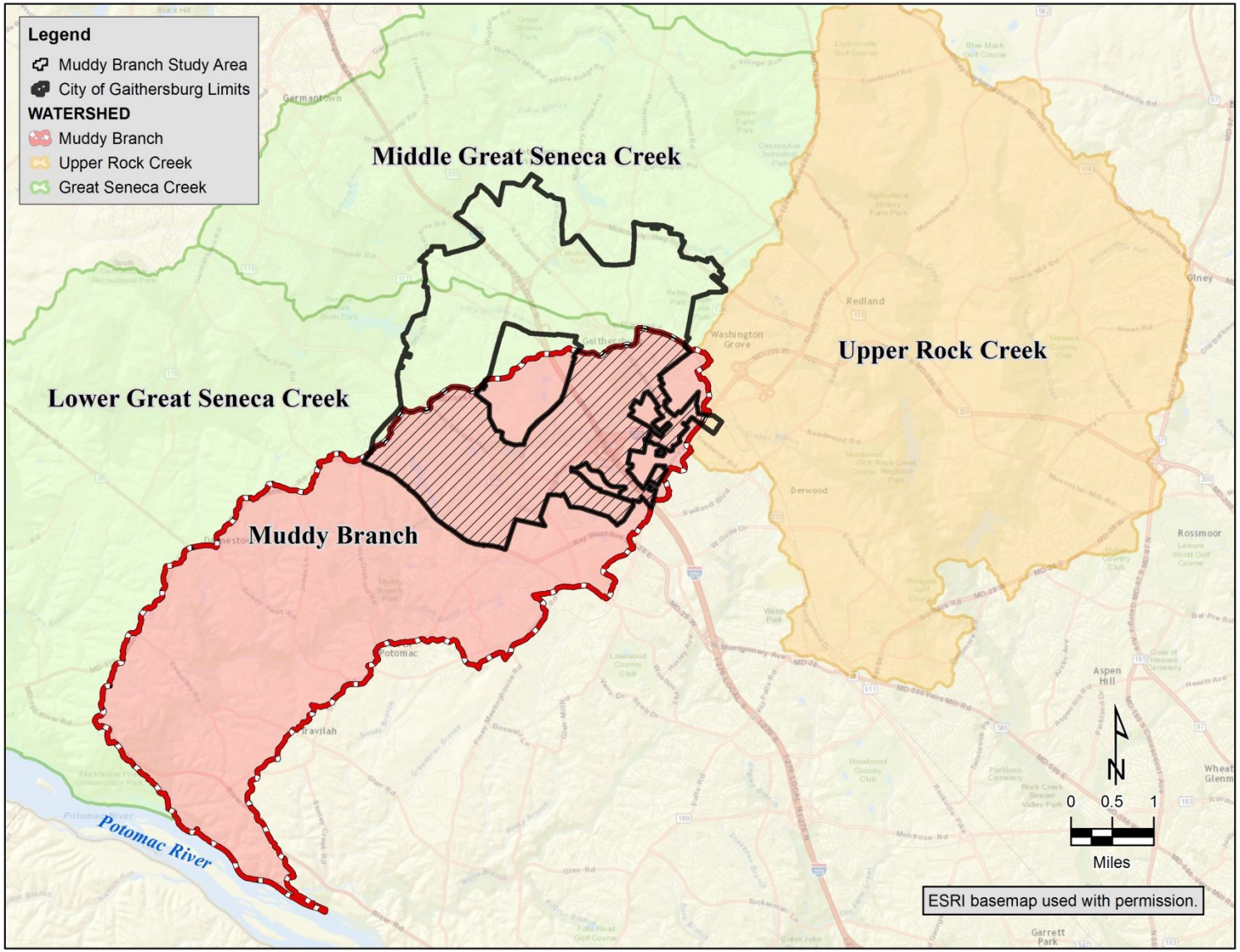


Figure 1.1: Muddy Branch Watershed and Study Area

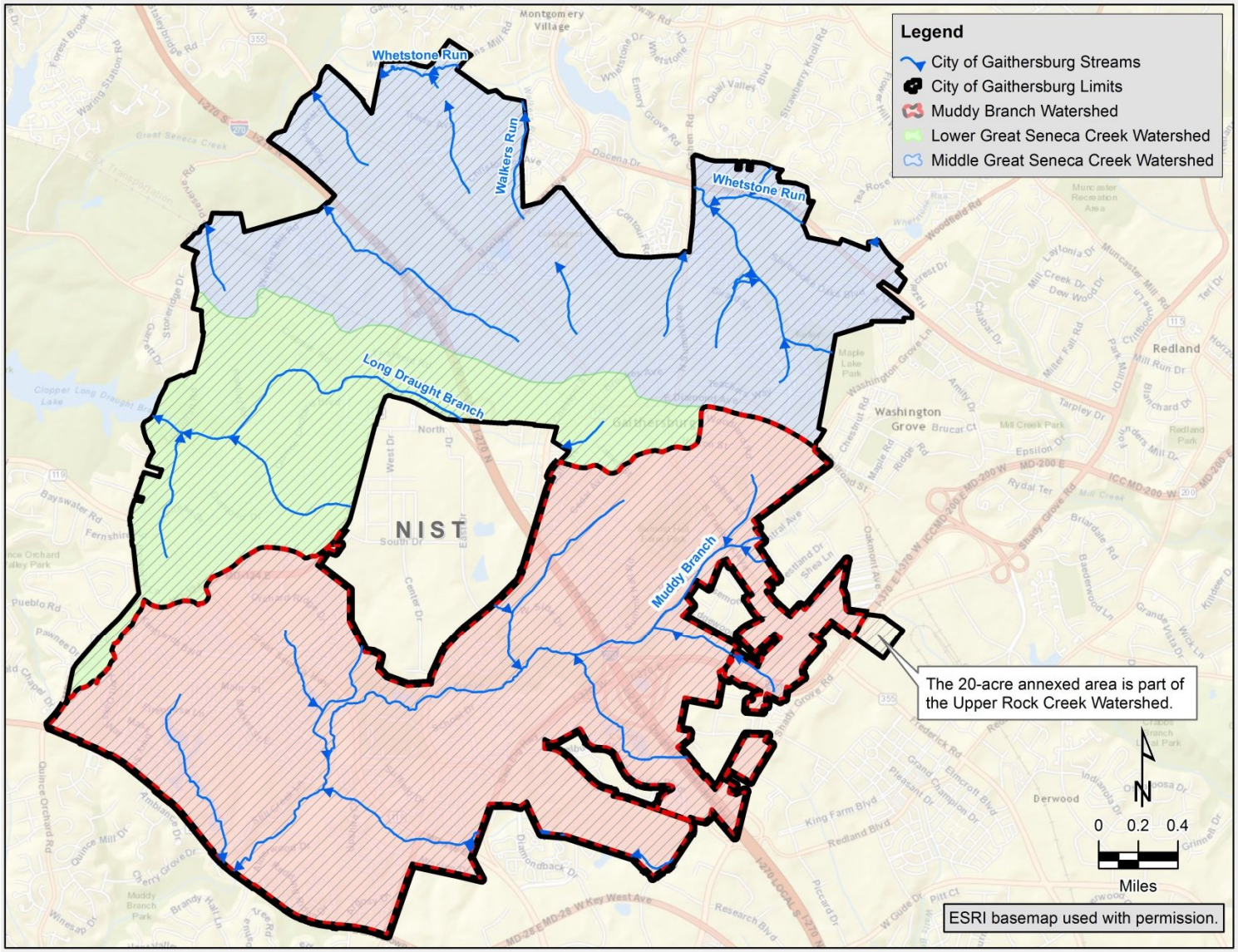


Figure 1.2: Watersheds in the City of Gaithersburg

Watershed Specific TMDLs and WIPs

Muddy Branch does not currently have any approved pollutant TMDLs. However, the Muddy Branch Watershed within the City of Gaithersburg drains to the Potomac River, which has been noted by the EPA as a Category 5 impaired water with problem pollutants including suspended solids, total phosphorous, polychlorinated biphenyls, and associated habitat limitations. The Potomac River has TMDLs for sediment and PCBs. Efforts in the Muddy Branch watershed will need to focus on preventing the sources of these pollutants from being discharged as a contributor to the Potomac pollutant loads.

1.2.3 Local Drivers and Strategies

Local drivers such as the Maryland Stormwater Management Act of 2007 (Act) and the Maryland Tributary Strategies show the forethought for incorporating ESD for water quality. The Act requires any new development or redevelopment that disturbs an area of greater than 5,000 square feet to address the stormwater runoff on the property by using ESD practices to the MEP. City Code is the tool for implementing stormwater and stream management to meet pollutant reduction requirements. Its ordinances include requirements for the use of ESD and stormwater management inspections that reflect the intentions of the Chesapeake Bay TMDL and WIPs.

1.3 CITY GOALS

The City's goals include meeting the MS4, WIP, and TMDL milestones as well as to use ESD to improve aesthetics in the watershed. Additional benefits would be protecting the community from drainage-related flooding.

Multiple Benefits to the City:

- Limit pollution to the Chesapeake Bay
- Permit compliance
- Improved aesthetics
- Improved Potomac River conditions for recreation and drinking water

1.4 MUDDY BRANCH WATERSHED STUDY

The Muddy Branch watershed study, initiated in early 2014, supports the City by determining possible projects for nutrient and sediment reductions, which are anticipated to be required by the MS4 permit and will help in the implementation of the WIP. This study, along with the Middle Great Seneca Creek Watershed Study published in 2013, and the Lower Great Seneca Creek Watershed Study published in 2014, will provide a comprehensive assessment of the City's watersheds.

This Muddy Branch Watershed Study includes:

Section Two – Watershed Characterization

Section Three – Stormwater Assessment

Section Four – Stream Assessment

Section Five – Other Existing Stormwater Management Strategies

Section Six –Recommendations

Section Seven – Comparison of City Watersheds

SECTION TWO: WATERSHED CHARACTERIZATION

A characterization approach consistent with the Middle Great Seneca and Lower Great Seneca Watershed studies was adopted for Muddy Branch watershed. This approach will provide the City with tools to compare the health of watersheds for long term planning goals. The characterization of the Muddy Branch watershed included analyses of existing land use, impervious area, soils, development and redevelopment plans and natural resources. The watershed conditions were analyzed using the GIS data provided by the City beginning of 2014. Updated BMP data provided by the City in July 2014 which was also used to evaluate the existing stormwater controls in the watershed. Field assessments were conducted to evaluate the current stream conditions, habitat, stormwater management facilities and potential pollutant sources. The data and analyses presented in this watershed characterization focus only on the Muddy Branch watershed within the City's existing municipal boundaries.

Previous studies and reports relating to the Muddy Branch watershed were obtained from various sources, including the City of Gaithersburg, Montgomery County, the State of Maryland, MDE and the EPA. GIS data provided by the City were reviewed to identify existing stormwater management, areas without adequate stormwater management, and potential stream restoration projects. A list of the studies, reports and GIS data that were reviewed is provided in Appendix A of this report.

2.1 WATERSHED COMPONENTS

The Muddy Branch watershed includes Muddy Branch mainstem and its tributaries, Decoverly Tributary, Lakes Tributary, Route 28 Tributary and several lakes including Inspiration Lake, Lake Halcyon, Lake Lynette, Lake Nirvana, Lake Placid and Three Sisters Lake. The watershed also includes historic sites such as Gaithersburg Latitude Observatory, Carriage House along with commercial areas Kentland's Square, Muddy Branch Square, Washingtonian Center and Downtown Crown. Approximately 20.5 miles of the Muddy Branch stream network in the City drains 3,191 acres (5.0 square miles) to southwest to eventually discharge into the Potomac River, and finally the Chesapeake Bay.

2.2 LAND USE

The land use distribution in Muddy Branch watershed is dominated by residential and commercial areas, which occupy approximately 48 percent of the watershed. Other predominant land uses in the watershed are transportation (20 percent) and open space (15 percent). Approximately 15 percent of the property in the watershed is owned by the City which primarily includes parks, buffers along streams, Casey Community Center, Gaithersburg Latitude Observatory, Future Aquatic Center and Bohrer Park at Summit Hall Farm and Activity

Land use, from the annexed Sears Property, draining to Upper Rock Creek Watershed includes:

- 6.85 acres Transportation
- 13.55 acres Commercial

Center. Table 2.1 and Figure 2.1 show the distribution of land use in the watershed based on City GIS data.

Table 2.1: Land Use Distribution in the Muddy Branch Watershed

Land Use	Area (square miles)	Area (acres)	Watershed Contribution
Residential	1.8	1139	36%
Commercial	0.6	369	12%
Transportation	1.0	652	20%
Open Space	0.8	485	15%
Industrial	0.2	97	3%
Institutional	0.3	189	6%
Mixed Use	0.3	177	6%
Other	0.1	84	2%
Total	**5.0**	**3191**	**100%**

Note: Interpreted GIS data (December 2013) from the City of Gaithersburg

The Muddy Branch watershed contains 3191 acres, of which 218 acres were developed pre-1985.

The land use distribution in the City is the result of development and urbanization. Areas developed before 1985, that are associated with a stormwater facility, account for 218 acres (7 percent) of the watershed. Most of these areas drain to wet/dry ponds that were designed mainly to provide quantity control for stormwater runoff. Though they may have some level of stormwater management, are assumed to not be adequately managed. The areas developed before 1985 are good locations to focus retrofit opportunities because limited stormwater management was used during development in that era. However, ownership issues can often make retrofits in these areas more difficult because very few opportunities are located on City-owned property.

2.3 SOILS

Majority of soils in Muddy Branch watershed are Soil Hydrologic Group B (54 percent) with filtration rates of 0.3 inch/hour–0.15inch/hour due to high silt loam or loam content. Implementing infiltration stormwater management techniques on these types of soils is generally economical as fewer soil amendments are needed. However, compaction of these soils as a result of construction in developed areas will result in lower infiltration rates and in such scenarios, aeration during implementation of stormwater management practices will enhance the infiltration rates. Table 2.2 shows the distribution of hydrologic soils groups in the watershed.

Table 2.2: Hydrologic Soil Distribution in the Muddy Branch Watershed per the Soil Survey Geographic Database

Hydrologic Soil Group	Area (Acres)	Watershed Coverage (%)
A	-	-
B	1725	54%
C	280	9%
D	1186	37%
Total	**3191**	**100%**

Soils with Hydrologic Group C and D occupy approximately 9 percent and 37 percent respectively and are mainly distributed along the stream corridors. Areas of residential and commercial development also have these soils; this is expected as the soils are subjected to compaction during construction work and as a result have low infiltration rates of 0 inch/hour–0.15 inch/hour. Implementation of stormwater management techniques in these areas is likely going to be more expensive as soil amendments and/or underdrains would be needed.

2.4 IMPERVIOUS AREA

Approximately 37 percent of the Muddy Branch watershed is impervious area. High impervious areas can cause detrimental effects on the health of the watersheds. Urban areas with greater than 25 percent impervious cover can impact the stream causing fair to poor water quality, unstable stream channels, erosion, and inability to support aquatic habitat. Figure 2.2 is a map of the impervious areas in the Muddy Branch watershed. The land use with the largest proportion of impervious area is residential areas (398 acres), followed by transportation (372 acres), and commercial areas (237 acres).

The annexed Sears Property, draining to Upper Rock Creek Watershed, includes 15.12 acres of impervious area. This includes 1.79 acres of County owned Shady Grove Road and 1.01 acre of State owned I-370.

Based on the assessment of current watershed conditions and the data provided by the City, new developments in the watershed such as Crown Farm would add additional impervious area to the watershed. However, to minimize the impacts of the increase in impervious cover, ESD to MEP will be implemented in all the developments as per the City and MDE requirements for new developments.

The **City owns approximately 49 percent (183 acres) of the impervious transportation area in the Muddy Branch watershed**. The City's proactive approach implementing Green Streets and providing street sweeping are valuable tools for providing improved water quality for this large amount of impervious surface area under City control. These types of alternatives will be needed after the City has focused on the priority retrofit projects.

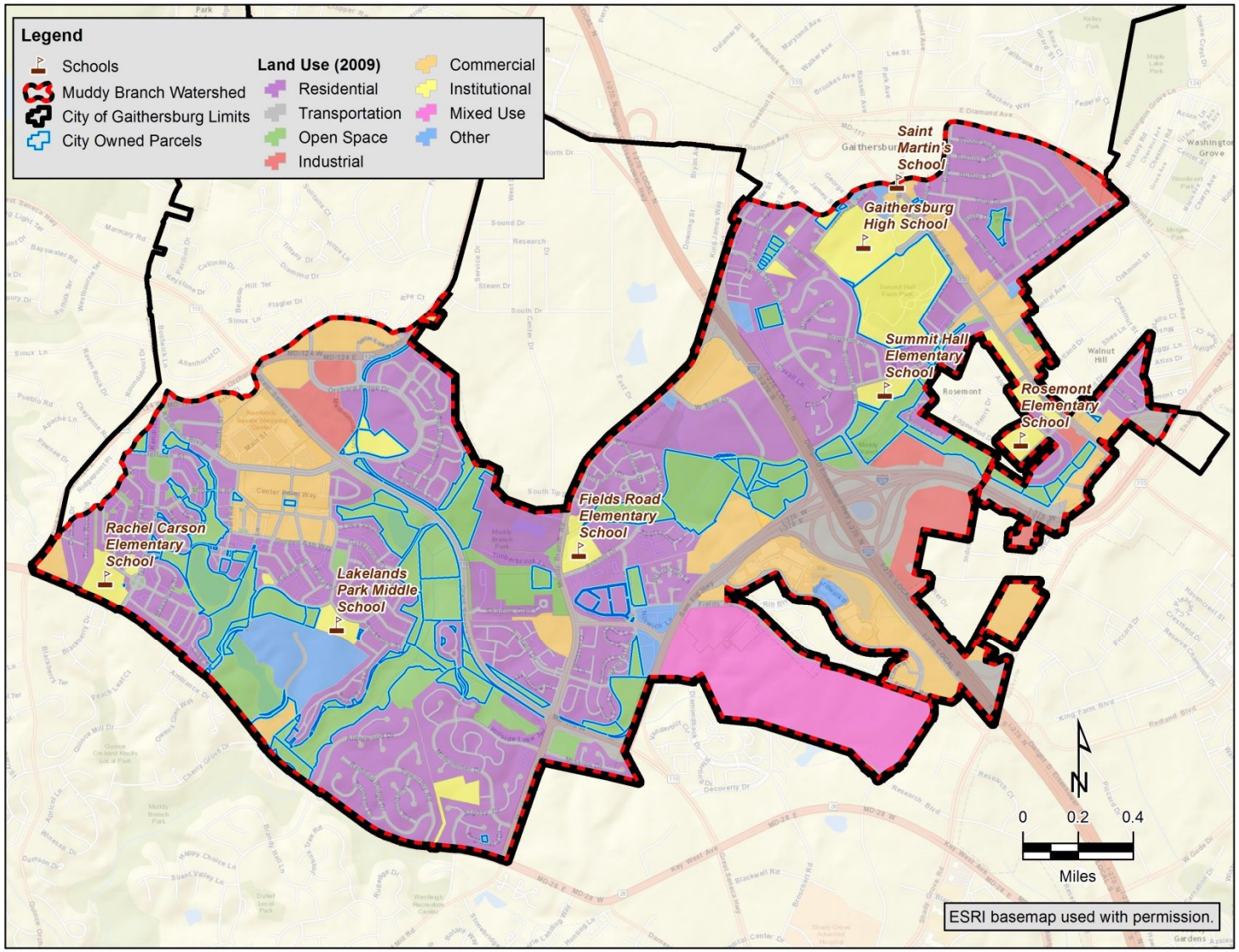


Figure 2.1: Existing Muddy Branch Watershed Land Use

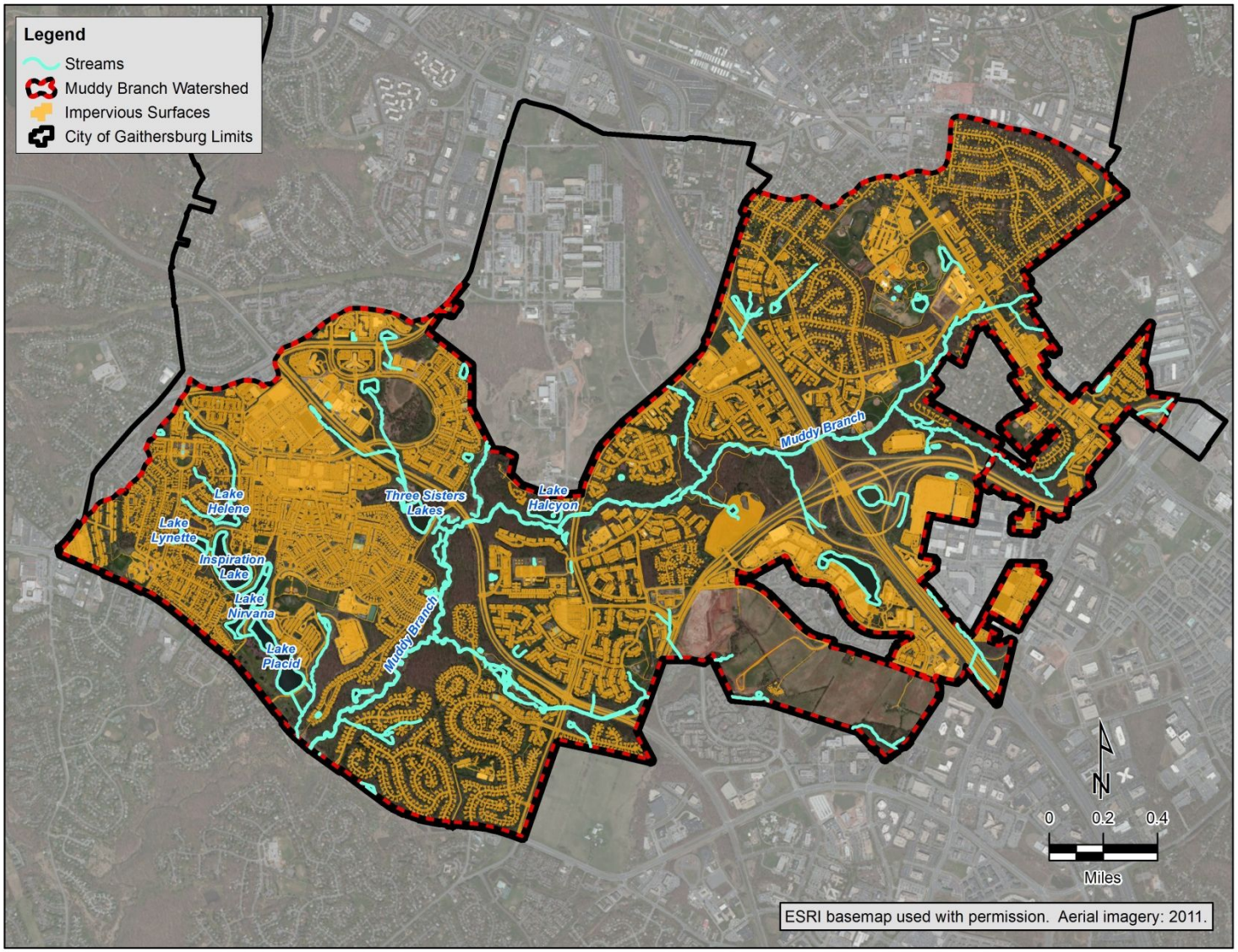


Figure 2.2: Impervious Area in the Muddy Branch Watershed

2.5 URBAN TREE CANOPY

Benefits from Urban Tree Canopy:

- Water Quality
- Air Quality
- Wildlife habitat
- Sound buffer
- Windbreaks
- Aesthetics
- Reduction of urban heat island effect

Urban tree canopy is the area of branches and leaves of trees and the ground area below this extent is generally shaded. This canopy provides multiple benefits to a watershed and can be a valuable tool in meeting upcoming permit requirements in areas where space does not allow for traditional or ESD stormwater practices. The City can obtain credit for tree planting from MDE if a survival rate of at least 100 trees per acre is met, and 50 percent of the trees are at least 2 inches in diameter and have a 4.5-foot-tall trunk.

As of 2008, the existing canopy in the City's Muddy Branch watershed covers approximately 420 acres or 13.2 percent of the watershed. The percentage is a slight underestimate as it was based on 2008 data from MNCPPC, and the City and active watershed and environmental organizations have been actively planting areas since that time.

The City has identified potential areas for reforestation to maximize the benefits of tree canopy within its jurisdiction. The City's 2013 GIS data outlining the potential reforestation areas was modified to remove overlap with the existing forested coverage. Per the 2013 GIS data, approximately 46.7 acres have been identified for potential reforestation in existing urban areas. Of the 46.7 acres, 28.8 are located in City tax parcels. Potential pollutant load reductions that the City could achieve based on the planned reforestation areas and MDE survival rate assumptions are shown in Table 2.3.

Table 2.3: Potential Water Quality Benefits for Planned Reforestation

Current Land Use	Acreage for Reforestation	TN Load Reduction (lb/yr)	TP Load Reduction (lb/yr)	TSS Load Reduction (tons/yr)	Impervious Credit (acres)
Pervious urban	46.7	292.8	20.5	1.9	17.7

TN = Total Nitrogen
TP = Total Phosphorus
TSS = Total Suspended Solids

The City and local organizations have planted trees along streams to improve stream buffers in Muddy Branch Watershed.

Most of the potential reforestation is located along Muddy Branch and its tributaries and would function as a stream buffer. Stream buffers are crucial to maintain stream health, by capturing pollutants from runoff, stabilizing stream banks, controlling erosion, and providing habitat for wildlife. Some of the areas already contain some tree cover. However, denser tree canopy would improve ecosystem health, and reforestation of bare patches would facilitate reconnection of the fragmented forest habitat. Implementation of tree planting for denser canopy, beyond the minimum MDE survival rate requirements (stated above), would not yield additional credits towards the NPDES permit.

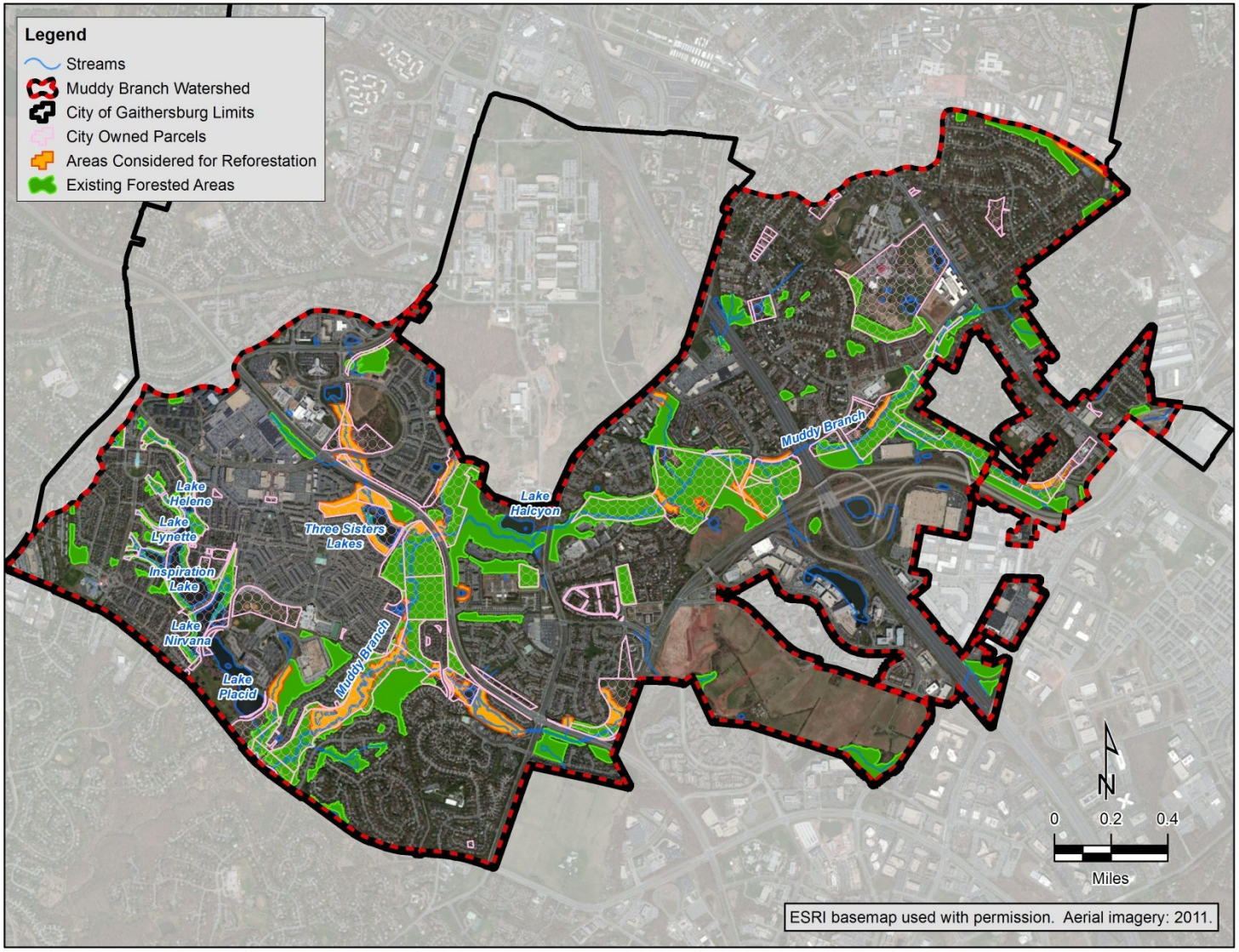


Figure 2.3: Tree Canopy in the Muddy Branch Watershed

2.6 STORMWATER HOTSPOTS

Potential hotspots were investigated through GIS analysis, research, discussions with City staff, and field investigations. Field reconnaissance was performed to determine the likelihood of whether pollutants could be discharged to surface waters from the site.

Muddy Branch watershed has four facilities with active NPDES permits for stormwater discharges in 2014. Two Medimmune facilities, Medimmune – The Meadows and Medimmune Areas 6 and 7 were covered under individual permits for stormwater discharges. The remaining two sites, Gaitherhouse Apartments and Governor Square Apartments, have minor NPDES permits. Table 2.4 lists the facilities with NPDES permits in the Muddy Branch watershed.

Table 2.4: List of NPDES Permits in the Muddy Branch Watershed

NPDES ID	Facility	Address	Permit Issued	Expiration Date
MDG766333	Gaitherhouse Apartments	501B S. Frederick Avenue	Apr-01-2013	Sep-30-2017
MDG767171	Govenor Square Apartments	409-A Muddy Branch Road	Jun-14-2013	Sep-30-2017
MD09I0293	Medimmune – The Meadows	Orchard Ridge Drive	Aug-17-2009	Aug-16-2014
MD09I0083	Medimmune Areas 6 and 7	1 Medimmune Way, Quince Orchard Park Corporate Center	Jun-08-2009	Jun-07-2014

In addition to the industrial permits above, field reconnaissance of the watershed was conducted to verify potential hotspot locations identified in the background investigation in commercial and residential areas. Salt piles were observed in the parking lot of Festival Shopping Center on Muddy Branch Road during the field reconnaissance. Though the location of the salt pile was private, the City took immediate measures to ensure the salt piles were taken off the parking lot to prevent discharge into storm drains. Locations such as gas stations were also checked in the field, but roofing and spill kits were available which limits the likelihood of a pollutant discharge.

Hotspot where an uncovered salt pile was observed in the parking lot of a shopping center.

Hotspot where trash was observed near the stormwater inlet.

The annexed Sears Property, draining to Upper Rock Creek Watershed, was not identified to contain hotspots at the time of this study's investigation.

The majority of residential areas in the watershed were well kempt, however, a hotspot in the Foxwood townhouse development along Buttry Road (shown above) was observed. Trash had been dumped in front of the curb adjacent to a stormwater inlet and evidence of sediment was observed in the parking area. Targeted outreach in this area for trash management should be done to prevent pollutants from being collected in stormwater runoff and sent into the stormwater system.

During the summer of 2014, the City discovered an illicit discharge at one of the Kentland outfalls; the pollutant was determined to be white paint. The paint was traced upland and the source was determined to be from a painting company that had recently done work in the drainage area but were not present at the time of the illicit discharge investigation.

This residential neighborhood undergoing construction covered open piles of soil to prevent stormwater from carrying it downstream and avoided becoming a hotspot.

A community meeting during the course of the study and follow-up site reconnaissance determined yard waste dumping occurring along the Muddy Branch Trail in the Lakelands. Branches, mulch, and old trees were observed to be discarded in a swale near Lindslade Street.

The hotspots observed during the field reconnaissance represent a snapshot of the watershed conditions. Factors such as recent rain events, recent trash pickup or site cleanup, and onsite activities can vary greatly from day to day. Although a specific site may not have appeared to be a hotspot during the reconnaissance, the site may have the potential to contribute pollutants.

2.7 WATER QUALITY CONDITIONS

Water quality conditions for the annexed Sears Property draining to Upper Rock Creek Watershed are outlined in:

- *Total Maximum Daily Load of Phosphorus in the Rock Creek Watershed, Montgomery County, Maryland*
- *Total Maximum Daily Load of Sediment in the Rock Creek Watershed, Montgomery County, Maryland*
- *Rock Creek Watershed Watershed Implementation Plan*

In 2012, the Montgomery County Muddy Branch and Watts Branch Subwatershed Implementation Plan identified the majority of the streams in the Muddy Branch subwatershed to be in "Fair" condition which was attributed to the increased development near the Cities of Gaithersburg and Rockville. There is a TMDL for sediment for Potomac River Montgomery County Watershed to which Muddy Branch is a tributary. Stream bank erosion in urban areas and 16 permitted active point sources which include Phase I and Phase II communities in the watershed were identified as the cause for sediment impairment.

The development anticipated in the watershed includes rezoning several areas currently designated as open space to residential and mixed-use development. Future development will further affect the stream and water quality in the watershed.

The City's Muddy Branch watershed contains headwaters that eventually flow to Potomac River. Expanding controls to prevent sediment, high runoff volumes, and inorganic pollutants should be implemented in the Muddy Branch watershed to further improve water quality downstream.

2.8 CURRENT CITY STORMWATER CONTROLS

In response to the watershed rankings from previous studies, the City has been implementing appropriate stormwater management strategies to improve water quality. Strategies including stormwater management maintenance, education and outreach, structural stormwater management retrofits, and Green Streets implementation are used in the watershed to reduce nutrient loading to stormwater. The Stormwater Management Program that the City is in the process of implementing will provide a system in which to expand these opportunities to private ownership.

Green Street amidst construction at Walder Park in the Muddy Branch watershed in Fall 2013.

The City has invested in stormwater retrofit and stream restoration projects to increase water quality within its jurisdiction. In the Muddy Branch watershed the City maintains approximately 232 stormwater management facilities, 2,507 inlets, 350 outfalls and 65 linear miles of storm drain system. The City has been proactive in identifying existing stormwater management facilities that can be retrofitted to add water quality treatment. In Muddy Branch watershed, three facilities with potential retrofit opportunities were identified by the City. A dry pond and a wet pond at Park Summit were retrofitted by the City in 2013 to add additional water quality treatment for the runoff. A wet pond on Alderwood Drive in The Woodlands neighborhood is scheduled to be retrofitted in 2014. In addition to this, approximately 30 sites have been identified in the Muddy Branch watershed for potential reforestation.

2.9 HIGH HAZARD DAMS

High hazard dams are those where a dam break or operation failure of the dam will cause detrimental human, economic and environmental effects to areas downstream of it. Based on the GIS data provided by the City during the initial phase of the study, seven high hazard dams are located in the Muddy Branch watershed. The City is responsible for maintaining six dams whereas one dam on Lake Vistas is privately owned. The City actively updates its GIS data to

reflect the ongoing watershed condition changes. A new GIS data set of stormwater management facilities was provided by the City to URS in July 2014 and according to this data, the dam on Lake Kersten maintained by the City was re-classified from no hazard dam to high hazard dam. Table 2.5 lists the lakes with high hazard dams in the watershed.

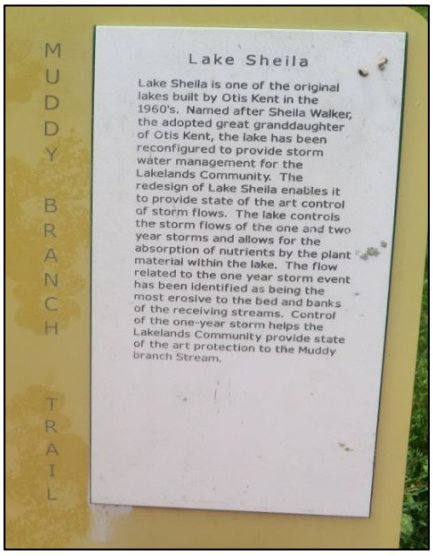
Table 2.5: High Hazard Dams in the Muddy Branch Watershed

Lake/Pond	Maintenance Responsibility
Kentlands/Inspiration Lake	City
Kentlands/ Lake Helene	City
Kentlands/Lake Lynette	City
Lakelands/ Lake Kersten*	City
Lakelands/Lake Nirvana	City
Lakelands/Lake Placid	City
Summit Hall Farm Park Front Pond	City
Vistas	Private

*In December 2013 was classified as "no hazard" and in July 2014 was updated to be "high hazard"

2.10 CURRENT OUTREACH AND EDUCATION

Outreach and education in the Muddy Branch watershed consists of the Rainscapes Rewards program, pet waste signage, clean-up events, pipe detectives, website and newsletter updates, and storm drain stenciling among others. The City's Rainscapes Rewards has encouraged activity in private stormwater management through ESD. Approximately sixteen rain barrels have been implemented in the Muddy Branch watershed. These citizens have implemented rain barrels on their property, based on the City's December 2013 GIS data. According to the data, no conservation landscaping has been implemented in the watershed. Pet waste signs are posted frequently throughout the watershed where it is common for people to walk dogs along with doggie bags and trash cans.



Outreach signs along the Muddy Branch trail show dedication to environmental outreach and education in the watershed.

Outreach signage is posted along trails near ponds and in parks in the watershed. These signs vary from discussion of stream bank erosion to the history and purpose of the wet pond that they are posted in front of.

The Muddy Branch Alliance and Izaak Walton League organizations are very active in events and activities for protecting the watershed and have been important allies to the City. Outreach is further discussed in Section 5 of this report.

2.11 FUTURE AND RE-DEVELOPMENT

Smart growth practices and green building techniques are encouraged to be adopted for future re-development and new development projects in the City. All future re-development and new development in the watershed will have to comply with the City's Master Plan Elements as well as with the MDE's requirements to include ESD to MEP. As these developments require consideration of stormwater management during the development phase, it is not cost effective for the city to implement retrofits or new facilities in these areas at this time. Considerations for stormwater management expansion are proposed.

Table 2.6: Development Plans and Associated Stormwater Management

Location	Development Type	Existing Land Use	Proposed Land Use	Area (acres)	Proposed SWM	Potential SWM for consideration
Crown Farm	New development	Open Space	Commercial and Residential	178.5	ESD practices Narrow roads Riparian buffer	Micro-bioretention Green roofs Tree box filters or ESD
Quince Orchard Park – Meadows	Re-zoning	Commercial-Industrial-Office	Mixed Use Development	22.3		Impervious surface removal Alternative pavement
Quince Orchard Park*	New development	Stream Valley, Buffer, Floodplain	Transportation	11.7	Retain stream valley buffer	Stream restoration Reforestation
Izaak Walton League of America	Re-zoning		Mixed Use Development	33.4		Bioretention or ESD Green Roof
Potomac Valley Shopping Center	Re-development	Commercial	Mixed Use Development	7.0	ESD practices	Impervious surface removal Alternative pavement Micro-bioretention
GE Technology Park	New development	Open Space and Forest	Recreational/ Mixed Use Development	7.4	ESD to MEP	Conservation of forested areas Alternative pavement parking lanes
Consumer Product Safety Commission	Re-zoning	Institutional	Mixed Use Development	9.5		Bioretention or ESD Alternative pavement
Rosedale and Casey Trust	New development	Open Space	Commercial-Office-Residential	17	ESD to MEP	Conservation of forested areas Alternative pavement Micro-bioretention

SWM = stormwater management

ESD = environmental site design

MEP = maximum extent practicable

*Maryland Transit Administration is looking at a site south of Great Seneca Highway as an alternative to this site

If significant areas of commercial rooftop are proposed for development, it may be cost-effective for the owner to use green roofs to reduce energy costs and provide ESD to the MEP during the planning phase of development. Green roof maintenance will be necessary on a regular basis, and can be performed by a qualified roofing contractor. Alternative pavement is another way for owners to provide stormwater management and road use.

SECTION THREE: STORMWATER ASSESSMENT

Stormwater management systems provide quantity and quality control to a specific drainage area. Quantity control measures collect stormwater runoff in a storage facility and release the runoff at a slower, controlled rate, reducing downstream erosion. Quality control measures usually involve filtering the stormwater runoff through sand, soil, gravel, plants, or a combination of the four. The filtering removes a percentage of harmful pollutants such as sediment, nitrogen, and phosphorus before the treated runoff is discharged into the storm drain network or a nearby stream.

Infiltration practices, such as this bioretention site at Still Creek Lane, are ESD quality control measures.

Dry ponds, like the one behind Fields Road Elementary School, are traditional quantity control measures.

The majority of the land in the City is owned privately, so incentives for private owners to add stormwater controls on their land is imperative for meeting local and regulatory goals. The City is in the process of developing and implementing a Stormwater Management Program and Stormwater Program Fee to provide sustainable support for retrofit developments in the City. The Stormwater Program Fee will likely be based on the percent of impervious area for each parcel. The Stormwater Management Program will provide credits, if stormwater controls are added, to reduce the parcel owner's Stormwater Program Fee. In such a developed watershed, it is likely that ESD practices will be more feasible drainage solutions on private lands than traditional techniques such as ponds due to the smaller footprint.

URS conducted a stormwater assessment of the Muddy Branch watershed, including:

- Evaluation of existing and potential stormwater facilities
- Hydrologic modeling to develop baseline condition models for the City
- Identification and prioritization of potential projects
- Development of conceptual designs for stormwater facilities chosen by the City

The City's ordinance requires developers to use ESD measures to the MEP before developers can consider implementing traditional stormwater management techniques such as ponds. This effort to preserve the environment and decrease impervious cover is consistent with state regulations.

The stormwater assessment was performed using the existing data and studies described in the previous sections, field work, modeling, and additional information provided by City staff.

3.1 EXISTING STORMWATER MANAGEMENT FACILITIES

The City currently owns and maintains 30 stormwater management facilities in the Muddy Branch watershed. The facilities include dry ponds, wet ponds, infiltration trenches, water quality inlets, underground quantity control, and a weir. There are 25 homeowners association-owned facilities in the watershed and 154 privately owned stormwater management facilities within the watershed (nine of these were added between December 2013 and July 2014). The City provided GIS data of the existing stormwater management facilities, as shown in Figure 3.1 and Table 3.1.

Table 3.1: Maintenance Responsibilities for Existing Stormwater Management Facilities[1]

Management Responsibility	Total Facilities	Dry Pond	Wet Pond	Infiltration Trench	Water Quality Inlet	Underground Quantity Control	Weir
City	30	4	13	2	7	3	1
HOA	25	2	8	9	5	1	0
Private	154	5	10	12	107	20	0
State	6	2	4	0	0	0	0
County	17	1	2	7	7	0	0
Total	**232**	**14**	**37**	**30**	**126**	**24**	**1**

HOA = Homeowners' Association

[1] The data in this table are based on data given to URS by the City in December 2013 and an update from July 2014. From December 2013 to July 2014 there has been one privately owned infiltration trench, 8 privately owned underground quality control devices, and one county owned wet pond added to the Muddy Branch watershed inventory.

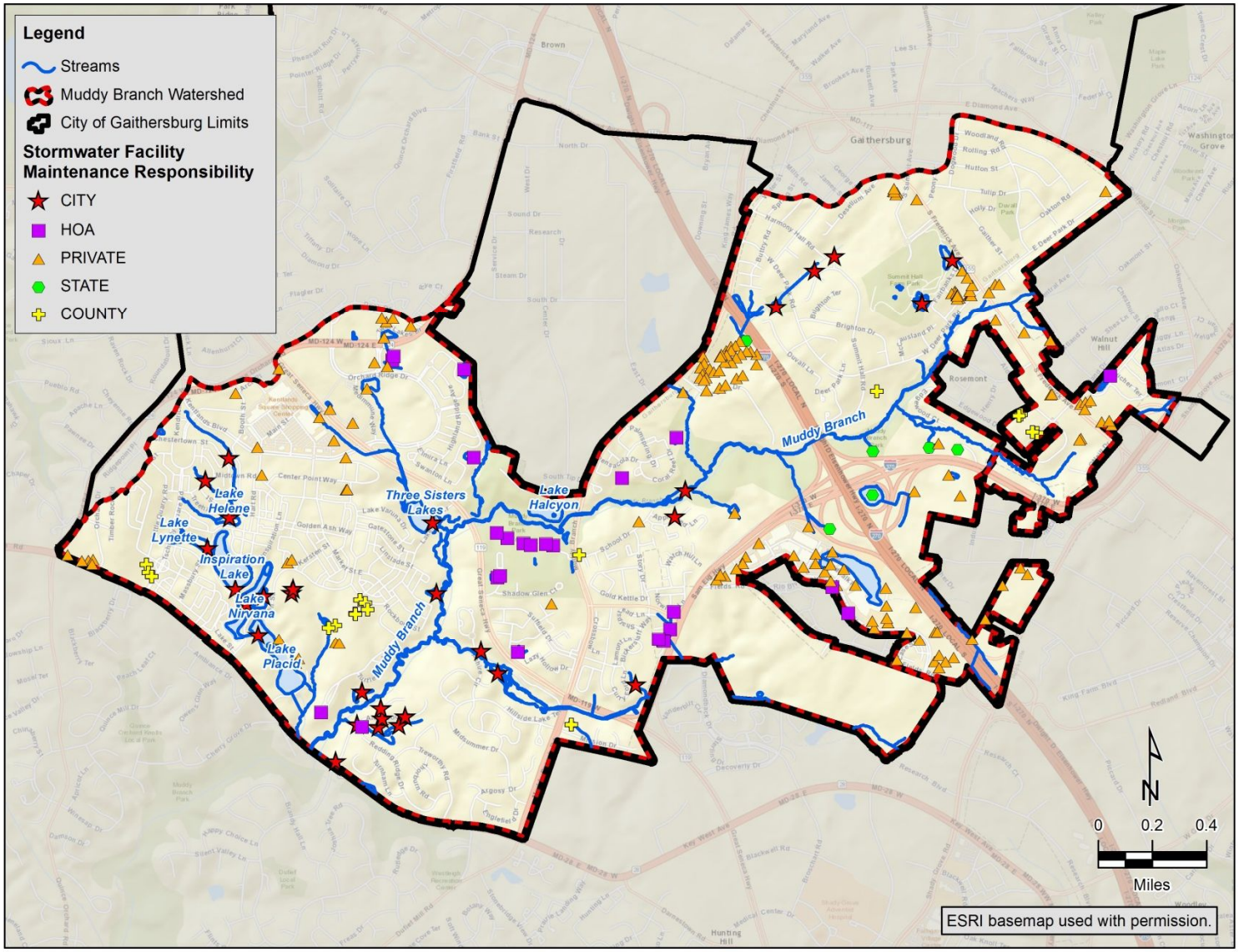


Figure 3.1: Existing Stormwater Management Facilities

Quantity control facilities (i.e., wet ponds, dry ponds, or weirs) account for approximately 2,160 acres or 89 percent of the treated drainage area. Quality control facilities (i.e. infiltration trenches, underground quantity control facilities, or water quality inlets) account for approximately 260 acres or 11 percent of the treated drainage area. Quality controls filter or separate harmful pollutants and debris from the runoff before they are discharged into the storm drain system. However, quality control facilities are designed to treat runoff from small frequent storms and typically do not control runoff from larger storms.

According to the City's list of stormwater management facilities, **runoff is captured by stormwater treatment facilities for approximately 2,420 acres (76 percent) of the Muddy Branch Watershed.**

The field work focused on identifying facilities that had the need or potential for restoration or retrofit.

Based on field visits and recommendations from the City, URS identified 29 sites in the City that were considered to have a potential for retrofit. Of those site, 12 were existing stormwater facilities and 17 were new sites. Facilities on private property (non-Homeowners' Association [HOA] property) were observed and documented, but not considered for improvements by the City at this time due to ownership.

Table 3.2 contains a list of the potential stormwater management improvement sites in Gaithersburg. A summary of the top 12 potential stormwater management improvement sites is provided below. The City selected four potential stormwater management improvements that would continue to the conceptual design phase.

Field visits considered the following elements when documenting potential retrofit feasibility:

- Ownership
- Approximate contributing drainage area
- Approximate impervious surface
- Type of facility
- Utility conflicts
- Environmental impacts
- Hydrologic soil group
- Approximate cost of retrofit

One potential site considered was the Arts Barn alley that could be converted to a green alley with an alternative pavement such as cellular grassed paving systems or other green infrastructure.

The top 12 potential sites are listed in Table 3.2. Other sites investigated include:

- Beatty Open Center 1 Dry Pond
- City Arts Barn Parking Lot
- Kent Square Road Median
- Kentlands Median at Leekes Lot Way
- Lakelands/Turtle Pond
- Main Street Pavilion
- Mansion
- Still Creek Lane Bioretention
- Still Creek Land and Turtle Pond Lane
- Summerfield Suites Hotel Dry Pond
- Summit Hall Farm Park Back Wet Pond
- Summit Hall Farm Front Wet Pond
- Walder Park Bioretention
- Washington Woods

Table 3.2: Potential Stormwater Management Facility Sites

Site Name	BMP Type	Maintenance Responsibility	Approximate Drainage Area (acres)	Impervious Area (acres)	Stormwater Management Era	Priority for the City	Investigated Further
Casey Community Center	Bioretention	City	2.3	1.8	Pre-1985	High	Yes
Green Park Dry Pond	Dry Pond Retrofit: Bioretention	City	26.4	8.8	1985-2000	High	Yes
Washington Woods Dry Pond	Dry Pond Retrofit: Bioretention	City	9.8	3.3	1985-2000	High	Yes
Washington Woods Park	Bioretention	City	2.8	1.1	1985-2000	High	Yes
Amberfield Dry Pond	Dry Pond Retrofit: Bioretention	City	60.1	31.5	1985-2000	Medium	No
Morris Park	Bioretention	City	1.1	0.8	1985-2000	Medium	No
Kentlands Mid/Upper Lake District Dry Pond	Dry Pond Retrofit: shallow wetland	City	1.7	0.3	1985-2000	Medium	No
Upshire Circle	Green Street	City	1.7	0.3	1985-2000	Medium	No
Inspiration Lane	Bioretention	City	3.9	2.0	1985-2000	Low	No
Stonemason Drive Playground	Bioswale or Bioretention	City	0.5	0.0	2000-2010	Low	No
West Deer Park Road	Green Street	City	0.1	0.1	Pre-1985	Low	No
Arts Barn	Green Alley	City	0.2	0.1	1985-2000	Low	No

BMP = Best Management Practice

3.1.1 Casey Community Center

Existing curb cut that directs the parking lot runoff directly down an approximately 3 foot drop to a drainage ditch.

Casey Community Center is located near the corner of Frederick Ave and O'Neill Drive. Runoff from the Casey Community Center building and parking lot drain to an asphalt channel and directly to a drainage ditch that flows to a tributary of Muddy Branch. The drainage area is 2.1 acres, including 1.5 impervious acres. This site was evaluated by URS for potential water quality treatment by diverting flow to a bioretention cell over the existing grass open space. The maximum recommended drainage area for a micro-bioretention is approximately 0.5 acres, while the maximum recommended drainage area for a full bioretention is 10 acres. Larger drainage areas are possible for either practice; however, removal efficiencies begin to decrease above this threshold. For this site a full bioretention is recommended. This site was selected as a high priority project by the City and a concept was developed for this site, which is provided in Appendix C.

3.1.2 Green Park Dry Pond

Existing inlet to Green Park dry pond shows evidence of sediment and trash debris

Green Park is located near the corner of Bickerstaff Way and Holdscroft Lane. The existing dry pond at Green Park was constructed in 1991 and was evaluated by URS for a potential retrofit. The dry pond is located entirely on city owned land and currently provides water quantity control for approximately 26 acres (including 8 impervious acres). There is an existing concrete wing wall at the primary inlet to the dry pond, and there is a corrugated pipe through an embankment at the outlet. There is available space at this site to provide water quality treatment by splitting the flow and diverting it to a bioretention cell, while avoiding negative impacts to newly planted trees. The soil is moderately well drained so the site is a good candidate for a filtration practice. This retrofit would provide water quality treatment in addition to the existing volume retention that is currently provided. This site was selected as a high priority project by the City and a concept was developed for this site, which is provided in Appendix C.

3.1.3 Washington Woods Dry Pond

The Washington Woods dry pond is located northeast of the intersection of Muddy Branch and Upshire Circle. The existing dry pond was constructed in 1989 and was evaluated by URS for a potential retrofit. The dry pond currently provides water quantity control for approximately 10 acres (including 3.3 impervious acres). There is available space at this site to provide water quality treatment by splitting the flow and diverting it to a bioretention cell or sand filter. This site was selected as a high priority project by the City and a concept was developed for this site, which is provided in Appendix C.

Washington Woods dry pond

3.1.4 Washington Woods Park

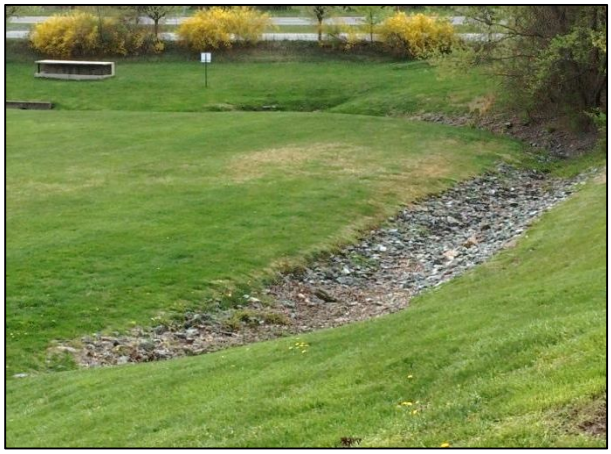
Washington Woods Park is located between Upshire Circle, Midsummer Court, and Great Seneca Highway. Runoff from a portion of the residential area at the Midsummer Court cul-de-sac concentrates in the grassy area south of the existing playground. The drainage area at this location is approximately 1 acre, including 0.3 impervious acres. This site was evaluated by URS for potential water quality treatment by constructing a bio-swale with a curb cut to intercept runoff from Great Seneca Highway. There are trees and existing storm drain pipe adjacent to the proposed site, but they would not be impacted by the proposed design. This site was selected as a high priority project by the City and a concept was developed for this site, which is provided in Appendix C.

Washington Woods Park

3.1.5 Amberfield Dry Pond

The Amberfield Dry Pond is located between Twisted Stalk Drive, Lazy Hollow Drive, and Great Seneca Highway. The existing dry pond was constructed in 1987 and was evaluated by URS for a potential retrofit. The dry pond is located entirely on land owned by the Amberfield HOA. The dry pond currently provides water quantity control for approximately 60 acres, including approximately 31 impervious acres. There are five inlets that discharge to the dry pond: four storm drain pipes, and a rip-rap channel. Runoff exits the dry pond via an outlet pipe, and a riser structure. Currently children are using the center of the dry pond as a soccer field, and there is available space at this site to provide water quality treatment by implementing

bioretention facilities on either side of the "soccer field". Benches and outreach signs could be added for community outreach to bolster both the environmental and recreation benefits at the site. The City had originally intended on installing a wet pond at this location, but the HOA leadership at the time decided that they preferred a dry pond. This retrofit would provide water quality treatment in addition to the existing volume retention that is currently provided. This site was not selected for concept design. Further improvements were not investigated at this site.

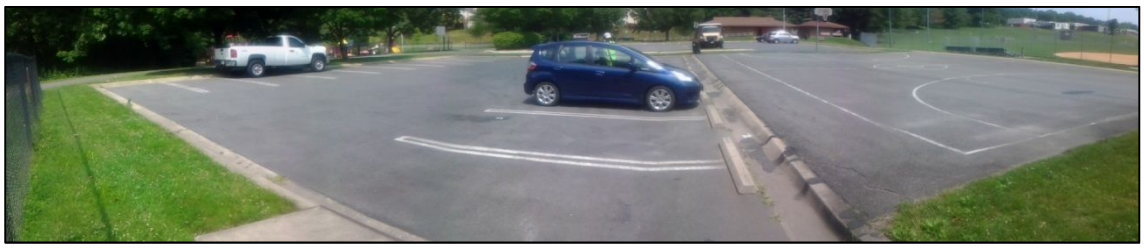


Riser structure and rip-rap channel at Amberfield Dry Pond

Amberfield Dry Pond

3.1.6 Morris Park

Morris Park is located at the southern limit of Summit Hall Road. Currently runoff from the parking lot, basketball court, and the area between the parking lot and Summit Hall Road drain to a storm drain pipe just south of the park. The storm drain pipe has a drainage area of 0.9 acres, including 0.8 impervious acres, and discharges directly to Muddy Branch. This site was evaluated by URS for potential water quality treatment by diverting flow to a bioretention cell. This could be done by removing two or three parking spaces, or by diverting flow to existing green space adjacent to the existing storm drain pipe. The maximum recommended drainage area for a micro-bioretention is approximately 0.5 acres, while the maximum recommended drainage area for a full bioretention is 10 acres. Larger drainage areas are possible for either practice; however, removal efficiencies begin to decrease above this threshold. For this site either multiple micro-bioretention cells or a single bioretention are recommended. Further improvements were not investigated at this site.



Morris Park was identified as a potential City-owned site where ESD would treat runoff from the parking lot, basketball court and part of the rooftops with good outreach potential as the site is located along a trail.

3.1.7 Kentlands Mid/Upper Lake District

Inlet storm drain pipe and outlet riser structure

The Kentlands mid/upper Lake District dry pond is located between Thursgood Street and Tschiffely Square Road. The dry pond was constructed in 1993. The dry pond is located entirely on city owned property, and currently provides water quantity control for approximately 26 acres (including 12 impervious acres). The dry pond has 2 storm drain pipe inlets, and a riser structure outlet. The existing conditions at the site could be retrofitted with micropools and shallow wetland plantings to provide nutrient uptake. The drainage area is too large for a pocket wetland design (maximum drainage area of 5 acres), but it is suitable for a shallow wetland (minimum drainage area of 25 acres), or micropool environmental design (minimum drainage area of 10 acres). This retrofit would provide water quality treatment in addition to the existing volume retention that is currently provided. Historic requirements in the Kentlands will need to be considered for design. Further improvements at this site were not investigated at this time due to private ownership on bounding properties.

3.1.8 Upshire Circle

Upshire Circle across from Washington Woods Park

A location on Upshire Circle, across from Washington Woods Park, was investigated for the potential application of a green street or bioretention measure. Approximately 1.6 acres (including 0.3 impervious acres) drain towards this area on Upshire Circle. The existing roadway is approximately 30 feet wide and was not observed to be heavily used for off-street parking. The existing curb cut could route stormwater from the roadway to a linear micro-bioretention to create a green street, parallel to the curb. Another variation could be using the curb cut and creating a bioswale in this area. Complications to these designs include existing trees, whose root spread could complicate the implementation of design, and whose leaf litter would require additional fall maintenance for the proposed stormwater system. A water pipe approximately 13 feet from the curb could also create limitations on the proposed system. Another design variation considered at this site, would be to create additional curb cuts further downslope to route stormwater from the road to a bioretention cell in the open space behind the tree line. This option would provide greater flexibility in design and would remove the existing tree and water line constrictions. An existing

storm drain pipe in the open area could be used to tie-in the underdrain to. Further improvements were not investigated at this site due to existing tree restrictions and off-street parking needs for the Washington Woods Park.

3.1.9 Inspiration Lane

Existing open space along Inspiration Lane

Potential for bioretention placement was investigated at the grassed open space near the intersection of Inspiration Lane and Selby Road, adjacent to Inspiration Lake. Approximately 3.8 acres drain towards this area and currently is captured by an existing storm drain at of this open space (including approximately 2 impervious acres). The drainage area includes a City parking lot and the roadway. Providing curb cuts and bioretention with an underdrain connecting to the existing storm drain could provide water quality treatment. Currently riprap is being installed on Inspiration Lake, so there is an existing access area that could be used for construction. Further improvements were not investigated at this site due to existing tree canopy.

3.1.10 Stonemason Drive Playground

The open area next to the playground on Stonemason Drive

The City-owned playground at Stonemason drive has some potential to be used for stormwater treatment due to its location downslope of neighborhoods and adjacent to the roadway. The potential drainage area it could treat would be approximately 0.5 acres with less than 0.1 acres of impervious area. Additionally, this area is located near the stream and a trail that currently has a stormwater outreach sign and the location could provide additional educational opportunities. There is some open area next to the playground that could be used for a bioswale or bioretention technique. However, significant effort would be required to divert water from the roadway to this location, which would raise costs and due to the limited drainage area that would benefit, further improvements were not investigated at this site.

3.1.11 West Deer Park Road

West Deer Park Road has curbed medians filled with mulch and vegetation on both sides of the road at various intervals along the length of the roadway. There is approximately 1-2 feet between the curbed median and the sidewalk where stormwater bypasses and continues downslope. The existing bump-out medians provide water quality by expanding the length and width (to the sidewalk), converting the expanded area to micro-bioretention, and using curb-cuts to capture stormwater. Complications include the existing planter tree design. If an open box planter was used then roots may make expanding the cells problematic. Water lines flow through the middle of the drivable lanes and should be considered, however, are not expected to constrict the design. Due to the complications of existing vegetation, further improvements were not investigated for this site.

Existing planters that currently allow stormwater to bypass the vegetation on West Deer Park Road could be expanded and modified to provide some stormwater treatment for runoff from the road.

3.1.12 Arts Barn

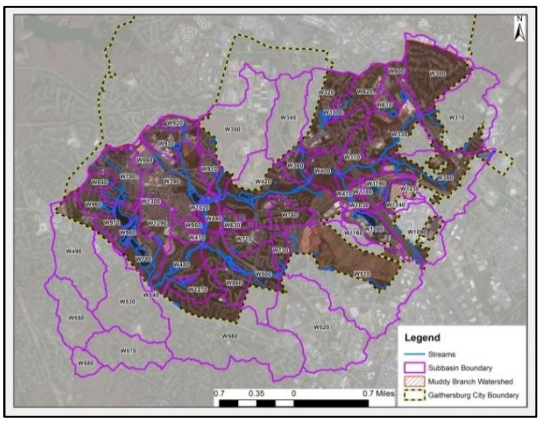
The Arts Barn is a historic feature in the City and the adjacent alley would be a location where combined goals for the City could be incorporated through the implementation of an innovative green infrastructure technique with outreach. Replacing the existing concrete alley with an alternative pavement, such as reinforced turf could provide water quality treatment and an opportunity for the arts community to interact with the system. Though it is common in the Kentlands to find utility lines in alleys, no utilities were found through GIS or field investigation to exist within the Arts Barn alley. Due to the limited drainage area that this site would treat, further improvements were not investigated for this site.

The Arts Barn alley is a good opportunity to integrate the active arts community with green infrastructure design and use a City property as an example of effective, attractive stormwater management.

3.2 HYDROLOGIC ANALYSIS

URS performed a hydrologic analysis of the Muddy Branch watershed to develop a baseline model for the City. Results of the analysis show how much water is flowing through the various streams and can be used by the City for future stormwater management and stream restoration projects.

URS developed the hydrologic model using GIS mapping and the U.S. Army Corps of Engineers HEC-HMS version 3.5 software as requested by the City. The 2009 land use data provided by the City was used in hydrologic modeling and calculations. URS developed the watershed delineation, and attribute management using the ArcGIS 10.1 based ArcHydro software and performed basin processing using Natural Resources Conservation Service HEC-GeoHMS software. ArcHydro tools are public domain utilities developed jointly by the Center for Research in Water Resources of the University of Texas at Austin and the Environmental Systems Research Institute, Inc. Appendix B of this report includes a detailed description of the hydrologic analyses.



Hydrologic modeling using Hec-HMS produces watersheds and flow rates for identified points in the watershed.

3.3 PROPOSED STORMWATER IMPROVEMENT PROJECTS

As discussed in Section 3.1, the following four sites were selected for conceptual design:

- Casey Community Center
- Green Park Dry Pond
- Washington Woods Dry Pond
- Washington Woods Park

The remaining sites were not considered for concept design at this time (see Section 3.1 for discussion). Table 3.3 summarizes the four potential stormwater improvement projects that were selected for concept designs.

Table 3.3: Potential Stormwater Improvement Projects

Site	Existing Conditions	Drainage Area (acres)	Proposed Measure	Potential NPDES Impervious Area Credits (acres)	Approximate Cost
Casey Community Center	Open space, City-owned	2.3	Bioretention	0.55	$165,178
Green Park Dry Pond	Dry Pond, City–owned	26.4	Bioretention	1.7	$279,640
Washington Woods Dry Pond	Dry Pond, City-owned	9.8	Bioretention	1.3	$200,905
Washington Woods Park	Open space, City-owned	2.8	Bioretention	1.1	$157,446

Table 3.2 shows the location of the stormwater improvement sites. Appendix C provides stormwater concept design information for these facilities.

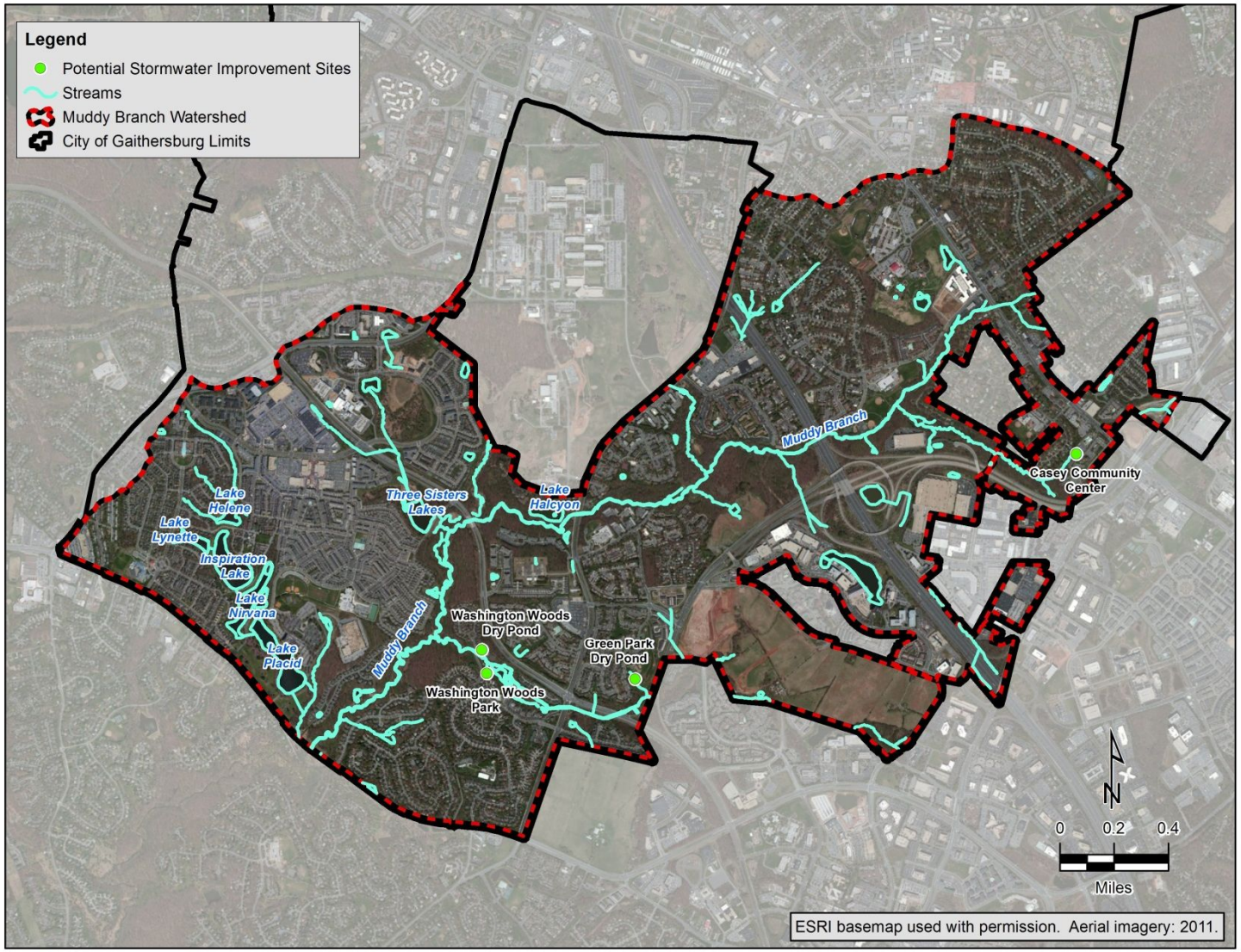


Figure 3.2: Locations of Stormwater Improvement Sites

SECTION FOUR: STREAM ASSESSMENT

Review of previous stream assessment studies was conducted to understand the history and baseline expectations of stream health in the watershed. A previous study of stream conditions within the City's Muddy Branch Watershed was performed in 2001 by Versar. Published in 2002, this was a comprehensive study that employed variety of detailed assessment methodologies. The present study in 2014 is intended provide a cost effective snap shot of how the watershed has fared since the prior study and to identify potential opportunities for stream restoration. A scope to meet these requirements was developed by URS and the City. Table 4.1 is a comparison of the 2001 Versar study assessment methods with the current study.

Table 4.1: Study Methodology Comparison to the 2001 Versar Stream Study

Study Methods and Tasks	2001 Versar Study	2014 URS Study
5 randomly selected sampling sites	✓	✓
3 targeted sampling sites	✓	✓
4 additional sampling sites	—	✓
Installed Rebar to identify Long Term Sites	✓	✓
Measured cross sections and water surface slope	✓	—
Velocity measurements	✓	—
Wolman pebble counts	✓	—
Bank pin installation	✓	—
Measured longitudinal profiles	✓	—
Summer habitat assessment (MBSS)	✓	—
Spring habitat assessment (Montgomery County)	✓	✓
Water quality field measurements	✓	✓
Macroinvertebrate sampling	✓	✓
Laboratory water chemistry analysis	—	✓
Calculation of Index of Biological Integrity	✓	—
Fish sampling	✓	—
Amphibian and reptile ID	✓	—
Bank Erosion Hazard Index	—	✓
Identification of areas for stream restoration	✓	✓
Cruising assessment of 11 mi. streams (CWP USA)	✓	✓
Outfall Assessment	—	✓
Four Stream Restoration concept plans	—	✓

MBSS = Maryland Biological Stream Survey

The 2001 and 2014 studies included all of the streams in the Muddy Branch Watershed within the City limits. The original 2001 study by Versar included 5 randomly selected sites and 3

specific sites identified by the City. The 2014 study included the eight locations assessed in 2001 and four additional targeted assessment sites selected by URS and approved by City staff. A comparison of study results is discussed in **Appendix D**.

The stream assessment portion of the watershed study was comprised of two phases; the initial phase (Maryland Biological Stream Survey [MBSS] habitat assessment, Bank Erosion Hazard Index [BEHI], and macroinvertebrate assessments) and the second phase (cruising stream assessment).

The initial phase consisted of re-establishing long-term monitoring sites where detailed evaluations were conducted in 2001, as well as establishing new sites on stream reaches not assessed during the first study. During this phase, eight original sites were relocated, marked with rebar and geo-located using GPS. Four new sites selected, marked and GPS collected. For each of these targeted monitoring sites, detailed information was collected, including physical habitat assessments, water quality parameters, macroinvertebrate abundance sampling and assessments of bank erosion hazard potential. These studies were conducted during the spring of 2014, prior to the end date of May 1st, stream macroinvertebrate sampling, followed the Maryland Biological Stream Survey protocol.

The second and more intensive study phase consisted of a rapid assessment of stream conditions (cruising stream assessment) with the goal of rating the reaches for potential restoration opportunity. Streams in the Muddy Branch watershed were separated into reaches based on natural or man-made breaks or to a maximum length of 1,800 feet, with several reaches exceeding this length). The average length for the assessed reaches was approximately 1,200 feet.

The cruising assessment used the same stream assessment form as the Versar 2001 study. This form is a composite of several different stream assessment protocols, including the Stream Corridor Assessment Survey (Yetman, 2001); the Rapid Bioassessment Protocol (Barbour et al., 1999); the Rapid Channel Assessment (Booth, 1994); and the Stream Keepers Field Guide (Murdoch and Cheo, 1999).

The cruising assessment data forms characterized reaches based on:

- Severity of impacts
- Extent of problems
- Degree to which site coincided with City's restoration goals
- Economic feasibility
- Variety of restoration opportunities available.

Additionally, evaluations of nearby stormwater outfalls were conducted during the cruising assessment using the Center for Watershed Protection, Unified Stream Assessment (USA) Outfall Assessment Form. In the Appendix D, Table D.10, color shades indicate the condition of each outfall, with red indicating the worst impairments observed, yellow indicating poor condition, green indicating moderate impairment and no shade indicating no issues were observed. Outfalls located within reaches identified as having a Selective Restoration Reach Opportunity are shown in bold.

Table 4.2 lists the targeted monitoring site locations and Appendix D provides detailed information on the assessment methodology and results. Figure 4.1 shows the targeted

monitoring site locations in the Muddy Branch watershed, and the overall assessed condition of each respective cruised stream reach.

Table 4.2: Detailed Stream Assessment Sites (Long Term Monitoring)

Stream Reach ID	Stream Name	Location
CS-1	Mainstem of Muddy Branch (M6) in Malcolm King Park below Brighton weir.	Access from Muddy Branch Road to School Road then onto Plum Grove Rd.
CS-2	Tributary to Muddy Branch, south of Frederick Avenue (MD 355) and west of I-370.	Access from Frederick Avenue to Westland Road, then onto Edgewood Road.
CS-7	Tributary to Muddy Branch downstream of Lake Placid.	Access via a trail at the end of Still Creek Lane in Lakelands.
MB-1	Mainstem of Muddy Branch (M5), east of MD-119 and Lake Varuna, west of Great Seneca Highway.	Access by School Road to Timberbrook apartments, follow hiker/biker trail from the parking lot northward.
MB-2	Mainstem of Muddy Branch (M3) in Lakelands, south of Lake Varuna.	Access by Lakelands Drive to Gentlewood Street then onto Stonemason Drive.
MB-3	(Unnamed) Tributary # 4 to Muddy Branch behind Brighton Village apartments.	Access from Muddy Branch Drive, after turning on West Side Drive, make first left turn; proceed to 9th apartment building on the right, near basketball court.
MB-5	Mainstem of Muddy Branch (M1) in Lakelands, east of Lake Placid.	Access by Still Creek Lane to Turtle Pond Lane.
MB-10	Mainstem Muddy Branch (M9) above I-270. In Morris Park.	Access from the terminus of Summit Hall Road at Gather Road, behind tennis courts.
Trib. 1.5	Unnamed Tributary south of Kentlands Boulevard and upstream of Lake Helene.	Access from southwest corner of Kentlands Boulevard and Booth Street, into unnamed commercial parking lot on Booth Street.
Trib 2.3	Unnamed Tributary upstream of Great Seneca Highway and Three Sisters Lakes.	Access from Great Seneca Highway to Orchard Ridge Drive and into the Medimmune driveway.
MB T 4.1	(Unnamed) Tributary # 6 to Muddy Branch, behind Brighton Village apartments, west of I-270.	From Muddy Branch Road, below the terminus of West Side Drive.
MB T1 B-1	(Unnamed) Tributary # 8, east of Lakelands and west of Great Seneca Highway.	From Muddy Branch Road to Midsummer Drive to Upshire Circle.

* mapped tributary number in parentheses

4.1 ASSESSMENT METHODOLOGY

4.1.1 MBSS Habitat Assessment

GPS was used to attempt to locate the 2001 study's site monuments; however no monuments were found and new rebar monuments were established at the GPS identified locations. Photographs were taken in the stream at the monument locations, as well as at areas of concern within the reach. A variety of evaluations were conducted at each long term monitoring site. Assessments included: Habitat assessment, macroinvertebrate assessment, bank erosion hazard

assessment, and physicochemical analysis. The results of each assessment were compiled and compared with the results from the 2001 study in order to provide an evaluation of stream trends.

Habitat is an important consideration to maintain a healthy ecosystem that can accommodate many species including the box turtle.

URS conducted a stream habitat assessment at each of the 12 stream assessment sites. The team completed the following field sheet (Appendix D):

- The Barbour and Stribling, Visual Based Habitat Assessment Form - Montgomery County Field Data Sheet for Riffle/Run Prevalent Streams

Using the Montgomery County data form allowed for direct comparisons to be made between the streams' current conditions and the conditions found during the 2001 study.

The Montgomery County qualitative habitat assessment method rates streams descriptively (example form is in Appendix D) based on the numerical assessment results as follows:

- Optimal: 166 to 200
- Sub-Optimal: 113 to 153
- Marginal: 60 to 100
- Poor: 0 to 47

Values falling between these category boundaries represent an intermediate condition (for example, a score of 55 would represent Marginal to Poor condition).

4.1.2 Benthic Macroinvertebrates

Biological indicators of stream health followed the protocol of the Rapid Stream Assessment Technique (RSAT). This protocol is qualitative in nature and does not require identification down to the family or genus level. Macroinvertebrate identification was performed at each riffle transect via a visual examination. Individuals were identified to their taxonomic order. Macroinvertebrate relative abundance categories used in the survey are comparable to EPA's Rapid Bioassessment Protocol level 1 and are as follows:

The RSAT protocol involves turning over 10 cobble-size stones (or larger), as well as, taking a minimum of three 1-square-foot, 30-second kick samples per riffle. The kick sampling was conducted with a 12-inch-wide D-net.

- Absent/no group found
- Scarce
- Scarce/common
- Common/abundant
- Abundant

The **RSAT** point range ratings are:

Excellent – 7-8

Good – 5-6

Fair – 3-4

Poor – 0-2

Once the abundances of the macroinvertebrate groups are established, an overall rating system is used to characterize the health of the stream. The stream rating system is based on the species in the stream and their relative abundance (according to the ranks above). Stream health is given a rating of excellent, good, fair, or poor.

View of Extreme bank erosion in Tributary 4.1. Bank erosion is rated by 5 parameters to determine the level of erosion occurring.

4.1.3 Bank Erosion Hazard Index

The BEHI is a rating system developed by Rosgen that measures the ability of stream banks to resist erosion. The BEHI methodology uses seven parameters to calculate the channel stability hazard index:

- Bank height relative to the bankfull height
- Rooting depth relative to bank height
- Density of the roots
- Bank material
- Stratification of bank material
- Angle of the bank
- Presence of protection at the toe of the bank (rock or large woody material)

BEHIs were performed on the 12 long term monitoring sites. Once these parameters are assessed the stream is assigned one of six descriptive ratings—very low, low, moderate, high, very high, or extreme.

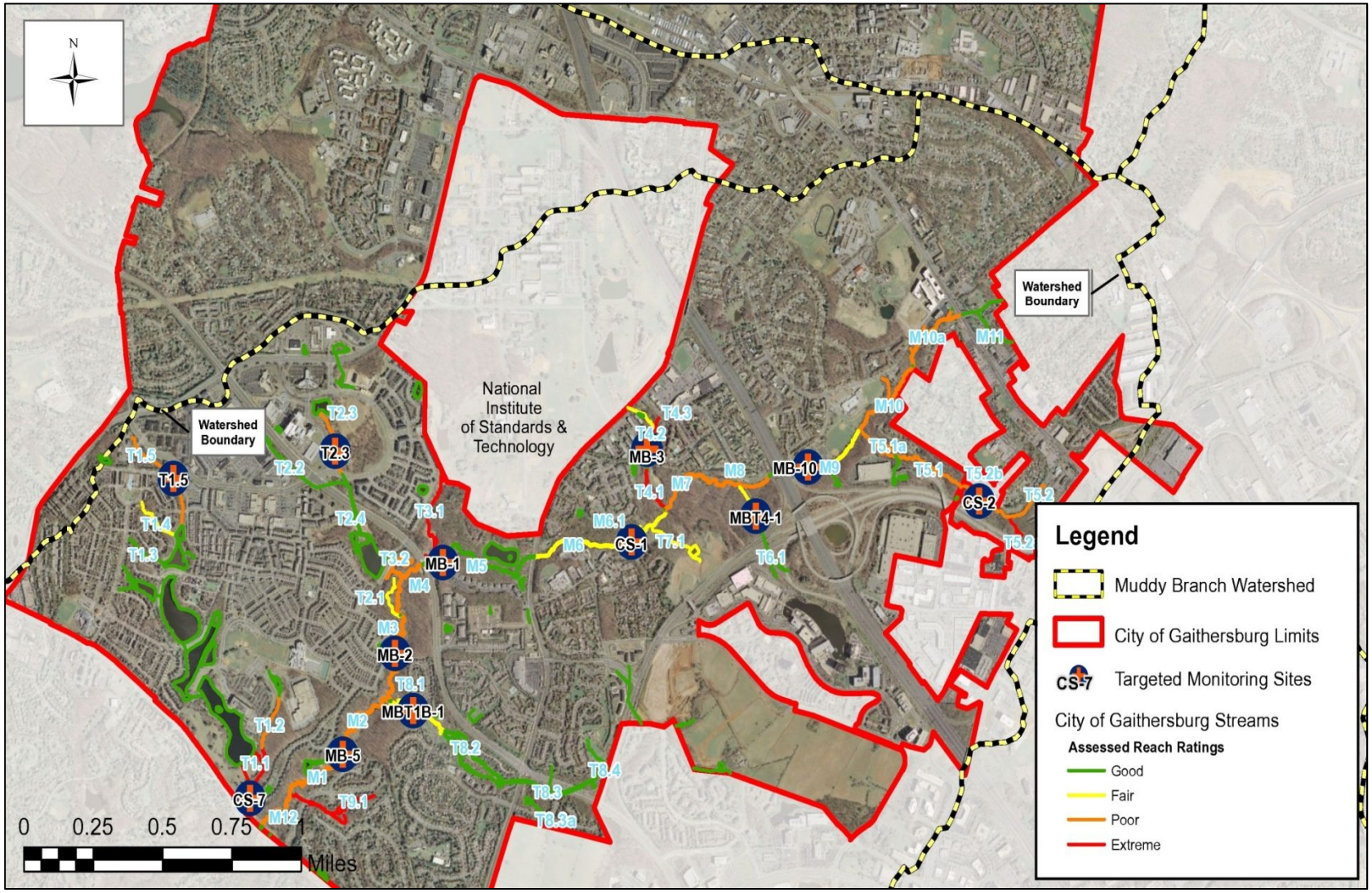


Figure 4.1: Stream Assessment Locations

4.1.4 Channel Dynamics and Erosion

As part of the watershed assessment, URS staff walked along all streams in the City's Muddy Branch Watershed to assess the extent, severity, and apparent causes of erosion. Stream erosion is part of the natural channel migration process, where streams meander, widen, and narrow to reach a stable equilibrium. The change in stream dimension, pattern and profile is the natural way a stream changes to allow flows to pass more efficiently, and applies to smaller, more frequent storms. Channel dynamics, or changes in stream channels, are described by these five terms:

Urbanization and the resulting increase in imperviousness changes stream dynamics by increasing the volume of water received by the stream in a shorter length of time. The extra force of the water adjusts the stream's flowpath, channel, and the type of material lining the streambed.

- 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 or downcutting: the streambed erodes and the channel becomes deeper or incised
- Bank erosion or stream widening: the stream banks erode and the channel becomes wider
- Head cutting: bed erosion migrates upstream at nick points, creating drop-offs or waterfalls within the channel

Combinations of these stream dynamics often occur at channel bends, confluences with other tributaries, and near a debris blockage. Manmade features, such as culverts, bridges, storm drain outfalls, and previous stream stabilization projects can increase the frequency of stream dynamics. A channel may be stable in one segment, but actively eroding a short distance upstream or downstream. Since channels changes over time, monitoring active erosion sites every few years will show the rate of erosion progression and can identify sudden failures caused by large storm events, debris jams, or other unusual circumstances.

View of Muddy Branch location showing widening, bank erosion, and deposits of sediment

Stream bank erosion removes streamside vegetation and can topple trees along the banks. Streams may be blocked by fallen trees or loose branches and can collect catch trash, leaves, and other debris. These stream blockages can cause vertical and lateral instability in the stream and cut new flowpaths. At channel bends, the banks often erode along the outside and have sediment point bars along the inner side. The sheer stress along tight bends encourages the channel to migrate laterally at those points. Storm drain outfalls randomly located along the length of the stream channels contribute to stress along the adjacent streambanks.

4.1.5 Cruising Assessment

Using the City provided GIS, the Muddy Brach streams were broken into reaches. Reach breaks were selected based on natural features such as, confluence with another tributary or the mainstem, changes in valley characteristics (steep narrow valley to wide flat valley), and significant changes in sinuosity. Manmade features like road crossings also provided practical locations for reach breaks. Some reach break locations were modified in the field based on site conditions. The 11 miles of stream in the Muddy Branch watershed were divided into 42 reach segments. The reaches were walked and assessed for the criteria included on the field form. This study did not include any streams located on National Institute of Standards and Technology (NIST) and Standards property, which is outside the City limits.

The assessment scores were summed and each reach assigned a rating. Based on the rating score, reaches were categorized as Good, Fair, Poor, or Extreme. This rating score describes the relative condition of the site. A site categorized as "Good" isn't necessarily in good condition, but relative to other sites in the watershed it is in good condition and not a candidate for reach restoration.

4.2 EXISTING CONDITIONS

This section describes results at the 12 long-term monitoring sites. The Visual Based Habitat Assessment results show habitat is in Sub-optimal to Marginal condition. The RSAT evaluation of macroinvertebrates evaluation for biological health showed biological scores ranged from Fair to Poor.

As shown in Table 4.3, during the 2001 evaluation, habitat scores ranged from 82 to 138, from marginal to sub-optimal. In 2001, the site with the best habitat score (141, sub-optimal) was MB-1, located on the mainstem of Muddy Branch, east of MD-119 and Lake Varuna, and west of Great Seneca Highway. During the 2014 evaluation, habitat results were again marginal to sub-optimal. The site with the best habitat score (134, sub-optimal) was MB-10, located in Morris Park on the main stem of Muddy Branch upstream of I-270 (see Appendix D for comparison of the 2001 and 2014 study results).

Table 4.3: Comparison of Physical Habitat Scores in 2001 and 2014

Year	CS-1	CS-2	CS-7	MB-1	MB-2	MB-3	MB-5	MB-10
2001 score	109	105	138*	141[1]	111	105	118	82
2001 rating	Sub-optimal	Sub-optimal	N/A	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Marginal
2014 score	105	105	112	116	143	104	123	134[2]
2014 rating	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal	Sub-optimal

*Site CS-7 was not shown in Table 2-9 of the 2001 Report, which shows scores and totals, therefore an estimated value from Figure 2-4 was used. [1] and [2] indicate the best rated stream of the sites evaluated in 2001 and 2014 respectively.

Table 4.4 shows the scores for the stream reaches selected in 2014. The site with the best habitat score (167, Optimal) was Reach T.4.1 on an unnamed tributary to Muddy Branch, located behind Brighton Village apartments and west of I-270.

Table 4.4: Physical Habitat Scores for New Targeted Sites (2014 only)

Year	MB T1-B1	T 1.5	T 2.3	T 4.1
2014 score	157	109	103	167
2014 rating	Sub-optimal	Sub-optimal	Sub-optimal	Optimal

As shown in Table 4.5, six of the Muddy Branch streams scored a Fair rating and six scored a poor rating; with two of those sites having no macroinvertebrates present. Different sampling methods were used in 2001 and 2014. The 2001 study used the Index of Biological Integrity, a more detailed protocol. The results of the 2014 RSAT Macroinvertebrate sampling are shown below:

Table 4.5: RSAT Macroinvertebrate Sampling Results

Location	RSAT Score	Stream Health Rating
CS-1	3	Fair
CS-2	1	Poor
CS-7	4	Fair
MB-1	2	Poor
MB-2	2	Poor
MB-3	0	Poor
MB-5	3	Fair

Location	RSAT Score	Stream Health Rating
MB-10	0	Poor
MB T1 B-1	4	Fair
T1.5	1	Poor
T2.3	3	Fair
MB T4-1	4	Fair

Field observations during the 2014 monitoring showed that species intolerant to poor water quality such as Ephemeroptera and Plecoptera taxa, were absent from all sites. Trichoptera, family Hydropsychidae was found at CS-7 along with moderately sensitive Diptera, consisting of families Tipulidae and Simuliidae.

BEHI scores indicated most stream banks evaluated had a Moderate to Extreme potential. Table 4.6 shows the physical health and erosion potential for the long-term monitoring sites. BEHI results are discussed in more detail in Appendix D.

Table 4.6: Physical Habitat and Erosion Potential for Long Term Monitoring Sites

Stream Reach ID	Visual Based Habitat Score & Rating	BEHI Erosion Potential Results
CS -1	105 / Sub-Optimal/ Marginal	39.7/ High
CS - 2	105 / Sub-Optimal/ Marginal	42.0/ Very High
CS -7	112 / Sub-Optimal/ Marginal	31.9/ High
MB-1	116 / Sub-Optimal	35.9/ High
MB-2	143 / Sub-Optimal	29.5/ Moderate
MB-3	104 / Sub-Optimal/ Marginal	46.2/ Extreme
MB-5	123 / Sub-Optimal	40.0/ Very High
MB-10	134 / Sub-Optimal	34.1/ High
T 1.5	109 / Sub-Optimal/ Marginal	37.7/ High
T 2.3	103 / Sub-Optimal/ Marginal	41.0/ Very High
T 4.1	167 / Optimal	50.5/ Extreme
MB T1 B-1	157 / Sub-Optimal	29.8/ Moderate

The field assessment results for both the 2001 study and the 2014 study represent snapshots in time of the stream conditions. Factors such as the sampling time, weather, and sampling location can affect the findings. More importantly, the study parameters are themselves subject to variability from either upstream contributions or localized conditions. A recent chemical spill or illicit discharge, a fallen tree across the stream, or a large intense rainstorm in the months before sampling can skew the results at a given location.

Stream Orders

Stream orders classify the size of a stream from 1-12.

1st order: Smallest stream; these are the most upstream tributaries or headwaters.

2nd order: two or more 1st order streams join to form this type of stream.

3rd order: two or more 2nd order streams join to form this type. This order would classify a stream that has less of a slope and slower flows than the 1st and 2nd orders

It is important to consider these stream reach assessments in the larger context of the City's streams or by the whole watershed. Upstream land use and streamside infrastructure conditions, the history and extent of existing erosion problems, the speed at which these problems progress and opportunities to improve the stream must be taken into account. The City may take action through stream restoration projects, but also through upstream stormwater management retrofitting, storm drain improvements, and enforcement against illicit discharges, water quality violations, or sediment control failures.

4.2.1 Long-Term Monitoring Sites

The following describes the results of the Visual Based Habitat Assessment for each of the 12 long-term monitoring sites. The descriptions include a locational inset map, a representative photo the physical and biological results from Tables 4.3 through Table 4.5.

Overall assessments for the reaches are indicated by color on the thumbnail maps:

- Green – Good
- Yellow – Fair
- Orange – Poor

CS-1

Health Scoring

Physical: Sub-optimal/ Marginal
Biological: Fair
Erosion: High

Ownership

City of Gaithersburg

CS-1 located in a third order stream (Tributary M6) in the central portion of the City, that begins east of I-270 and is also downstream of the National Institute of Standards and Technology (NIST). The stream lies within a forested area in Malcom King Park. The cruising assessment scored this reach as Fair (indicated by yellow in the above map) and the habitat assessment

scored the targeted monitoring site as sub-optimal/ marginal (score 105). The targeted monitoring site received low scores for vegetative bank protection, bank stability, low stream channel flow and embeddedness (streambed materials covered by sediment). The macroinvertebrates sample results indicated fair water quality and habitat.

CS-2

Health Scoring

Physical: Sub-optimal/ Marginal Biological: Poor Erosion: Very High

Ownership

City of Gaithersburg

CS-2 is a second order stream (T 5.2) to Muddy Branch, located south of Frederick Avenue (MD 355) and west of I-370. The stream lies on City property within narrow parcels located between I-370 and a residential subdivision. The cruising assessment scored this reach as Poor (indicated by orange in the above map) and the habitat assessment scored the targeted monitoring site as sub-optimal/marginal (score 105). The channel is less altered and has some in-stream fish cover, but exhibited poor bank stability on both banks. The channel also exhibited marginal scores for vegetative bank protection, sediment deposition and a low frequency of riffles. The macroinvertebrates sample results indicated poor water quality and habitat.

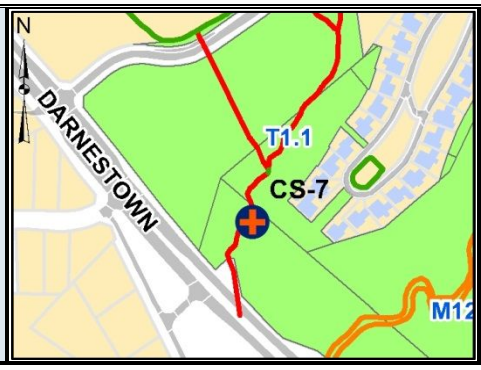
CS-7

Health Scoring

Physical: Sub-optimal/Marginal Biological: Fair Erosion: High

Ownership

City of Gaithersburg



CS-7 is a second order stream (T1.1) located between the Montgomery County Police Department and Still Creek Lanes in Lakelands. Much of the drainage to this reach is routed through stormwater management and storm drains. There is widespread severe bank erosion throughout the reach, but especially in the area upstream of the targeted monitoring site. Much of

the eroded sediment has accumulated in the flatter lower extent of the reach. Grade is being controlled by a debris dam at the bottom of the reach just above Darnestown Road. The cruising assessment scored this reach as Extreme (indicated by red in the above map) and the habitat assessment scored the targeted monitoring site as sub-optimal/marginal (score 112). The monitoring site had marginal scores for instream fish cover, epifaunal substrate, embeddedness, sediment deposition, low frequency of riffles, and low flow in the channel, vegetative bank protection, and bank stability. The macroinvertebrates sample results indicated fair water quality and habitat.

MB-1

Health Scoring

Physical: Sub-optimal
Biological: Poor
Erosion: High

Ownership

City of Gaithersburg

MB-1 is located on the Mainstem of Muddy Branch (M5), east of the MD-119 (Great Seneca Highway) bridge over Muddy Branch. The cruising assessment scored this reach as Good (indicated by green in the map above) and the habitat assessment scored the targeted monitoring site as sub-optimal (score 116). The habitat assessment shows marginal scores in bank vegetation protection, bank stability, sediment deposition, and embeddedness. The site received better scores in channel alteration (the lack of), more prevalent riffles, and presence of a riparian vegetation zone. The macroinvertebrates sample results indicated poor water quality and habitat.

MB-2

Health Scoring

Physical: Sub-optimal
Biological: Poor
Erosion: Moderate

Ownership

HOA
Private

MB-2 is located on the Mainstem of Muddy Branch (M3) in Lakelands, south of Lake Varuna. The cruising assessment scored this reach as Poor (indicated by orange in the map above) and the habitat assessment scored the targeted monitoring site as sub-optimal (score 143). The cruising assessment noted reach M3 exhibits widespread bank erosion, sediment deposition, failing trees, debris jams, avulsions, and several floodplain wetland headcuts.

The habitat assessment shows better scores in channel flow, frequency of riffles, and less embeddedness. It shows marginal scores in bank vegetation protection, bank stability, and a reduced riparian vegetation zone along the right bank. The macroinvertebrates sample results indicated fair water quality and habitat.

MB-3

Health Scoring

Physical: Sub-optimal/ Marginal
Biological: Poor
Erosion: Extreme

Ownership

Seventy S Association

MB-3 is located on a second order stream (unnamed tributary 4) to Muddy Branch behind Brighton Village apartments. The cruising assessment scored this reach as Fair (indicated by yellow in the map above) and the habitat assessment scored the targeted monitoring site as sub-optimal/marginal (score 104). The habitat assessment indicated marginal scores in bank vegetation protection, bank stability, channel flow, embeddedness, and sediment deposition. The macroinvertebrates sample results indicated poor water quality and habitat.

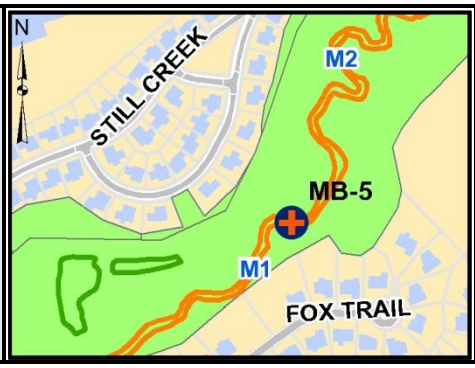
MB-5

Health Scoring

Physical: Sub-optimal
Biological: Fair
Erosion: Very High

Ownership

City of Gaithersburg



MB-5 is located on the Mainstem of Muddy Branch between M2 and M1, located upstream and downstream, respectively. The site is located in the Lakelands, east of Lake Placid. The cruising assessment scored this reach as Poor (indicated by orange in the map above) and the habitat assessment scored the targeted monitoring site as sub-optimal (score 123). The habitat assessment showed marginal scores in bank vegetation protection, bank stability, sediment deposition, embeddedness, and epifaunal substrate. The macroinvertebrates sample results indicated fair water quality and habitat.

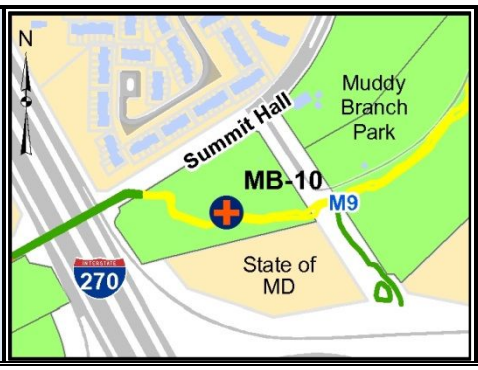
MB-10

Health Scoring

Physical: Sub-optimal
Biological: Poor
Erosion: High

Ownership

City of Gaithersburg



MB-10 is located in Muddy Branch Park on the Mainstem Muddy Branch (M9) upstream from I-270. The cruising assessment scored this reach as Fair (indicated by yellow in the map above) and the habitat assessment scored the targeted monitoring site as sub-optimal (score 134). The habitat assessment showed suboptimal scores in instream fish cover, channel flow, channel alteration, bank vegetation protection, bank stability, and sediment deposition. The macroinvertebrates sample results indicated poor water quality and habitat.

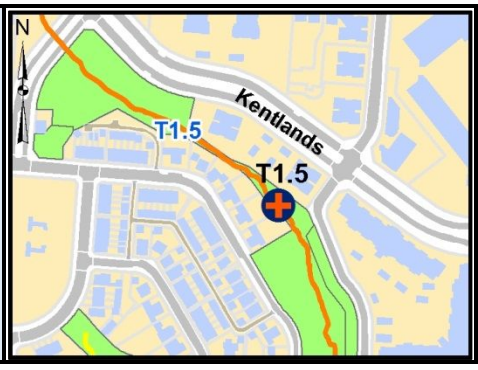
T 1.5

Health Scoring

Physical: Sub-optimal/Marginal
Biological: Poor
Erosion: High

Ownership

City of Gaithersburg



T 1.5 is located in a first order unnamed tributary south of Kentlands Boulevard and upstream of Lake Helene. The cruising assessment scored this reach as Poor (indicated by orange in the map above) and the habitat assessment scored the targeted monitoring site as sub-optimal/marginal

(score 109). The habitat assessment shows marginal scores in channel flow, riparian vegetation zone width, frequency of riffles, and epifaunal substrate, factors related to fish populations. The macroinvertebrates sample results indicated poor water quality and habitat. Other habitat assessment scores were sub-optimal, including bank vegetation protection, bank stability, sediment deposition, and embeddedness.

T 2.3

Health Scoring

Physical: Sub-optimal/ Marginal
Biological: Fair
Erosion: Very High

Ownership

State
Private
Montgomery County

T 2.3 is located in a first order unnamed tributary upstream of Great Seneca Highway and Three Sisters Lakes. The cruising assessment scored for this small segment of stream is Poor (indicated by orange in the map above) and the habitat assessment scored the targeted monitoring site as sub-optimal/marginal (score 103). The tributary begins from a stormwater management pond and flows through low quality woodlands. The habitat assessment shows sub-optimal to marginal bank vegetation protection and marginal scores for bank stability, sediment deposition and epifaunal substrate, and frequency of riffles. The macroinvertebrates sample results indicated poor water quality and habitat.

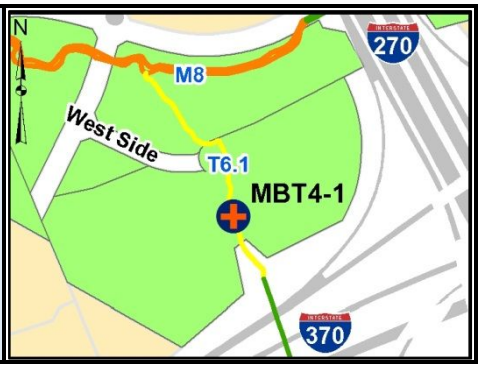
T 4.1

Health Scoring

Physical: Optimal
Biological: Fair
Erosion: Extreme

Ownership

State
Private
Montgomery County



T 4.1 located in a second order stream, unnamed tributary (T 6.1) to Muddy Branch, behind Brighton Village apartments, west of I-270. The cruising assessment scored this reach as Fair

(indicated by yellow in the map above) and the habitat assessment scored the targeted monitoring site as optimal (score 167). This reach had the best habitat assessment scores of all targeted monitoring sites. Channel flow, channel alteration, frequency of riffles, sediment deposition, and epifaunal substrate were optimal. All other factors were rated sub-optimal. The macroinvertebrates sample results indicated fair water quality and habitat.

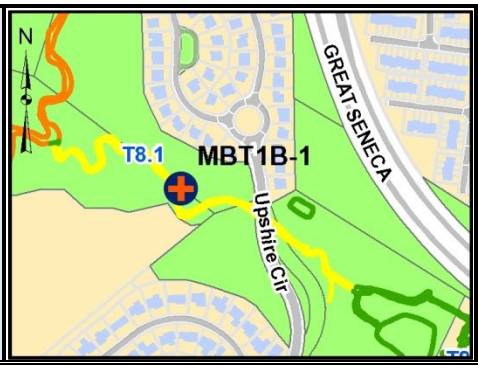
MB T1 B-1

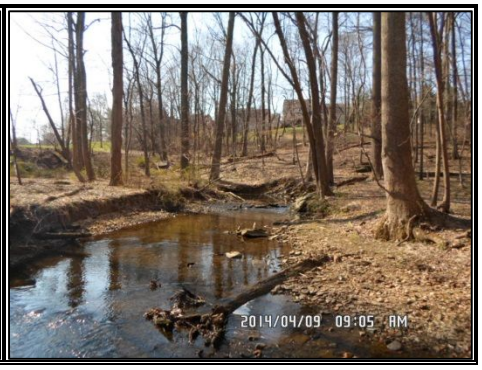
Health Scoring

Physical: Sub-optimal
Biological: Fair
Erosion: Moderate

Ownership

State
Private
Montgomery County





MB T1 B-1 is located on the Decoverly Tributary to Muddy Branch (T 8.1), east of Lakelands and west of Great Seneca Highway. The cruising assessment scored this reach as Fair (indicated by yellow in the map above) and the habitat assessment scored the targeted monitoring site as sub-optimal (score 157). This site had optimal scores in channel flow, frequency of riffles, channel alteration, epifaunal substrate, sediment deposition, and embeddedness. All other factors, such as instream fish cover, bank vegetation protection, bank stability, and riparian vegetation zone were scored sub-optimal. The macroinvertebrates sample results indicated fair water quality and habitat.

4.3 CONCLUSION

A previous study of stream conditions within the City's Muddy Branch Watershed was performed in 2001 by Versar. Published in 2002, this was a comprehensive study that employed variety of detailed assessment methodologies. The present study in 2014 is intended provide a cost effective snap shot of how the watershed has fared since the prior study

During the 2001 evaluation, habitat scores ranged from 82 to 138, from marginal to sub-optimal. The site with the best habitat score (141, sub-optimal) was MB-1, located on the mainstem of Muddy Branch, east of MD-119 and Lake Varuna, and west of Great Seneca Highway. The worst site (82, marginal) was MB-10, located in Morris Park on the main stem of Muddy Branch upstream of I-270.

During the 2014 evaluation, habitat results were again marginal to sub-optimal. The site with the best habitat score (134, sub-optimal) was MB-10, located in Morris Park on the main stem of Muddy Branch upstream of I-270. The sites with the worst scores were MB-3, CS-1 and CS-2

(104, 105 and 105, respectively, sub-optimal). MB-3 and CS-1 are located in the central portion of the watershed, while CS-2 is located south of Frederick Avenue (MD 355) and west of I-370. These sites had similar scores and the same qualitative value of sub-optimal during the 2001 study. While the macroinvertebrates methodologies were different between the 2001 and 2014 studies, the sites scored similarly. In the 2001 study, pollution intolerant species were absent from all sites but MB-10, which contained one taxa (Table 2-19, Versar, 2002). For the 2014 study, RSAT (a rapid evaluation) was used, and intolerant taxa were absent from all sites.

Reach T4.1 on Tributary 4 was rated as Extreme due to streambank erosion and bar formation.

The stream walks revealed that all of the streams are degraded to varying degrees. Observed impairments to stream health included channel incision and over-widening, streambank erosion, excessive sediment deposition in the channel, excessive bar formation, erosion at storm drain outfalls, and lack of riparian vegetation. BEHI scores indicated most stream banks evaluated had a Moderate to Extreme potential.

4.4 PROPOSED STREAM RESTORATION PROJECTS

Using the Reach Assessment Ratings Matrix, stream reaches were categorized as Good, Fair, Poor, or Extreme (see Appendix D). This rating score describes the relative condition of the site. A site categorized as “Good” isn’t necessarily in good condition, but relative to other sites in the watershed it is in good condition and not a candidate for reach restoration.

Using the rating system, seven reaches where identified as Extreme. These reaches were presented to the City for further evaluation and consideration for concept level restoration design development.

Targeted selective restoration options were identified. Some of these are located within the reaches identified as Extreme, but they provide the City with the option of a scaled down restoration project as opposed to a full watershed restoration. Some targeted sites are located in reaches that were not identified as restoration reaches. While overall these reaches were not deemed candidates for full scale restoration, these targeted restorations could provide the City with opportunities to undertake smaller less expensive projects that would provide significant environmental benefits. These eleven potential “Selective Restoration” projects were also presented to the City as small projects of limited scope that could be developed in the future. Table 4.6 shows the reaches identified as Extreme Reaches, Candidates for Restoration and Selective Restoration Sites.

Table 4.7: Reach Assessments Summary

Extreme Reaches: Candidates for Restoration		
Stream Reach ID	**Stream Name & Location**	**Assessment**
Reach T4.3	Tributary 4, Westside Drive/Brighton Village	83 Extreme
Reach T1.1	Tributary 1, Edison Park Drive	83 Extreme
T 3.1	Tributary 3, Below NIST Quince Orchard Park	81 Extreme
T 5.2a	Tributary 5, I-370	78 Extreme
T 4.1	Tributary 4, Brighton Village	76 Extreme
T 9.1	Tributary 9, The Woods	76 Extreme
M2	Muddy Branch, Future City Park	74 Extreme
Selective Restoration Sites		
Stream Reach ID	**Stream Name & Location**	**Assessment**
T5.2	Tributary 5, Casey Comm Center	reach score 61 Poor
M9	Muddy Branch, Morris Park/Summit Hall ES	reach score 55 Fair
MS10	Muddy Branch, Morris Park/Summit Hall ES	reach score 66 Poor
M7	Muddy Branch, Malcom King Park	reach score 76 Extreme
T7.1	Tributary 7, Malcom King Park	reach score 56 Fair
M6	Muddy Branch, Malcom King Park – Inline Weir	reach score 57 Fair
T3.1	Muddy Branch, Izaak Walton-Great Seneca Hwy	reach score 49 Good
T3.2	Tributary 3, Lakelands	reach score 71 Extreme
T3.1	Tributary 3, Below NIST Quince Orchard Park	reach score 81 Extreme
T8.1	Tributary 8, Washingtonian Woods Park	reach score 56 Fair
T1.5	Tributary 1, Kentland Manor apt.	reach score 70 Poor

Of the seven extreme condition reaches presented to the City, four projects (Table 4.7) were selected for concept level restoration design. These four proposed projects are shown in Figure 4.2 and described in detail in Appendix E.

Table 4.8: Overview of Proposed Stream Restoration Projects

Stream Reach	Existing Conditions	Reach Length (linear feet)	Proposed Measures	Potential NPDES Impervious Area Credits (acres)	Approximate Cost
M2 Future City Park	Widespread bank erosion & sediment deposition, debris jams, poor aquatic habitat	1,720	Rock Toe protection & grade control, a deflector and root wads	17.2	$1,031,000
T 3.1 Quince Orchard Park	Lateral channel migration, active lateral headcuts, poor aquatic habitat	1,540	Rock Toe protection & grade control	15.4	$1,001,813
T 4.1 Brighton Village	Unstable banks, widespread bank erosion adjacent to properties, falling trees	970	Rock Toe protection & grade control	9.7	$701,844
T 5.2a I-370 Outfall	Poor aquatic habitat unstable banks and streambed	460	Rock Toe protection & grade control	4.6	$860,000

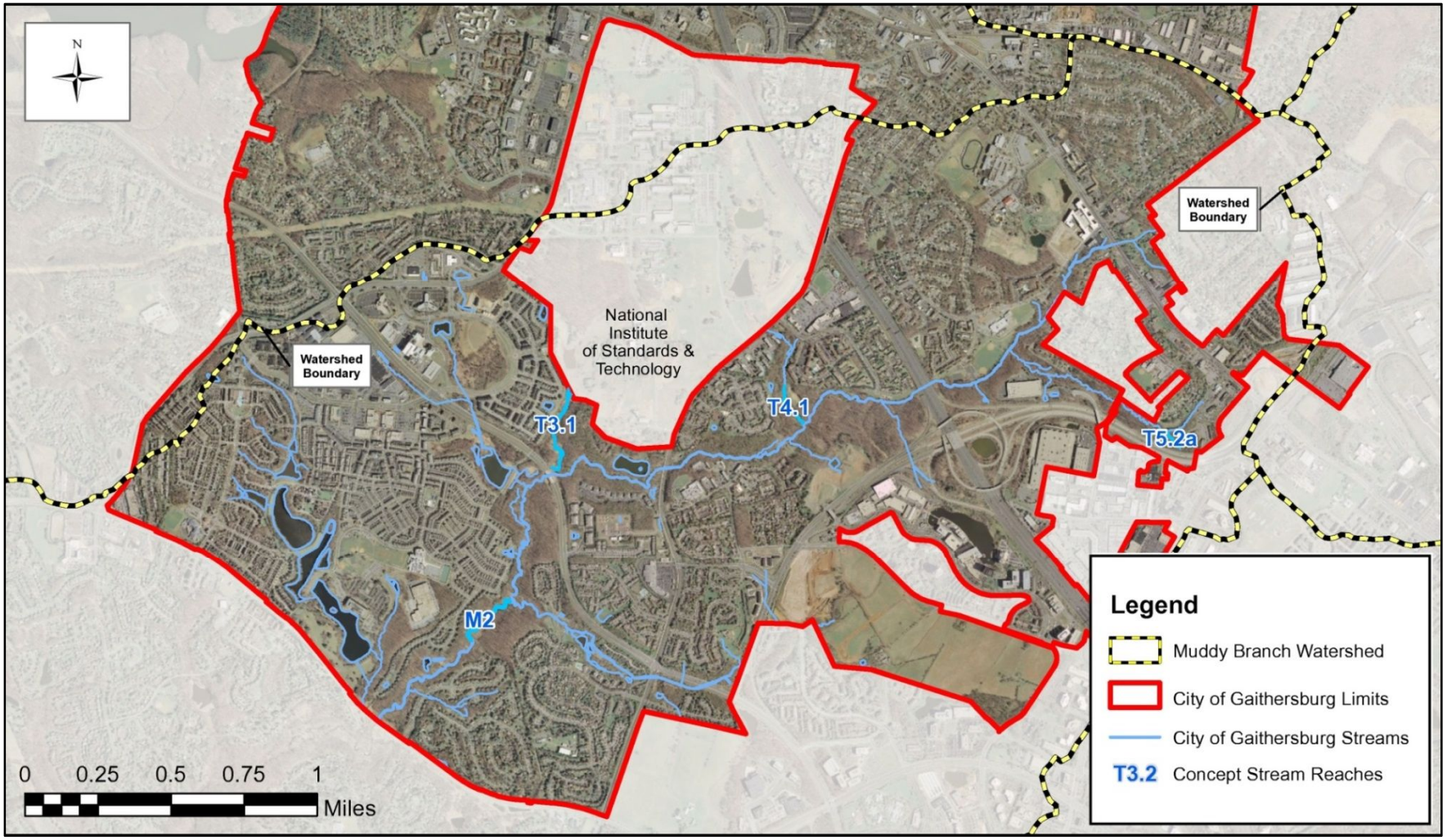


Figure 4.2: Stream Restoration Concept Locations

SECTION FIVE: OTHER EXISTING STORMWATER MANAGEMENT STRATEGIES

Alternative stormwater strategies were considered to help improve stormwater management in the watershed based on information provided by the City, the community, research, and field observations. Strategies such as education and outreach, watershed stewardship, and environmental site design can join the community together to improve water quality in ponds, lakes, and streams. The City has incorporated many methods into its current stormwater management; however, enhancement of these strategies will help the City meet NPDES Phase II MS4 requirements. Investment in the organization and set-up of these strategies will be necessary to gain momentum, and the City will be implementing a Stormwater Program Fee in fiscal year 2016 to support these strategies.

5.1 ENVIRONMENTAL SITE DESIGN

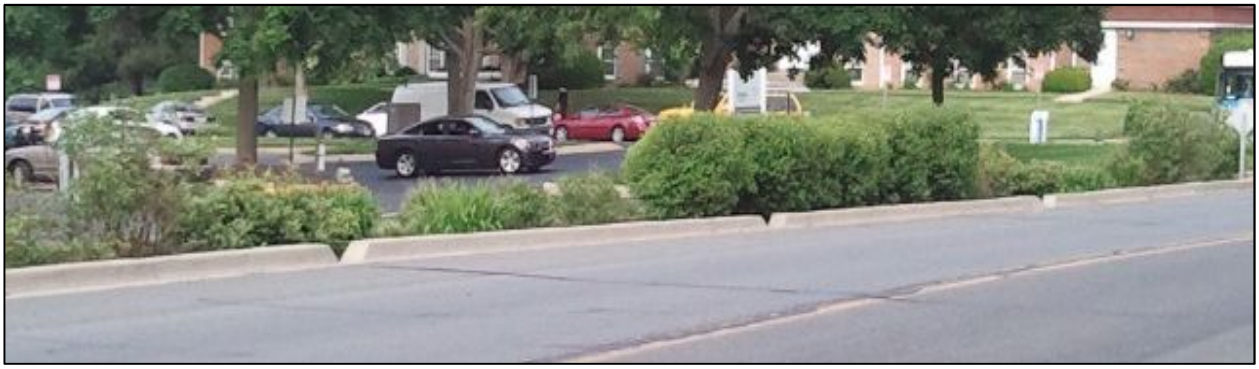
5.1.1 Green Streets

According to MDE guidance, Green Streets provide the following nutrient reductions for a runoff depth of 1 inch:

- Total nitrogen: 57 percent
- Total phosphorous: 66 percent
- Total suspended solids: 70 percent

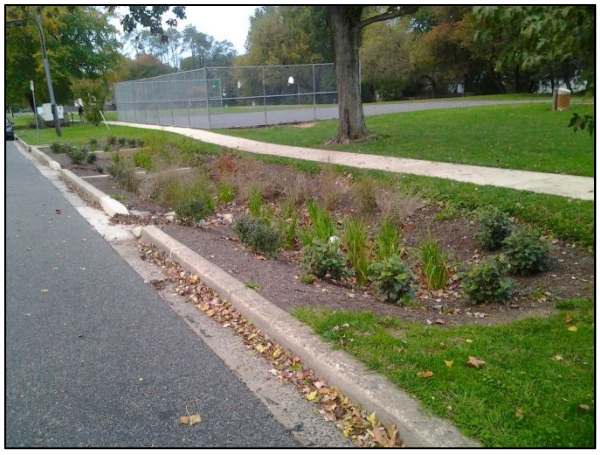
Green Streets are a useful tool in urban watersheds that are used to meet regulatory requirements. These facilities are a variation of a bioretention design that bumps out the curb of the road and uses soil and vegetation media to filter stormwater runoff and remove pollutants. These facilities can often be used as an integration of planning tools including stormwater management, traffic calming, impervious surface reduction, and economic development through improvement of aesthetics. These designs use curb cuts to divert a design-specific volume of stormwater runoff from the roadway into the cell. The volume diverted, called the water quality volume, is based on the contributing drainage area, contributing impervious area, soil recharge factor, and 1 inch of rainfall.

Implementing Green Streets during roadway improvements or utility pipe upgrade projects can be a strategic way for municipalities to obtain stormwater treatment, obtain NPDES credits, and combine projects to save money. Incorporating a local regulation that would require consideration of an ESD project and coordination with the City during transportation or utility improvements would provide a way to make projects more cost-effective.



The first Green Street on Rabbitt Road is the result of the City's progressive approach towards stormwater management.

The implementation of Green Streets in the watershed is an ongoing initiative. High priority locations for Green Streets include older neighborhoods with little or no existing stormwater management, drainage problems, and little or no room for traditional methods. An example of the City's progressive nature is shown by its initiative to construct its first Green Street in 2008 and conduct an assessment in 2012 to identify additional public streets where Green Street design would be feasible. The City has constructed five additional Green Streets since 2012, one of which is located in the Muddy Branch watershed at Walder Park. This study has identified several additional locations that could be considered for Green Street design in the future.



The City's newest Green Street was constructed in the Muddy Branch Watershed at Walder Park.

5.1.2 Disconnection of Rooftop Runoff

Disconnection of rooftop runoff is a common practice that disconnects rooftops from storm drain systems. The practice involves directing runoff flow from downspouts to vegetated areas where it can infiltrate into soil. Turf grass is the most common groundcover used in this practice, although trees, shrubs, and other herbaceous plants will also induce infiltration and evapotranspiration. The applicability of this practice is based on the existing soil infiltration rate, the flow path length, and the ground slope. This technique offers water quality benefits with limited impacts if pervious groundcover is available. Disconnected rooftop runoff was observed in the majority of residential areas in the watershed and is practiced at the City's Kentlands Mansion.

According to MDE guidance, proper disconnection of rooftop runoff includes:

- Roof drainage area of less than 500 sq. ft.
- Directing flow to a pervious area at least 15 feet long
- A pervious area (HSG A, B, or C) with an average slope of less than 5 percent
- Directed at least 10 feet away from nearest impervious surface

5.1.3 Rainscapes

Initially modeled after the Montgomery County program, the City's Rainscapes Rewards Program offers rebates for residents who improve stormwater runoff conditions by installing rain barrels, cisterns, or using conservation landscaping techniques on residential, HOA, private education, or multifamily properties.

More than thirty rain barrels have been implemented throughout the City as a result of this program, eighteen of which are in the Muddy

According to MDE guidance, the current Rainscapes techniques provide the following nutrient reductions for a runoff depth of 1 inch:

- Total nitrogen: 57 percent
- Total phosphorous: 66 percent
- Total suspended solids: 70 percent

Branch watershed. Only seven are identified as Rainscape Rebates. Field reconnaissance has verified conservation landscaping in several of the neighborhoods in the watershed, however GIS data currently does not yet reflect these conditions.

Rain barrels near the City's Arts Barn and community gardens are used to capture roof stormwater volume for watering landscaping.

The City is currently working on a Stormwater Management Program that will include incentives for private residential, commercial, and industrial property owners to implement and maintain stormwater management on their properties. This program will be a separate entity than the Rainscapes Rewards Program. It is expected that rebates for rain barrels, cisterns, and conservation landscaping will continue under the Rainscapes Rewards program with the potential for the addition of rain gardens and tree planting.

5.2 OUTREACH AND VOLUNTEER OPPORTUNITIES

The City's Environmental Services staff supports public education and participation through many outreach programs in the watershed including; Green Week, Environmental Awards Program, Environmental Affairs Committee, Team Up to Green Up, and other community programs.

Watershed and stream clean up events are prime opportunities to engage and educate citizens on the health of the watershed.

The City hosts an annual Green Week event, centered on Arbor Day that includes volunteer and educational events for the community to participate in. The ceremony for the Environmental Awards Program occurs during Green Week; awards are presented to deserving organizations and individuals based on environmental service projects to the City. This awards program further encourages watershed stewardship.

The City's Environmental Affairs Committee (EAC) is a volunteer committee of citizens and City staff that meets with the Mayor and Council to advise on environmental matters in the City.

Team Up to Green Up is a City-wide program that individuals or organizations can adopt parks or streams and commit to removing trash or invasives, or supporting steam rehabilitation. Those committed to the program get City support in the form of supplies, and a posted outreach sign recognizing the volunteer commitment.

Other community programs in the watershed include opportunities for citizens to report illegal discharges and dumping, storm drain stenciling, clean-up events, tree planning events, and volunteer stream monitoring. Additional information on the City website includes information for businesses on stormwater pollution prevention best practices and illegal discharges.

A unique attribute of the Muddy Branch watershed is the active environmental organizations that the City works closely with. These include several non-profit environmental groups with ties to the Muddy Branch watershed including the Muddy Branch Alliance and the Izaak Walton League.

Both of these organizations promote responsible watershed stewardship within the Muddy Branch Watershed in Gaithersburg while playing key roles in collaboration between the City and residents. Organization activities include organizing volunteer efforts, promoting and facilitating existing environmental programs, performing independent water quality testing, reforestation, and working with local schools to promote environmentally responsible programs.

Muddy Branch Alliance and Izaak Walton League are active in the Stormwater Partners Network and social media including:

- Facebook
- LinkedIn
- MeetUp
- Twitter
- Tumblr

The Izaak Walton League in partnership with the Muddy Branch Alliance, the City of Gaithersburg, and the Montgomery County Department of Environmental Protection received a grant from the Chesapeake Bay Trust's "Green Streets, Green Jobs, Green Towns" program. The grant will assist 12 homeowners, in the Muddy Branch watershed, to design and install native plant landscapes with onsite consolations in the watershed through the end of 2015. Additionally, these organizations have worked together to host a "Save Our Streams" workshop to train volunteers on how to conduct stream sampling for water quality and habitat.

Storm drain stenciling is one of many outreach activities available to residents of Gaithersburg.

Effort by the EAC, Izaak Walton League, and Muddy Branch Alliance are very important; behavioral changes in the management of water and pollutants in the watershed can control problems at the source and prevent increased costs of pollutant removal downstream. Education and outreach are important tools in obtaining buy-in to the City's projects and goals. The collaboration of communities in the watershed and the City is essential to ensuring that environmental and community health goals are met and are a key goal in meeting regulatory requirements.

Additionally, the City attained the Sustainable Maryland Certification from the University of Maryland's Environmental Finance Center. The City is also an EPA Green Power Partner and received the Tree City USA award for the 25th consecutive year. These certifications

and recognitions show the City's commitment to sustainability and environmental stewardship.

5.3 GIS DATA

The City's existing GIS data is a good starting point to meet future permit requirements as well as for continued planning and maintenance for stormwater management. The City has identified existing stormwater facilities within the watershed and developed a GIS point shapefile with appropriate attributes such as year of construction, who has maintenance responsibility, and regulation era standard. The City updated the data to include a performance code which indicates whether or not the BMP is performing as intended. This information has helped the City plan and manage stormwater within its jurisdiction. In addition, the City has estimated drainage areas associated with some of the existing stormwater facilities, which is a start in determining and prioritizing future facility retrofits.

The City, as of fall of 2014, is in the process of updating stormwater GIS data to include newly constructed facilities, all facility drainage areas, retrofits, correcting erroneous data, and ensuring consistency between as-builts and GIS data. The City may consider completing drainage areas for approximately 9,000 outfalls. This project will be completed by 2015 and will help the City in developing the Stormwater Management Program and 2016 Stormwater Program Fee. This work is necessary for the City to accurately evaluate the amount of already adequately treated areas and the areas that do not currently have adequate stormwater management and will be an important step for the City to fully and accurately understand the costs and level of effort required to meet the MS4 permit expectations. These GIS data will need to be continually maintained and updated in order to show regulatory agencies the progress the City makes each year toward meeting Chesapeake Bay TMDL and MS4 permit goals and requirements.

> The City is currently updating stormwater GIS data to have a complete and consistent set of urban BMPs, associated contributing drainage areas, based on 2014 terrain and stormwater facility as-built plans. This information will be vital to understanding the amount of impervious surface that the City will need to treat in order to meet NPDES requirements.

5.4 STORMWATER MANAGEMENT PROGRAM

The City will be applying a Stormwater Management Program in FY 2016 that will provide Stormwater Program Fee discounts for private properties that implement certain stormwater management techniques in accordance with City regulations. Funding for this program will be obtained from a Stormwater Program Fee or other Council-approved funds. Current discussion on the program indicates that it will include credits for stormwater management on residential parcels, non-profit parcels, industrial MS4 permit-holding parcels, and all parcels that provide stormwater treatment for runon from offsite areas. A draft manual for this program is expected in early 2015. Though specific practices have not yet been indicated for inclusion in the crediting program, consideration should be given to BMPs including, but not limited to, impervious surface removal (or replacement with alternative pavement), green roofs, and pond retrofits for water quality.

SECTION SIX: RECOMMENDATIONS

The City's goals for the Muddy Branch Watershed Study are to gain an understanding of the characteristics of the watershed and stream conditions and to develop recommendations and projects that can become part of the capital improvement budgets and the Stormwater Management Program to further improve watershed health. This study is the third and final of a trilogy outlining the conditions and recommendations for each of the City's main watersheds. Recommendations for the Muddy Branch watershed represent a compilation of proposed improvement projects and management strategies. The City will implement the projects and management strategies based on available funding, City staff availability, and changing City priorities. The City will reassess projects based on changing requirements and field conditions on an annual basis. An important consideration when prioritizing projects is the cost-benefit comparison of each project in relation to the NPDES impervious area treatment credit that could be achieved. Some of the recommendations expand beyond the Muddy Branch watershed and could be implemented on a City-wide basis.

This infiltration trench is an example of how structural improvements can be implemented on private property.

6.1 STORMWATER AND STREAM IMPROVEMENTS

URS developed concept designs for improvements at eight sites in the watershed as shown in Table 6.1. The improvements include four stormwater management measures and four stream restoration measures.

Table 6.1: Concept Designs Recommended for Implementation

New Stormwater Management Facilities	Stream Restoration
Casey Community Center	M2 – Future City Park
Green Park Dry Pond	Reach T3.1 – Quince Orchard Park
Washington Woods Park	Reach T4.1 – Brighton Village
Washington Woods Dry Pond	Reach T5.2a – I-370 Outfall

The recommended projects may take several years to fully implement, so these eight projects are described at the concept level. The design details for the stormwater and stream concepts are provided in Appendix C and E, respectively. At the time of full design, the latest design guidelines, technology, and standards should be considered. The concepts can be refined to achieve the maximum benefit for the watershed and to meet any updated City goals.

6.2 HOTSPOTS MONITORING

Potential hotspots in the Muddy Branch watershed consist primarily of gas stations, commercial parcels with NPDES permits, and a few residential area practices. Gas stations observed were stocked with appropriate spill kits and signage for pollution prevention and the locations identified with NPDES permits were not observed during field reconnaissance to be discharging pollutants. Due to the activities occurring at these sites, they will continue to be considered potential hotspots as there is a higher chance of pollutant spills. Continued monitoring and BMPs at both potential and confirmed hotspots will be an important consideration. The City should continue outreach to properties with vehicle operations, outdoor material storage, or waste management to ensure proper pollution prevention practices by the private owner are in place.

Potential hotspots that transfer, store, or maintain waste, petroleum, or chemicals can become hotspots if BMPs are not used.

An uncovered salt pile was observed during field reconnaissance to be draining to a stormwater inlet in a commercial shopping center. Similarly, in a residential area, trash was placed in the curb directly next to a storm drain inlet. The salt from the pile and pollutants from leachate from the trash bags would result in deteriorated stream conditions. The City was proactive and took immediate action to contact the owner to remove the hotspots. Integrating more education and outreach, plus incentives for pollution prevention practice into the upcoming Stormwater Management Program may be options to reach private owners and prevent these events from occurring.

6.3 EDUCATION AND OUTREACH EXPANSION

The City has a widespread and active education and outreach program (discussed in Section 5.2) and keenly partners with other environmental organizations in advocacy. These efforts provide citizens an understanding of how their actions affect the environment and the community and help to provide incentive for improving watershed conditions. Behavioral changes can be an effective way to incorporate source pollutant control as a management strategy. This is recognized as an important tool by regulatory agencies and as such, education and outreach is required by the NPDES permit.

Targeted nutrient and pesticide management outreach should be a priority in the Muddy Branch watershed.

Habits in the watershed observed during field reconnaissance show a need for targeted outreach in residential, commercial, and industrial areas. To enhance the City's existing pollution prevention outreach and education program, it may be helpful for the City to host a workshop to educate private properties on BMPs for source pollution control (this could include important seasonal tips). Pesticide and nutrient use in lawn care in residential areas, City parks, and some commercial areas were noted to be prevalent. The City could set up a program to offer free soil testing for citizens who submit a soil sample to encourage proper fertilizing behavior. Flyers could be distributed to promote the program that could include both extrinsic rewards such as saving money and intrinsic benefits discussing the environmental benefits to the watershed. The results of the soil test would provide the citizen with specific fertilizer recommendations. This would require additional City staff and resources so it may be beneficial to determine potential participation by surveying applicable parcel owners.

A community meeting and field observations confirmed that yard waste dumping is occurring in the Lakelands. Targeting this area with increased outreach for the City's existing bulk pick-up, loose leaf collection, holiday tree recycling, and yard waste mulching at the Department of Public Works may be a cost-effective method to improve this problem. Posting signs at known locations of dumping with the proper method of disposal could be one way of targeting problem areas. This strategy has been used in Columbia, Maryland as a prevention tool.

The Muddy Branch watershed is unique amongst the City's watersheds in that it contains the highest amount of residential land and open space areas. Conservation and enhancement of the existing riparian buffers along the streams and tributaries in this watershed are important to maintain and improve watershed conditions. The inclusion of the active Muddy Branch Alliance, Izaak Walton League, and Montgomery County schools in programs to plant trees in these areas should be continued and expanded. These types of activities can double as both water quality improvements and community outreach.

Unique outreach techniques have involved the arts, engineering, and the environmental communities to provide interactive approaches to understanding watershed restoration. One project in Massachusetts installed a methane digester in a popular dog park that would turn on a park light when it was fed with dog waste. This interactive approach of outreach in a popular area could combine efforts to prevent dog waste in runoff, reduce energy use in the park, and provide outreach to the community with a sign explaining the project. A similar concept combines

The City could host a design competition for an interactive restoration and outreach project, to include engineering, arts, and outreach in a restoration design. This type of project would provoke thought in the community about how to meet environmental needs while supporting other watershed uses concurrently.

trail planning with stream restoration and outreach. This could include designing rocks used for a cross vane or dissipater in the stream to align with a forested trail so that users could walk on the cross vane rocks to get across the stream during low water conditions. Inclusion of art in the design could include unique colors, shapes, or other methods to provide thought provocation.

6.3.1 Rainscapes Rewards

The City's Rainscapes Rewards program offers incentives and rebates for residential, private education, nonprofits, and multifamily dwellings that participate in the Rainscapes Rewards Program by implementing rain barrels, cisterns, or conservation landscaping on their property. Residential areas are the highest percentage of land use in the watershed and therefore, it is important to continue to encourage expansion of the program in these areas. Suggested expansion could include the addition of rain gardens and tree plantings and to include commercial and industrial properties for cistern rewards. Due to the City's development of the Stormwater Management Program which will provide incentives for private properties to add structural stormwater management, Rainscapes expansion should be limited to practices that would not require significant City staff time. Native soil properties including infiltration rates and may require City review before installation may need to be considered. The City could provide outreach instructions (a simple inexpensive factsheet) for a double-ring infiltrometer test for residents if infiltration rates will need consideration prior to inclusion in the Rainscapes program.

Residents can participate in the Rainscapes Rewards program and be reimbursed for installing rain barrels to capture roof runoff on their property.

The City could work with the County to adapt monitoring and maintenance materials for Rainscapes Rewards practices for the municipality. Tracking for this program is important to obtain credit from regulatory agencies in meeting outreach goals. A streamlined approach to the implementation and tracking of Rainscapes Rewards facilities throughout the County and City could be developed for the management of these programs as participation increases.

6.3.2 Partnerships

The City actively partners with environmental groups such as the Izaak Walton League and the Muddy Branch Alliance to host outreach activities for the watershed. Partnering with NIST on projects that could improve water quality in both jurisdictions should be the primary consideration. These

The City of Rockville, Montgomery County, HOAs, and the Maryland State Highway Administration should continue to be organizations for the City to work with to achieve communal watershed goals.

partnerships could be crucial to meeting overall Montgomery County WIP and Maryland WIP pollutant reduction goals.

In Muddy Branch, high priority partnerships should continue to be with the environmental organizations, the HOAs, and the commercial property owners, as these land uses contribute most to the impervious area in the watershed. High impervious area in the residential areas could be combatted with ESD projects but will need the buy-in of the owner, the planning from the City, and the encouragement and volunteers from dedicated environmentalist organizations. Joint grants have been proven successful with these partners for outreach and restoration projects and should continue to be a joint effort. The social networking that these organizations have established should be leveraged when working as a group to pull as many citizens as possible into outreach activities. Expansion to include local Garden Clubs, Scouting groups, 4-H Clubs, Engineering and Robotic Youth organizations could provide additional education and expansion of watershed stewardship and provide interest and volunteers for implementation and monitoring of stormwater management facilities in the upcoming milestone years.

Public-private partnerships for stormwater management can provide an effective way to address stormwater management issues by mitigating costs and sharing liability. This partnership leverages the innovation and technical depth that the private industry provides while maximizing public funds to provide the greatest cost-benefits from a water quality perspective to meet the NPDES requirements. Long-term private funds initially invested are returned over the life of the partnership on an availability payment structure. Responsibility for the design, build, financing, operations, and maintenance of the stormwater treatment practices are assumed by the private partner. This strategy helps to standardize design in the subject area and reduces costs through bulk material and service procurement.

Public-private partnerships (P3s) are contractual agreements between public agencies and a private sector entity and could be used in the stormwater management sector. Municipalities such as Prince George's County MD are exploring these agreements.

6.4 GIS DATA MANAGEMENT

The City has many datasets that are updated and used regularly; the City is in the process of updating all stormwater GIS data and plans to have a completed dataset of stormwater management, associated drainage areas, and outfall drainage areas by early 2015. Additional datasets would be useful for the City's permit compliance as well as continued routine operations such as maintenance, inspections, and watershed management. The following GIS data management measures are recommended:

- **Street Sweeping and Catch Basin Cleanout.** Creating shapefiles for locations of street sweeping and catch basin cleanouts would be beneficial as a tracking tool for the City. Records of sweeping and cleanouts could be maintained similar to stormwater facility maintenance data. Keeping records of sweeping and catch basin cleanouts in a shapefile would make them easy to access and allow for easy calculation of permit credits for pollutant reduction for this practice.

- **Urban Downsizing.** Impervious surface elimination is considered an alternative restoration measure by the MDE. Keeping track of urban downsizing, if any, would assist in accounting for impervious acres treated in Muddy Branch watershed, which is needed to obtain restoration credit.
- **Nonstructural Technique Tracking.** As the City implements its outreach programs, data will be needed to be tracked using GIS in order to receive credit for the NPDES permit efforts as well as with the public, mayor, and city council. The City has created a shapefile to track Rainscapes techniques, however, only rain barrels have been included at this time. Cisterns and conservation landscaping locations need to be updated and any expansion of the Rainscapes techniques should be included as well. Data such as outreach events, number of participants, and amount of pet waste removed from City properties, and number of stormwater inlets filtered could be additional items to include as nonstructural or outreach techniques in GIS data format.
- **Stormwater Management Program Fee and Credits.** Once the City starts to implement the Stormwater Management Program Fee and Credits, GIS datasets will need to be continually maintained to ensure appropriate impervious area is being considered for the fee at each property and that appropriate monitoring and maintenance records for any private stormwater management techniques being credited by the City are meeting the designed management standards.

The City will need to update the datasets over time as stormwater facilities and management evolve; this may require additional staff or consultants as the City needs progress.

6.5 STORMWATER MANAGEMENT PROGRAM

The City is proactive in planning a Stormwater Management Program and Stormwater Program Fee which will expand the incentives for private properties to implement and maintain stormwater management on their properties. The City has been using the Water Quality Protection Charge in coordination with Montgomery County to partially fund stormwater needs in the watershed; however, the City has identified a need to establish its own funding program in place of the County's. The development of this program and fee meets one of the goals for the City established by the Montgomery County WIP. The Stormwater Program Fee will match the County Fee in fiscal year 2015 and in 2016 will be updated based on parcel imperviousness. The Stormwater Program Fee funds will help the City maintain its successful "pay-as-you-go" finances and will help cover the projects the City must implement prior to 2025 to meet NPDES and TMDL requirements.

Commercial development, such as the Kentlands, could be incentivizedby the City's Stormwater Management Program to reduce impacts of impervious surfaces by implementing and maintaining private stormwater management facilities.

The Stormwater Management Program will provide

opportunities for property owners to be incentivized to provide new or retrofit stormwater management on their properties. Existing stormwater management practices will be credited if they meet current MDE standards, and are maintained as designed (if they are not maintained the credits could be revoked in future years). Each property will be assessed based on imperviousness, and if they implement stormwater management practices, credits will be given to discount the fee amount. Inspections on facilities by City staff will ensure that stormwater management facilities continue to remove pollutants as designed over time.

Though specific practices have not yet been indicated for inclusion in the crediting program, consideration should be given to bioretention, green roofs, impervious surface removal (or replacement with alternative pavement), dry wells, filters, urban tree planting, and pond retrofits for water quality. The program should leave room for crediting for future technological advancements in water quality techniques, such as floating wetlands.

6.6 SUMMARY

The City's goals for the study are to gain an understanding of the overall health of the watershed, to develop meaningful recommendations and to identify projects that can become part of the Capital Improvement Program budgets and plans. The proposed stormwater management projects will improve the water quality conditions in the Muddy Branch watershed by decreasing the amount of runoff and pollutants that enter Muddy Branch and its tributaries. The proposed stream restoration projects will improve miles of stream channel and enhance habitat conditions within the reaches that are recommended for concept design. The recommendations will help restore degraded areas and prevent further erosion and pollution, thus providing the City with credits toward its regulatory requirements and promote a healthier living space for City residents.

Watershed health in Muddy Branch should be continue to be monitored and improved so that the community can continue to enjoy the many aesthetic and life-supporting benefits it provides for generations.

SECTION SEVEN: COMPARISION OF CITY WATERSHEDS

The City of Gaithersburg drains to the Potomac River through two main streams that include Great Seneca and Muddy Branch. Based on the hydrologic characteristics and drainage patterns, the City can be divided into three main watersheds; Lower Great Seneca Creek, Middle Great Seneca Creek and Muddy Branch. The 20-acre Sears property, annexed by the City in 2012, drains to Rock Creek prior to discharging to the Potomac River and is part of the Upper Rock Creek Watershed.

The findings of this study will better position the City to address the demands of stormwater management in the increasingly urban City of Gaithersburg.

In order to meet the regulatory requirements such as the upcoming NPDES MS4 permit, the Chesapeake Bay TMDL and local TMDLs, the City initiated the watershed studies to identify potential restoration measures that can be implemented to improve water quality conditions, enhance habitat conditions and meet the Chesapeake Bay TMDL pollutant reduction goals including treating 20 percent of the City's impervious surfaces that are currently not adequately managed. URS, under separate contracts, assisted the City in analyzing all the watersheds and recommended a suite of structural and nonstructural measures to meet City's goals. The sections below provide a comparison of the City watersheds.

7.1 LAND USE AND IMPERVIOUS AREA

Residential land use with an area of 2,233 acres is the predominant (34 percent) land use in the City. Transportation and commercial land uses that encompass 1,276 acres (19 percent) and 1,040 (16 percent) acres are the next dominant land uses in the City. The Table 7.1 below provides distribution of land use in each watershed.

Table 7.1: Distribution of Land Use in the City of Gaithersburg

	Area (Acres)				
Land Use	**City Total**	**Middle Great Seneca Creek**	**Lower Great Seneca Creek**	**Muddy Branch**	**Upper Rock Creek**
Residential	**2233**	645	449	1139	0
Commercial	**1040**	550	108	369	13
Transportation	**1276**	359	258	652	7
Open Space	**850**	219	146	485	0
Industrial	**303**	67	139	97	0
Institutional	**331**	75	67	189	0
Other	**336**	115	44	177	0
Mixed Use	**263**	135	44	84	0
Total	**6,632**	**2,166**	**1,255**	**3,191**	**20**

Note: Interpreted GIS data (December 2013) from the City of Gaithersburg

The City of Gaithersburg has a total of approximately 2,308 acres of impervious area. The Muddy Branch and Middle Great Seneca Creek contribute the most impervious cover to the City (each contribute approximately 37 percent to the City's impervious area). Table 7.2 provides the impervious area distribution per watershed.

Table 7.2: Impervious cover distribution and management in the City

Watershed	Total Area (acres)	Percent of City Impervious Area	Watershed Impervious Area (acres)	Impervious Area Managed (2003-present) (acres)	Impervious Area Partially Managed (1985-2002) (acres)	Impervious Area Unmanaged (Pre-1985) (acres)	Impervious Area management yet to be determined*
Middle Great Seneca	2,166	33.0%	862	35	527	82	218
Lower Great Seneca	1,255	21.5%	561	23	215	167	156
Muddy Branch	3,191	45.0%	1,176	343	598	83	152
Upper Rock Creek	20	0.6%	15	4	0	0	11
City Total	**6,632**	**100%**	**2,614**	**405**	**1,340**	**332**	**537**

*This area was not included in study GIS stormwater drainage areas and should be evaluated as GIS data are upgraded.

MDE takes an era of development approach based on stormwater management regulations as a way to estimate managed versus unmanaged drainage areas. Development prior to 1985 is assumed to be unmanaged. Areas developed between 1985–2002 generally were developed to have flood control but water quality treatment is variable and should be confirmed with as-builts. Areas developed post 2002 are assumed to be adequately managed and do not count towards the amount of impervious surface to be restored for the 20 percent NPDES requirement.

In the City, runoff from approximately 2,077 acres of impervious area is captured by stormwater management facilities. Of the total runoff captured, 20 percent is adequately treated, 65 percent may be partially treated, while the other 15 percent is considered unmanaged due to the contributing drainage area having been developed prior to 1985 stormwater management standards. The areas that may be partially treated could be good potential sites for water quality retrofits to achieve additional pollutant removal in land already dedicated to stormwater use. The areas not currently managed, have the potential for addition of new stormwater facilities to capture and treat urban runoff.

The City will need to treat 20 percent of unmanaged impervious areas in the City. Assuming all partially managed areas (1985–2002) and unmanaged areas will be included; stormwater management techniques will be needed to treat approximately 334 acres.

This estimate will need to be updated based on water quality treatment from as-built designs for stormwater facilities between 1985–2002. It will also need to include any impervious area untreated that has not yet been determined.

7.2 WATER QUALITY IMPROVEMENT PROJECTS

7.2.1 Stormwater and Stream Project Improvement Benefits

As a part of the watershed studies, URS conducted field reconnaissance to identify potential stormwater and stream management opportunities in the watersheds. At least 20 stormwater sites and 10 stream sites were identified in each watershed, including both retrofit and opportunities for new stormwater management facilities or stream restoration opportunities. In each study, 4 stormwater projects and up to 4 stream restoration sites were conceptualized. Table 7.3 lists impervious credits that would be achieved by implementing the concepts in each watershed that are under consideration.

Table 7.3: Potential impervious credits from proposed structural management projects

Watershed	Location	Approximate Cost	Potential Impervious Credits (Acres)
Middle Great Seneca Creek Watershed	Hyde Park Dry Pond	$220,000	3.9
	Victory Farm Stormwater Management Facility	$41,000	Variable
	Woodland Hills Dry Pond	$410,000	3
	Woodland Hills/Old Carriage Hills Dry Pond	$590,000	3.8
	Whetsone Run Stream Restoration	$440,000	4
	Watkins Mill Run (south)	$120,000	1.3
	Watkins Mill Run (north)	$140,000	4
	Whetstone Run Tributary	$170,000	9
	Unnamed Tributary Upstream of Girard Street	$720,000	10
Lower Great Seneca Creek Watershed	Gaithersburg City Hall	$180,000	0.73
	Summit Avenue Parking Lot and City Police Property	$130,000	0.27
	Quince Orchard Boulevard (implemented 2014)	$190,000	0.79
	Eaves Apartment Complex Outfall	$170,000	0.8
	Stream East of Solitaire Court	$280,000	6.5
Muddy Branch Watershed	Casey Community Center	$165,178	0.55
	Green Park Dry Pond	$279,640	1.7
	Washington Woods Dry Pond	$200,905	1.3
	Washington Woods Park	$157,446	1.1
	M2- Future City Park	$1,031,000	17.2
	T 3.1 Quince Orchard Park	$1,001,813	15.4
	T 4.1 Brighton Village	$701,844	9.7
	T 5.2a I-370 Outfall	$860,000	4.6
City-Wide	**22 Structural Projects**	**$8,198,826**	**99.64**

The conceptualized sites in each watershed that were considered to have a high potential for pollutant reduction benefit. A more detailed analysis was conducted for these sites to determine the feasibility of implementation of the proposed project and estimate the pollutant removal and the impervious credit that would be achieved. Table 7.4 lists the pollutant removals that would be achieved from the sites selected for concept designs.

Table 7.4: Potential pollutant load reductions from proposed structural projects

Watershed	Impervious Credits (acres)	Estimated Pollutant Load Reductions (lbs/yr)		
		Total Nitrogen	Total Phosphorus	Total Suspended Solids
Middle Great Seneca	39.73	225	30	20,592
Lower Great Seneca	8.36	157	51	250,552
Muddy Branch	51.55	333	170	776,016
City Total	**99.64**	**715**	**251**	**1,047,250**

lbs/yr = pounds per year

The structural projects and associated benefits were only a sampling of the potential project sites identified throughout the three watershed studies. The additional sites identified during interim study discussion with the City could be further investigated for implementation of projects as well. These additional sites could provide additional impervious acre credit and nutrient reduction benefits for the City. The structural projects proposed are only one way for the City to meet requirements and improve watershed conditions. Structural projects are limited in the City due to ownership, use, and space constraints. The City uses other techniques to improve water quality in its watersheds as well and is in the process of tracking these.

7.2.2 Other Water Quality Improvement Projects

The City uses a variety of nonstructural techniques to try to inhibit the transport of pollutants into stormwater in its jurisdiction. These include Green Streets, conservation landscaping, tree planting, permeable pavements, and rooftop disconnection. Other outreach and education projects are also implemented (discussed in Section 5), however, benefits are difficult to calculate as limited tracking exists and the actual reductions are dependent on how each individual interprets and changes due to the outreach.

The City has been progressive in identifying and implementing Green Streets on roads within its jurisdiction. In 2012, the Green Streets Retrofit Evaluation Report identified 75 feasible projects based on a desktop analysis. If it is assumed that each location could be implemented and that an average impervious contribution to each site is approximately 0.2 acres, then the City could gain a maximum of 15 acres of impervious credits towards its MS4 permit.

Conservation landscaping is a program that the City encourages through its Rainscapes Rewards program. The minimum size for reimbursement is 200 square feet. Approximately 220 residences would need to implement this minimum size for the City to achieve an acre of impervious MS4 credit.

The City owns approximately 330 acres of road right-of-way and if it is assumed that 5 percent of this area would meet the design considerations for alternative pavement, then approximately 12 acres of impervious MS4 credit could be achieved.

Rooftop disconnection in the City has been observed to exist in many areas of each watershed already. There are approximately 130 acres of detached single-family rooftops in the City and if it is assumed that an average flow path of 40 feet is available and that 10 percent of residences would implement rooftop disconnection then the City could achieve 7 acres of impervious MS4 credit.

7.3 OVERALL RECOMMENDATIONS

The City has taken the first step in improving watershed conditions by studying the current conditions, practices, and behaviors within its jurisdiction on a sub-watershed basis and has identified project sites and targeted areas for nonstructural improvements. The unique characteristics and specific recommendations for each watershed can be located in each respective watershed study report. The findings in these reports should help the City take next steps in improving watershed health.

The next steps for the City are to:

- Finish upgrading GIS data to determine the extent of area needing upgrades to meet MS4, TMDL, and WIP milestones
- Finish developing the Stormwater Management Program and Fee, which will help to provide sustainable funding and a prioritization structure to implement watershed improvement strategies
- Prioritize and implement the structural and nonstructural management practices
- Maintain and monitor structural practices to maintain nutrient reductions over time
- Continually track and report progress to local and state regulators
- Re-evaluate City goals and watershed needs regularly to ensure stormwater management meets the City's needs

If all concept designs developed in the watershed studies are implemented, the City could make significant progress towards meeting its NPDES requirements, Chesapeake Bay TMDL goals, and WIP milestones.

The City is in the process of upgrading its GIS data, establishing the NPDES impervious area baseline, and developing a sustainable Stormwater Management Program. Each year the City has been adding new stormwater infrastructure. Future prioritization and implementation of structural and nonstructural practices will be necessary to meet regulatory needs. Currently, the City uses 290 man hours each year to maintain stormwater facilities. Additionally, the City has been spending an average of $100,000 each year to mow and repair stormwater management areas. These maintenance costs are projected to increase by 5 to 10 percent per year. The City should consider this growth when establishing Stormwater Management Fees. The increase in facilities will require the City to put significant effort into maintaining and monitoring its stormwater investments. A stormwater facility's ability to remove pollutants decreases substantially if not maintained properly. The increase in facilities will require an escalation of staff or consultants needed to monitor, maintain, track, and report the progress of nutrient reductions.

SECTION EIGHT: REFERENCES

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Appendices

Appendix A
Existing Data Summary

As part of Task 1, URS reviewed existing records to lay the groundwork for a successful watershed study. The results of the study will provide a basis for achieving the City's goals. This appendix summarizes the review of existing resources. The resources reviewed include local strategies and other watershed studies, Total Maximum Daily Load (TMDL) studies, stream monitoring data, and geographic information system (GIS) data provided by the City.

The development of the Muddy Branch Watershed Study relied extensively on available GIS data. URS reviewed GIS data from the City of Gaithersburg originally provided in December 2013 and with updated stormwater data in July 2014 to identify existing stormwater management facilities, land use, impervious area, and drainage areas. The GIS data listed in Table A.1 were reviewed.

Table A.1: GIS Data Reviewed During the Study

Physical	Non-Physical
Buildings	Historic sites
Bike and pedestrian pathways	Land use
Green treatment lines, points, & polygons	Municipal boundaries
Topographic data	Outfall drainage areas
Impervious areas	Points of interest
Stormwater management facilities	Planned reforestation areas
Storm drain pipes, inlets, and manholes	Zoning
Streams & hydrography	Property boundaries
Streets	Stormwater management drainage areas
WSSC piping	Watershed boundaries
Easements	Aerial imagery

A review of local strategies and watershed plans was performed to better understand the baseline condition of the watershed. Additionally, URS evaluated potential restoration opportunities based on the benefit they would provide to the City of Gaithersburg.

The local strategies and watershed plans that URS reviewed include the following:

City of Gaithersburg

- City of Gaithersburg Water Resources: A Master Plan Element, 2009
- Erosion and Sediment Control and Stormwater Management Ordinance, City of Gaithersburg, 2010
- State of the Environment Report, City of Gaithersburg, 2000
- An Ecological Assessment of Streams in Gaithersburg, Maryland, Versar, Inc., 2002
- City of Gaithersburg Green Streets Retrofit Evaluation – Summary Memo, Biohabitats, 2012

- City of Gaithersburg Mayor and City Council Stormwater Management Fee Draft Program and Rate Policy Decisions, Work Session, 2014

Montgomery County

- Annual Report for 2010 National Pollutant Discharge Elimination System (NPDES) Municipal Separate Storm Sewer System (MS4) Permit, MCDEP
- Montgomery County, MD MS4 Phase I/II Watershed Improvement Plan Contributions, 2011

Maryland Department of the Environment

- Maryland Department of the Environment (MDE) NPDES MS4
- Maryland Stormwater Design Manual, MDE, 2009
- Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated (Draft), MDE, 2011
- Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated, MDE, 2014
- Total Maximum Daily Load of Sediment in the Potomac River, Montgomery County Watershed, Montgomery an d Frederick Counties, Maryland, MDE, 2011

Other Sources

- Muddy Branch and Watts Branch Subwatersheds Implementation Plan, Horsley Witten Group, Inc., 2012
- Great Seneca Creek/Muddy Branch Watershed Fact Sheet, U.S. Army Corps of Engineers, 2012
- Hydrologic Analysis of the Muddy Branch Watershed, Montgomery County, Maryland, U.S. Army Corps of Engineers, Baltimore District, 2008.
- EPA Evaluation of Maryland's 2012-2013 and 2014-2015 Milestones, EPA, 2014

Appendix B
Hydrologic Analysis Results

1 INTRODUCTION

URS performed a hydrologic analysis as part of the Muddy Branch Watershed Study for City of Gaithersburg. The results of the hydrologic modeling will aid in future watershed improvement assessments and the City's management strategies for the watershed. Additionally, the City can use this model to support future stream restoration and stormwater management design projects. This hydrologic study focused on the portion of the Muddy Branch Watershed within the City of Gaithersburg.

The hydrologic model for the Muddy Branch Watershed within the City was developed using current Geographic Information System (GIS) datasets from the City of Gaithersburg and precipitation data from the Maryland Stormwater Design Manual (MDE, 2009). The following report summarizes the process used in developing the model.

2 WATERSHED DATA

After reviewing project specifications and recommendations, and understanding the project's goal and objectives, specific data needs were defined and collected. The data sets used in the hydrologic modeling are described below.

Digital Elevation Model (DEM): Topographic data from the U.S. Geological Survey's National Elevation Dataset (NED) was used to supplement the City-provided DEM. This data was used courtesy of the Natural Resources Conservation Service (NRCS) Geospatial Data Gateway.

Soil Data: The Soil Survey Geographic (SSURGO) database (NRCS, 2013), available on the Internet (URL: http://SoilDataMart.nrcs.usda.gov/), was used to obtain GIS soil data coverage for modeling and its tributaries within the City of Gaithersburg.

Land Use Data: GIS land use data was provided by the City of Gaithersburg. The 2009 Gaithersburg Land Use data was used to represent existing conditions land use. Land use data was updated where applicable. For example, areas labeled as "Open Space" that were actually forested land were adjusted in the Curve Number determination.

Rainfall Infiltration Curve Number: Rainfall infiltration losses were estimated using the NRCS Curve Number (CN) methodology. The 2009 Gaithersburg Land Use data was reclassified into 11 categories based on their similarity in hydrologic responses. Each of these categories has a different CN value depending on the hydrologic soil group classification of the land. Table 1 summarizes CN values for the different land use categories and four hydrologic soil groups.

Table 1: Land Use and CN Values from TR-55

			CN Value by Soil Type			
No.	2009 Gaithersburg Land Use Categories	Equivalent TR-55 Category	A	B	C	D
1	Commercial	Urban Districts: Commercial and Business	89	92	94	95
2	Forest	Woods : Good	30	55	70	77
3	High-density Residential	Residential districts: 1/8 acre lots or less	77	85	90	92
4	Industrial	Urban Districts: Industrial	81	88	91	93
5	Institutional	Urban Districts: Commercial and Business	89	92	94	95
6	Low-density Residential	Residential districts: 1/2 acre lots	54	70	80	85
7	Medium-density Residential	Residential districts: 1/4 acre lots	61	75	83	97
8	Open Space	Open Space: Fair condition	49	69	79	84
9	Open Space	Open Space: Good condition	39	61	74	80
10	Water	Water	98	98	98	98
11	Transportation	Impervious areas: Streets and Roads - Paved; curbs and storm sewers	98	98	98	98

3 HYDROLOGIC MODEL

URS developed the hydrologic model using the 2009 Gaithersburg GIS Land use data and the U.S. Army Corps of Engineers (USACE) HEC-HMS version 3.5. (USACE, 2010). HEC-HMS is a modeling program that takes the input watershed data and outputs the volume of water that is released during a given rainstorm at the provided outfalls in the watershed. URS developed the terrain preprocessing, watershed delineation, and attribute management using the ArcGIS 10 (ESRI, 2010) based ArcHydro tool (CRWR, 2011), and performed basin processing using and HEC-GeoHMS (USACE, 2010). ArcHydro tools are a set of public domain utilities developed jointly by the Center for Research in Water Resources (CRWR) of the University of Texas at Austin and the Environmental Systems Research Institute, Inc. (ESRI).

The hydrologic analysis for the City of Gaithersburg for Federal Emergency Management Agency's (FEMA) Flood Insurance Study (FIS) was prepared in 1980; therefore the discharges from the FIS may not be representative of the current watershed conditions. URS used U.S. Geological Survey (USGS) regression equations for validations to be consistent with the previous two City of Gaithersburg watershed studies.

3.1 Watershed Parameters

Key hydrologic parameters that are required for the HEC-HMS rainfall-runoff model include watershed-related parameters and precipitation data associated with design storms. Watershed-related input parameters needed for the HEC-HMS model include rainfall infiltration losses, drainage area size, rain-runoff time of concentration, and data for hydrograph routing through the watershed channels.

Rainfall Infiltration Curve Number: Rainfall infiltration losses were estimated using the NRCS CN methodology, wherein the CN is the parameter used to define rainfall infiltration losses. CN values for each sub-area were derived based on soil types in the study area, land uses in the study area and the relationships among soil type, land use, and CN value given in Table 1. The polygon generation tool in the HEC Geo-HMS model was used to derive the area-weighted CN values presented in Table 2.

Table 2: Hydrologic Parameters for Subbasins

Subbasin	Drainage Area (sq. mi.)	Drainage Area within City Limits (%)	Curve Number	Time of concentration (hrs)
W1000	0.012	100%	76.87	11.32
W1020	0.017	100%	67.55	16.78
W1030	0.027	100%	94.93	9.73
W1080	0.098	97%	90.3	11.98
W1090	0.241	44%	77.86	20.86
W1160	0.027	0%	75.76	19.65
W1180	0.016	100%	98	16.44
W1190	0.072	100%	89.82	15.04
W1230	0.03	86%	86.43	5.69
W1240	0.056	63%	87.07	12.95
W1270	0.1	100%	76.33	16.37
W1290	0.101	100%	80.75	12.76
W1300	0.009	100%	91.07	6.63
W300	0.295	87%	76.78	21.24
W310	0.37	24%	80.99	23.25
W320	0.308	78%	81.5	24.88
W330	0.257	76%	80.36	28.87
W340	0.247	5%	90.96	32.88
W350	0.454	15%	89.72	30.85
W360	0.068	100%	76.5	12.31
W370	0.132	100%	76.88	17.93

Subbasin	Drainage Area (sq. mi.)	Drainage Area within City Limits (%)	Curve Number	Time of concentration (hrs)
W380	0.376	54%	80.74	34.71
W390	0.296	100%	84.61	25.29
W400	0.098	100%	73.92	18.73
W410	0.035	100%	82.94	10.35
W420	0.419	79%	83.2	26.55
W440	0.052	100%	68.63	18.11
W470	0.056	100%	80.35	8.61
W480	0.146	99%	75.02	14.95
W490	0.354	16%	80.48	24.34
W500	0.267	74%	75.14	23.42
W510	0.817	43%	78.69	36.56
W520	0.509	2%	82.46	35.37
W530	0.384	3%	79.85	22.62
W540	0.003	0%	84.01	4.34
W550	0.196	0%	80.08	20.28
W560	0.68	16%	80.06	34.38
W570	0.211	0%	77.24	23.29
W580	0.052	0%	66.51	14.01
W600	0.066	99%	89.19	8.22
W610	0.041	100%	92.31	4.45
W620	0.123	99%	82.83	20.05
W630	0.037	100%	79.97	12.38
W710	0.098	100%	82.88	20.91
W730	0.042	100%	72.98	7.63
W760	0.082	100%	77.9	12.86
W780	0.137	90%	85.22	17.50
W790	0.173	99%	84.25	14.97
W840	0.041	100%	85.12	3.82
W860	0.05	95%	92.15	12.85
W910	0.044	100%	82.42	14.71
W920	0.036	94%	92.42	6.28
W930	0.107	99%	87.98	15.50
W940	0.085	100%	77.08	13.99
W950	0.022	100%	76.68	3.60
W960	0.063	100%	82.3	10.48

Subbasin	Drainage Area (sq. mi.)	Drainage Area within City Limits (%)	Curve Number	Time of concentration (hrs)
W970	0.074	100%	84.01	9.38
W980	0.044	100%	80.3	10.14

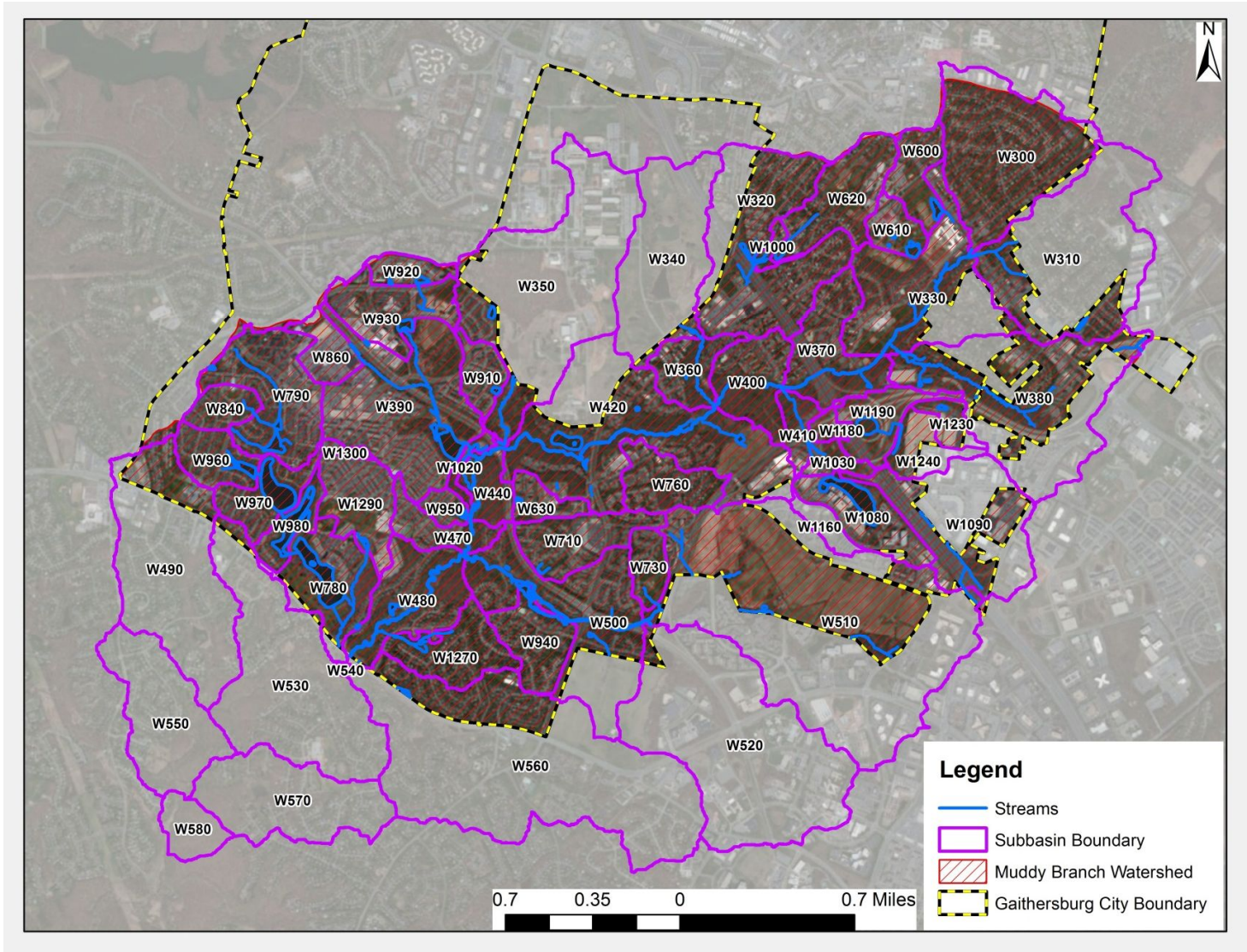

Figure 1: Subbasin boundaries for hydrologic analysis

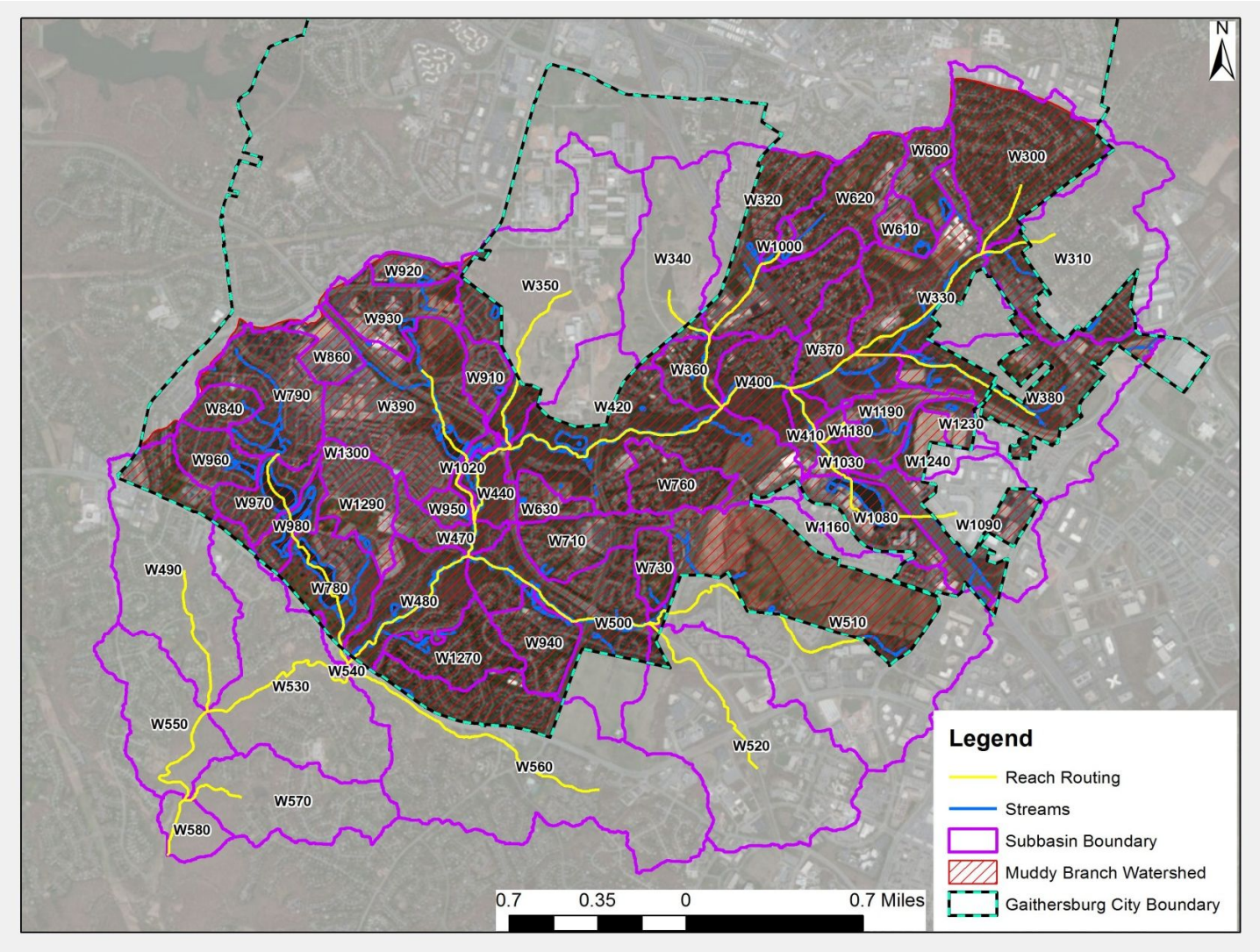

Figure 2: Reaches used in HEC-HMS hydrologic modeling for the City of Gaithersburg

Drainage Area Size: The watershed subbasins shown in Figure 1 were delineated and the enclosed areas were calculated using HEC Geo-HMS. The subbasin sizes summarized in Table 2 were then input into the HEC-HMS model for the hydrologic simulation.

Subbasin Time of Concentration: Time of concentration (T_c) is defined as the time it takes for stormwater runoff to travel from the most hydraulically distant point of the watershed to a point of interest within the watershed. T_c values for each subbasin were determined using the T_c estimation method described in Natural Resources Conservation Service (NRCS) Technical Release (TR)-55. Runoff from each sub-area was divided into a sheet flow segment (non-concentrated runoff from the most distant point), shallow concentrated flow segment, and channel flow.

T_c values for sheet and shallow concentrated flows were estimated using generalized curves that relate surface and channel conditions, slope, and flow velocity. A maximum sheet flow segment length of 100 feet was used, as this is conservative and in accordance with NRCS recommendations. Shallow concentrated flow lengths were assumed to extend from the end of the sheet flow portion of runoff to the origin of a well-defined channel segment.

Velocities for channel flows were calculated using Manning's equation and the bankfull discharges. Hydraulic roughness characteristics were based on aerial imagery and general assumptions. These assumptions include assuming an n-value of 0.05 for all channels within the City. Channel geometries were estimated using drainage-area-dependent equations developed for Maryland's Piedmont Region by the U.S. Fish and Wildlife Service .

The bankfull discharge is recommended by the NRCS for the calculation of T_c because it is assumed to be the most efficient flow-carrying capacity for the naturally formed channel shape. Channel flow calculations were made for multiple channel segments based on stream length, drainage area changes, and slope changes. Travel times through ponds were assumed to be zero, which yields slightly shorter and, therefore, the most conservative T_c values.

The calculated travel time (T_t) values for sheet flow, shallow concentrated flow, and channel flow were summed to give the total T_c value for each sub-area. The estimated T_c values for the sub-areas are summarized in Table 2.

Base-flow: Base-flows were assumed to be negligible and hence were not included as a subbasin input in the mode.

Hydrograph Routing Parameters: The Muskingum-Cunge routing procedure was used for the hydrologic routing of sub-area hydrographs and combinations of hydrographs through the watershed channels. HEC-HMS uses the peak of the inflow hydrograph as a reference discharge to determine a constant routing coefficient. Stream cross-section data tables were created for reaches using the DEM. Routing was included in the hydrologic modeling to account for transient channel storage attenuation and travel lag times between flow concentration points.

Precipitation Data: Precipitation data used as input in the HEC-HMS model include rainfall amounts and temporal distribution on the subwatersheds for the storm events analyzed. The 24-

hour duration 1-, 2-, 10- and 100-year rainfall events were used to calculate the discharges at the 100-, 50-, 10- and 1-percent-annual-chance events, respectively. The 24-hour precipitation frequency estimates were obtained from the Maryland Stormwater Design Manual (MDE, 2009) and are presented in Table 3.

Table 3: Precipitation Amount for the Muddy Branch Watershed within the City of Gaithersburg based on the Maryland Stormwater Design Manual

Average Recurrence Interval (years)	24-Hour Precipitation Frequency Estimate (inches)
1	2.6
2	3.2
10	5.1
25	5.8
100	7.2

4 SUMMARY RESULTS

Results of the hydrologic simulations are summarized in Table 4. Results of the HEC-HMS model are reported by reach name or subbasin name.

Table 4: Results from Hydrologic Simulations

Subbasin	Subbbasin Drainage Area (sq.miles)	Cumulative Drainage Area (sq.miles)	Storm Event Flows (cfs)				
			1 yr	2 yr	10 yr	25 yr	100 yr
W1000	0.01	0.14	17.6	32.4	66.1	76	93.4
W1020	0.02	0.53	125.7	176.8	344.3	397.3	522.9
W1030	0.03	0.39	113.2	175.6	403.5	490.7	648.3
W1080	0.10	0.37	105.5	164.9	382.2	465.8	618.3
W1090	0.24	0.24	100.9	156.6	356.1	434.3	594.2
W1160	0.03	0.03	10.1	16.3	38.8	47.8	66.3
W1180	0.02	0.17	102.1	132.8	244.6	287.9	368
W1190	0.07	0.16	82.7	108.4	204.3	241.4	309.4
W1230	0.03	0.03	0	0.9	17.6	24.7	35.4
W1240	0.06	0.09	55.1	75.5	156	189.1	249.1
W1270	0.10	0.10	201.7	201.7	201.7	201.7	267.7
W1290	0.10	0.11	14.4	18.8	133.7	197.7	297.4
W1300	0.01	0.01	14.4	18.8	32.9	38	48.2
W300	0.29	0.29	112.9	178.6	417.1	511.2	703.8
W310	0.37	0.37	179.6	266.2	566.4	681.6	915.3
W320	0.31	0.44	150.5	237.1	518.3	621.4	825.9
W330	0.26	1.03	401.8	613.8	1345.8	1627.4	2197.6
W340	0.25	0.25	164.3	217.3	385.6	447.3	570.1
W350	0.45	0.50	315.9	429.1	785.2	913.8	1168.2
W360	0.07	0.76	319.2	465.2	916.8	1088.6	1429.4
W370	0.13	2.14	724.6	1103	2435.9	2953.6	3986.5
W380	0.38	0.38	134.8	201	431.9	521	701.6
W390	0.30	0.49	122.6	163.9	295.7	360.8	463.2
W400	0.10	2.24	719.4	1109.9	2462.7	2989.3	4048
W410	0.04	0.60	195.7	287.9	626.9	761	1012.4
W420	0.42	3.53	1051.9	1661.5	3584.3	4334.5	5863.1
W440	0.05	4.08	1212.7	1919.3	4118.5	4956.8	6663.7
W470	0.06	4.67	1282.2	2001.6	4335.6	5224.5	7024.8
W480	0.15	6.73	1782.3	2731.5	5977.6	7203.7	9631
W490	0.35	0.35	161	240.4	517.5	624.1	840.7
W500	0.27	1.82	541.8	814.1	1727.2	2127.5	2888.2

Subbasin	Subbbasin Drainage Area (sq.miles)	Cumulative Drainage Area (sq.miles)	Storm Event Flows (cfs)				
			1 yr	2 yr	10 yr	25 yr	100 yr
W510	0.82	0.86	250.3	385	859.8	1044.3	1421.1
W520	0.51	0.51	201.2	293.1	608	728.1	970.2
W530	0.38	8.44	1905.8	2934.8	6354.7	7641.7	10384.2
W540	0.003	7.38	1761.2	2698.4	5944.3	7170.6	9602.8
W550	0.20	8.99	1951.3	3003.7	6514.2	7829.6	10643.1
W560	0.68	0.68	234.3	352.9	769.3	930.6	1258.1
W570	0.21	0.21	78.2	122.9	284.3	347.8	477.7
W580	0.05	9.25	1754.8	2710.4	6047.2	7311.2	9991.2
W600	0.07	0.07	14.7	24.4	43.5	48.7	57
W610	0.04	0.04	16.5	18.9	24.6	26.3	29.2
W620	0.12	0.12	16.7	30.8	62.7	72	87.6
W630	0.04	0.04	2.8	6.2	29.4	40	66.1
W710	0.10	0.10	42.3	51.7	137	150.8	193.1
W730	0.04	0.04	6.3	9	14	15.2	17.1
W760	0.08	0.08	46.3	70.9	152.4	182.4	241.4
W780	0.14	0.64	26.8	33.2	169	233.8	337.6
W790	0.17	0.21	28.9	59.1	131.6	144.7	159
W840	0.04	0.04	21.6	33.2	58	63	72.3
W860	0.05	0.05	27	31	42.2	45.9	52.6
W910	0.04	0.04	18.7	32.9	64.3	73.2	89.5
W920	0.04	0.04	59.5	77.1	132.3	152.4	192.4
W930	0.11	0.14	96.2	136	254.1	291.6	362.5
W940	0.09	0.09	43.8	68.4	156.5	190.9	261.1
W950	0.02	0.02	1	9.2	44.7	53.3	68.2
W960	0.06	0.06	0	3.4	24.8	30.8	40.7
W970	0.07	0.35	28.9	59.1	131.6	144.7	159
W980	0.04	0.40	9.6	20.1	41.2	46.9	56.9

Stormwater Management facilities with drainage areas over 20 acres were included in the hydrologic model. The City of Gaithersburg provided documents as were available in digital or hard copy format for these facilities and the relevant available information was extracted and used at each facility, where available. The stormwater management facilities delineated in subbasins include:

- Great Seneca North P1
- Amberfield
- Green Park
- Shady Grove Village/Lakewood Commons
- Kentlands Mid/Upper Lake District
- Beatty Open Center 1
- Quince Orchard Park II
- Medimmune/Quince Orchard Corporate Center
- Washington Woods
- Lake Varuna
- Lake Lynette
- Inspiration Lake
- Summit Hall Park Front Pond
- Summit Hall Park Back Pond
- Lake Helene
- Lake Nirvana
- Christman Pond
- Lake Shiela
- Washington Center Lake
- Lake Placid
- I-270/I-370 Interchange
- Hughes
- Woods at Muddy Branch/ The Woodlands
- Lake Edison

5 CONCLUSION

Results from the HEC-HMS model are consistent with what was expected from field studies, which showed locations of highly eroded streams and the need for storm drain improvement and replacement. Additionally, a comparison of regression equations showed that the results of the analysis were consistent with flow values expected in this urban area. The results of this study can be used by the City for future stormwater management improvements or stream restoration projects.

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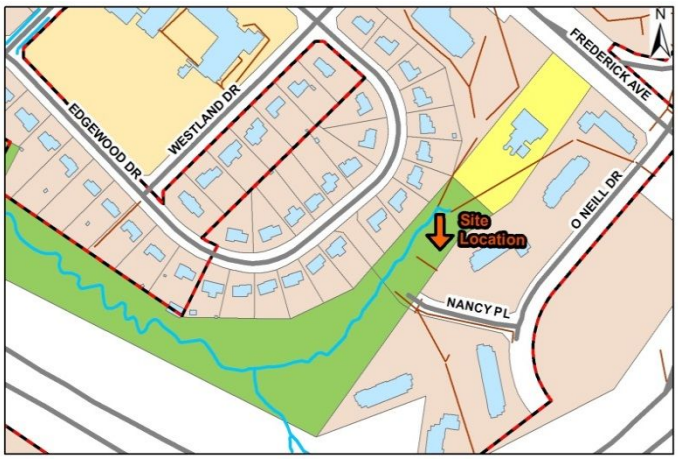
Appendix C
Stormwater Concept Designs

Casey Community Center Concept



Total Treated Drainage Area: 2.33 acres
Total Treated Impervious Area: 1.83 acres (79%)
Total Water Quality Volume (WQv): ~1,960 cu.-ft, ~0.05 ac-ft
Annual Nutrient Removal:

- TN: 11.35 lbs
- TP: 1.29 lbs
- TSS: 810 lbs

Site Description

The Casey Community Center is located at 810 South Frederick Avenue in Gaithersburg. The project site is located in the back parking lot, adjacent to a drainage ditch that flows to a tributary of Muddy Branch. This stormwater concept is just upstream of the proposed stream concept, "Reach T5.2a I-370 Outfall." Implementing a stormwater project upland of stream restoration can provide additional benefits such as increased water quality and volume control and a lengthened life span of the stream restoration.

Existing Site: The existing parcel where the project is proposed is owned by the City, and contains the Community Center building, a large parking area, a playground, and a walking trail parallel to the stream. The Community Center hosts Tot Time and is available to the public to rent for special events. There are two existing inlets that capture flow from the northern portion of the site and roof (1.33 acres) but do not provide water quality treatment and discharge through storm pipes directly to the drainage ditch. Stormwater in the southern half of the lot (1.00 acres) flows as sheet flow to either an existing curb cut and paved channel (which provides no treatment) or a grass buffer. Both locations discharge the stormwater directly to the drainage ditch. Several medians reduce the overall site drainage area imperviousness to 79%, though curbing isolates the trees from receiving and mitigating the parking lot runoff. The existing grading in the parking lot slopes from northeast to southwest towards the curb cut and stream bank. Figure C.1 shows the existing site.

Existing Storage: Water quality, storage, or channel protection is not provided at the site currently, as these considerations were not part of stormwater and development regulations at the time of the lot's design.

Soils: The soils in the drainage area are hydrologic soil groups B and C. Hydrologic soil group C is the primary soil in the area of the proposed bioretention cell location. This type of soil is dominantly clay or clay loam, and does not transmit or drain water well. Soil tests and infiltration tests to determine the specific onsite soil characteristics and infiltration rates are recommended to

be performed in the project filter bed location during final engineering design. Resulting infiltration rates could modify the final design (to potentially add infiltration and recharge below the bioretention facility if the soils are found to provide adequate percolation rates).

Retrofit Goals: The primary goals for the proposed new retrofit are to provide the most water quality benefits as possible by reducing pollutants, thereby attaining NPDES credits, while limiting grading and maintaining the existing parking spaces. Secondary goals were to provide a facility that would have community acceptance by being aesthetically pleasing, and providing stormwater and water quality outreach in a location that is used for City events.

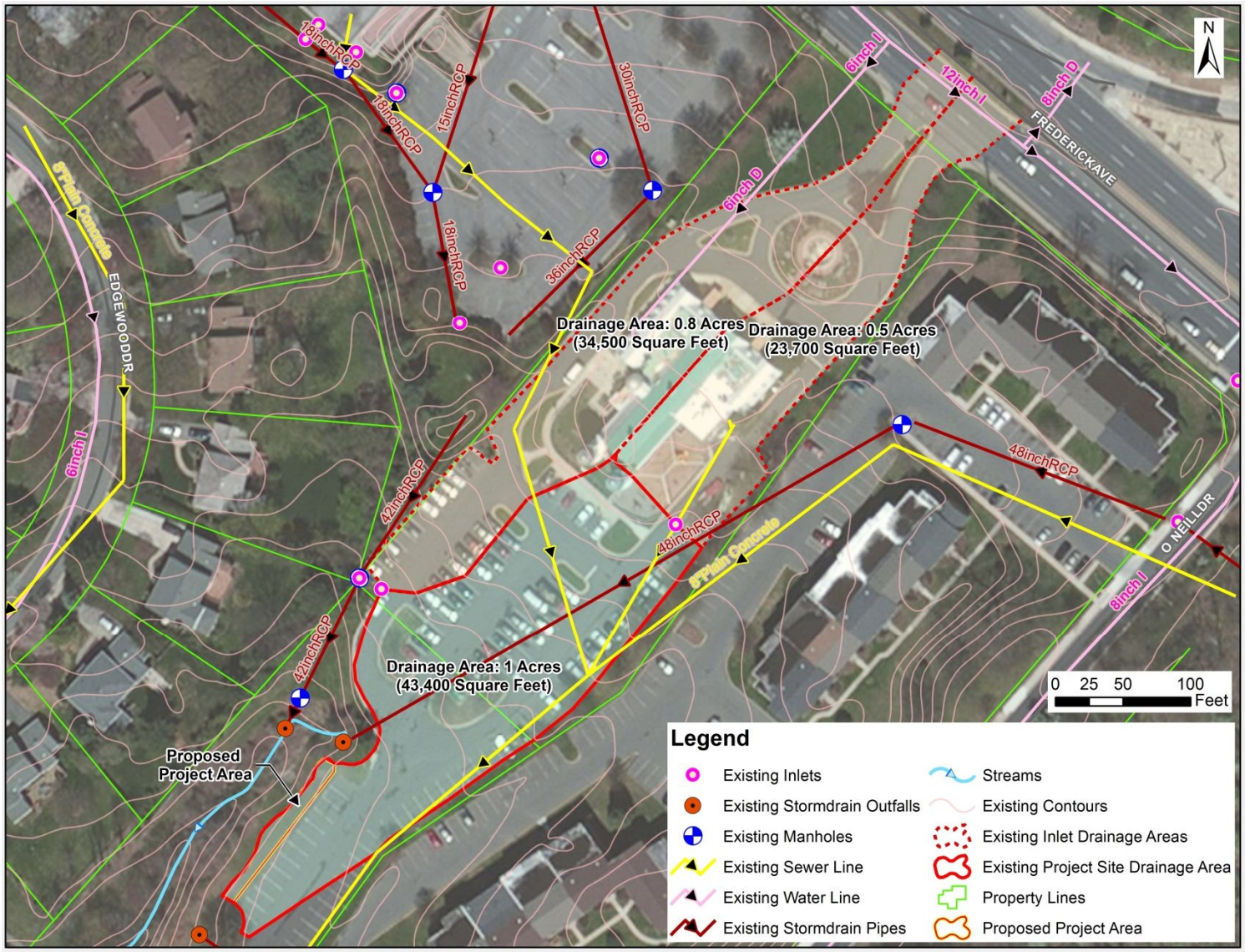


Figure C.1: Existing Facility and Drainage Area (Casey Community Center)

Proposed Retrofit

The proposed site was analyzed for various retrofit options based on its topography and physical parameters. The retrofit is located adjacent to a drainage channel but was determined to not be within a FEMA floodplain area. Since the site is in a public area, adding a filtering system would be aesthetically pleasing, would provide water quality treatment for runoff, and would provide the City more NPDES credits than other options. The proposed project at the site includes converting grassed area to a linear bioretention cell with an underdrain and yard inlet. This conversion will provide water quality treatment for this untreated impervious parking lot runoff.

The existing area will need to be modified to implement the proposed bioretention cell. The modifications include changing the existing curb cut and paved channel to redirect flow towards the bioretention cell. It will also require adding curbing along a portion of the existing parking spaces near the proposed forebay. The parking lot is already graded towards the proposed project, as sheet flow from the lot runs off towards the western part of the lot and then discharges either into the curb cut or over the channel bank adjacent to the curb cut as sheet flow. The existing storm inlets in the northern half of the lot will need to be modified to bypass the 0.32 inch storm (one conceptual option is to add a small concrete lip at the inlets to bypass the small storm but allow volume from larger storms to be captured).

The contributing drainage area to the project site will be approximately 2.33 acres when 2 existing inlets in the lot are blocked from receiving the bioretention design storm (0.32 inch storm). For the purpose of this concept, it is assumed that blocking these inlets is possible, thus, the concept was designed to treat 2.33 acres. If the existing inlets are not blocked then the drainage area received at the proposed project location is reduced to 1 acre. The northern half of the lot flows to two existing inlets and the southern half of the lot flows to the existing drainage ditch banks before discharging. Due to the drainage area, flow patterns, and limited space, bioretention was the proposed project of choice.

Existing Curb Cut to Concrete Channel that discharges Casey Community Center runoff

The cell that is designed for the southern part of the parking lot will require modifying the existing curb cut and will use a forebay as pre-treatment for the runoff received at the curb cut. A curb will be added in an “L” shape from the curb cut to the side of the first parking spot to prevent drivers

from accidentally driving into the forebay. Additionally, a stone diaphragm level spreader will be added between the end of the parking spaces and the grassed area to provide dissipation and spread the overland flow received, equally into the filter bed. A yard inlet and underdrains installed in the cell will connect to a proposed 6-inch PVC storm pipe that will discharge to the drainage ditch. Outlet protection will be added at the discharge location to prevent erosion. A small retaining wall could be added to the stream side of the bioretention cell and two weirs could be added to the cell to encourage ponding. During construction of this site, the existing rusted storm drain pipe (to the south of the proposed project), could be replaced to avoid duplicate cost and efforts in the same area. Figure C.2 shows the proposed improvements for the Casey Community Center. According to the MDE *Stormwater Water Design Manual*, the proposed retrofit would treat the 0.32-inch water quality storm. The proposed bioretention system will capture and filter runoff through layers of bio-engineered media prior to entering an underdrain system and ultimately the drainage ditch that flows to a tributary of Muddy Branch. According to the MDE *Stormwater Management Design Manual*, a 6-inch diameter pipe underdrain is preferred for micro-bioretention facilities; therefore that is what this concept includes.

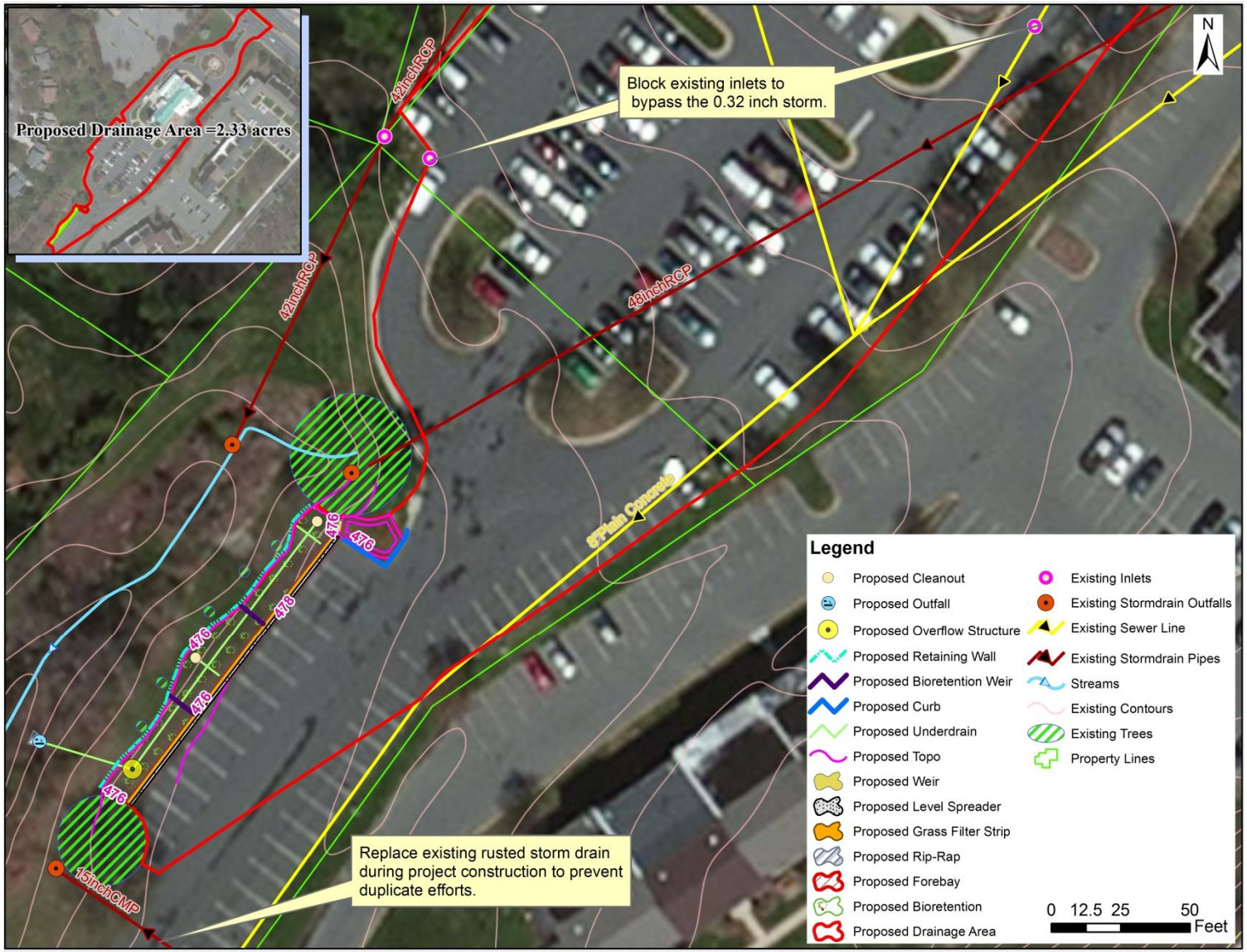


Figure C.2: Proposed Retrofit Concept Design (Casey Community Center)

Other Retrofits Considered

The site location and land use for this area was the prime reason why bioretention was chosen. The parking lot capacity was important to maintain; therefore, it was not possible to have projects that would necessitate removing spaces. Additionally, recent efforts to plant trees along the bank of the drainage ditch limit the available space for the project. The Community Center is rented for various events such as weddings, birthdays, family reunions and business meetings. These details suggested a need for an aesthetically pleasing and inviting practice that would not hinder the active parking lot use. Sand filters were not considered due to aesthetics. Sheet flow to conservation area was considered; however, the dimensions of the available land did not meet MDE standards for this practice. Landscape infiltration was not chosen due to the hydrologic soil group C soils that are unacceptable from MDE standards; however site specific soil tests may show that soils have acceptable infiltration rates for this practice.

Example of a Micro-Bioretention facility

A modification of the proposed design could include using water quality inlet devices for the existing inlets that drain the northern 1.33 acres of the lot; the proposed bioretention cell would then provide water quality treatment for 0.70 inches of the remaining 1.00 acre drainage area. An addition to the proposed design could include a second bioretention cell to the southwest of the proposed cell; this extension would provide additional treatment equating to water quality treatment for approximately 2.0 inches of the additional 0.20 acre drainage area. An optional consideration for the drainage ditch would be to add cross vanes as a channel improvement.

Project Improvements and Benefits: The current site is not designed to provide quantity control or water quality treatment. The proposed bioretention cell would treat the 0.32-inch storm for 2.33 acres if modifications to two existing storm drain inlets are made.

The proposed retrofit would be beneficial to the City in terms of meeting its NPDES Municipal Separate Storm Sewer System (MS4) permit requirements. The permit requires restoration of impervious areas to meet water quality and Total Maximum Daily Load (TMDL) requirements. According to the guidance "Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated" (August, 2014), bioretention facilities are categorized as Runoff Reduction (RR) Practices and the proposed facility will have the following efficiencies based on the treated runoff depth of 0.32 inches:

35 percent for total nitrogen (TN)

40 percent for total phosphorus (TP)

45 percent for Total Suspended Solids (TSS, sediment)

There is currently a TMDL for sediment for the Potomac Watershed in Frederick and Montgomery County. By implementing the proposed project, the treatment efficiency at this location would increase to 45 percent for TSS. Furthermore, sediment, TN, and TP are major pollutants to the Chesapeake Bay. Because runoff that flows into the Muddy Branch flows up to Chesapeake Bay, the proposed retrofit benefits the health of the Chesapeake Bay. Additionally, based on the estimated storage this system would provide, the project would receive credit for 0.55 acre of impervious area treated from MDE.

Project Design Considerations: Several considerations should be taken into account when considering this potential retrofit. To accommodate the design of bioretention to treat curbed flow, the existing curb cut will need to be modified to direct flow to the forebay. No utilities were noted during concept investigation; however, further investigation should be conducted during full design to ensure there are no hidden utilities that would be problematic to design.

Pruning of trees may be required prior to any development to usher the trees roots and limbs in a certain way to prevent problems during bioretention construction. An arborist may be helpful during testing to determine the best way to do this. The design for the cell was prepared in such a way to keep the existing trees, but additional investigation during site testing and project implementation may result in a change to the design or the need to remove/relocate trees.

Due to the existing flow pattern of the site top- grading will be limited, however, a total depth of approximately 4 feet is needed for the bioretention cell, so excavation will be necessary. The engineered planting media in the filter bed should meet the requirements in Appendix B.4.C of the MDE Stormwater Design Manual.

To allow for 1 foot of ponding depth prior to overflow discharge, a yard inlet will be used and would extend 1 foot above the media. Plantings can be specifically located to hide the yard inlets for aesthetics. Plantings should abide by Appendix A.4 of the MDE Stormwater Design Manual.

A retaining wall and two weirs may be included in final design to encourage ponding and prevent interior erosion within the bioretention cell.

Feasibility Assessment

Construction Access: Construction access will be available from the Casey Community Center parking lot. Another access road would be from O'Neill Drive which turns into Nancy Place; however, entry on this side of the project may need to be coordinated with the parcel owner. Equipment can be parked near the facility in the Casey Community Center parking lot overflow area, and traffic can be routed around. The parking lot and proposed area both have slopes that are 5 percent or less, so they should be navigable by equipment. Since the parking lot is City owned, major construction access issues are not anticipated.

Property Ownership: Casey Community Center is owned by the City, therefore no major property ownership issues anticipated. However, if the use of the O'Neill Drive is necessary, appropriate permissions may be required.

Utility Conflicts: There are no sanitary sewer lines or water lines in the project area. Though there were no indicators of underground electric at the project site (no light poles or utility boxes), confirmation should be obtained during detailed design.

Environmental Impacts: Potential tree impacts determined using Google Street view, field reconnaissance, and aerial imagery are anticipated as a potential challenge with this project. The cells were designed to avoid critical tree root mass within the drip line of the tree depending on the size of the tree and associated canopy. In-field testing and implementation will determine actual tree root location and may require modifications to design.

Maintenance Considerations: MDE guidance on the maintenance of stormwater management facilities should be followed in maintaining the proposed bioretention systems. Additionally, Montgomery County has maintenance fact-sheets that allow for quick understanding of the maintenance of these systems.

MDE guidance on the maintenance of stormwater management facilities should be followed for the proposed bioretention areas. Some common maintenance items include, but are not limited to, removing trash and debris at inlet and outlet areas, removing accumulated sediment and invasive species, checking for ponding waters, checking the cleanout pipe, pruning and replacing plants as needed, and replacing mulch annually in the main filter bed.

Plans and Permitting: Several construction documents and plans would need to be obtained to implement a stormwater management retrofit, including, but not limited to:

Plans/Permits	Timeframe	Potential Difficulties
Site/Schematic Development Application	With Concept Review	
Natural Resource Inventory & Forest Stand Delineation	Before Concept Review	
Forest Conservation Plan	Before Concept Review	
Stormwater Management Plan	Before Concept Review	Review agency may request changes in design and could delay approval
Temporary Traffic Control Plan	Before Preliminary Review	
Sediment and Erosion Control Plan	Before Construction	
Grading and Erosion Sediment Control Permit	Before Construction	
Tree Removal Permit	Before Removal	

If the total land disturbance were greater than 1 acre, a NPDES permit application would be needed as well. However, for this project, the total land disturbance is less than 1 acre so a NPDES permit application would not be required.

Funding

Funding for the implementation of stormwater management in the watershed can be achieved from a variety of sources. A Stormwater Utility Fee, currently being used, is a local source of revenue that can help to cover the cost of stormwater management projects in the watershed. Grants and cost-share agreements are additional ways in which to fund projects. Some examples of potential funds could be from:

National Fish and Wildlife Foundation: Chesapeake Bay Small Watershed Grants Program

Chesapeake Bay Trust Grants

EPA Sponsored Grant

MD DNR Watershed Assistance Grants

MDE Stormwater Pollution Control Cost-Share Program

Other opportunities to reduce overall costs of stormwater projects could include the convergence of public outreach with the monitoring and maintenance of facilities. The encouragement for local organizations to monitor stormwater facilities could reduce City staff time and costs and allow the City to maintain awareness of the stormwater facility maintenance needs.

Costs

Table C.1 summarizes the costs associated with this concept design.

Retrofit Concept Calculations

The MDE Stormwater Management Design Manual was used to determine what would be the required environmental site design volume to be treated if this facility was a re-development.

Impervious cover was determined from available GIS data for the given drainage area of the existing stormwater facility. Existing facility drainage areas used were based on the City's most current stormwater drainage area GIS layer.

The filter bed depth was maximized based on the known parameters and limitations of the existing site. Greater background on these calculations is discussed at the end of this appendix.

Table C.1: Estimated Project Costs for Casey Community Center

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL
Concrete Curb and Gutter	35	LF	$12.00	$420
Excavation	229	CY	$25.00	$5,725
Grading	184	SY	$3.50	$646
Gravel Bed	35	CY	$55.00	$1,901
Planting Media	130	CY	$150.00	$19,444
Mulch	13	CY	$30.00	$389
Bioretention Plantings- Trees*	3	EA	$175.00	$544
Bioretention Plantings- Shrubs*	19	EA	$35.00	$681
Bioretention Plantings- Herbaceous Plants*	311	EA	$7.00	$2,178
Rip-Rap	6	CY	$150.00	$878
6-inch perforated PVC underdrains	198	LF	$35.00	$6,930
Cleanout Pipes	2	EA	$120.00	$240
Yard Inlet	1	EA	$3,000.00	$3,000
Retaining Wall	5	CY	$800.00	$3,852
Weirs	1	CY	$800.00	$770
Replace Existing 15-inch CMP pipe	80	LF	$60.00	$4,800
Modification to existing inlets	2	EA	$2,500.00	$5,000

CY = cubic yard
EA = each
LF = linear foot
SY = square yard

Initial Project Costs		$57,398.22
Material Contingency	5%	$2,870
Erosion and Sediment Control	10%	$5,740
Base Construction Costs		$66,008
Mobilization	5%	$33,003.98
Subtotal 1		$99,012
Construction Contingency	15%	$14,852
Subtotal 2		$113,864
Engineering		$51,314
Total		$165,178

***See Maryland Stormwater Design Manual Appendix A for planting lists**

Table C.2: Water Quality Volume (WQv) Calculations

Design Parameters	Site Value
Treated Drainage Area (ac), A	2.33
Percent Impervious Cover, I	79
Rainfall Depth (inches), P	0.32
Volumetric Runoff Coefficient, R_v	0.76
Water Quality Volume (acre-feet), WQ_v	**0.04**
Water Quality Volume (cubic-feet), WQ_v	**1,960**

Table C.3: Bioretention Sizing Calculations

Surface Area of Filter Bed (square-feet)	Coefficient of Permeability of the Filter Media (ft/day), K	Planting Soil Depth (ft). d_f	Average Height of Water above Filter Bed (ft), h_f	Design Filter Bed Drain Time (days), t_f	Water Quality Volume Provided (cf), WQ_v	Rainfall Depth Treated (in)	NPDES Credit Earned (impervious acres)
1,400	0.5	2.5	1	2	1,960	0.32	0.55

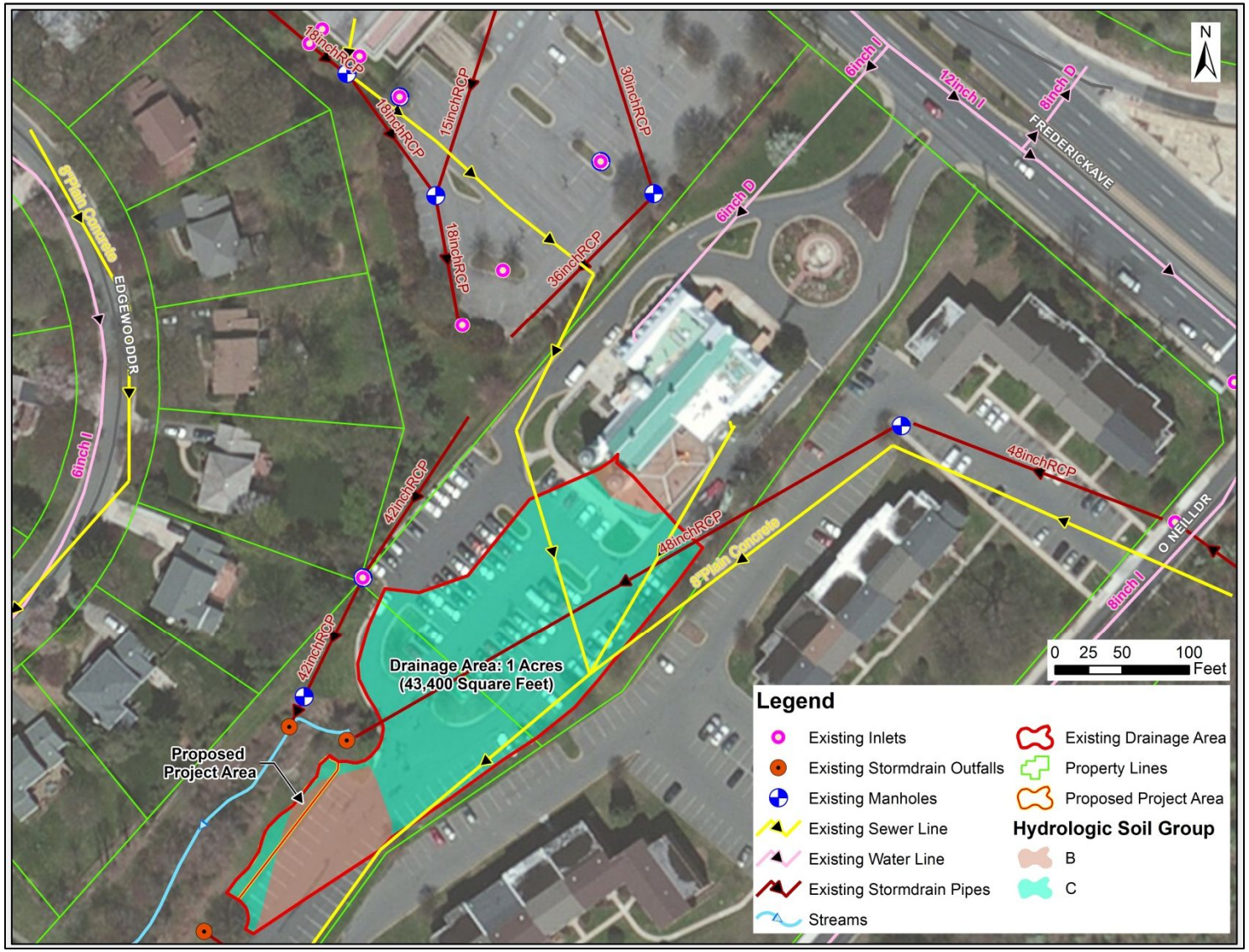
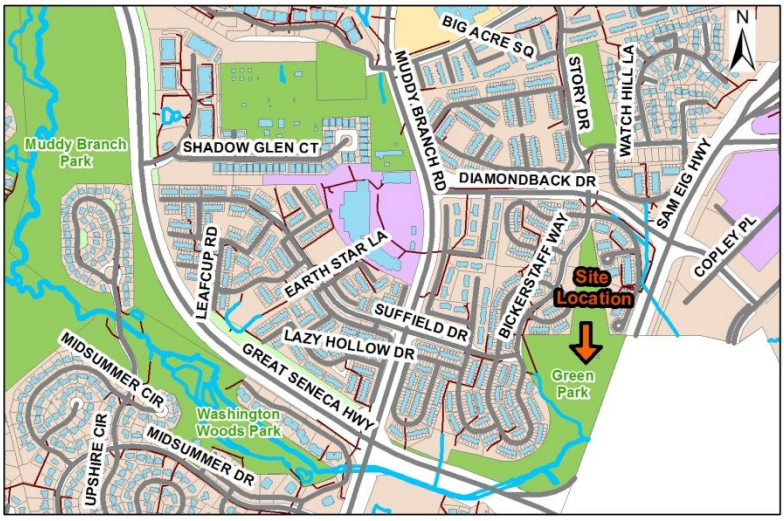


Figure C.3: Soils Map (Casey Community Center)

Green Park Dry Pond Retrofit

Total Drainage Area = 26.35 acres
Total Impervious Area = 8.84 acres (34%)
Treated Drainage Area = 5.0 acres
Total Water Quality Volume (WQ_v): ~33,677 cubic feet, ~0.77 acre-feet
Annual Nutrient Removal:

- TN: ~79 lbs
- TP: ~5 lbs
- TSS: ~3036 lbs



Site Description

The existing dry pond is located in the City owned Green Park in the Hunting Hill neighborhood, east of Curry Ford Lane.

Existing Design:

Green Park is a City owned Park and includes a tot lot, a play area, basketball courts, a tennis court, hiking trails and a dog exercise area. The park can be accessed from Curry Ford Lane, Bickerstaff Way or Holdcroft Lane. The southern portion of the park has a dry pond that was built in 1991 using the 1985 stormwater management regulations. The dry pond has two inlets, a 48-inch corrugated metal pipe (CMP) and a 15-inch reinforced concrete pipe (RCP) that capture runoff from the high density residential area upstream. The 48-inch CMP captures stormwater runoff from rooftops and parking lots of the high density residential areas along Sharpstead Lane, Lamont Lane and Holdcroft Lane. The inlet also captures stormwater runoff from the impervious surfaces in Green Park. The 48-inch CMP is scheduled for maintenance that would include lining the pipe and would be performed along with the proposed retrofit. The 15-inch RCP captures stormwater runoff from a portion of rooftops and parking lots of the high density residential area along Curry Ford Lane. The two inlets capture stormwater runoff from approximately 26.35 acres of drainage area of which 8.84 acres are impervious. The stormwater runoff is conveyed from the inlet to the outlet pipe through a small grass channel. The pond has a large embankment which is approximately 10 feet high. Two trees with more than 24-inch diameter were observed in the rip-rap area in the channel and one tree with more than 24-inch diameter was observed next to the channel. In addition to this, the City identified this site as a potential reforestation area and previously planted trees along both the sides of the channel. Figure C.4 shows the existing site.

Existing Storage:

The existing dry pond was implemented using the 1985 stormwater regulations which were aimed to provide quantity control for stormwater runoff. The facility does not provide any water quality treatment for the stormwater runoff. Also, the facility was implemented prior to 2002, and as a result does not follow the current Maryland stormwater standards.

Soils:

The soils at the site are hydrologic type B and D soils. Approximately 81 percent of the drainage area is occupied by hydrologic type D soils, which have high runoff potential when wetted and very low infiltration rates. These characteristics are due to a high percentage of clay in the soil and often as a result there is high shrink-swell potential. Approximately 19 percent of the drainage area, mainly the park area, is occupied by hydrologic type B soils, which are well drained, have up to 6 inches of silt loam, and can transmit water relatively quickly. Soil tests and infiltration tests to determine the onsite soil characteristics and infiltration rates are recommended to be performed at the site during final engineering design.

Retrofit Goals:

The primary goals for the proposed project are to provide water quality treatment for the rooftop, and parking lot runoff from the upstream high density residential area by converting the dry pond to a bioretention facility. This would also help the City in achieving the National Pollutant Discharge Elimination System (NPDES) credits. Secondary goals of this project were to provide a facility that would be aesthetically pleasing and acceptable in a public area and that would provide stormwater and water quality outreach opportunity for the City.

Figure C.4: Existing Site and Drainage Area (Green Park Dry Pond)

Proposed Project

The proposed site was analyzed for various retrofit options based on its topography and physical parameters. As the site is located in a public area, aesthetically pleasing stormwater management options such as bio-filtering systems were considered a good option. The area south of the pond, next to the embankment, and areas along the banks of the existing channel have been identified as potential reforestation areas by the City, therefore the proposed bioretention will be placed such that the reforestation area is not disturbed.

Existing inlet, trees and newly planted trees in the dry pond

The proposed retrofit at the site includes converting the open area east of the channel to a bioretention facility with underdrains and overflow structure which will provide water quality treatment and volume treatment for the untreated rooftop, parking lot of the residential areas in the drainage area. The bioretention would be designed following the *Maryland Department of Environment (MDE) Stormwater Design Manual* and will treat 1 inch of water quality storm from approximately 5 acres of drainage area of which 1.7 acres are impervious.

Runoff from the existing channel will be diverted to the proposed bioretention facility through a proposed 12-inch polyvinyl chloride (PVC) pipe which will convey design flows to the proposed bioretention. The proposed bioretention will include a pretreatment sediment forebay which will receive the flows from the proposed 12-inch pipe and reduce the amount of sediment entering the bioretention facility. Runoff from sediment forebay will be conveyed to the bioretention facility through a weir which is required to be sized to convey design flows. A rip-rap area will be added downstream of the inlet pipe and weir in the sediment forebay and the bioretention to dissipate energy from concentrated flows.

An underdrain system which will include 6-inch perforated PVC will be implemented in the bioretention system to capture the treated runoff that is filtered through layers of mulch, planting soil and gravel. The treated runoff will be conveyed back to the existing channel through a 15 inch RCP. If the proposed 15-inch RCP cannot convey enough water, excess water will overflow the bioretention area banks and flow back to the existing channel. A rip-rap area over filter cloth will be provided at the outfall to prevent erosion. An overflow structure will be provided in the bioretention system to convey excess flows to the existing channel.

Additionally, based on the MDE guidance, the bioretention will include plants, shrubs and trees that will be planted in the bioretention which will be aesthetically pleasing. Figure C.5 provides the proposed design for the site.

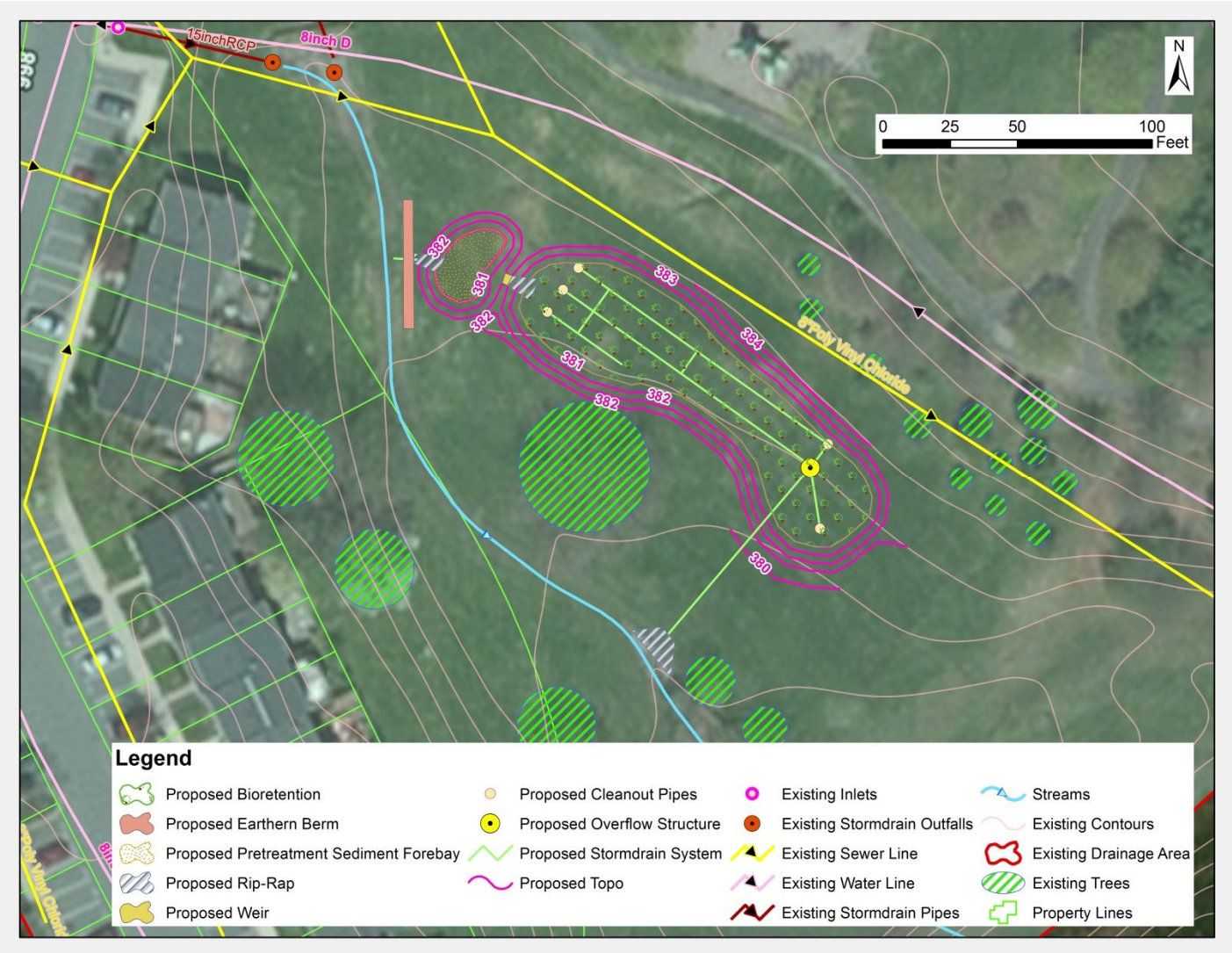


Figure C.5: Proposed Concept Design (Green Park Dry Pond)

Other Retrofits Considered

The location of the site and the surrounding land use were the primary factors that were considered for selecting a bioretention facility at the City. The City was provided a list of potential stormwater management facilities including sand filters that could be implemented at the site. However, aesthetics were considered for selecting the proposed bioretention facility as the site is located in a public park and would be visible to all the park goers and the residents in the neighborhood. Another option at this site would be to rebuild the entire pond by excavating it to the design storage volume including the bottom of the 48-inch CMP; however this option is not considered by the City as it is not cost effective. Retrofitting the pond to an extended detention facility is also not considered as NPDES credits for such retrofits is lower and the City will not be able to achieve quantifiable benefits.

Project Improvements and Benefits:

The existing dry pond was constructed in 1991 using the 1985 stormwater regulations primarily for quantity control and limited quality treatment for the runoff and does not meet the current MDE standards. The proposed bioretention will treat a 1-inch storm from 5 acres of drainage area. Even though the proposed bioretention will not provide water quality treatment for the entire drainage area, it would still provide water quality benefits to 19% of the drainage area.

The proposed retrofit would be beneficial to the City in terms of meeting its NPDES Municipal Separate Storm Sewer System (MS4) permit requirements. The permit requires restoration of impervious areas to meet water quality and Total Maximum Daily Load (TMDL) requirements. According to the guidance "Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated" (August, 2014), bioretention facilities are categorized as Runoff Reduction (RR) Practices and the proposed facility will have the following efficiencies based on the treated runoff depth of 0.2 inches:

26 percent for total nitrogen (TN)

30 percent for total phosphorus (TP)

32 percent for Total Suspended Solids (TSS, sediment)

There is currently a TMDL for sediment for Potomac Watershed in Frederick and Montgomery County. By implementing the proposed project, the treatment efficiency at this location would increase to 32 percent for TSS. Furthermore, sediment, TN, and TP are major pollutants to the Chesapeake Bay. Because runoff that flows into the Muddy Branch flows up to Chesapeake Bay, the proposed retrofit benefits the health of the Chesapeake Bay. Additionally, based on the estimated storage this system would provide, the project would receive credit for 1.7 acre of impervious area treated from MDE.

Project Design Considerations:

Several considerations should be taken into account when considering the proposed bioretention. In order to implement the proposed bioretention facility with pretreatment forebay, excavation

and grading will be required at the project site. A 12-inch PVC pipe is proposed to be implemented at the existing channel to divert the design flows to the pretreatment sediment forebay. Pretreated runoff from the sediment forebay will be conveyed to the bioretention basin through a weir. To avoid erosion and to convey the flows in safe manner, rip-rap is proposed to be placed downstream of both the inlet pipe and the weir. Sewer and water lines are located within 15-20 feet from the project area; however, no impacts are anticipated. No utility conflicts were anticipated during the concept design, however electric, cable and any underground utilities must be investigated during the final design.

Few large trees and newly planted trees by the City are located in the project vicinity; therefore the bioretention concept is designed such that minimal tree impacts occur during project implementation. Additional investigation during site testing and project implementation should be conducted using an arborist to investigate any impacts to large trees in the project area.

Due to the existing drainage pattern of the site, excavation will be required for grading, for the pretreatment sediment forebay as well as for the filter bed depth of 3.5 feet required for the bioretention cell. The engineered planting media in the filter bed should meet the requirements in Appendix B.3.B of the MDE Stormwater Design Manual.

To allow for 1 foot of ponding depth, an overflow structure will be used and would extend 1 foot above the media. Plantings can be specifically located to hide the yard inlet for aesthetics. Plantings should abide by Appendix A.4 of the MDE Stormwater Design Manual, and specifically for this site.

The proposed underdrain system will be connected back to the existing channel using the proposed 15 inch RCP outlet pipe. The existing site drainage pattern will provide adequate grade for the outfall pipe. A rip-rap area is proposed to be provided at the outfall pipe to dissipate erosive velocities.

Feasibility Assessment

Construction Access: Construction access will be available from either Curry Ford Lane or Holdcroft Lane; however, the proposed project site is closer from the park entrance on Curry Ford Lane. The facility has open area on the other side of the channel next to the townhomes, where the equipment can be parked. The open area has slightly steeper slopes of 5-10 percent around the project site, therefore construction equipment that is easily navigable in these slopes is recommended to be used. Since the parking lot is City owned, major construction access issues are not anticipated.

Property Ownership: Green Park is owned by the City, therefore no major property ownership issues anticipated.

Utility Conflicts: There is an existing sewer line owned by the Washington Suburban Sanitary Commission (WSSC) and it runs along the walking path approximately 120 feet from the channel centerline. There is also an existing water line owned by WSSC that runs along the

walking path approximately 150 feet from the channel centerline. The proposed project is graded such that minimal impacts to water and sewer lines are anticipated during project implementation.

Environmental Impacts: Potential tree impacts were evaluated using Google Street view, field reconnaissance, and winter aerial imagery. Two trees with over 24-inch diameter were observed in the channel and one tree with more than 24-inch diameter was observed adjacent to the channel. In addition to this, the City has recently planted trees on either side of the channel as well as south of the park as a part of reforestation efforts. The proposed project is recommended to be graded around the trees such that minimal tree impacts are anticipated. The tree drip line was assumed to be approximately 2-6 feet from the trunk based on tree size and canopy determined from winter aerial imagery.

The project site would be re-graded to provide for storage for the proposed facility. Proposed erosion and sediment control measures should be in place during any proposed grading practices.

Maintenance Considerations: MDE guidance on the maintenance of stormwater management facilities should be followed in maintaining the proposed bioretention system. Additionally, Montgomery County has maintenance fact-sheets that allow for quick understanding of the maintenance of these systems.

Some common maintenance items include, but are not limited to, removing trash and debris at inlets and outlet areas, removing accumulated sediment and invasive species, checking for ponding waters, checking the cleanout pipe, pruning and replacing plants as needed, and replacing mulch annually in the main filter bed.

The existing 48-inch CMP inlet to the pond is failing and as a result lining of the pipe is also recommended as a part of maintenance efforts at the site.

Plans and Permitting: Several construction documents and plans would need to be obtained to implement this project, including, but not limited to:

Plans/Permits	Timeframe	Potential Difficulties
Site/Schematic Development Application	With Concept Review	
Natural Resource Inventory & Forest Stand Delineation	Before Concept Review	
Forest Conservation Plan	Before Concept Review	
Stormwater Management Plan	Before Concept Review	Review agency may request changes in design and could delay approval

Plans/Permits	Timeframe	Potential Difficulties
Temporary Traffic Control Plan	Before Preliminary Review	
Sediment and Erosion Control Plan	Before Construction	
Grading and Erosion Sediment Control Permit	Before Construction	
Tree Removal Permit	Before Removal	

If the total land disturbance were greater than 1 acre, a NPDES permit application would be needed as well. However, for this project, the total land disturbance is less than 1 acre so a NPDES permit application would not be required.

Funding

Funding for the implementation of stormwater management in the watershed can be achieved from a variety of sources. A Stormwater Utility Fee, currently being used, is a local source of revenue that can help to cover the cost of stormwater management projects in the watershed. Grants and cost-share agreements are additional ways in which to fund projects. Some examples of potential funds could be from:

National Fish and Wildlife Foundation: Chesapeake Bay Small Watershed Grants Program

Chesapeake Bay Trust Grants

EPA Sponsored Grants

MD DNR Watershed Assistance Grants

MDE Stormwater Pollution Control Cost-Share Program

Other opportunities to reduce overall costs of stormwater projects could include the convergence of public outreach with the monitoring and maintenance of facilities. The encouragement for local organizations to monitor stormwater facilities could reduce City staff time and costs and allow the City to maintain awareness of the stormwater facility maintenance needs.

Costs

The estimated cost for the Green Park retrofit project includes the proactive cost of lining the existing 48-inch CMP inlet with a 42-inch high-density polyethylene (HDPE) pipe. Table C.4 summarizes the costs associated with this concept design.

Retrofit Concept Calculations

The MDE Stormwater Management Design Manual was used to estimate the design water quality volume to be treated if this facility was a re-development. This is based off the 1-inch 24 rainfall event for the Eastern Rainfall Zone in Maryland. Impervious cover was determined from available GIS data for the given drainage area of the existing stormwater facility. Existing facility drainage provided by the City was modified based on the City provided 2-foot Lidar data and stormdrain system information. The filter bed depth was maximized based on known parameters and limitations of the existing site. Table C.5 and C.6 provide the design calculations.

Table C.4: Estimated Project Costs for Green Park Dry Pond Retrofit

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL
Excavation	620	CY	$25.00	$15,500
Grading	1300	SY	$3.50	$4,550
Gravel Bed	120	CY	$55.00	$6,600
Planting Media	430	CY	$150.00	$64,500
Mulch	50	CY	$30.00	$1,500
Bioretention Plantings- Trees*	10	EA	$175.00	$1,750
Bioretention Plantings- Shrubs*	70	EA	$35.00	$2,450
Bioretention Plantings-Herbaceous Plants*	1020	EA	$7.00	$7,140
Lining of Existing 48-inch CMP with 42-inch HDPE	300	LF	$95.00	$28,500
Sand	10	CY	$40.00	$400
Rip-Rap	10	CY	$150.00	$1,500
12-inch PVC	10	LF	$35.00	$350
15-inch RCP	80	LF	$60.00	$4,800
6-inch perforated PVC underdrains	330	LF	$35.00	$11,550
Cleanout Pipes	4	EA	$120.00	$480
Overflow Structure	1	EA	$3,000.00	$3,000

CY = cubic yard
EA = each
LF = linear foot
SY = square yard

Initial Project Costs		$154,570
Material Contingency	5%	$7,729
Erosion and Sediment Control	10%	$15,457
Base Construction Costs		$177,756
Mobilization	5%	$8,888
Subtotal 1		$186,643
Construction Contingency	15%	$27,996
Subtotal 2		$214,640
Engineering		$65,000
	Total	**$279,640**

***See Maryland Stormwater Design Manual Appendix A for planting lists**

Table C.5: Water Quality Volume (WQ_v) Calculations

Design Parameters	Site Value
Total Drainage Area (ac), A	26.35
Total Percent Impervious Cover, I	34%
Treated Drainage Area (ac)	5.0
Rainfall Depth (inches), P	1.00
Volumetric Runoff Coefficient, R_v	0.35
Total Water Quality Volume (acre-feet), WQ_v	**0.77**
Total Water Quality Volume (cubic-feet), WQ_v	**33,677**
Treated Water Quality Volume (acre-feet), WQ_v	**0.15**
Treated Water Quality Volume (cubic feet), WQ_v	**6,390**

Table C.6: Bioretention Sizing Calculations

Surface Area of Filter Bed (square-feet)	Coefficient of Permeability of the Filter Media (ft/day), K	Planting Soil Depth (ft). d_f	Average Height of Water above Filter Bed (ft), h_f	Design Filter Bed Drain Time (days), t_f	Water Quality Volume Provided (cf), WQ_v	Rainfall Depth Treated (in)	NPDES Credit Earned (impervious acres)
4,565	0.5	2.5	1	2	6,390	0.2	1.70

Figure C.6: Soils Map (Green Park Dry Pond)

Washington Woods Dry Pond Retrofit

Total Drainage Area: 9.8 acres
Area that is Impervious: 3.3 acres
Percent Impervious: 33%
Water Quality Volume (WQ_v): ~4,990 cubic-feet, ~0.114 acre-feet
Annual Nutrient Removal:

- TN: ~47 lbs
- TP: ~3.9 lbs
- TSS: ~1880 lbs

Site Description

The Washington Woods bioretention project is located in the Washingtonian Woods neighborhood, to the east of Upshire Circle adjacent to Muddy Branch.

Existing Site: The existing dry pond was constructed in 1989 and is located entirely on City property. The dry pond is bounded by a private property to the northwest, Upshire Circle to the west, and City owned property on all other directions. The existing dry pond provides water quantity control for approximately 9.8 acres of which 3.3 acres are impervious. The drainage area includes the northern portion of Upshire Circle, houses, grassed lawns, and wooded areas. Runoff is conveyed into the dry pond by a 27-inch reinforced concrete pipe at the northwest corner of that pond that outfalls to riprap inflow protection. Runoff leaves the pond through a vertical 6-inch perforated riser connected to a 6" PVC pipe southwest of the pond that outfalls to Muddy Branch. There is 7-foot wide stone lined overflow channel with 2 to 1 slopes southwest of the pond. Under existing conditions there are four deciduous trees of 12-24 inches diameter on the northwest slope of the facility, and five additional trees northwest of the facility. As a part of concept design, more detailed investigation was conducted to delineate a drainage area which represented existing conditions and as a result it differs from the drainage area reported in the field investigation report. Figure C.1 shows the existing site conditions.

Existing Storage: The existing facility provides water quantity control and channel protection. The facility was implemented prior to 2002, and as a result does not follow the current Maryland stormwater standards. To qualify for water quality control the facility would need to be rebuilt to the current MDE standards.

Soils: The soils at the site are hydrologic type B and D soils. Approximately 94 percent of the drainage area is occupied by hydrologic type B soils, which are well drained, have up to 6 inches of silt loam, and can transmit water relatively quickly. Approximately 6 percent of the drainage area (including the entire area of the existing dry pond and proposed retrofit) is occupied by hydrologic type D soils, which have high runoff potential when wetted and very low infiltration

rates. These characteristics are due to a high percentage of clay in the soil, and there is often high shrink-swell potential as a result. Soil tests and infiltration tests to determine the onsite soil characteristics and infiltration rates are recommended to be performed at the site during final engineering design.

Retrofit Goals: The primary goals for the proposed project were to rebuild the stormwater management facility to meet current MDE standards to provide the most water quality benefits possible by reducing pollutants, thereby attaining NPDES credits, while limiting grading and maintaining existing land use. Secondary goals of the proposed project were to provide facilities that would have community acceptance by being aesthetically pleasing, while providing water quality benefits.

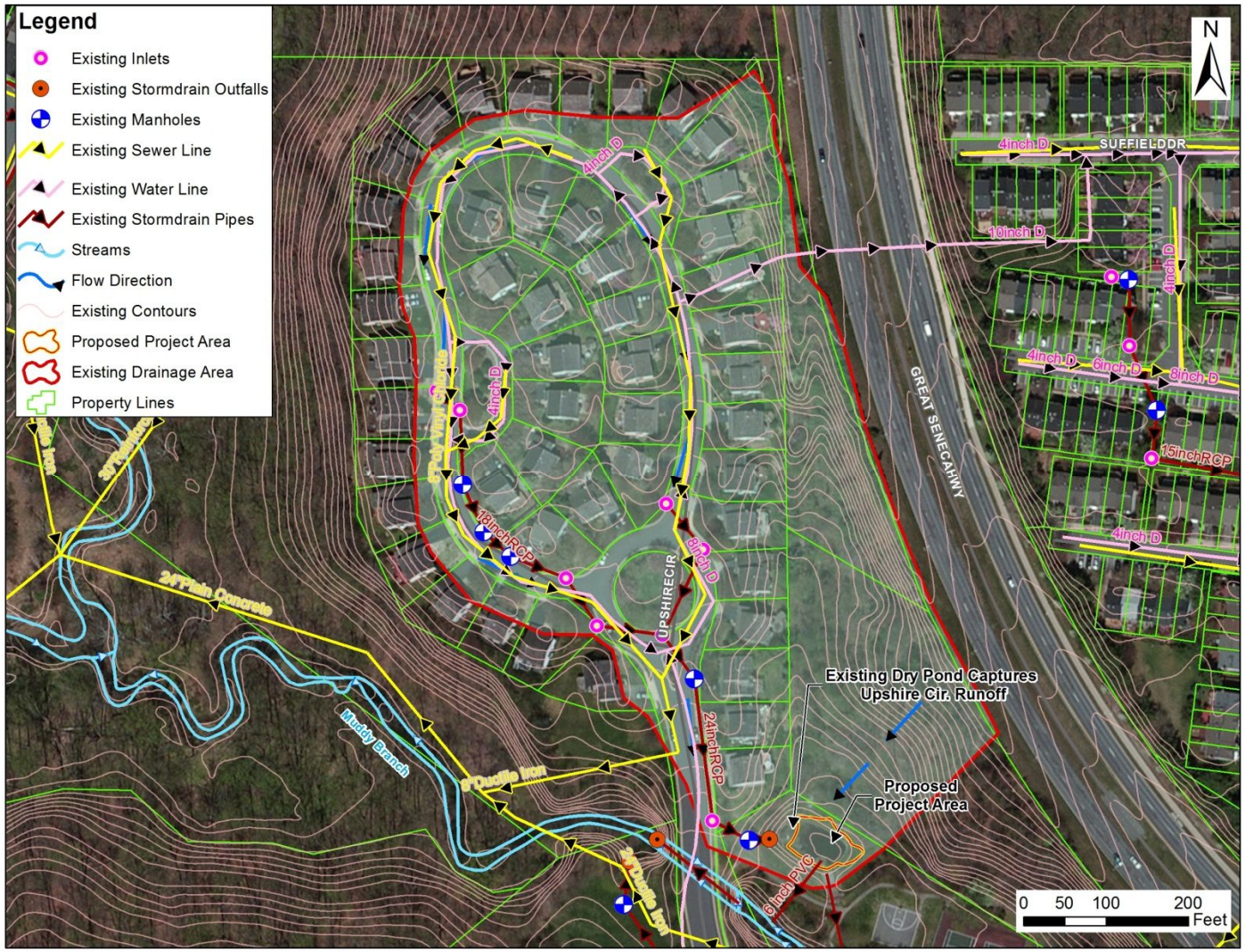


Figure C.7: Existing Site and Drainage Area (Washington Woods Dry Pond)

Proposed Retrofit

Based on the physical parameters of the site, and the objective to provide water quality treatment, a bioretention system is proposed. The bioretention system would capture runoff from the existing 27-inch CMP pipe on the northwest side of the site and treat it for water quality before it flows into Muddy Branch. The proposed bioretention system would include a pretreatment sediment forebay practice to reduce sedimentation in the bioretention facility. An underdrain system would also be provided to drain treated water to the existing 6-inch PVC pipe. The existing PVC riser would be removed and replaced by a yard inlet, while the only change made to the existing overflow structure would be the removal of the existing gabions to avoid water flowing through the side of the facility. The proposed design would require excavation to expand the existing dry pond banks outward to increase the water quality volume.

The City prefers to avoid negative impacts to existing trees if possible. The existing dry pond is surrounded by trees, so the available space for construction is limited. As a result the practice cannot capture and treat the water quality volume generated from the entire site. Following the bioretention system design criteria provided in the MDE *Stormwater Management Design Manual* the proposed bioretention system will capture and treat 0.4-inch of water quality storm from approximately 9.8 acres of drainage area. Typically the maximum drainage area recommended for bioretention facilities is 5 acres, although the drainage area can be larger in some instances. Only 3.3 impervious acres would be treated by this facility, so the increased area is deemed to be reasonable. Verification will be required from MDE during final design; otherwise the flow could be split into two separate facilities. The proposed bioretention would be in-line due to space constraints and aesthetics.

Bio-filtering practices include plants and shrubs; implementation of these practices would be aesthetically pleasing and would provide water quality treatment that otherwise does not exist at this site. To meet city preferences a minimum 2-inch tree diameter is recommended, with trees placed toward the edge of the bioretention away from inlets, outlets, and off the slope. Plants, shrubs, and trees will be selected based on the MDE *Stormwater Management Design Manual.*

Existing Dry Pond at Washington Woods

The proposed bioretention would capture and treat impervious runoff from the roadway and treat it through a filter bed of planting media. Plants will provide pollutant uptake capacity to remove pollutants from stormwater. Figure C.8 shows the proposed concept design.

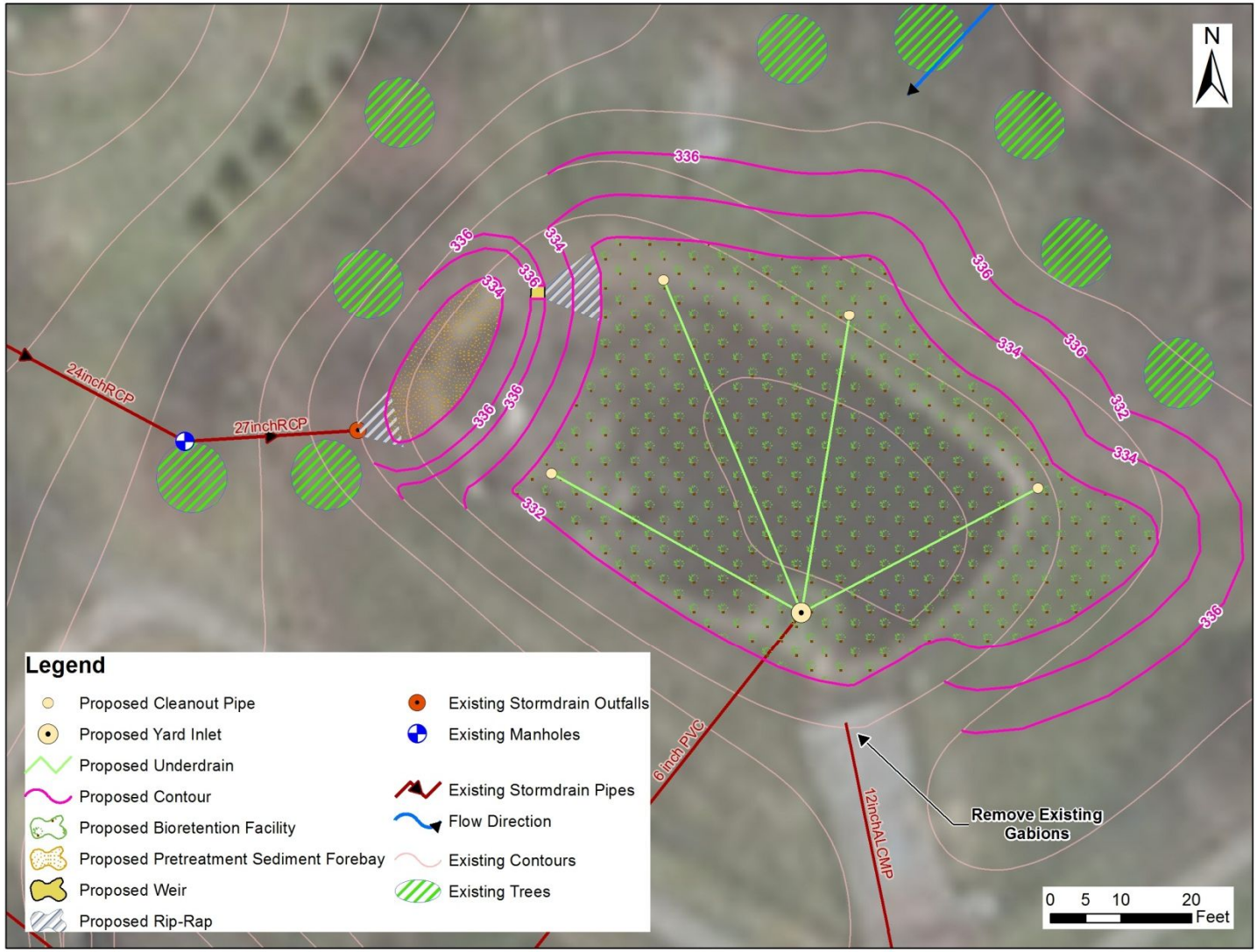


Figure C.8: Proposed Retrofit Concept Design (Washington Woods Dry Pond)

Other Retrofits Considered

The site location and land use for this area was the primary reason bioretention was selected. The existing dry pond is bounded by trees and Upshire Circle so the site footprint could not be changed substantially. Additionally, there are walking paths to the south of the site that make it an area of high visibility. These details suggested a need for an aesthetically pleasing and inviting practice that would not hinder access to Washington Woods Park. Sand filters were not considered due to aesthetics, and ESD (e.g., micro-bioretention) were not considered due to the drainage area of the site.

Project Improvements and Benefits: The existing dry pond was constructed in 1989 for water quantity control and limited water quality treatment. The water quality treatment does not meet the specifications of the current MDE Stormwater Design Manual. The proposed bioretention would increase the current storage capacity of the dry pond, and would treat a 0.4-inch storm. This would provide water quality benefits that equate to approximately 40% of the impervious drainage area.

Example of a Bioretention Facility

There has been sedimentation buildup within the existing dry pond since it was constructed. The proposed sediment forebay will intercept the majority of the sediment that would otherwise enter the bioretention facility.

The proposed retrofit would be beneficial to the City in terms of meeting its NPDES Municipal Separate Storm Sewer System (MS4) permit requirements. This permit requires restoration of impervious area to meet water quality and Total Maximum Daily Load (TMDL) requirements. According to the guidance "Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated" published by MDE, a bioretention facility that treats 0.4-inch storm has treatment efficiencies of:

39 percent for total nitrogen (TN)

46 percent for total phosphorus (TP)

50 percent for Total Suspended Solids (TSS, sediment)

There is currently a TMDL for sediment in the Muddy Branch Watershed. By implementing the proposed retrofit, the treatment efficiency at this location would increase to 50 percent for TSS. Furthermore, sediment, TN, and TP are major pollutants to the Chesapeake Bay. Because runoff that flows into the Muddy Branch Watershed flows to the Chesapeake Bay, the proposed retrofit

benefits the health of the Bay. Additionally, the project would receive credit for 1.3 acres of impervious area treated from MDE.

Project Design Considerations: Several considerations should be taken into account when considering this potential retrofit.

Pruning of trees may be required prior to any development to usher the trees roots and limbs in a certain way to prevent problems during bioretention construction. An arborist may be helpful during testing to determine the best way to do this. The design for the bioretention cell was prepared in such a way to keep the existing trees, but additional investigation during site testing and project implementation may result in a change to the design or the need to remove/relocate trees.

To connect the bioretention underdrain to the existing low flow PVC drain pipe, the existing perforated PVC riser pipe will need to be removed. The proposed underdrain systems will be connected to the existing stormwater pipe to allow the treated runoff an outlet at the Muddy Branch. From existing as-built drawings the invert of the pipe is at approximately 0.5 feet above the surface of the proposed bioretention facility. Information on this pipe was not included in GIS data, and therefore some adjustments to the design may be necessary based on actual depth and slopes.

To prevent sediment build-up in the sediment forebay the invert of the 27-inch pipe should be higher than the weir elevation. Field verification of the invert elevation will be required at the site during final engineering design.

Due to the existing flow pattern of the site top-grading will be required on the east side of the facility. Excavation will be required for this grading, as well as for the filter bed depth of 3.5 feet required for the bioretention cell. Some of the excavated soil will be used to construct the sediment forebay. The engineered planting media in the filter bed should meet the requirements in Appendix B.4.C of the MDE Stormwater Design Manual.

To allow for 1 foot of ponding depth, a yard inlet will be used and would extend 1 foot above the media. Plantings can be specifically located to hide the yard inlet for aesthetics. Plantings should abide by Appendix A.4 of the MDE Stormwater Design Manual, and specifically for this site, include evergreens.

Feasibility Assessment

Construction Access: Construction access will be available from Upshire Circle. Equipment can be parked near the proposed bioretention cell on City land. There are slopes that are 5% or less toward the southwest of the pond near the existing walking paths. Since the property is City owned, major construction access issues are not anticipated.

Property Ownership: The project area is owned by the City.

Utility Conflicts: According to GIS, there are no sanitary sewer lines or water lines in the vicinity of the project. Although there was no evidence of underground electric lines it is possible that they could be present, and this will be confirmed during detailed design.

Environmental Impacts: Potential tree impacts determined using Google Street view, field reconnaissance, and aerial imagery, are anticipated as a potential challenge with this project. The cell and all earthwork were designed to avoid critical tree root mass within 2-6 feet around the trunk depending on the size of the tree and associated canopy. Approximate canopy coverage was determined using winter aerial imagery. In-field testing and implementation will determine actual tree root location and may require modifications to design. It may be beneficial to have an arborist prune tree limbs and/or roots in preparation far in advance of the implementation of the bioretention cell design to avoid any severe impacts on trees.

Maintenance Considerations: MDE guidance on the maintenance of stormwater management facilities should be followed in maintaining the proposed bioretention. Additionally, Montgomery County has maintenance fact-sheets that allow for quick understanding of the maintenance of this system.

Some common maintenance items include, but are not limited to, removing trash and debris at inlet and outlet areas, removing accumulated sediment and invasive species, checking for ponding waters, checking the cleanout pipes, pruning and replacing plants as needed, and replacing mulch annually.

Plans and Permitting: Several construction documents and plans would need to be obtained to implement a stormwater management retrofit, including, but not limited to:

Plans/Permits	Timeframe	Potential Difficulties
Site/Schematic Development Application	With Concept Review	
Natural Resource Inventory & Forest Stand Delineation	Before Concept Review	
Forest Conservation Plan	Before Concept Review	
Stormwater Management Plan	Before Concept Review	Review agency may request changes in design and could delay approval
Temporary Traffic Control Plan	Before Preliminary Review	
Sediment and Erosion Control Plan	Before Construction	
Grading and Erosion Sediment Control Permit	Before Construction	
Tree Removal Permit	Before Removal	

Total land disturbance is estimated to be less than 1 acre and therefore, an NPDES permit application will not be needed.

Funding

Funding for the implementation of stormwater management in the watershed can be achieved from a variety of sources. A Stormwater Utility Fee, currently being used, is a local source of revenue that can help to cover the cost of stormwater management projects in the watershed. Grants and cost-share agreements are additional ways in which to fund projects. Some examples of potential funds could be from:

National Fish and Wildlife Foundation: Chesapeake Bay Small Watershed Grants Program

Chesapeake Bay Trust Grants

EPA Sponsored Grants

MD DNR Watershed Assistance Grants

MDE Stormwater Pollution Control Cost-Share Program

Other opportunities to reduce overall costs of stormwater projects could include the convergence of public outreach with the monitoring and maintenance of facilities. The encouragement for local organizations to monitor stormwater facilities could reduce City staff time and costs and allow the City to maintain awareness of the stormwater facility maintenance needs.

Costs

Table C.7 summarizes the costs associated with this concept design.

Retrofit Concept Calculations

The MDE Stormwater Management Design Manual was used to determine the design water quality volume to be treated if this facility was a re-development.

Impervious cover was determined from available GIS data for the given drainage area of the existing stormwater facility. Existing facility drainage areas used were based on the City's most current stormwater drainage area GIS layer.

The filter bed depth was maximized based on the known parameters and limitations of the existing site. Greater background on these calculations is discussed at the end of this appendix.

Table C.7: Estimated Project Costs for Washington Woods Dry Pond

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL
Excavation	880	CY	$25.00	$22,000
Removal of existing Riser	10	LF	$20.00	$200
Grading	730	SY	$3.50	$2,555
Gravel Bed	90	CY	$55.00	$4,950
Planting Material	330	CY	$150.00	$49,466
Mulch	40	CY	$30.00	$1,200
Bioretention Plantings- Trees*	10	EA	$175.00	$1,750
Bioretention Plantings- Shrubs*	50	EA	$35.00	$1,750
Bioretention Plantings-Herbaceous Plants*	800	EA	$7.00	$5,600
RipRap	10	CY	$150.00	$1,500
6-inch perforated PVC underdrains	180	LF	$35.00	$6,300
Cleanout Pipes	4	EA	$120.00	$480
Yard Inlet	1	EA	$3,000.00	$3,000
CY = cubic yard EA = each LF = linear foot SY = square yard	Initial Project Costs			$100,751
	Material Contingency		5%	$5,038
	Erosion and Sediment Control		10%	$10,425
	Base Construction Costs			$119,889
	Mobilization		5%	$5,793
		Subtotal 1		$121,657
	Construction Contingency		15%	$18,249
		Subtotal 2		$139,905
	Engineering			$61,000
			Total	**$200,905**

***See Maryland Stormwater Design Manual Appendix A for planting lists**

Table C.8: WQ_V Volume Calculations

Design Parameters	Site Value
Drainage Area (ac), A	9.8
Percent Impervious Cover, I	33%
Rainfall Depth (inches), P	0.4
Volumetric Runoff Coefficient, R_v	0.35
Ponding Depth (ft)	1.0
Water Quality Volume (acre-feet), WQ_v	**0.11**
Water Quality Volume (cubic-feet), WQ_v	**4,990**

Table C.9: Bioretention Cell Sizing Calculations

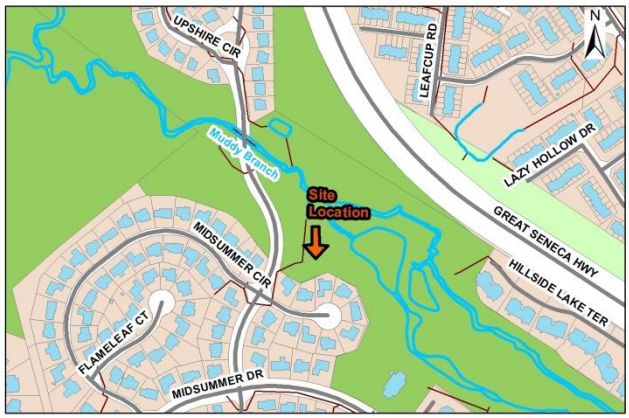
Surface Area of Filter Bed (square-feet)	Coefficient of Permeability of the Filter Media (ft/day), K	Surface Area of Filter Bed (square-feet)	Planting Soil Depth (ft)	Average Height of Water above Filter Bed (ft)	Design Filter Bed Drain Time (days)	Water Quality Volume Provided (cf), WQv	Rainfall Depth Treated (in)	NPDES Credit Earned (impervious acres)
3,562	0.4	3,562	2.5	1	2	4,990	0.4	1.3

Figure C.9: Soils Map (Washington Woods Dry Pond)

Washington Woods Park Bioretention

Total Drainage Area: 2.8 acres
Area that is Impervious: 1.1 acres
Percent Impervious: 40%
Water Quality Volume (WQv): 0.1 ac-ft
Annual Nutrient Removal:

- TN: ~20 lbs
- TP: ~1.7 lbs
- TSS: ~860 lbs



Site Description

The Washington Woods Park bioretention project is located just north of Midsummer Court between Upshire Circle and Muddy Branch.

Existing Site: The area where the project is proposed is owned by the City, and contains an open grassed area that currently has no specific use, but is part of Washington Woods Park. The site is located south of the existing Washington Woods park playground at 314 Upshire Circle.

Existing Open Space at Washington Woods Park

Existing storm drains that were installed in the 1980s and 1990s collect runoff from residential areas to the south and west, including runoff from Upshire Circle and Midsummer Court. The storm drains outfall to a tributary of Muddy Branch. Runoff from the north of Midsummer Court residential area flows to this area as sheet flow, before concentrating and entering an existing grate inlet located in the open space. Runoff from Upshire Circle flows into a curb inlet on Upshire Circle, and runoff from the southern portion of Midsummer Court flows into a curb inlet on Midsummer Court. There is a 21-inch RCP pipe between the two curb inlets and another between the Upshire Circle curb inlet and the grate inlet. There is a 24-inch RCP from the grate inlet to the outfall. The targeted drainage area for this concept design is focused on the runoff from the Midsummer Court residential area, as well as runoff at the intersection of Upshire Circle and Midsummer Court. Runoff from this drainage area would still outfall to the tributary of Muddy Branch via the 24-inch RCP pipe. The drainage area is approximately 2.8 acres including 1.1 impervious

acres. Several trees are located north of the residential area and east of Upshire Circle. Figure C.10 shows the existing site.

Existing Storage: The majority of stormwater runoff from Upshire Circle and Midsummer Court is directly conveyed to the existing storm drain system without any treatment for either quality or quantity. Sheet flow from northern Midsummer Court flows over a grass filter strip prior to entering the storm drain system offering some water quality treatment.

Soils: The soils at the facility and the drainage area are all hydrologic soil group B which are well drained, have up to 6 inches of silt loam, and can transmit water relatively quickly. Soil tests and infiltration tests to determine the onsite soil characteristics and infiltration rates are recommended to be performed at the site during final engineering design.

Retrofit Goals: The primary goals for the proposed new retrofit were to provide the most water quality benefits possible by reducing pollutants, thereby attaining NPDES credits, while limiting grading and maintaining existing land use. Secondary goals were to provide a facility that would have community acceptance and provide outreach. Aesthetics and location of the facility were taken into consideration for design type for the secondary goals.

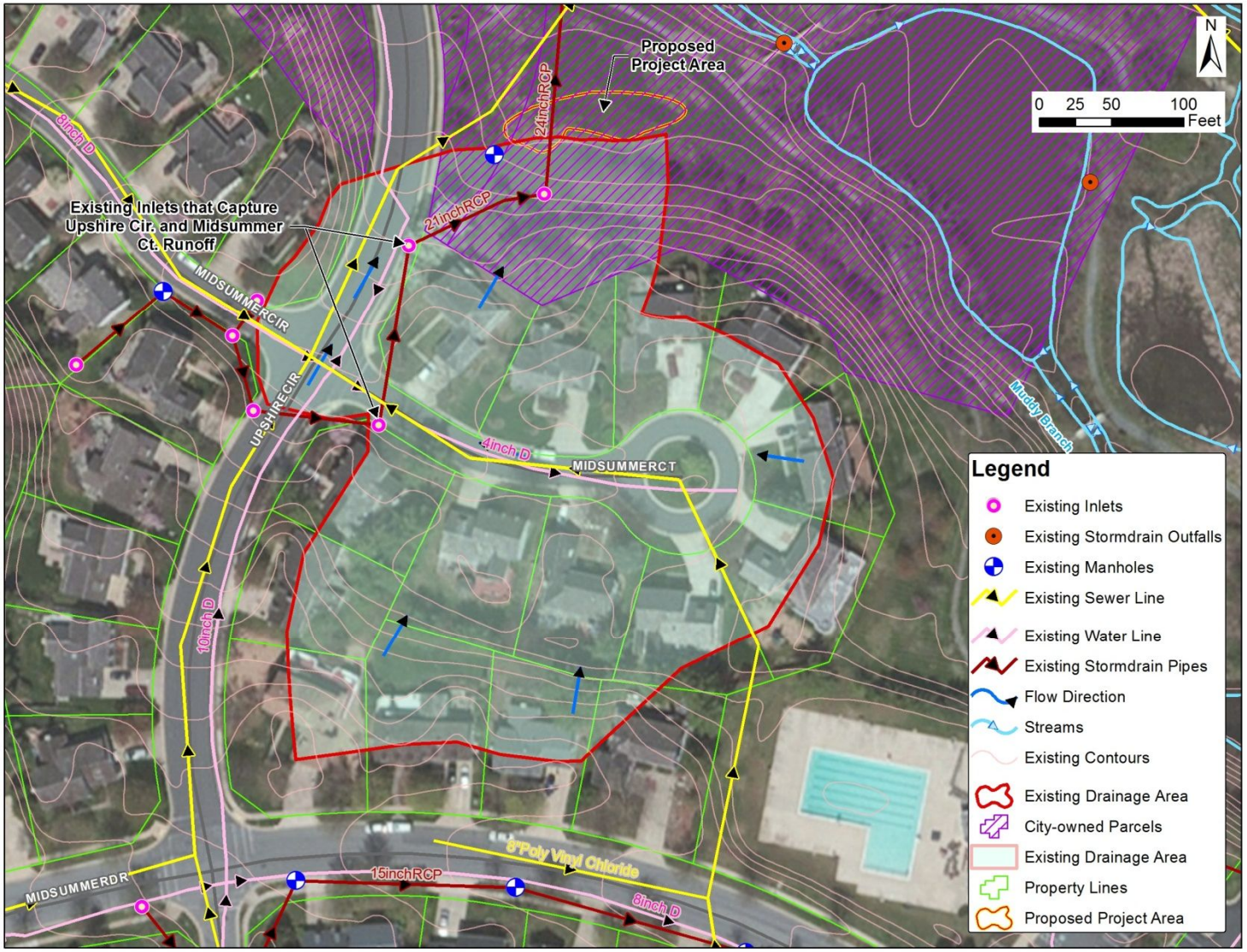


Figure C.10: Existing Site and Drainage Area (Washington Woods Park)

Proposed Retrofit

The proposed site was analyzed for various retrofit options based on its topography and physical parameters. Since the site is in a public area, adding a filtering system would be aesthetically pleasing, would provide water quality treatment for runoff, and would provide the City more NPDES credits than other options. The proposed retrofit at the site includes converting open space where runoff from Midsummer Court previously congregated to a bioretention cell with an underdrain system and yard inlet.

The existing area will need to be modified to implement the proposed bioretention cell. The modifications include blocking two existing stormwater inlets (ID 562 and 447) from receiving runoff. The road is already graded towards the proposed projects.

The bioretention cell will require a curb cut along the east side of Upshire Circle. Due to the location of the sidewalk immediately adjacent to the road, a curb cut will need to be modified to remove several blocks of the existing sidewalk and replace it with a sidewalk inlet. A stone diaphragm is to be placed underneath the sidewalk inlet with at least 1-foot available for surface flow. The stone diaphragm would transition to the filter strip elevation (at least 3-inches below the stone diaphragm level). The stone diaphragm will disperse the flow to the grassed slope and then to the proposed bioretention cell. These pretreatment techniques will dissipate the concentrated runoff from the road and allow for settling of pollutants prior to contact with the filter bed. The existing grate inlet will be raised if necessary to provide overflow to the existing storm drain system and will be connected to an underdrain that will allow the collection of filtered water to enter the existing 24-inch RCP pipe. According to the MDE *Stormwater Management Design Manual*, a 6-inch diameter pipe underdrain is preferred for bioretention facilities; therefore that is what this concept includes.

Example of a Sidewalk Inlet at Quince Orchard Boulevard

Bio-filtering practices include plants and shrubs; implementation of these practices would be aesthetically pleasing and would provide water quality treatment that otherwise does not exist at this site. To meet City preferences a minimum 2-inch tree diameter is recommended, with trees placed toward the edge of the bioretention away from inlets, outlets, and off the slope. Plants, shrubs, and trees will be selected based on the MDE *Stormwater Management Design Manual.*

The proposed bioretention cell would treat the 1-inch storm and Figure C.11 shows the proposed improvements for the Washington Woods Park site.

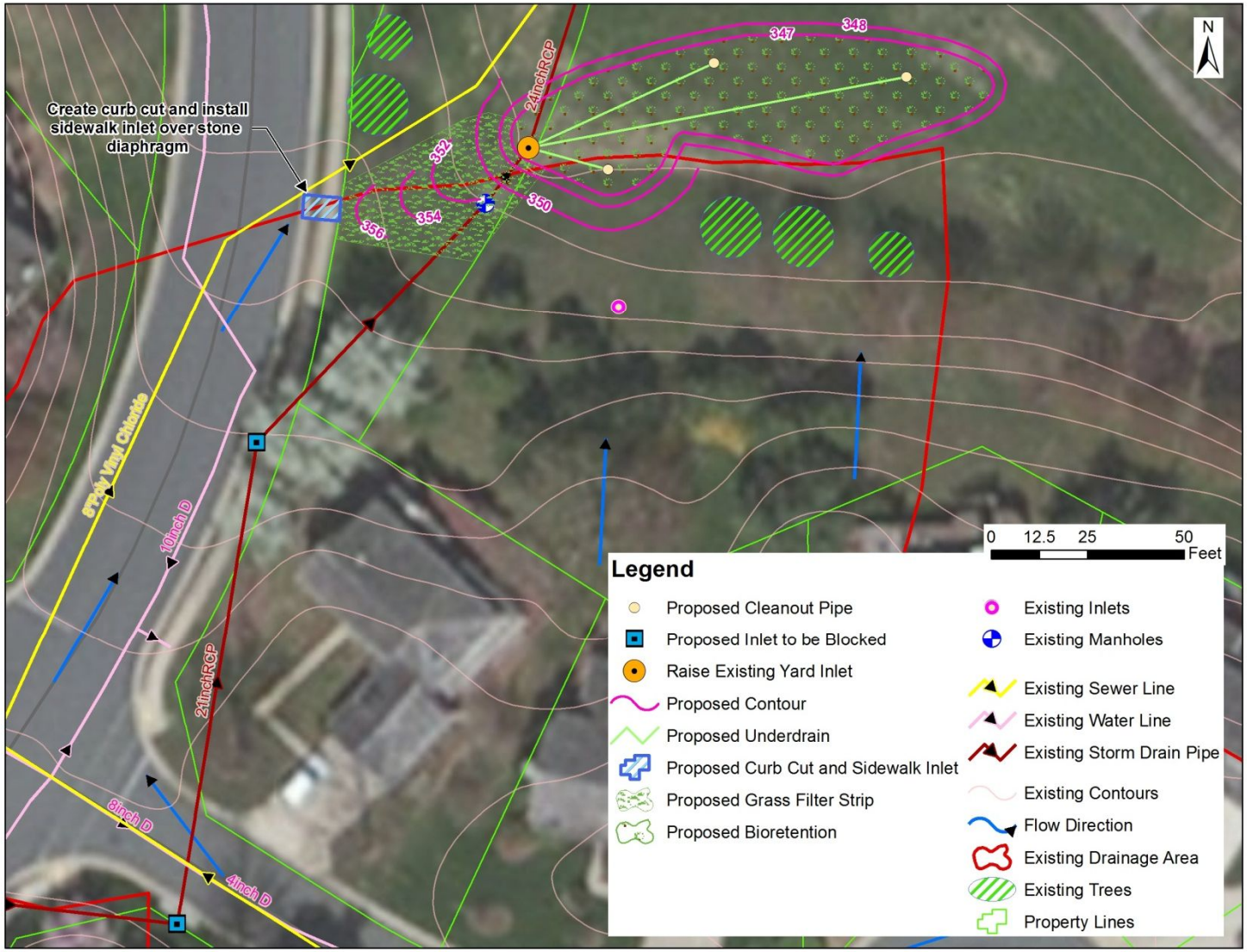


Figure C.11: Proposed Concept Design (Washington Woods Park)

Other Retrofits Considered

The site location, land use, and potential nutrient reductions were the prime reasons why bioretention was chosen. ESD was also considered (bio-swale), although the City preferred to include a larger drainage area by blocking two inlets, resulting in a drainage area that exceeded ESD limits. The bioretention design treats stormwater in a specific location and preserves open space. An aesthetically appealing practice was preferred at this site since the practice will be visible from Upshire Circle and the Washington Woods Park playground. By placing an attractive bioretention cell next to open recreational area, a simple opportunity to provide outreach (with a signpost) is provided.

Project Improvements and Benefits: The current roadway stormwater infrastructure is not designed to provide quantity control or water quality treatment for the runoff from Upshire Circle and Midsummer Court. Sheet flow from northern Midsummer Court flows over a grass filter strip prior to entering the storm drain system offering some water quality treatment. The proposed bioretention cells would treat the 1-inch storm. This would provide water quality benefits that equate to the entire impervious drainage area.

The proposed retrofit would be beneficial to the City in terms of meeting its NPDES Municipal Separate Storm Sewer System (MS4) permit requirements. This permit requires restoration of impervious area to meet water quality and Total Maximum Daily Load (TMDL) requirements. According to the guidance "Accounting for Stormwater Wasteload Allocations and Impervious Acres Treated" published by MDE, a bioretention facility that treats 1-inch storm has treatment efficiencies of:

57 percent for total nitrogen (TN)

66 percent for total phosphorus (TP)

70 percent for Total Suspended Solids (TSS, sediment)

There is currently a TMDL for sediment in the Muddy Branch Watershed. By implementing the proposed retrofit, the treatment efficiency at this location would increase to 70 percent for TSS. Furthermore, sediment, TN, and TP are major pollutants to the Chesapeake Bay. Because runoff that flows into the Muddy Branch Watershed flows to the Chesapeake Bay, the proposed retrofit benefits the health of the Bay. Additionally, the project would receive credit for 1.1 acres of impervious area treated from MDE.

Project Design Considerations: Several considerations should be taken into account when considering this potential retrofit. To accommodate the design of bioretention to treat road runoff, a section of the existing sidewalk needs to be removed; replaced by modified curb cuts, and stormwater inlet upland will need to be blocked off from runoff flow. Additionally, protection of an existing light post may be needed. There is an existing sewer line north of the proposed facility that would not be impacted by construction. No other utilities were noted during concept investigation, however, electric or cable should be investigated further during final design.

The proposed underdrain systems will be connected to an existing grate inlet that outfalls to a tributary of Muddy Branch. To allow for 1 foot of ponding depth, the existing grate inlet may need a riser installed over it so the inlet is effectively elevated 1 foot above the media. Plantings can be specifically located to hide the inlet for aesthetics. Plantings should abide by Appendix A.4 of the MDE Stormwater Design Manual, and include a mix of deciduous and evergreen shrubs, and the City specifies a minimum 2-inch tree diameter, with trees placed toward the edge of the bioretention. Other planting considerations should include salt-tolerant species due to winter road salting.

Due to the existing flow pattern of the site, top- grading will be limited; however, a filter bed depth of 2.5 feet is needed for the bioretention cell so excavation will be necessary. The engineered media in the filter bed should meet the requirements in Appendix B.4.C of the MDE Stormwater Design Manual.

Blocking existing inlets presents several challenges that will need to be considered during final design. Detailed survey will be required to verify that runoff would not pond by the existing inlets, and to verify that the runoff previously intercepted by those inlets would be expected to flow toward the proposed inlet. A detailed hydraulic analysis would also be required to verify that the quantity of water would not inundate the Upshire Circle, and to size the proposed inlet. A trench drain in the roadway may be required to intercept the additional sheet flow from the two blocked inlets. A trench drain would also improve maintenance access, as sediment and debris could be removed directly from the trench drain, instead of from over the stone diaphragm; however, it would require more construction within the roadway, and would be more costly.

Feasibility Assessment

Construction Access: Construction access will be available from Upshire Circle. Equipment can be parked near the proposed bioretention cell on City land, or on the eastern edge of Upshire Circle. The slopes from Upshire Circle to the proposed site range from 10% to 15%, although the slope in the construction area is less than 5%. Since the property is City owned, major construction access issues are not anticipated.

Property Ownership: The project area is owned by the City and construction access should not be problematic.

Utility Conflicts: There are no sanitary sewer lines or water lines deemed to be problematic with project activities. Existing water lines are on the west bound lane of Upshire Circle, while sewer lines are located north of the proposed bioretention. There is a light post located adjacent to the sidewalk that will need to be planned around or relocated. Concept design was done to avoid these areas but locations should be confirmed during final design. There could possibly be underground electric lines, which should be confirmed during final design. Based on Google Street view, field reconnaissance, and aerial imagery, the location of the storm drain system east of Upshire Circle in the City GIS did not match existing site conditions. The locations of the existing storm drain pipe and grate-inlet have been modified from City data for this concept design to agree with site conditions.

Existing light post east of Upshire Circle

Environmental Impacts: Potential tree impacts determined using Google Street view, field reconnaissance, and aerial imagery, may be a potential challenge with this project toward the southern limit of the proposed bioretention. The location of the proposed bioretention was selected as a compromise between avoiding tree impacts, and lying within the existing concentrated flow path from Midsummer Court. The cell and all earthwork were designed to avoid critical tree root mass within 2-6 feet around the trunk depending on the size of the tree and associated canopy. Approximate canopy coverage was determined using winter aerial imagery. In-field testing and implementation will determine actual tree root location and may require modifications to design. It may be beneficial to have an arborist prune tree limbs and/or roots in preparation far in advance of the implementation of the bioretention cell design to avoid any severe impacts on trees.

Maintenance Considerations: MDE guidance on the maintenance of stormwater management facilities should be followed in maintaining the proposed bioretention. Additionally, Montgomery County has maintenance fact-sheets that allow for quick understanding of the maintenance of this system.

Some common maintenance items include, but are not limited to, removing trash and debris at inlet and outlet areas, removing accumulated sediment and invasive species, checking for ponding waters, checking the cleanout pipes, pruning and replacing plants as needed, and replacing mulch annually.

Plans and Permitting: Several construction documents and plans would need to be obtained to implement a stormwater management retrofit, including, but not limited to:

Plans/Permits	Timeframe	Potential Difficulties
Site/Schematic Development Application	With Concept Review	
Natural Resource Inventory & Forest Stand Delineation	Before Concept Review	
Forest Conservation Plan	Before Concept Review	
Stormwater Management Plan	Before Concept Review	Review agency may request changes in design and could delay approval
Temporary Traffic Control Plan	Before Preliminary Review	
Sediment and Erosion Control Plan	Before Construction	
Grading and Erosion Sediment Control Permit	Before Construction	
Tree Removal Permit	Before Removal	

Total land disturbance is estimated to be less than 1 acre and therefore, an NPDES permit application will not be needed.

Funding

Funding for the implementation of stormwater management in the watershed can be achieved from a variety of sources. A Stormwater Utility Fee, currently being used, is a local source of revenue that can help to cover the cost of stormwater management projects in the watershed. Grants and cost-share agreements are additional ways in which to fund projects. Some examples of potential funds could be from:

National Fish and Wildlife Foundation: Chesapeake Bay Small Watershed Grants Program

Chesapeake Bay Trust Grants

EPA Sponsored Grants

MD DNR Watershed Assistance Grants

MDE Stormwater Pollution Control Cost-Share Program

Other opportunities to reduce overall costs of stormwater projects could include the convergence of public outreach with the monitoring and maintenance of facilities. The encouragement for local organizations to monitor stormwater facilities could reduce City staff time and costs and allow the City to maintain awareness of the stormwater facility maintenance needs.

Costs

Table C.10 summarizes the costs associated with this concept design.

Retrofit Concept Calculations

The MDE Stormwater Management Design Manual was used to determine the design water quality volume to be treated if this facility was a re-development.

Impervious cover was determined from available GIS data for the given drainage area of the existing stormwater facility. Existing facility drainage areas used were based on the City's most current stormwater drainage area GIS layer.

The filter bed depth was maximized based on the known parameters and limitations of the existing site.

Table C.11 and Table C.12 display the calculated and design values for the water quality volume and bioretention design.

Table C.10: Estimated Project Costs for Washington Woods Park Bioretention

ITEM	QUANTITY	UNITS	UNIT COST	TOTAL
Excavation	540	CY	$25.00	$13,500
Grading	490	SY	$3.50	$1,715
Gravel Bed	80	CY	$55.00	$4,400
Planting Material	278	CY	$150.00	$41,732
Mulch	30	CY	$30.00	$900
Bioretention Plantings- Trees	10	EA	$175.00	$1,750
Bioretention Plantings- Shrubs	50	EA	$35.00	$1,750
Bioretention Plantings-Herbaceous Plants	670	EA	$7.00	$4,690
RipRap	3	CY	$150.00	$450
6-inch perforated PVC underdrains	180	LF	$35.00	$6,300
Cleanout Pipes	3	EA	$360.00	$360
Remove and Dispose of Concrete Curb and Gutter	10	LF	$12.00	$120
Remove and Dispose of Concrete Sidewalk	3	SY	$12.00	$36
Grass Seeding	150	SY	$0.75	$113
Sidewalk Inlet	1	EA	$1,000.00	$1,000

CY = cubic yard
EA = each
LF = linear foot
SY = square yard

Initial Project Costs			$78,816
Material Contingency		5%	$3,941
Erosion and Sediment Control		10%	$7,882
Base Construction Costs			$90,638
Mobilization		5%	$4,532
	Subtotal 1		$95,170
Construction Contingency		15%	$14,276
	Subtotal 2		$109,446
Engineering			$48,000
		Total	$157,446

***See Maryland Stormwater Design Manual Appendix A for planting lists**

Table C.11: WQ_V Volume Calculations

Design Parameters	Site Value
Drainage Area (ac), A	2.84
Percent Impervious Cover, I	40%
Rainfall Depth (inches), P	1
Volumetric Runoff Coefficient, R_v	0.41
Ponding Depth (ft)	1
Water Quality Volume (acre-feet), WQ_v	**0.10**
Water Quality Volume (cubic-feet), WQ_v	**4,210**

Table C.12: Bioretention Cell Sizing Calculations

Surface Area of Filter Bed (square-feet)	Coefficient of Permeability of the Filter Media (ft/day), K	Planting Soil Depth (ft)	Average Height of Water above Filter Bed (ft)	Design Filter Bed Drain Time (days)	Water Quality Volume Provided (cf), WQv	Rainfall Depth Treated (in)	NPDES Credit Earned (impervious acres)
3,005	0.4	2.5	1	2	4,210	1	1.1

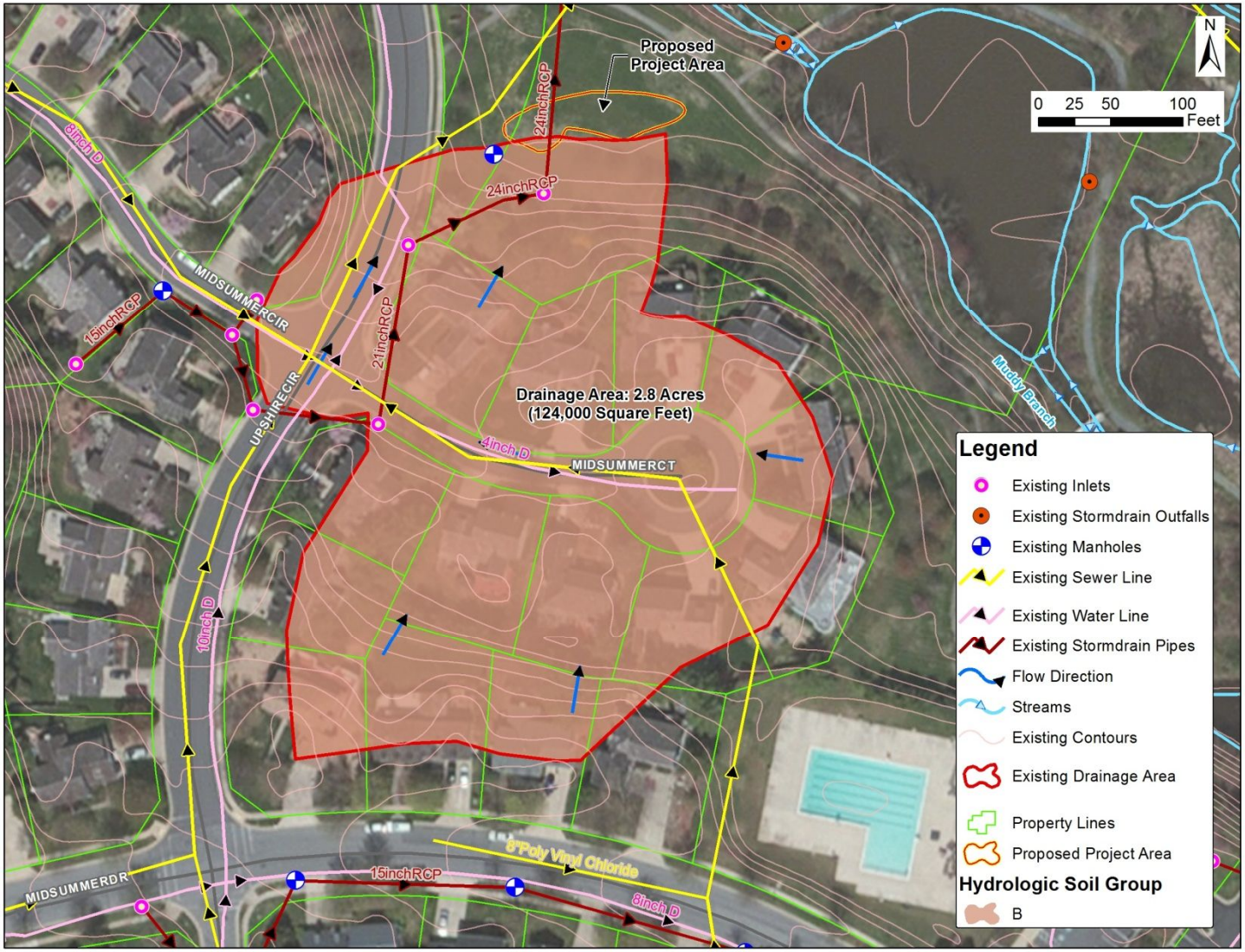


Figure C.12: Soils Map (Washington Woods Park)

Appendix D
Stream Assessment Results

Habitat Assessment

URS conducted a stream habitat assessment at the 12 long term monitoring sites using the Barbour and Stribling, Visual Based Habitat Assessment Form - Montgomery County Field Data Sheet for Riffle/Run Prevalent Streams. An example the data sheet is located at the end of this appendix. Using the Montgomery County data form allowed for direct comparisons to be made between the streams' current conditions and the conditions found during the 2001 study. Because Barbour and Stribling assessment evaluates more parameters than the Maryland Biological Stream Survey Spring Index form, the MBSS form was omitted from this current study.

Table D.1 shows how each site was rated for each parameter assessed by the Montgomery County protocol. Once assessed, these parameters are summed to provide a final tally for each site. Table D.2 compares the 2013 results with the 2001 results.

Table D.1: Comparison of 2001 and 2014 Montgomery County Habitat Assessment Results

Year	CS-1	CS-2	CS-7	MB-1	MB-2	MB-3	MB-5	MB-10
2014	105	105	112	116	143	104	123	134
2001	109	105	138	141	111	105	118	82

The habitat assessment method rates streams descriptively (example form is in *Appendix D*) based on the numerical assessment results as follows:

- Optimal: 166 to 200
- Sub-Optimal: 113 to 153
- Marginal: 60 to 100
- Poor: 0 to 47

Values falling between these category boundaries represent an intermediate condition (for example, a score of 55 would represent Marginal to Poor condition). The final habitat assessment ratings for the original 8 targeted monitoring sites Muddy Branch Watershed are shown below:

Table D.2: Comparison of 2001 and 2014 Montgomery County Habitat Assessment Ratings

Year	CS-1	CS-2	CS-7	MB-1	MB-2	MB-3	MB-5	MB-10
2014	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal
2001	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Sub-Optimal	Marginal

During the 2001 study of the eight sites (Table 4.3A), habitat scores ranged from 82 to 138, within the same Marginal to Sub-optimal range observed in 2014. During the 2001 evaluation, the site with the best habitat score (141, sub-optimal) was MB-1, located on the mainstem of Muddy Branch, east of MD-119 and Lake Varuna, and west of Great Seneca Highway. During

the 2014 evaluation, the site with the best habitat score (134, sub-optimal) was MB-10, located in Morris Park on the main stem of Muddy Branch upstream of I-270.

Table D.3 shows the scores for the stream reaches selected in 2014. The site with the best habitat score (167, Optimal) was Reach T.4.1 on an unnamed tributary to Muddy Branch, located behind Brighton Village apartments and west of I-270.

Table D.3:
Montgomery County Habitat Assessment Ratings for New Targeted Sites in 2014

	T 1.5	T 2.3	T 4.1	MB T1-B1
Raw score	109	103	167	157
Rating	Sub-optimal	Sub-optimal	Optimal	Sub-optimal

Table D.4: Habitat Assessment – Montgomery County Protocol (2014)

Station	Instream Cover	Epifaunal Substrate	Embedded-ness	Channel Alteration	Sediment Deposition	Frequency of Riffles	Channel Flow Status	Bank Veg. Protection LB	Bank Veg. Protection RB	Bank Stability LB	Bank Stability RB	Riparian Width LB	Riparian Width RB	Total Habitat Score
CS-1	11	8	8	15	11	6	7	5	6	4	6	9	9	**105**
CS-2	13	9	9	16	7	10	12	5	5	2	3	8	6	**105**
CS-7	8	9	8	17	7	9	10	6	6	6	8	9	9	**112**
MB-1	13	11	9	17	9	15	8	5	6	2	4	9	9	**116**
MB-2	13	15	16	12	13	16	17	8	5	6	8	9	5	**143**
MB-3	14	11	9	13	10	10	9	3	5	3	4	4	9	**104**
MB-5	9	8	14	17	13	13	10	7	5	5	4	9	9	**123**
MB-10	14	11	11	13	12	10	15	8	8	8	8	7	9	**134**
T 1.5	8	9	11	17	14	7	8	6	6	6	7	5	5	**109**
T 2,3	15	8	7	11	8	10	9	6	4	5	3	9	8	**103**
T 4.1	15	17	18	18	17	17	18	7	7	7	8	9	9	**167**
T1 B-1	11	16	16	17	18	20	17	6	6	8	6	8	8	**157**

Table D.5: Habitat Assessment – Montgomery County Protocol (2001)

Station	Instream Cover	Epifaunal Substrate	Embedded-ness	Channel Alteration	Sediment Deposition	Frequency of Riffles	Channel Flow Status	Bank Veg. Protection LB	Bank Veg. Protection RB	Bank Stability LB	Bank Stability RB	Riparian Width LB	Riparian Width RB	Total Habitat Score
CS-1	17	14	15	9	5	12	7	5	4	3	3	6	9	**109**
CS-2	12	10	9	13	6	10	8	5	4	5	5	9	9	**105**
CS-7	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	**138 est.**
MB-1	15	13	15	14	13	13	14	8	5	8	6	9	8	**141**
MB-2	13	11	13	9	8	12	9	7	7	5	7	1	9	**111**
MB-3	10	8	14	12	13	7	13	4	3	4	6	9	2	**105**
MB-5	15	10	14	17	7	10	9	5	5	5	6	9	6	**118**
MB-10	11	8	6	7	6	6	8	3	2	7	7	2	9	**82**
T 1.5	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
T 2,3	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
T 4.1	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**
T1 B-1	-	-	-	-	-	-	-	-	-	-	-	-	-	**-**

Bank Erosion Hazard Index

The Bank Erosion Hazard Index (BEHI) is a rating system that measures the ability of stream banks to resist erosion. The BEHI methodology uses five parameters to calculate the hazard index, which is assigned one of six descriptive ratings: very low, low, moderate, high, very high, or extreme. The five parameters are:

1. The ratio of streambank height to bankfull height
2. The root depth to bankfull height
3. The weighted root density (%)
4. Bank angle (degrees)
5. Bank protection

Table D.6 shows the BEHI values for the 12 Muddy Branch stream reaches.

Table D.6: Bank Erosion Hazard Index Results

Stream Reach	BEHI Results	BEHI Erosion Potential Rating
CS-1	39.7	High
CS-2	42.0	Very High
CS-7	31.9	High
MB-1	35.9	High
MB-2	29.5	Moderate
MB-3	46.2	Extreme
MB-5	40.0	Very High
MB-10	34.1	High
T 1.5	37.7	High
T 2.3	41.0	Very High
T 4.1	50.5	Extreme
MB T1 B-1	29.8	Moderate

The high, very high and extreme BEHI ratings are a reflection of the following:

- All of the streams are incised to some degree
- In general the weighted rooting densities are low
- Bank angles are steep
- There is little or no rock, roots, or other material to protect the banks from erosion

Benthic Macroinvertebrate Sampling

Biological indicators of stream health followed the protocol of the Rapid Stream Assessment Technique (RSAT). This protocol is qualitative in nature and does not require identification down to the family or genus level. The protocol involves turning over 10 cobble-size stones (or larger), as well as, taking a minimum of three 1-square foot, 30 second kick samples per riffle. The kick sampling was conducted with a 12-inch wide D-net.

Macroinvertebrate identification was performed at each riffle transect via a visual examination. Individuals were identified to taxonomic order. Macroinvertebrate relative abundance categories used in the survey are comparable to EPA's Rapid Bioassessment Protocol level 1.

The RSAT point ranges are as follows:
Excellent – 7-8
Good – 5-6
Fair – 3-4
Poor – 0-2
Six of the Muddy Branch streams scored a Fair rating and six scored a poor rating; with two of which no macroinvertebrates present during the sampling. Table D.7 below shows the results of the sampling.

Table D.7 RSAT Macroinvertebrate Sampling Results

Year	CS-1	CS-2	CS-7	MB-1	MB-2	MB-3	MB-5	MB-10	T1.5	T2.3	MB T4-1	MB T1 B-1
2014	3	1	4	2	2	0	3	0	1	3	4	4
2001	Fair	Poor	Fair	Poor	Poor	Poor	Fair	Poor	Poor	Fair	Fair	Fair

Field observations during the 2014 monitoring showed Ephemeroptera and Plecoptera taxa, those intolerant of poor water quality, were absent from all sites. Trichoptera, family Hydropsychidae was found at CS-7 along with moderately sensitive Diptera, consisting of families Tipulidae and Simuliidae. The sampling results are shown in Table D.8.

Table D.8: Benthic Macroinvertebrate Sampling Results

Site	Sensitive Organisms				Moderately Sensitive Organisms												Tolerant Organisms								RSAT Score
	Order Ephemeroptera (Mayfly)		Order Plecoptera (Stonefly)		Order Trichoptera (Caddisfly)		Order Megaloptera (Alderfly)		Order Diptera (Crane Fly)		Order Odonata (Damselfly)		Order Amphipoda (Scud)		Order Coleoptera (Riffle Beetle)		Order Diptera (non-biting Midge)		Order Hirudineaa (Leech)		Class Oligochaeta (Aquatic worm)		Class Gastropoda (Pouch Snail)		
	Number of Individuals	Abundance	Number of Individuals	Abundance	Number of Individuals	Abundance	Number of Individuals	Abundance	Number of Individuals	Abundance	Number of Individuals	Abundance	Number of Individuals	Abundance	Number of Individuals	Abundance	Number of Individuals	Abundance	Number of Individuals	Abundance	Number of Individuals	Abundance	Number of Individuals	Abundance	
2012-1	0	Absent	0	Absent	13	Abundant	0	Absent	0	Absent	0	Absent	0	Absent	1	Rare	0	Absent	0	Absent	13	Abundant	19	Abundant	**3**
2012-2	0	Absent	0	Absent	35	Abundant	1	Rare	0	Absent	0	Absent	0	Absent	24	Abundant	1	Rare	1	Rare	2	Rare	0	Absent	**4**
2012-3	0	Absent	0	Absent	0	Absent	0	Absent	0	Absent	0	Absent	0	Absent	0	Absent	21	Abundant	0	Absent	6	Common	0	Absent	**1**
2012-4	0	Absent	0	Absent	0	Absent	0	Absent	0	Absent	0	Absent	0	Absent	0	Absent	1	Rare	0	Absent	22	Abundant	9	Common	**1**
CS-5	0	Absent	0	Absent	1	Rare	1	Rare	0	Absent	0	Absent	0	Absent	1	Rare	2	Rare	0	Absent	14	Abundant	1	Rare	**1**
CS-6	0	Absent	0	Absent	10	Abundant	1	Rare	0	Absent	0	Absent	0	Absent	0	Absent	0	Absent	0	Absent	0	Absent	1	Rare	**3**
CS-8	0	Absent	0	Absent	11	Abundant	0	Absent	0	Absent	0	Absent	1	Rare	7	Common	2	Rare	0	Absent	3	Rare	0	Absent	**3**
GST-1	0	Absent	0	Absent	0	Absent	3	Rare	0	Absent	0	Absent	0	Absent	11	Abundant	6	Common	2	Rare	18	Abundant	1	Rare	**2**
GST-2	0	Absent	0	Absent	2	Rare	5	Common	0	Absent	0	Absent	0	Absent	10	Abundant	0	Absent	0	Absent	24	Abundant	0	Absent	**3**
GST-8	0	Absent	1	Rare	8	Common	2	Rare	0	Absent	0	Absent	0	Absent	0	Absent	4	Common	0	Absent	3	Rare	4	Common	**4**

Water quality parameters were recorded during the macroinvertebrates sampling. A handheld Horiba U52 was used unit was used to record temperature, pH, conductivity, salinity and turbidity. The Horiba unit did not appear to function properly when collecting turbidity (turbidity was observed but the unit recorded 0.0). Therefore, turbidity was added to the requested for the chemical analyses performed by Enviro-Chem Laboratories, Inc. For this analysis, samples were delivered to and accepted by Enviro-Chem., results were processed within one day, and final reports were sent via email. Lab sampling included Nitrate and Nitrite, Phosphorous, suspended solids and turbidity. Enviro-Chem Water Quality reports and chain of custody sheets and results using the Horiba handheld unit are included in the **Stream Assessment Example Field Sheets** section below. Water chemistry results are shown below in Table D.9. The results showed dissolved oxygen was sufficient to support aquatic species and pH was within an acceptable range.

Table D.9: Water Chemistry Results, Spring 2014

Water chemistry results from spring sampling, City of Gaithersburg stream assessment, April 2014										
	Site	Water Temperature (°C)	Dissolved Oxygen (mg/L)	pH	Conductivity (mS/cm)	Turbidity (NTU)	Nitrate (as N) (mg/L)	Nitrite (as N) (mg/L)	Phosphorus, P (mg/L)	Suspended Solids (mg/L)
Random	T 1.5	15.21	14.10	8.72	0.57	22.3	1.1	<0.2	0.21	64.8
	T 2.3	17.55	14.07	7.61	0.82	12.2	1.8	<0.2	<0.05	37.6
	T4-1	12.32	11.76	7.21	1.51	3.5	0.6	<0.2	<0.05	6.4
	T1-B1	15.35	13.89	7.11	1.03	5.2	1.5	<0.2	<0.05	4
Targeted	CS 1	8.01	11.84	6.95	0.83	3.2	0.9	<0.2	<0.05	2.2
	CS 2	12.00	12.73	7.34	1.32	2.4	2.3	<0.2	<0.05	2.2
	CS 7	18.60	13.62	8.80	0.79	9.1	<0.2	<0.2	<0.05	18
	MB 1	18.04	13.89	9.03	0.98	2.4	1.1	<0.2	<0.05	2
	MB 2	15.77	13.66	8.31	0.80	5.3	0.9	<0.2	<0.05	3.6
	MB 3	11.70	11.99	7.48	0.42	6.4	1	<0.2	<0.05	4.8
	MB 5	15.71	14.00	8.37	0.77	3.3	1.1	<0.2	<0.05	3.2
	MB 10	11.41	12.39	7.49	0.93	18.2	1.2	<0.2	<0.05	27.8

4.1.3 Cruising Assessment

Using the City provided GIS, the Muddy Brach streams were broken into reaches. Reach breaks were selected based on natural features such as, confluence with another tributary or the mainstem, changes in valley characteristics (steep narrow valley to wide flat valley), and significant changes in sinuosity. Manmade features like road crossings also provided practical locations for reach breaks. Some reach break locations were modified in the field based on site conditions. The 11 miles of stream in the Muddy Branch watershed were divided into 42 reach segments. The reaches were walked and assessed for the criteria included on the field form. The Reach Assessment Ratings Matrix, used to obtain assessment scores, is shown in Table D.10.

Outfall Assessments

The URS team assessed 72 storm drain outfalls encountered during the cruising assessment using the Center for Watershed Protection, Unified Stream Assessment (USA) Outfall Assessment Form. Each numeric Outfall ID corresponds to a USA assessment form with supporting photos. The condition of outfalls within each assessed stream reach is shown in Table D.10. In the table,

color shades indicate the condition of each outfall, with red indicating the worst impairments observed, yellow indicating poor condition, green indicating moderate impairment and no shade indicating no issues were observed. The assessments results identified four outalls in "worst condition," two in poor condition, 13 in moderate condition and 53 with no issues. Outfalls in the worst condition were observed in stream reaches T 4.3, T 1.1 and T 8.2. Outfalls in poor condition were located in reaches T1.1 and T 5.1. Outfalls located within reaches identified as having a Selective Restoration Reach Opportunity are shown in Bold in Table D.10. Ten outfalls with identified impairments are located within a Selective Restoration Reach Opportunity sites.

Table D.10: Reach Assessment Ratings Matrix

Selective Restoration Opportunity	Long Term Monitoring Site ID	Site ID	Total Score (max 100)	Date Assessed	Reach Length (feet)	Severity of Stream Impacts: Hydrological Modifications			Channel Condition						Instream Habitat						Riparian Habitat				Water Quality					
						Impairment form Blockage	Impairment form Stormdrain or other Pipe	Impairmant from Chanel Alterations	Excaessive Sediment Deposition	Excaessive Bar Formation	Unstable Substrate	Accelerated Lateral Channel Migration	Channel Downcutting	Widespread Bank Instability	Heavily Silted Substrate	Lack of Instream Fish Cover	Lack of Epifaunal Substrate	Lack of Woody Debris	Lack of Bank Vegetative Protection	Poor Stream Shading	Narrow Buffer Width	Breaks in Buffer	Vegetation Showing Signs of Stress	Existing Wetlands Adjacent to Area	Excessive Algae	Organic Scum	High Turbidity	Obvious Spills, Discharges, plumes, Odors	Trash Problem	Category Score (max 40)
		T4.3	83	3/24/2014	450.00	1	1	3	3	2	3	3	2	3	2	3	3	2	3	2	3	2	3	3	3	2	3	1	3	33
	CS-7	T1.1	83	4/3/2014	1000.00	3	1	2	3	3	3	3	3	3	3	2	3	2	3	2	2	2	3	3	2	1	1	1	1	31
*		T3.1	81	3/26/2014	1000.00	2	1	1	3	2	2	3	3	3	2	3	3	3	3	3	1	3	3	3	2	1	1	1	1	29
*		T5.2a	78	3/10/2014	425.00	1	3	1	2	3	1	3	1	3	1	3	2	3	3	2	1	1	1	1	1	1	1	1	1	23
		T4.1	76	3/19/2014	890.00	2	1	1	3	3	3	2	3	3	2	3	3	2	2	2	2	3	3	3	1	1	1	1	2	29
		T9.1	76	4/2/2014	1500.00	2	2	1	3	3	3	3	3	3	3	2	3	1	3	3	2	3	3	3	2	1	1	1	2	31
		M2	74	4/2/2014	1900.00	3	1	1	3	3	3	3	2	3	2	2	2	2	2	1	1	2	3	3	1	1	1	1	1	26
*		M7	73	3/19/2014	2400.00	3	1	1	3	3	3	3	2	3	2	2	2	2	2	2	1	1	3	3	2	1	1	1	1	27
		T1.2	73	4/3/2014	1100.00	1	1	2	3	3	3	3	3	3	2	3	3	1	2	1	2	1	3	1	2	1	1	1	1	26
	MB-5	M4	73	3/26/2014	1250.00	1	1	1	3	3	3	3	1	3	3	2	2	1	2	1	1	2	3	2	2	1	2	1	1	25
	MB-2	M3	71	3/26/2014	2000.00	2	1	1	3	3	3	3	1	3	2	2	2	2	3	1	1	2	3	2	2	1	2	1	1	26
	CS-2	T5.2b	71	3/10/2014	1200.00	2	1	1	2	3	2	3	1	3	1	2	1	2	3	1	1	1	3	3	1	1	1	1	2	23
*		T3.2	71	3/26/2014	1000.00	1	1	3	3	2	2	3	3	3	2	2	2	3	3	3	2	2	2	3	2	2	1	1	1	29
		M12	70	4/2/2014	1200.00	3	1	1	3	3	3	2	1	2	2	2	1	2	1	1	2	3	2	1	1	1	1	1	1	23
*	New T-1.5	T1.5	70	4/3/2014	1400.00	3	1	3	1	1	2	2	3	2	2	2	2	1	1	1	2	1	2	3	1	1	1	2	2	23
		M1	67	4/2/2014	1700.00	3	1	1	3	3	2	2	2	2	2	2	2	1	2	1	1	2	3	3	1	1	1	1	1	24
	New T-2.3	T2.3	67	3/26/2014	900.00	1	1	3	2	1	3	3	3	3	1	2	2	2	2	1	2	1	2	2	2	1	1	1	1	24
		T5.1	67	3/10/2014	1600.00	2	2	3	3	2	2	3	2	3	2	1	2	1	2	1	1	1	1	3	2	1	1	1	1	24
*		M10	66	3/10/2014	1600.00	3	1	1	2	2	2	3	1	3	2	2	2	1	3	1	1	1	1	3	2	1	1	1	3	24
		T5.2	61	3/10/2014	960.00	1	1	2	1	1	1	1	1	1	1	2	1	1	2	1	3	3	3	1	1	1	1	1	1	18
		M8	60	3/13/2014	700.00	1	1	1	1	1	1	2	1	2	1	2	1	2	1	2	2	2	1	1	1	1	2	1	2	18
		M10a	60	3/10/2014	1500.00	1	1	1	2	2	2	1	1	1	1	2	1	2	3	1	1	1	1	2	1	1	1	1	2	18
		T5.1a	60	3/10/2014	1100.00	1	1	1	1	1	2	2	1	1	1	2	2	2	2	1	1	1	1	3	1	1	1	1	1	18
	MB-3	T4.2	57	3/24/2014	1300.00	1	1	1	2	2	2	3	2	2	2	2	2	2	1	1	1	1	2	3	3	2	2	1	2	24
*	CS-1	M6	57	3/26/2014	2600.00	2	1	1	1	2	1	2	2	2	2	1	1	1	1	1	1	1	2	2	2	2	1	1	1	19
		T2.1	56	3/26/2014	900.00	1	1	1	1	1	1	1	2	1	1	3	3	1	1	1	1	1	1	2	3	1	1	1	1	18
*		T7.1	56	3/24/2014	850.00	2	1	1	2	1	1	2	2	1	1	3	2	2	1	1	1	1	1	1	1	1	1	1	1	18
		M6.1	56	3/24/2014	500.00	3	1	1	1	1	2	2	1	2	2	1	1	1	1	1	1	1	1	2	1	1	1	1	1	17
	T1b.4	T8.1	56	4/2/2014	1000.00	2	1	1	2	2	2	2	2	2	2	2	2	1	1	1	1	2	2	2	1	1	1	1	1	21
*	MB-10	M9	55	3/10/2014	1600.00	1	1	1	1	1	1	1	1	1	1	2	2	1	1	1	2	2	1	1	2	1	1	1	1	16
		T1.4	54	4/3/2014	840.00	3	1	1	1	1	2	1	3	2	1	2	2	1	1	1	2	1	2	2	1	1	1	2	2	21
	T4-1	T6.1	54	3/19/2014	900.00	1	1	1	1	1	1	1	1	1	1	1	1	2	1	1	1	2	1	2	1	1	1	1	1	15
		M11	52	3/13/2014	900.00	3	1	1	1	1	1	1	1	2	1	1	1	1	2	1	3	3	2	1	1	1	1	1	2	19
		T2.4	50	3/26/2014	500.00	1	1	1	1	1	1	1	1	1	1	2	2	2	1	2	1	2	2	2	1	1	1	1	1	17
*		T8.2	50	4/2/2014	3000.00	2	1	1	2	2	1	1	2	1	2	1	2	2	2	2	1	2	2	3	1	1	1	1	1	21
		T1.3	49	4/3/2014	803.00	1	1	1	1	1	2	2	3	3	1	2	1	1	1	1	2	1	1	1	1	1	1	1	1	18
*	MB-1	M5	49	3/13/2014	2700.00	3	1	1	2	2	2	2	1	2	1	1	1	1	1	1	1	1	3	1	2	1	1	1	1	19
		T2.4a	47	3/26/2014	400.00	1	1	1	1	1	1	1	1	2	1	2	2	2	2	2	2	2	1	2	2	1	1	1	1	19
		T8.3	46	4/2/2014	850.00	1	1	1	1	1	1	1	1	1	1	3	1	2	1	1	1	1	1	3	1	1	3	1	1	17
		T8.4	42	4/2/2014	800.00	1	1	1	1	1	1	1	1	1	1	2	1	2	1	2	2	1	1	1	1	1	3	1	1	17
		T2.2	41	3/26/2014	850.00	1	1	1	2	1	2	1	2	1	1	2	3	1	1	1	1	2	2	1	1	1	1	1	1	18
		T8.3a	40	4/2/2014	360.00	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	13

Site ID	Extent of Problem: Relative Extent of Problem	Category Score (max 20)	City Restoration Goals: Safety Issues	Infrastructure Threathened	Infrastructure Damaged	Sufficient Adjacent Land for Restoration	Adjacent Property Severley Impacted	Category Score (max 20)	Economic Feasibility: Site on City Owned Land	Suitable Access for Equipment & Maintenance	Relative Potential Cost (Low = 3, Moderate = 2, High =1)	Category Score (max 20)
T4.3	3	20	3	3	3	2	2	17	1	3	2	13
T1.1	3	20	2	2	1	3	3	15	3	3	2	18
T3.1	3	20	3	2	1	3	1	13	3	3	2	18
T5.2a	3	20	3	2	2	3	3	17	3	3	2	18
T4.1	3	20	3	1	1	3	1	12	3	3	1	16
T9.1	3	20	2	2	1	2	2	12	2	2	2	13
M2	3	20	3	1	1	3	1	12	3	3	1	16
M7	3	20	3	2	1	3	1	13	2	3	1	13
T1.2	3	20	2	2	2	3	1	13	1	3	2	13
M4	3	20	3	1	1	3	1	12	3	3	1	16
M3	3	20	3	1	1	3	1	12	3	2	1	13
T5.2b	3	20	3	1	1	3	1	12	3	3	1	16
T3.2	2	13	2	1	1	3	1	11	3	3	2	18
M12	3	20	3	1	1	3	1	12	3	2	2	16
T1.5	2	13	2	2	2	3	1	13	3	3	3	20
M1	2	13	3	1	1	3	1	12	3	3	2	18
T2.3	2	13	3	1	1	3	1	12	3	3	2	18
T5.1	2	13	3	1	1	3	1	12	3	3	2	18
M10	2	13	2	1	1	3	1	11	3	3	2	18
T5.2	2	13	3	1	1	3	1	12	3	3	2	18
M8	2	13	2	1	1	3	1	11	3	3	2	18
M10a	2	13	2	1	1	3	1	11	3	3	2	18
T5.1a	2	13	3	2	1	3	1	13	3	2	2	16
T4.2	1	7	2	2	1	2	1	11	3	2	2	16
M6	1	7	3	2	1	3	1	13	3	3	2	18
T2.1	1	7	3	1	1	3	1	12	3	3	3	20
T7.1	1	7	3	1	1	3	1	12	3	3	3	20
M6.1	1	7	3	1	1	3	1	12	3	3	3	20
T8.1	1	7	3	1	1	2	1	11	3	2	3	18
M9	1	7	3	1	1	3	1	12	3	3	3	20
T1.4	1	7	2	1	1	2	1	9	3	2	3	18
T6.1	1	7	3	1	1	3	1	12	3	3	3	20
M11	1	7	2	1	1	3	1	11	1	3	3	16
T2.4	1	7	2	1	1	3	1	11	3	2	2	16
T8.2	1	7	2	1	1	2	1	9	1	3	2	13
T1.3	1	7	2	1	1	2	1	9	3	1	3	16
M5	1	7	3	1	1	3	1	12	1	2	2	11
T2.4a	1	7	2	1	1	1	1	8	3	1	2	13
T8.3	1	7	3	1	1	2	1	11	1	2	2	11
T8.4	1	7	3	1	1	1	1	9	1	1	2	9
T2.2	1	7	2	1	1	1	1	8	1	1	2	9
T8.3a	1	7	2	1	1	2	1	9	1	1	3	11

Site ID	Restoration Opportunities (Good = 3, Fair = 2, Poor = 1): Bank Stabilization	Grade Protection	Channel Realignment	Profile Adjustment	Instream Habitat	Low Flow Channel	Riparian Buffer Enhancement	Wetland Protection/Creation	SWM Facility - New	SWM Facility - Retrofit	Fish Passage	Category Score (max 33)	Outfall Assessed in Reach				
T4.3	3	2	3	2	3	2	3	3	2	1	1	25	52	52a	51		
T1.1	3	3	3	3	3	3	2	3	1	1	2	27	98	99	100	102	
T3.1	3	3	3	3	3	2	3	3	1	3	2	29	62				
T5.2a	3	3	1	3	3	3	1	3	1	1	1	23	4				
T4.1	3	3	3	3	3	1	2	3	2	1	2	26	49	50			
T9.1	3	3	3	3	3	1	3	3	1	2	1	26	81	81a	80	80a	
M2	3	2	3	2	3	3	2	2	1	1	1	23					
M7	3	3	3	2	3	3	1	3	2	1	1	25	44	45	46	47	48
T1.2	3	3	2	3	2	1	1	1	1	1	2	20	101				
M4	3	3	3	2	3	3	2	2	1	1	1	24	92	93			
M3	3	2	3	2	3	3	2	2	1	1	1	23	76				
T5.2b	3	3	3	3	3	3	1	3	1	1	1	25	5				
T3.2	3	3	3	2	2	1	3	3	1	1	2	24	63	64			
M12	3	2	3	2	3	3	2	2	1	1	1	23					
T1.5	2	3	2	3	2	1	1	3	1	3	1	22	103	104	105		
M1	3	2	2	2	3	3	2	2	1	1	1	22					
T2.3	3	3	3	3	3	1	2	3	1	2	1	25	70	73	74		
T5.1	3	3	3	3	2	3	1	3	1	1	3	26	6	7	8	9	
M10	3	3	2	3	3	2	1	3	1	1	1	23	12	13			
T5.2	2	1	1	1	2	1	3	1	3	1	1	17	1	2	3		
M8	3	1	1	2	2	1	3	1	3	1	1	19	41				
M10a	2	3	2	2	2	2	1	2	1	1	2	20	14	15	16		
T5.1a	2	2	1	2	2	1	1	3	1	1	1	17					
T4.2	3	2	3	1	3	2	2	3	1	3	1	24	53	54	55		
M6	3	3	2	1	2	2	1	2	1	1	2	20	57	58			
T2.1	1	3	1	1	2	1	1	1	1	1	1	14					
T7.1	2	2	1	2	2	1	1	1	1	1	1	15					
M6.1	2	1	1	1	1	1	1	2	1	1	1	13					
T8.1	3	2	2	2	2	1	1	2	1	1	1	18	85				
M9	1	1	1	1	2	1	1	1	1	1	1	12	10	11			
T1.4	3	3	1	3	2	1	1	2	1	3	1	21	106	107	108		
T6.1	2	1	1	1	2	1	1	2	1	1	2	15					
M11	2	2	2	1	3	1	3	1	1	1	1	18					
T2.4	2	1	1	1	2	1	2	2	1	1	2	16	69				
T8.2	2	3	1	2	2	1	2	3	1	2	2	21	87	88	89	91	91a
T1.3	2	3	1	2	1	1	1	1	1	1	1	15					
M5	3	2	2	1	2	3	2	1	1	3	1	21	60	61			
T2.4a	2	1	1	1	2	1	2	2	1	1	2	16	68	69			
T8.3	1	1	1	1	1	1	1	1	1	1	1	11	94	95	96	97a	
T8.4	1	1	1	1	3	1	1	1	3	3	2	18					
T2.2	2	2	1	2	2	1	2	1	1	2	1	17	75a				
T8.3a	1	1	1	1	1	1	1	2	1	1	1	12					

Stream Assessment Example Field Sheets

Barbour & Stribling Habitat Assessment Habitat Assessment Data Sheet (page 1 of 2)

HABITAT ASSESSMENT FIELD DATA SHEET — ***RIFFLE/RUN PREVALENT STREAMS***

STREAM: MUDDY BR T6 — DATE: 4-9-14

SITE: T4.1 — INVESTIGATOR: R. Gonzalez

Riffle/Run Prevalent Streams are those in moderate to high gradient landscapes that sustain water velocities of approximately 1 ft/sec or greater. Natural streams have substrates primarily composed of coarse sediment particles (i.e., gravel or larger) or frequent coarse particulate aggregations along stream reaches.

Habitat Parameter	Category			
	Optimal	Suboptimal	Marginal	Poor
1. Instream Cover (Fish)	Greater than 50% mix of snags, submerged logs, undercut banks, or other stable habitat.	30-50% mix of stable habitat; adequate habitat for maintenance of populations.	10-30% mix of stable habitat; habitat availability less than desirable.	Less than 10% mix of stable habitat; lack of habitat is obvious.
SCORE 15	20 19 18 17 16	(15) 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
2. Epifaunal Substrate	Well-developed riffle and run; riffle is as wide as stream and length extends two times the width of stream; abundance of cobble.	Riffle is as wide as stream but length is less than two times width; abundance of cobble; boulders and gravel common.	Run area may be lacking; riffle not as wide as stream and its length is less than 2 times the stream width; gravel or large boulders and bedrock prevalent; some cobble present.	Riffles or run virtually nonexistent; large boulders and bedrock prevalent; cobble lacking.
SCORE 17	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
3. Embeddedness	Gravel, cobble, and boulder particles are 0-25% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 25-50% surrounded by fine sediment.	Gravel, cobble, and boulder particles are 50-75% surrounded by fine sediment.	Gravel, cobble, and boulder particles are more than 75% surrounded by fine sediment.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
4. Channel Alteration	Channelization or dredging absent or minimal; stream with normal, sinuous pattern.	Some channelization present, usually in areas of bridge abutments; evidence of past channelization, i.e., dredging, (greater than past 20 yr) may be present, but recent channelization is not present.	New embankments present on both banks; and 40 to 80% of stream reach channel-ized and disrupted.	Banks shored with gabion or cement; over 80% of the stream reach channelized and disrupted.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
5. Sediment Deposition	Little or no enlargement of islands or point bars and less than 5% of the bottom affected by sediment deposition.	Some new increase in bar formation, mostly from coarse gravel; 5-30% of the bottom affected; slight deposition in pools.	Moderate deposition of new gravel, coarse sand on old and new bars; 30-50% of the bottom affected; sediment deposits at obstruction, constriction, and bends; moderate deposition of pools prevalent.	Heavy deposits of fine material, increased bar development; more than 50% of the bottom changing frequently; pools almost absent due to substantial sediment deposition.
SCORE 17	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0

Barbour and Stribling, Visual-Based Habitat Assessment, Figure 10

Barbour & Stribling Habitat Assessment Data Sheet (page 2 of 2)

T4.1

RIFFLE/RUN PREVALENT STREAMS

Habitat Parameter	Category: Optimal	Suboptimal	Marginal	Poor
6. Frequency of Riffles	Occurrence of riffles relatively frequent; distance between riffles divided by the width of the stream equals 5 to 7; variety of habitat.	Occurrence of riffles infrequent; distance between riffles divided by the width of the stream equals 7 to 15.	Occasional riffle or bend; bottom contours provide some habitat; distance between riffles divided by the width of the stream is between 15 to 25.	Generally all flat water or shallow riffles; poor habitat; distance between riffles divided by the width of the stream is between ratio >25.
SCORE 17	20 19 18 (17) 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
7. Channel Flow Status	Water reaches base of both lower banks and minimal amount of channel substrate is exposed.	Water fills >75% of the available channel; or <25% of channel substrate is exposed.	Water fills 25-75% of the available channel and/or riffle substrates are mostly exposed.	Very little water in channel and mostly present as standing pools.
SCORE 18	20 19 (18) 17 16	15 14 13 12 11	10 9 8 7 6	5 4 3 2 1 0
8. Bank Vegetative Protection (score each bank) Note: determine left or right side by facing downstream.	More than 90% of the streambank surfaces covered by native vegetation, including trees, understory shrubs, or nonwoody macrophytes; vegetative disruption, through grazing or mowing, minimal or not evident; almost all plants allowed to grow naturally.	70-90% of the streambank surfaces covered by native vegetation, but one class of plants is not well-represented; disruption evident but not affecting full plant growth potential to any great extent; more than one-half of the potential plant stubble height remaining.	50-70% of the streambank surfaces covered by vegetation; disruption obvious; patches of bare soil or closely cropped vegetation common; less than one-half of the potential plant stubble height remaining.	Less than 50% of the streambank surfaces covered by vegetation; disruption of streambank vegetation is very high; vegetation has been removed to 2 inches or less in average stubble height.
SCORE 7 (LB)	Left Bank 10 9	8 (7) 6	5 4 3	2 1 0
SCORE 7 (RB)	Right Bank 10 9	8 (7) 6	5 4 3	2 1 0
9. Bank Stability (score each bank)	Banks stable; no evidence of erosion or bank failure; little potential for future problems.	Moderately stable; infrequent, small areas of erosion mostly healed over.	Moderately unstable; up to 60% of banks in reach have areas of erosion; high erosion potential during floods.	Unstable; many eroded areas; "raw" areas frequent along straight sections and bends; obvious bank sloughing; 60-100% of bank has erosional scars.
SCORE 7 (LB)	Left Bank 10 9	8 (7) 6	5 4 3	2 1 0
SCORE 8 (RB)	Right Bank 10 9	(8) 7 6	5 4 3	2 1 0
10. Riparian Vegetative Zone Width (score each bank riparian zone)	Width of riparian zone >18 meters; human activities (i.e., parking lots, roadbeds, clear-cuts, lawns, or crops) have not impacted zone.	Width of riparian zone 12-18 meters; human activities have impacted zone only minimally.	Width of riparian zone 6-12 meters; human activities have impacted zone a great deal.	Width of riparian zone <6 meters: little or no riparian vegetation due to human activities.
SCORE 9 (LB)	Left Bank 10 (9)	8 7 6	5 4 3	2 1 0
SCORE 9 (RB)	Right Bank 10 (9)	8 7 6	5 4 3	2 1 0

Total Score 167

Barbour and Stribling, Visual-Based Habitat Assessment. Figure 10. p 2

Field Observations of Macrobenthos Spring 2014

4/17/14
Muddy Branch → T4-1

FIELD OBSERVATIONS OF MACROBENTHOS

Indicate estimated abundance: 0 = Absent/Not Observed, 1 = Rare (1-3 organisms), 2 = Common (3-9 organisms), 3= Abundant (>10 organisms), 4 = Dominant (>50 organisms)

Porifera	0	1	2	3	4	Anisoptera	0	1	2	3	4	Chironomidae	0	1	2	3	4
Hydrozoa	0	1	2	3	4	Zygoptera	0	1	2	3	4	Ephemeroptera	0	1	2	3	4
Platyhelminthes	0	1	2	3	4	Hemiptera	0	1	2	3	4	Trichoptera	0	1	2	3	4
Turbellaria	0	1	2	3	4	Coleoptera	0	1	2	3	4	Other	0	1	2	3	4
Hirudinea	0	1	2	3	4	Lepidoptera	0	1	2	3	4						
Oligochaeta	0	1	2	3	4	Sialidae	0	1	2	3	4						
Isopoda	0	1	2	3	4	Corydalidae	0	1	2	3	4						
Amphipoda	0	1	2	3	4	Tipulidae	0	1	2	3	4						
Decapoda	0	1	2	3	4	Empididae	0	1	2	3	4						
Gastropoda	0	1	2	3	4	Simuliidae	0	1	2	3	4						
Bivalvia	0	1	2	3	4	Tabinidae	0	1	2	3	4						
						Culcidae	0	1	2	3	4						

ID'd by: S. Ligon

Rapid Bioassessment Protocols For Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition - Form 1 A-25

Bank Erosion Hazard Index Variable Worksheet

BANK 1 75' + 20' + 30'
Photo 70

BEHI Form

Stream: Muddy Br. T6 Reach: T4.1 Cross Section: Date: Crew:

Erodibility Variable/Value			Index	Bank Erosion Potential
Bank Height/Bankfull Height				
Bank Height (ft) A	Bankfull Height (ft) B	A/B	7.9	High
3.4	1.7	2.0		
Root Depth/Bank Height				
Root Depth (ft) C	C/A		6.8	High
0.8	0.24			
Weighted Root Density				
Root Density (%) D	D*(C/A)		10	Extreme
5	1.2			
Bank Angle				
Bank Angle (degrees)			7.9	High
90				
Surface Protection				
Surface Protection (%)			7.9	High
15				
Materials: Upper-sandy loam. Lower-gravel with sand matrix			0	
Stratification: Boundary between sandy loam and gravel			0	
TOTAL SCORE:			50.5	EXTREME

Bank Erosion Hazard Index

Erodibility Variable		Bank Erosion Potential: Very Low	Low	Moderate	High	Very High	Extreme
Bank Height/ Bankfull Height	Value	1.0 - 1.1	1.11 - 1.19	1.2 - 1.5	1.6 - 2.0	2.1 - 2.8	>2.8
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Root Depth/ Bank Height	Value	1.0 - 0.9	0.89 - 0.5	0.49 - 0.3	0.29 - 0.15	0.14 - 0.05	<0.05
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Weighted Root Density	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 5.0	<5.0
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Bank Angle	Value	0 - 20	21 - 60	61 - 80	81 - 90	91 - 119	>119
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10
Surface Protection	Value	100 - 80	79 - 55	54 - 30	29 - 15	14 - 10	<10
	Index	1.0 - 1.9	2.0 - 3.9	4.0 - 5.9	6.0 - 7.9	8.0 - 9.0	10

Bank Materials

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

Stratification

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

Total Score

Very Low	Low	Moderate	High	Very High	Extreme
5-9.5	10-19.5	20-29.5	30-39.5	40-45	46-50

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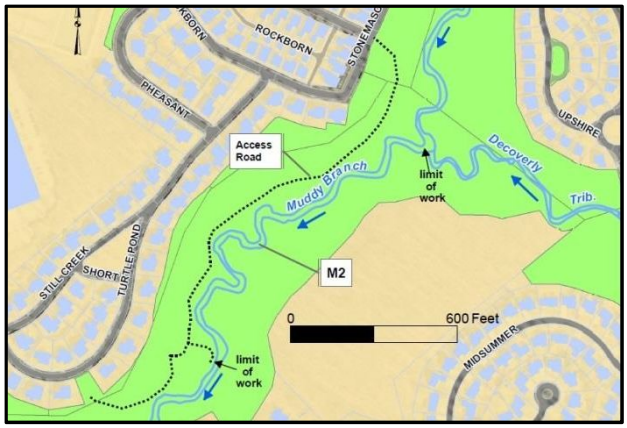
Josh:C/My Documents/Class

Horiba Unit Water Quality Results

No.	SITE	Date	Time	Temperature	Dissolved Oxygen	pH	Conductivity
	T1B-1	4/14/2014	9:12	15.35	13.890	7.11	1.030
2	MB-2	4/14/2014	8:23:26	15.77	13.660	8.31	0.799
4	MB-5	4/14/2014	9:10:53	15.71	14.000	8.37	0.772
6	CS-7	4/14/2014	10:04:04	18.60	13.620	8.8	0.793
7	T2.3	4/14/2014	11:44:00	17.87	15.650	7.66	0.826
8	T2.3	4/14/2014	11:47:21	17.23	12.490	7.55	0.814
				17.55	14.070	7.605	0.820
9	T1.5	4/14/2014	12:41:47	15.09	15.700	8.71	0.571
10	T1.5	4/14/2014	12:44:51	15.26	13.630	8.74	0.569
11	T1.5	4/14/2014	12:47:51	15.28	12.960	8.72	0.567
				15.21	14.097	8.723333	0.569
12	MB-1	4/14/2014	13:36:06	18.04	14.110	9.02	0.976
13	MB-1	4/14/2014	13:39:04	18.04	13.660	9.03	0.976
				18.04	13.885	9.025	0.976
14	CS-1	4/17/2014	6:58:02	8.04	11.520	6.98	0.888
17	CS-1	4/17/2014	7:13:42	7.98	12.150	6.91	0.773
				8.01	11.835	6.945	0.831
18	T4-1	4/17/2014	8:56:22	12.31	12.570	7.22	1.510
19	T4-1	4/17/2014	8:59:06	12.32	10.950	7.2	1.510
				12.32	11.760	7.21	1.510
20	MB-3	4/17/2014	9:42:31	11.65	12.130	7.58	0.424
21	MB-3	4/17/2014	9:45:46	11.74	11.850	7.38	0.413
				11.70	11.990	7.48	0.419
22	MB-10	4/17/2014	11:05:08	11.40	13.040	7.5	0.926
23	MB-10	4/17/2014	11:11:38	11.42	11.740	7.47	0.926
				11.41	12.390	7.485	0.926
24	CS-2	4/17/2014	12:01:33	11.90	13.930	7.36	1.310
25	CS-2	4/17/2014	12:09:25	12.10	11.520	7.31	1.320
				12.00	12.725	7.335	1.315

Appendix E
Stream Restoration Concept Designs

Reach M2 – Future City Park



Drainage Area (in the City): 4,270 acres
Length of Restoration: 1,720 feet

Restoration Estimated Captures:

- TN: 65 lbs per year
- TP: 58 lbs per year
- TSS: 110 tons per year

Site Description: The existing M-2 reach is a highly degraded third order stream in the southwest portion of the City on Muddy Branch. The reach lies within the Muddy Branch Stream Valley Park. The upper limit of the reach is located at the confluence of Muddy Branch with Decoverly Tributary (per the Muddy Branch Alliance). The stream is characterized by high steep banks with a broad floodplain that is moderately forested with abundant low vegetation across the floodplain. Much of the instability appears to be caused by a combination of channel incision (±2 feet), erodible bank material, and woody debris. The channel appears to have incised resulting in undermining of trees along the reach. Trees that are undermined within the reach and others that have washed in from upstream have created debris jams. Once the debris jams are established, the banks erode causing significant channel and bank instability within the reach. There are two riffles that are unstable and direct flow into bank(s). In other areas, debris jams have caused the channel to cut off meander bends. In-stream cover for aquatic organisms is limited to occasional woody material that has collected along the stream bank and debris jams. There are heavy deposits of sand and gravel in the stream and oversized point and mid-channel bars, indicating excess sediment supply from bed and bank erosion in the watershed.

Heavy bank erosion at confluence of Decoverly Tributary with Muddy Branch. Rock toe protection and bank grading will stabilize bank.

Overwidened channel with cutoff meander bend caused by upstream debris jam. Current channel alignment direct flow into downstream bank. Old meander bend should be restored/repaired after debris removal.

Restoration Goals: The goals of this concept are to reduce shear stress on the stream banks, remove debris from the channel, restore lateral stability, minimize stream incision, and improve aquatic habitat. By addressing these goals, water quality downstream should be improved.

Proposed Restoration: The proposed M-2 stream restoration should involve a reach wide approach that addresses channel layout, channel stability, bank cutting, tree removal, and restoring migrated stream channel meanders.

After survey, the channel dimensions, pattern, and profile will be established from data collected in a

stable stream channel/reference reach, if available. Where no reference reach is available, the channel characteristics will be obtained from published sources and the published characteristics will be mimicked to create a stable reach. Since much of the floodplain appears to be stable, there is little need to relocate the channel. Reconnection of the channel to the floodplain will be very costly. If a new channel is created at a new location, great care should be taken to ensure measures are included to maintain lateral stability of the stream due to erodible floodplain materials.

Channel stability after layout includes the use of grade control structures such as rock cross vanes or constructed riffles as coordinated with local, State, and Federal permitting agencies. Use of other features such as rock toe protection (primarily at bends), rock vanes, single/double wing deflectors (rock), and J-hooks should be used to maintain lateral stability and promote aquatic habitat. The use of boulders, root wads, and other standard practices can be considered to promote aquatic habitat enhancement at this site.

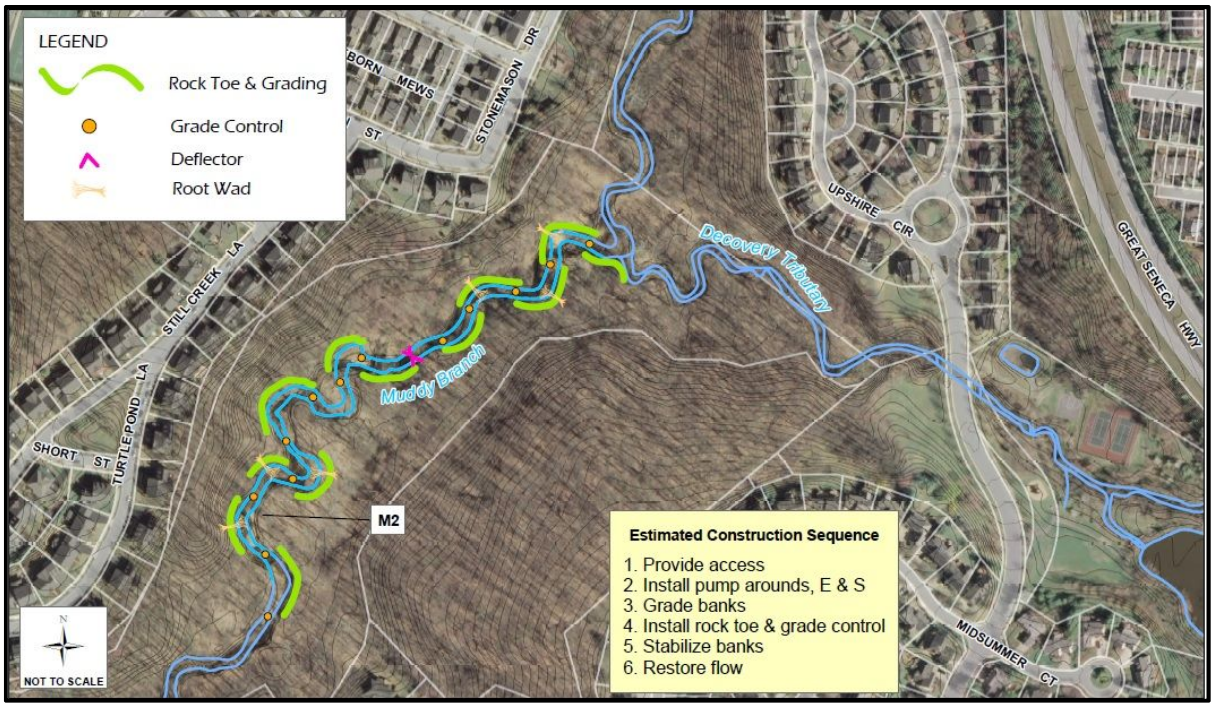
Bank grading (cutting) within the limits of the M2 reach would assist greatly in promoting long term stability of the channel. While the floodplain is moderately forested, there is ample ground cover to suggest that vegetated stabilization should thrive on the stream banks above the bankfull elevation. To promote healthy stands of vegetation a 3:1 slope is preferred; however, a 2:1 maximum slope could be used to help minimize impacts to adjacent trees.

Erosion around and under trees is causing trees to fall into channel, therefore, much of the lateral channel instability appears to be from tree falls. While tree falls and trees washing into the reach cannot be eliminated, a mitigation measure to minimize this condition could include flush cutting of trees adjacent to the incised channel. The root mass of the cut tree would remain to stabilize the bank and additional trees could be planted. Planting of new trees along the banks will introduce diversity within the watershed and promote bank stability, cover for wildlife, and enhance food sources.

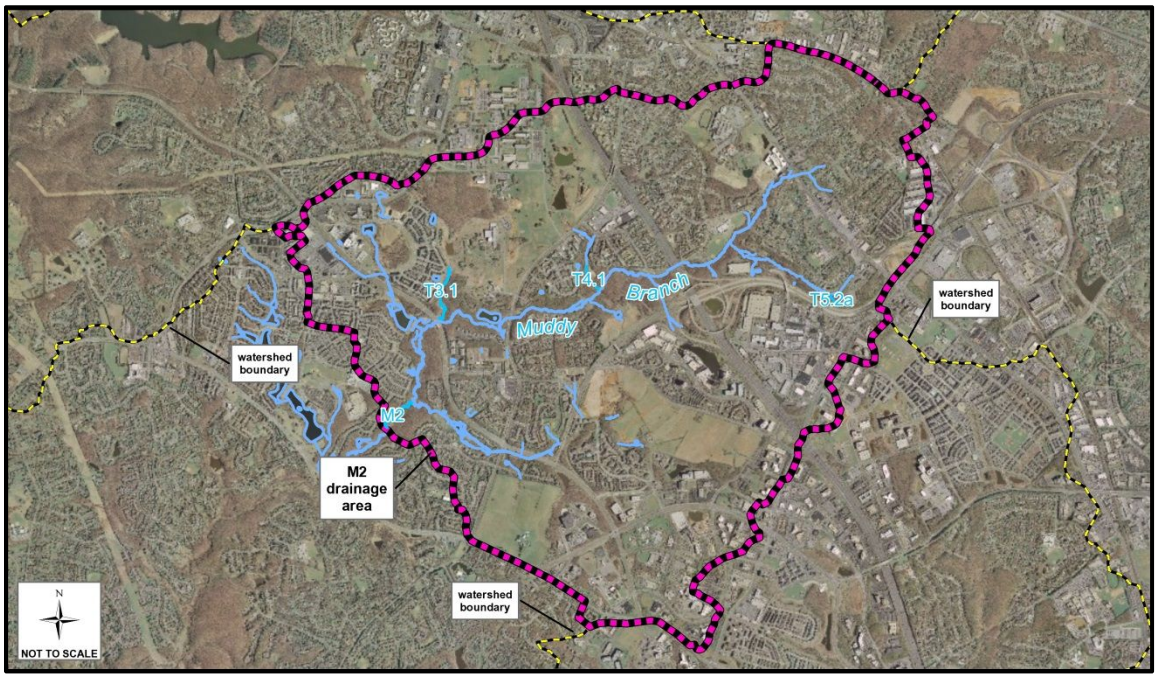
Reconstruction of meander bends to acceptable radii of curvature (radius of curvature/stream width equal to or greater than 2.5) will be accomplished by realigning the channel in at least four locations. Reconstruction to pre migration condition could potentially restore the oxbow bend noted in the trailside placard. The outside meander bends will need be protected to ensure that lateral migration does not recur once the channel restoration has been completed. The bank protection will likely take the form of single or double rock toe using boulders sized for the maximum stream velocity and shear stresses in the bend. The toe rocks should only be extended to bankfull depth with graded banks occurring above the toe rocks. Depending on the hydraulic study, the stream banks will be graded to provide vegetated flat bankfull floodplains or sloped flood-prone areas to reduce shear stress in the active channel.

Very few specimen trees (24” DBH or greater) will need to be removed for this project (fewer than 10 are anticipated). Approximately 1,720 linear feet of stream would be restored at this reach. Additional stream channel will be restored by installing the cross vanes as the channel narrows and heals over time.

Reach M2 – Future City Park Concept Plan



M2 Drainage Area Map



Project Improvements and Benefits: Opportunities for new stormwater management facilities and retrofits to existing stormwater management facilities are limited in the City; therefore, stream restoration may contribute significantly to attaining the objectives of the Muddy Branch study and complying with the City's Municipal Separate Storm Sewer System (MS4) permit.

In January, 2012, the Chesapeake Bay Program (CBP) approved interim nutrient and sediment removal rates for stream restoration projects, pending the outcome of a study performed by an expert panel on stream restoration credits. This study is titled *Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects.* The study is currently under review by the CBP. The interim removal rates approved by the CBP are as follows:

Total Nitrogen (TN) – 0.075 pounds/foot/year

Total Phosphorus (TP) – 0.068 pounds/foot/year

Total Suspended Solids (TSS) – 248 pounds/foot/year

The 1,720 feet of stream restoration at Reach M2 is estimated to provide the following pollutant reduction credits per year:

65 pounds of TN

58 pounds of TP

110 tons of TSS

Potential NPDES impervious area credit for Reach M2 is estimated to be 17.2 acres.

Alternative Measures Considered:

An alternative restoration project considered included the complete realignment of the stream channel. This alternative was deemed infeasible since the surrounding overbanks have steep grades and it would not be cost-effective.

Project Design Considerations:

Access to Reach M2 can be from either Stonemason Drive (across from Lot 501) or Turtle Pond Lane (Lot 760-798). Both access locations would require nearly 2,300 linear feet of path/road. An existing narrow grass road parallels the channel between these potential access locations. Both sites have a small clearing located adjacent to the access route that may be considered for staging/stockpile areas. Access points will need to be defined along the stream channel to minimize impacts on trees and their critical root zones. The access will also need to consider the possible presence of utilities in the area. Stream diversions will be needed at each of the stream restoration locations. No constructability issues have been identified to date that would make the project

Trees projecting into channel should be removed or armored to prevent tree falls that cause channel instability in the reach.

infeasible.

No storage of equipment and materials within the floodplain during construction may be a condition of permit authorization. Equipment/materials will likely need to be stored within the floodplain; however, it would be preferable to give the contractor the option of keeping equipment near the road if large storms are forecasted. Trees impacted for construction of the road would need to be replaced after the stream work is completed. The cost estimate includes native trees; approximate 2-inch caliper and minimum spacing of 20' on center with shrubs. Replanting of 1300 LF access path (0.36 acres) includes 45 trees (a combination of sycamores in flat areas and oaks in dry slope areas) and 360 shrubs. Cost per tree includes installation mulching and watering. The remaining access path utilizes an existing path and will not be reforested.

Newly fallen tree into channel with green leaves and root mass perpendicular to flow. Causing severe erosion on both banks.

Plans and Permitting: Construction documents and plans may be needed to implement a stream restoration project, including, but not limited to:

- Natural Resource Inventory/Forest Stand Delineation Plan (NRI/FSD)
- Forest Conservation Plan (FCP)

Several permits or approvals may be needed to implement a stream restoration project, including, but not limited to:

- MDE Nontidal Wetland and Waterway Permit & U.S. Army Corps of Engineers (USACE) approval (MDE advises to allow one year for permit processing)
- Floodplain permit application and study
- Grading and Erosion Sediment Control Permit
- National Pollutant Discharge Elimination System (NPDES) Construction Permit
- Stormwater Concept application (permit waiver is assumed)

A kickoff meeting and pre-application coordination with the permitting agencies is recommended.

Property Ownership: Reach M2 and both potential access points are located on property owned by the City of Gaithersburg. Montgomery County GIS indicates they are Parcel F, J, and V of the Lakelands Development (Subdivision 292).

Utility Conflicts:
No utility conflicts are expected; however, gravity sewer lines may exist within the project corridor. Special design or avoidance may be necessary when constructing the access road or channel protection.

Cost Estimate

The cost for the Reach M2 restoration project is estimated to be $1,157,000. This estimate includes construction, engineering, surveys, and permitting. Engineering costs cover supplemental items such as TTCP and SEC specifications. Construction inspection and administration (by the City) is proposed for the duration of the construction. Post-construction monitoring is suggested but not required to provide feedback regarding the effects of the stream restoration and potentially justify greater efficiency credits from MDE. Tree sizes are suggested at 12 foot minimum height (2-inch caliper). Below is the cost estimate for Reach M2.

Reach M2 Future City Park

Item	Quantity	Unit	Unit Cost	Total
Stakeout	1	EA	$3,500	$3,500
Maintenance of Traffic	1	EA	$2,000	$2,000
Stabilized Construction Entrance	1	EA	$6,000	$6,000
Clearing and Grubbing	1	EA	$40,000	$40,000
Maintenance of Stream Flow	3	EA	$10,000	$30,000
Excavation & Removal from Site	3100	CY	$25	$77,500
Select Backfill	500	CY	$40	$20,000
Cross Vanes/Riffle Grade Control	14	EA	$7,500	$105,000
Double Rock Toe Protection	800	LF	$125	$100,000
Coir Log (20-inch)	800	LF	$40	$32,000
Topsoil	510	CY	$32.50	$16,575
Tree Protection Fence	500	LF	$2.20	$1,100
Temporary Mulch Access Road	2,300	LF	$35.00	$80,500
Temporary Stream Crossings	2	EA	$3,500	$7,000
Temporary Matting	4600	SY	$4.00	$18,400
Silt Fence	500	LF	$5.50	$2,750
Seed Mix	4600	SY	$1.00	$4,600
Live Stakes	500	EA	$3.00	$1,500
Shrubs – containerized	360	EA	$45.00	$16,200
2-Inch Caliper Trees	45	EA	$250.00	$11,250
			Base Construction Cost*	$576,000
			Construction Inspection and Administration (15%)*	$87,000
			Mobilization (10%)*	$58,000
			Subtotal 1	$721,000
			Contingency (25%)*	$181,000
			Subtotal 2	$902,000
			Engineering	$190,000
			Surveys	$35,000
			Permits	$30,000
			Estimated Project Cost	**$1,157,000**
			Optional Post Construction Monitoring (5 years)	$50,000
			Estimated Cost w/ Additional Options	**$1,207,000**

Legend

CY = Cubic Yard

EA = Each

LF = Linear Foot

SY = Square Yard

** - Denotes values rounded to nearest thousand*

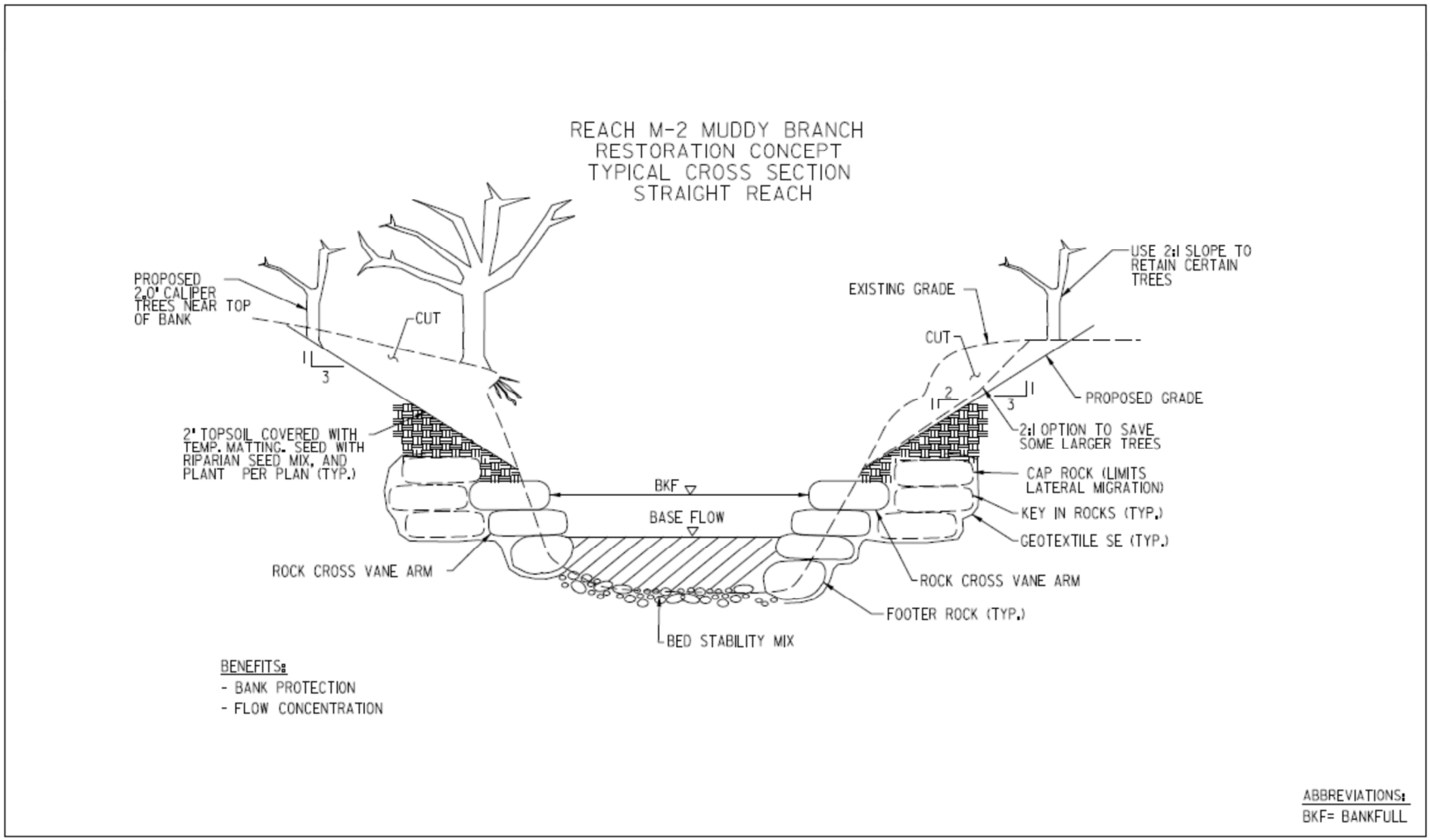
Stream Length = 1720 LF

Approx. Number of Imp. Area Credits = 17.2 acre

Cost/LF = $673

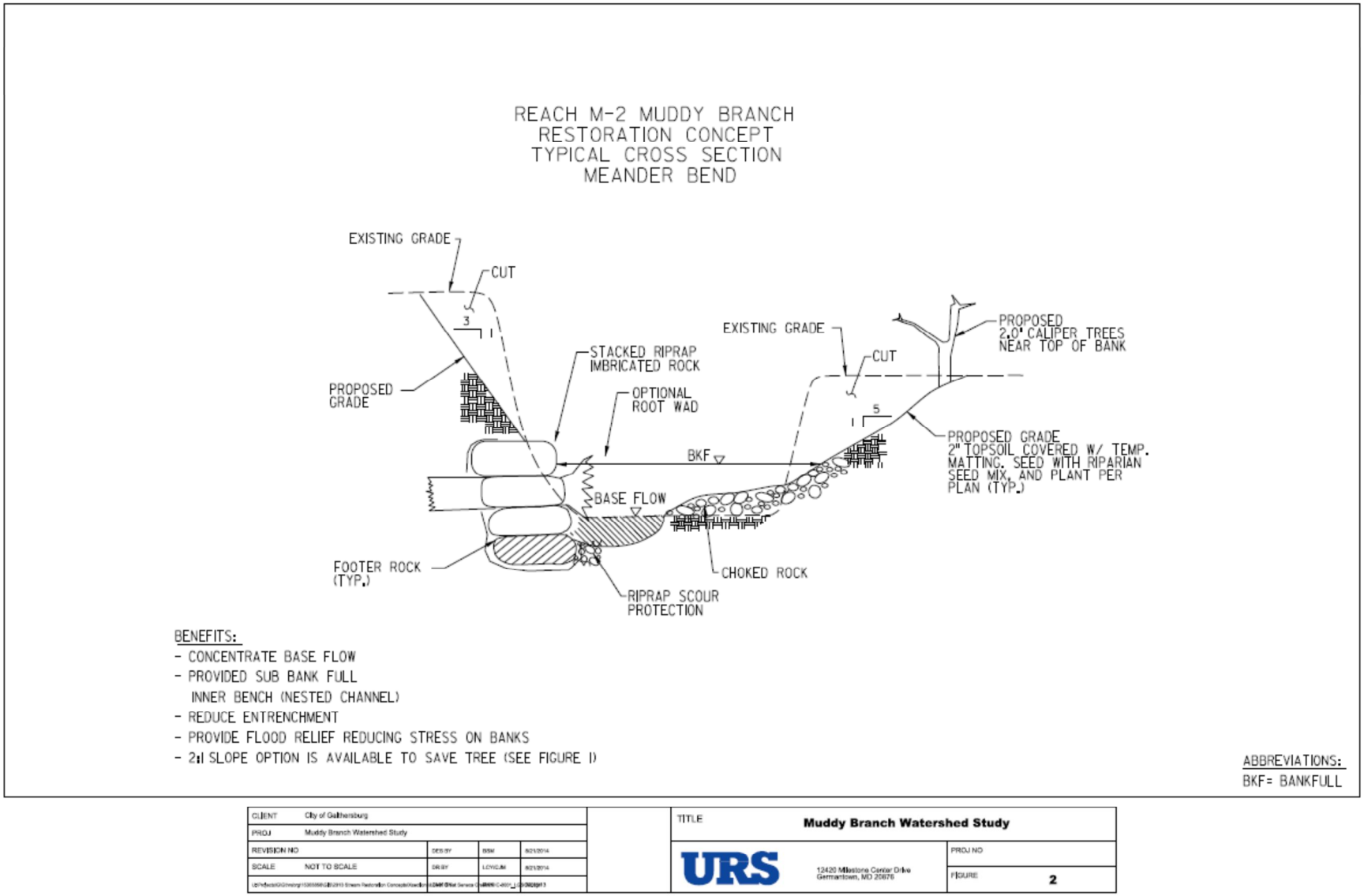
Cost/Credit = $70,174

Typical Cross Section for Reach M2 – Straight Channel Section:



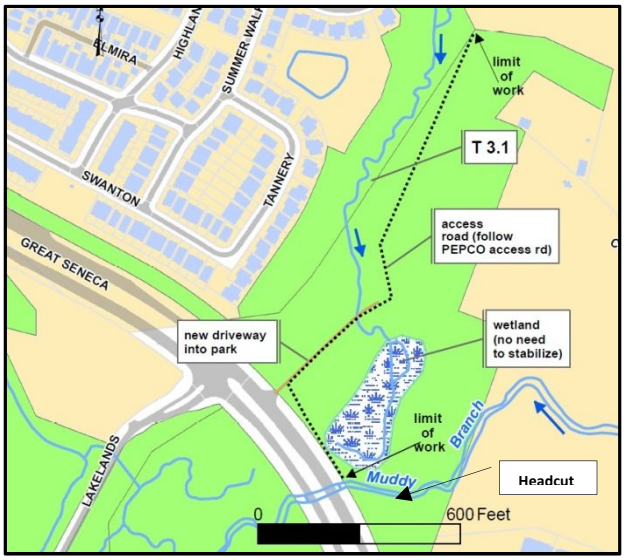
CLIENT	City of Gaithersburg				TITLE	Muddy Branch Watershed Study
PROJ	Muddy Branch Watershed Study				URS 12420 Milestone Center Drive Germantown, MD 20876	PROJ NO
REVISION NO		DES BY	BSM	8/21/2014		FIGURE 1
SCALE	NOT TO SCALE	DR BY	LOYCJM	8/21/2014		

Typical Cross Section for Reach M2 – Meander Bend:



Reach T3.1 Quince Orchard Park

Drainage Area (in the City): 345 acres
Length of Restoration: 1,540 feet



Restoration Estimated Captures:

- TN: 58 lbs per year
- TP: 52 lbs per year
- TSS: 100 tons per year

Site Description: The tributary outlet for Reach T3.1 is located north of the Muddy Branch bridge crossing for Great Seneca Highway (MD 119). The upper limit of the reach is at the fence for the National Institute of Standards and Technology (NIST). Overall, the upper 100 feet of the reach is stable; however, there is a confluence with a sub-tributary and the channel starts degrading just downstream of the confluence and becomes more pronounced as the channel proceeds downstream. At the downstream limit of Reach T3.1, there is a large wetland shown on Google Maps as Lake Elysium. The channel within the wetland area is small and deep with wetland vegetation along both banks. Due to wetland impacts and limited benefit from channel stabilization, the wetland area is not considered to be part of the project. However, a head cut is forming at the outlet of the wetland. Stabilization of this headcut is essential for long term stability within the reach. A new driveway/access is under construction from Great Seneca Highway and includes a culvert that has a plunge pool at the outfall. Limited benefit is expected from the newly constructed improvements between the new driveway and wetland. However, the channel upstream appears to have started a headcut above the culvert. The headcut is allowing the stream to undercut the channel banks below the existing root mass causing bank failure along the reach. The stream banks range from 1-3 feet high at the headwaters to 3-5 feet high closer to the new driveway. The channel banks are nearly vertical at the outside meander bends. The instability is causing the stream to incise in the rangeof inches (at the headwater) to feet (near the driveway) above the bankfull elevation.

Dashed line shows limit of channel widening and bank failure plane along channel. Bank failure is leaving an exposed soil bank that will allow channel instability and bank erosion.

Restoration Goals: The goals of this restoration project are to stabilize the eroding stream banks, reduce channel incision, reduce the discharge of sediment and associated nutrients downstream, and improve aquatic habitat.

Bank failure lines are evident in the field as indicated by the red dashed line. Undercut of the banks is causing the banks to fail a couple feet back from the existing bank.

Proposed Restoration: The restoration for Reach T3.1 would involve the following:

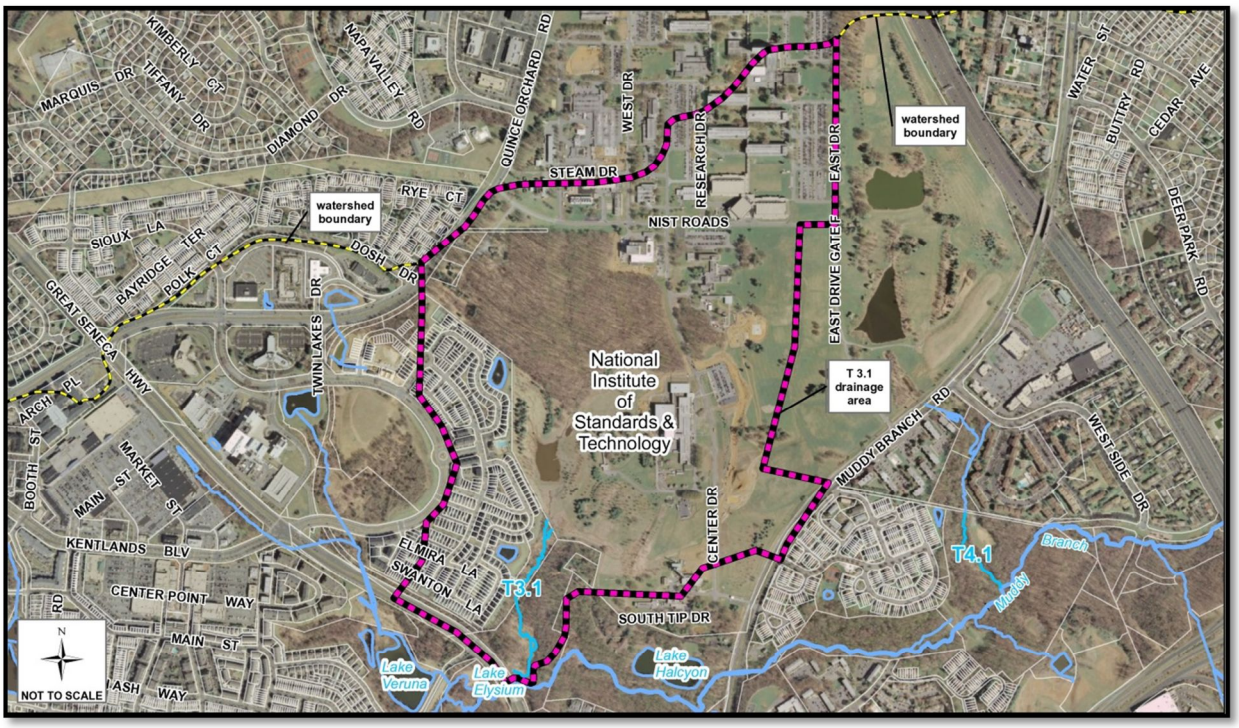
- Reconnect the stream to the floodplain in the upper reaches (where possible)
- Grading of the banks to provide bankfull benches or increasing the floodprone area by grading the banks back at a 3:1 slope
- Stabilizing the graded banks with native plants and live stakes
- Realigning the stream channel in selected areas to improve the horizontal geometry of the stream
- Repair the channel connection by stabilizing the headcut forming at the outfall at Lake Elesium.

Due to high potential for groundwater from the wetland, step pools or other grade control features would be required. Site access should avoid the wetland to the extent practicable as wetland planking will increase the overall project cost. The wetland planking costs were not included in the estimate for Reach T3.1.

Installing grade control structures such as cross vanes, sills, and step pools to direct the energy of high flows toward the center of the channel, to reduce future bed degradation, and to improve aquatic habitat.

Reach T3.1 Quince Orchard Park Concept Plan

T3.1 Drainage Area Map



The drainage area for this concept contains flow from the NIST property. While there is no proposed work within the NIST property, it would be beneficial to the project to ensure that the downstream channel can convey peak discharges from the NIST property. Data requested from NIST should included peak flows or any information that can be shared on the ultimate buildout of the NIST pproperty. NIST is a separate juridiction within the limits of the City of Giathersburg. Due to this overlap in jurisdiction, the City will need to coordinate and promote outreach with NIST. Any work agreed to within the boundary of NIST will increase the cost of the project. Work on Federal Land can include numerous reviews and special conditions for design and construction.

Coordination is recommended during design and constrution to ensure that NIST is aware of the work due to sensitive instrumentation located within the facility.

Project Improvements and Benefits: Opportunities for new stormwater management facilities and retrofits to existing stormwater management facilities are limited in the City; therefore, stream restoration may contribute significantly to attaining the objectives of the Muddy Branch study and complying with the City's MS4 permit.

Based on the interim sediment and nutrient removal rates for stream restoration projects that were approved by the CBP in January, 2012, the Reach T3.1 stream restoration is estimated to provide the following pollutant reductions per year:

58 pounds of TN

52 pounds of TP

100 tons of TSS

Potential NPDES impervious area credit for Reach T3.1 is estimated to be 15.4 acres.

Alternative Measures Considered: An alternative restoration project evaluated included the complete realignment of the stream channel which was deemed infeasible due to high costs and would result in elimination of more trees than would be necessary to obtain stream health.

Eroding banks roughly half way down the reach. Slightly incised channel may be able to reconnect with heavily vegetated floodplain.

Project Design Considerations: Construction access is a concern; however, the new driveway/access off of Great Seneca Highway would have the best potential for access. Access for this site will impact several trees; however, many of the larger trees should be avoided with planning. In order to prevent compaction of the root zone and rutting of the floodplain, mulch access path would be preferred to stone. The conceptual access road would be 12 feet wide and approximately 1,580 LF in order to traverse the entire reach.

Equipment and materials storage should be located outside of the floodplain; however, temporary stockpile areas within the floodplain would require permit authorization. Trees impacted for construction of the access road would need to be replaced after the stream work is completed. Where feasible, the trees should be selected to promote a diversity of vegetation within the reach. The cost estimate includes native trees; approximate 3/4-inch caliper and five feet in height planted at a spacing of 20' on-center with shrubs. Replanting the 1,580 LF access path (0.44 acres) includes 50 trees and 810 shrubs. Cost per tree includes installation mulching and watering.

Undercutting of bank undermines bank vegetation and promotes bank failure. Upper reaches could be reconnected with floodplain with grade control.

Plans and Permitting: Construction documents and plans may be needed to implement a stream restoration project, including, but not limited to:

- Natural Resource Inventory/Forest Stand Delineation Plan (NRI/FSD)
- Forest Conservation Plan (FCP)

Additionally, several permits or approvals may be needed to implement a stream restoration project, including, but not limited to:

- MDE Nontidal Wetland and Waterway Permit & U.S. Army Corps of Engineers (USACE) approval (MDE advises allowing one year for permit authorization)
- Floodplain permit application and study
- Grading and Erosion Sediment Control Permit
- National Pollutant Discharge Elimination System (NPDES) Construction Permit
- Stormwater Concept application (permit waiver is assumed)

A kickoff meeting and pre-application coordination with the permitting agencies is recommended.

Property Ownership: Reach T3.1 and potential access point are located on property owned by the City of Gaithersburg. Montgomery County GIS indicates they are Parcel F of the Quince Orchard Park Development (Subdivision 290 and Subdivision 201).

Utility Conflicts: No utility conflicts are expected.

Cost Estimate

The cost for the Reach T3.1 project is estimated to be $1,115,000. This estimate includes construction, engineering, surveys, and permitting. Engineering costs cover supplemental items such as TTCP and SEC specifications. Construction management and administration (by the City) is proposed for the duration of the construction. Post-construction monitoring is suggested but not required to provide feedback regarding the effects of the stream restoration and potentially justify greater efficiency credits from MDE. Tree sizes are suggested to be a minimum height of 12 feet (2-inch caliper). Below is the cost estimate for Reach T3.1.

Reach T3.1 Quince Orchard Park

Item	Quantity	Unit	Unit Cost	Total
Stakeout	1	EA	$3,500	$3,500
Maintenance of Traffic	1	EA	$2,000	$2,000
Stabilized Construction Entrance	1	EA	$6,000	$6,000
Clearing and Grubbing	1	EA	$40,000	$40,000
Maintenance of Stream Flow	3	EA	$10,000	$30,000
Excavation & Removal from Site	2800	CY	$25	$70,000
Select Backfill	500	CY	$40	$20,000
Small Cross Vanes/Riffle Grade Control	35	EA	$3,500	$122,500
Double Rock Toe Protection	800	LF	$125	$100,000
Coir Log (20-inch)	800	LF	$40	$32,000
Topsoil	460	CY	$32.50	$14,950
Tree Protection Fence	500	LF	$2.20	$1,100
Temporary Mulch Access Road	1,800	LF	$35.00	$63,000
Temporary Stream Crossings	2	EA	$3,500	$7,000
Temporary Matting	4,200	SY	$4.00	$16,800
Silt Fence	500	LF	$5.50	$2,750
Seed Mix	4,200	SY	$1.00	$4,200
Live Stakes	500	EA	$3.00	$1,500
Shrubs – containerized	270	EA	$45.00	$12,150
2-Inch Caliper Trees	50	EA	$250.00	$12,500

Base Construction Cost*	$562,000
Construction Inspection and Administration (15%)*	$85,000
Mobilization (10%)*	$57,000
Subtotal 1	$704,000
Contingency (25%)*	$176,000
Subtotal 2	$880,000
Engineering	$170,000
Surveys	$35,000
Permits	$30,000
Estimated Project Cost	**$1,115,000**
Optional Post Construction Monitoring (5 years)	$50,000
Estimated Cost w/ Additional Options	**$1,165,000**

Legend

CY = Cubic Yard

EA = Each

LF = Linear Foot

SY = Square Yard

** - Denotes values rounded to nearest thousand*

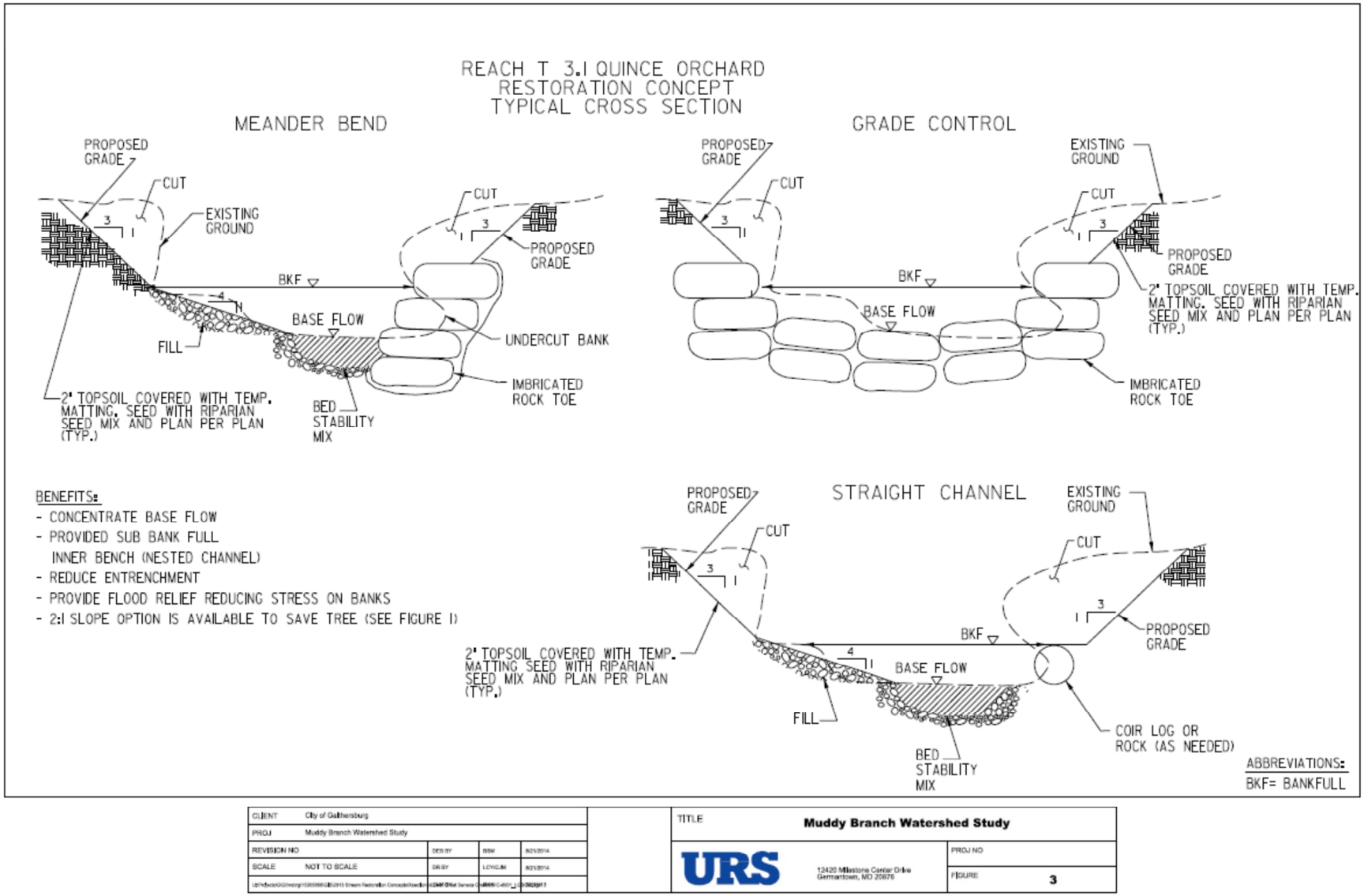
Stream Length = 1540 LF

Approx. Number of Imp. Area Credits = 15.4 acre

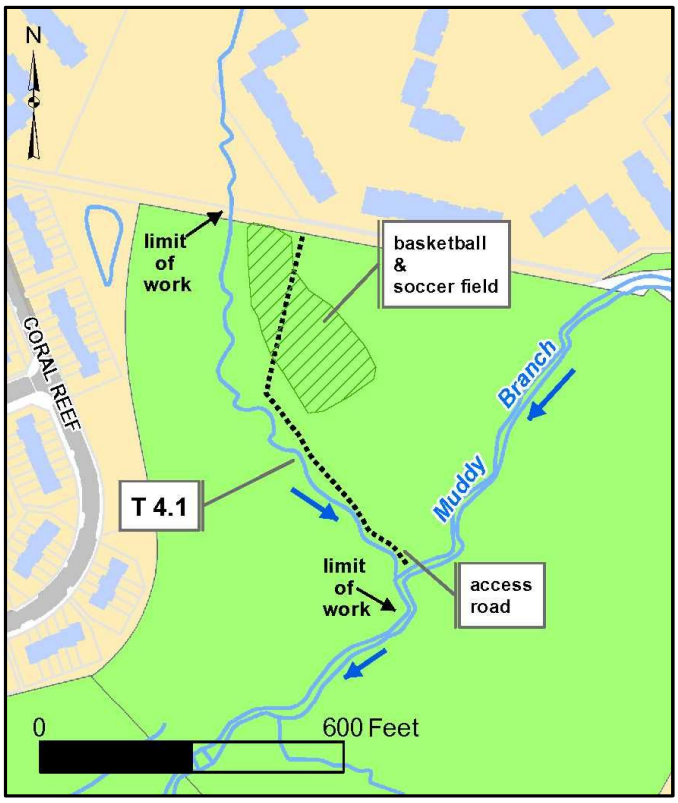
Cost/LF = $756

Cost/Credit = $75,649

Typical Cross Section for Reach T3.1:



Reach T4.1 – Brighton Village



Drainage Area (in the City): 490 acres
Length of Restoration: 970 feet

Restoration Estimated Captures:

- TN: 36 lbs per year
- TP: 33 lbs per year
- TSS: 65 tons per year

Site Description: The existing T4.1 reach is a highly degraded second order stream reach in the southwest portion of the City on Muddy Branch. The reach lies within Malcom King Park. The upper limit of the reach is located upstream of the quadruple culverts under the park trail. The downstream limit is the confluence with Muddy Branch. The stream is on a relatively flat longitudinal slope and incised with vertical banks around meander bends. What vertical and lateral stability the reach is due to clay seams. In general, the stream is characterized by high steep banks with a broad floodplain that is moderately forested with abundant low vegetation across the floodplain. Much of the instability appears to be caused by a combination of channel incision (perhaps ±1 foot), erodible bank material, and woody debris. The channel appears to have incised and is undermining trees along the reach. Trees that are undermined within the reach are promoting debris jams within the reach. Once the debris jams are established the banks erode causing significant channel instability within the reach. There are a couple of riffles that are not stable and directing flow into bank(s). Other areas, debris jams have caused the channel to over widen. In-stream cover for fish is limited to shallow pools and occasional woody material that is associated with debris jams. There are heavy deposits of silt and some gravel point bars in the stream.

Recommended start point is 50 feet upstream of quadrupal 30 inch culvert. Left outer barrel is blocked by sediment. Better channel alignment will help prevent clogging.

Clay seam around bends is affording some vertical and lateral stability to the reach. Rocks dislodges from bank allow holes that offer continued erosion points along banks.

Restoration Goals: The goals of this concept are to reduce shear stress on the stream banks, remove debris from channel, restore lateral stability, minimize stream incision, and improve aquatic habitat. By addressing these goals, water quality downstream should be improved.

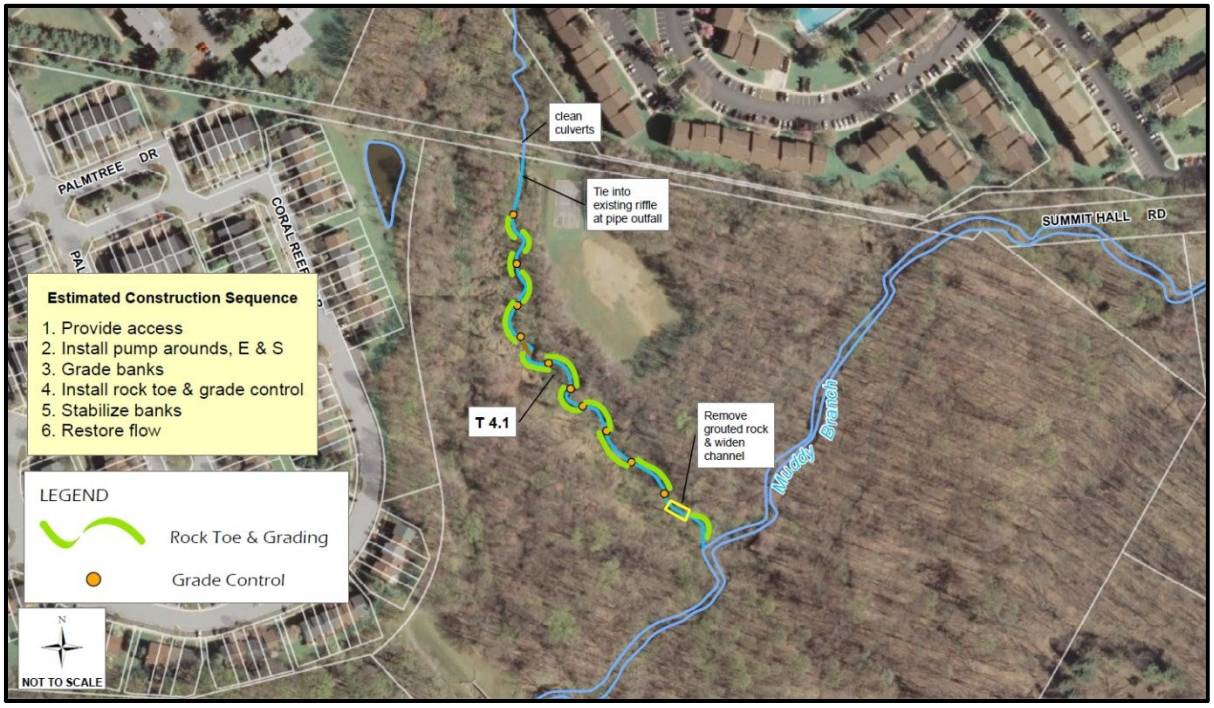
Proposed Restoration: The restoration for Reach T4.1 would involve the following:

Remove existing grouted rock flume and provide grade control at apropriate stream width to promote aquatic passage. Based on adjacent WSSC manholes, this may be a utility crossing.

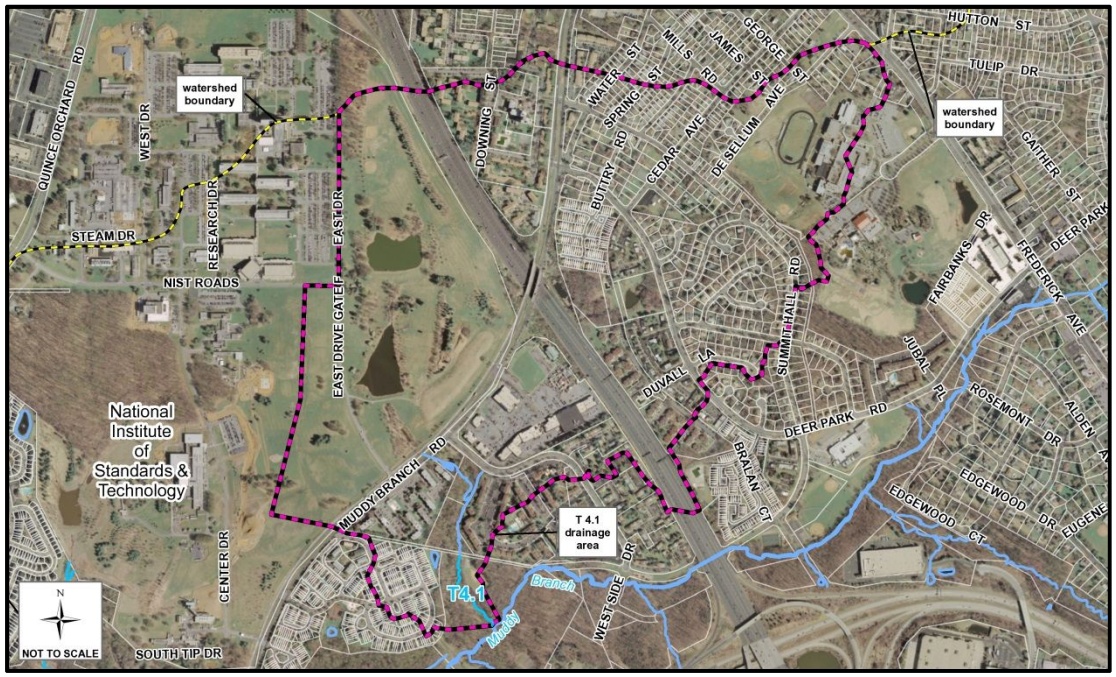
- Remove grouted rock and restore channel dimensions at downstream limit of reach
- Remove debris jams, leaning trees, and invasive vegetation from reach to promote healthy canopy and understory growth
- Install low rock toe walls and grade channel banks to reduce shear stresses on bends
- Establish profile by installing grade control features to reconnect the stream with the floodplain
- Realigning the stream channel in selected areas to improve the horizontal geometry of the stream
- Provide better alignment of channel with multi-cell culvert at upstream limit of reach
- Reduce stream cross section where channel is overwidened with coir logs or wing deflectors

Installing grade control structures such as cross vanes, sills, and step pools to direct the energy of high flows toward the center of the channel, to reduce future bed degradation, and to improve aquatic habitat.

Reach T4.1 – Brighton Village Concept Plan



Reach T4.1 – Brighton Village Drainage Area Map



Project Improvements and Benefits: Opportunities for new stormwater management facilities and retrofits to existing stormwater management facilities are limited in the City; therefore, stream restoration may contribute significantly to attaining the objectives of the Muddy Branch study and complying with the City's Municipal Separate Storm Sewer System (MS4) permit.

In January, 2012, the Chesapeake Bay Program (CBP) approved interim nutrient and sediment removal rates for stream restoration projects, pending the outcome of a study performed by an expert panel on stream restoration credits. This study is titled *Recommendations of the Expert Panel to Define Removal Rates for Individual Stream Restoration Projects.* The study is currently under review by the CBP. The interim rates approved by the CBP are as follows:

Total Nitrogen (TN) – 0.075 pounds/foot/year

Total Phosphorus (TP) – 0.068 pounds/foot/year

Total Suspended Solids (TSS) – 248 pounds/foot/year

The 970 feet of stream restoration at Reach T4.1 would therefore provide the following pollutant reduction credits per year:

36 pounds of TN

33 pounds of TP

65 pounds of TSS

Potential NPDES impervious area credit for Reach T4.1 is estimated to be 9.7 acres.

Alternative Measures Considered:

An alternative restoration project could have been the complete realignment of the stream channel which was deemed infeasible since the surrounding overbanks include a park with playing fields.

Project Design Considerations:

Section of overwidened channel with debris jam at downstream limit. Realigned channel with bankfull bench to restore channel.

One of the design considerations for this project is construction access. Due to right-of-way issues, the project will have to be accessed from either Coral Reef drive or West Side drive. Closer access would be through the Brighton West Parcel; however, there is no defined public access for the site that is indicated from the County's GIS map database. During the field walk, a City maintenance truck was observed crossing the multi-cell culvert. Based on maintenance truck use, it is anticipated that the contractor will be able to deliver material to the site via the park maintenance road from the West Side Drive cul-de-sac. If access requires additional protection, it will increase expected project cost. Conceptual access is to access the upstream site from the west side of the multi-cell culvert; whereas, the downstream areas can be accessed by hugging the perimeter of the area cleared for the basketball court and playing field. Once past the playing fields (in the wooded area), the contractor would selectively clear the area through the wooded floodplain to remove trees noted on the plans or as revised in the field. Mulch access road would be utilized to ensure the playing fields are not damaged and to minimize root compaction within the wooded areas. The conceptual access road would be 12 feet wide and extend approximately 1000 feet along the restoration reach. Mulch is proposed rather than stone due to cost. Mulch is expected to remain stable because the majority of the access road is flat topography.

Due to the wide floodplains, storage of equipment and materials outside the floodplain during construction may not be possible and may be a condition of permit authorization. Trees impacted for construction of the road would need to be replaced after the stream work is completed. The cost estimate includes native trees; approximate 2-inch caliper and a minimum of 12 feet in height planted at a spacing of 20 feet on center with shrubs. Replanting the 600 LF access path (0.2 acre) includes 100 trees (a combination of sycamores in flat areas and oaks in dry slope areas) and 300 shrubs. Cost per tree includes installation mulching and watering. The remaining access path utilizes an existing path and will not be reforested.

Plans and Permitting: Construction documents and plans may be needed to implement a stream restoration project, including, but not limited to:

- Natural Resource Inventory/Forest Stand Delineation Plan (NRI/FSD)
- Forest Conservation Plan (FCP)

Several permits or approvals may be needed to implement a stream restoration project, including, but not limited to:

- MDE Nontidal Wetland and Waterway Permit & U.S. Army Corps of Engineers (USACE) approval (MDE advises allowing 1 year of permit authorization)
- Floodplain permit application and study
- Grading and Erosion Sediment Control Permit
- National Pollutant Discharge Elimination System (NPDES) Construction Permit
- Stormwater Concept application (permit waiver is assumed)

A kickoff meeting and pre-application coordination with the permitting agencies is recommended.

Property Ownership: Reach T4.1 is located on property owned by the City of Gaithersburg. However, there is at least one potential utility crossing within the reach. Investigation of utility easements and coordination with the respective utilities should be completed as part of the design process.

Utility Conflicts:
There is at least one potential utility crossing within the reach. Investigation of utility easements and coordination with the respective utilities should be completed as part of the design process.

Cost Estimate

The cost for the Reach T4.1 restoration project is estimated to be $742,000. This estimate includes construction, engineering, surveys, and permitting. Engineering costs cover supplemental items such as TTCP and SEC specifications. Construction management and administration (by the City) is proposed for the duration of the construction. Post-construction monitoring is suggested but not required to provide feedback regarding the effects of the stream restoration and potentially justify greater efficiency credits from MDE. Tree sizes are suggested to be a 12 minimum height (2-inch caliper). Below is the cost estimate for Reach T4.1.

Reach T4.1 Brighton Village

Item	Quantity	Unit	Unit Cost	Total
Stakeout	1	EA	$2,000	$2,000
Maintenance of Traffic	1	EA	$2,000	$2,000
Stabilized Construction Entrance	1	EA	$6,000	$6,000
Clearing and Grubbing	1	EA	$40,000	$40,000
Maintenance of Stream Flow	3	EA	$10,000	$30,000
Excavation & Removal from Site	1000	CY	$25	$25,000
Select Backfill	300	CY	$40	$12,000
Small Cross Vanes/Riffle Grade Control	18	EA	$4,500	$81,000
Double Rock Toe Protection	485	LF	$125	$60,625
Coir Log (20-inch)	450	LF	$40	$18,000
Topsoil	220	CY	$32.50	$7,150
Tree Protection Fence	500	LF	$2.20	$1,100
Temporary Mulch Access Road	1,000	LF	$35.00	$35,000
Temporary Stream Crossings	2	EA	$3,500	$7,000
Temporary Matting	1940	SY	$4.00	$7,760
Silt Fence	500	LF	$5.50	$2,750
Seed Mix	1940	SY	$1.00	$1,940
Live Stakes	500	EA	$3.00	$1,500
Shrubs – containerized	300	EA	$45.00	$13,500
2-Inch Caliper Trees	25	EA	$250.00	$6,250

Base Construction Cost*	$361,000
Construction Inspection and Administration (15%)*	$55,000
Mobilization (10%)*	$37,000
Subtotal 1	$453,000
Contingency (25%)*	$114,000
Subtotal 2	$567,000
Engineering	$120,000
Surveys	$25,000
Permits	$30,000
Estimated Project Cost	**$742,000**
Optional Post Construction Monitoring (5 years)	$50,000
Estimated Cost w/ Additional Options	**$792,000**

Legend

CY = Cubic Yard

EA = Each

LF = Linear Foot

SY = Square Yard

** - Denotes values rounded to nearest thousand*

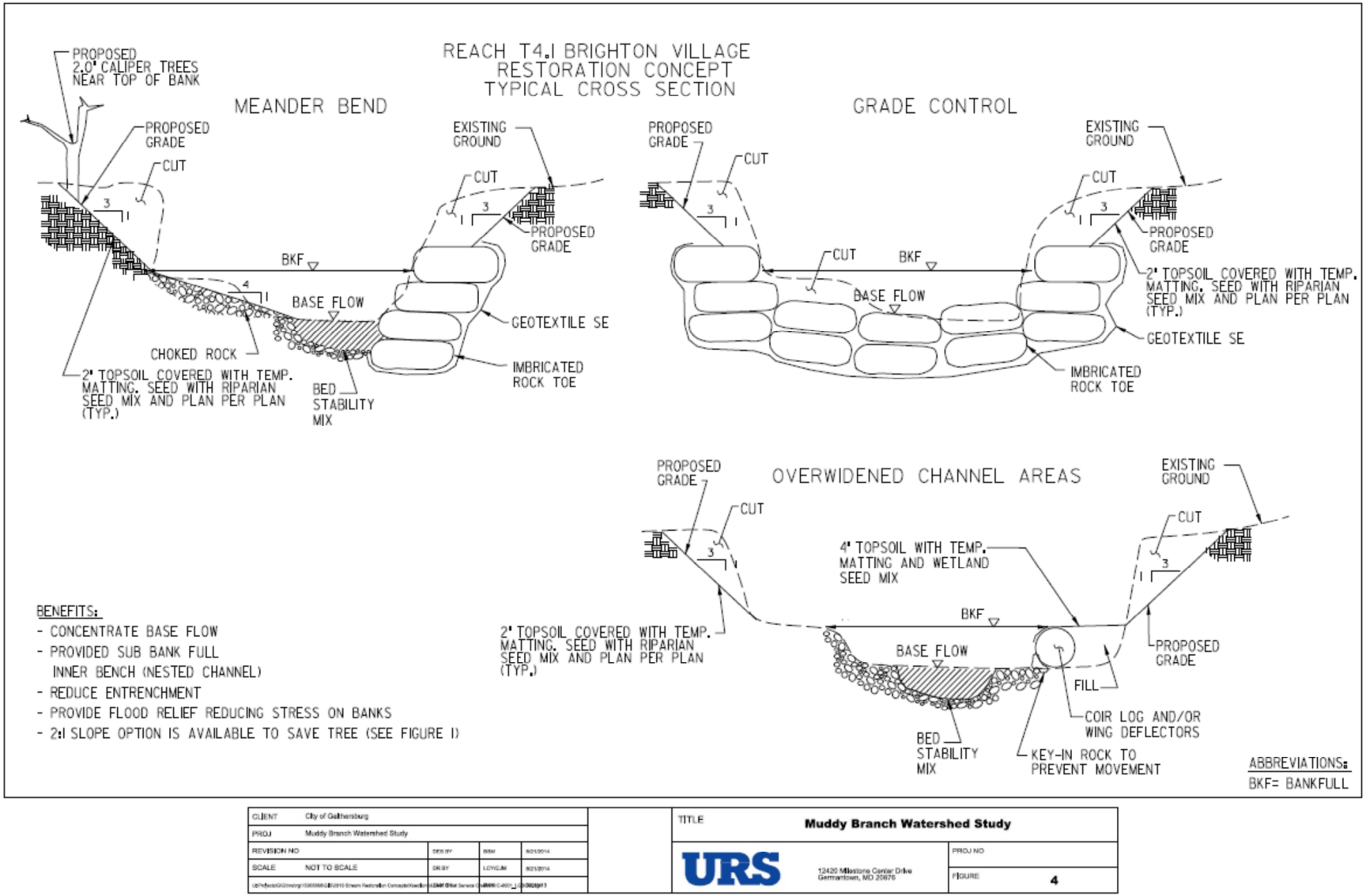
Stream Length = 970 LF

Approx. Number of Imp. Area Credits = 9.7 acre

Cost/LF = $816

Cost/Credit = $81,649

Typical Cross Section for Reach T4.1:



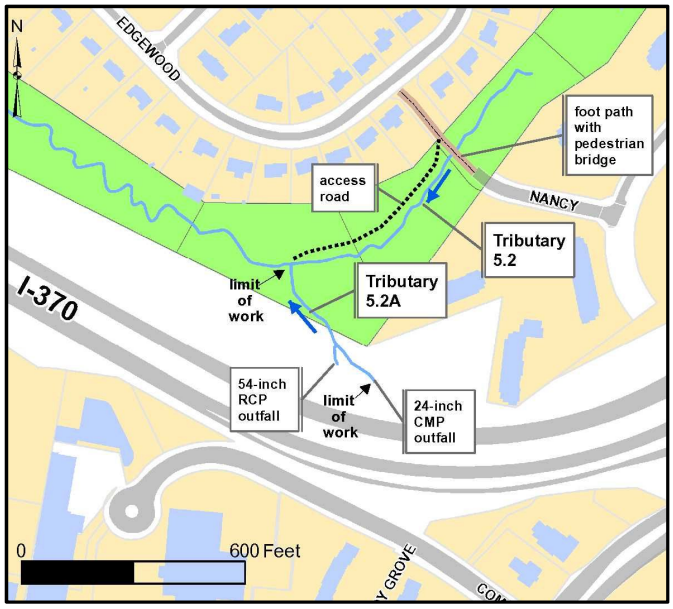
CLIENT	City of Gaithersburg			TITLE	Muddy Branch Watershed Study
PROJ	Muddy Branch Watershed Study			URS 12420 Milestone Center Drive Germantown, MD 20876	PROJ NO
REVISION NO		DES BY	BSM		FIGURE 4
SCALE	NOT TO SCALE	DR BY	LCYCLM		

Reach T5.2a – I-370 Outfall

Drainage Area (in the City): 50 acres
Length of Restoration: 460 feet

Restoration Estimated Captures:

- TN: 17 lbs per year
- TP: 16 lbs per year
- TSS: 30 tons per year



Site Description: The I-370 outfall channel is located on an unnamed tributary to Muddy Branch, downstream of the proposed Casey Community Center stormwater concept. The tributary is fed by two culverts on the I-370 right-of-way. Each culvert has a separate channel and the channels combine prior to crossing under the right-of-way fence. The longer channel has a a 24-inch CMP and the shorter channel has a roughly 54-inch reinforced concrete pipe. The 24-inch pipe outfalls to a preformed scour pool and the 54-inch pipe outfalls into possibly rock step pools. The largest rocks are estimated to be MSHA Class III stone size. The channel degrades abruptly at the end of the step-pool channel about 20 yards upstream of the right-of-way fence. The degraded T5.2a channel is relatively uniform from the end of the step-pool channel to the downstream confluence. The channel is approximately 25-30 feet wide with 8 foot high nearly vertical banks. The banks are erodible and will not maintain the vertical slope and trees are expected to fall into the channel as the banks erode. The trees in the channel will cause additional channel instability and additional widening of the channel and loss of sediment into the tributaries of Muddy Branch. The access and project reach are located near Nancy Place and in the same vicinity as the Casey Community Center stormwater concept.

Approximately 54-inch culvert at upstream limit of channel. Orange flow shows evidence of oxidized iron from bacterial conversion. This may indicate a groundwater component to the flow from the I-370 storm drain.

Right-of-way fence failure with debris jam and tree fallen across fence. Channel degradation begins 20 yards upstream of fence. Channel stabilization upstream of fence would require application for MSHA access permit.

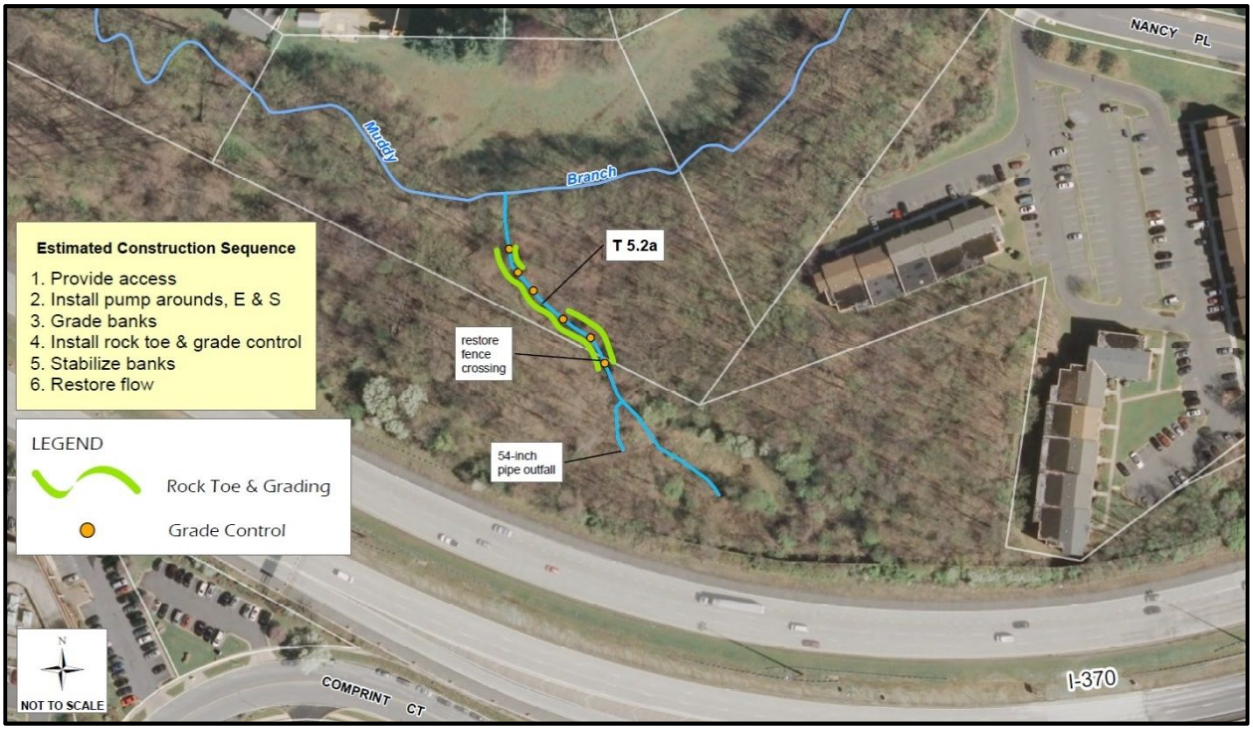
Restoration Goals: The goals of this restoration project are to stabilize the eroding stream banks, reduce channel incision, reduce the discharge of sediment and associated nutrients downstream, and improve aquatic habitat.

Proposed Restoration: The restoration for Reach T5.2 would involve the following:

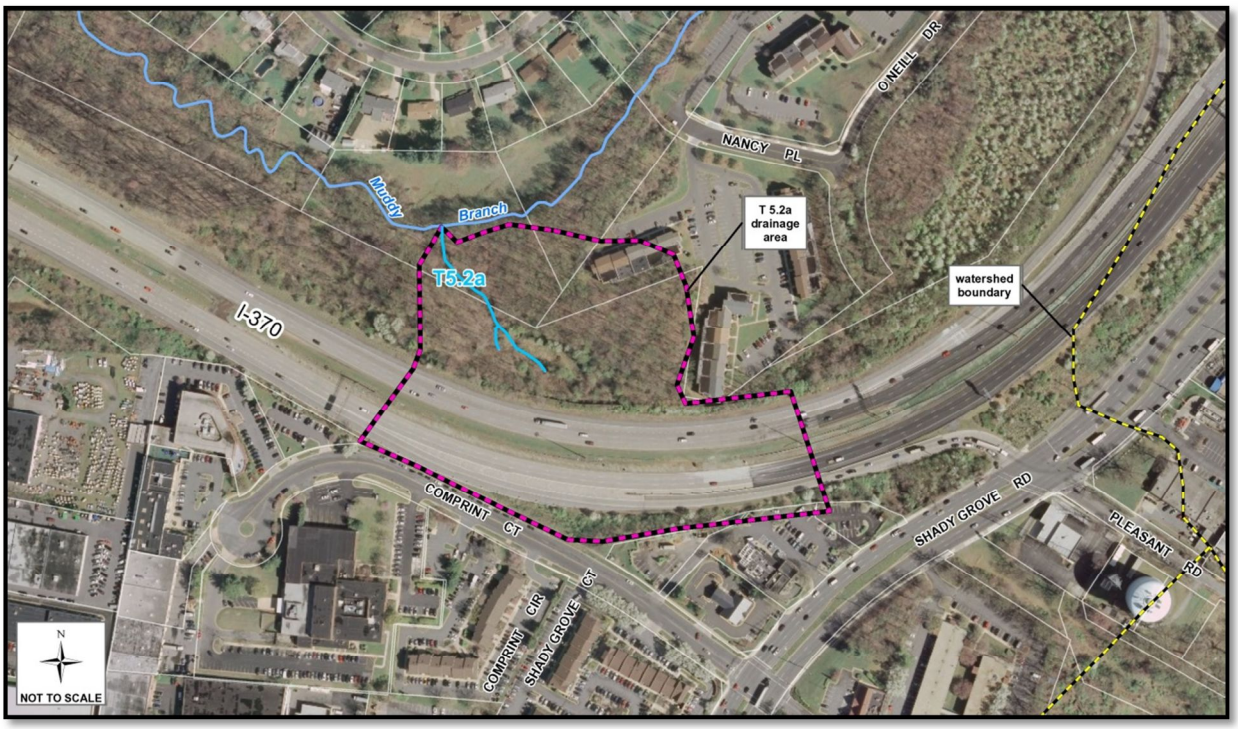
Eroded bank heights of about 8 feet along existing channel.

- Collect as-built drawings, computations and other available information on the outfalls from MSHA to get an accurate drainage area and estimate accurate bankfull dimensions based on avaiable data
- Grading of the banks to provide bankfull benches or increasing the floodprone area by grading the banks back at a 3:1 slope
- Stabilizing the graded banks with native plants and live stakes
- Realigning the stream channel in selected areas to avoid I-370 fence, but otherwise develop a stable channel in the existing overwidened banks to improve the horizontal geometry of the stream
- Installing grade control structures such as cross vanes and J-hook vanes to direct the energy of high flows toward the center of the channel, to reduce future bed degradation, and to improve aquatic habitat.
- Install deflectors, coir logs, and/or soil lifts to stabilize banks between grade control features as needed.

Reach T5.2a – I-370 Outfall Concept Plan



Reach T5.2a – I-370 Outfall Concept Plan



Project Improvements and Benefits: Opportunities for new stormwater management facilities and retrofits to existing stormwater management facilities are limited in the City; therefore, stream restoration may contribute significantly to attaining the objectives of the Muddy Branch study and complying with the City's MS4 permit.

Based on the interim sediment and nutrient removal rates for stream restoration projects that were approved by the CBP in January, 2012, the Reach T5.2a stream restoration would therefore provide the following pollutant reductions per year:

17 pounds of TN

16 pounds of TP

30 tons of TSS

Potential NPDES impervious area credit for Reach T5.2a is estimated to be 4.6 acres.

Alternative Measures Considered: An alternative restoration project could have been the complete realignment of the stream channel which was deemed not feasible due to high costs and the elimination of more trees than would be necessary to obtain stream health.

Project Design Considerations: The preferred access will be from Edgewood Drive along the existing footpath and through the City Park Rosedale Sub-division. The alternative is to cross from Nancy Lane; however, this access would require a second bridge/culvert crossing that is not included in the cost estimate. A temporary mulch access road would be needed along the length of the restoration reach (650 linear feet), plus approximately 550 linear feet of additional mulch access road to get to the construction site. The cost estimate reflects this access scenario. The access road adjacent to the stream would require the removal of trees that would be replaced once the project has been completed. The conceptual access road would be 12 feet wide and would extend from Edgewood Drive to the restoration site via existing City owned property. Part of the access would extend through an area that appears to have been planted for reforestation; however, there is still what appears to be a maintenance/access road that extends adjacent to the mouth of Reach 5.2a. A stream crossing of 25 feet would be required to access reach 5.2a. Use of access from Nancy Drive would be costly requiring the addition of another stream crossing and potential closure of a pedestrian bridge during construction. Mulch is proposed rather than stone due to cost.

Existing channel looking upstream from near midpoint on reach. Very little base flow, but channel has large discharges from stom drain pipes.

While it is anticipated that staging/stockpile areas can be located above the 100-year floodplain, storage of equipment and materials near the floodplain during construction may be a condition of permit authorization. Trees impacted for construction of the road would need to be replaced after the stream work is completed. The cost estimate includes native trees; approximate 2-inch caliper and minimum height of 12 feet planted with a spacing of 12 feet on center with shrubs. Replanting the 650 LF of access path (0.2 acre) includes 25 trees and 300 shrubs. Cost per tree includes installation mulching and watering. The remaining access path utilizes an existing path and will not be reforested.

Plans and Permitting: Construction documents and plans may be needed to implement a stream restoration project, including, but not limited to:

- Natural Resource Inventory/Forest Stand Delineation Plan (NRI/FSD)
- Forest Conservation Plan (FCP)

Additionally, several permits or approvals may be needed to implement a stream restoration project, including, but not limited to:

- MDE Nontidal Wetland and Waterway Permit & U.S. Army Corps of Engineers (USACE) approval (MDE advises to schedule for 1 year of permit processing)
- Floodplain permit application and study
- Grading and Erosion Sediment Control Permit

- National Pollutant Discharge Elimination System (NPDES) Construction Permit
- Stormwater Concept application (permit waiver is assumed)

A kickoff meeting and pre-application coordination with the permitting agencies is recommended.

Property Ownership: Reach T5.2a is located on property owned by the City of Gaithersburg. Montgomery County GIS indicates they are N853 of the Rosedale City Parklands Unit 4 Development (Subdivision 201). The access points are located on Unit 3 and Unit 2. The preferred access from Edgewood Drive is owned by the Casey, Betty B et al Trust and is listed as R/W to access the Rosemont Sction 3 (subdivision 214) from Nancy Place.The stream is located within a forested corridor owned by the City. The upper limits of the channel in the vicinity of the outfall is located on property owned by the Maryland State Highway Administration.

Utility Conflicts: No utility conflicts are expected; however, the site should be fully assessed for utilities during design.

Cost Estimate

The cost for the ReachT5.2a project is estimated to be $904,000. This estimate includes construction, engineering, surveys, and permitting. Engineering costs cover supplemental items such as TTCP and SEC specifications. Construction management and administration (by the City) is proposed for the duration of the construction. Post-construction monitoring is suggested but not required to provide feedback regarding the effects of the stream restoration and potentially justify greater efficiency credits from MDE. Tree sizes are suggested at a minimum height of 12 feet (2-inch caliper). Below is the cost estimate for Reach T5.2a.

Reach T5.2a I-370 Outfall

Item	Quantity	Unit	Unit Cost	Total
Stakeout	1	EA	$2,000	$2,000
Maintenance of Traffic	1	EA	$2,000	$2,000
Stabilized Construction Entrance	1	EA	$6,000	$6,000
Clearing and Grubbing	1	EA	$40,000	$40,000
Maintenance of Stream Flow	3	EA	$10,000	$30,000
Excavation & Removal from Site	3500	CY	$25	$87,500
Select Backfill	1500	CY	$40	$60,000
Small Cross Vanes/Riffle Grade Control	11	EA	$5,500	$60,500
Double Rock Toe Protection	460	LF	$125	$57,500
Coir Log (20-inch)	460	LF	$40	$18,400
Topsoil	280	CY	$32.50	$9,100
Tree Protection Fence	500	LF	$2.20	$1,100
Temporary Mulch Access Road	1,200	LF	$35.00	$42,000
Temporary Stream Crossings	1	EA	$7,000	$7,000
Temporary Matting	2500	SY	$4.00	$10,000
Silt Fence	500	LF	$5.50	$2,750
Seed Mix	2500	SY	$2.80	$7,000
Live Stakes	500	EA	$5.00	$2,500
Shrubs – containerized	300	EA	$45.00	$13,500
2-Inch Caliper Trees	25	EA	$250.00	$6,250

Base Construction Cost*	$466,000
Construction Inspection and Administration (15%)*	$70,000
Mobilization (10%)*	$47,000
Subtotal 1	$583,000
Contingency (25%)*	$146,000
Subtotal 2	$729,000
Engineering	$120,000
Surveys	$25,000
Permits	$30,000
Estimated Project Cost	**$904,000**
Optional Post Construction Monitoring (5 years)	$50,000
Estimated Cost w/ Additional Options	**$954,000**

Legend

CY = Cubic Yard

EA = Each

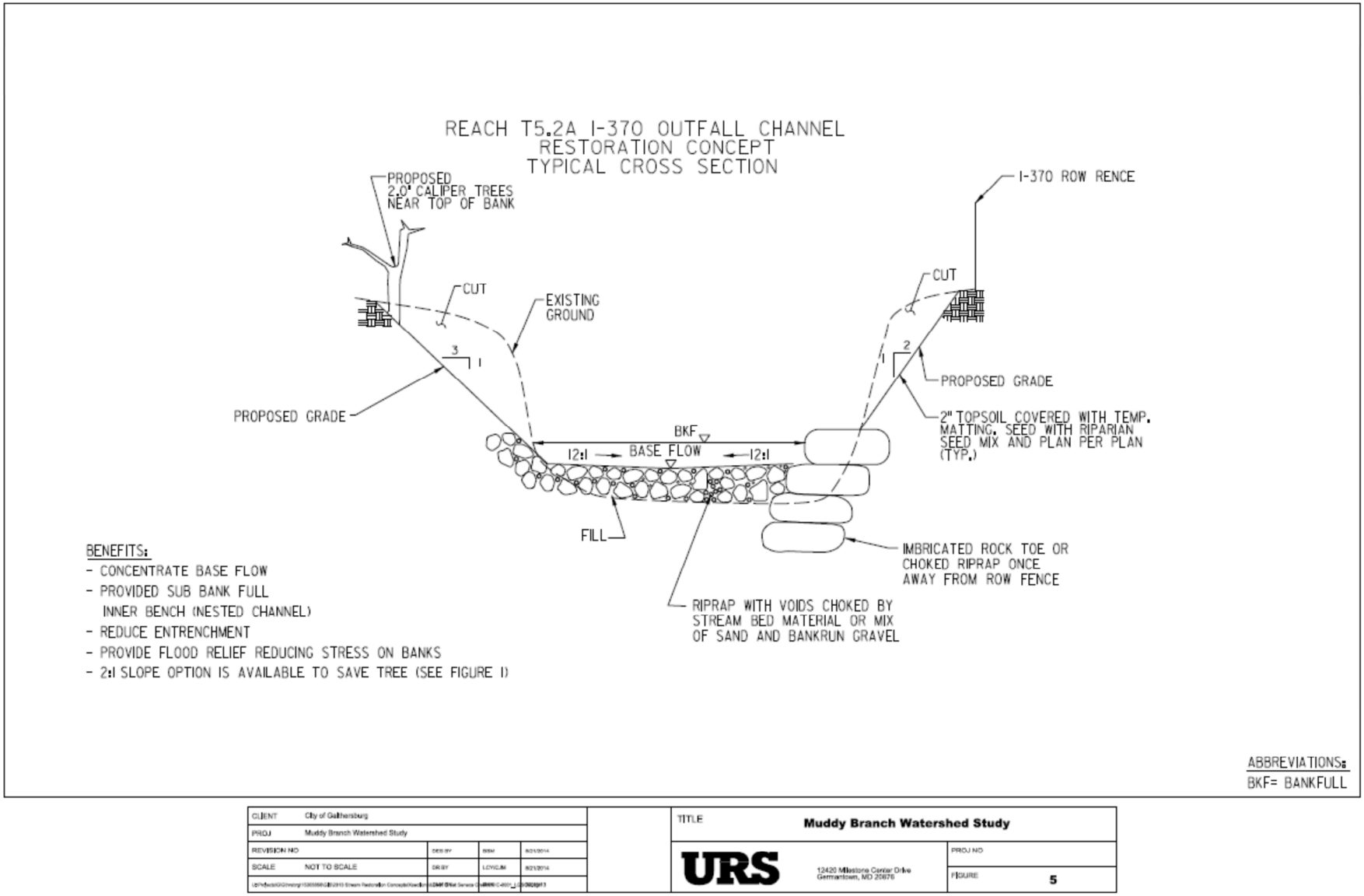
LF = Linear Foot

SY = Square Yard

** - Denotes values rounded to nearest thousand*

Stream Length =	460	LF	Cost/LF =	$2,070
Approx. Number of Imp. Area Credits =	4.6	acre	Cost/Credit =	$207,390

Typical Cross Sections for Reach T5.2a:



CLIENT	City of Gaithersburg			TITLE	Muddy Branch Watershed Study
PROJ	Muddy Branch Watershed Study			URS 12420 Milestone Center Drive Germantown, MD 20876	PROJ NO
REVISION NO		DES BY	BBM		FIGURE 5
SCALE	NOT TO SCALE	DR BY	LDYCJM		