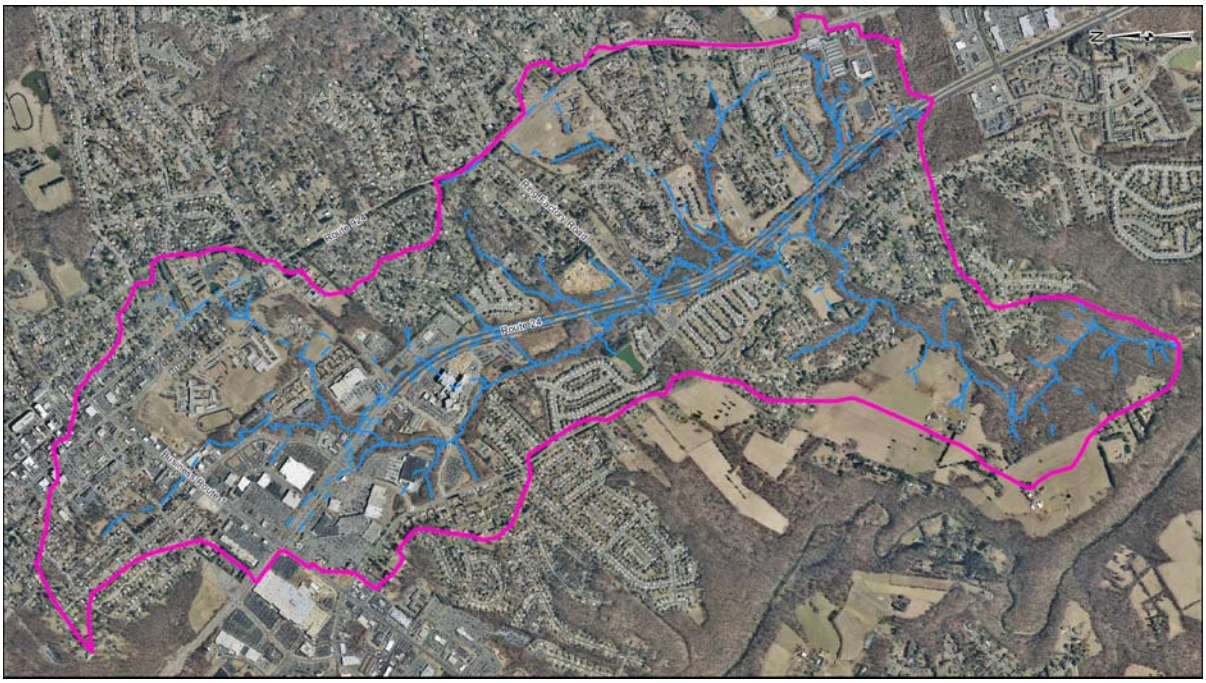
Plumtree Run Watershed
Small Watershed Action Plan



Prepared for
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Division of Water Resources
Bel Air, Maryland

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SMALL WATERSHED ACTION PLAN

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Chapter 1 Project Introduction

I. Background

The Plumtree Run watershed is located in Bel Air, Maryland. Over the last four decades the Bel Air area, as well as Harford County in general, has experienced a rapid growth in population that has transformed this once rural area to suburban, residential and commercial land uses. These changes have had a tremendous effect on the natural resources of the County. In particular, increased sedimentation from construction activities, stream channel erosion in response to increased storm water runoff, and an overall increase in pollutant loadings due to the conversion from forest and cultivated land to residential and commercial uses have significantly degraded the water quality, reduced flood storage capacity, and damaged public infrastructure as well as public and private land along the County's stream corridors. Of particular concern is the contribution unmanaged stormwater runoff and unstable headwater streams make to sedimentation and water quality declines in Atkisson Reservoir, a large open water habitat located immediately downstream of the Plumtree River watershed.

In response to these concerns, the Harford County Department of Public Works, Water Resources Engineering have prepared Watershed Management Plans focused on identifying water quality problems and developing strategies for correcting those problems. In addition, the Department of Public Works (DPW) initiated capital improvement programs focused on remediation of erosion and sedimentation problems caused by uncontrolled or inadequately controlled stormwater runoff. These programs include installation of new water quality best management practices, rehabilitation of old storm drain systems, installation and retrofitting storm water management ponds, and implementation of stream restoration projects.

Plumtree Run is a second order tributary to Atkisson Reservoir and Winters Run in the Bush River watershed. Maryland Department of Natural Resources working in cooperation with Harford County DPW completed the Bush River Watershed Characterization report in 2002. The Center for Watershed Protection completed the Bush River Watershed Management Plan in 2003. Both documents cite erosion and sedimentation associated with uncontrolled or inadequately controlled stormwater runoff in the Winters Run and Bush River watersheds as problems that need remediation.

It is the intention of the Harford County DPW, Water Resources Engineering to control runoff from developed areas, correct stream channel instability problems, reduce sediment loadings and improve the overall water quality of Plumtree Run and the Atkisson Reservoir.

Therefore, BayLand Consultants & Designers, Inc. (BayLand) and Clear Creeks Consulting, LLC (Clear Creeks) teamed to conduct a retrofit assessment and field reconnaissance of the Plumtree Run watershed to identify channel instability and sedimentation problems, identify opportunities for implementing stormwater retrofits and channel restoration projects, and prepare a report of preliminary findings with

recommendations. Based on the findings of these studies, restoration recommendations and design concepts were developed, as well as preliminary cost estimates for design and construction. The findings of the assessment and recommendations for stormwater retrofits and stream restoration projects were presented in the Plumtree Run Watershed Assessment Findings Report, March 2011 and are presented in this report.

II. U.S. EPA Watershed Planning "A-I Criteria"

In 2003, the U.S. Environmental Protection Agency (EPA) began to require that all watershed restoration projects funded under Section 319 of the federal Clean Water Act to be supported by a watershed plan that includes the following nine minimum elements, known as the "a-i criteria":

a) Identification of the causes and sources that will need to be controlled to achieve the load reductions estimated in the watershed plan
b) Estimates of pollutant load reductions expected through implementation of proposed nonpoint source (NPS) management measures
c) A description of the NPS management measures that will need to be implemented
d) An estimate of the amount of technical and financial assistance needed to implement the plan
e) An information/education component that will be used to enhance public understanding and encourage participation
f) A schedule for implementing the NPS management measures
g) A description of interim, measurable milestones
h) A set of criteria to determine load reductions and track substantial progress towards attaining water quality standards
i) A monitoring component to determine whether the watershed plan is being implemented

This watershed plan meets the a-i criteria. Table 1.1 shows where these criteria are addressed throughout this watershed plan.

Table 1.1 U.S. EPA Watershed Planning Criteria									
Chapter of the Report	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**I**
Chapter 1 Project Introduction									
Chapter 2 Characterization	**X**								
Chapter 3 Watershed Goals and Public Outreach					**X**				
Chapter 4 Subwatershed Field Assessment	**X**								
Chapter 5 Stormwater Management Plan	**X**		**X**						
Chapter 6 Stream Restoration Strategies	**X**		**X**	**X**					
Chapter 7 Pollutant Load Analysis		**X**						**X**	
Chapter 8 Monitoring Plan									**X**
Chapter 9 Implementation and Summary				**X**		**X**	**X**		

Chapter 2 Characterization

I. Study Area

The study area for the current project includes Plumtree Run and its tributaries from their headwaters near Business Route 1 to the confluence with Atkisson Reservoir (Figure 2.1).

II. Scope of Studies

Existing data was collected, compiled and reviewed. Modeling and field studies were conducted to evaluate the current conditions along Plumtree Run and its tributaries throughout the watershed. All streams, excluding roadside channels within the watershed were assessed. The data collected was utilized to determine which stream reaches within the watershed to restore and the extent of the restoration effort required. Existing data was also used to evaluate a select number of existing stormwater management facilities that may be suitable for retrofit and to evaluate potential new stormwater BMP facility locations. Restoration and management recommendations, design concepts and preliminary cost estimates for restoration and management strategies were developed as part of the stream assessment. Stormwater BMP and retrofit recommendations, design concepts and preliminary cost estimates were developed for stormwater management analysis.

Neither the stream or stormwater management assessments included wetland delineations, identification of significant plant or animal habitat, or other environmental studies that may be required by local, State or federal permitting agencies.

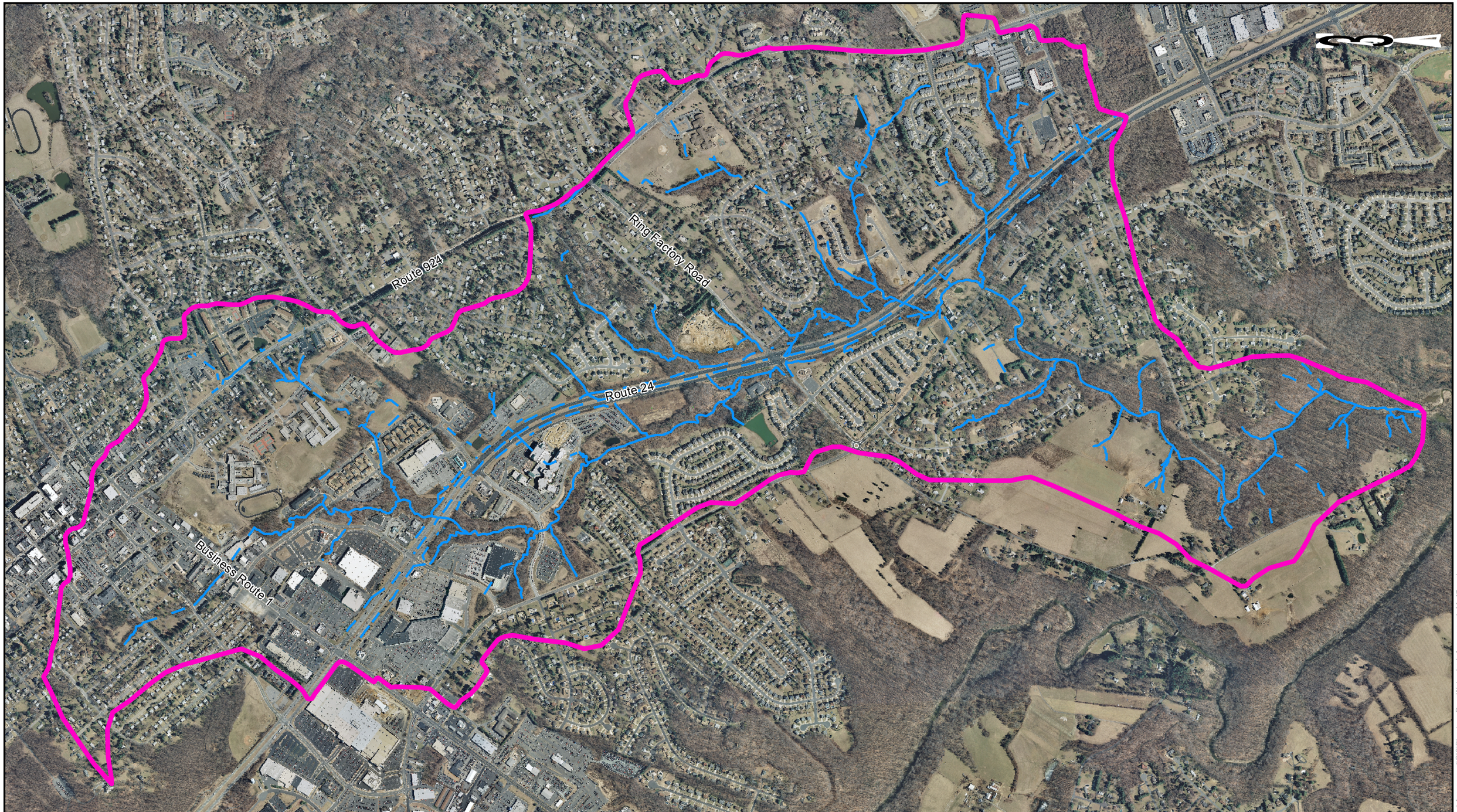
III. Watershed Characterization

Existing information on watershed characteristics and land use was collected, compiled and reviewed. The data collected included: topographic, soils, geology and land use maps; meteorological data; hydrologic and hydraulic data; and published technical reports. The following characterization of the Plumtree Run watershed was developed from this information.

A. Physiography and Basin Morphometry

Plumtree Run watershed is located in Harford County in the northeast-central section of Maryland. This region is situated along the eastern edge of the Piedmont physiographic province and is characterized by gently rolling to hilly topography.

The total watershed area at its confluence with the Atkisson Reservoir is 1,651 acres. The upper portion of the watershed is characterized by gentle to hilly topography with slopes ranging from 3% to 15%. Except where development has encroached on the floodplain, the valley in the upper watershed is relatively broad. Channel gradient ranges from 0.009 to 0.013 feet/feet. The valley in the middle watershed is narrow in



NOTES:
1. IMAGERY FROM HARFORD COUNTY 2007 AERIAL PHOTOGRAPHY.
2. WATERSHED BASED ON HARFORD COUNTY DELINEATION, REFINED BY BAYLAND CONSULTANTS BASED ON TOPOGRAPHY AND FIELD INVESTIGATION.
3. HYDRO LAYER REFINED IN THE FIELD TO INDICATE SWALE/PIPED SYSTEMS BY CLEAR CREEKS CONSULTING DECEMBER 2009.

Plumtree Run Watershed - 1,651 Acres
Hydro Line
Swale / Piped System

1,100 550 0 1,100 2,200 Feet
1" = 1,100'

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Plumtree Run Watershed Assessment Watershed Map

Figure 2.1

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the upper reaches but broadens into a wide floodplain downstream of Route 24. Channel gradient ranges from 0.0044 to 0.008 feet/feet. The valley in the lower watershed is broad in the upper reaches but narrows and the channel is confined by adjacent hill slopes as the creek nears the reservoir. Channel gradient averages around 0.01 feet/feet. Gradient through the bedrock canyon on the Harford Glen property is about 0.035 feet/feet. Downstream, where the creek enters the backwaters of the reservoir, the floodplain is very broad and the channel gradient flattens to 0.001 feet/feet.

B. Climate

Harford County experiences moderate winters and warm summers. Mean annual temperature is 53.6°F. Mean daily temperatures range from 22.2° to 41.4ºF in January and 63.5° to 86.1ºF in July.

Mean annual precipitation is 45.83 inches. The distribution of monthly precipitation is fairly uniform throughout the year. Monthly precipitation varies from a low of 2.81 inches in October to a high of 5.11 inches in August. Thunderstorms may vary widely from place to place and from season to season; however, most occur in July and August. Mean annual snowfall is 22 inches, but varies considerably from year to year.

C. Geology and Soils

According to the Maryland Geological Survey (Geologic Map of Maryland – 1968), the Plumtree Run watershed is underlain primarily by Port Deposit Gneiss, part of the Paleozoic Granitic Series, with a portion of the upper watershed underlain by Baltimore Gabbro Complex. Port Deposit Gneiss is described as a moderately to strongly deformed intrusive complex composed of gneissic biotite quartz diorite, hornblende-biotite quart diorite, and biotite grandiorite; all rocks foliated and some strongly sheared. Baltimore Gabbro Complex is described as hypersthenes gabbro with subordinate amounts of olivine gabbro, norite, anorthositic gabbro, and pyroxenite; igneous minerals and textures well preserved in some rocks, other rocks exhibit varying degrees of alteration and recrystallization, and still others are completely recrystallized with a new metamorphic mineral assemblage.

According to the mapped soils in the Soil Survey of Harford County (SCS, 1975) the dominant upland soils weathered from these rocks are Aldino, Chester, Glenelg and Neshaminy on the ridges and sideslopes in the upper watershed; Chester and Glenelg in the upper middle watershed; Aldino, Brandywine, Chester, Glenelg, Manor, Legore and Neshaminy on the ridges and sideslopes in the lower middle watershed; and Brandywine, Chester, Glenelg and Manor on the ridges and sideslopes in the lower watershed.

The Aldino silt loams are moderately deep, moderately well drained soils that weathered from serpentine bedrock. Slow permeability and moderate to high erosion

hazard characterize these soils. Brandywine gravelly loams are deep, somewhat excessively drained soils that weathered in place from gneiss. Permeability is moderately rapid and erosion hazard is severe to very severe. Chester silt loams are deep, well-drained soils that weathered in place from acid crystalline rocks, most commonly mica schist. They are characterized by moderate permeability and a moderate to severe erosion hazard. Glenelg loams and gravelly loams are deep, well-drained soils that weathered in place from acid crystalline rocks, most commonly mica schist. Permeability is moderate and erosion hazard is slight to severe. Legore silt loams and silty clay loams are deep, well drained soils that weathered from dark-colored basic rock such as diabase and gabbro. Moderate permeability and moderate erosion hazard characterize the silt loams. Moderately slow permeability and severe erosion hazard characterize the silty clay loams of this series. Manor loam and Manor channery loams are deep, well drained to somewhat excessively drained soils that weathered from acid crystalline rock mostly mica schist or granitized schist. Moderate to moderately rapid permeability characterize these soils. This series is highly susceptible to erosion. Neshaminy silt loams are deep, well drained soils that weathered from basic rocks or mixed basic and acidic rocks. Moderate permeability and slight to severe erosion hazard characterize these soils depending on slope.

The dominant headwater and floodplain soil along upper Plumtree Run and its tributaries is Watchung. The floodplain along the upper middle and lower middle Plumtree Run is comprised of alluvial soils. The dominant soils along the lower Plumtree Run are Alluvial, Codorus and Hatboro series. The soils along the tributaries in the upper middle, lower middle and lower watershed are Glenville.

Glenville silt loams are moderately deep, moderately well drained soils often over a fragipan that formed in material weathered from micaceous rock or alluvium. Permeability is slow and erosion hazard is high. Codorus silt loams are deep, moderately well drained to somewhat poorly drained soils that formed in loamy recent alluvium that originally washed from areas where the soils were weathered from crystalline rocks. These soils are subject to flooding. Permeability is moderate and erosion hazard is moderate. Hatboro silt loams are deep, poorly drained soils that formed in loamy recent alluvium that originally washed from areas where the soils were weathered from crystalline rocks. These soils are subject to flooding. Permeability is moderate and erosion hazard is moderate. Watchung silt loams are deep, poorly drained soils that formed in alluvium derived from hard basic rocks such as diabase. Permeability is slow and erosion hazard is high.

For hydrologic modeling purposes, the different soil types were grouped by their hydraulic conductivity, or the rate at which infiltration occurs. Soil maps for the Plumtree Run watershed were obtained from the Harford County GIS Mapping and Data Services.

D. Land Use

The dominant land use in the upper Plumtree Run watershed is for commercial uses, such as, Bel Air Town Center, Tollgate Market Place, Bel Air Plaza and Home Depot located along Business Route 1 and Route 24, and for institutional land uses such as Bel Air High School, Bel Air Middle School and Homestead Wakefield Elementary School. The remaining sections of the upper watershed are medium and high density residential subdivisions. The dominant land use in the upper middle Plumtree Run watershed includes the Upper Chesapeake Medical Campus, the Maryland Motor Vehicle Administration and various commercial properties in the upper section. Low and medium density residential subdivisions are clustered along the eastern and western ridge tops off Tollgate Road, Route 924 and secondary roads. The dominant land use in the lower middle Plumtree Run watershed includes commercial properties such as ezStorage and Plumtree Professional Center, as well as institutional land uses, such as, Ring Factory Elementary School and Emmorton Baptist Church. Low and medium density residential subdivisions are clustered along the eastern and western ridge tops off Tollgate Road, Route 924 and secondary roads. The dominant land use in the lower Plumtree Run watershed is low and medium density residential, pasture, and forest on farms along the eastern and western ridges. The ridges within the Harford Glen Environmental Education Center property are predominantly forest. With the exception of a few stream sections, the stream valleys throughout most of the Plumtree Run watershed are forest.

Aerial photographs and land use maps for the Plumtree Run watershed were obtained from the Harford County GIS Mapping and Data Services. The Harford County Division of Planning Zoning Classification Summary was used to correlate the existing land use to the SCS land use classifications.

E. Hydrology

A hydrologic analysis of existing conditions was performed for the Plumtree Run watershed. For this analysis, the watershed was divided into 25 subsheds so that a study could be performed at separate hydrologic study points. A watershed map displaying the 25 study points, contributing subsheds and connecting reaches can be found in Appendix to this report.

The watershed and subshed boundaries, as well as runoff characteristics were generated using images from 2007 Harford County orthophotography in conjunction with planimetric data from Harford County GIS. Data used for model development included but was not limited to; 2-foot contour data, impervious surface areas (i.e. buildings, roads and parking lots), existing stormwater infrastructure (i.e. storm drains and stormwater management facilities) and soil types. A site visit was also conducted to verify field conditions and refine modeling parameters such as drainage divides and flow paths.

The intention of the preliminary hydrologic analysis was to develop peak discharge estimates for the 1-, 2-, 10- and 100-year rainfall events at each identified study point. Peak flow rates generated from the hydrologic analysis are intended to verify empirically developed flow data based on field observations, as well as to reflect existing runoff and stream flow characteristics in the watershed.

For this study, the peak discharge rates were estimated using HydroCAD 7.00, which is based on TR-55 and TR-20 developed by the Soil Conservation Service (SCS/NRCS). The model was used to compute direct runoff and develop hydrographs from each contributing subshed. Runoff from each subshed was combined with upstream flows by routing through successive receiving reaches. Subsheds were delineated for each study point and represented in the model with unique runoff parameters developed from County data and field reconnaissance. Land-use and hydrologic soil group data were used to determine an SCS runoff curve number (CN) for each subshed, and ground cover, topography and stormwater infrastructure data were used to establish flow paths and subsequent times of concentration. Additionally, field surveyed channel cross-sections attained during the gage calibration and field reconnaissance surveys were utilized in the model to further refine channel flow and subshed routing characteristics. The potential impacts of stormwater management facilities identified in the watershed, the majority of which were approved prior to implementation of the 2000 Maryland Stormwater Design Manual, were disregarded for this study.

To ensure accuracy of the estimated peak discharge rates in the project watershed, the model was calibrated to a USGS gage station located on the main stem of Plumtree Run near the downstream end of the watershed on Plumtree Road. This location corresponds with Study Point 24 in the model.

Based on recommendations presented in “Application of Hydrologic Methods in Maryland” (Maryland Hydrology Panel, 2005) the model was calibrated to the gage station by adjusting flow velocities in the time of concentration calculations, and modifying the Antecedent Moisture Condition (AMC) to account for different ground saturation and available storage prior to the different design storms, as well as varying the duration of the NRCS Type II design storm for different frequency storm events. Specifically, the model represents dry soil conditions (AMC=1) immediately prior to the 1- and 2-year storm events, normal soil conditions (AMC=2) immediately prior to the 10-year storm, and wet soil conditions (AMC=3) immediately prior to the 100-year storm. Model flows most closely reflected USGS gage estimates when the 1- and 2-year hydrographs were developed from a 6-hour design storm duration, the 10-year hydrograph was developed from a 12-hour design storm duration, and the 100-year hydrograph was developed from a 24-hour design storm duration. Comparisons of the modeled flows to gage data are found in Table 2.1.

Table 2.1 – Estimated Flow Comparisons USGS Gage VS. HydroCAD				
Storm Event	**Gage Data (cfs)**			**HydroCad (cfs)**
	Estimated Flow	**Lower Confidence**	**Upper Confidence**	
1-YR	104	17	220	201
2-YR	561	287	1,036	371
10-YR	2,064	1,103	7,792	2,075
100-YR	7,745	3,023	86,530	3,909

Once the model was calibrated to the gage station, peak discharge rates were determined at the remainder of project study points. The results of the model are found in Table 2.2.

Table 2.2 – HydroCAD Modeled Peak Discharge Estimates (cfs)					
Study Point	**DA (mi^2)**	**1-YR**	**2-YR**	**10-YR**	**100-YR**
1	0.41	131	223	828	1,169
2	0.19	47	90	451	661
3	0.66	184	321	1,299	1,868
4	0.04	41	59	159	182
5	0.08	32	59	311	411
6	0.72	195	339	1,365	1,967
7	0.85	204	356	1,445	2,107
8	0.076	21	39	187	267
9	0.88	203	355	1,455	2,129
10	1.09	199	356	1,542	2,321
11	0.05	1	6	127	225
12	0.028	0.1	0.5	43	98
13	0.15	3	11	251	507
14	1.36	203	369	1,714	2,753
15	1.39	199	363	1,708	2,758
16	0.21	3	12	263	558
17	1.71	203	375	1,884	3,291
18	1.83	202	376	1,934	3,438
19	0.045	12	26	203	263
20	0.11	7	19	194	345
21	0.18	11	28	271	505
22	2.14	205	385	2,045	3,806
23	2.27	205	387	2,069	3,865
24	2.4	201	371	2,075	3,909
25	2.58	197	357	2,073	3,935

Output files from the HydroCAD 7.00 computer program are included in the Appendix of this report.

Chapter 3 Watershed Goals and Public Outreach

I. Watershed Goals

Harford County DPW prioritizes projects by evaluating opportunities identified in watershed plans. The Plumtree Run Watershed Assessment was selected to due to the findings of the 2002 Bush River Watershed Characterization Report and the 2003 Bush River Watershed Management Plan. The Plumtree Run Subwatershed contains the greatest amount of development within Harford County, with approximately 60% of the land developed. Plumtree Run drains to the Atkisson Reservoir which has lost 81 % of its water storage capacity due to sedimentation. This watershed was prioritized due to the benefit to overall watershed health, public input and concerns and the protection of public infrastructure and private and public lands as well as its drainage to Atkisson Reservoir.

Harford County DPW has set the following goals to restore the Plumtree Run watershed:

- Control runoff from developed areas.
- Repair stream instability problems.
- Reduce sediment loadings.
- Improve water quality of Plumtree Run and Atkisson Reservoir.

II. Public Outreach

The Bush River Management Plan included goals for public outreach and stakeholder support. The following programs were recommended in the Bush River Management Plan:

- Establish a Bush River WAMP Implementation Committee
- Foster the development of a watershed group for Bush River
- Create a website to encourage watershed stewardship
- Implement Recommendations of the Harford County Site Planning Roundtable
- Establish an Adopt-a-Pond Program
- Improve ESC Implementation, Inspection and Enforcement

Many of these recommendations were incorporated into the County's plan for outreach and education of the Plumtree Run subwatershed of Bush River. The County held a public meeting on the Plumtree Run Watershed Assessment to go over the finding and recommendations of the Report. The County has created a Blog just for Plumtree Run to post specific actions going on within the watershed and for the public to be able to comment. Besides the website, Harford County continues to mail informational brochures to residents on watershed stewardship, stormwater pollution and ways residents can help. Examples of public outreach documents are included in the Appendix to this report.

Chapter 4 Subwatershed Field Assessment

I. Field Studies for Plumtree Run Watershed Assessment

A. Field Study Methods

1. Gage Calibration Survey

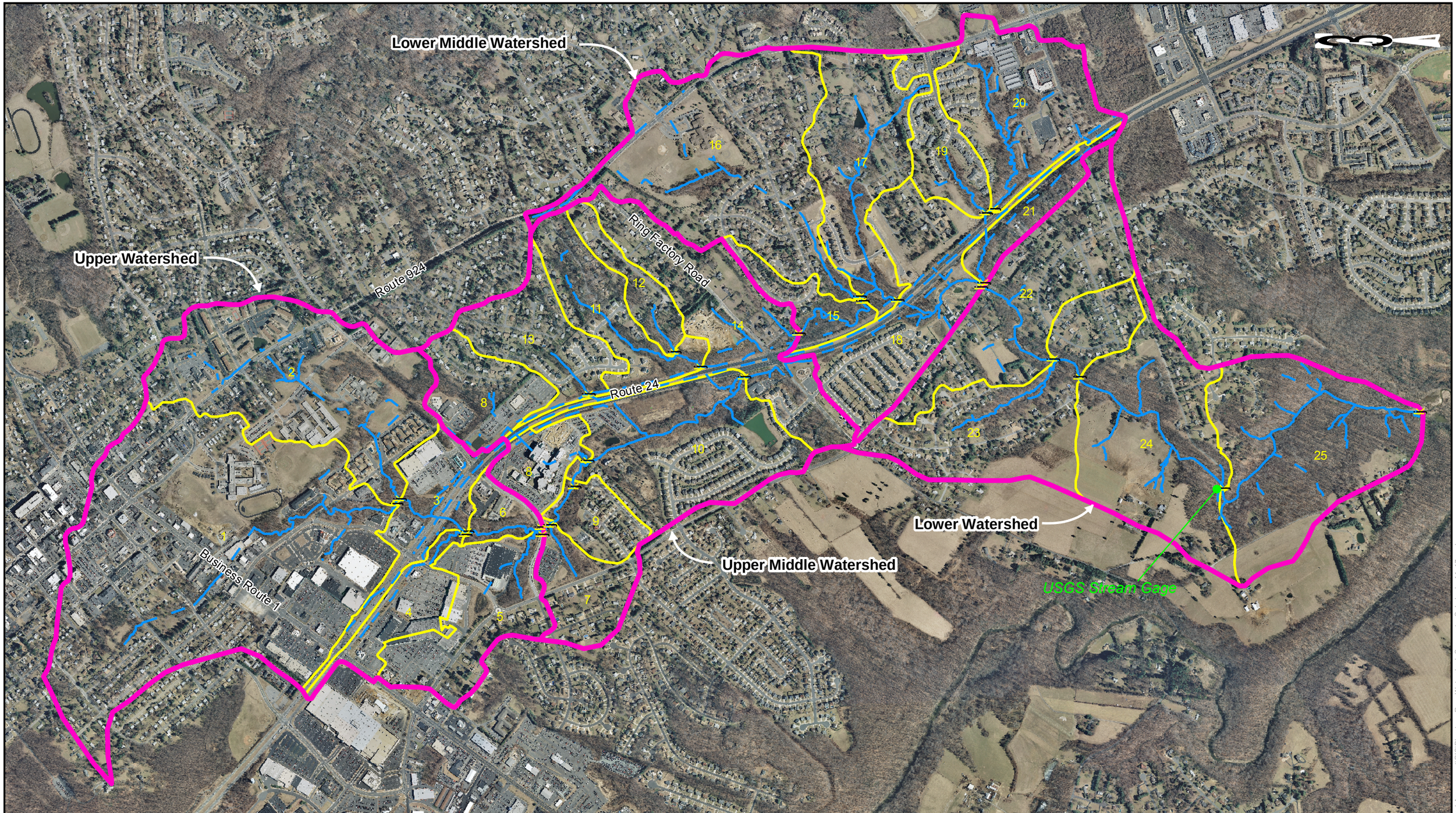
A part of the watershed assessment included classifying stream reaches by Rosgen stream types. Rosgen (1989) recommends that field calibration surveys be conducted at USGS stream gage stations in the project watershed or nearby watersheds prior to conducting stream assessments. This field exercise is critical for verifying field indicators associated with the bankfull channel and for developing regional relationships between drainage area and bankfull discharge, as well as drainage area and bankfull channel dimensions. If existing regional regressions are not available, a field calibration survey provides a basis for developing project specific regressions. This information is also utilized to verify the predictive value of existing regional regression equations for a specific watershed.

For this project a field calibration survey was conducted at the USGS gage station on Plumtree Run at Plumtree Road. The data collected at the gage was compared to the predicted values for bankfull discharge and bankfull channel dimensions using regional regression equations developed in rural watersheds of the Piedmont region of Maryland and Delaware (U.S.F&WS, 2002). Because the percent impervious in the Plumtree Run watershed is around 29%, the data was also compared to predicted values using regional regression equations developed for urban watersheds (Powell, Pentz and Gemmill, 1999) and updated by Powell (2002).

In addition to the cross-sections surveyed at the gage site, channel cross-sections were measured at several other locations in the watershed, prior to initiating the field reconnaissance. In Table 4.1, the results of this field exercise indicated that the urban regional regressions provided the best method for determining bankfull discharge and verifying field indicators for the bankfull channel during the overall watershed assessment.

2. Field Reconnaissance Survey

A field reconnaissance survey was conducted to document and assess existing conditions along Plumtree Run and its tributaries from the headwaters upstream of Route 1 and Route 24 to the confluence with Atkisson Reservoir. A total of 8.84 miles (46,674 linear feet) of Plumtree Run and its tributaries were reconnoitered and mapped. To facilitate the field work and evaluation Plumtree Run and its tributaries were divided into four separate watershed segments. The segments include: 1) Upper Plumtree Run; 2) Upper Middle Plumtree Run; 3) Lower Middle Plumtree Run; and 4) Lower Plumtree Run. Each watershed segment was further divided into subsheds. The entire Plumtree Run watershed is comprised of 25 subsheds (Figure 4.1). Individual watershed segment maps are included in the Map Appendix.



Watershed Segment Boundary

Sub-watershed Boundary

Study Point

Hydro Line

Swale / Piped System

1,100 550 0 1,100 2,200 Feet

NOTES:
1. IMAGERY FROM HARFORD COUNTY 2007 AERIAL PHOTOGRAPHY.
2. WATERSHED BASED ON HARFORD COUNTY DELINEATION, REFINED BY BAYLAND CONSULTANTS BASED ON TOPOGRAPHY AND FIELD INVESTIGATION.
3. SUBWATERSHEDS DELINEATED BY BAYLAND CONSULTANTS.
4. IMPERVIOUS SURFACE COMPILED BY BAYLAND CONSULTANTS USING 2008 HARFORD COUNTY GIS DATA.
5. HYDRO LAYER REFINED BASED ON FIELD VERIFICATION BY CLEAR CREEKS CONSULTING DECEMBER 2009.

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Plumtree Run Watershed Assessment Watershed Segments and Subsheds

Figure 4.1

P:\4_2901_Plumtree Run Watershed Assessment\GIS\Plumtree_Run_Watershed_Segments_Subsheds_11x17.mxd

The County's GIS topographic maps were utilized as a base for the maps used in the field reconnaissance. The field reconnaissance maps were developed at a scale of 1 inch = 50 feet to allow recording field notes (e.g., channel dimension measurements, bank heights, etc.) and drafting of specific conditions observed in the field (e.g., eroding banks, depositional features, debris jams, etc.). Field reconnaissance maps are included in the Map Appendix.

The reconnaissance survey included photographic documentation and mapping the channel and adjacent floodplain and slopes. It focused on verifying existing land use activities and land cover, identifying and documenting unstable conditions in upland and riparian areas, characterizing stream channel morphology and condition, and identifying unstable stream reaches.

As part of the morphological evaluation, stream reaches were classified by Rosgen stream types. As noted, channel cross-sectional measurements were conducted during the gage calibration survey and pre-assessment phase of the studies. During the field reconnaissance survey additional measurements were taken along representative reaches throughout the watershed to facilitate the classification. The measurements were checked against values predicted by regional regressions to verify that bankfull channel had been accurately identified. The data is shown in Table 4.1.

Table 4.1 - Bankfull Discharge and Channel Cross-Sectional Area Predicted from Urban Regression Equations[1] vs Field Data

Study Point	Drainage Area (mi^2)	Predicted Q_{bf} (cfs)	Field Data Manning's Qbf (cfs)	Predicted A (ft^2)	Field Data A (ft^2)
1	0.41	95.7	92	21.7	21.6
2	0.19	52	60	12.7	15.1
3	0.66	139.5	138	30.2	35.2
4	0.04	ND	ND	ND	ND
5	0.08	ND	ND	ND	ND
6	0.72	149.4	165	33.7	37.6
7	0.85	170.4	ND	37.8	ND
8	0.08	ND	ND	ND	ND
9	0.88	175.1	168	38.7	37.5
10	1.09	207.4	198	44.9	43
11	0.05	ND	ND	ND	ND
12	0.03	ND	ND	ND	ND
13	0.15	ND	ND	ND	ND
14	1.36	247.1	ND	52.3	ND
15	1.39	251.4	235	53.1	50.0
16	0.21	56.4	ND	14.3	ND

(Continued on next page)

Table 4.1 (cont'd) - Bankfull Discharge and Channel Cross-Sectional Area Predicted from Urban Regression Equations[1] vs Field Data					
Study Point	**Drainage Area (mi^2)**	**Predicted Q_{bf} (cfs)**	**Field Data Manning's Qbf (cfs)**	**Predicted A (ft^2)**	**Field Data A (ft^2)**
17	1.71	296.1	243	61.3	50.7
18	1.83	312.4	294	64.3	60.0
19	0.05	ND	ND	ND	ND
20	0.11	ND	ND	ND	ND
21	0.18	ND	ND	ND	ND
22	2.14	353.6	343	71.7	70.0
23	2.27	370.5	360	74.7	72.0
24[2]	2.40	387.1	344/362.5	77.6	77.1/74.1
25	2.58	409.9	400	81.6	80.0

Notes:

1. *The drainage areas of the gage sites used to develop the urban regional regressions ranged from 0.21 – 7.46 mi^2. To ensure the reliability of the predicted values, subwatersheds with drainage areas smaller than 0.21 mi^2 were not determined (ND).*
2. *Gage Site – records indicate discharges – 1.33 YR = 324 cfs, 1.6 YR = 378 cfs, and 2 YR = 401 cfs*

Another critical component of the field survey was identifying opportunities for implementing stormwater retrofit, wetland creation and stream channel restoration projects.

B. Findings of Field Studies

This section summarizes the results of the field studies conducted in the Plumtree Run watershed.

1. General

Historic aerial photographs show that, with the exception of headwater areas near Route 1 and along Route 924, the Plumtree Run watershed was still relatively rural in the early 1970's. As late as the mid-1980's, some areas along the upper and middle mainstem, as well as, along some tributaries were still relatively undeveloped. However, by the late 1980's and early 1990's the upper watershed was nearly completely developed and development had spread into the few remaining farms in the middle watershed shortly thereafter. The lower watershed has remained relatively undeveloped.

Changes in the hydrologic and sediment regimes associated with historic clearing of forests for agriculture and subsequent commercial and residential development have caused Plumtree Run and its tributaries to undergo significant morphological changes throughout the watershed. Changes in hydrology as well as

alterations to the stream and adjacent floodplain to accommodate development have contributed to unstable channel conditions. The unstable conditions include incision of the streambed, streambank erosion, widening of the channel, lateral migration and aggradation throughout much of the watershed. These channel adjustments have contributed a significant amount of sediment to downstream stream reaches and to Atkisson Reservoir.

2. Upper Plumtree Run Watershed (Upstream of MacPhail Road)

The Upper Plumtree Run Watershed Segment includes Subsheds 1 – 6. It is characterized by high density commercial, institutional and residential land uses and includes 50% impervious surfaces.

Subshed 1

Subshed 1 includes the mainstem of Plumtree Run and a single tributary. Its subshed drains 265 acres of high density commercial and residential land and is 53% impervious surfaces. The mainstem starts in the residential neighborhoods west of Route 1. It is intermittently open channel and piped sections until it outfalls at the rear of Bel Air High School. It joins with Subshed 2 upstream of Route 24. The single tributary flows from the Bel Air Plaza and enters the mainstem channel downstream of Market Place Drive.

With the exception of the most upstream reach and a few short stream reaches along the middle and lower sections of the subshed, conditions can be characterized as unstable C4 and B4c stream reaches. The instability includes bank erosion, debris jams and aggradation, with chute cutoffs forming on the tightest meander bends. The presence of old meander cutoffs indicate that the unstable conditions have existed for some time.

Bank heights along these unstable reaches range from 3 to 4 feet in the upper section, 2.5 to 9 feet in the middle section and 2 to 13 feet in the lower section The middle section, situated downstream of Bel Air High School and upstream of Atwood Road has the highest percentage of unstable channel. Although the high school has recently constructed a stormwater management pond, the majority of the watershed upstream of this section has no stormwater controls at all.

The tributary that flows from the Bel Air Plaza is a G4 stream channel in the section upstream of Market Place Drive. Severe gully erosion with multiple headcuts and bank erosion was evident throughout this section. Although there is a pond at the head of this tributary it provides no stormwater runoff control. Recently placed rip-rap has not corrected the problem. Downstream of Market Place Drive the tributary was a relatively stable B4c channel.

Photos are located in Appendix B

Subshed 2

Subshed 2 is a tributary to Plumtree Run. It drains 119 acres of medium to high density residential and institutional land and is 36% impervious surfaces. The tributary originates at a pond upstream of Route 924 and joins with the mainstem Plumtree Run upstream of Route 24. With the exception of the middle section, most of the stream reaches in this subshed are relatively stable C4, B4c, E4 and DA4 channels. The majority of the watershed has no stormwater controls.

The upper section is moderately stable with localized bank erosion and headcuts. Along the upper section some banks have been lined with gabions or rip-rap. A major portion of the middle section has been piped beneath school property. The piped section outfalls at the edge of a wooded area at the rear of Bel Air Middle School and Wakefield – Homestead Elementary School. It flows through a residential community upstream of Atwood Road. This section has the highest percentage of unstable channel. The instability includes bank erosion, under cutting of storm drain outfalls and adjacent parking lots. The lower section flows through a wooded wetland downstream of Atwood Road. Along this area the primary issue is aggradation. Multiple channels and the presence of scour traces in the floodplain indicate that the stream is evolving into an anastomosed (DA4) channel.

Although a small commercial property along the eastern boundary of upper Subshed 2 has a stormwater management pond the majority of this subshed has no stormwater controls.

Photos are located in Appendix B

Subshed 3

This subshed includes a mainstem reach of Plumtree Run which starts at the confluence of Subsheds 1 and 2 upstream of Route 24 and ends at the confluence of Subsheds 4 and 6 downstream of Route 24. The subshed drains 384 acres of high density commercial, institutional and residential land and is 48% impervious surfaces.

Conditions can be characterized as unstable C4 and B4c stream reaches. The instability includes severe bank erosion, debris jams and aggradation, with old meander cutoffs in the floodplain and exposed sanitary sewer manholes. The presence of old meander cutoffs indicate that the unstable conditions have existed for some time. Bank heights range from 3.5 to 7 feet in the upper section and are consistently 5.5 feet in the lower section.

Although the Weis Market Plaza along the eastern boundary of Subshed 3 has a stormwater management pond, the majority of the watershed upstream of this section has minimal stormwater controls.

Photos are located in Appendix B

Subshed 4

Subshed 4 is a tributary to Plumtree Run. It drains 26 acres of commercial property and is 74% impervious surfaces. The tributary originates at a storm drain outfall downstream of Market Place Drive in the Tollgate Marketplace Shopping Center and joins with the mainstem Plumtree Run approximately 300 feet downstream of Route 24. The watershed has no stormwater controls.

The first 100 feet below the outfall is lined with rip-rap and is stable. With the exception of a short section of channel along the upper middle section, the majority of the tributary can be characterized as unstable C4 and B4c stream reaches. The instability includes bank erosion, debris jams and aggradation. Bank heights along these unstable reaches range from 1.5 to 4 feet.

Photos are located in Appendix B

Subshed 5

Subshed 5 is a tributary to Plumtree Run. This subshed drains 53 acres of high density commercial and medium density residential land and is 54% impervious surfaces. The tributary originates at a storm drain outfall downstream of Tollgate Road and joins with the mainstem Plumtree Run approximately 25 feet upstream of MacPhail Road.

The channel conditions, as well as the factors influencing its condition, vary considerably along the length of this tributary. The storm-drain system, which outfalls at the upstream end of the tributary, drains Tollgate Road and the residential neighborhood of Silver Spring Heights. The lack of stormwater control and highly erosive nature of the soils in this area of the subshed has resulted in highly unstable conditions along the entire upper reach. Although the storm drain outfall had been stabilized with a gabion mattress, an actively eroding head-cut has undermined the gabion mattress such that half its length is hanging into an 8-foot deep gully. Immediately downstream, a tributary gully draining from the right terrace threatens to undermine the rip-rapped outfall of an old sediment basin. Along most of the length of the upper reach additional tributary gullies are actively eroding into the terraces along both sides of the channel. Bank heights along this reach range from 6 to 9 feet.

For much of its length the middle reach flows along the toe of a high retaining wall at the rear of the Home Depot. A large storm drain pipe outfalls from beneath the retaining wall at the upstream end of the middle reach. This storm-drain pipe carries flow from a stormwater management pond situated at the intersection of Tollgate Road and Market Place Drive. The outfall channel lined with rip-rap is stable. The middle reach below the outfall is a moderately stable E4 channel transitioning into a B4c channel downstream. Along the section where the channel is closest to the wall the bank has been armored with rip-rap. Bank heights along this reach range from 1 to 3 feet.

The lower reach can be characterized as unstable along most of its length. The instability includes bank erosion along most meander bends as well as minor debris jams and aggradation. A stormwater management pond situated along the south side of the Home Depot property discharges into this reach. Although the pond outfall had been stabilized with a gabion mattress, an actively eroding head-cut has undermined the gabion mattress such that half its length is hanging into a 3-foot deep gully. Bank heights along this reach range from 4.5 to 7 feet.

Photos are located in Appendix B

Subshed 6

Subshed 6 is a mainstem reach of Plumtree Run. This subshed drains 445 acres of high density commercial, institutional and residential land and is 50% impervious surfaces. The subshed starts at the confluence of Subsheds 3 and 4 downstream of Route 24 and ends at MacPhail Road. Although there are some site specific stormwater management facilities in the subsheds upstream the majority of the watershed has no stormwater controls at all. A stormwater management pond located on the Bel Air Twenty Four LLC commercial property outfalls along the eastern edge of the floodplain near the downstream end of the reach.

This reach is an unstable C4 and F4 channel along its entire length. The instability includes severe bank erosion, numerous large debris jams and significant aggradation. Numerous sanitary sewer manholes have been exposed or threatened by lateral erosion. Bank heights along this unstable reach range from 4 to 6 feet.

Photos are located in Appendix B

The results of the reconnaissance survey indicate that 6,049 linear feet (67%) of the total 9,029 linear feet of channel along the Upper Plumtree Run Segment is affected by some type of instability. The poor conditions along most of the reaches threaten private property and public infrastructure. In addition, Upper Plumtree Run is a significant source of sediment to downstream reaches and Atkisson Reservoir. Table 4.2 summarizes the stream conditions along the Upper Plumtree Run Segment.

Table 4.2 – Summary of Stream Conditions Upper Plumtree Run

Stream Reaches/ Geomorphic Map	Condition	Stream Type	Length (ft)	Description
Subshed 1				
Upper MS Section 1 Map 1	Stable	B4c/E4	350	Stable Channel, disturbed buffer
Upper MS Section 2 Map 1	Unstable	B4c/G4	550 (total) 375 (unstable) 68%	Gully erosion - headcuts and bank erosion, parking lots adjacent
Middle MS* Maps 2 & 3	Unstable	E4/G4	1,200 (total) 938 (unstable) 78%	Bank erosion, aggradation, debris jams, chute-cutoff forming
Lower MS* Map 3	Unstable	C4/E4	1,054 (total) 650 (unstable) 62%	Bank erosion, aggradation, debris jams, old meander cutoff
Tributary** Maps 3 & 21	Unstable	G4/B4c E4	500 (total) 338 (unstable) 68%	Deeply incised, multiple headcuts, slumping banks
Total Length			3,654	
Percent Unstable			63%	
Subshed 2				
Upper Section Map 18	Moderately Stable	E4 B4c/G4	825 (total) 225 (unstable) 27%	Localized bank erosion, headcuts
Middle Section* Map 19	Unstable	C4/B4c	575 (total) 400 (unstable) 70%	Bank erosion, undercutting SD outfalls and adjacent parking lot
Lower Section Map 3	Moderately Stable	DA4/E4	450 (total) 100 (unstable) 22%	Multiple channels, some aggradation along upper and middle sections, Localized bank erosion and head-cut in lower single thread channel section
Total Length			1,850	
Percent Unstable			39%	

Degree of Instability: * = Moderate; ** = High; and *** = Extreme

Table 4.2 (cont'd) – Summary of Stream Conditions Upper Plumtree Run				
Stream Reaches/ Geomorphic Map	**Condition**	**Stream Type**	**Length (ft)**	**Description**
Subshed 3 & 4				
MS*** Map 4	Unstable	C4/F4	825 (total) 800 (unstable) 97%	Severe bank erosion, aggradation, debris jams, two old meander cutoff channels
Tributary Map 21	Unstable	E4/B4c	700 (total) 525 (unstable) 75%	Moderate bank erosion throughout
Total Length			1525	
Percent Unstable			87%	
Subshed 5				
Tributary** Maps 5 & 21	Unstable	G4/E4/B4c/G4	1,000 (total) 700 (unstable)	UPS - Deeply incised, multiple large headcuts, slumping banks, undercut and failing SD outfalls, Middle - stable, DS - bank erosion, failing SWM outfall
Total Length			1000	
Percent Unstable			70%	
Subshed 6				
MS*** Maps 4 & 5	Unstable	C4/F4	1,000 (total) 1,000 (unstable)	Severe bank erosion, aggradation, debris jams throughout, exposed utilities
Total Length			1,000	
Percent Unstable			100%	
Upper Plumtree Run				
Total Length			9,029	
Percent Unstable			67%	

Degree of Instability: * = Moderate; ** = High; and *** = Extreme

3. <u>Upper Middle Plumtree Run Watershed (MacPhail Road to Ring Factory Road)</u>

The Upper Middle Plumtree Run Watershed Segment includes Subsheds 7 – 14. It is characterized by commercial and medium density residential land uses and includes 42% impervious surfaces.

Subshed 7

Subshed 7 is a tributary to Plumtree Run. This subshed drains 29 acres of medium density residential land and is 23% impervious surfaces. The tributary originates at a storm drain outfall downstream of Tollgate Road and joins with the mainstem Plumtree Run approximately 25 feet downstream of MacPhail Road. There are no stormwater controls in this subshed.

Although the channel was historically straightened along the upper section it can be characterized as a relatively stable E4 transitioning to a B4c stream reach with localized bank erosion. The middle and lower section are unstable B4c transitioning to a G4 channel. The instability includes bank erosion and multiple head-cuts. Bank heights range from 1 to 2 feet in the upper section and 3.5 to 5 feet in the middle and lower sections.

A stormwater management pond was installed to manage runoff from a Chesapeake Medical Center parking lot along MacPhail Road. Due to its proximity to the stream the pond's embankment encroaches on the floodplain of the middle section of this tributary.

Photos are located in Appendix B

Subshed 8

Subshed 8 is a tributary to Plumtree Run. This subshed drains 53 acres of medium density residential and institutional land and is 51% impervious surfaces. The tributary originates at a storm drain outfall downstream of Belcrest Road in the Wakefield Meadows neighborhood. A small pond was constructed on a spring in the rear yard of one of the residences along Belcrest Road. The discharge from the pond joins the stream approximately 50 feet downstream from the storm drain outfall. The stream is piped beneath the Motor Vehicle Administration parking lot, Route 24 and the Chesapeake Medical Center. It outfalls from the pipe at the rear of the Medical Center property and flows through a wooded wetland before joining the mainstem Plumtree Run in the upper section of Subshed 10.

Stormwater runoff from the Motor Vehicle Administration property is controlled by a stormwater management pond. The Chesapeake Medical Center has an underground stormwater management facility. There are no stormwater controls in the Wakefield Meadows community.

The upper and lower sections of this tributary are characterized as stable E4 channels.

Photos are located in Appendix B

Subshed 9

Subshed 9 is a mainstem reach of Plumtree Run. This subshed drains 539 acres of high density commercial, institutional and residential land and is 49% impervious surfaces. The subshed starts downstream of MacPhail Road and ends 350 feet upstream of the confluence of Subsheds 8 and 10. Although there are some site specific stormwater management facilities in the subsheds upstream the majority of the watershed has no stormwater controls at all.

With the exception of a few sections of channel where bedrock outcrops provide lateral control and/or low stable banks provide access to the floodplain, conditions along this reach can be characterized as unstable incising C4 and incised F4 stream reaches. The instability includes severe bank erosion, large debris jams and significant aggradation. Bank heights along the stable sections range from 1.5 to 2.5 feet. Bank heights along this unstable section range from 4 to 7 feet.

Photos are located in Appendix B

Subshed 10

Subshed 10 includes a mainstem reach of Plumtree Run and two tributary drainages. This subshed drains 592 acres of high density commercial, institutional and residential land and is 49% impervious surfaces. The subshed starts 350 feet upstream from its confluence with Subshed 8 and ends 450 feet upstream of the intersection of Ring Factory Road and Route 24. Although there are some site specific stormwater management facilities in the subsheds upstream the majority of the watershed has no stormwater controls at all.

An old barn, old farm pond, old tractor paths, as well as the remnants of several old tractor crossings and associated cattle guards along the mainstem reaches in Subshed 10 provide evidence that this property was an active farm in the recent past.

The upper mainstem reach of Subshed 10 is a moderately stable C4 channel with localized bank erosion and aggradation in its upstream section. A chute cut-off is forming on a very tight meander bend in the upper section. The middle and lower sections of this reach are stable with bedrock outcrops providing vertical and lateral control and low stable banks providing access to the floodplain. Bank heights along the unstable upper section range from 4.5 to 5 feet. Bank heights along the stable middle and lower sections range from 2.5 to 5 feet. As previously noted, the downstream reach of Subshed 8 joins the upper mainstem reach of Subshed 10 at the rear of the Chesapeake Medical Center and flows through a wooded wetland along the floodplain.

With the exception of the upstream section, the middle mainstem reach of Subshed 10 is an unstable C4 channel. The instability includes severe bank erosion, large debris jams and significant aggradation. A large chute cut-off is forming on a very tight meander bend. Sanitary sewer manholes are exposed or threatened by lateral

erosion. Bank heights along the stable sections range from 3 to 5 feet. Bank heights along the unstable section range from 3 to 6 feet.

The lower mainstem reach of Subshed 10 is an unstable C4 channel. The upper and lower sections of the reach have been armored with rip-rap presumably to protect the sanitary sewer line which runs immediately adjacent to the channel. In some areas the revetment has failed with the rip-rap rock rolled away from the banks and piled up in the channel. In general these sections are stable. The middle section of the lower reach is unstable. Bank erosion has exposed the sanitary sewer in some locations. Bank heights along this reach range from 3 to 4 feet.

Tributary 1 of Subshed 10 is the downstream reach of Subshed 13 after it flows beneath Route 24. This tributary is moderately stable. An unstable G4 channel in its upper section near the Route 24 outfall, it transitions downstream into a stable E4 channel. An actively eroding head-cut at the confluence with the middle mainstem reach of Subshed 10 threatens not only the stable E channel but the outfall to a stormwater pond installed to manage runoff from a Chesapeake Medical Center parking lot situated adjacent to the tributary. Bank heights along the unstable section range from 4 to 8 feet. Bank heights along the stable section range from 0.5 to 1.5 feet.

Tributary 2 of Subshed 10 is the downstream reach of Subshed 11 after it flows beneath Route 24. This tributary is a moderately stable DA4 channel that flows through a wooded wetland. The DA transitions downstream into a stable E4 channel. Actively eroding head-cuts along some of the back channels threaten not only the stable DA channel but the wetlands through which it flows. Bank heights along the stable sections range from 0.5 to 1.5 feet. Bank heights along the unstable section range from 1.5 to 3 feet.

Photos are located in Appendix B

Subshed 11

Subshed 11 is a tributary to Plumtree Run. This subshed drains 39 acres of medium density residential land in the Forest Lawn neighborhood and is 15% impervious surfaces. The tributary originates at storm drain outfall at the rear of residences fronting on Forest Drive. It is piped beneath Hibiscus Court, joins Subshed 12 and is piped beneath Route 24 where it joins with the mainstem Plumtree Run along the lower reach of Subshed 10. There are no stormwater controls in the neighborhood draining this subshed.

The upper section is a moderately stable E4 channel. Instability includes localized bank erosion, head-cuts and aggradation. Numerous landowner projects have encroached on the channel and its floodplain contributing to the instability observed along the upper section. These projects include a shed which straddles the channel; several small ponds constructed with fencing and stacked cinder blocks; footbridges, and timber retaining walls. Bank heights along this section range from 0.5 to 3 feet.

The lower section is an unstable B4c channel transitioning to a very unstable G4 channel. Instability includes multiple head-cuts, debris jams and lateral erosion undermining banks and trees along the rear yards of residences. Bank heights along this section range from 3 to 6.5 feet.

Photos are located in Appendix B

Subshed 12

Subshed 12 is a tributary to Plumtree Run. This subshed drains 18 acres of medium density residential land and is 18% impervious surfaces. The tributary originates at a storm drain outfall at the rear of a residence fronting on Huntington Place in the Forest Lawn neighborhood and joins with Subshed 11 approximately 350 feet upstream of Route 24. There are no stormwater controls in this subshed.

This tributary is an unstable G4 channel. The instability includes bank erosion, undercut and falling trees and debris jams throughout. Bank heights range from 2.5 to 4 feet along this reach.

Photos are located in Appendix B

Subshed 13

Subshed 13 is a tributary to Plumtree Run. This subshed drains 40 acres of medium density residential land and is 25% impervious surfaces. The tributary originates at the storm drain outfall at the rear of residences fronting on Heather Road. It flows beneath Heather Road entering a MDSHA stormwater management pond before being piped under Route 24. The tributary outfalls downstream of Route 24 where it is identified as Tributary 2 in Subshed 10. There are no stormwater controls in this subshed.

The upper reach of this tributary is an unstable G4 transitioning to an unstable F4 channel. The instability includes bank erosion, debris jams, aggradation and multiple small head-cuts. Bank heights range from 3 to 6 feet in the upper reach.

The lower reach of this tributary is an unstable G4 transitioning to a stable E4 channel. Downstream of Heather Road the upper section of this reach is stabilized with rip-rap. The middle section is deeply incised G4 channel with severe lateral erosion and head-cuts. The lower section is a stable E4 channel that flows through a scrub-shrub wetland that has developed in the stormwater management pond. Bank heights range from 4.5 to 8 feet in the middle section and 0.5 to 1 foot in the lower section.

Photos are located in Appendix B

Subshed 14

Subshed 14 includes a mainstem reach and two tributaries. This subshed drains 689 acres of high density commercial, institutional and residential land and is 45% impervious surfaces. The subshed starts approximately 450 feet upstream of the intersection of Ring Factory Road and Route 24, flows beneath Route 24 and ends approximately 150 feet downstream of the intersection. Although there are some site specific stormwater management facilities in the subsheds upstream the majority of the watershed has no stormwater controls at all.

The upstream section of the mainstem reach is a stable C4 channel transitioning to an F4 channel. Although entrenched along the lower section, the channel is stable because it is lined with rip-rap from bank to bank along its entire length. As part of the stabilization work rip-rap was placed to form a low flow channel with meanders. The downstream section of the mainstem reach is an unstable F4 channel transitioning to an unstable C4 channel. Along the MDSHA right of way, instability includes bank erosion and a debris jam held in place by a chain link fence, which has collapsed into the channel.

Tributary 1 starts at a pond in a new residential subdivision fronting on Ring Factory Road. It flows parallel with the road for approximately 750 feet until it enters a pipe, flows beneath Ring Factory Road, and outfalls into a ditch before joining the mainstem. Although historically straightened, the channel along its upper section is a relatively stable E4 channel that flows through an emergent wetland. Along the middle section the stream transitions into a moderately stable B4c channel with localized bank erosion. A stormwater management pond constructed to manage runoff from the new subdivision outfalls into the tributary along this section. The lower section is a relatively stable E4 channel that flows through a wooded wetland.

Tributary 2 starts at a wetland seep at the rear of residences fronting on Regent Drive flows along the back yards of these homes for approximately 400 feet and enters a wooded wetland before joining with the mainstem. Although historically straightened, the channel along its upper and middle section is a relatively stable E4 channel. The landowners maintain the riparian area as mowed lawn. They have landscaped the banks, constructed several footbridges, as well as a small gazebo. The lower section is an unstable G4 channel. Bank erosion and actively head-cuts threaten the stable E channel as well as the wetland.

Photos are located in Appendix B

The results of the reconnaissance survey indicate that 4,977 linear feet (44%) of the total 11,312 linear feet of channel along the Upper Middle Plumtree Run Segment is affected by some type of instability. The poor conditions along many of the reaches in this segment threaten private property and public infrastructure. In addition, Upper Middle Plumtree Run is a source of sediment to downstream reaches and Atkisson Reservoir. Table 4.3 summarizes the stream conditions along the Upper Middle Plumtree Run Segment.

Table 4.3 – Summary of Stream Conditions Upper Middle Plumtree Run

Stream Reaches/ Geomorphic Map	Condition	Stream Type	Length (ft)	Description
Subshed 7				
Tributary* Maps 5 & 23	Unstable	E4/G4	750 (total) 350 (unstable	UPS and Upper Middle - stable, Lower Middle and DS - G4 with multiple headcuts and lateral erosion
Total Length			750	
Percent Unstable			47%	
Subshed 8				
Tributary Upper Section Map 22	Stable	E4	250	Small on-line pond at headwaters, piped beneath DMV parking lot
Tributary Lower Section Map 6	Stable	E4	175	Outfalls at rear of Chesapeake Medical Center (CMC) parking lot, flows through wooded wetland
Total Length			425	
Percent Unstable			0%	
Subshed 9				
MS** Map 5	Unstable	C4/F4	775 (total) 650 (unstable	Severe bank erosion, aggradation, large debris jams
Total Length			775	
Percent Unstable			84%	
Subshed 10				
Upper MS* Map 6	Moderately Stable	C4	1,175 (total) 400 (unstable) 34%	UPS - Localized bank erosion, aggradation, chute-cutoff forming Middle and DS - stable
Middle MS** Maps 6 & 7	Unstable	C4	1,150 (total) 563 (unstable) 49%	UPS - Stable, Middle and DS - Severe bank erosion, debris jams aggradation, chute-cutoff forming, exposed utilities

Degree of Instability: * = Moderate; ** = High; and *** = Extreme

Table 4.3 (cont'd) – Summary of Stream Conditions Upper Middle Plumtree Run				
Stream Reaches/ Geomorphic Map	**Condition**	**Stream Type**	**Length (ft)**	**Description**
Subshed 10 (cont'd)				
Lower MS* Map 7	Unstable	C4	375 (total) 150 (unstable) 40%	Bank erosion, exposed utilities
Tributary 1 Maps 6 & 26 Flows from Subshed 13	Moderately Stable	G4/E4	537 (total) 100 (unstable) 19%	UPS - outfall at Rte 24, incised with bank erosion near outfall, Middle and DS - stable except head-cut at confluence
Tributary 2 Map 7 Flows from Subshed 11	Moderately Stable	DA4/E4	700 (total) 100 (unstable) 14%	Outfalls at Rte 24, flows through wooded wetland, active head-cuts
		Total Length	3,937	
		Percent Unstable	33%	
Subshed 11				
Tributary Upper Section Maps 24 & 25	Moderately Stable	E4	750 (total) 275 (unstable) 37%	Multiple small headcuts, localized bank erosion and aggradation. Multiple small cinder block dams, footbridges and shed built over the channel
Tributary Lower Section* Maps 25 & 8	Unstable	B4c/G4	1,450 (total) 1,350 (unstable) 93%	Multiple small headcuts, lateral erosion and debris jams along rear yards of residences
		Total Length	2,200	
		Percent Unstable	74%	
Subshed 12				
Tributary Map 25	Unstable	G4	650 (total) 450 (unstable)	Bank erosion and debris jams throughout.
		Total Length	650	
		Percent Unstable	69%	
Subshed 13				
Tributary Upper Section* Map 26	Unstable	G4/F4	350 (total) 225 (unstable) 64%	Incised, bank erosion, debris jams and aggradation, multiple small headcuts

Degree of Instability: * = Moderate; ** = High; and *** = Extreme

Table 4.3 (cont'd) – Summary of Stream Conditions Upper Middle Plumtree Run				
Stream Reaches/ Geomorphic Map	**Condition**	**Stream Type**	**Length (ft)**	**Description**
Subshed 13 (cont'd)				
Tributary Lower Section* Map 26	Unstable	G4/E4	325 (total) 100 (unstable) 31%	UPS - stabilized outfall, Mid – incised, with severe lateral erosion and headcuts, DS - stable channel flows through scrub-shrub wetland
Total Length			675	
Percent Unstable			48%	
Subshed 14				
MS* Map 8	Unstable	C4/G4	600 (total) 150 (unstable) 25%	UPS Route 24 – stable, rip-rapped with constructed meandering low flow channel DS Route 24 – bank erosion, SHA collapsed and fence blocking channel
Tributary 1 Map 8	Moderately Stable	E4/B4c/E4	750 (total) 75 (unstable) 10%	UPS – stable, flows through emergent wetland, Middle – Head-cut, minor localized bank erosion, DS – stable, flows through wooded wetland
Tributary 2 Map 8	Moderately Stable	E4/G4	550 (total) 100 (unstable) 18%	UPS - flows through rear of mowed yards, landscaped and footbridges DS – flows through wooded wetland, active head-cut, incised, bank erosion
Total Length			1,900	
Percent Unstable			17%	
Upper Middle Plumtree Run				
Total Length			11,312	
Percent Unstable			44%	

Degree of Instability: * = Moderate; ** = High; and *** = Extreme

4. Lower Middle Plumtree Run Watershed (Ring Factory Road and Tollgate Road)

The Lower Middle Plumtree Run Watershed Segment includes Subsheds 15 – 21. It is characterized by commercial, institutional and medium density residential land uses and includes 36% impervious surfaces.

Subshed 15

Subshed 15 is a mainstem reach of Plumtree Run. This subshed drains 768 acres of high density commercial, institutional and residential land and is 42% impervious surfaces. The subshed starts approximately 150 feet downstream of the intersection of Ring Factory Road and Route 24 and ends approximately 1500 feet downstream at the confluence of Subsheds 16 and 17. Although there are some site specific stormwater management facilities in the subsheds upstream the majority of the watershed has no stormwater controls at all.

This reach is an unstable C4 channel throughout its entire length. The instability includes severe bank erosion and lateral migration, large debris jams, a chute-cutoff forming on a tight bend and significant aggradation.

Conditions are particularly unstable along the downstream end of the upper section of this reach. In this area the stream is eroding into a high terrace in the rear yards of residences fronting on West Riding Drive. The presence of large debris jams is forcing storm flows to undercut the terrace causing it to slump into the channel. A large chute cut-off has formed through the meander bend immediately downstream of the terrace.

Along the middle section bank erosion is causing the channel to migrate laterally into the MDSHA right-of-way along Route 24, such that the top of bank is less than 30 feet from the road. Bedrock along some areas is providing grade control, preventing the channel from incising, which would exacerbate the current stability problems. Bank heights along this reach range from 2.5 to 13 feet with most banks in the 5.5 to 8 foot range. Bank erosion hazard is severe.

Photos are located in Appendix B

Subshed 16

Subshed 16 is a tributary to Plumtree Run. This subshed drains 134 acres of institutional and medium density residential land and is 21% impervious surfaces. The tributary originates from a wet seep at the rear of Ring Factory Elementary School. It flows across the school property for approximately 1,200 feet before entering a pipe at the rear of residences fronting on Regent Drive. Piped for 880 feet, it outfalls upstream of Cheltenham Lane, flows a short distance, is piped under Cheltenham Lane, and flows

approximately 1,000 feet downstream where it joins the mainstem Plumtree Run. There are two stormwater management ponds at Ring Factory Elementary School which discharge into the upper reach of this tributary. There are no other stormwater controls in this subshed.

The upper reach of this tributary flows through a wooded area at the rear of the Ring Factory Elementary School property. In this area the stream area is a stable E4 channel transitioning abruptly to an unstable B4c. Due to vertical instability it transitions quickly to an unstable G4 channel. The instability includes bank erosion, undercut and fallen trees, and multiple head-cuts throughout. Bank heights range from 2.5 to 4.5 feet along the upper reach. A 10-foot deep gully has eroded at the outfall of one of the stormwater management ponds. Multiple, actively eroding headcuts have already undermined the outfall such that half it is hanging in the gully. Bank erosion hazard is high along the tributary and extreme along the gully. The presence of a footbridge, trails, steps providing access to the water's edge at various points along the channel, and signage along the trails indicate that the wooded area and stream were at one time utilized by the school as part of the environmental science curriculum. Its current unstable conditions detract from that experience and pose a safety risk for students and teachers.

Upstream of Cheltenham Lane, the middle reach of this tributary is a moderately stable F4 channel. Its high banks and bed are lined with rip-rap. Although there is significant aggradation throughout, many of the sediment bars have been stabilized by colonizing willows and sycamores.

Downstream of Cheltenham Lane, the lower reach is an unstable F4 transitioning to an unstable C4 channel. The high banks and bed along the upper section are lined with rip-rap. Boulder cross vanes were installed when a restoration project was completed at sometime in the recent past. Some of these structures are failing. Instability along the middle and lower section includes bank erosion, lateral migration and debris jams throughout. Bank heights range from 4 to 9 feet along these sections of the lower reach.

Photos are located in Appendix B

<u>Subshed 17</u>

Subshed 17 includes a mainstem reach of Plumtree Run and one tributary. The mainstem reach drains 921 acres of high density commercial, institutional and residential land and is 39% impervious surfaces. The tributary subshed drains 68 acres of medium density residential land and is 15% impervious surfaces. The mainstem reach starts at the confluence of Subsheds 15 and 16 and ends at the Route 24 culvert. The tributary originates from a wet seep at the rear of residences fronting on Pine Forest Court in the Barrington Community. The stream flows through the Evergreen Heights and East Valley Oaks Communities where it joins with the mainstem reach approximately 300 feet upstream of the Route 24 culvert. There is one stormwater

management pond in the East Valley Oak Community which discharges into the lower reach of the tributary. There are no other stormwater controls in this subshed.

The mainstem reach is an unstable C4 channel throughout its entire length. The instability includes severe bank erosion and lateral migration, undercut and fallen trees, large debris jams, and significant aggradation. Channel width to depth ratios are high and bank heights range from 2.5 to 6 feet along the reach. Bank erosion hazard is severe.

The upper reach of the tributary flows through a wooded area at the rear of the Barrington Community. In this area the stream is a stable E4 channel transitioning abruptly to an unstable G4 channel. The instability includes multiple headcuts and bank erosion. Bank heights range from 2 to 3 feet along the upper section. Bank erosion hazard is moderate to high. Where the stream enters the Evergreen Heights Community, the first 100 feet has been piped by a landowner. Emerging from the pipe it flows for another 100 feet along a small channel with stable banks and boulder grade control. Bank erosion hazard is low. It is piped beneath Lake Drive.

Downstream of Lake Drive, the upper middle reach is a moderately stable E4 channel with localized bank erosion. Bank heights range from 3 to 5 feet. Bank erosion hazard is moderate. The outflow from a recreational pond in the Evergreen Heights Community enters the upper middle reach along this section.

The stream transitions abruptly to an unstable G4 channel dropping over a 6 foot knick-point. The roots of a large sycamore tree are providing a temporary grade control. The instability along this lower section includes multiple severe headcuts and bank erosion. Bank heights range from 4.5 to 7.5 feet. Bank erosion hazard is moderate to high.

Uncontrolled runoff has eroded a deep gully at the rear of a residential property on Bonnie Lane. The landowner has unsuccessfully attempted to stabilize the gully with a small rock berm along the top of bank. Bank heights along the gully range from 2.5 to 4.5 feet. The gully joins the upper middle reach approximately 125 feet upstream from Bonnie Lane. Bank erosion hazard is moderate to high.

Downstream of Bonnie Lane, conditions along the lower middle reach vary considerably. The upper section is an unstable G4 channel. The instability includes severe bank erosion. Bank heights range from 4.5 to 5.5 feet along this section. Bank erosion hazard is severe. The middle section transitions to an unstable B4c and then a moderately stable E4 channel as bank heights decrease from 4 feet to 2 feet in a downstream direction.

A short distance downstream channel conditions change again, as debris jams and aggradation have raised the streambed further reducing bank heights from 1.5 to 0.5 feet. In this area the channel transitions rapidly from a vertically unstable E4 to a

moderately stable DA4 with multiple channels carrying storm flows throughout the adjacent wetlands and floodplain.

The lower section of the lower middle reach is an unstable B4c channel. Bank heights are consistently 3 feet along this section. Bank erosion hazard is moderate to high. At the interface of the B4c and the upstream DA4 channel multiple headcuts are actively eroding head-ward threatening to degrade the wetlands.

The lower reach of the tributary is downstream of Oak Valley Drive. The upstream section of this reach is a stable E4 channel flowing through a wooded wetland. Bank heights range from 0.5 to 1.5 feet along this section. Bank erosion hazard is low. The downstream section of the lower reach is an unstable G4 channel with eroding banks throughout. Bank heights are consistently 4 feet along this section. Bank erosion hazard is moderate to high.

A stormwater management pond in the East Valley Oaks Community is situated at the edge of the floodplain between Subsheds 16 and 17. Discharges from the pond are carried by a small, stable channel traversing the floodplain. The discharge channel joins the lower reach of Subshed 17 approximately 50 feet upstream from the mainstem Plumtree Run. Because the discharge channel drops vertically into the lower reach of the tributary a head-cut has formed at the confluence. This actively eroding head-cut threatens the stability of the discharge channel.

Photos are located in Appendix B

Subshed 18

Subshed 18 is a mainstem reach of Plumtree Run. The reach drains 989 acres of high density commercial, institutional and residential land and is 37% impervious surfaces. The reach starts at the Route 24 culvert meandering across a wooded floodplain in its upper section, along fenced pastures in its lower section and ends at Tollgate Road. A small tributary meanders through wetlands in the wooded floodplain. There is one stormwater management pond located in the West Valley Oaks Community which discharges into the upper section of this reach. There are no other stormwater controls in this subshed.

The upper section of this reach is an unstable C4 channel. The instability includes bank erosion and lateral migration, and significant aggradation. Bank heights range from 2.5 to 5.5 feet along the reach. Bank erosion hazard is moderate to high. Of particular concern is an area where the channel is eroding into an adjacent terrace. This erosion threatens a stormwater management pond located on the terrace. The situation is exacerbated by the fact that the discharge from the pond is creating gully erosion over the slope where it enters the reach.

The stream flows out of the woods onto the Bel Air Veterinary property. Along this lower section the adjacent floodplain is fenced pasture and stables for livestock. A

road crossing, which connects the front and back pasture, has created a backwater area on the upstream side and a significant drop off on the downstream side.

The lower section is an unstable B4 channel that transitions quickly to an unstable G4/G1 channel. Further downstream the stream transitions to an unstable C4 channel. The instability includes bank erosion and lateral migration, debris jams and aggradation. Bank heights range from 1.5 to 7 feet along the reach. Bank erosion hazard is moderate to very high. Along the G4 portion of this section the channel has incised to bedrock. Harford County DPW identified this lower section for restoration and is currently in design.

Photos are located in Appendix B

Subshed 19

Subshed 19 is a tributary to Plumtree Run. This subshed drains 29 acres of medium density residential land and is 32% impervious surfaces. The tributary originates from a storm drain outfall at the end of Barrington Drive in the Barrington Community. It traverses a wooded open space in the community picking up additional storm drainage along its route before entering a MDSHA stormwater management pond adjacent to Route 24. Although there are several small water quality basins in the subdivision, there are no stormwater facilities designed to provide peak discharge control in this subshed.

This tributary is an unstable G4 channel along its entire length. The instability includes severe bank erosion, undercut and fallen trees, and multiple head-cuts throughout. Bank heights range from 3 to 8 feet along the reach. Bank erosion hazard is very high to severe. The remnants of a pond embankment were observed in the upper section of the tributary.

Several of the storm drain outfalls have created significant gully erosion where they drop into the incised channel. At one outfall the gully erosion has undermined the outfall protection and threatens the pipe as well. Another area of concern is the downstream end near the MDSHA SWM pond. An 8 foot deep gully has eroded at the inlet of the stormwater management pond. Multiple, actively eroding headcuts are moving upstream threatening greater instability and depositing a significant amount of sediment in the pond.

Photos are located in Appendix B

Subshed 20

Subshed 20 is a tributary to Plumtree Run. This subshed drains 70 acres of commercial, institutional and medium density residential land and is 30% impervious surfaces. The tributary originates from a wet seep at the rear of commercial properties fronting on Route 924 and Plumtree Road and flows through a wooded area until it

enters the MDSHA right-of-way along Route 24. There it joins a roadside ditch that flows into the MDSHA stormwater management pond at the downstream end of Subshed 19.

There are two stormwater management ponds in this subshed. One pond manages the ezStorage property and discharges into the upper section of the tributary. The other pond manages the Emmorton Baptist Church property and discharges into the lower section of the tributary. There are no other stormwater controls in this subshed.

The stream along the upper and middle sections of the tributary is unstable G4 channel. Conditions along this area include: multiple collapsing sinkholes at the upstream end of the tributary; multiple head-cuts; severe bank erosion and lateral migration creating very tight meander bends, some with chute cutoffs; undercut and fallen trees; large debris jams and aggradation throughout. Bank heights along the upper and middle sections range from 2 to 9 feet. Bank erosion hazard is very high to severe.

Uncontrolled runoff from adjacent commercial properties has contributed to the unstable conditions along this tributary. As a result, the unstable conditions are impacting the adjacent properties. Field observations indicate that the commercial properties in the headwaters are experiencing problems such as undermining and collapse of parking lots, retaining walls, fences and storm drain outfalls. Concrete rubble and debris stacked along the slopes at the rear of the properties may represent property owner's efforts to stabilize these areas. A five-foot deep gully has formed where the discharge from the ezStorage SWM pond enters the tributary. The rip-rapped outfall protection has already been undermined and an actively eroding head-cut is threatening the outfall pipe.

Two side drainages join the tributary in the middle section. The larger of the two drains the Plumtree Partnership LLC property. Although generally stable, there is a short section where significant aggradation has completely filled the channel. An active head-cut is eroding a new channel through the deposited material. The smaller side drainage picks up runoff from the Emmorton Baptist Church property and is stable throughout its length.

The lower section of the tributary is in a part of the subshed where the valley widens and the gradient flattens. Along this section the channel transitions to a moderately stable E4 channel. Although the banks are stable this section is affected by aggradation. The huge amount of sediment from eroding channels upstream, as well as a channel blockage created by the fence along the MDSHA right-of-way has impacted this section. As noted above, the tributary enters a roadside ditch along Route 24 and flows into the MDSHA stormwater management pond at the downstream end of Subshed 19.

Photos are located in Appendix B

Subshed 21

Subshed 21 is a tributary to Plumtree Run. This subshed drains 117 acres of commercial, institutional and medium density residential land, as well as side drainage from Route 24 and is 29% impervious surfaces. The Subshed 21 tributary is a second order stream and the downstream reach of the two first order streams draining Subsheds 19 and 20. As noted previously both subsheds enter the MDSHA SWM pond upstream of Route 24. This subshed starts at the outfall of the Route 24 culvert. It flows across the Bel Air Veterinary property and joins with mainstem Plumtree Run in Subshed 18 approximately 25 feet upstream of Tollgate Road. Other than the MDSHA SWM pond and the two stormwater management facilities noted for Subshed 20, there are no other stormwater controls in this subshed.

The tributary is an unstable B4c/G4 channel. The instability includes debris jams and aggradation at the upstream end and bank erosion on meander bends and livestock impacts throughout. Bank heights range from 2 to 5 feet along the reach. Bank erosion hazard is moderate to high.

Photos are located in Appendix B

The results of the reconnaissance survey indicate that 11,014 linear feet (83%) of the total 13,270 linear feet of channel along the Lower Middle Plumtree Run Segment is affected by some type of instability. The poor conditions along many of the reaches in this segment threaten private property and public infrastructure. In addition, Lower Middle Plumtree Run is a significant source of sediment to downstream reaches and Atkisson Reservoir. Table 4.4 summarizes the stream conditions along the Lower Middle Plumtree Run Segment.

Table 4.4 – Summary of Stream Conditions Lower Middle Plumtree Run

Stream Reaches/ Geomorphic Map	Condition	Stream Type	Length (ft)	Description
Subshed 15				
MS*** Map 9	Unstable	C4	1,500 (total) 1,500 (unstable)	Severe lateral erosion, high banks at rear of residences slumping, large debris jams and aggradation
Total Length			1,500	
Percent Unstable			100%	
Subshed 16				
Tributary** Upper Reach Map 29	Unstable	E4/B4c/G4	1,200 (total) 1,025 (unstable) 85%	UPS and Middle - Bank erosion undercut and fallen trees; multiple headcuts & severe gully erosion at outfall to SWM pond - rear of elementary school; DS - piped
Tributary Middle Reach Map 30	Moderately Stable	F4	150 (total)	Rip-rapped bed and banks, significant aggradation throughout
Tributary Lower Reach* Maps 30 & 9	Unstable	F4/C4	1,015 (total) 625 (unstable) 62%	UPS – Rip-rapped banks, previous restoration project installed boulder cross vanes, some failing DS – Lateral erosion and debris jams throughout
Total Length			2,365	
Percent Unstable			70%	
Subshed 17				
MS*** Map 9	Unstable	C4	550 (total) 550 (unstable)	Severe bank erosion, undercut and fallen trees, debris jams and significant aggradation throughout

Degree of Instability: * = Moderate; ** = High; and *** = Extreme

Table 4.4 (cont'd) – Summary of Stream Conditions Lower Middle Plumtree Run				
Stream Reaches/ Geomorphic Map	**Condition**	**Stream Type**	**Length (ft)**	**Description**
Subshed 17 (cont'd)				
Tributary Upper Reach Map 31	Moderately Stable	G4/E4	500 (total) 100 (piped) 100 (stable) 300 (unstable) 60%	UPS – Multiple head-cuts, bank erosion, Middle – piped' DS – stable with boulder grade control
Tributary Upper Middle Reach** Map 32	Unstable	E4/G4	965 (total) 915 (unstable) 95%	UPS – Stable DS – Incised with multiple severe head-cuts, bank erosion, Gullies at rear of residences
Tributary Lower Middle Reach** Maps 32 & 30	Unstable	G4/E4/Da4/B4c	965 (total) 915 (unstable) 95%	UPS – Incised with severe bank erosion, Mid – Stable E4 transitioning to unstable E4 and Da4 – significant aggradation and multiple active head-cuts, DS – bank erosion
Tributary Lower Reach* Maps 30 & 9	Unstable	E4/G4	600 (total) 425 (unstable) 71%	UPS – Stable DS – Incised with bank erosion
Total Length			3,580	
Percent Unstable			87%	
Subshed 18				
MS Upper Section** Maps 9 & 10	Unstable	C4	500 (total) 450 (unstable) 90%	Bank erosion, aggradation, backwater due to crossing
MS Lower Section** Maps 9 & 10	Unstable	B4c/G4/C4	650 (total) 650 (unstable) 100%	Incised, lateral erosion, debris jams and aggradation
Total Length			1,150	
Percent Unstable			96%	
Subshed 19				
Tributary*** Maps 35 & 36	Unstable	G4	725 (total) 725 (unstable)	Old pond embankment at upstream end, multiple headcuts and lateral erosion throughout large headcuts at downstream end near SHA SWM pond
Total Length			725	
Percent Unstable			100%	

Degree of Instability: * = Moderate; ** = High; and *** = Extreme

Table 4.4 (cont'd) – Summary of Stream Conditions Lower Middle Plumtree Run				
Stream Reaches/ Geomorphic Map	**Condition**	**Stream Type**	**Length (ft)**	**Description**
Subshed 20				
Tributary*** Maps 33 & 35	Unstable	G4/E4	3,350 (total) 2,400 (unstable)	UPS and middle– multiple old ponds, multiple collapsing sinkholes, multiple head-cuts, severe bank erosion, undercut and fallen trees, severe meander bends with lateral migration, large debris jams and aggradation throughout, DS – E4 with aggradation - SHA fence blocking downstream end
Total Length			3,350	
Percent Unstable			72%	
Subshed 21				
Tributary* Maps 36 & 10 Flows from Subsheds 19 & 20	Unstable	B4c/G4	600 (total) 600 (unstable)	Bank erosion, livestock impacts
Total Length			600	
Percent Unstable			100%	
Lower Middle Plumtree Run				
Total Length			13,270	
Percent Unstable			83%	

Degree of Instability: * = Moderate; ** = High; and *** = Extreme

5. Lower Plumtree Run Watershed (Tollgate Road to Atkisson Reservoir)

The Lower Plumtree Run Watershed Segment includes Subsheds 22 – 25. It is characterized by medium to low density residential, pasture and forest land uses and includes 29% impervious surfaces.

Subshed 22

Subshed 22 includes a mainstem Plumtree Run reach and one tributary. This subshed drains 1,181 acres of high density commercial, institutional and medium density residential land and is 36% impervious surfaces. The subshed starts at the

Tollgate Road culvert and ends at the confluence with the tributary in Subshed 23. There are few stormwater controls upstream of this reach and none in this subshed.

The mainstem reach is an unstable B4c in its upper section, an unstable C4 in its middle section and an unstable B4c in its lower section. The instability includes severe bank erosion, undercut and fallen trees, debris jams and aggradation throughout. Bank heights range from 3 to 6 feet along the reach. Bank erosion hazard is very high to severe. An area of particular concern is the severe bank erosion along the rear yards of residences fronting on Cypress Drive in the Cedar Springs Community. Landowners have unsuccessfully attempted to stabilize their banks with rip-rap and concrete slabs.

A small tributary joins the mainstem in the upper section. The tributary carries uncontrolled runoff from a storm drain outfall along Cypress Drive. The tributary is an unstable G4 channel with eroding banks along most of its length.

Photos are located in Appendix B

Subshed 23

Subshed 23 includes a short reach of the mainstem Plumtree Run and one tributary. The mainstem portion of the subshed drains 1,262 acres of high density commercial, institutional and residential land and is 34% impervious surfaces. The mainstem reach starts approximately 1,550 feet downstream of Tollgate Road and ends 400 feet further downstream. The tributary subshed drains 83 acres of medium density residential and is 17% impervious surfaces. The tributary starts at a storm drain outfall off Camelot Drive in the Camelot Community and flows downstream through a wooded area to its confluence with the mainstem Plumtree Run. There are few stormwater controls in the overall watershed upstream of the mainstem reach and none in the subshed of this tributary.

The mainstem reach is a stable C4 channel with minor and localized bank erosion. Bank heights range from 2.5 to 12 feet along the reach. Bedrock outcrops provide lateral control along the highest banks. Bank erosion hazard is low to moderate.

The tributary is a second order stream and an unstable G4 channel along its entire length. The instability includes severe gully erosion below the storm drain outfall at the upstream end of the tributary. Along the upper section, landowners have installed a variety of grade control measures including boulders, concrete slabs and sheet piling. Banks along some areas are completely covered with yard waste.

Instability along the middle and lower sections includes severe bank erosion, debris jams and aggradation throughout. Bank heights range from 1 to 5.5 feet along the reach. Bank erosion hazard is high to severe.

A small first order tributary joins the main tributary at the upstream end of the lower section. This tributary is a stable E4 channel along its upstream section and an unstable G4 channel along its lower section. Uncontrolled runoff from storm drain outfalls has created several headcuts where out of bank storm flow drops into the G channel. These head-cuts threaten the stable E channel.

Photos are located in Appendix B

Subshed 24

Subshed 24 includes a mainstem Plumtree Run reach and three tributaries. The mainstem portion of the subshed drains 1,345 acres of high density commercial, institutional and residential land and is 33% impervious surfaces. The mainstem reach starts approximately 1,950 feet downstream of Tollgate Road and ends at Plumtree Road. Tributary 1 starts at a wet seep in a pasture on the O'Connell Farm and joins the mainstem 350 feet downstream. Tributary 2 starts at a spring near Plumtree Road, flows for a short distance, is piped beneath a private driveway then flows downstream through a wooded area to its confluence with the mainstem. Tributary 3 starts at a wet seep in a pasture on the Magness Farm and joins the mainstem 800 feet downstream. There are few stormwater controls in the overall watershed upstream of the mainstem reach and none in the subshed of this tributary.

The mainstem reach is a moderately stable C4 channel. Several short sections of channel are affected by localized bank erosion, large debris jams and associated gravel bars. Bank heights range from 2 to 8 feet along the reach. Bedrock outcrops provide lateral control along most meander bends. Bank erosion hazard is low to moderate.

Tributary 1 is a first order stream and is a moderately stable B4 channel along its entire length. The instability is mostly related to livestock impacts such as trails, trampled banks and bare soil in loafing areas. The landowner has placed boulders at various points along the channel to provide grade control.

Tributary 2 is a first order stream and is an unstable B4 channel along the upper and middle sections of the reach. This tributary receives uncontrolled runoff from Plumtree Road. The instability includes bank erosion and aggradation throughout along the upstream section. Bank heights range from 1 to 5.5 feet along the reach. Bank erosion hazard is moderate to high. Natural boulder steps provide grade control at various points along the channel. The lower section of the reach is a stable E4 channel. A two foot head-cut at the confluence with the mainstem is temporarily held in place by fallen trees. However, when the trees are removed by storm flows the head-cut will erode upstream causing instability along the stable lower section.

Tributary 3 is a first order stream and is a moderately stable B4 channel along its entire length. The instability is mostly related to livestock impacts such as trails,

trampled banks and bare soil in loafing areas. The landowner has placed boulders at various points along the channel to provide grade control.

Photos are located in Appendix B

Subshed 25

Subshed 25 includes a mainstem Plumtree Run reach and two small tributaries. The mainstem portion of the subshed drains 1,441 acres of high density commercial, institutional and residential land and is 32% impervious surfaces. The mainstem reach starts at Plumtree Road and ends at Atkisson Reservoir. The Tributary 1 subshed drains the area adjacent to Plumtree Road. The tributary starts as rip-rapped roadside ditch and joins the mainstem 400 feet downstream. Tributary 2 subshed drains a forested wetland. The tributary starts at a spring on the Harford Glen property and flows 400 feet through a wooded area to its confluence with the mainstem.

The upper section of the mainstem reach on private land includes moderately stable B4c and C4 channels. Several short sections of channel are affected by localized bank erosion, large debris jams and associated gravel bars. Along one section the channel is eroding into a high terrace. Bank heights range from 2 to 12 feet along the reach. Bedrock outcrops provide lateral control along most meander bends. With the exception of the eroding high terrace, bank erosion hazard is low to moderate. Along the terrace erosion hazard is very high.

The lower section of the mainstem reach on public land transitions from a moderately stable C4 channel in the upstream portion to a moderately stable G1 channel in the middle portion and back to a moderately stable C4 channel in the downstream portion. Several short sections along the upstream C4 channel are affected by localized bank erosion, large debris jams and associated gravel bars. Bank heights range from 2 to 8 feet along the reach. Bedrock outcrops provide lateral control along most meander bends. Bank erosion hazard is low to moderate. The G1 channel area is a bedrock canyon with bedrock/boulder bed and bedrock outcrops along the left terrace. The right terrace is affected by localized erosion. There is a large debris jam and associated gravel bar at the downstream end of this section. The C4 channel in the downstream area has relatively stable streambanks. Because this section is affected by the backwater from Atkisson Reservoir aggradation and flooding are significant problems. This area is part of Harford Glen which provides environmental education programs for Harford Public Schools. Trails, wetland boardwalks, footbridges, observation decks and outdoor classrooms have been constructed along Plumtree Run to support these programs. Frequent flooding has damaged many of the structures requiring continuous maintenance.

Tributary 1 is an unstable G4 channel along its entire length. Starting as a road side ditch along Plumtree Road the first 100 feet is stabilized with rip-rap. Runoff from the road drops over a four-foot head-cut into the deeply incised G4 channel. The instability includes gully erosion, debris jams and fallen trees.

Tributary 2 is a stable E4 channel along its entire length. As noted above, the tributary starts at a spring on the Harford Glen property and flows 400 feet through a wooded wetland to its confluence with the mainstem.

Photos are located in Appendix B

The results of the reconnaissance survey indicate that 7,007 linear feet (59%) of the total 13,063 linear feet of channel along the Lower Plumtree Run Segment is affected by some type of instability. The poor conditions along many of the reaches in this segment threaten private property and public infrastructure. In addition, Lower Plumtree Run is a significant source of sediment to downstream reaches and Atkisson Reservoir. Table 4.5 summarizes the stream conditions along the Lower Plumtree Run Segment.

Table 4.5 – Summary of Stream Conditions Lower Plumtree Run

Stream Reaches/ Geomorphic Map	Condition	Stream Type	Length (ft)	Description
Subshed 22				
MS*** Maps 10 & 11	Unstable	B4c/C4/B4c	1,550 (total) 1,550 (unstable) 100%	Severe bank erosion at rear of residences, debris jams and aggradation
Tributary* Map 10	Unstable	G4	175 (total) 175 (unstable) 100%	Bank erosion
Total Length			1,725	
Percent Unstable			100%	
Subshed 23				
MS Map 12	Stable	C4	400 (total)	Stable with bedrock outcrops and grade control, minor aggradation and localized bank erosion
Tributary** Map 11	Unstable	E4/G4	2,100 (total) 2,100 (unstable) 100%	UPS - Severe gully erosion at SD outfall, landowners installing boulders and sheet piling for grade control, Middle and DS - Severe bank erosion, debris jams and aggradation throughout Small drainage tributary – E channel with multiple head-cuts and bank erosion
Total Length			2,500	
Percent Unstable			84%	

Degree of Instability: * = Moderate; ** = High; and *** = Extreme

Table 4.5 (cont'd) – Summary of Stream Conditions Lower Plumtree Run				
Stream Reaches/ Geomorphic Map	**Condition**	**Stream Type**	**Length (ft)**	**Description**
Subshed 24				
MS* Maps 12, 13, 14 & 15	Moderately Stable	C4	3,013 (total) 850 (unstable) 28%	Bed rock outcrops provide lateral control on most bends, Minor aggradation and localized bank erosion, large debris jams
Tributary 1 Maps 12 & 13	Moderately Stable	B4	350 (total)	Livestock impacts
Tributary 2 Map 12	Unstable	B4/E4	775 (total) 600 (unstable) 77%	UPS – bank erosion and aggradation DS – multiple head-cuts, bank erosion
Tributary 3 Map 13	Moderately Stable	B4c	800 (total)	Livestock impacts
Total Length			4,938	
Percent Unstable			59%	
Subshed 25				
MS* Upper Section* Maps 14 & 15	Moderately Stable	B4c/C4	1,900 (total) 600 (unstable) 32%	Bed rock outcrops provide lateral control on most bends, Minor aggradation and localized bank erosion, large debris jams
MS* Lower Section* Maps 15 & 17 Bd of Ed Property	Moderately Stable	C4/G1/C4	1,600 (total) 900 (unstable) 56%	UPS - Bank erosion, large debris jams and aggradation Middle - bedrock canyon stable with localized bank erosion, DS – aggradation due to backwater from reservoir
Tributary 1* Map 14	Unstable	G4	400 (total) 300 (unstable) 75%	Upper section rip-rapped, gully erosion debris jams to confluence
Tributary 2 Map 17 Bd of Ed Property	Stable	E4	400	Stable channel flows through wooded wetland
Total Length			4,300	
Percent Unstable			42%	
Lower Plumtree Run				
Total Length			13,063	
Percent Unstable			59%	

Degree of Instability: * = Moderate; ** = High; and *** = Extreme

C. Ranking Watershed Segments and Stream Reaches by Stream Condition

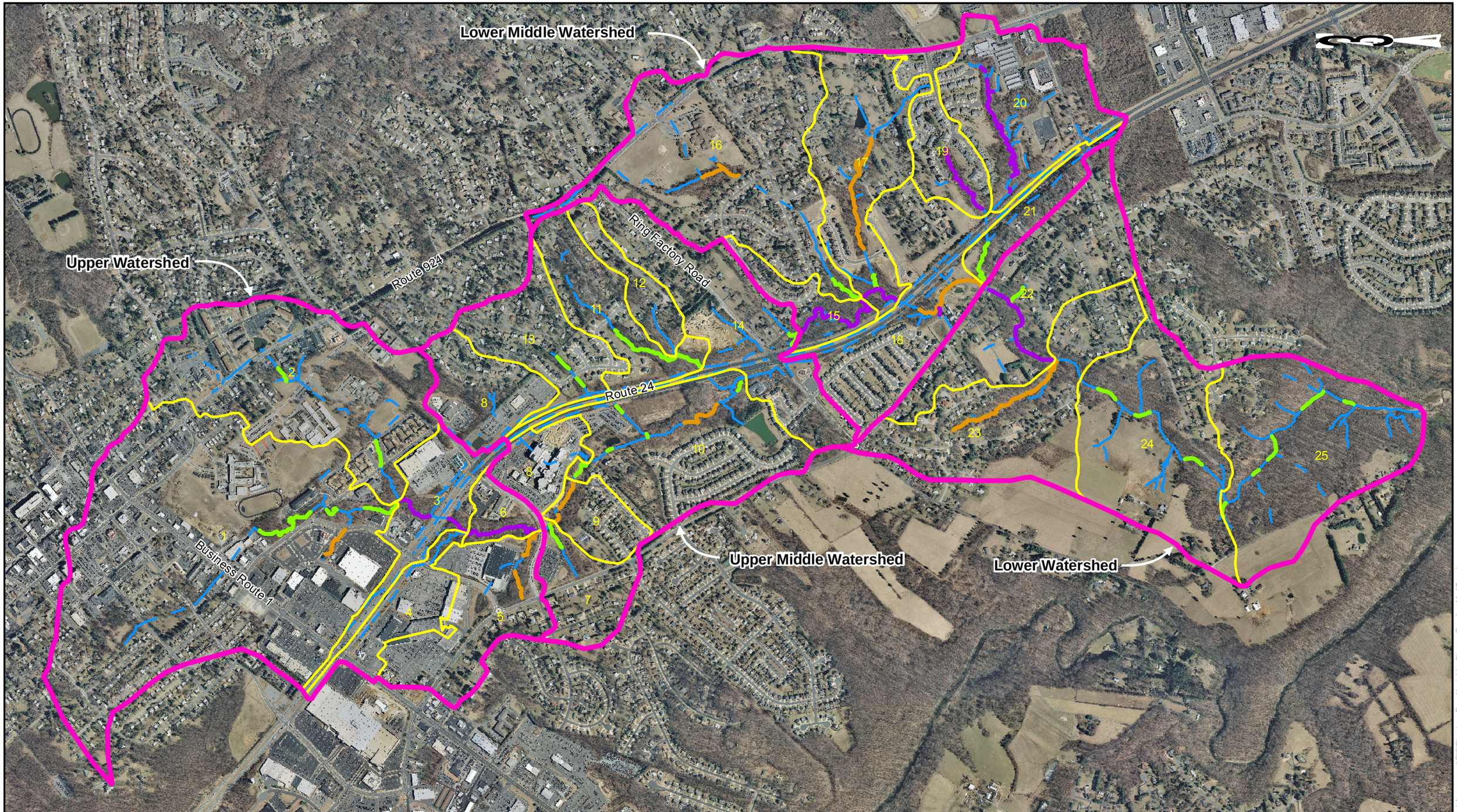
1. Methodology

As noted previously, the Plumtree Run watershed was divided into four segments and 25 subsheds. To facilitate a more detailed evaluation of stream conditions, subsheds were further divided into stream reaches and stream sections. A total of 55 stream reaches/sections were evaluated. The evaluation process considered: 1) total length of stream channel that was unstable, 2) percentage of total length of stream channel that was unstable, and 3) percentage of stream length identified as unstable that rated as moderately to highly unstable. The first two factors were based simply on calculations utilizing stream length. However, the third factor required developing criteria for determining degree of instability.

Even in undisturbed watersheds streambanks erode and sediment deposits along streambeds. As a consequence, the mere presence of these conditions does not necessarily warrant concern or intervention. However, it is well documented that the rate and degree of erosion and sedimentation are significantly altered in urbanizing watersheds. Changes in the hydrologic and sediment regimes caused by increased runoff from impervious surfaces and the installation of storm drain systems almost always lead to changes in channel morphology and widespread instability. Although it may take decades, these unstable channels will evolve towards a different but stable form. Unfortunately, changing land use patterns can reset the evolutionary clock numerous times. Damage to public or private property, as well as public infrastructure associated with these channel adjustments has been a concern for centuries. More recently, the impacts to water quality, in-stream habitat, and biological communities have gained nearly equal status.

To provide a better understanding of stream conditions throughout the Plumtree Run watershed it was critical that a means of differentiating stream reaches exhibiting natural levels of erosion and sedimentation from those situations warranting concern and/or intervention. Developing evaluation criteria to meet this objective involved using a channel evolution model to determine whether the current conditions along a given unstable reach indicated it was evolving towards greater stability or greater instability.

Field observations indicating conditions that could affect public safety, existing or potential damage to public infrastructure, and damage to private and public property also guided the evaluation process. Using the evaluation criteria unstable stream reaches were categorized into Very Low, Low, Moderate, and High categories related to degree of instability. Stream reaches that had been determined to be stable, moderately stable, that is generally stable but with minor and localized erosion or sedimentation, or very low instability were not evaluated further. Unstable stream reaches are show in Figure 4.2.



NOTES:
1. IMAGERY FROM HARFORD COUNTY 2007 AERIAL PHOTOGRAPHY.
2. WATERSHED BASED ON HARFORD COUNTY DELINEATION, REFINED BY BAYLAND CONSULTANTS BASED ON TOPOGRAPHY AND FIELD INVESTIGATION.
3. SUBWATERSHEDS DELINEATED BY BAYLAND CONSULTANTS.
4. IMPERVIOUS SURFACE COMPILED BY BAYLAND CONSULTANTS USING 2008 HARFORD COUNTY GIS DATA.
5. HYDRO LAYER REFINED IN THE FIELD TO INDICATE SWALE/PIPED SYSTEMS BY CLEAR CREEKS CONSULTING DECEMBER 2009.

Watershed Segment Boundary
Sub-watershed Boundary
Hydro Line
Swale / Piped System
Study Point

Unstable Stream Reaches
Low Instability
Moderate Instability
High Instability

1,100 550 0 1,100 2,200 Feet

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Plumtree Run Watershed Assessment Unstable Stream Reaches

Figure 4.2

F:\4_2901_Plumtree Run Watershed Assessment\GIS\Plumtree_Run_Unstable_Stream_Reaches11x17.mxd

2. Ranking Watershed Segments

The Lower Middle Segment ranked first in all three categories. It had 11,080 linear feet of unstable stream channel or 84% of its total length. In addition, 82% of the stream reaches identified as unstable were rated as moderately to highly unstable.

The Upper Segment ranked third in length with 6,051 linear feet of unstable channel. However, because it included a significantly shorter total length of stream channel it ranked second with 67% of its overall length exhibiting unstable conditions. Of the reaches identified as unstable 47% were rated as moderately to highly unstable.

The Lower Segment had the second highest length of unstable channel 7,250 linear feet. However, because it included a significantly greater total length of stream channel the percentage of unstable reaches ranked third at 56%. Of the reaches identified as unstable 45% were rated as moderately to highly unstable.

The Upper Middle Segment ranked fourth in all three categories with 5,038 linear feet of unstable channel and 45% of its total length exhibiting unstable conditions. Of the reaches identified as unstable 24% were rated as moderately unstable. No reaches were rated as highly unstable.

Based on this evaluation the watershed segments were ranked - Lower Middle - 1st, Upper – 2nd, Lower – 3rd, and Upper Middle – 4th. Table 4.6 shows the length of unstable stream reaches and ranking by watershed segment.

Table 4.6 – Unstable Reach Length (ft) and Ranking By Watershed Segment

Watershed Segment	Very Low	Low	Moderate	High	Total
Upper	1,225	1,988	1,038	1,800	6,051
Upper Middle	1,100	2,725	1,213	-	5,038
Lower Middle	300	1,650	3,955	5,175	11,080
Lower	1,175	2,825	1,700	1,550	7,250
Total	3,800	9,188	7,906	8,525	29,419

3. Ranking Stream Reaches and Stream Sections

With the objective of providing a more detailed evaluation of stream condition, the 47 stream reaches/sections determined to be unstable were further evaluated. Although unstable, five of the reaches/sections evaluated were determined to have problems that would have little potential impact in their subshed and were dropped from further consideration. The remaining 42 unstable reaches/sections were ranked relative

to degree of instability. Table 4.7 ranks those reaches/sections with the highest degree of instability ranking first and the lowest degree of instability ranking forty second.

Table 4.7 – Ranking of Stream Reaches Relative to Degree of Instability

Ranking	Subshed/Reach	Ranking	Subshed/Reach
1	15MS	22	1MMS
2	17MS	23	1LMS
3	22MS	24	7Trib
4	6MS	25	13UTrib
5	3MS	26	10LMS
6	19Trib	27	14MS
7	20Trib	28	10UMS
8	16UTrib	29	24MS
9	5Trib	30	25UMS
10	10MMS	31	25LMS
11	1Trib	32	25Trib
12	17UMTrib	33	17LTrib
13	23Trib	34	22Trib
14	18LMS	35	21Trib
15	17LMTrib	36	4Trib
16	18UMS	37	24Trib2
17	9MS	38	12Trib
18	16LTrib	39	1UMS
19	13LTrib	40	2UTrib
20	2MMS	41	14Trib2
21	11LTrib	42	10Trib2

D. Linking Land Use and Stream Condition

The research literature shows that percent imperviousness is a consistently reliable predictor of stream condition. Studies evaluating stream condition using many different criteria, such as pollutant loads, habitat quality, channel stability, aquatic species diversity and abundance, and other factors show consistent results relative to percent imperviousness and stream degradation. As shown in Figure 4.3, watersheds with greater than 10% percent imperviousness exhibit measurable impacts. When percent imperviousness exceeds 25% stream condition is markedly degraded.

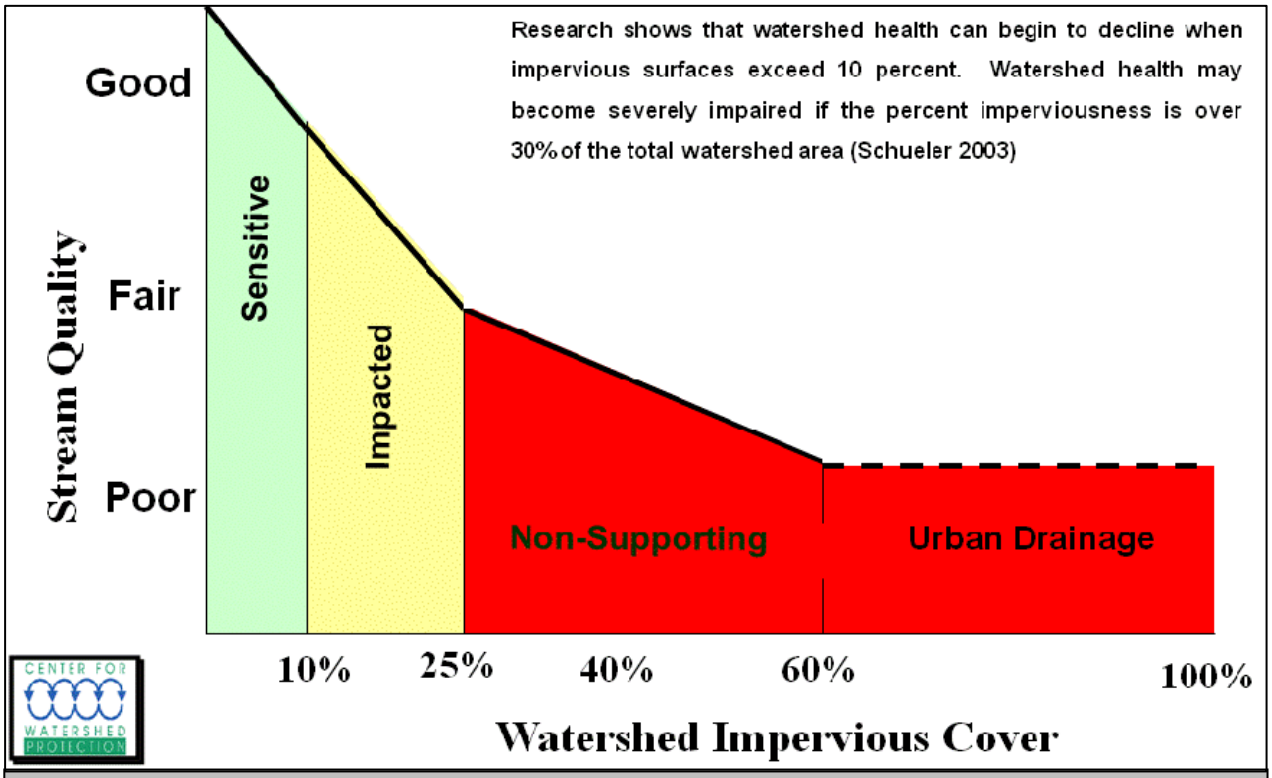


Figure 4.3 – Relationship of Imperviousness to Stream Quality

The high percent imperviousness and general lack of stormwater management throughout the Plumtree Run watershed is the principal factor contributing to the unstable conditions observed. Gully erosion, stream bank erosion and lateral migration, channel blockages created by undercut and fallen trees, and streambed aggradation are common problems along the mainstem and tributaries. The problems are most severe in subsheds with high percent impervious surfaces, direct conveyance to stream channels, and no stormwater controls. However, the effects of the altered hydrologic and sediment regimes were evident along the mainstem Plumtree Run even in the lower watershed with predominantly rural land use.

Table 4.8 demonstrates that the highly urban nature of the upper watershed has cumulative effects that explain conditions in the lower watershed. For example, in the highly urbanized upper Plumtree Run subsheds the percent impervious surfaces range from 33 – 74%. Although the percent impervious surfaces in the rural lower Plumtree Run subsheds range from 3 – 17%, when viewed from a cumulative perspective the percent impervious surfaces draining to these subsheds is actually 32 – 36%. Even at the most downstream point in the study area the percent impervious surfaces is 29%.

Table 4.8 - Percent Impervious by Subshed and Cumulatively			
Subwatershed	**Subwatershed (acres)**	**Impervious (acres)**	**Percent Impervious**
Upper Watershed (UW)			
1	265	140	53%
2	119	43	36%
3	35 (384)	21 (183)	60% (48%)
4	26	19	74%
5	53	29	54%
6	12 (445)	4 (223)	33% (50%)
Subtotal	510	256	50%
Upper Middle Watershed (UMW)			
7	29	7	23%
8	53	27	51%
9	19 (539)	4 (263)	23% (49%)
10	84 (592)	18 (290)	21% (49%)
11	39	6	15%
12	18	3	18%
13	40	10	25%
14	79	17	22%
Subtotal	361 (768)	92 (326)	26% (42%)
Lower Middle Watershed (LMW)			
15	19 (768)	4 (326)	21% (42%)
16	134	28	21%
17	68	11	15%
18	75 (989)	17 (369)	23% (37%)
19	29	9	32%
20	70	21	30%
21	18	4	20%
Subtotal	414 (1181)	94 (420)	23% (36%)
Lower Watershed (LW)			
22	81 (1,181)	14 (420)	17% (36%)
23	83 (1,262)	14 (434)	17% (34%)
24	96 (1,345)	7 (448)	7% (33%)
25	106 (1,441)	4 (455)	3% (32%)
Subtotal	365 (1,651)	37 (479)	10% (29%)

Note: Cumulative watershed area, impervious area and % impervious area along the Mainstem of Plumtree Run is shown in parenthesis.

The current study included developing recommendations for stormwater management best management practices that Harford County DPW and the City of Bel Air could implement to control runoff from the highly impervious subsheds. In addition, recommendations were developed for restoration and management measures to be implemented along the unstable stream reaches in the watershed. Those recommendations are presented in the following sections of this report.

Chapter 5 Stormwater Management Plan

I. Introduction

As presented previously, Harford County Department of Public Works, Water Resources Engineering Division intends to restore the Plumtree Run watershed. These objectives will be accomplished by implementing an effective, long-term watershed restoration plan that includes implementation of stormwater best management practices identified in this section of the report and implementation of the stream restoration measures identified in the following sections of this report. These strategies focus on managing the quantity and quality of stormwater runoff from the watershed and stabilizing unstable slopes and stream reaches along Plumtree Run and its tributaries that are the principal source of sediment to the Atkisson Reservoir.

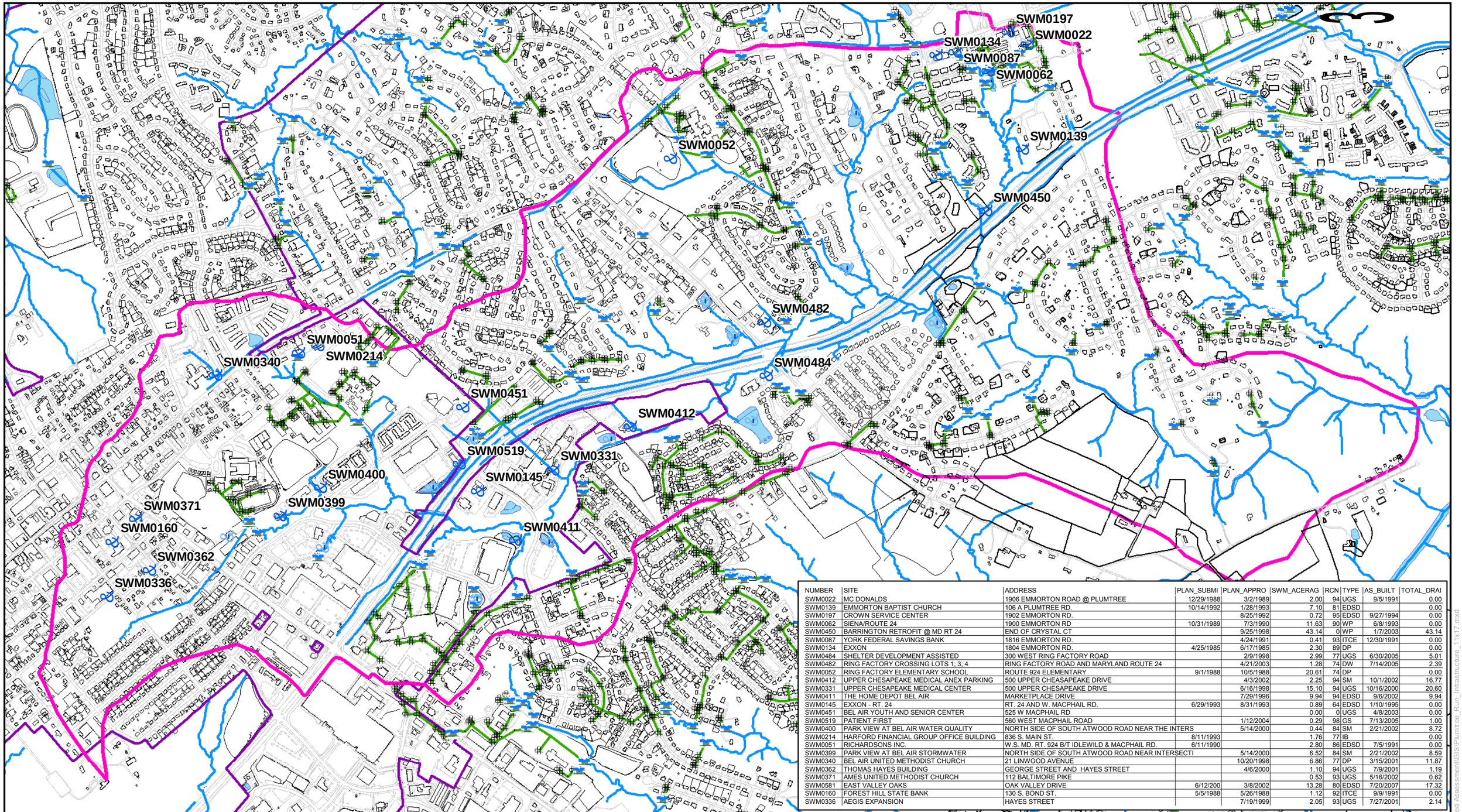
II. Scope of Stormwater Assessment

A strategic assessment of potential stormwater best management practices (BMPs) was conducted in order to identify opportunities to replace or restore lost flood storage capacity and to enhance stormwater quality. This stormwater assessment incorporates field observations, data and findings from the watershed assessment described in the previous sections of this report, and includes a desktop analysis of stormwater infrastructure and independent field assessments of short listed BMP sites. From these assessments, a stormwater management plan was developed that identifies and prioritizes stormwater opportunities that would most effectively benefit the watershed. Site data sheets that include observation of existing conditions, water quality and quantity treatment potential and recommended actions were developed for the short listed stormwater BMPs. These BMPs were further evaluated and prioritized to allow design concepts to be developed for the seven highest rated BMP sites.

III. Retrofit Site Selection

Development of retrofit strategies began by locating and assessing existing stormwater facilities within the watershed. A list of 39 facilities was compiled from an inventory of 26 sites included in Harford County GIS data, plus 13 additional sites that were identified during the watershed field reconnaissance or via desktop review of ortho-photos (Figure 5.1). Criteria were developed to refine the candidate list and to identify facilities worthy of additional investigation.

The first criteria in refining the list of candidate retrofit sites was to eliminate stormwater management (SWM) facilities with low retrofit potential such as underground storage tanks, grass swales, infiltration trenches, and dry wells. These sites generally have limiting site constraints, would require significant site disturbance for retrofit, or were sized for smaller drainage areas and provide minimal opportunity to provide additional water quality volume or peak flow attenuation. Facilities designed after implementation of the 2000 Maryland Stormwater Design Manual were also eliminated from consideration as they were assumed to meet current stormwater regulations. By regulation, these facilities would have been designed to provide water quality volume (WQ_V) and channel protection volume (Cp_V) for the contributing drainage areas.



NUMBER	SITE	ADDRESS	PLAN_SUBMI	PLAN_APPRO	SWM_ACERAG	RCN	TYPE	AS_BUILT	TOTAL_DRAI
SWM0022	MC DONALDS	1906 EMMORTON ROAD @ PLUMTREE	12/29/1988	3/2/1989	2.00	94	UGS	9/5/1991	0.00
SWM0139	EMMORTON BAPTIST CHURCH	106 A PLUMTREE RD.	10/14/1992	1/28/1993	7.10	81	EDSD		0.00
SWM0197	CROWN SERVICE CENTER	1902 EMMORTON RD.		8/25/1992	0.72	95	EDSD	9/27/1994	0.00
SWM0062	SIENA/ROUTE 24	1900 EMMORTON RD	10/31/1989	7/3/1990	11.63	90	WP	6/8/1993	0.00
SWM0450	BARRINGTON RETROFIT @ MD RT 24	END OF CRYSTAL CT		9/25/1998	43.14	0	WP	1/7/2003	43.14
SWM0087	YORK FEDERAL SAVINGS BANK	1816 EMMORTON RD.		4/24/1991	0.41	93	ITCE	12/30/1991	0.00
SWM0134	EXXON	1804 EMMORTON RD.	4/25/1985	6/17/1985	2.30	89	DP		0.00
SWM0484	SHELTER DEVELOPMENT ASSISTED	300 WEST RING FACTORY ROAD		2/9/1998	2.99	77	UGS	6/30/2005	5.01
SWM0482	RING FACTORY CROSSING LOTS 1; 3; 4	RING FACTORY ROAD AND MARYLAND ROUTE 24		4/21/2003	1.28	74	DW	7/14/2005	2.39
SWM0052	RING FACTORY ELEMENTARY SCHOOL	ROUTE 924 ELEMENTARY	9/1/1988	10/5/1988	20.61	74	DP		0.00
SWM0412	UPPER CHESAPEAKE MEDICAL ANEX PARKING	500 UPPER CHESAPEAKE DRIVE		4/3/2002	2.25	94	SM	10/1/2002	16.77
SWM0331	UPPER CHESAPEAKE MEDICAL CENTER	500 UPPER CHESAPEAKE DRIVE		6/16/1998	15.10	94	UGS	10/16/2000	20.60
SWM0411	THE HOME DEPOT BEL AIR	MARKETPLACE DRIVE		7/29/1996	9.94	94	EDSD	9/6/2002	9.94
SWM0145	EXXON - RT. 24	RT. 24 AND W. MACPHAIL RD.	6/29/1993	8/31/1993	0.89	64	EDSD	1/10/1995	0.00
SWM0451	BEL AIR YOUTH AND SENIOR CENTER	525 W MACPHAIL RD			0.00	0	UGS	4/8/2003	0.00
SWM0519	PATIENT FIRST	560 WEST MACPHAIL ROAD		1/12/2004	0.29	98	GS	7/13/2005	1.00
SWM0400	PARK VIEW AT BEL AIR WATER QUALITY	NORTH SIDE OF SOUTH ATWOOD ROAD NEAR THE INTERS		5/14/2000	0.44	84	SM	2/21/2002	8.72
SWM0214	HARFORD FINANCIAL GROUP OFFICE BUILDING	836 S. MAIN ST.	8/11/1993		1.76	77	IB		0.00
SWM0051	RICHARDSONS INC.	W.S. MD. RT. 924 B/T IDLEWILD & MACPHAIL RD.	6/11/1990		2.80	86	EDSD	7/5/1991	0.00
SWM0399	PARK VIEW AT BEL AIR STORMWATER	NORTH SIDE OF SOUTH ATWOOD ROAD NEAR INTERSECTI		5/14/2000	6.52	84	SM	2/21/2002	8.59
SWM0340	BEL AIR UNITED METHODIST CHURCH	21 LINWOOD AVENUE		10/20/1998	6.86	77	DP	3/15/2001	11.87
SWM0362	THOMAS HAYES BUILDING	GEORGE STREET AND HAYES STREET		4/6/2000	1.10	94	UGS	7/9/2001	1.19
SWM0371	AMES UNITED METHODIST CHURCH	112 BALTIMORE PIKE			0.53	93	UGS	5/16/2002	0.62
SWM0581	EAST VALLEY OAKS	OAK VALLEY DRIVE	6/12/200	3/8/2002	13.28	80	EDSD	7/20/2007	17.32
SWM0160	FOREST HILL STATE BANK	130 S. BOND ST.	5/5/1988	5/26/1988	1.12	92	ITCE	9/9/1991	0.00
SWM0336	AEGIS EXPANSION	HAYES STREET		7/19/1999	2.05	93	UGS	7/27/2001	2.14

Plumtree Run Watershed
& Manhole Covers
Planimetrics
Railroads
Storm Drain Outfalls
@ Inflow/Inlets
Roadways
Structures
Storm Drains
Hydro Line
Sewerlines
& SWM Facilities in Harford County GIS Database
& SWM Facilities identified by BayLand (13 Facilities)
Waterlines
Vegetation
Hydro
Bel Air Corporate Limits

WATERSHED - 1,651 ACRES

1,100 550 0 1,100 2,200 Feet

1" = 1,100'

Notes:
1. BASEMAP DATA FROM 2007 HARFORD COUNTY GIS.
2. WATERSHEDS BASED ON HARFORD COUNTY DELINEATION, REFINED BY BAYLAND CONSULTANTS BASED ON TOPOGRAPHY AND FIELD INVESTIGATION.

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Plumtree Run Watershed Assessment Existing Stormwater Infrastructure

Figure 5.1

P:\4_2001_Plumtree Run Watershed Assessment\GIS\Plumtree_Run_Infrastructure_11x17.mxd

Remaining stormwater management facilities were prioritized by comparing and weighing additional considerations, including location of facilities within the project watershed. Retrofit opportunities were especially targeted in subsheds with greater than 25% impervious area. Research has shown that watersheds with greater percent impervious cover yield increased degradation in stream quality and often experience substantial water quality degradation as described in the previous section to this report.

Therefore, in order to determine the most effective locations for stormwater BMPs, the GIS impervious surfaces layer was overlaid onto the subwatershed boundary map (Figure 5.2). Table 5.1 was created showing the area and percentage of impervious cover by subwatershed.

Table 5.1 – Plumtree Run Subwatersheds Impervious Surfaces by Subwatershed

Subwatershed	Subwatershed Area (acres)	Impervious Area (acres)	Percent Impervious
Upper Watershed (UW)			
1	265	140	53%
2	119	43	36%
3	35	21	60%
4	26	19	74%
5	53	29	54%
6	12	4	33%
UW Total	**511**	**255**	**50%**
Upper Middle Watershed (UMW)			
7	29	7	23%
8	53	27	51%
9	19	4	23%
10	84	18	21%
11	39	6	15%
12	18	3	18%
13	40	10	25%
14	79	17	22%
UMW Total	**361**	**92**	**26%**
Lower Middle Watershed (LMW)			
15	19	4	21%
16	134	28	21%
17	68	11	15%
18	75	17	23%
19	29	9	32%
20	70	21	30%
21	18	4	20%
LMW Total	**414**	**94**	**23%**
Lower Watershed (LW)			
22	81	14	17%
23	83	14	17%
24	96	7	7%
25	106	4	3%
LW Total	**365**	**37**	**10%**
TOTAL	**1651**	**479**	**29%**

Plumtree Run Subwatersheds			
Subwatershed	Subwatershed (acres)	Impervious (acres)	Percent Impervious
Upper Watershed (UW)			
1	265	140	53%
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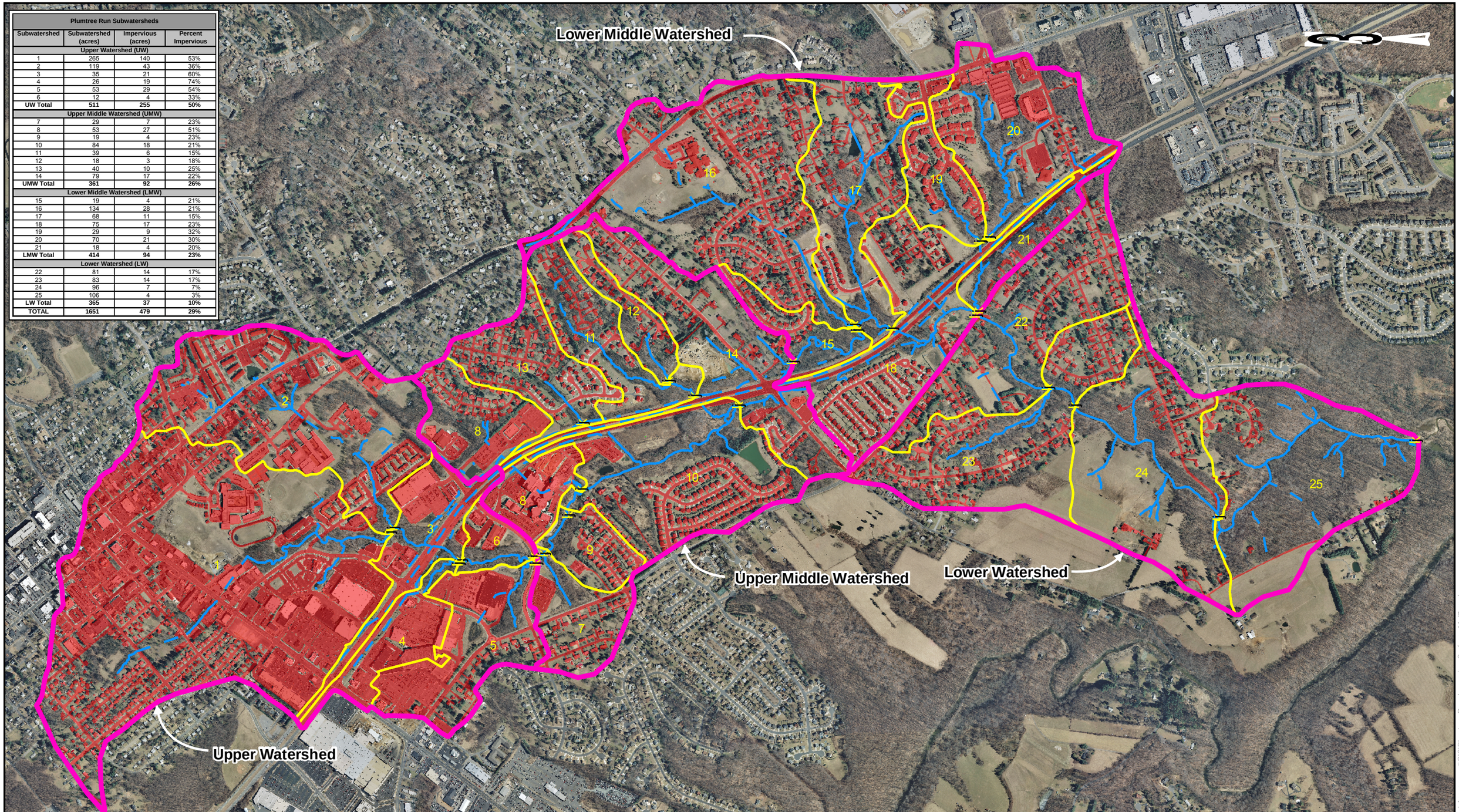
LW Total	**365**	**37**	**10%**
TOTAL	**1651**	**479**	**29%**



NOTES:
1. IMAGERY FROM HARFORD COUNTY 2007 AERIAL PHOTOGRAPHY.
2. WATERSHED BASED ON HARFORD COUNTY DELINEATION, REFINED BY BAYLAND CONSULTANTS BASED ON TOPOGRAPHY AND FIELD INVESTIGATION.
3. SUBWATERSHEDS DELINEATED BY BAYLAND CONSULTANTS.
4. IMPERVIOUS SURFACE COMPILED BY BAYLAND CONSULTANTS USING 2008 HARFORD COUNTY GIS DATA.
5. HYDRO LAYER REFINED BASED ON FIELD VERIFICATION BY CLEAR CREEKS CONSULTING DECEMBER 2009.

Watershed Segment Boundary
Sub-watershed Boundary
Impervious Surface - 479 Acres (29% Impervious)
Study Point
Hydro Line
Swale / Piped System

1,100 550 0 1,100 2,200 Feet

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Plumtree Run Watershed Assessment Impervious Surfaces

Figure 5.2

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Analysis of the impervious surface data and map show that the most densely developed and impervious areas are in the Upper Watershed (Subsheds 1-6) as well as Subsheds 8, 19 and 20. As a result, retrofit opportunities were sought in these subwatersheds in order to have maximum effect on overall water quality and peak flow attenuation in downstream reaches. Based on the size of the Plumtree Run Watershed, candidate retrofit sites were further screened based on the size of contributing drainage area. Facilities treating less than five (5) acres of runoff were considered to have minimal downstream benefits.

In addition to the criteria described above, constructability issues were also assessed for the remaining retrofit sites. Structural (i.e. adjacent roadways/utilities) and environmental (i.e. forests, wetlands, unmapped streams) site constraints, land use restrictions, number of private easements, permitting requirements, and construction access were also evaluated in the retrofit site short listing process.

Through consideration of all criteria described above, nine (9) potential stormwater retrofit sites were identified for additional field investigation (see Table 5.2). These short-listed facilities are primarily dry ponds with highly impervious contributing drainage areas and were designed prior to implementation of current stormwater management regulations. The facilities generally provide some extended detention but present opportunity to store additional WQ_V as well as limited Cp_V.

Table 5.2 – Short-listed Stormwater BMP Retrofit Sites

Project	Subshed #
Bel Air Plaza SWM Pond	Subshed 1
Bel Air United Methodist Church SWM Pond	Subshed 2
Superfresh Shopping Center SWM Pond	Subshed 3
Tollgate Marketplace SWM Pond	Subshed 5
The Home Depot Bel Air SWM Pond	Subshed 5
Ring Factory Elementary School	Subshed 16
East Valley Oaks SWM Pond	Subshed 17
Barrington Retrofit SWM Pond at MD Route 24	Subshed 19
Emmorton Baptist Church SWM Pond	Subshed 20

IV. New Facility Site Selection

In addition to identifying potential stormwater management facility retrofits within the watershed, an assessment was performed to locate opportunities to implement new stormwater controls. To identify new facilities, a desktop assessment was performed to locate storm drain outfalls discharging uncontrolled runoff from highly impervious drainage areas. Opportunities were especially sought for regional facilities that would provide at-the-source management of large, impervious areas from multiple contributing highly impervious subsheds. Regional facilities provide the flexibility to locate stormwater management where open space may exist and provides the opportunity to

capture and treat the aggregate runoff from larger areas without the need to identify specific point sources. Regional facilities also have an advantage in terms of generally involving fewer total number of individual land owners throughout the watershed. Though the land area required at each regional facility location to meet stormwater management goals is larger than an individual site-specific BMP site, the number of site-specific locations required to achieve the same level of treatment is greatly decreased, thus decreasing the number of involved individual land owners for regional stormwater facilities. The benefits associated with regional facilities oftentimes can be more easily understood and recognized as having broader application to the general public than a site-specific, more localized BMP and, therefore, may present additional justification for government funding and implementation.

The same criteria used for retrofit site selection was applied in consideration of new stormwater management facilities. Specifically, new facilities were targeted in subsheds with greater than 25% impervious area, the Upper Plumtree Run Watershed and Subsheds 8, 19 and 20. Within those subwatershed sites, locations were sought that would allow for treatment of drainage areas greater than 5 acres. Site locations were also identified concurrent with or upstream of proposed stream restoration reaches such that improvements in stormwater management would contribute to the success of downstream stabilization. Like the retrofit sites, constructability issues were also assessed for the new stormwater management sites such as structural (i.e. adjacent roadways/utilities) and environmental (i.e. wetlands, unmapped streams) site constraints, land use restrictions, number of private easements, permitting requirements, and construction access.

Through consideration of all criteria described above, seven (7) potential new stormwater management sites were identified for additional field investigation (see Table 5.3). These facilities are primarily located at storm drain outfalls, which discharge uncontrolled runoff from highly impervious drainage areas, or are located upstream of culverts with opportunity for impoundment and extended detention of runoff from multiple subsheds. The facilities generally provide Cp_V by creating temporary storage areas, with some limited opportunities for additional WQ_V storage.

Table 5.3 – Potential New Stormwater Management Sites

Project	Subshed #
Bel Air High School Outfall	Subshed 1
Bel Air Middle School/Wakefield Elementary School	Subshed 2
Regional Facility at MD Route 24	Subshed 3
Tollgate Marketplace Outfall	Subshed 4
Tollgate Road Outfall	Subshed 5
Barrington Place Outfall	Subshed 19
Barrington Village Court and Rollins Court Outfalls	Subshed 20

V. Stormwater Permitting Issues

Many of the proposed new facilities are designed as on-line impoundments and take advantage of adjacent floodplain areas for extended detention of available Cp_V. Plumtree Run is designated as a Use I waterway. Although environmental restrictions are less stringent in Use I waterways, there are a number of regulatory issues relating to the impacts of on-line impoundments on existing stream resources that must be addressed. The following outline indicates potential impacts and briefly addresses their relevance to the proposed on-line stormwater impoundment facilities:

A. Loss of Riparian Forest – Many of the proposed impoundment sites require clearing of adjacent wooded areas to maximize available storage area and incorporate shallow marsh areas for enhanced habitat and water quality benefits. Impacts to riparian forest areas should be minimized through design and landscaping components of the project.

B. Loss of In-Stream Habitat – The majority of proposed impoundment sites are located in areas with limited in-stream habitat due to their proximity to pipe outfalls and severely degraded channel reaches. Design components of proposed temporary impoundment facilities aim to enhance habitat by incorporating concurrent stream stabilization activities as well as converting uplands to high value wetland areas.

C. Fish Migration Barriers – Most proposed impoundment sites are already impacted by existing barriers, especially upstream piped sections and downstream culvert crossings. In spite of these constraints, design objectives for on-line impoundments include avoiding creation of additional fish barriers through incorporation of fish passage ways.

D. Thermal Impacts – The temperature of runoff from developed urban areas generally exceeds optimal conditions for most cool water species of fish. The proposed stormwater wetlands and impoundment areas are not likely to attenuate the elevated temperatures caused by the runoff from all of the impervious surfaces; however, incorporating islands, peninsulas, and adjacent riparian areas planted with native trees and shrubs will shade the stormwater wetland areas and ensure that the impoundments do not increase temperatures further.

These regulatory issues should be addressed during project development in order to anticipate and accommodate permitting requirements.

VI. Prioritization and Development of Stormwater BMP Sites

In order to facilitate prioritization of the nine (9) stormwater retrofit sites and the seven (7) new stormwater BMP sites, a map was developed showing the location of these shortlisted sites in proximity to the unstable stream reaches that are identified in

Figure 5.3. The spacial proximity with unstable stream reaches would become a new prioritization criteria since the location of the stormwater BMPs could have a profound effect on the cost, longevity and overall success of downstream restoration.

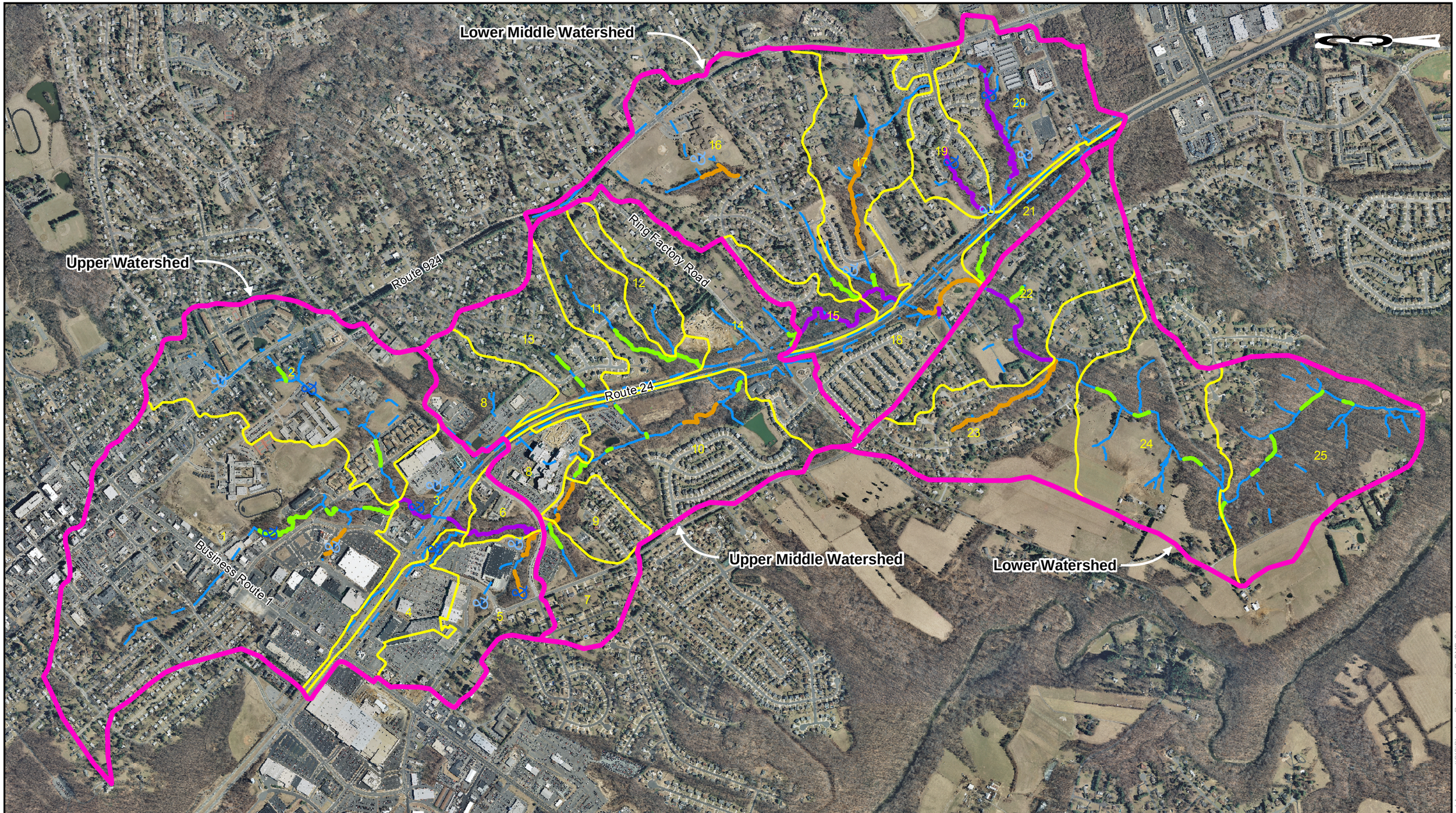
Site visits were conducted for all 16 candidate stormwater BMP sites to verify and document existing site conditions. Relevant existing condition features of each site were summarized including:

- Drainage Area to the Facility;
- Impervious Area;
- Percent Impervious;
- Ownership;
- Design/Construction Date (as available for retrofits);
- Description of SWM Pond Features (for retrofits);
- Description of Site and Adjacent Features; and
- Description of Downstream Conditions.

Drainage areas to the 16 candidate stormwater BMP sites were refined and reassessed to compare size and percent imperviousness of contributing drainage areas to the BMP sites. Site restrictions and rough geometry of potential BMPs was further evaluated in order to assess each site's potential to provide WQ_V and Cp_V.

Based on the magnitude of impervious area, the degree of downstream degradation and the limited space for expansion of existing stormwater management facilities, it was determined that the most beneficial BMP attribute that could be developed for retrofit sites would be to provide stormwater storage for water quality volume (WQ_V) through excavation of a normal pool below the low flow channel protection orifice. New facilities would generally be better suited to take advantage of available floodplain areas to provide storage of channel protection volume (Cp_V) in dry storage areas to manage peak discharge rates and thereby reduce stream degradation and its associated habitat and water quality impacts. In some instances, floodplains adjacent to stream channels could be used to establish shallow wetlands or micropools to provide additional WQ_V as well as promote habitat enhancement.

Although all 16 sites are recommended for implementation, a two tiered prioritization was established to facilitate BMP implementation. Since most of the stream degradation throughout the watershed is directly attributable to impervious cover and associated lost flood storage capacity, new BMP sites with superior flood storage capacity (Cp_V) would contribute greater value towards the watershed's restoration. New BMP sites were targeted for impervious subwatersheds and were sighted immediately upstream of unstable stream reaches. This bolsters their effectiveness to reduce expansion of unstable reaches and related erosion and sediment/nutrient transport. Five of the seven new BMPs were sighted to be coincidental with unstable stream reaches and could be developed as headwater wetland systems. These headwater wetland systems would replace the existing degraded and dysfunctional stream habitat. These five BMPs would effectively eliminate the need for 2,200 feet of stream



BMP - Retrofit

BMP - New

Watershed Segment Boundary

Sub-watershed Boundary

Hydro Line

Swale / Piped System

Study Point

Unstable Stream Reaches

Low Instability

Moderate Instability

High Instability

1,100 550 0 1,100 2,200 Feet

NOTES:
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Plumtree Run Watershed Assessment Unstable Stream Reaches and Stormwater BMP Sites

Figure 5.3

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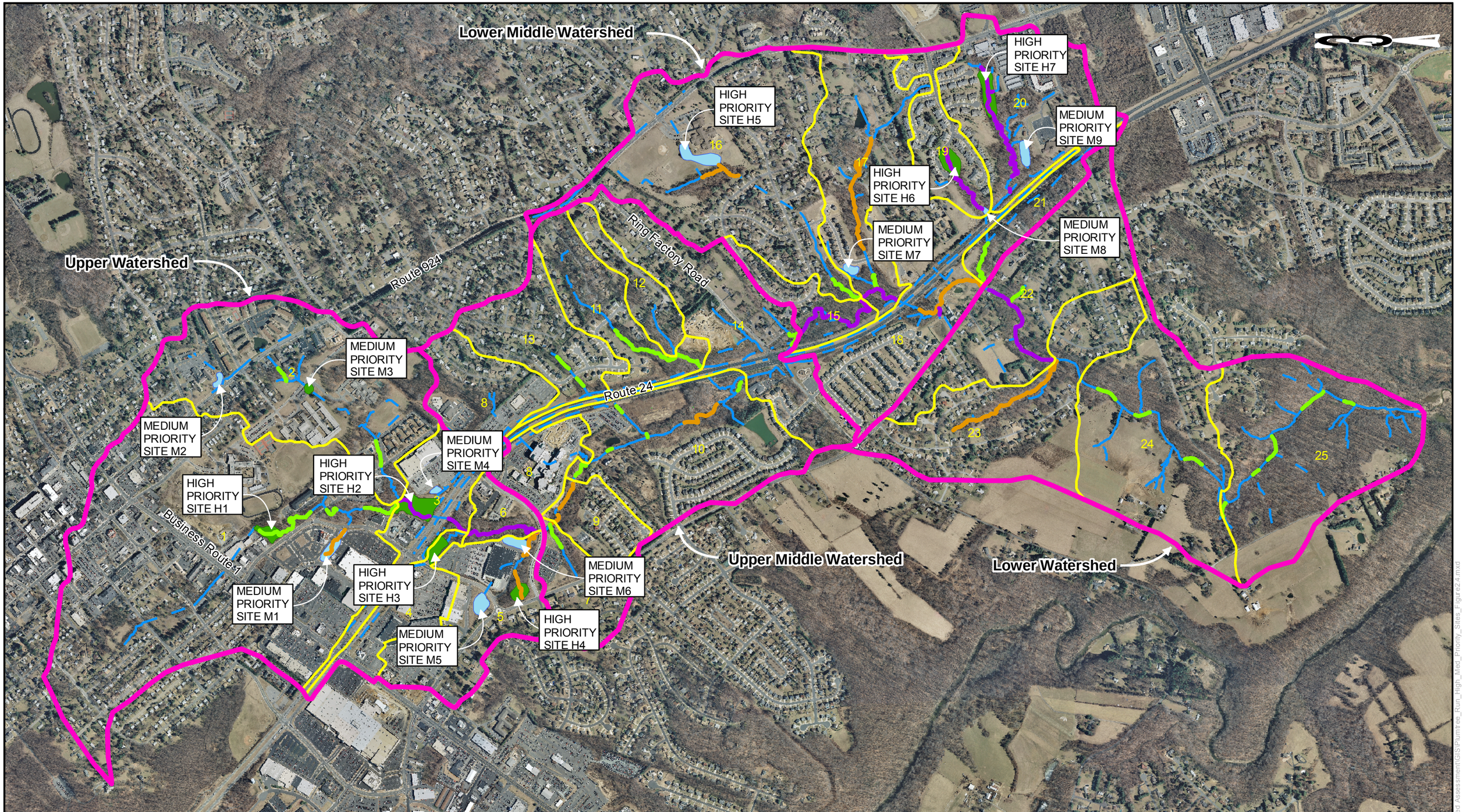
restoration and reduce the overall stream restoration budget for the watershed by $470,000. With the exception of the Bel Air Middle School/Wakefield Elementary School site, all new stormwater BMP sites were ranked high priority for implementation. The Bel Air Middle School/Wakefield Elementary School site was lowered to medium priority since the existing school expansion plans would severely limit the size and extent of a new facility for offsite stormwater management.

Since each of the stormwater retrofit sites had limited potential to provide Cp_V and were more disconnected with the unstable stream reaches, retrofits were assigned a lower priority. The exception would be the retrofit site at Ring Factory Elementary School which could be altered to provide adequate WQ_V and Cp_V to meet Maryland 2000 Stormwater Regulations. This retrofit site also discharged directly into an unstable stream reach. Therefore, the site was elevated to a high priority BMP.

These analyses resulted in the identification of seven (7) high priority and (9) medium priority BMP sites as shown in Table 5.4 and on Figure 5.4.

Table 5.4 – Stormwater BMP Site Selection
Medium Priority Projects
1 – Bel Air Plaza SWM Pond – Retrofit
2 – Bel Air United Methodist Church SWM Pond – Retrofit
3 – Bel Air Middle School/Wakefield Elementary School – New Facility
4 – Superfresh Shopping Center SWM Pond – Retrofit
5 – Tollgate Marketplace SWM Pond – Retrofit
6 – The Home Depot Bel Air SWM Pond – Retrofit
7 – East Valley Oaks SWM Pond – Retrofit
8 – Barrington Retrofit SWM Pond at MD Route 24 – Retrofit
9 – Emmorton Baptist Church SWM Pond – Retrofit
High Priority Projects
1 – Bel Air High School Outfall – New Facility
2 – Regional Facility at MD Route 24 – New Facility
3 – Tollgate Marketplace Outfall – New Facility
4 – Tollgate Road Outfall – New Facility
5 – Ring Factory Elementary School – Retrofit
6 – Barrington Place Outfall – New Facility
7 – Barrington Village Court and Rollins Court Outfalls – New Facility

It is noted that the prioritization in the above table is based upon technical criteria described within this section of the report. However, it must be recognized that other criteria can affect the priority and order of BMP implementation including such things as funding source limitations; property ownership; permitting and public input.



BMP - NEW (N)

BMP - RETROFIT (R)

Watershed Segment Boundary

Sub-watershed Boundary

Hydro Line

Swale / Piped System

Study Point

Unstable Stream Reaches

Low Instability

Moderate Instability

High Instability

1,100 550 0 1,100 2,200 Feet

NOTES:
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Plumtree Run Watershed Assessment Priority BMP Sites

Figure 5.4

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VII. Medium Priority Stormwater BMP Projects

For medium priority projects, a checklist of water quality treatment potential was developed along with a summary of existing conditions, site considerations, and recommendations for each site. The checklist and summary of each medium priority project is as follows.

Site M1: Bel Air Plaza SWM Pond (Subshed 1) – Retrofit

Existing Conditions

- Drainage Area – Bel Air Plaza parking lot
- Ownership – C&E Realty Company
- Design/Constructed – *Circa 1996*
- Site Features:
    - Sediment forebay at upstream end of facility;
    - Highly degraded channel, identified as a medium priority restoration reach (approximately 375 LF) conveys flow from sediment forebay to culvert under parking lot thru-way. Culvert discharges to approximately 100 LF of open channel before stormwater is carried off-site via culvert under Marketplace Drive;
    - No permanent pool; WQ_V is not provided;
    - No quantity control upstream of culverts; Cp_V is not provided;
    - Adjacent sign identifies facility as "Conservation Area"; apparent environmental stewardship opportunity;
    - Sanitary sewer manholes and pump-station located in facility;
    - Site constrained by adjacent parking areas and roadway;
    - Outfall is stable.
- Downstream condition – Culvert outfalls to stable receiving reach located approximately 350 LF upstream of a recommended low priority stream stabilization reach.

Water Quality/Quantity Treatment Potential

☐ Expand facility laterally (Cp_V / WQ_V)

☐ Raise facility embankment (Cp_V / WQ_V)

☑ Install/Modify outlet control structure (Cp_V / WQ_V)

☑ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)

☐ Retrofit with forebays, diversions, etc. to enhance settling (WQ)

☑ Create wetlands / marsh / plantings (WQ)

☐ Repair/Retrofit outfall (WQ)

Recommended Actions

- Excavate sediment forebay to restore design capacity;
- Construct outfall control weirs with low flow orifices upstream of culverts to provide extended detention of available Cp_V storage;

- Excavate micropools and shallow wetland areas for WQ_V storage;
- Install marsh plantings to provide additional water quality benefits and enhanced habitat.

Site M2: Bel Air United Methodist Church SWM Pond (Subshed 2) – Retrofit

Existing Conditions

- Drainage Area – Church property, including parking lot
- Ownership – Bel Air United Methodist Church
- Design/Constructed – Plan approved 10/20/98, As-built 3/15/01
- Site Features:
    - No permanent pool; WQ_V is not provided;
    - Concrete riser with low flow orifice appears to provide quantity control of 2 and 10-year storms; Cp_V is not provided;
    - Facility adjacent to church entrance and children's playground/daycare (i.e. high pedestrian traffic area).
- Downstream condition – Outflow enters closed pipe network upstream of stable stream channel.

Water Quality/Quantity Treatment Potential

☐ Expand facility laterally (Cp_V / WQ_V)

☐ Raise facility embankment (Cp_V / WQ_V)

☐ Install/Modify outlet control structure (Cp_V / WQ_V)

☑ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)

☐ Retrofit with forebays, diversions, etc. to enhance settling (WQ)

☑ Create wetlands / marsh / plantings (WQ)

☐ Repair/Retrofit outfall (WQ)

Recommended Actions

- Excavate shallow wetland for WQ_V storage.
- Install marsh plantings to provide additional water quality benefits and enhanced habitat.

Site M3: Bel Air Middle School/Wakefield Elementary School (Subshed 2) – New Facility

Existing Conditions

- Drainage Area – School property as well as adjacent/up-slope development
- Ownership – Board of Education of Harford County
- Site Features:
    - Stormwater runoff from the school facilities, as well as development from upper portions of the subshed, is conveyed through the site via closed storm drain network.
    - Construction of new buildings is planned on existing open space.

- Downstream condition – Outflow enters closed pipe network upstream of stable stream channel.

Water Quality/Quantity Treatment Potential

☑ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)
☑ Install outlet control structure (Cp_V)
☐ Available floodplain adjacent to stream (if applicable) (Cp_V / WQ_V)
☑ Provide regional management through treatment of off-site runoff (Cp_V / WQ_V)
☑ Construct forebays, diversions, etc. to enhance settling (WQ)
☑ Create wetlands / marsh / plantings (WQ)
☐ Work done in conjunction with recommended stream stabilization efforts (WQ)

Recommended Actions

- Coordinate with Board of Education to incorporate stormwater controls that would exceed new development requirements by incorporating additional off-site drainage for regional management.

Site M4: Superfresh Shopping Center SWM Pond (Subshed 3) – Retrofit

Existing Conditions

- Drainage Area – Superfresh shopping center
- Ownership – Chesapeake Dicks Associates LLC
- Design/Constructed – Circa 1998
- Site Features:
    - No permanent pool; WQ_V is not provided;
    - Concrete riser with low flow orifice appears to provide quantity control of 2 and 10-year storms; Cp_V is not provided;
    - Site constrained by adjacent parking lot and MD Route 24.
- Downstream condition – Facility discharges to a stable outfall channel approximately 250 LF upstream of confluence with Plumtree Run at triple-arch culvert crossing under MD Route 24. The downstream receiving reach of Plumtree run is a recommended moderate priority stream stabilization reach.

Water Quality/Quantity Treatment Potential

☐ Expand facility laterally (Cp_V / WQ_V)
☐ Raise facility embankment (Cp_V / WQ_V)
☐ Install/Modify outlet control structure (Cp_V / WQ_V)
☑ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)
☐ Retrofit with forebays, diversions, etc. to enhance settling (WQ)
☑ Create wetlands / marsh / plantings (WQ)
☐ Repair/Retrofit outfall (WQ)

Recommended Actions

- Excavate permanent pool for WQ_V storage.
- Incorporate safety/aquatic benches and marsh plantings to provide additional water quality benefits and enhanced habitat.

Site M5: Tollgate Marketplace SWM Pond (Subshed 5) – Retrofit

Existing Conditions

- Drainage Area – Rear portion of the Tollgate Marketplace shopping center
- Ownership – Bel Air Square LLC
- Design/Constructed – Circa 1995
- Site Features:
    - Existing stormwater management pond collects runoff from shopping center roof drains and parking lot;
    - Existing permanent pool; unknown WQ_V is provided;
    - Concrete riser with low flow orifice appears to provide quantity control of 2 and 10-year storms; Cp_V is not provided;
    - Woody vegetation present in impoundment area of facility.
- Downstream condition – Outflow enters closed pipe network and discharges to a stable outfall channel.

Water Quality/Quantity Treatment Potential

☐ Expand facility laterally (Cp_V / WQ_V)

☐ Raise facility embankment (Cp_V / WQ_V)

☐ Install/Modify outlet control structure (Cp_V / WQ_V)

☑ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)

☐ Retrofit with forebays, diversions, etc. to enhance settling (WQ)

☑ Create wetlands / marsh / plantings (WQ)

☐ Repair/Retrofit outfall (WQ)

Recommended Actions

- Excavate additional permanent pool depth to meet current WQ_V requirements.
- Incorporate aquatic/safety bench with marsh plantings to provide additional water quality benefits and enhanced habitat.

Site M6: The Home Depot Bel Air SWM Pond (Subshed 5) – Retrofit

Existing Conditions

- Drainage Area – Home Depot shopping center
- Ownership – Bel Air Tollgate Limited Partnership
- Design/Constructed – Approved 8/31/93, As-built 1/10/95
- Site Features:
    - No permanent pool; WQ_V is not provided;

  - Concrete riser with low flow orifice appears to provide quantity control of 2 and 10-year storms; Cp_V is not provided;
  - Site constrained by adjacent parking lot and stream valley.
- Downstream condition – Facility discharges to a recommended moderate priority stream stabilization reach.

Water Quality/Quantity Treatment Potential

☐ Expand facility laterally (Cp_V / WQ_V)

☐ Raise facility embankment (Cp_V / WQ_V)

☐ Install/Modify outlet control structure (Cp_V / WQ_V)

☑ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)

☐ Retrofit with forebays, diversions, etc. to enhance settling (WQ)

☑ Create wetlands / marsh / plantings (WQ)

☐ Repair/Retrofit outfall (WQ)

Recommended Actions

- Excavate micropools and shallow wetland areas for WQ_V storage.
- Install marsh plantings to provide additional water quality benefits and enhanced habitat.

Site M7: East Valley Oaks SWM Pond (Subshed 17) – Retrofit

Existing Conditions

- Drainage Area – Development along Oak Valley Drive
- Ownership – East Valley Oaks Home Owners Association
- Design/Constructed – Approved 3/8/02, As-built 7/20/07
- Site Features:
  - No permanent pool; WQ_V is not provided;
  - Concrete riser with low flow orifice appears to provide Cp_V.
- Downstream condition – Facility discharges to a stable outfall channel located approximately 275 LF upstream of a recommended low priority stream stabilization reach, and 325 LF upstream of a recommended high priority stream stabilization reach.

Water Quality/Quantity Treatment Potential

☐ Expand facility laterally (Cp_V / WQ_V)

☐ Raise facility embankment (Cp_V / WQ_V)

☐ Install/Modify outlet control structure (Cp_V / WQ_V)

☑ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)

☑ Retrofit with forebays, diversions, etc. to enhance settling (WQ)

☑ Create wetlands / marsh / plantings (WQ)

☐ Repair/Retrofit outfall (WQ)

Recommended Actions

- Excavate permanent pool for WQ_V;
- Incorporate forebays at pond inflow locations to provide pre-treatment of stormwater.
- Incorporate aquatic/safety bench along pond perimeter with marsh plantings to provide additional water quality benefits and enhanced habitat.

Site M8: Barrington Retrofit SWM Pond at MD Route 24 (Subshed 19) – Retrofit

Existing Conditions

- Drainage Area – Subsheds 19 and 20
- Ownership – Maryland State Highway Administration
- Design/Constructed – Approved 9/25/98, As-built 1/7/03
- Site Features:
    - Permanent pool currently showing signs of siltation; unknown WQ_V is provided;
    - Concrete riser with low flow orifice appears to provide Cp_V;
    - Facility receives inflow from two recommended high priority stream stabilization reaches, which is causing apparent sedimentation of the wet pool.
- Downstream condition – Facility outfalls to a stable channel upstream of a culvert crossing under Route 24; the culvert discharges to a recommended low priority stream stabilization reach.

Water Quality Treatment Potential

☐ Expand facility laterally (Cp_V / WQ_V)

☐ Raise facility embankment (Cp_V / WQ_V)

☐ Install/Modify outlet control structure (Cp_V / WQ_V)

☑ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)

☑ Retrofit with forebays, diversions, etc. to enhance settling (WQ)

☑ Create wetlands / marsh / plantings (WQ)

☐ Repair/Retrofit outfall (WQ)

Recommended Actions

- Excavate existing wet pool to provide additional WQ_V;
- Incorporate forebays at pond inflow points to provide pre-treatment of stormwater.
- Incorporate aquatic/safety bench with marsh plantings to provide additional water quality benefits and enhanced habitat.

Site M9: Emmorton Baptist Church SWM Pond (Subshed 20) – Retrofit

Existing Conditions

- Drainage Area – Church property; including parking lot.
- Ownership – Emmorton Baptist Church
- Design/Constructed – Approved 1/28/93, As-built unknown
- Site Features:
    - No permanent pool; WQ_V is not provided;
    - Concrete riser with low flow orifice appears to provide quantity control of 2 and 10-year storms; Cp_V is not provided;
- Downstream condition – Facility discharges to a stable outfall channel located approximately 175 LF upstream from confluence with a recommended high priority stream stabilization reach.

Water Quality Treatment Potential

☐ Expand facility laterally (Cp_V / WQ_V)

☐ Raise facility embankment (Cp_V / WQ_V)

☐ Install/Modify outlet control structure (Cp_V / WQ_V)

☑ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)

☐ Retrofit with forebays, diversions, etc. to enhance settling (WQ)

☑ Create wetlands / marsh / plantings (WQ)

☐ Repair/Retrofit outfall (WQ)

Recommended Actions

- Excavate shallow wetland for WQ_V storage.
- Install marsh plantings to provide additional water quality benefits and enhanced habitat.

VIII. High Priority Stormwater BMP Projects

For high priority BMP sites, a similar checklist of water quality treatment potential, summary of existing site conditions, site considerations and recommendations was developed. Conceptual sketches and design computations for targeted water quality attainment goals were also made for each high priority BMP site. Water quality attainment goals were established for each site by computing the drainage area and associated impervious area to the site. The WQ_V for candidate sites was computed based on requirements of the 2000 Maryland Stormwater Design Manual. Based on guidelines provided by the Center for Watershed Protection, Cp_V volume in this region is approximately 20% greater than the WQ_V. Therefore, for this study, all Cp_V goals were established as 1.2 x WQ_V.

The summary of existing conditions, water quality treatment potential, recommended actions and a summary of site performance are provided along with photographs of each high priority site. Stormwater BMP concepts and cost estimates

were also developed and are provided for each site in the following pages. The cost estimates include the following items:

- Design and Permitting Cost – includes consultant professional fees for surveying, base map preparation, site assessment, hydrology and hydraulic analysis, final design plans and construction documents, engineer's certification, and permit application and agency meetings.
- Construction Cost – includes contractor mobilization, clearing and grubbing, construction stakeout, sediment control and dewatering, earthwork, installation of outfall structures, erosion control matting, seeding and mulching. It does not include: consultant professional fees for on-site construction management or as-built surveys.

It is noted that water quality enhancement BMPs such as wetland creation and marsh plantings could be developed as a secondary design goal for each site. Wetland creation and marsh plantings would be well suited for retrofit of dry storage BMP sites with limited capacity for permanent pools, as well as shallow marsh and temporary impoundment areas. Furthermore, landscaping and habitat enhancement may promote stakeholder involvement and partnerships with communities, government and other institutions. Specific detailed features and amenities should be developed during the design of each BMP site.

SITE H1: Bel Air High School Outfall (Subshed 1) – New Facility

<u>Existing Conditions</u>

- Drainage Area – 179 Acres
- Impervious Area – 88.5 Acres (49% impervious)
- Ownership – Town of Bel Air, 331 Baltimore Pike LLC, George Gallant
- Site Features:
    - Stream channel runs through wooded area between Bel Air High School and Atwood Road, with commercial property adjacent to western bank;
    - Headwater of stream channel receives direct discharge from four (4) separate storm drain outfalls, as well as overland runoff from adjacent commercial properties;
        - 60-inch RCP discharges unmanaged runoff from the school and portions of the parking lot;
        - 15-inch RCP discharges unmanaged runoff from the track and field area;
        - 36-inch RCP discharges storm flows from adjacent stormwater management facility, which treats runoff from portions of the school parking lot;
        - 36-inch RCP discharges storm flows from development in upper portions of the subshed. Three under-ground storage tanks and one infiltration trench, which treat a total combined drainage area of approximately 5 acres, were identified from the County BMP inventory.

  - Stream channel receives unmanaged discharge from two 42-inch storm drain outfalls as well as roadside drainage ditch approximately 150 LF downstream of headwater pipe outfalls;
  - Available floodplain along eastern bank of stream channel provides opportunity for attenuation of storm flows; stream channel is fairly constrained by adjacent commercial properties along western bank with limited available floodplain area;
  - Potential construction access from Bel Air High School, Atwood Road, or adjacent commercial property.
- Downstream condition – Site incorporates the upstream portion of a recommended low priority stream stabilization reach.

Water Quality Goals

- WQ_V required per 2000 Maryland Stormwater Design Manual = 7.4 ac.-ft.; therefore, Cp_V = 8.9 ac.-ft. Calculated volumes account for the entire contributing drainage area and do not consider stormwater management provided in upper portions of the subshed.

Water Quality Treatment Potential

- ☑ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)
- ☑ Install control structure (i.e. weir or riser) (Cp_V)
- ☑ Available floodplain adjacent to stream (if applicable) (Cp_V / WQ_V)
- ☑ Provide regional management through treatment of off-site runoff (Cp_V / WQ_V)
- ☐ Construct forebays, diversions, etc. to enhance settling (WQ)
- ☑ Create wetlands / marsh / plantings (WQ)
- ☑ Work done in conjunction with recommended stream stabilization efforts (WQ)

Recommended Actions

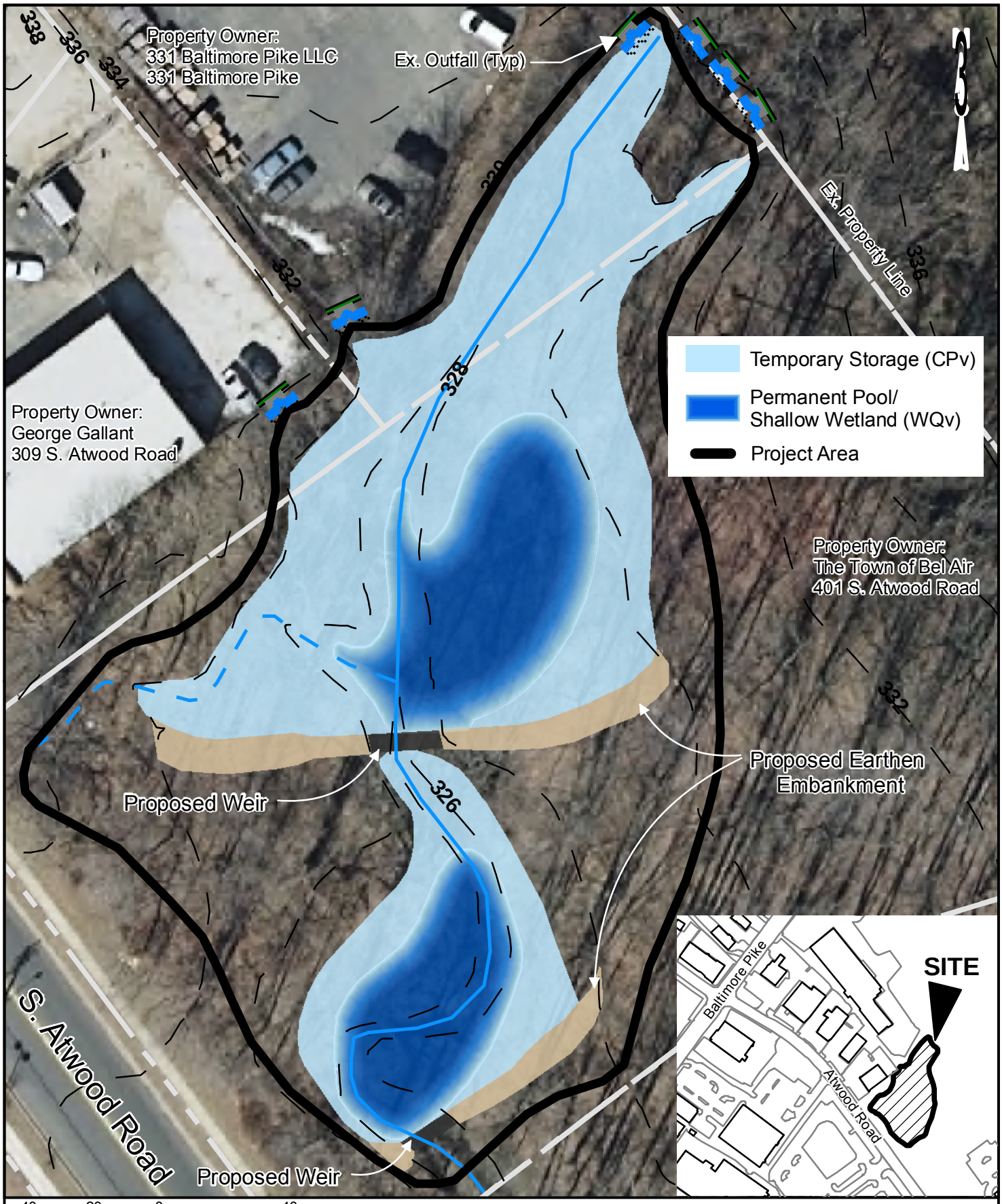
- Perform minor site grading to maximize available floodplain storage area, especially along eastern bank of channel.
- Install weir structures with low flow orifices (approximately 2 – 3 structures with 3 – 6 foot height) and earthen embankments in series across stream valley to create temporary impoundment areas in the adjacent floodplain and provide extended detention of approximately 1.5 ac.-ft. of Cp_V.
- Excavate permanent pool (6-inch to 18-inch depth) with additional deep water micropools and establish shallow wetlands within floodplain area to provide approximately 0.4 ac.-ft. of WQ_V as well as habitat enhancement.

Summary of Site Performance and Cost

- Potential WQ_V Provided – 0.4 ac.-ft.
- Potential Cp_V Provided – 1.5 ac.-ft.
- Cost Estimate
    - Permitting/Design $70,000
    - Construction $110,000
    - Total Project Cost $180,000
- Targeted WQ_V Goal – 7.4 ac.-ft.
- Targeted Cp_V Goal – 8.9 ac.-ft.

Site H1 – Bel Air High School Outfall

Site H1 – Bel Air High School Outfall (Continued)



40 20 0 40
Feet

NOTES:
1. Aerial photography from 2007 Harford County GIS.
2. Topographic contours are 2 ft interval from Harford County GIS.
3. Basemap data from Harford County GIS.
4. Cadastral data from Harford County GIS dated January 2010.
5. Outfalls field verified by BayLand Consultants, locations are approximate.

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Site H1
Bel Air High School
Outfall

Figure 5.5

P:\4_2901_Plumtree Run Watershed Assessment\GIS\Plumtree_Run_Reccomendation_Site1.mxd

SITE H2: Regional Facility at MD Route 24 (Subshed 3) – New Facility

Existing Conditions

- Drainage Area – 402 Acres
- Impervious Area – 200 Acres (50% impervious)
- Ownership – ELOS LLC, MD SHA, Chesapeake Dicks Associates LLC
- Site Features:
    - Stream channel runs through wooded area between Marketplace Drive and MacPhail Road, with adjacent commercial properties on either side;
    - Stream channel crosses under MD Route 24 via triple-arch culvert;
    - Site is located downstream of confluence of Subshed 1 and 2 stream channels and receives stormwater runoff from highly developed upper portions of the Plumtree Run watershed;
    - Site intercepts discharge from BMP on adjacent commercial property, constructed prior to implementation of MDE 2000 Stormwater Design Manual;
    - Available floodplain along eastern bank of stream channel provides opportunity for attenuation of storm flows; stream channel is fairly constrained with limited floodplain along western bank;
    - Potential construction access from adjacent commercial property on eastern side of channel.
- Downstream condition – Site incorporates the upstream portion of a recommended medium priority stream stabilization reach, which extends downstream of the Route 24 culvert outfall.

Water Quality Goals

- WQ_V required per 2000 Maryland Stormwater Design Manual = 16.7 ac.-ft.; therefore, Cp_V = 20 ac.-ft. Calculated volumes account for the entire contributing drainage area and do not consider stormwater management provided in upper portions of the subshed.

Water Quality Treatment Potential

- ☑ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)
- ☑ Install control structure (i.e. weir or riser) (Cp_V)
- ☑ Available floodplain adjacent to stream (if applicable) (Cp_V / WQ_V)
- ☑ Provide regional management through treatment of off-site runoff (Cp_V / WQ_V)
- ☑ Construct forebays, diversions, etc. to enhance settling (WQ)
- ☑ Create wetlands / marsh / plantings (WQ)
- ☑ Work done in conjunction with recommended stream stabilization efforts (WQ)

Recommended Actions

- Perform site grading to maximize available floodplain storage area, especially along eastern bank of channel.

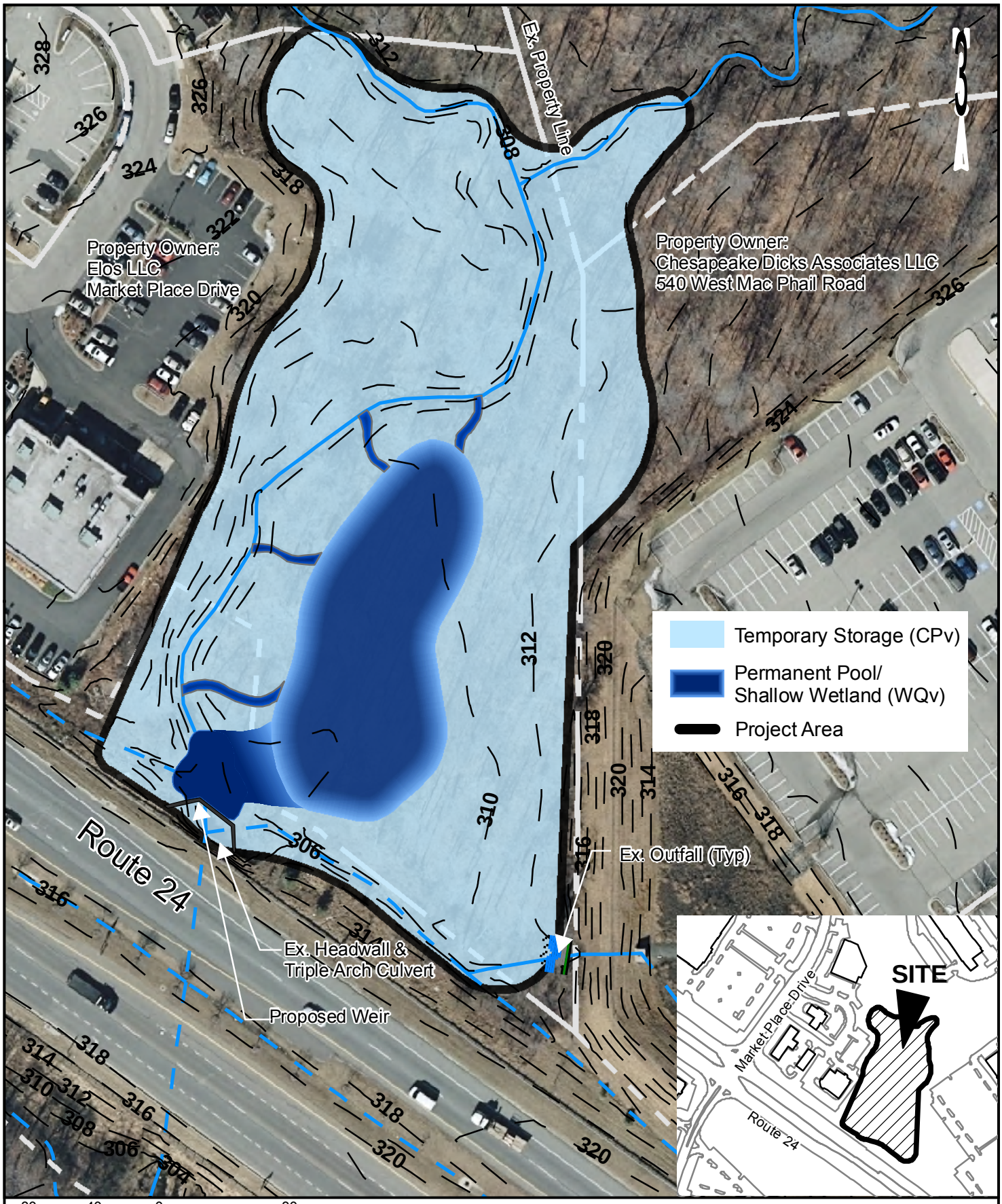
- Install weir structure with low flow orifice (approximate 3 – 4 foot height) at existing headwall of culvert crossing to permit passage of base flow while providing temporary storage of approximately 3.4 ac.-ft. of Cp_V in the adjacent floodplain.
- Excavate permanent pool (6-inch to 18-inch depth) with additional deep water micropools and establish shallow wetlands within floodplain area to provide approximately 0.5 ac.-ft. of WQ_V as well as habitat enhancement.
- Incorporate diversions from the main channel to the wetland area to lengthen flow paths and enhance water quality treatment.
- Construct micropool immediately upstream of proposed weir structure to allow for sediment deposition and prevent clogging of low flow orifice upstream of MD SHA culvert.

<u>Summary of Site Performance and Cost</u>

- Potential WQ_V Provided – 0.5 ac.-ft.
- Potential Cp_V Provided– 3.4 ac.-ft.
- Cost Estimate
    - Permitting/Design $110,000
    - Construction $220,000
    - Total Project Cost $330,000
- Targeted WQ_V Goal – 16.7 ac.-ft.
- Targeted Cp_V Goal – 20 ac.-ft.

Site H2 – Regional Facility at MD Route 24

Site H2 – Regional Facility at MD Route 24 (Continued)



80 40 0 80
Feet

NOTES:
1. Aerial photography from 2007 Harford County GIS.
2. Topographic contours are 2 ft interval from Harford County GIS.
3. Basemap data from Harford County GIS.
4. Cadastral data from Harford County GIS dated January 2010.
5. Outfalls field verified by BayLand Consultants, locations are approximate.

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Site H2
Regional Facility at
MD Route 24

Figure 5.6

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SITE H3: Tollgate Marketplace Outfall (Subshed 4) – New Facility

Existing Conditions

- Drainage Area – 25 Acres
- Impervious Area – 18 Acres (72% impervious)
- Ownership – Bel Air Tollgate Limited Partnership
- Site Features:
    - Stream channel runs through wooded area between MD Route 24 and the Bel Air Home Depot;
    - Headwater of stream channel receives unmanaged discharge from storm drain network that conveys runoff from the front portion of the Tollgate Marketplace shopping center, as well as overland runoff from a drainage ditch along south-bound MD Route 24;
    - Available floodplain along north-eastern bank of stream channel provides opportunity for attenuation of storm flows; stream channel is constrained by adjacent commercial property along south-western bank with limited available floodplain area;
    - Potential construction access from Marketplace Drive.
- Downstream condition – Stable outfall is located approximately 600 LF upstream of confluence with a recommended medium priority stream stabilization reach.

Water Quality Goals

- WQ_V required per 2000 Maryland Stormwater Design Manual = 1.5 ac.-ft.; therefore, Cp_V = 1.8 ac.-ft.

Water Quality Treatment Potential

☐ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)
☑ Install control structure (i.e. weir or riser) (Cp_V)
☑ Available floodplain adjacent to stream (if applicable) (Cp_V / WQ_V)
☐ Provide regional management through treatment of off-site runoff (Cp_V / WQ_V)
☐ Construct forebays, diversions, etc. to enhance settling (WQ)
☑ Create wetlands / marsh / plantings (WQ)
☐ Work done in conjunction with recommended stream stabilization efforts (WQ)

Recommended Actions

- Perform site grading to maximize available floodplain storage area, especially along north-eastern bank of channel.
- Install weir structure with low flow orifice (approximate 4 – 6 foot height) and earthen embankments across stream valley to create temporary impoundment area and provide extended detention of approximately 0.6 ac.-ft. of Cp_V in the adjacent floodplain.
- Provide micropool upstream of weir structure to prevent clogging of low flow orifice and provide additional water quality storage.

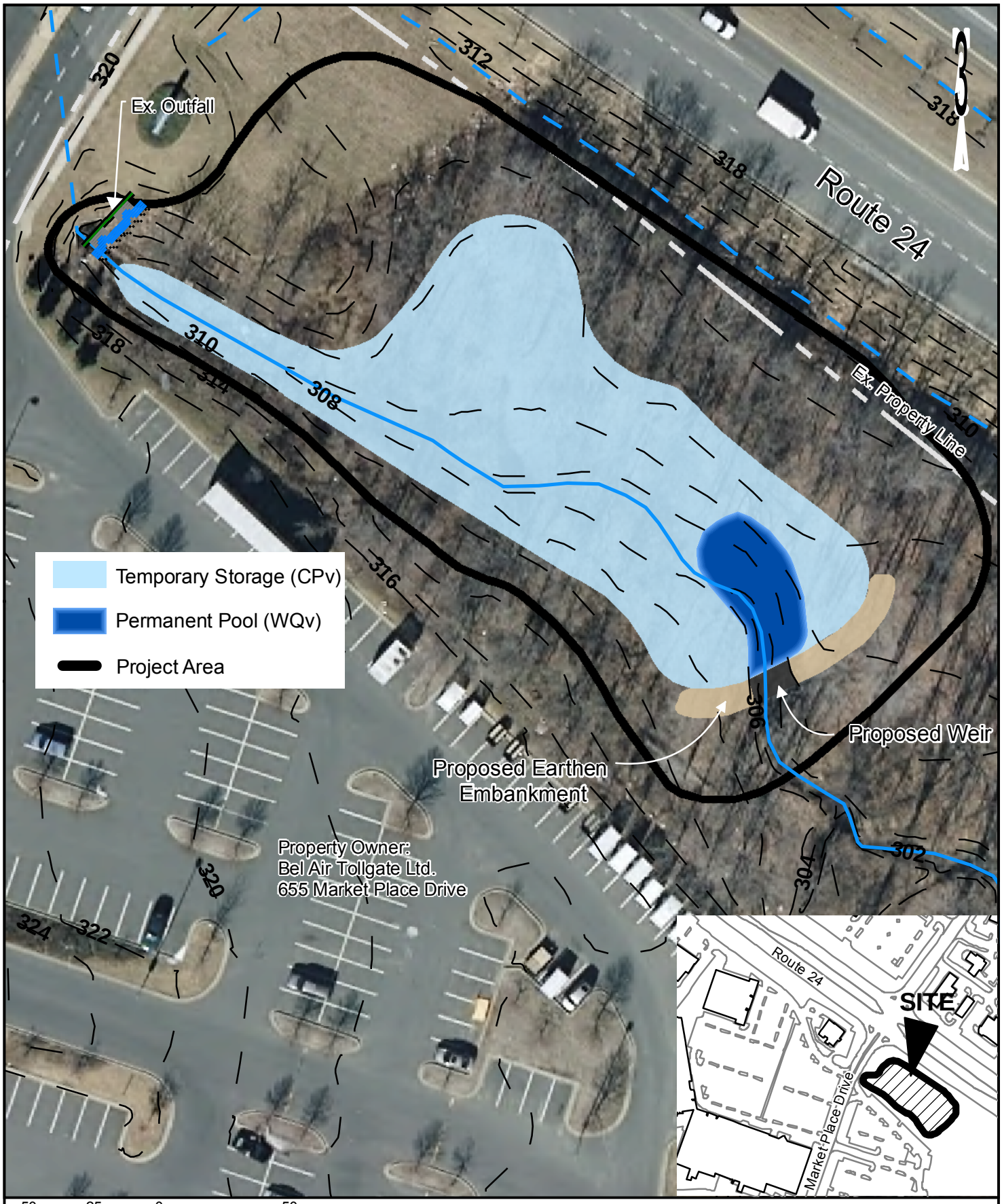
- Incorporate shallow marsh areas and plantings in proposed temporary storage area to provide additional water quality benefits, enhanced habitat and limited storage of WQ_V.

<u>Summary of Site Performance and Cost</u>

- Potential WQ_V Provided – Low
- Potential Cp_V Provided – 0.6 ac.-ft.
- Cost Estimate
    - Permitting/Design $65,000
    - Construction $70,000
    - Total Cost $135,000
- Targeted WQ_V Goal – 1.5 ac.-ft.
- Targeted Cp_V Goal – 1.8 ac.-ft.

Site H3 – Tollgate Marketplace Outfall

Site H3 – Tollgate Marketplace Outfall (Continued)



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NOTES:
1. Aerial photography from 2007 Harford County GIS.
2. Topographic contours are 2 ft interval from Harford County GIS.
3. Basemap data from Harford County GIS.
4. Cadastral data from Harford County GIS dated January 2010.
5. Outfalls field verified by BayLand Consultants, locations are approximate.

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Site H3
Tollgate Marketplace Outfall

Figure 5.7

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SITE H4: Tollgate Road Outfall (Subshed 5) – New Facility

Existing Conditions

- Drainage Area – 16 Acres
- Impervious Area – 4 Acres (25% impervious)
- Ownership – Bel Air Tollgate Limited Partnership
- Site Features:
    - Stream channel runs through wooded area between Tollgate Road, MacPhail Road, and the Bel Air Home Depot;
    - Headwater of stream channel receives unmanaged discharge from storm drain network that conveys runoff from upper portion of the subshed;
    - Storm drain discharges to an abandoned sediment trap immediately upstream of approximate 8-ft head-cut to receiving stream channel;
    - Potential construction access from Tollgate Road, Marketplace Drive, or The Home Depot.
- Downstream condition – Site incorporates the upstream portion of a recommended medium priority stream stabilization reach.

Water Quality Goals

- WQ_V required per 2000 Maryland Stormwater Design Manual = 0.4 ac.-ft.; therefore, Cp_V = 0.5 ac.-ft.

Water Quality Treatment Potential

☑ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)
☑ Install control structure (i.e. weir or riser) (Cp_V)
☑ Available floodplain adjacent to stream (if applicable) (Cp_V / WQ_V)
☐ Provide regional management through treatment of off-site runoff (Cp_V / WQ_V)
☑ Construct forebays, diversions, etc. to enhance settling (WQ)
☑ Create wetlands / marsh / plantings (WQ)
☑ Work done in conjunction with recommended stream stabilization efforts (WQ)

Recommended Actions

- Construct wet pond for stormwater management per requirements of the MDE 2000 Design Manual.
    - Excavate permanent water quality pool with approximate 6-foot depth and 3,000 square foot surface area to provide 0.4 ac.-ft. of WQ_V. Water quality pool should include a sediment forebay at the pond inflow point for storage of approximately 10% of the water quality volume;
    - Provide additional dry storage above water quality pool for extended detention of approximately 0.5 ac.-ft. of Cp_V.
    - Install outlet control structure with low flow orifice sized to provide 24-hour extended detention of 0.5 ac.-ft. of Cp_V, as well as a concrete culvert through the earthen embankment to discharge flows to a stable outfall channel.

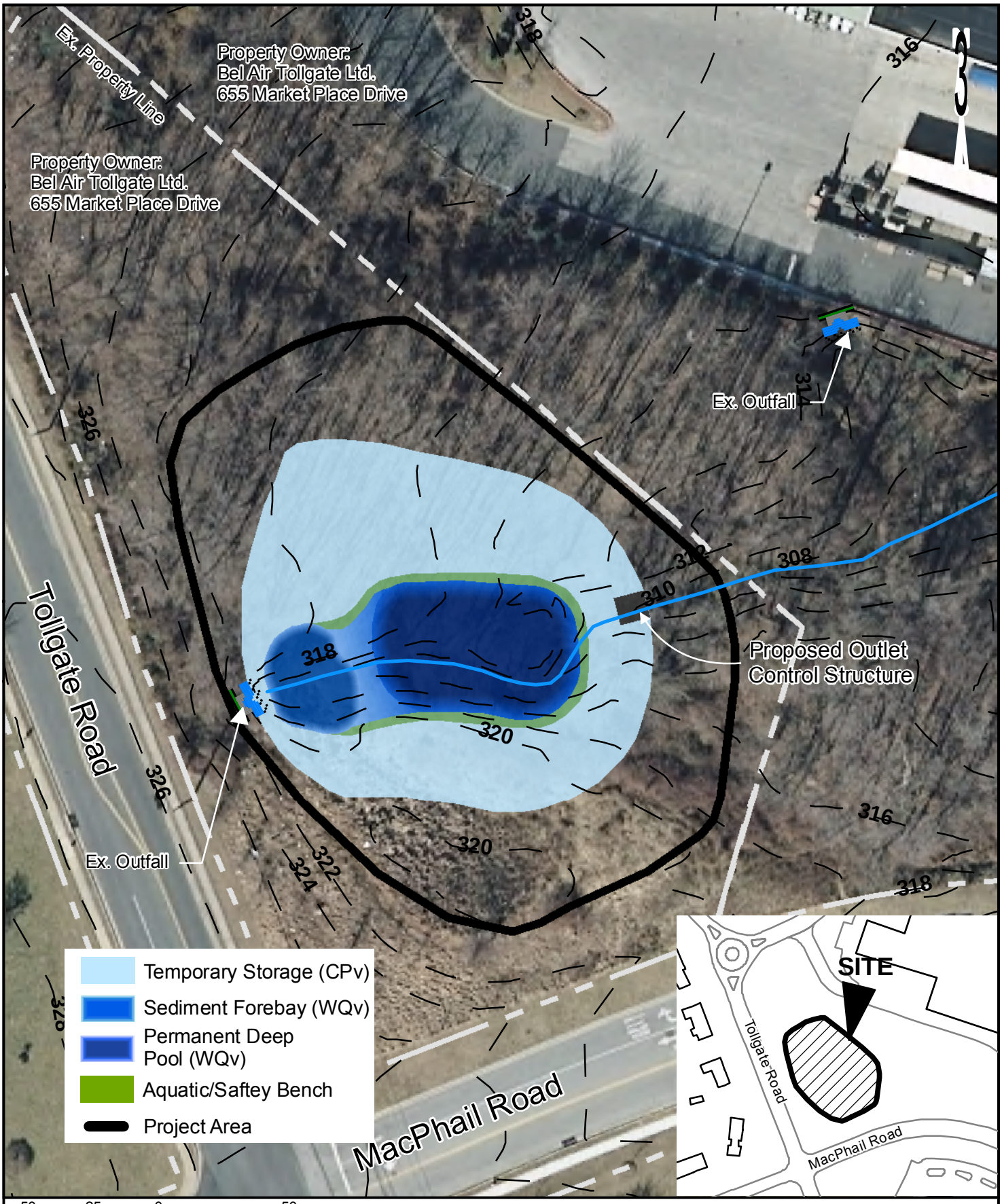
- Incorporate aquatic/safety bench along perimeter of water quality pool with marsh plantings to provide additional water quality benefits and enhanced habitat.

<u>Summary of Site Performance and Cost</u>

- Potential WQ_V Provided – 0.4 ac.-ft.
- Potential Cp_V Provided – 0.5 ac.-ft.
- Cost Estimate
  - Permitting/Design $80,000
  - Construction $100,000
  - Total Project Cost $180,000
- Targeted WQ_V Goal – 0.4 ac.-ft.
- Targeted Cp_V Goal – 0.5 ac.-ft.

Site H4 – Tollgate Road Outfall

Site H4 – Tollgate Road Outfall (Continued)



50 25 0 50
Feet

NOTES:
1. Aerial photography from 2007 Harford County GIS.
2. Topographic contours are 2 ft interval from Harford County GIS.
3. Basemap data from Harford County GIS.
4. Cadastral data from Harford County GIS dated January 2010.
5. Outfalls field verified by BayLand Consultants, locations are approximate.

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Site H4
Tollgate Road
Outfall

Figure 5.8

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SITE H5: Ring Factory Elementary School (Subshed 16) – Retrofit

Existing Conditions

- Drainage Area – 23 Acres
- Impervious Area – 8 Acres (35% impervious)
- Ownership –Board of Education of Harford County
- Designed/Constructed – Approved 10/5/88, As-built unknown
- Site Features:
    - No permanent pool; WQ_V is not provided;
    - Concrete riser with low flow orifice appears to provide quantity control of 2 and 10-year storms; Cp_V is not provided;
    - 36-inch RCP culvert conveys flow from concrete riser structure to a ponded outfall area, which also receives stormwater runoff via 24-inch storm drain from additional school property and rear portion of adjacent residential lots;
    - Discharge from ponded outfall area is currently controlled by a rock spillway;
    - Potential construction access from school parking lot.
- Downstream condition – Facility outfalls directly to a recommended medium priority stream stabilization reach with approximate 5-ft headcut downstream of rock spillway.

Water Quality Goals

- WQ_V required per 2000 Maryland Stormwater Design Manual = 0.7 ac.-ft.; therefore, Cp_V = 0.8 ac.-ft.

Water Quality Treatment Potential

☑ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)
☑ Install control structure (i.e. weir or riser) (Cp_V)
☐ Available floodplain adjacent to stream (if applicable) (Cp_V / WQ_V)
☐ Provide regional management through treatment of off-site runoff (Cp_V / WQ_V)
☐ Construct forebays, diversions, etc. to enhance settling (WQ)
☑ Create wetlands / marsh / plantings (WQ)
☑ Work done in conjunction with recommended stream stabilization efforts (WQ)

Recommended Actions

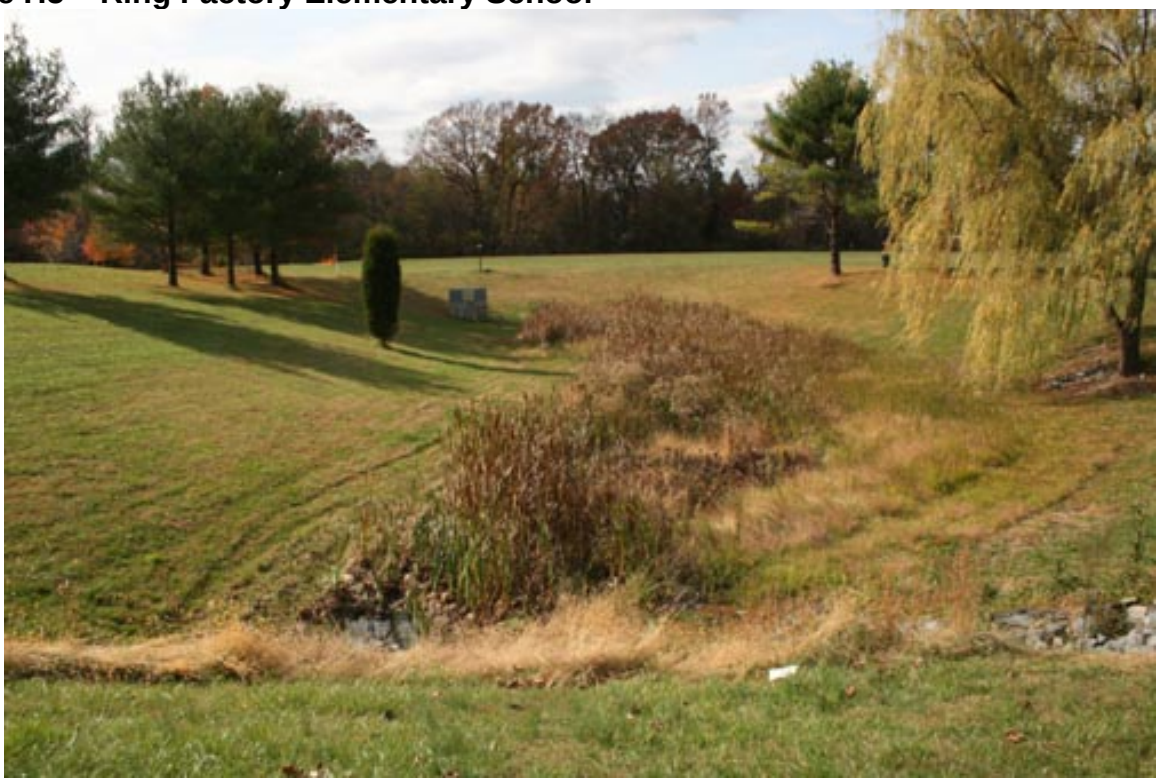
- Excavate shallow wetland area upstream of existing concrete riser to provide approximately 0.2 ac.-ft. of WQ_V.
- Expand footprint of pipe outfall area and excavate permanent water quality pool with approximate 6-foot depth and 3,600 square foot surface area to provide remaining 0.5 ac.-ft. of WQ_V.
- Provide additional dry storage above water quality pool for extended detention of approximately 0.8 ac.-ft. of Cp_V.

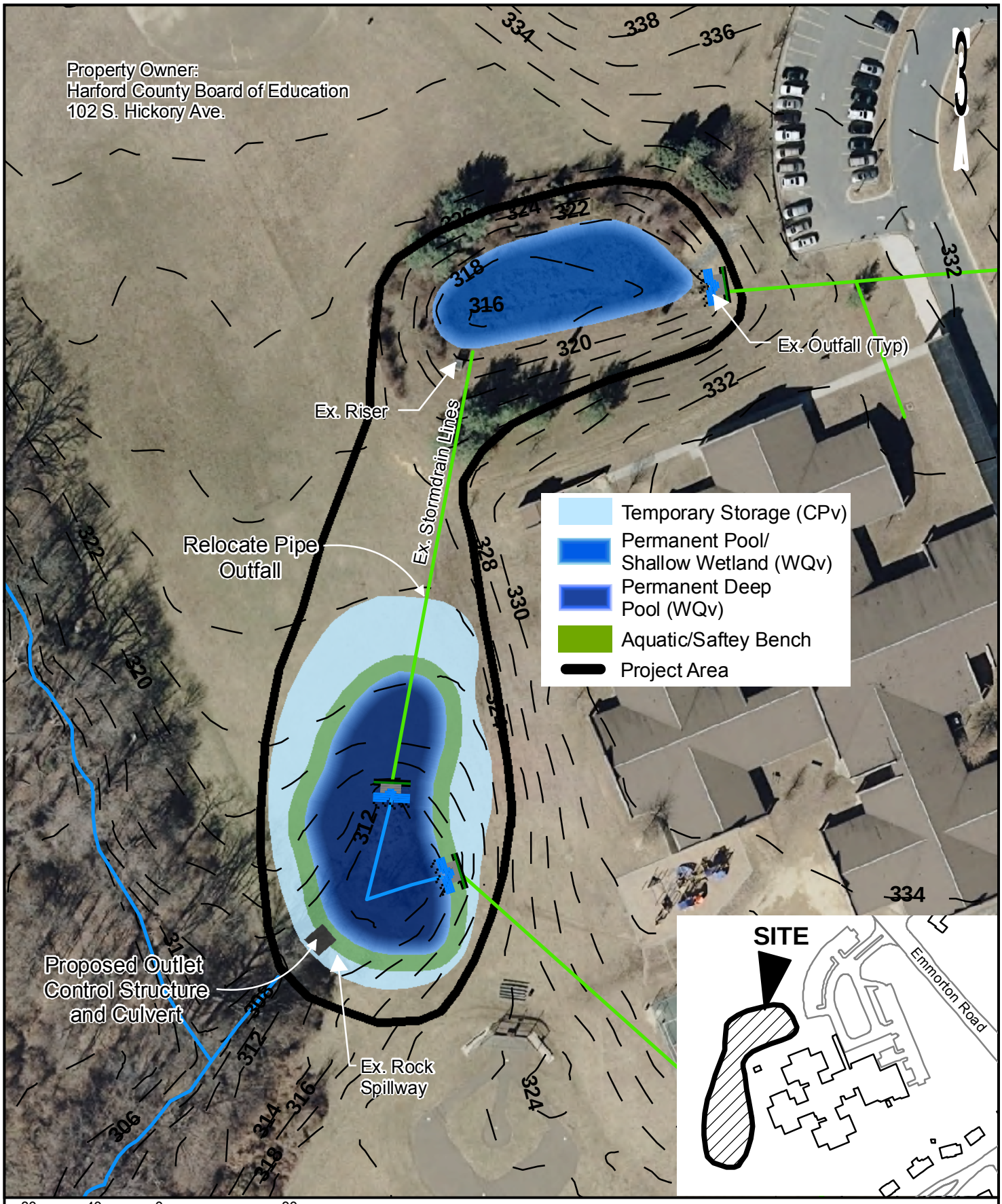
- Install outlet control structure with low flow orifice sized to provide 24-hour extended detention of 0.8 ac.-ft. of Cp_V, as well as a concrete culvert through the earthen embankment to discharge flows to a stable outfall channel.
- Incorporate aquatic/safety bench along pond perimeter with marsh plantings to provide additional water quality benefits and enhanced habitat.

<u>Summary of Site Performance and Cost</u>

- Potential WQ_V Provided – 0.7 ac.-ft.
- Potential Cp_V Provided – 0.8 ac.-ft.
- Cost Estimate
    - Permitting/Design $75,000
    - Construction $135,000
    - Total Project Cost $210,000
- Targeted WQ_V Goal – 0.7 ac.-ft.
- Targeted Cp_V Goal – 0.8 ac.-ft.

Site H5 – Ring Factory Elementary School





NOTES:
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2. Topographic contours are 2 ft interval from Harford County GIS.
3. Basemap data from Harford County GIS.
4. Cadastral data from Harford County GIS dated January 2010.
5. Outfalls field verified by BayLand Consultants, locations are approximate.

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Site H5
Ring Factory Elementary School

Figure 5.9

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SITE H6: Barrington Place Outfall (Subshed 19) – New Facility

Existing Conditions

- Drainage Area – 23 Acres
- Impervious Area – 8 Acres (35% impervious)
- Ownership – Barrington Community Association Inc.
- Site Features:
    - Stream channel runs through wooded area between Barrington Place and Crystal Court;
    - Stream channel receives unmanaged discharge from storm drain network that conveys runoff from the Barrington Place housing development;
    - Discharge at storm drain outfall locations is currently split at the final manhole structures between two pipes to provide limited management of direct discharge to the existing stream channel;
    - Highly degraded stream channel with active headcut moving upstream. Incised channel has resulted in cantilevered pipe outfalls, and the channel has been disconnected from the adjacent floodplain;
    - Potential construction access from Barrington Place and Crystal Court.
- Downstream condition – Site incorporates the upstream portion of a recommended high priority stream stabilization reach. Active channel degradation currently provides heavy sediment loads to a downstream MD SHA stormwater management pond.

Water Quality Goals

- WQ_V required per 2000 Maryland Stormwater Design Manual = 0.7 ac.-ft.; therefore, Cp_V = 0.8 ac.-ft.

Water Quality Treatment Potential

☐ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)
☑ Install control structure (i.e. weir or riser) (Cp_V)
☑ Available floodplain adjacent to stream (if applicable) (Cp_V / WQ_V)
☐ Provide regional management through treatment of off-site runoff (Cp_V / WQ_V)
☐ Construct forebays, diversions, etc. to enhance settling (WQ)
☑ Create wetlands / marsh / plantings (WQ)
☑ Work done in conjunction with recommended stream stabilization efforts (WQ)

Recommended Actions

- Perform site grading to maximize available floodplain storage area.
- Install weir structures with low flow orifices (approximately 2 – 4 structures with 4 – 6 foot height) and earthen embankments in series across the stream valley to create temporary impoundment areas and provide extended detention of approximately 0.8 ac.-ft. of Cp_V in the adjacent floodplain.
- Provide micropools upstream of weir structures to prevent clogging of low flow orifice and provide approximately 0.1 ac.-ft. of WQ_V.

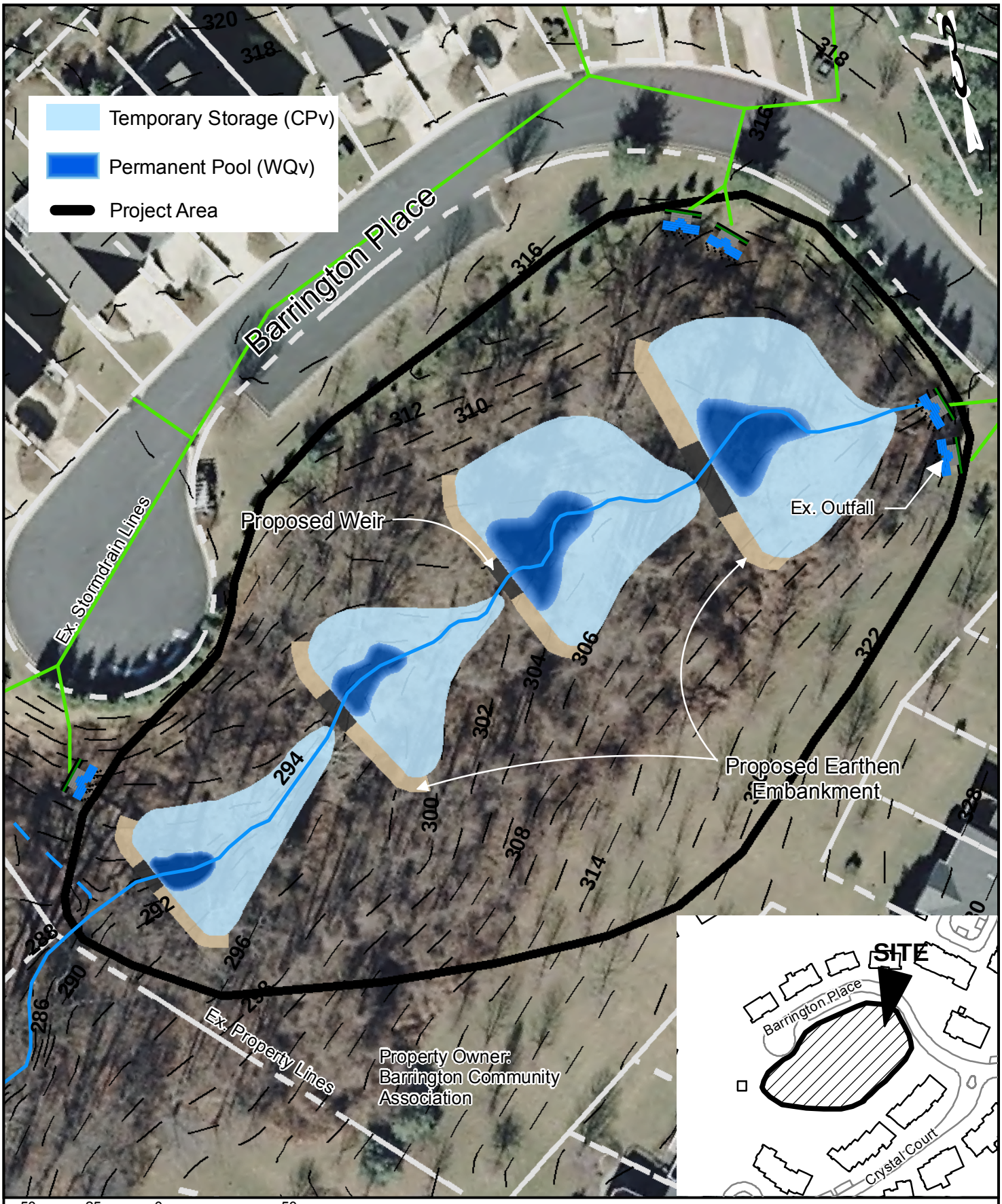
- Incorporate shallow marsh areas and plantings in proposed temporary storage areas to provide additional water quality benefits, enhanced habitat and limited storage of WQ_V.

<u>Summary of Site Performance and Cost</u>

- Potential WQ_V Provided – 0.1ac.-ft.
- Potential Cp_V Provided – 0.8 ac.-ft.
- Cost Estimate
    - Permitting/Design $80,000
    - Construction $110,000
    - Total Project Cost $190,000
- Targeted WQ_V Goal – 0.7 ac.-ft.
- Targeted Cp_V Goal – 0.8 ac.-ft.

Site H6 – Barrington Place Outfall

Site H6 – Barrington Place Outfall (Continued)



50 25 0 50 Feet

NOTES:
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3. Basemap data from Harford County GIS.
4. Cadastral data from Harford County GIS dated January 2010.
5. Outfalls field verified by BayLand Consultants, locations are approximate.

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Site H6
Barrington Place Outfall

Figure 5.10

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SITE H7: Barrington Village Court and Rollins Court Outfalls (Subshed 20) – New Facility

Existing Conditions

- Drainage Area – 28 Acres
- Impervious Area – 13.5 Acres (48% impervious)
- Ownership – Barrington Community Association Inc., Emmorton Road Land Limited Partnership, Plumtree Partners LLC
- Site Features:
    - Stream channel runs through wooded area bordered by the Barrington Place housing development to the north, and commercial properties to the east and south.
    - Stream channel receives unmanaged discharge from two separate storm drain networks that convey runoff from Barrington Village Court and Rollins Court respectively in the Barrington Place housing development.
    - In addition to storm drain discharge, stream channel receives outflow from adjacent commercial stormwater management facility, approved and constructed prior to implementation of 2000 Maryland Stormwater Design Manual.
    - The channel is constrained by high embankments leading to adjacent development; however, portions of the channel have available floodplain with limited room for expansion, which provides opportunity for attenuation of storm flows.
    - Potential construction access from Barrington Village Court.
- Downstream condition – Site incorporates the upstream portion of a recommended high priority stream stabilization reach. Active channel degradation currently provides heavy sediment loads to a downstream MD SHA stormwater management pond.

Water Quality Goals

- WQ_V required per 2000 Maryland Stormwater Design Manual = 1.1 ac.-ft.; therefore, Cp_V = 1.3 ac.-ft.

Water Quality Treatment Potential

☐ Excavate permanent pool (i.e. pond or shallow wetland) (WQ_V)
☑ Install control structure (i.e. weir or riser) (Cp_V)
☐ Available floodplain adjacent to stream (if applicable) (Cp_V / WQ_V)
☑ Provide regional management through treatment of off-site runoff (Cp_V / WQ_V)
☐ Construct forebays, diversions, etc. to enhance settling (WQ)
☑ Create wetlands / marsh / plantings (WQ)
☑ Work done in conjunction with recommended stream stabilization efforts (WQ)

Recommended Actions

- Perform site grading to maximize available floodplain storage area.

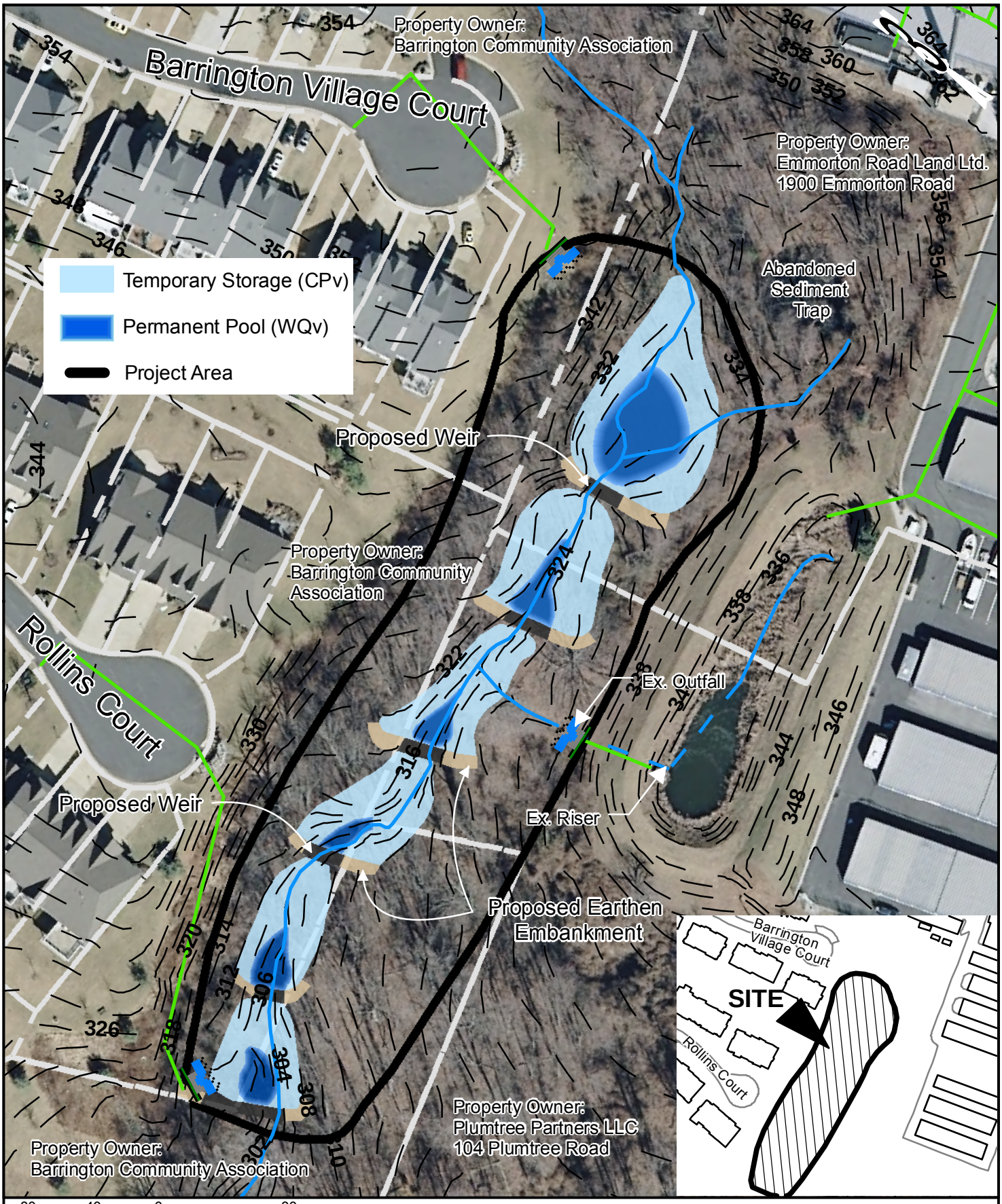
- Install weir structures with low flow orifices (approximately 5 – 7 structures with 4 – 6 foot height) and earthen embankments in series across the stream valley to create temporary impoundment areas and provide extended detention of approximately 1.3 ac.-ft. of Cp_V in the adjacent floodplain.
- Provide micropools upstream of weir structures to prevent clogging of low flow orifice and provide approximately 0.1 ac.-ft. of WQ_V.
- Incorporate shallow marsh areas and plantings in proposed temporary storage areas to provide additional water quality benefits, enhanced habitat and limited storage of WQ_V.

<u>Summary of Site Performance and Cost</u>

- Potential WQ_V Provided – 0.1 ac.-ft.
- Potential Cp_V Provided – 1.3 ac.-ft.
- Cost Estimate
    - Permitting/Design $80,000
    - Construction $150,000
    - Total Project Cost $230,000
- Targeted WQ_V Goal – 1.1 ac.-ft.
- Targeted Cp_V Goal – 1.3 ac.-ft.

Site H7 – Barrington Village Court and Rollins Court Outfalls

Site H7 – Barrington Village Court and Rollins Court Outfalls (Continued)



80 40 0 80
Feet

NOTES:
1. Aerial photography from 2007 Harford County GIS.
2. Topographic contours are 2 ft interval from Harford County GIS.
3. Basemap data from Harford County GIS.
4. Cadastral data from Harford County GIS dated January 2010.
5. Outfalls field verified by BayLand Consultants, locations are approximate.

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Site H7
Barrington Village Court and Rollins Court Outfalls

Figure 5.11

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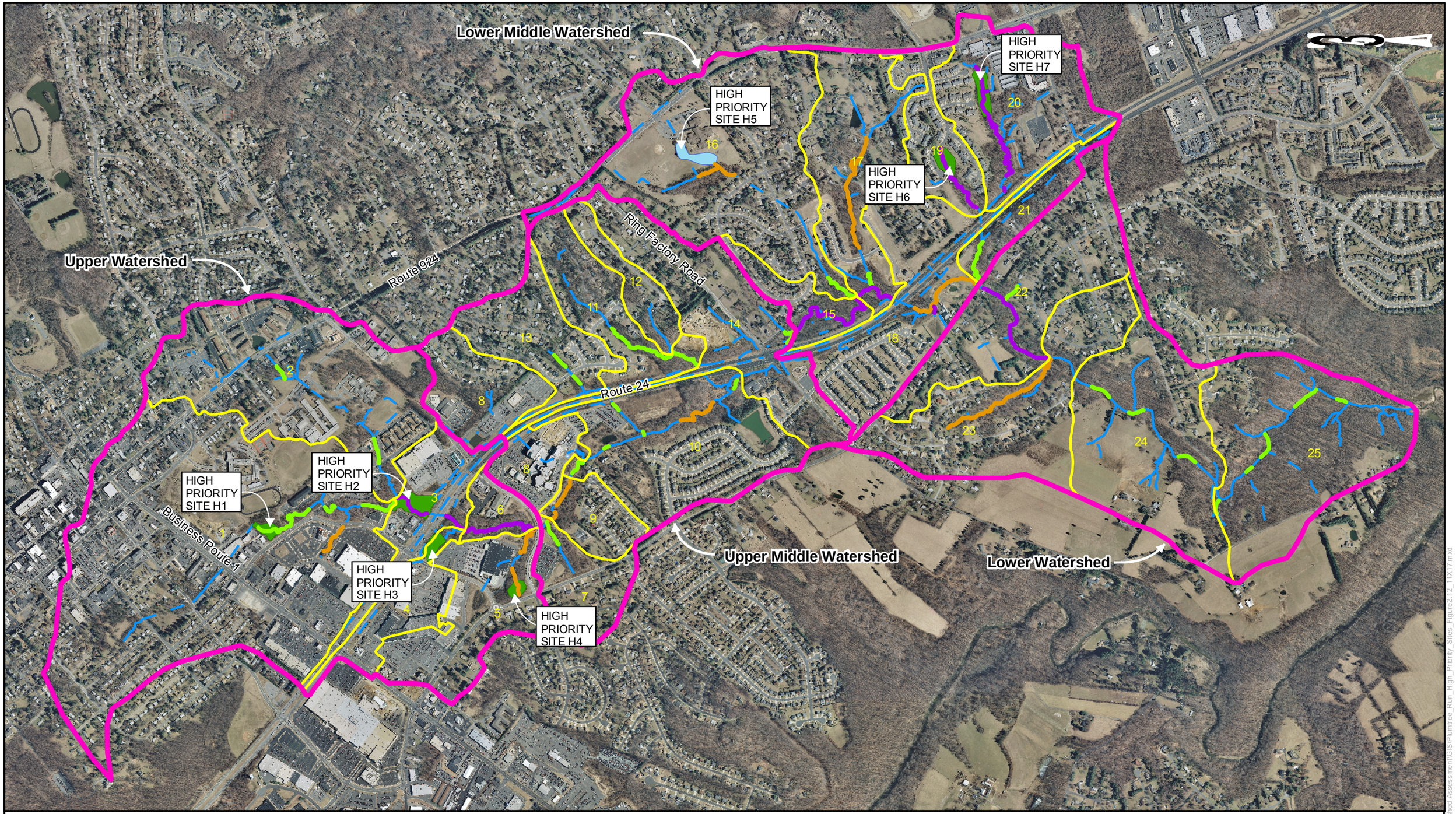
IX. Summary of High Priority Stormwater BMP Projects

A summary of each high priority BMP site is provided in Table 5.5. Key BMP features have been imported directly from the preceding high priority project data sheets. A unit cost was calculated, expressed as cost per acre-feet of WQ_V plus Cp_V provided ($/ac.-ft.). This unit cost for stormwater storage was used to evaluate the cost efficiency of each site expressed as a cost per acre-foot of Cp_V plus WQ_V provided. The unit cost per acre-foot ranges from $85,000/ac-ft to $225,000/ac-ft making the most cost efficient BMP approximately 2.6 times less expensive per acre-foot compared to the least cost efficient BMP. Normally the cost efficiency of stormwater BMPs are used as a guide to assist in prioritizing the implementation of stormwater BMPs. However, based on the significant shortfall of WQ_V/Cp_V provided compared to the targeted WQ_V/Cp_V, it is recommended that all seven (7) of the high priority sites (Figure 5.12) be implemented to provide a total of 11.1 ac-ft of stormwater storage and related benefits for the Plumtree Run watershed.

Table 5.5 – Summary of Stormwater BMP Sites

WQ_V Target (ac.-ft.)*	Cp_V Target (ac.-ft.)*	WQ_V Provided (ac.-ft.)	Cp_V Provided (ac.-ft.)	Design and Permitting Costs	Construction Costs	Unit Cost ($/ac.-ft.)	Cost Efficiency Rank
Site H1 – Bel Air High School Outfall							
7.4	8.9	0.4	1.5	$70,000	$110,000	$95,000	*2*
Site H2 – Regional Facility at MD Route 24							
16.7	20.0	0.5	3.4	$110,000	$220,000	$85,000	*1*
Site H3 – Tollgate Marketplace Outfall							
1.5	1.8	-----	0.6	$65,000	$70,000	$225,000	*7*
Site H4 – Tollgate Road Outfall							
0.4	0.5	0.4	0.5	$80,000	$100,000	$200,000	*5*
Site H5 – Ring Factory Elementary School							
0.7	0.8	0.7	0.8	$75,000	$135,000	$140,000	*3*
Site H6 – Barrington Place Outfall							
0.7	0.8	0.1	0.8	$80,000	$110,000	$210,000	*6*
Site H7 – Barrington Village Court and Rollins Court Outfalls							
1.1	1.3	0.1	1.3	$80,000	$150,000	$165,000	*4*
Totals							
28.5	34.1	2.2	8.9	$560,000	$895,000	---	---
Total Cost		11.1		$1,455,000			

* Target WQ_V is based on drainage area and impervious area contributing to each proposed BMP and is calculated based on the Maryland 2000 Stormwater Design Manual. Target Cp_V was computed as 1.2 x WQ_V.



BMP - NEW (N)

BMP - RETROFIT (R)

Watershed Segment Boundary

Sub-watershed Boundary

Hydro Line

Swale / Piped System

Study Point

Unstable Stream Reaches

Low Instability

Moderate Instability

High Instability

1,100 550 0 1,100 2,200 Feet

NOTES:
1. IMAGERY FROM HARFORD COUNTY 2007 AERIAL PHOTOGRAPHY.
2. WATERSHED BASED ON HARFORD COUNTY DELINEATION. REFINED BY BAYLAND CONSULTANTS BASED ON TOPOGRAPHY AND FIELD INVESTIGATION.
3. SUBWATERSHEDS DELINEATED BY BAYLAND CONSULTANTS.
4. IMPERVIOUS SURFACE COMPILED BY BAYLAND CONSULTANTS USING 2008 HARFORD COUNTY GIS DATA.
5. HYDRO LAYER REFINED IN THE FIELD TO INDICATE SWALE/PIPED SYSTEMS BY CLEAR CREEKS CONSULTING DECEMBER 2009.

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Plumtree Run Watershed Assessment High Priority BMP Sites

Figure 5.12

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Chapter 6 Stream Restoration Strategies

I. Introduction

As presented previously, Harford County Department of Public Works, Water Resources Engineering Division intends to restore the Plumtree Run watershed. These objectives will be accomplished by implementing an effective, long-term watershed restoration plan that includes implementation of stormwater best management practices identified in the following section and implementation of the stream restoration measures identified in this section of the report. These strategies focus on managing the quantity and quality of stormwater runoff from the watershed and stabilizing unstable slopes and stream reaches along Plumtree Run and its tributaries that are the principal source of sediment to the Atkisson Reservoir.

II. Stream Restoration

A. General Comments on Approaches to Restoration Design

Often restoration projects are exercises in treating symptoms rather than an effective effort at finding a solution for what caused or is maintaining an unstable situation. The traditional restoration effort is project-oriented rather than system- or process-oriented. The project-oriented approach focuses on the obvious eroding stream banks or aggrading streambeds, and flood waters overtopping stream banks. It fails to recognize the natural processes that shape and maintain stream channels, the interactions between the channel and adjacent riparian areas, and how these processes and interactions are affected by channel and floodplain maintenance practices and land use in the watershed.

The traditional approach is commonly associated with engineered channels, that is, a relatively straight, wide, trapezoidal channel, with a uniform profile designed to convey all flows (baseflow, bankfull flow, and flood flow). The channel banks are often armored with rip-rap or gabions (concrete revetment in more urbanized areas) in an effort to maintain this engineered form, and grade control structures may be installed to maintain bed stability. This engineered approach invites long-term problems due to the negative feedback mechanisms inherent in all stream systems.

A geomorphic approach to restoration utilizing natural stability concepts is recommended for stream restoration projects in the Plumtree Run watershed. This approach is system-oriented and works with, rather than against, the natural processes that shape and maintain stream channels. Restoration efforts are focused on: restoring a stable, self-maintaining channel form; reestablishing the critical interactions between the stream and adjacent riparian areas; restoring the natural functions of floodplains; modifying channel and floodplain maintenance practices that are inconsistent with these objectives; and minimizing the effects of land use by installing stormwater controls, and adopting land use controls throughout the watershed that are based on landscape capabilities.

This approach also recognizes that natural streams are composed of three distinct channels: a thalweg or low flow channel; a bankfull channel; and a floodplain, which conveys flows greater than bankfull. Finally, this approach emphasizes bio-engineered stream bank stabilization techniques that utilize natural materials (e.g., rootwads, logs, boulders, etc.) and live plantings.

The next few pages include schematic drawings of channel stabilization techniques and examples of projects that were designed utilizing a natural channel design approach and specific techniques that are directly applicable to the stability problems identified along Plumtree Run and its tributaries.

GRADE CONTROL STRUCTURES

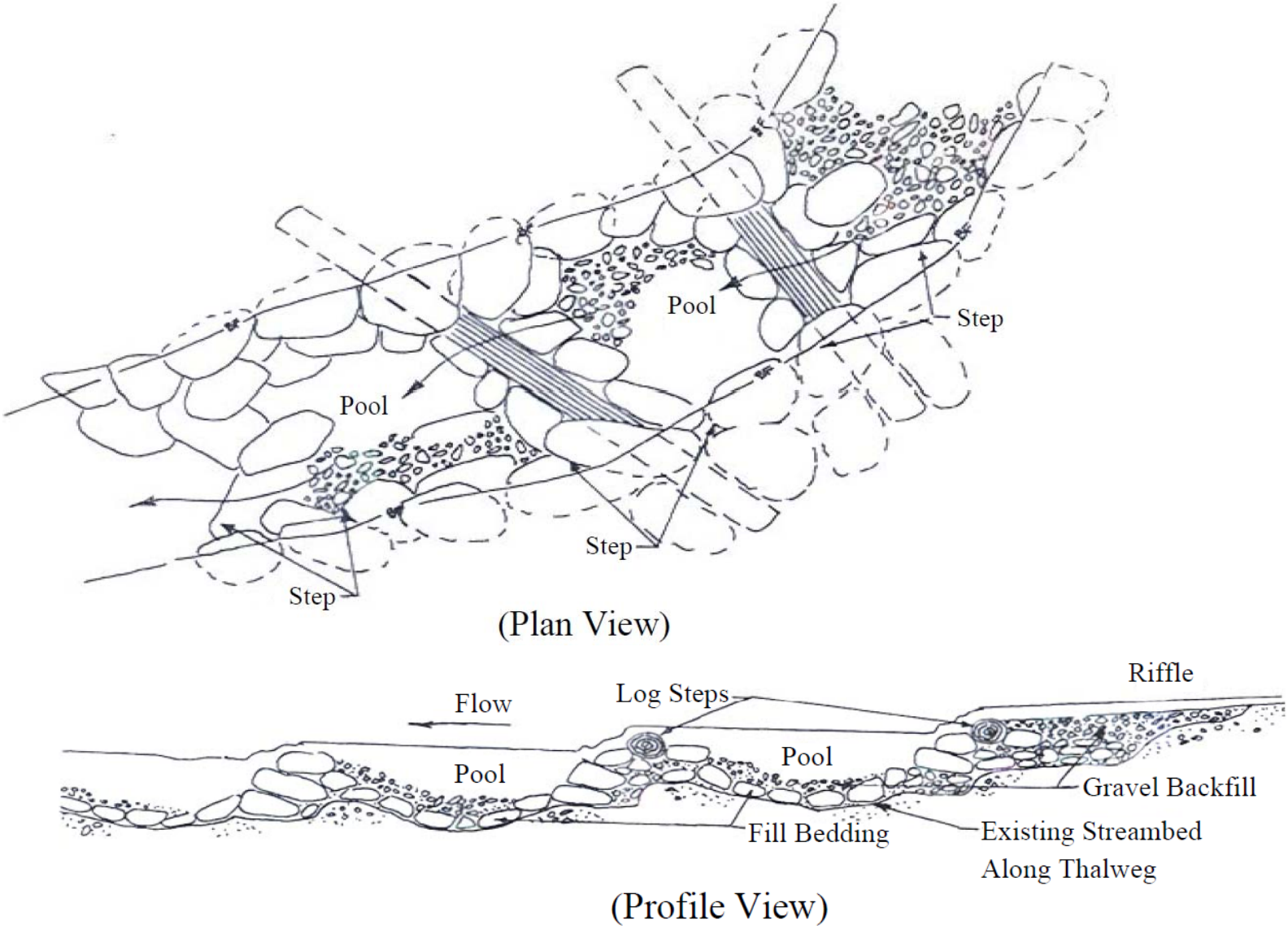


Figure 6.1 – Log/Boulder Step-Pools

GRADE CONTROL STRUCTURES

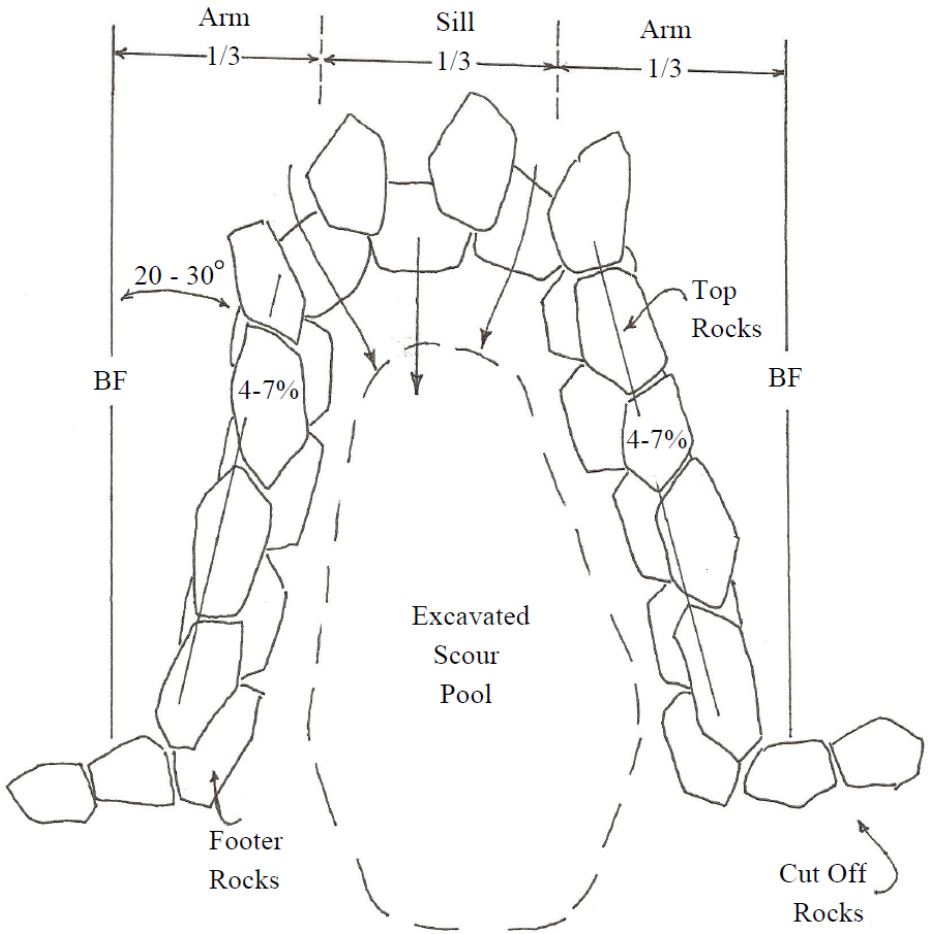


Figure 6.2 – Cross Vane

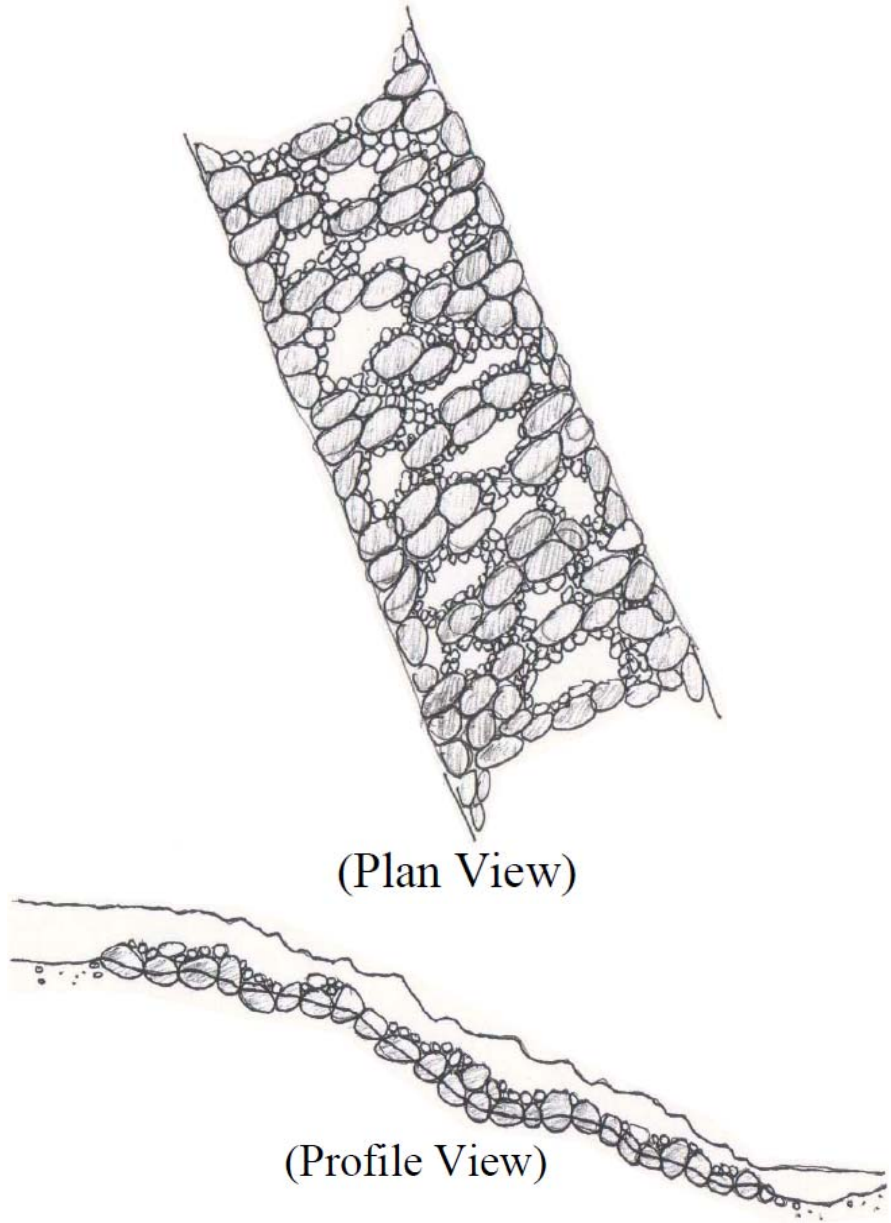


Figure 6.3 – Boulder Cascade

FLOW DIVERSION STRUCTURES

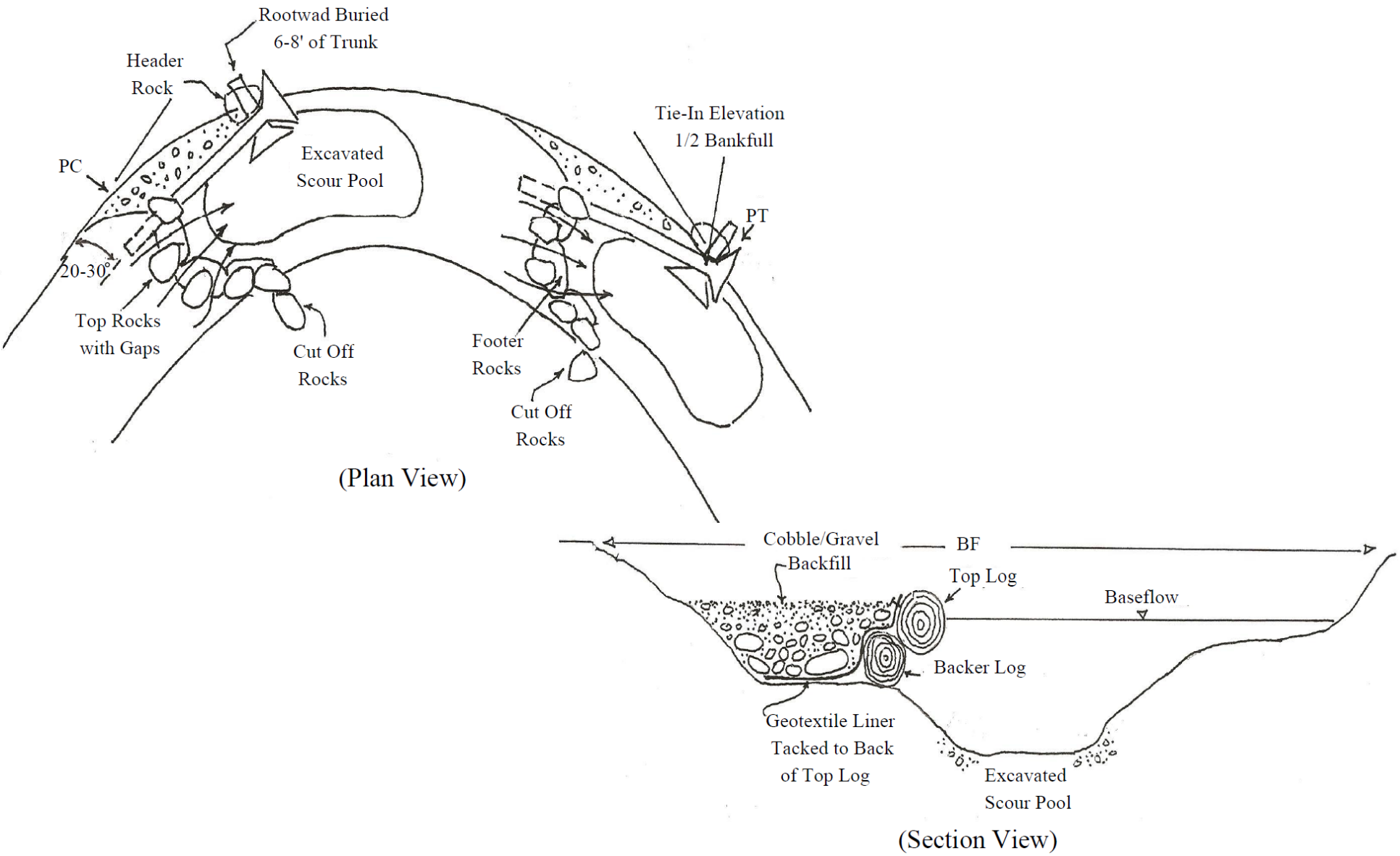


Figure 6.4 – Log Boulder J-Hook

FLOW DIVERSION STRUCTURES

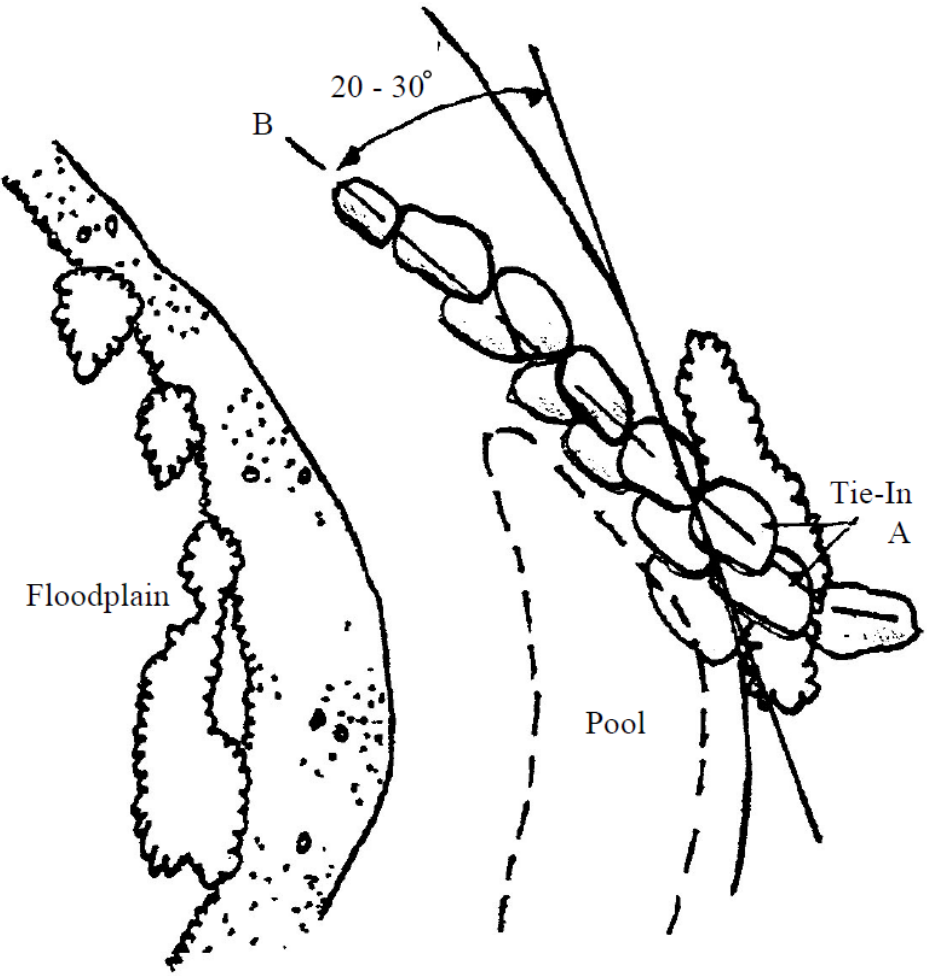


Figure 6.5 – Rock Vane

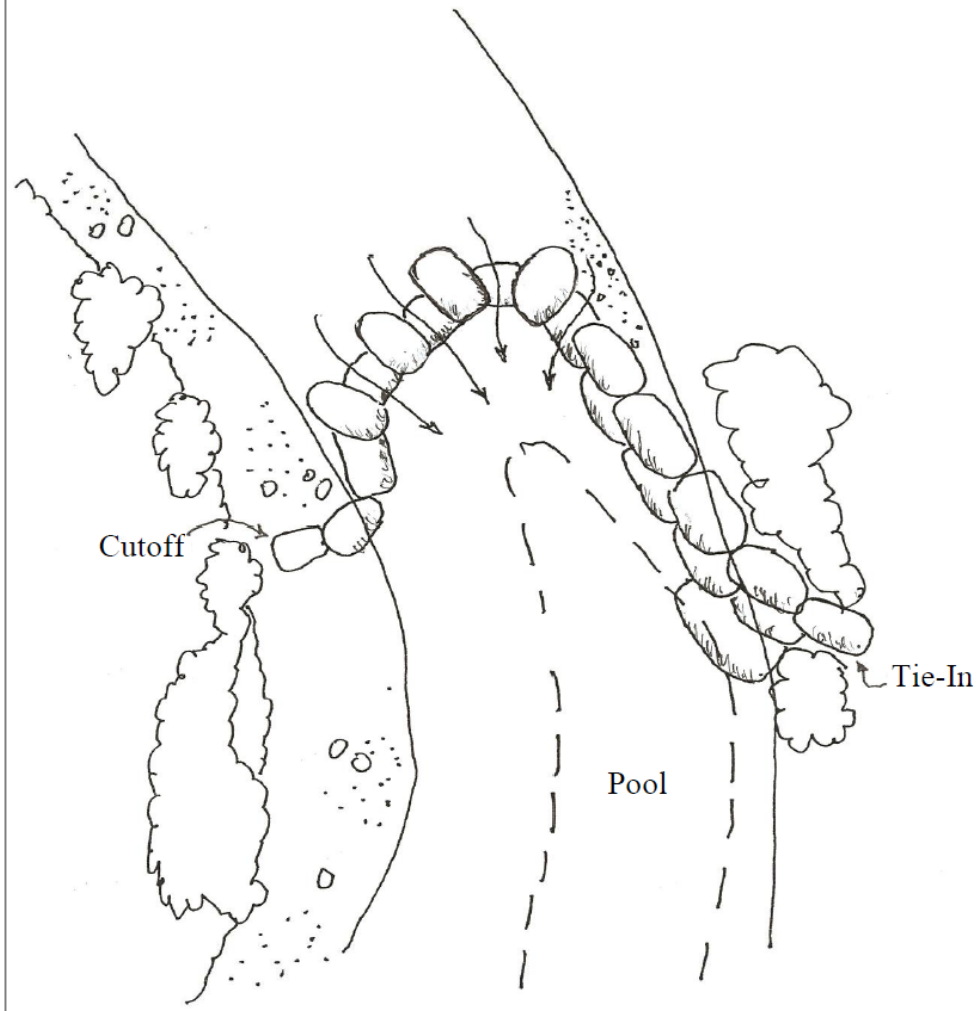


Figure 6.6 – Boulder J-Hook

BANK RECONSTRUCTION/STABILIZATION STRUCTURES

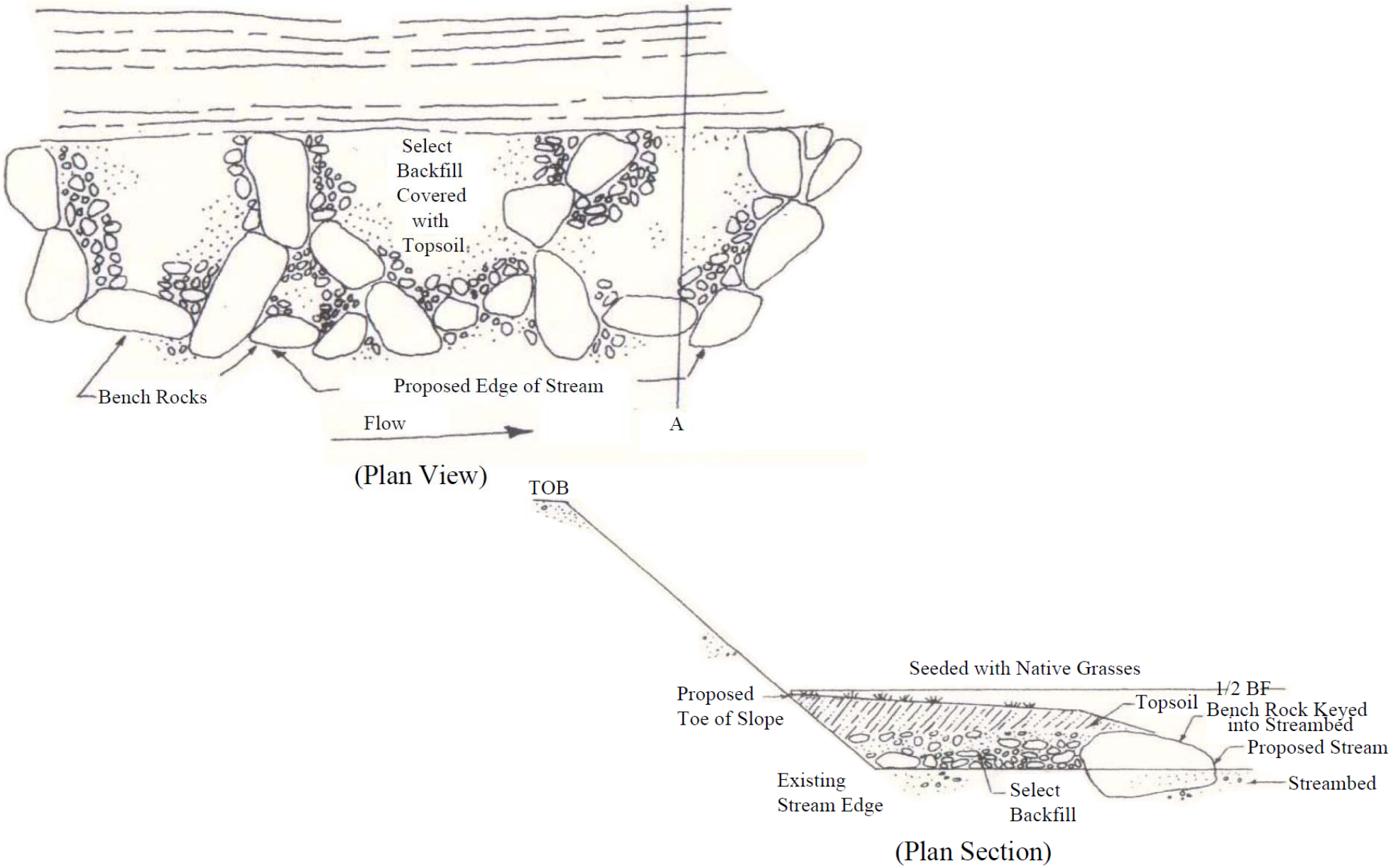


Figure 6.7 – Toe Benches

BANK RECONSTRUCTION/STABILIZATION STRUCTURES

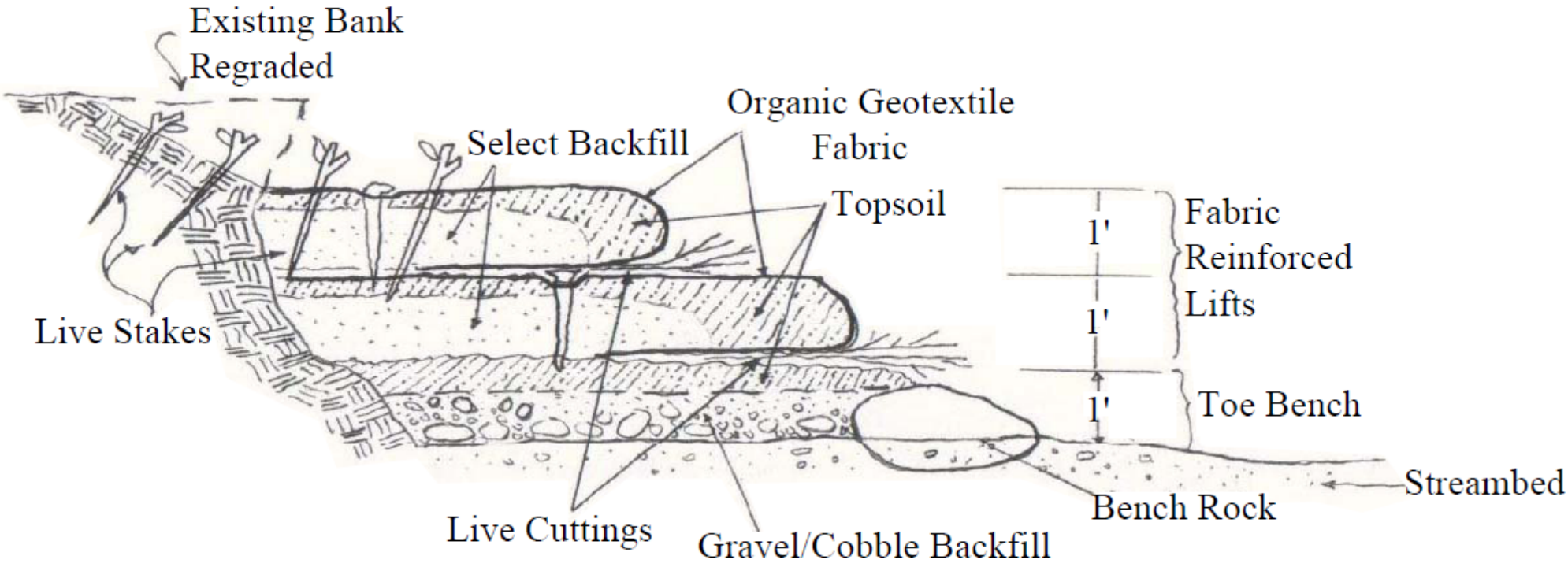


Figure 6.8 – Toe Benches and Soil Fabric Lifts

BANK STABILIZATION STRUCTURES

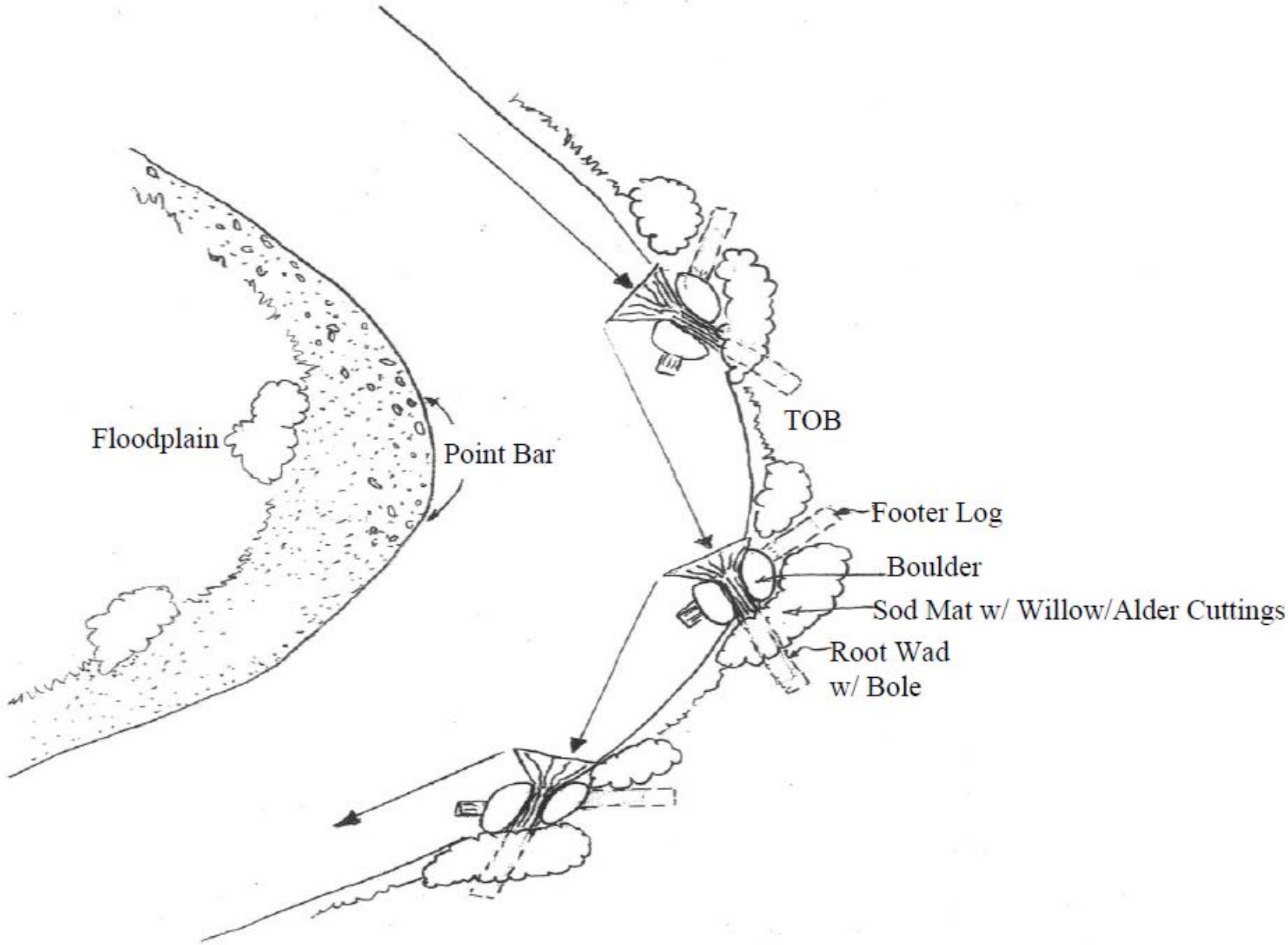


Figure 6.9 – Rootwad Revetment

BANK RECONSTRUCTION/STABILIZATION STRUCTURES

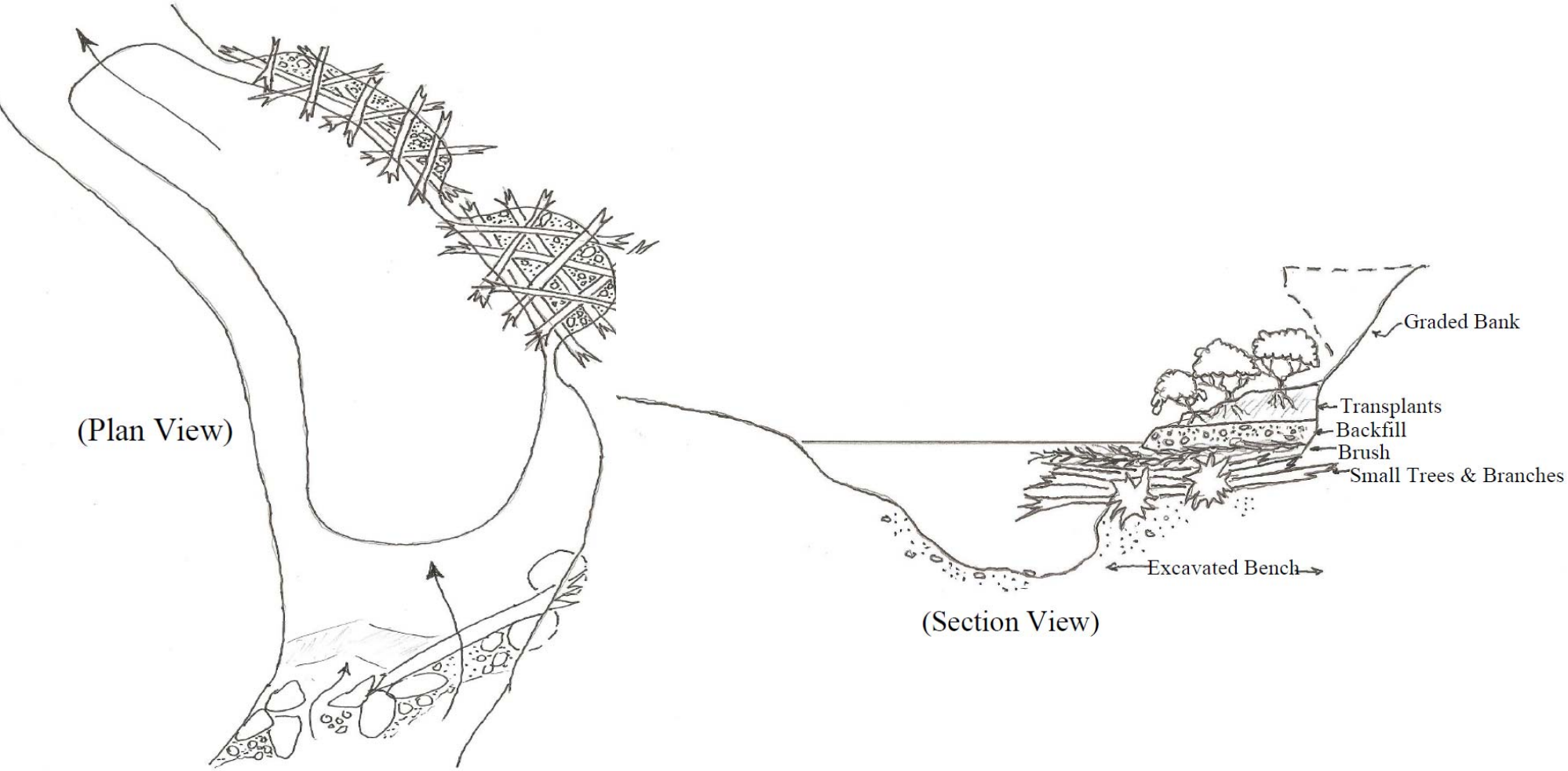
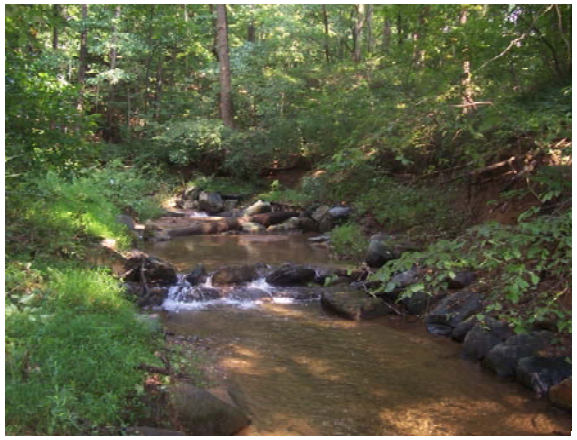


Figure 6.10 – Toe Wood Revetment

NATURAL CHANNEL DESIGN PROJECTS

(a) Unstable stream reach

(b) Same reach immediately after stabilization with log/boulder step-pools and toe benches. Note bank trees not disturbed during construction



(c) Seven years after restoration

(a) Unstable stream reach

(b) Same reach during installation of soil fabric lifts

(c) Four years after restoration

NATURAL CHANNEL DESIGN PROJECTS

(a) Unstable stream reaches

(b) Same reaches six months after restoration with log/boulder step-pools

NATURAL CHANNEL DESIGN PROJECTS

(a) Unstable reach

(b) Four months after restoration with toe benches. Note channel has been narrowed significantly.

(c) Three years after restoration

NATURAL CHANNEL DESIGN PROJECTS

(a) Unstable reach

(b) Same reach six months after restoration with toe benches and soil fabric lifts

NATURAL CHANNEL DESIGN PROJECTS

(a) Unstable reach

(b) Same reach four months after restoration with toe benches and soil fabric lifts. Note channel has been shifted away from failing slope and narrowed.

(c) Three years after restoration

NATURAL CHANNEL DESIGN PROJECTS

(a) Unstable reach

(b) Same reach one year after restoration. Note channel narrowed and constructed riffle and log-boulder J-Hook installed to provide vertical and lateral control

NATURAL CHANNEL DESIGN PROJECTS

(a) Unstable reach

(b) Same reach one year after restoration. Note channel narrowed and bank reconstructed with toe wood to provide lateral control

NATURAL CHANNEL DESIGN PROJECTS

(a) Unstable reach

(b) Same reach one year after restoration. Note meander bends smoothed, channel narrowed and constructed riffle and log-boulder J-Hook installed to provide vertical and lateral control.

III. Stream Restoration Measures for Plumtree Run Watershed

A. Identifying and Prioritizing Potential Stream Restoration Projects

A comprehensive analysis was conducted to identify and prioritize potential restoration projects.

The first part of this process was relatively straightforward and utilized the results of the stream reach ranking. A total of 55 stream reaches were evaluated. Those stream reaches determined to be unstable were set aside for further evaluation and ranking. For those stream reaches that had been determined to be moderately stable, that is generally stable but with minor and localized erosion or sedimentation, the unstable sections of those reaches were included in the evaluation. Stream reaches that had been determined to be stable, were not evaluated further.

Ranking the unstable stream reaches involved using a channel evolution model to determine whether the current conditions along a given unstable reach indicated it was evolving towards greater stability or greater instability. In addition, it considered whether existing or future channel conditions could affect public safety, damage public infrastructure, and/or damage private and public property. Using the evaluation criteria unstable stream reaches were categorized into Very Low, Low, Moderate and High categories related to degree of instability. The unstable stream reaches were then ranked in descending order from highest to lowest degree of instability.

Several of the reaches that ranked very low were eliminated during the first round of the evaluation. It was assumed that conditions along the remaining stream reaches warranted some level of intervention and further consideration as potential restoration projects. The feasibility of implementing specific restoration projects at the selected problem sites was evaluated. This included a planning level, qualitative analysis used to screen the projects for ease of implementation, project cost and long-term maintenance, and landowner acceptance.

Ease of implementation was based on consideration of issues such as construction access (e.g., distance from public roads, terrain that must be traversed and/or vegetation that must be avoided, etc.), availability of staging and stockpile areas, special equipment and/or material needs, natural constraints (e.g., valley confinement, clay and bedrock channels, outcroppings along hill slopes, unusually high banks along terraces, etc.), and man-made constraints (e.g., location of infrastructure – roads, bridges and culverts, utility lines, and structures – parking lots, commercial buildings, residences, sheds, etc.)

Capital costs were based on consideration of the initial costs of installing a particular restoration measure. Long-term maintenance was based on two inter-related issues: the probability of problems requiring maintenance developing over the long-term and the degree of intervention required to correct the problems if they developed. More

complex problems and solutions were considered to have a higher probability of future problems developing.

Landowner acceptance was based on anticipated reactions to proposed restoration measures. The analysis did not disregard potential concerns (e.g., restrictions on land use, long-term maintenance, etc). However, it also considered the likelihood that landowners would ultimately view a project as beneficial and worth implementing in spite of these concerns.

Table 6.1 shows the ranking relative to degree of instability and stream length for those stream reaches for which potential restoration projects were determined to be feasible.

Table 6.1 – Potential Restoration Reaches

Ranking	Subshed/Reach	Length	Ranking	Subshed/Reach	Length
1	15MS	1,500	19	2MTrib	400
2	17MS	550	20	11LTrib	1,350
3	22MS	1,550	21	1MMS	938
4	6MS	1,000	22	1LMS	650
5	3MS	800	23	7Trib	350
6	19Trib	725	24	13UTrib	225
7	20Trib	2,400	25	10LMS	150
8	16UTrib	1,025	26	14MS	150
9	5Trib	700	27	10UMS	400
10	10MMS	563	28	24MS	850
11	1Trib	338	29	25UMS	600
12	17UMTrib	915	30	25LMS	900
13	23Trib	2,400	31	25Trib1	300
14	17LMTrib	915	32	17LTrib	425
15	18UMS	450	33	22Trib	175
16	9MS	650	34	2UTrib	225
17	16LTrib	625	35	14Trib2	100
18	13LTrib	100	36	10Trib1	100

Given the number and type of problems identified along these stream reaches, it was considered critical that some additional guidance be provided to focus available funding and resources where they will provide the most benefit.

Harford County DPW generally implements stream stabilization and restoration projects utilizing one of two contracting procedures. Small scale projects may be implemented by County Highway crews or under On-Call Design-Build contracts. Typical small scale projects are 50 – 350 LF in length and include stabilization of storm drain outfalls, stabilization of approaches to culverts and bridges, and localized streambank stabilization. Large scale projects are usually implemented as individual

competitive bid capital improvement projects. Typical large scale projects are 1,000 – 3,500 LF in length and include channel reconstruction and streambank stabilization along significant sections of channel.

As shown in Table 6.1 the 36 stream reaches identified as potential restoration projects vary in length from 100 – 2,400 LF. Only six reaches are greater than 1,000 LF in length. Twenty reaches are from 350 – 1,000 LF in length and eight reaches are less than 350 LF.

The cost of restoration can vary considerably from project to project. The differences are generally due to differences in the size of the project, the severity of the problems and the level of intervention needed to correct the problems, and site constraints that limit implementation of design criteria. Every project requires a given minimum level of assessment, design and permitting work. Although, small projects involving minor bank reshaping and plantings over a short length of channel generally require less assessment, design, and permitting effort and are easier to construct, there is a definite economy of scale associated with larger projects.

Therefore, the final phase of identifying restoration projects involved combining stream reaches selected from the 36 potential restoration reaches. The objective was to identify reaches that could logically be combined to form projects of 1,000 – 3,500 LF in length. As a result 30 stream reaches were combined to form ten large scale projects of 1,350 – 3,650 LF in length. Six of the remaining stream reaches stand as individual small scale projects of 100 – 350 LF in length.

Figure 6.11 shows the location of the ten large scale projects and Table 6.2 shows the restoration projects ranked in order of priority from highest to lowest. A brief description related to the existing conditions, as well as recommended restoration measures is included.

The projects listed here do not include the Best Management Practice (BMP) facilities outlined in the Stormwater Management Plan Section of the report. However, successful implementation of the channel restoration and stabilization projects is greatly increased when upstream stormwater BMP facilities are installed to control peak flows and improve water quality conditions. Controlling the peak flows is critical to the long-term success of the stream restoration projects.

Table 6.2 – Plumtree Run Large Scale Stream Restoration/Stabilization Projects			
Project ID (Stream Reaches)	**Length (feet)**	**Existing Problems**	**Proposed Solutions**
Project-1 (14MS, 14Trib2, 15MS, 17MS, 18UMS)	2,750	14MS - DS Route 24 – 150 LF - bank erosion, SHA collapsed and fence blocking channel; 14Trib2 – 100 LF - active head-cut, incised, bank erosion; 15MS – 1,500 LF – Severe lateral erosion, high banks at rear of residences slumping, large debris jams and aggradation; 17MS – 550 LF - Severe bank erosion, undercut and fallen trees, debris jams and significant aggradation throughout; 18UMS – 450 LF - aggradation, backwater due to crossing, head-cut along slope caused by SWM pond outfall	14MS – Grade and stabilize eroding streambanks; modify SHA fence to reduce potential for future debris jams; install flow diverting structures for lateral control; plant with native trees and shrubs. 14Trib2 - Grade and stabilize eroding streambanks; install grade control structure to stabilize head-cut; plant with native trees and shrubs. 15MS – 17MS – Remove debris jams; grade and stabilize eroding streambanks throughout; shift channel away from high terrace/banks along residential area in 15 and Route 24 in 17; narrow channel in over-wide sections to improve sediment transport; install flow diverting structures for lateral control; plant with native trees and shrubs. 18UMS - narrow channel in over-wide sections to improve sediment transport; shift channel away from high terrace where SWM pond is located, install flow diverting structures for lateral control; stabilize head-cut along outfall channel from SWM pond; plant with native trees and shrubs.
Project 2 (3MS, 6MS, 5Trib, 1Trib)	2,838	3MS – 800 LF - Severe bank erosion, aggradation, debris jams, two old meander cutoff channels;	3MS – DS section has been identified as a potential SWM BMP site. BMP implementation will reduce restoration length. Remove debris jams; grade and stabilize eroding streambanks throughout; backfill old meander cutoff channels; narrow channel in over-wide sections to improve sediment transport; install flow diverting structures for lateral control; plant with native trees and shrubs.

Project ID Stream Reaches	Length (feet)	Existing Problems	Proposed Solutions
Project 2 (cont'd)		6MS – 1,000 LF - Severe bank erosion, aggradation, debris jams throughout, exposed utilities 5Trib – 700 LF – UPS – Deeply incised, multiple large headcuts, slumping banks, undercut and failing SD outfalls; Middle – stable, DS – bank erosion, failing SWM outfall 1Trib – 338 LF – UPS – Deeply incised, multiple headcuts, slumping banks	6MS – Remove debris jams; grade and stabilize eroding streambanks throughout; shift channel away from exposed utilities; narrow channel in over-wide sections to improve sediment transport; install flow diverting structures for lateral control; plant with native trees and shrubs. 5Trib – UPS section has been identified as a potential SWM BMP site. BMP implementation will reduce restoration length. Reconstruct channel through UPS gully section with boulder step-pools; grade and stabilize eroding streambanks; plant with native trees and shrubs. DS – grade and stabilize eroding streambanks throughout; plant with native trees and shrubs; reconstruct failing SWM outfall 1Trib – UPS section has been identified as a potential SWM BMP site. BMP implementation will replace channel restoration. Reconstruct channel through UPS gully section with boulder step-pools; grade and stabilize eroding streambanks; plant with native trees and shrubs.
Project 3 (22MS and 23Trib)	3,650	22MS – 1,550 LF – Severe bank erosion at rear of residences, debris jams and aggradation;	22MS – Remove debris jams; grade and stabilize eroding streambanks throughout; narrow channel in over-wide sections to improve sediment transport; install flow diverting structures for lateral control; plant with native trees and shrubs;

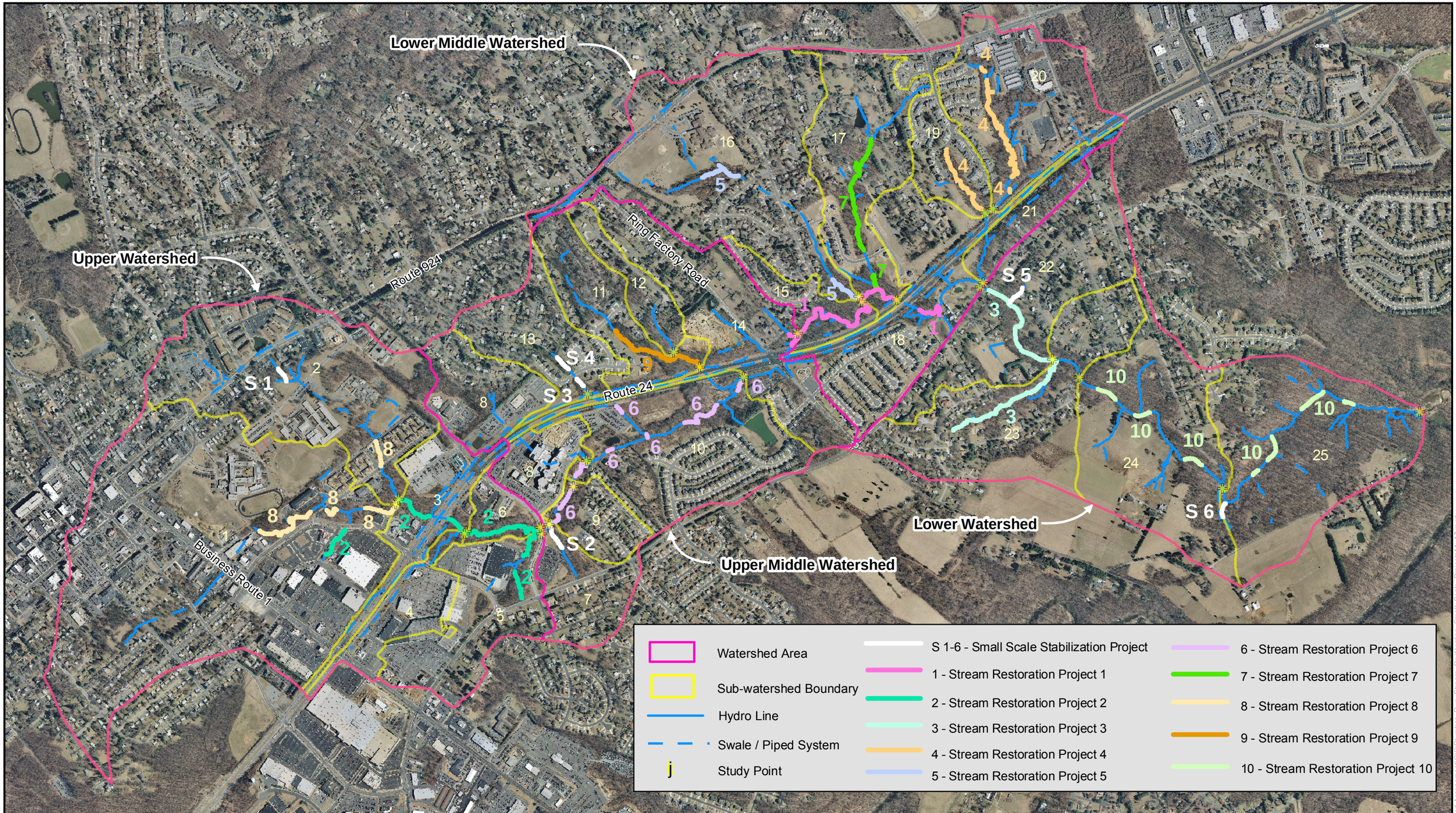
Project ID Stream Reaches	Length (feet)	Existing Problems	Proposed Solutions
Project 3 (cont'd)		23Trib – 2,400 LF – UPS - Severe gully erosion at SD outfall, landowners installing boulders and sheet piling for grade control, Middle and DS - Severe bank erosion, debris jams and aggradation throughout	23Trib - Reconstruct channel through UPS gully section with boulder step-pools; grade and stabilize eroding streambanks. DS – remove debris jams; grade and stabilize eroding streambanks throughout; reconstruct channel through avulsion section; plant with native trees and shrubs along all sections.
Project 4 (19Trib and 20Trib)	3,125	19Trib - Old pond embankment at upstream end, multiple headcuts and lateral erosion throughout; failing storm drain outfalls undercut by gully erosion; large headcuts at downstream end near SHA SWM pond; 20Trib – 2,400 LF - UPS and middle– multiple old ponds, multiple collapsing sinkholes, multiple head-cuts, failing storm drain and SWM pond outfalls undercut by gully erosion; severe bank erosion, undercut and fallen trees, severe meander bends with lateral migration, large debris jams and aggradation throughout, DS – E4 with aggradation - SHA fence blocking downstream end	19Trib – UPS section has been identified as a potential SWM BMP site. BMP implementation will reduce restoration length. Install grade control structures to stabilize head-cuts; grade and stabilize eroding streambanks throughout; reconstruct failing storm drain outfalls with boulder step-pools. DS – reconstruct gully section near SHA SWM pond with step-pools; grade and stabilize eroding streambanks throughout; plant with native trees and shrubs along all sections. 20Trib – UPS section has been identified as a potential SWM BMP site. BMP implementation will reduce restoration length. UPS – Grade and stabilize slopes to eliminate sinkholes and general instability; construct retaining walls with stormwater runoff routed through drop manholes at rear of commercial properties; install grade control structures to stabilize head-cuts; grade and stabilize eroding streambanks throughout; reconstruct SWM pond outfall with step-pools. Middle section – Remove debris jams; reconstruct channel with a stable meander geometry; shift channel away from terrace; install grade control and flow diverting structures for vertical and lateral control; plant with native trees and shrubs along all sections. DS – Modify SHA fence to reduce potential for future debris jams.

Project ID Stream Reaches	Length (feet)	Existing Problems	Proposed Solutions
Project 5 (16UTrib and 16LTrib)	1,650	16UTrib – 1,025 LF – UPS and Middle - Bank erosion undercut and fallen trees; multiple headcuts & severe gully erosion at outfall to SWM pond - rear of elementary school; 16LTrib – 625 LF - DS – Lateral erosion and debris jams throughout	16UTrib – The SWM ponds at the elementary school have been identified as a potential SWM BMP retrofit sites. BMP implementation will not affect restoration length. Install grade control structures to stabilize head-cuts; grade and stabilize eroding streambanks throughout; reconstruct failing storm drain outfalls with boulder step-pools; plant with native trees and shrubs along all sections. 16LTrib – Remove debris jams; grade and stabilize eroding streambanks throughout; plant with native trees and shrubs along all sections.
Project 6 (9MS, 10UMS, 10MMS, 10LMS, 10Trib2)	1,863	9MS – 650 LF – Severe bank erosion, aggradation, large debris jams; head-cuts at side drainage 10UMS – 400 LF – UPS – Localized bank erosion, aggradation, chute-cutoff forming 10MMS – 563 LF – Middle and DS – Severe bank erosion, debris jams aggradation, chute-cutoff forming, exposed utilities 10LMS – 150 LF – Bank erosion, exposed utilities 10Trib1 – UPS – Outfall at Rte 24, incised with bank erosion near outfall, DS – Head-cut at confluence	9MS – Remove debris jams; grade and stabilize eroding streambanks throughout; stabilize headcuts at side drainage with boulder step-pools; plant with native trees and shrubs. 10UMS – Reconstruct meander bend to eliminate chute-cutoff channel; grade and stabilize eroding streambanks throughout; plant with native trees and shrubs. 10MMS – Remove debris jams; reconstruct channel with a stable meander geometry; shift channel away from banks with exposed utilities; narrow channel in over-wide sections to improve sediment transport; install grade control and flow diverting structures for vertical and lateral control; plant with native trees and shrubs. 10LMS – Shift channel away from banks with exposed utilities; install grade control and flow diverting structures for vertical and lateral control; plant with native trees and shrubs. 10Trib1 – Stabilize outfall at Rte 24 and head-cut at confluence

Project ID Stream Reaches	Length (feet)	Existing Problems	Proposed Solutions
Project 7 (17UMTrib, 17LMTrib, 17LTrib)	2,255	17UMTrib – 915 LF - DS – Incised with multiple severe head-cuts, bank erosion, Gullies at rear of residences 17LMTrib – 915 LF - UPS – Incised with severe bank erosion, Mid – Stable E4 transitioning to unstable E4 and D4 – significant aggradation and multiple active head-cuts, DS – bank erosion 17LTrib - DS – Incised with bank erosion, head-cut at Outfall channel from SWM pond	17UMTrib – Reconstruct channel at upstream head-cut with boulder step-pools; grade and stabilize eroding streambanks throughout; reconstruct gully at rear of residence with boulder step-pools; grade and stabilize eroding streambanks throughout; plant with native trees and shrubs along all sections. 17LMTrib – UPS - Grade and stabilize eroding streambanks throughout; Middle section – reconstruct stable E4 channel through existing D4 section; Install grade control structures to stabilize head-cuts; DS - grade and stabilize eroding streambanks throughout; plant with native trees and shrubs along all sections. 17LTrib - Grade and stabilize eroding streambanks throughout; Install grade control structures to stabilize head-cuts; plant with native trees and shrubs along all sections
Project 8 (1MMS, 1LMS, 2MTrib)	1,988	1MMS – 938 LF - Bank erosion, aggradation, debris jams, chute-cutoff forming 1LMS – 650 LF - Bank erosion, aggradation, debris jams, old meander cutoff 2MTrib – 400 LF - Bank erosion, undercutting SD outfalls and adjacent parking lot	1MMS - UPS section has been identified as a potential SWM BMP site. BMP implementation will reduce restoration length. Remove debris jams; grade and stabilize eroding streambanks throughout; reconstruct meander bends to eliminate chute-cutoff channels; shift channel away from terrace and SWM pond; reconstruct SWM pond outfall to tie-in to new channel; stabilize all storm drain outfalls; install grade control and flow diverting structures for vertical and lateral control; plant with native trees and shrubs along all sections.

Project ID Stream Reaches	Length (feet)	Existing Problems	Proposed Solutions
Project 8 (cont'd)			1LMS - Remove debris jams; grade and stabilize eroding streambanks throughout; backfill old meander cutoff; shift channel away from terrace; stabilize all storm drain outfalls; install grade control and flow diverting structures for vertical and lateral control; plant with native trees and shrubs along all sections. 2MTrib – Grade and stabilize eroding streambanks throughout; backfill old meander cutoff; shift channel away from parking lot; stabilize all storm drain outfalls; install grade control and flow diverting structures for vertical and lateral control; plant with native trees and shrubs along all sections.
Project 9 (11LTrib)	1,350	Multiple small headcuts, lateral erosion and debris jams along rear yards of residences	Grade and stabilize eroding streambanks throughout; Install grade control structures to stabilize head-cuts; plant with native trees and shrubs along all sections
Project 10 (24MS, 25UMS, 25LMS)	1,750	24MS – 850 LF - Minor aggradation and localized bank erosion, large debris jams 25UMS – 600 LF - Minor aggradation and localized bank erosion, channel eroding high terrace; large debris jams 25LMS – 900 LF – UPS - Bank erosion, large debris jams and aggradation; DS – aggradation due to backwater from reservoir	24MS - Remove debris jams; grade and stabilize eroding streambanks; narrow channel in over-wide sections to improve sediment transport; install flow diverting structures for lateral control. 25UMS - Remove debris jams; grade and stabilize eroding streambanks; narrow channel in over-wide sections to improve sediment transport; shift channel away from high terrace; install flow diverting structures for lateral control

Project ID Stream Reaches	Length (feet)	Existing Problems	Proposed Solutions
Project 10 (cont'd)			25LMS – The aggradation due to the backwater from reservoir cannot be changed. However, streambanks adjacent to outdoor classroom should be stabilized and footbridge relocated to a point upstream where banks are higher to allow floodwaters to pass beneath structure without damaging it.
Plumtree Run Total	23,219		



NOTES:
1. IMAGERY FROM HARFORD COUNTY 2007 AERIAL PHOTOGRAPHY.
2. WATERSHED BASED ON HARFORD COUNTY DELINEATION, REFINED BY BAYLAND CONSULTANTS BASED ON TOPOGRAPHY AND FIELD INVESTIGATION.
3. SUBWATERSHEDS DELINEATED BY BAYLAND CONSULTANTS.
4. IMPERVIOUS SURFACE COMPILED BY BAYLAND CONSULTANTS USING 2008 HARFORD COUNTY GIS DATA.
5. HYDRO LAYER REFINED IN THE FIELD TO INDICATE SWALE/PIPED SYSTEMS BY CLEAR CREEKS CONSULTING DECEMBER 2009.

1,100 550 0 1,100 2,200
Feet

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Plumtree Run Watershed Assessment Stream Restoration Projects and Small Scale Stabilization Projects

Figure 6.11

B. Preliminary Cost Estimates

Table 6.3 below provides preliminary cost estimates for design, permitting and construction of the stream restoration/stabilization projects presented in this study.

Design and Permitting Cost includes: consultant professional fees for surveying, base map preparation, stream assessment, hydrology and hydraulic analysis, final design plans and construction documents, engineer's certification, and permit application and agency meetings.

Construction Cost includes: contractor mobilization, clearing and grubbing, construction stakeout, sediment control and dewatering, earthwork, rock for and installation of in-stream structures, erosion control matting, seeding and mulching, and landscaping. It does not include: consultant professional fees for geotechnical studies, on-site construction management, or as-built surveys.

Table 6.3 – Plumtree Run Stream Restoration Projects Design and Construction Cost Estimates

Project ID	Type Project	Project Length (feet)	Design and Permitting Cost	Construction Cost
Project 1	Stream Restoration	2,750	$206,250	$618,750
Project 2	Stream Restoration	2,838	$212,850	$638,550
Project 3	Stream Restoration	3,650	$273,750	$821,250
Project 4	Stream Restoration	3,125	$234,375	$703,125
Project 5	Stream Restoration	1,650	$123,750	$371,250
Project 6	Stream Restoration	1,863	$139,725	$419,175
Project 7	Stream Restoration	2,255	$169,125	$507,375
Project 8	Stream Restoration	1,988	$149,100	$447,300
Project 9	Stream Restoration	1,350	$101,250	$303,750
Project 10	Stream Restoration	1,750	$131,250	$393,750
Total Projects		22,719	$1,741,425	$5,224,275
Total Cost			$6,965,700	

It is recommended that at a minimum, Harford County DPW implement those large scale projects with the highest potential for continued instability. These include Projects 1 – 5, which make up 60% (14,013 LF) of the total unstable stream length prioritized for restoration. The County could correct the most significant problems for approximately $4,203,900.

The six small scale projects identified are particularly amenable to implementation under DPW On-Call Design-Build contracts. Table 6.4 shows the small project stream reaches, lengths, and a brief description of the existing conditions and recommended stabilization measures. These small scale projects are also shown in Figure 6.11.

Table 6.4 – Plumtree Run Small Scale Stabilization Projects

Project ID (Stream Reaches)	Length (feet)	Existing Problems	Proposed Solutions
Project SS-1 (13LTrib)	100	Incised, bank erosion, debris jams and aggradation, multiple small headcuts	Remove debris jams, grade and stabilize banks, install grade control to stabilize headcuts, plant with native trees and shrubs along all sections
Project SS-2 (7Trib)	350	Lower Middle and DS - G4 with multiple headcuts and lateral erosion	Grade and stabilize banks, install grade control to stabilize headcuts, plant with native trees and shrubs along all sections
Project SS-3 (13UTrib)	225	Mid – incised, with severe lateral erosion and headcuts,	Grade and stabilize banks, install grade control to stabilize headcuts, plant with native trees and shrubs along all sections
Project SS-4 (25Trib1)	300	Upper section rip-rapped, gully erosion debris jams to confluence	Remove debris jams, grade and stabilize banks, install grade control to stabilize headcuts, plant with native trees and shrubs along all sections
Project SS-5 (22Trib)	175	Bank erosion	Grade banks, install grade control, plant with native trees and shrubs along all sections
Project SS-6 (2UTrib)	225	Localized bank erosion, headcuts	Grade and stabilize banks, install grade control to stabilize headcuts, plant with native trees and shrubs along all sections

Chapter 7 Pollutant Load Analysis

I. Pre-project Annual Pollutant Loads

The Simple Method, developed by Schueler (1987), provides a reasonable level of accuracy for estimating pollutant loading for urban areas for stormwater runoff. This method was utilized to estimate the Pre-project annual pollutant loads for the Plumtree Branch Watershed, and for each of the Medium and High Priority BMP projects drainage areas. It requires several input parameters such as drainage area, amount of impervious coverage, annual precipitation, and pollutant concentrations to estimate the pollutant loading. The input concentrations can either be specific to the type of land use within the drainage area, or utilize more generalized pollutant concentrations for urban runoff. More generalized pollutant concentrations for urban runoff were selected to develop the annual pollutant load estimates for this study. Equation 1 list the Simple method of calculating annual pollutant loads (lbs/yr) and Table 7.1 lists the input parameters utilized in the simple method to develop the annual pre-project annual pollutant loads.

Equation 1: $L = [(P) (Pj) (Rv) / 12] (C) (A) (2.72)]$, where $Rv = [0.05 + (0.9 Ia)]$

Table 7.1 – Simple Method Annual Pollutant Loading Model Input Parameters

Parameter	Symbol	Input Value
Annul Precipitation (in/yr)	P	43.85
Fraction of Runoff Producing Events	Pj	0.9
Runoff Coefficient	Rv	Site Dependant
Drainage Area (Acres)	A	Site Dependant
Drainage Area Impervious (%)	Ia	Site Dependant
Mean Concentration of Total Phosphorous (mg/L)	C - TP	0.26
Mean Concentration of Total Nitrogen (mg/L)	C - TN	2.00
Mean Concentration of Total Suspended Solids (mg/L)	C - TSS	54.50

Table 7.2 delineates the total impervious area for the watershed by land use.

Table 7.2 – Plumtree Watershed Impervious Area by Land Use

Land Use	Amount (Acres)	Impervious (%)	Amount Impervious
2 Acre Residential	66.5	11	7.3
1 Acre Residential	223.5	14	31.3
1/2 Acre Residential	227.5	21	47.8
1/3 Acre Residential	82	25	20.5
1/4 Acre Residential	183	28	51.2
1/8 Acre Residential	93.5	33	30.9
Commercial	248.5	70	173.9

Table 7.2 – Plumtree Watershed Impervious Area by Land Use			
Land Use	**Amount (Acres)**	**Impervious (%)**	**Amount Impervious**
Industrial	77.5	56	43.4
Institutional	67.5	38	25.7
Open Space	28.5	9	2.6
Pasture	62	2	1.2
Roads	45.5	100	45.5
Woods	312	0	0
Total	**1,651**	**29**	**481**

Table 7.3 lists the annual pollutant loading for the watershed and the pre-project drainage areas. The drainage areas to existing BMPs (Retrofit Projects) do not take into account any pollutant removal achieved with the existing BMPs. The drainage area and impervious area for project, M3, were estimated based on a reasonable level of redevelopment for any new project associated with Bel Air Middle/Wake Field Elementary School.

Table 7.3 – Annual Pollutant Loading for Pre-project Drainage Areas						
Project ID	**Project Description**	**DA (Acres)**	**Imp. Area (%)**	**Amount Impervious**		
				TP (lbs/yr)	**TN (lbs/yr)**	**TSS (lbs/yr)**
WS	Plumtree Run Watershed	1651	29	1,244	9,572	260,858
M1	Retrofit - Convert Dry Detention Pond to Permanent Pool	38	70	62.6	481.8	13,127.7
M2	Retrofit- Convert Extended Detention Pond to Permanent Pool	8	38	7.6	58.5	1,593.2
M3	New Facility -Construct new facility under redevelopment regulations	5	50	6.1	46.6	1,270.1
M4	Retrofit - Convert Dry Detention Pond to Permanent Pool	10	38	9.5	73.1	1,991.5
M5	Retrofit - Enlarge existing wet pond facility	19	85	37.5	288.7	7,867.0
M6	Retrofit - Convert Dry Detention Pond to Permanent Pool	10	70	16.5	126.8	3,454.7
M7	Retrofit - Convert Dry Detention Pond to Permanent Pool	13.3	21	7.7	59.3	1,614.9
M8	Retrofit - Enlarge existing wet pond facility	99	30.6	78.1	600.6	16,366.3
M9	Retrofit - Convert Dry Detention Pond to Permanent Pool	43	21	24.9	191.6	5,221.1
M10	Retrofit - Convert Dry Detention Pond to Permanent Pool	7	21	4.1	31.2	849.9
H1	New Facility - Wet pond/Shallow Wetland	179	49	213.0	1,638.6	44,651.1
H2	New Facility - Wet pond/Shallow	402	50	487.2	3,747.4	102,115.9

Table 7.3 – Annual Pollutant Loading for Pre-project Drainage Areas						
Project ID	**Project Description**	**DA (Acres)**	**Imp. Area**	**Amount Impervious**		
	Wetland					
H3	New Facility - Wet pond/Shallow Wetland	25	72	42.3	325.3	8,865.3
H4	New Facility - Wet pond/Shallow Wetland	16	25	10.7	82.0	2,235.4
H5	Retrofit - Convert Dry Detention Pond to Permanent Pool Facility	23	35	20.3	156.5	4,265.0
H6	New Facility - Wet pond/Shallow Wetland	23	35	20.3	156.5	4,265.0
H7	New Facility - Wet pond/Shallow Wetland	28	48	32.7	251.6	6,856.5

II. Pollutant Removal Efficiencies and Load Reductions

Current stormwater best management practices pollutant removal efficiencies as detailed in Section 6 of the Chesapeake Bay Watershed Model Phase 5.3 were utilized to evaluate the potential pollutant load reductions that could be achieved with each of the proposed projects. Table 7.4 lists the Efficiency Effectiveness Estimate used for each of the existing and proposed BMPs.

Table 7.4 – Chesapeake Bay Watershed Model Phase 5.3: Pollutant Removal Efficiency Effectiveness Estimate			
Urban Best Management Practice	**Target Pollutant Removal Efficiencies**		
	TP (%)	**TN (%)**	**TSS (%)**
Wet Pond and Wetlands	30	50	80
Dry Detention and Hydrodynamic Structures	5	10	10
Dry Extended Detention Ponds	30	20	60

Pollutant Removal Efficiencies of retrofit upgrades to existing BMP structures were calculated by reducing the target pollutant removal efficiency by the pollutant removal efficiency of the type of facility already present. For new BMP sites, the target pollutant removal efficiencies were assigned as previously defined in Table 7.4. Table 7.5 lists the target removal efficiencies for each of the proposed stormwater BMP projects.

Table 7.5 – Target Pollutant Removal Efficiency for the Proposed Stormwater BMP Projects				
Project ID	**Project Description**	**Target Pollutant Removal Efficiencies**		
		TP (%)	**TN (%)**	**TSS (%)**
M1	Retrofit - Convert Dry Detention Pond to Permanent Pool	25	40	70
M2	Retrofit- Convert Extended Detention Pond to Permanent Pool	0	30	20
M3	New Facility -Construct new facility under redevelopment regulations	30	50	80
M4	Retrofit - Convert Dry Detention Pond to Permanent Pool	25	40	70
M5	Retrofit - Enlarge existing wet pond facility	30	50	80
M6	Retrofit - Convert Dry Detention Pond to Permanent Pool	25	40	70
M7	Retrofit - Convert Dry Detention Pond to Permanent Pool	25	40	70
M8	Retrofit - Enlarge existing wet pond facility	30	50	80
M9	Retrofit - Convert Dry Detention Pond to Permanent Pool	25	40	70
M10	Retrofit - Convert Dry Detention Pond to Permanent Pool	25	40	70
H1	New Facility - Wet pond/Shallow Wetland	30	50	80
H2	New Facility - Wet pond/Shallow Wetland	30	50	80
H3	New Facility - Wet pond/Shallow Wetland	30	50	80
H4	New Facility - Wet pond/Shallow Wetland	30	50	80
H5	Retrofit - Convert Dry Detention Pond to Permanent Pool Facility	0	30	20
H6	New Facility - Wet pond/Shallow Wetland	30	50	80
H7	New Facility - Wet pond/Shallow Wetland	30	50	80

The benefits of Stream Restoration projects can be quantified as load reductions of the pollutants. The Chesapeake Bay Watershed Model Phase 5.3 does not define an effectiveness estimate for stream restoration, citing the need to control peak flows as the method of controlling stream channel erosions and pollutant loading. However, comprehensive natural stream restoration projects can reduce pollutant loading as well as providing habitat and revitalization of important channel functions. This was confirmed in Spring Branch Watershed Small Watershed Action Plan, whose long term monitoring of a natural channel stream restoration completed in 1997 of over 14,000 linear feet of restoration, resulted in a significant reduction of pollutant loads. Spring Branch watershed is located in Baltimore County, within the same geographical vicinity as Plumtree Branch watershed. The monitored Spring Branch load reductions from the stream restoration project are shown in Table 7.6 and where used to estimate the

potential load reductions for the Plumtree Branch Proposed Stream Restoration Projects.

Table 7.6 – Stream Restoration Pollutant Load Reductions			
Spring Branch Stream Restoration Load Reductions	**Target Pollutant Removal Efficiencies**		
	TP (lbs/ft)	**TN (lbs/ft)**	**TSS (lbs/ft)**
Stream Restoration	0.02	0.0035	2.558

The proposed water quality benefits for each of the proposed projects were then normalized with the target water quality to produce an efficiency percentage as defined in equation 2 and listed in table 7.7.

Equation 2: Efficiency Percentage (EP) = Proposed WQv / Target WQv

The efficiency percentage was then used to calculate an actual estimate of annual pollutant load removal for each of the proposed projects as defined in equation 3.

Equation 3: EP x Target Pollutant Removal Efficiency x Annual Pre-project Pollutant Load = Potential Post-Project Annual Pollutant Removal

Since the Medium Priority BMP projects were not conceptualized for this report, the efficiency percentage has been estimated. For medium priority BMP projects that are converting a dry extended detention pond to a wet pond the efficiency percentage has been estimated as 20%. Existing wet pond facilities that are proposed to be enlarged (M5 and M8) were estimated with an efficiency percentage of 10%. Proposed new Medium Priority BMP facilities (M3) are estimated with an efficiency percentage of 100%. Table 7.7 lists the pollutant removal efficiencies and the potential post-project annual pollutant removal for each of the projects.

Table 7.7 – Pollutant Removal Efficiencies and Potential Annual Pollutant Removals for Proposed Stormwater BMPs						
Project ID	**Target WQv (ac/ft)**	**Proposed WQv (ac/ft)**	**Efficiency Percentage**	**Potential Post-project Annual Pollutant Removal**		
				TP (lbs/yr)	**TN (lbs/yr)**	**TSS (lbs/yr)**
M1	n/a	n/a	20.0%	3.1	38.5	1,837.9
M2	n/a	n/a	20.0%	0.0	3.5	63.7
M3	n/a	n/a	100.0%	1.8	23.3	1,016.1
M4	n/a	n/a	20.0%	0.5	5.8	278.8
M5	n/a	n/a	10.0%	1.1	14.4	629.4
M6	n/a	n/a	20.0%	0.8	10.1	483.7
M7	n/a	n/a	20.0%	0.4	4.7	226.1

Table 7.7 – Pollutant Removal Efficiencies and Potential Annual Pollutant Removals for Proposed Stormwater BMPs						
Project ID	**Target WQv**	**Proposed WQv**	**Efficiency Percentage**	**Potential Post-project Annual Pollutant Removal**		
M8	n/a	n/a	10.0%	2.3	30.0	1,309.3
M9	n/a	n/a	20.0%	1.2	15.3	731.0
M10	n/a	n/a	20.0%	0.2	2.5	119.0
H1	7.4	0.4	5.4%	3.5	44.3	1,930.9
H2	16.7	0.5	3.0%	4.4	56.1	2,445.9
H3	1.5	0.1	6.7%	0.8	10.8	472.8
H4	0.4	0.4	100.0%	3.2	41.0	1,788.3
H5	0.7	0.7	100.0%	0.0	47.0	853.0
H6	0.7	0.1	14.3%	0.9	11.2	487.4
H7	1.1	0.1	9.1%	0.9	11.4	498.7
Total				**26.5**	**386.3**	**15,881.5**

Table 7.8 lists the potential annual pollutant load reductions for the proposed stream restoration projects.

Table 7.8 – Potential Annual Pollutant Load Reductions for Proposed Stream Restoration Projects				
Project ID	**Reach Length (LF)**	**Potential Post-project Annual Pollutant Removal**		
		TP (lbs/yr)	**TN (lbs/yr)**	**TSS (lbs/yr)**
S1	2,750	55.0	9.6	7,012.5
S2	2,838	56.8	9.9	7,236.9
S3	3,650	73.0	12.8	9,307.5
S4	3,125	62.5	10.9	7,968.8
S5	1,650	33.0	5.8	4,207.5
S6	1,863	37.3	6.5	4,750.7
S7	2,255	45.1	7.9	5,750.3
S8	1,988	39.8	7.0	5,069.4
S9	1,350	27.0	4.7	3,442.5
S10	1,750	35.0	6.1	4,462.5
Total		**464.5**	**81.2**	**59,208.6**

III. Discussion

The Plumtree Branch watershed is a subbasin of the Atkisson Reservoir, a first order tributary to Winters Run and a second order tributary to Bush River. All three watersheds are defined by MDE as Category 5, impaired waterbody, under Section 303(d) requirements of the Federal Clean Water Act. An impaired waterbody does not attain the full extent of its designated use as defined in Maryland water quality

regulations and requires the establishment of Total Maximum Daily Loads (TMDLs) for the waterbody. TMDLs are the maximum amount of pollutant a given waterbody can assimilate and still meet the standards for its designated use. A waterbody may have multiple impairments and multiple TMDLs to address them. MDE is responsible for establishing TMDLs. As to date, no TMDL has been assigned for Atkisson Reservoir, Winters Run or Bush River.

The proposed stormwater BMPs and stream restoration projects can achieve significant reductions in the pollutant loading of Plumtree Branch and the downstream water bodies. The pollution reductions, combined with public outreach and other management strategies, will assist the county in meeting the TMDLs (once established) and other water quality standards for the waterbody.

Chapter 8 Monitoring Plan

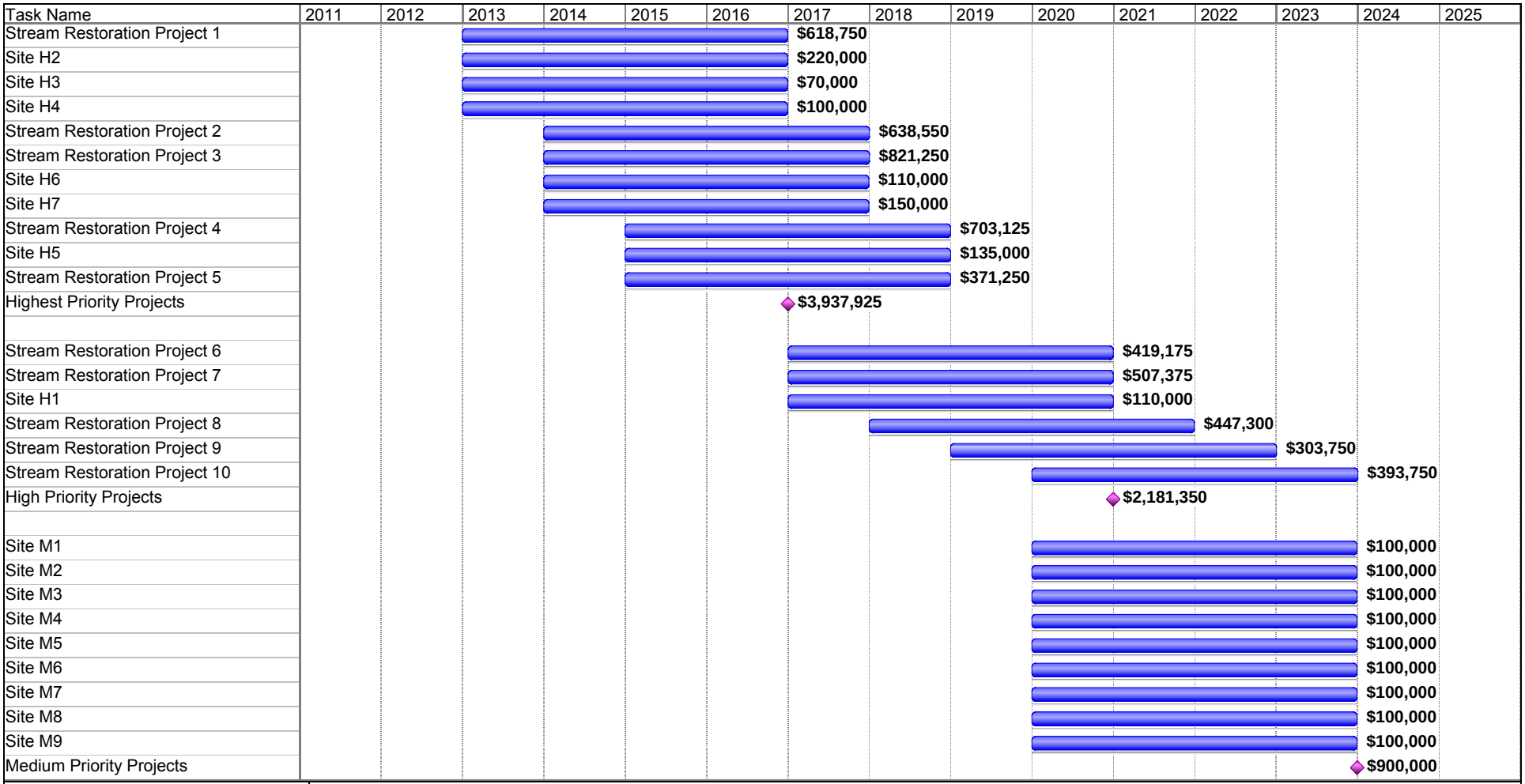
The County, restoration partners and the stakeholders have a vested interest in measuring the success of the implemented restoration projects. Success can be measured by direct results such as reduced pollutant loads or indirectly through the number of volunteer efforts. The monitoring plan for Plumtree Run consists of placing sentinel (fixed, long-term) monitoring stations in strategic locations to measure the trends of key indicators. At a minimum, the stations would be placed at the current USGS Gage Station on Plumtree Run and a station created near the intersection of Route 24 and Ring Factory Road. The USGS Gage Station encompasses all but the least priority stream restoration project and will act as a benchmark for the entire watershed improvements. The monitoring station created at Route 24 and Ring Factory Road will provide a benchmark for the Upper and Lower Middle Watersheds which contain many of the high priority projects. Project monitoring stations will be established prior to the first restoration project until after completion of all of the individual restoration projects to determine the benefits of each project.

Managing the magnitude of data from the monitoring plan is an important aspect of the long-term goals. The County plans to create a GIS system to help illustrate, store and track the results of the monitoring plan. The GIS system can also track the status of the restoration projects as they move through permitting, design, construction and monitoring to ensure nothing is falling behind. Reports can easily be made to keep the County, restoration partners and the stakeholders informed of the restoration efforts and progress.

Chapter 9 Implementation and Summary

I. Schedule

A schedule has been established on the next page to include a timeline of when each stream restoration should be implemented based on priority ranking. High priority upstream stormwater BMPs are scheduled concurrently with each stream restoration project to help bolster the effect of pollutant removal and to help preserve and sustain the investments made in the higher cost stream restorations. The schedule includes pertinent milestones to highlight funding needs prior to implementation.



Project: 10-year Schedule
Date: Fri 5/13/11

Task		Milestone		External Tasks	
Split		Summary		External Milestone	
Progress		Project Summary		Deadline	

Page 1

II. Summary and Integration of Watershed Restoration Projects

The character of the Plumtree Run watershed has changed drastically in the past 20 years. The creation of impervious cover from commercial, residential and institutional development has lead to considerable degradation of the streams, floodplains and general habitat within the watershed. Government sponsored impervious infrastructure such as roads and highways, schools and public buildings has also contributed to this situation.

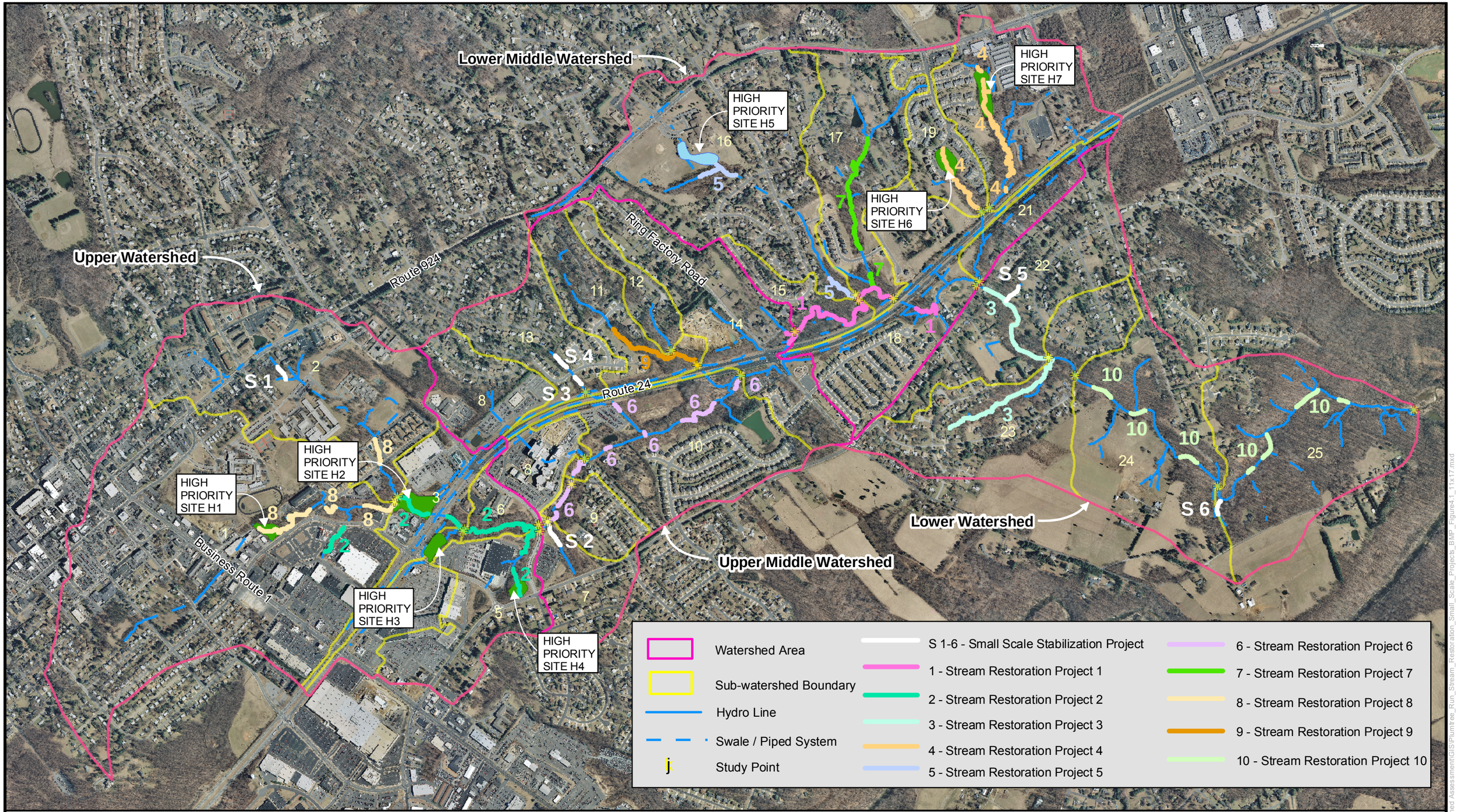
This assessment report has addressed technical solutions to the degradation and offers a menu of restoration and best management practices to incorporate into the existing landscape. Naturally, the more aggressive these remedies and restorations are pursued the greater the odds become for existing streams, floodplains, habitats and natural areas to continue to be sustained.

Ten (10) stream restoration projects have been developed as described in this report with a total budgeting requirement of nearly $7 million. Based on stream restoration alone, it was recommended that the highest priority stream restoration projects (Stream Restoration Projects 1-5) be programmed in the near term at a cost of $4.2 million.

Sixteen (16) stormwater BMPs were identified and seven (7) high priority stormwater BMP projects were developed and recommended as described in this report and should be pursued as soon as possible at $1.5 million. This is considered a minimum level of stormwater BMP effort to dampen ongoing stream degradation and habitat loss.

The highest priority stream restoration and stormwater BMP projects would require near term funding of $5.7 million.

It is noted that all stormwater BMPs are located upstream of degraded stream reaches but certain stormwater BMP sites are located coincidentally with portions of stream restoration projects and if implemented, would result in a direct savings to the stream restoration projects. For example, high priority BMP sites #6 and #7 are intended to be sited within the upper 1,100 feet of the severely degraded channels of Stream Restoration Project 4 and if implemented, would result in an approximately $225,000 savings to that project. Likewise, high priority BMP Sites #2 and #4 would eliminate 700 feet of restoration in Stream Restoration Project 2 for a cost savings of $155,000. BMP Site #1 would eliminate 400 feet of restoration in Stream Restoration Project 8 for a cost savings of $90,000. Therefore, cost savings associated with combining all of these stormwater BMPs with the identified stream restoration projects would be $470,000. Additional permitting, design and construction packaging efficiencies and related cost savings are likely to be recognized by strategically combining these stormwater BMP and stream restoration projects. Figure 9.1 was developed to show the relationship and integration potential of the stormwater BMPs and stream restoration projects to facilitate the most efficient packaging of these projects for inclusion into appropriate capital improvement project budgets.



NOTES:
1. IMAGERY FROM HARFORD COUNTY 2007 AERIAL PHOTOGRAPHY.
2. WATERSHED BASED ON HARFORD COUNTY DELINEATION, REFINED BY BAYLAND CONSULTANTS BASED ON TOPOGRAPHY AND FIELD INVESTIGATION.
3. SUBWATERSHEDS DELINEATED BY BAYLAND CONSULTANTS.
4. IMPERVIOUS SURFACE COMPILED BY BAYLAND CONSULTANTS USING 2008 HARFORD COUNTY GIS DATA.
5. HYDRO LAYER REFINED IN THE FIELD TO INDICATE SWALE/PIPED SYSTEMS BY CLEAR CREEKS CONSULTING DECEMBER 2009.

BMP - NEW (N)
BMP - RETROFIT (R)

1,100 550 0 1,100 2,200 Feet

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Plumtree Run Watershed Assessment Stream Restoration Projects and Small Scale Stabilization Projects

Figure 9.1

It is also noted that should certain high priority stormwater BMPs not become implementable, medium tier stormwater BMPs identified in this report should be pursued in their stead. Although this assessment study was to develop six to nine stormwater BMP sites, the magnitude and contiguousness of impervious surfaces and associated stream habitat and water quality degradation may warrant further, more intense study of other new or regional stormwater BMPs. Stormwater facilities that provide both flow volume attenuation and water quality treatment are considered essential for the watershed in order to compensate for impervious area development that has already taken place.

Finally, active stakeholder participation is a key element to initiate and implement this restoration program for the Plumtree Run watershed. Partnerships between Harford County government, the City of Bel Air, State and Federal government, businesses, and community stakeholders would also create the capacity to seek and develop innovative funding to support the full and long term management and implementation of this restoration program.

REFERENCES

1. BayLand Consultants & Designers, Inc., 2011. Plumtree Run Watershed Assessment Findings Report. Prepared for Harford County Department of Public Works, Bel Air, MD. March 2011

2. Center for Watershed Protection, 2003. Bush River Watershed Management Plan. Prepared for Harford County Department of Public Works, Bel Air, MD. April 2003.

3. Center for Watershed Protection, 2008. Lower Jones Falls Watershed Small Watershed Action Plan. Prepared for the Baltimore County Department of Environmental Protection and Resource Management and the U.S. EPA. October 2008.

4. Hammer, T.R., 1972. Stream Channel Enlargement Due to Urbanization. In D.R. Coates (ed). Environmental Geomorphology and Landscape Conservation, Volume II: Urban Areas. 1974. Dowden, Hutchinson and Rose, Inc. Stroudsburg, PA.

5. Historic Aerial Photographs and USGS Quadrangle Maps 1985 – 1994. Terraserver-USA.com Website

6. Leopold, L.B., M.G. Wolman, and J.P. Miller, 1964. Fluvial Processes in Geomorphology. Freeman, San Francisco, CA: 552 pp.

7. Maryland Department of the Environment, 2002. 2002 List of Impaired Surface Waters [303(d) List] and Integrated Assessment of Water Quality in Maryland. September 2002.

8. Maryland Geologic Survey 1968 Geologic Map of Maryland.

9. National Geographic, 2001. Mid-Atlantic USA. USGS Topographic Maps on CD-ROM

10. National Oceanographic and Atmospheric Administration - National Climate Data Center Website, 2004. Annual Climatological Summary- Temperature and Precipitation Records 1871-2003 for Baltimore, Maryland.

11. Powell, R. O., 2002. Regional Regressions for Hydraulic–Geometry and Bankfull Discharge for Urban Streams in the Piedmont and Coastal Plain Regions of Maryland.

12. Powell, R., N. Pentz, and E. Gemmill, 1999. Hydrologic, Hydraulic and Geomorphologic Assessment of Streams in the Piedmont and Western Coastal

Plain Regions of Maryland. Baltimore County Department of Environmental Protection and Resource Management, Towson, MD.

13. Robinson, A.M., 1976. The Effects of Urbanization on Stream Channel Morphology. National Symposium on Urban Hydrology, Hydraulics and Sediment Control.

14. Rosgen, D.L., 1996. Applied River Morphology. Wildland Hydrology. Pagosa Springs, Colorado.

15. Schueler, T.R., 1987. Controlling Urban Runoff: A Practical Manual for Planning and Designing Urban BMPs. Metropolitan Washington Council of Governments.

16. Schueler, T.R., P.A. Kumble and M.A. Heraty, 1992. A Current Assessment of Urban Best Management Practices: Techniques for Reducing Non-Point Source Pollution in the Coastal Zone. Metropolitan Washington Council of Governments.

17. "Spring Branch Subwatershed – Small Watershed Action Plan," Baltimore County Department of Environmental Protection and Resource Management, Towson, MD 21204. March 2008.

18. U.S. EPA, 2008. Handbook for Developing Watershed Plans to Restore and Protect Our Waters. EPA 841-B-08-002 Office of Water, Nonpoint Source Control Branch, Washington, DC. March 2008.

19. U.S. EPA, 2010. Chesapeake Bay Phase 5 Community Watershed Model In preparation EPA R03-OW-2010-0736 Chesapeake Bay Program Office, Annapolis, Maryland. December 2010.

20. U.S. Fish and Wildlife Service, 2002. Bankfull Discharge and Channel Characteristics of Streams in the Piedmont Hydrologic Region. CBFO-S02-01.

21. U.S. Department of Agriculture, Soil Conservation Service, 1975. Soil Survey of Harford County, Maryland.

22. Weinkam, C., 2000. Hydrologic, Hydraulic and Geomorphologic Assessment of Dead Run at Franklintown, MD.