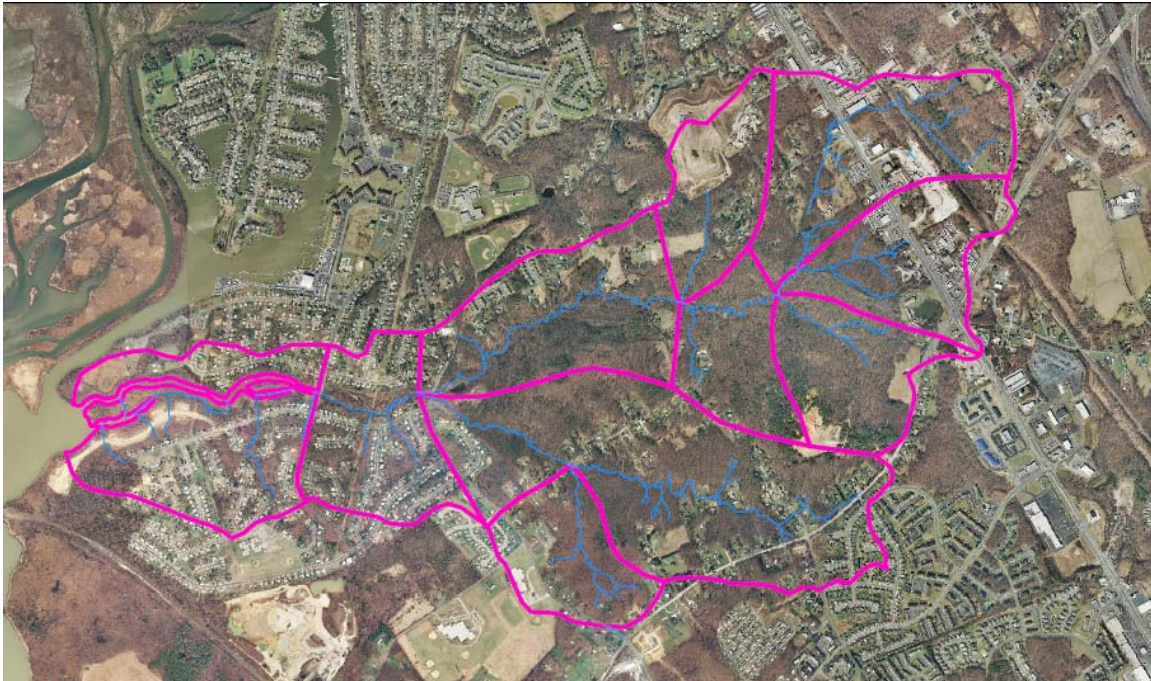


Foster Branch Watershed Small Watershed Action Plan



Prepared for
Harford County Department of Public Works
Division of Water Resources
Bel Air, Maryland



Prepared by
BayLand Consultants & Designers, Inc.
and Clear Creeks Consulting, LLC
1321 Mercedes Drive, Suite A
Hanover, Maryland 21076



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**FOSTER BRANCH WATERSHED
SMALL WATERSHED ACTION PLAN**

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Chapter 1 Project Introduction

I. Background

Foster Branch, a third order tributary to the Gunpowder River, is located in Joppatowne, Maryland. Over the last four decades the Joppatowne 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 stormwater 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 unstable headwater streams make to sedimentation problems in tidal creeks that necessitate costly maintenance dredging in order to restore water depths and eliminate secondary impacts from boater prop wash and sediment resuspension.

In response to these concerns, the Harford County Department of Public Works (DPW), Bureau of Water Resources Engineering have prepared Watershed Management Plans focused on identifying water quality problems and developing strategies for correcting those problems. In addition, the 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 stormwater management ponds, and implementation of stream restoration projects.

It is the intention of the Harford County DPW, Bureau of Water Resources Engineering to control runoff from developed areas, to correct stream channel instability problems, to reduce sediment loadings and to improve the overall water quality of Foster Branch and the Gunpowder River.

Therefore, BayLand Consultants & Designers, Inc. (BayLand) and Clear Creeks Consulting, LLC (Clear Creek) have teamed to conduct a sediment abatement assessment of the Foster Branch watershed to identify sources of channel instability contributing to sediment problems and to identify opportunities for implementing stormwater retrofits, sediment retention facilities and channel restoration projects. Based on the results of these studies, a report of findings was prepared with sediment abatement recommendations, design concepts, and preliminary cost estimates for design and construction. The findings of the assessment and recommendations for stormwater retrofits, sediment retention facilities and stream restoration projects 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 (Appendix A). 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									
Chapter 3 Watershed Field Assessment	X								
Chapter 4 Sediment Reduction Strategies			X	X					
Chapter 5 Pollutant Load Analysis		X						X	
Chapter 6 Monitoring Plan			X					X	X
Chapter 7 Implementation Schedule			X	X		X	X	X	
Chapter 8 Watershed Goals and Public Outreach					X				

Chapter 2 Characterization

I. Study Area

The study area for the current project includes Foster Branch and its tributaries from their headwaters near Pulaski Highway (Route 40) to the tidal portion of the creek below Joppa Farm Road (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 Foster Branch and its tributaries throughout the watershed.

The data collected was utilized to develop recommendations for reducing sediment loadings throughout the watershed and to the tidal portion of the creek. This included determining which stream reaches within the watershed to restore and the extent of the restoration effort required. It also included an evaluation of opportunities to implement stormwater retrofits and sediment retention facilities. Restoration recommendations and design concepts as well as preliminary cost estimates for restoration and sediment retention strategies were developed.

The study did not include wetland delineations, identification of significant plant or animal habitat, or other environmental studies that may be required by local, State or Federal permitting agencies.

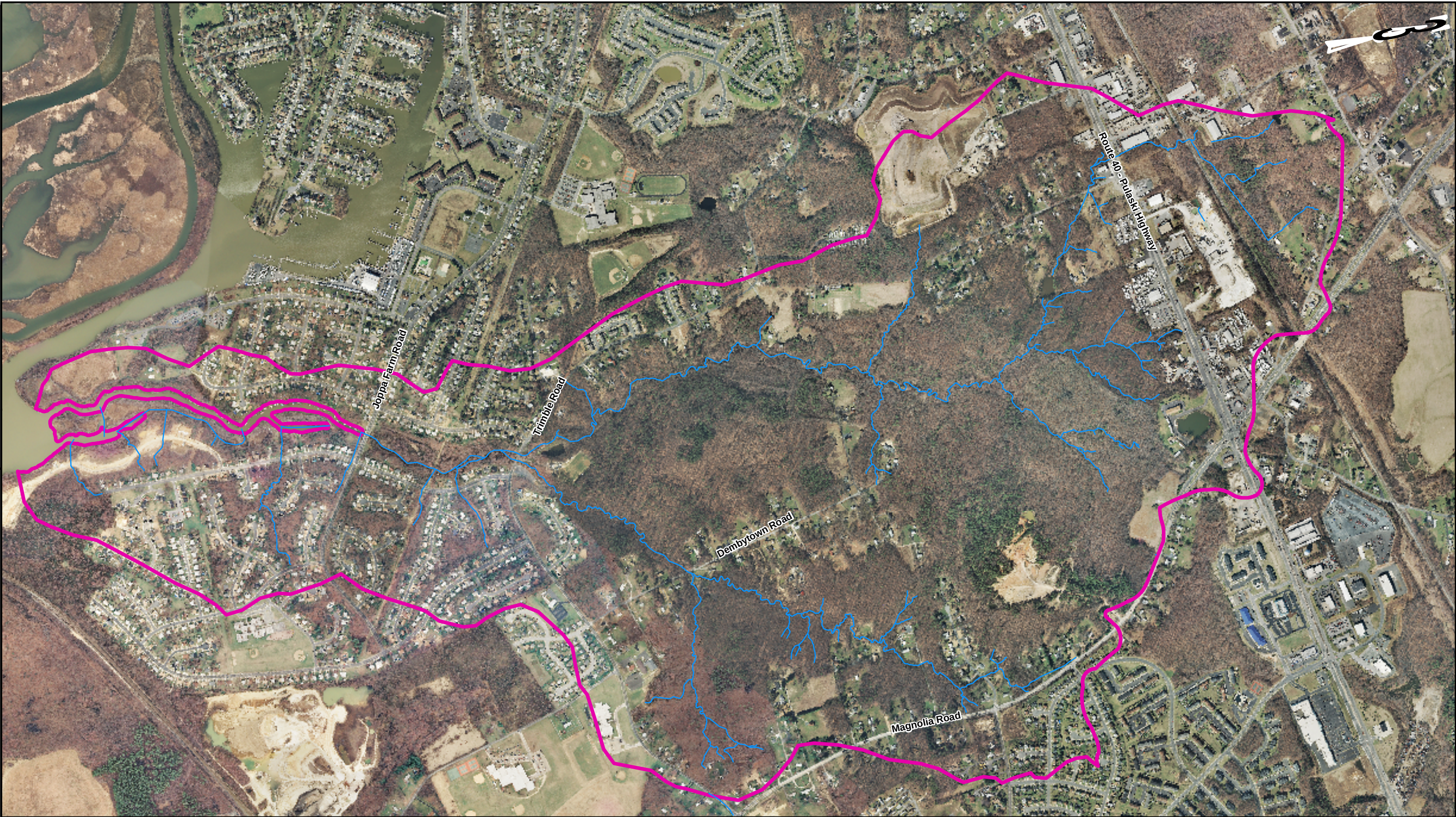
III. Watershed Characterization

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 data; and the Foster Branch Watershed Study (Harford County DPW, Water Resources Engineering, 1997). The following characterization of the Foster Branch watershed was developed from this information.

A. Physiography and Basin Morphometry

The Foster Branch watershed is located in Harford County in the northeast-central section of Maryland. This region is situated along the boundary between the Piedmont and Coastal Plain physiographic provinces and is characterized by gently rolling to hilly topography.

The watershed is composed of two major subwatersheds upstream of Trimble Road. The West Branch is the larger of the two subwatersheds with a drainage area of 743 acres. The East Branch, the smaller subwatershed drains 395 acres. The smaller subwatersheds downstream of Trimble Road drain directly to tidal waters. The total watershed area at the downstream end of the study area is 1,423.7 acres.

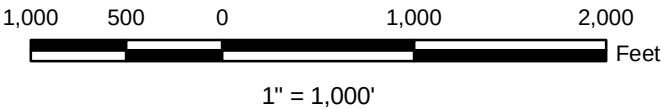


- Notes:
1. Basemap Data from 2007 Harford County GIS.
 2. Aerial Photography from Harford County GIS dated 2007.
 3. Watershed and Storm Drain Features from 2010 Harford County GIS.

 Watershed Boundary

 Hydro/Stream

Total Watershed Area - 1,423.7Acres



BayLand
Consultants & Designers, Inc.
"Integrating Engineering and Environment"

1321 Mercedes Drive, Suite A Phone: (410) 694-9401
Hanover, Maryland 21076 Fax: (410) 694-9405
bayland@baylandinc.com

Figure 2.1
Foster Branch
Watershed

The upper portion of the watershed drains to the West Branch and is characterized by gentle to hilly topography. Narrow ridgelines drop over slopes ranging from 15% to 35% into relatively narrow stream valleys. Channel gradient ranges from 0.008 to 0.028 feet/foot. The middle watershed includes a central ridge that separates the West and East Branch. The side slopes of this ridge range from 15% to 30%. The tributaries dropping off the ridge have narrow valleys and are relatively steep. As the creeks approach Trimble Road the main valleys broaden into wider, flatter floodplains. In these areas the channel gradient ranges from 0.002 to 0.008 feet/foot. The West and East Branch join just downstream of Trimble Road. In spite of a broader floodplain, the lower watershed of Foster Branch is still confined by adjacent ridges as it flows into tidal waters. The tributaries draining the ridge to the east are characterized by steep narrow valleys. The lower west ridge is drained predominantly by storm drain systems.

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 41.4°F in January and 63.5° to 86.1°F in July.

Mean annual precipitation is 45.83 inches. The distribution 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, this region of Harford County is underlain by Quaternary and Cretaceous sedimentary deposits of sand, gravel, silt and clay (MGS, 1968).

According to the mapped soils in the Soil Survey of Harford County (SCS, 1975) the dominant upland soils weathered from these rocks are Beltsville silt loam, Evesboro loamy sand, Joppa gravelly sandy loam, and Loamy Clayey soils on the ridges and side slopes in the upper watershed; Beltsville silt loam, Loamy Clayey, Sassafras sandy loam, and Sassafras and Joppa gravelly sandy loam in the middle watershed; and Beltsville silt loam, Loamy Clayey, Sassafras, and Sassafras and Joppa gravelly sandy loam, and Matapeake and Mattapex silt loam soils on the ridges and side slopes in the lower watershed.

The Beltsville series consist of moderately well drained, nearly level to moderately sloping soils on uplands of the Coastal Plain. These soils are only moderately deep over a fragipan. They formed in loamy sediment deposited over very old loamy or gravelly deposits. These soils are characterized by slow permeability, perched water table above the fragipan, and moderate to severe erosion hazard increasing with slope.

The Evesboro series consists of deep, excessively drained, moderately sloping sandy soils. These soils formed in thick upland deposits of sand and loamy sand. These soils are characterized by rapid permeability and a severe erosion hazard. The Joppa series consists of deep, well drained to excessively drained, gently sloping to steep gravelly soils. These soils formed in thick deposits of sandy and gravelly sediment that contains small amounts of silt and clay. These soils are characterized by moderately rapid to very rapid permeability and a moderate erosion hazard. Loamy Clayey land consists of very old clay deposits overlain by more recent deposits of sandy loam, loam or silt loam. These soils are characterized by variable permeability. The clay is very plastic and sticky when wet. Its most important characteristic is its poor stability. Clay slides, slumps and flows are common where the soils have been disturbed. The Sassafras series consists of deep, well drained, gently sloping to steep soils on undulating uplands. These soils formed in old marine deposits of sandy sediment containing moderate amounts of silt and clay. These soils are characterized by moderate permeability and a moderate to severe erosion hazard increasing with slope. The Matapeake series consists of deep, well drained soils on nearly level and gently sloping soils on broad smooth uplands of the Coastal Plain. These soils formed in old deposits of loamy material and underlying older, coarser textured sediment. These soils are characterized by moderate permeability and a moderate erosion hazard. The Mattapex series consists of deep, moderately well drained soils on nearly level and gently sloping soils on broad smooth uplands of the Coastal Plain. These soils formed in old deposits of loamy material and underlying older, coarser textured sediment. These soils are characterized by moderate permeability and a moderate erosion hazard.

The dominant headwater and floodplain soils along upper Foster Branch and its tributaries are Fallsington loam and Woodstown loam. The floodplain along the middle Foster Branch and its tributaries is comprised of alluvial soils. The dominant soil along the lower Foster Branch floodplain is Cut and Fill Land.

The Fallsington series consists of deep, poorly drained, nearly level soils on upland interfluvial flats of the Coastal Plain. These soils formed in old marine deposits of sandy sediment containing moderate amounts of silt and clay. These soils are characterized by a seasonally high water table, moderate permeability and a low to moderate erosion hazard. The Woodstown series consists of deep, moderately well drained, nearly level and gently sloping soils on gently undulating uplands of the Coastal Plain. These soils formed in old marine deposits of sandy sediment containing moderate amounts of silt and clay. These soils are characterized by a seasonally high water table, moderate permeability and a moderate erosion hazard.

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 Foster Branch watershed were obtained from the Harford County GIS Mapping and Data Services.

D. Land Use

The dominant land use in the upper Foster Branch watershed is commercial uses located along Pulaski Highway (US Route 40). The sections of the upper watershed along Philadelphia Road are low density residential. The dominant land use in the interior of the middle watershed is forest. However, the eastern boundary of the watershed is characterized by medium to high density residential development along Magnolia Road and low density residential development along secondary roads. Magnolia Elementary School is situated along this boundary as well. The dominant land use in the lower watershed includes medium density residential subdivisions clustered along Trimble Road and Joppa Farm Road and secondary roads. The floodplain upstream and downstream of Trimble Road is public land that includes Robert Copenhaver Park. With the exception of a few stream sections, the stream valleys throughout most of the watershed are forest.

Aerial photographs and land use maps for the Foster Branch 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 Foster Branch watershed. This hydrologic analysis provides peak discharges at key study points to provide data for analysis of the annual stream bank erosion rate and sedimentation loading of Foster Branch.

1. Topographic and Land Use Data

Topographic and land use data was compiled from a combination of published and field collected data. The published data consisted of the Harford County 2008 GIS from Harford County GIS Office and Harford County Land Cover 2007 from Maryland Office of Planning. The collected data was used to develop hydrologic parameters consistent with Soil Conservation Service (SCS) methodology as detailed in the hydrologic model section of this report. Table 2.1 shows the percentage of SCS land uses for the Foster Branch watershed.

Table 2.1 – Watershed Land Use (Percent)					
	Impervious	Forest	Open	Meadow	Barren
Watershed	17.6%	51.8%	24.1%	2.5%	3.9%

2. Soil Classification

Soils can be classified according to their run-off potential using NRCS Hydrologic Soil Classification, which characterizes the soils and their potential to generate runoff. These categories range from Hydrologic Soil Group A, low runoff potential and high

infiltration to Hydrologic Soil Group D, high runoff potential and very slow infiltration. Hydraulic Soil Classifications for the existing soils found in the watershed were obtained from a combination of Harford County 2008 GIS and the USDA online soil survey website. Appendix B Hydrologic Analysis, Attachment 1 includes a table of the soil series present within the watershed, along with their respective Hydrologic Soil Classifications. Table 2.2 shows the percentage of soil type, by Hydrologic Soil Classification, for the watershed. The majority of the watershed is Hydrologic Soil Classification Group C that has a moderate infiltration rate and moderate runoff potential.

Table 2.2 – Soil Coverage (Percent)				
	A	B	C	D
Watershed	4.1	35.3	51.3	9.3

3. Hydrologic Model

The Foster Branch watershed was delineated into 13 sub-basins that corresponded to study points selected for the stream assessment. The USDA Soil Conservation Service (SCS) Technical Release 55 (TR-55) computer program was utilized to compute the runoff curve number (RCN) and time of concentration (Tc) for each of the proposed drainage areas from the sub-basins land use, soils and the physiographic properties. Table 2.3 lists the 13 delineated sub-basins for the Foster Branch watershed stream assessment along with their respective drainage area characteristics.

Table 2.3 – Sub-Basins Drainage Area Characteristics				
Sub-Basin	Area (Acres)	Area (Square Miles)	Runoff Curve Number (RCN)	Time of Concentration (Hours)
1	208.0	0.3251	74	0.44
2	80.0	0.1250	78	0.33
3	6.2	0.0097	80	0.26
4	106.4	0.1663	68	0.38
5	99.9	0.1561	69	0.39
6	81.0	0.1265	71	0.37
7	161.4	0.2521	69	0.43
8	22.8	0.0356	85	0.23
9	182.9	0.2857	70	0.45
10	94.0	0.1468	74	0.38
11	95.4	0.1490	70	0.38
12	108.6	0.1697	77	0.34
13	177.2	0.2769	75	0.34

Along with the watershed sub-basins, study points were selected at the confluences of the major stream branches to provide accurate peak discharges estimates for the stream assessment. Table 2.4 shows the computed areas and associated impervious area percentages for each of the proposed restoration reach study points.

Table 2.4 – Stream Assessment Study Points				
Study Point	Cumulative Area (Acres)	Cumulative Area (Square Miles)	Impervious Area (Percent)	Sub-Basins
SP 1	208.0	0.3251	24.7%	DA 1
SP 2	80.0	0.1250	43.7%	DA 2
SP 3	294.3	0.4598	29.3%	DA 1-3
SP 4	106.4	0.1663	7.8%	DA 4
SP 5	500.6	0.7821	19.9%	DA 1-5
SP 6	81.0	0.1265	4.4%	DA 6
SP 7	742.9	1.1608	16.5%	DA 1-7
SP 8	22.8	0.0356	38.0%	DA 8
SP 9	205.7	0.3213	13.4%	DA 8-9
SP 10	94.0	0.1468	22.8%	DA 10
SP 11	395.0	0.6171	15.0%	DA 8-11
SP 12	1246.5	1.9476	17.0%	DA 1-12
SP 13	1423.7	2.2245	17.6%	DA 1-13

SCS TR-20 computer model was then utilized to route selected storm events with the computed sub-basins drainage area characteristics and existing stormwater management facilities hydraulics to develop peak discharges for the selected study points. The TR-20 model is a deterministic hydrologic model that synthesizes a single event runoff hydrograph as a function of a rainfall input and drainage area characteristics. The model is designed to operate on a time varying rainfall to produce a hydrograph that simulates the role of the watershed area; land cover; hydrologic soil types; antecedent runoff conditions; topography; storage basins; characteristics of the overland, shallow confined and channel flow paths; and storage attenuation such as that created by flood plains, wetlands, structures and ponds. The hydrologic model was calibrated as described within the Calibration of the Hydrologic Model section of this report. The full hydrologic model can be found in Appendix B Hydrologic Analysis, Attachment 2.

4. Regional Regression Equations

Estimating flood frequency and magnitude based solely on gauged sites does not provide accurate spatial representation. Regression analysis utilizes a “region of influence” method to correlate gauged and ungauged sites and is useful in determining whether the hydrologic model has been sufficiently calibrated to provide the most accurate estimate of peak discharges for the reach. Regional regression equations

from “Evaluation of Alternative Statistical Methods for Estimating Frequency of Peak Flows in Maryland (SP907C4B)” by Maryland Department of Transportation State Highway Administration, October 2006 was employed to analyze the calibrated peak discharges of the hydrologic model. The hydrologic model was considered successfully calibrated if the peak discharges were within one standard error of the regional regression peak discharge estimates. Appendix B Hydrologic Analysis, Attachment 3 lists the MD SHA regional regression equations used to determine the success of the hydrologic model calibration.

5. Calibration of the Hydrologic Model

The hydrologic model drainage area characteristics and inputs are calibrated with statistical methods to overcome the inherent limitations of the SCS TR-20 hydrologic modeling software to over predict peak flows for all return periods. Regional regression equations use USGS stream gaging stations which can provide a reasonable indication of existing runoff conditions and therefore, can provide a base for calibration of the hydrologic model. Table 2.5 list the TR-20 input element and the application for calibration based on multiple storm frequency models.

Table 2.5 – TR-20 Calibration for Multiple Storm Frequency Models	
Input Element / Calibration Variable	Application
Drainage Area	Same for all storms
Time of Concentration variables	Same for all storms
RCN conditions	Same for all storms
Reach Length	May increase for greater return periods but not reverse
Dimensionless Unit Hydrograph	Same for all storms
Rainfall Table – 24-hr duration	Use for 25-yr to 500-yr storms
Rainfall Table – 12-hr duration	May use for the 2- through 10-yr storms.
Rainfall Table – 6-hr duration	May use for 2-, 5- and 10-yr storms.
ARC (Antecedent Runoff Condition)	Use 2- for 25-yr and greater return period storms. May use <2 for the 2-yr to 10-yr storms provided that it does not decrease for greater return period storms. ARC of >2 may be considered for storms of 200+-yrs providing that it does not decrease with greater return period storms

The Antecedent Runoff Conditions (ARC) for the TR-20 input represents a preliminary soil conditions right before the storm event. An ARC of 2 represents the initial wetting of the ground surface and filling of small depressions and thus is appropriate for major flooding conditions present in severe storm events (10-yr though 100-yr). An ARC of 1 is a dry soil condition that would be applicable to short duration summer storms. Because TR-20 does not allow the utilization of fractional ARCs, the

following equation was utilized to calibrate the RCN to account for the fractional ARC value.

$$\begin{aligned} \text{For ARC} < 2: & \quad \text{RCN}(x) = [10 + 5.8(x - 2)] \text{RCN2} / 10 + 0.058(x - 2) \text{RCN2} \\ \text{For ARC} > 2: & \quad \text{RCN}(x) = [10 + 13(x - 2)] \text{RCN2} / 10 + 0.13(x - 2) \text{RCN2} \end{aligned}$$

where x = ARC value and is a real number between 1 and 3

Table 2.6 list the calibrated inputs used for the various storm events for each drainage area.

Table 2.6 – TR-20 Calibrated Inputs			
Storm Event	Rainfall Distribution	Rainfall (Inches)	Selected ARC
1-YR	6-hr Type II	2.6	1.7
2-YR	6-hr Type II	3.2	1.7
5-YR	12-hr Type II	4.2	1.75
10-YR	12-hr Type II	5.1	1.75
50-YR	24-hr Type II	6.3	2.0
100-YR	24-hr Type II	7.2	2.0

Table 2.7 lists the computed calibrated peak discharges for each study point.

Table 2.7 – Calibrated TR-20 Peak Discharges						
Study Point	1-YR (cfs)	2-YR (cfs)	5-YR (cfs)	10-YR (cfs)	50-YR (cfs)	100-YR (cfs)
SP 1	38	90	207	335	659	810
SP 2	28	58	119	181	328	396
SP 3	51	114	253	394	793	970
SP 4	8	26	76	136	298	379
SP 5	56	125	285	454	961	1187
SP 6	10	29	74	124	258	317
SP 7	62	137	308	492	1224	1521
SP 8	18	32	52	72	126	149
SP 9	27	70	170	286	591	731
SP 10	19	45	103	165	321	390
SP 11	44	110	262	407	913	1130
SP 12	101	233	512	831	1820	2265
SP 13	115	251	573	933	2033	2528

6. Results

Table 2.8 through 2.20 compares the regional regression equations with the calibrated TR-20 Peak Discharges to determine whether the calibration was successful in achieving the target values within one standard error of the regional regression equations.

Table 2.8 – Peak Discharge Results, SP 1

Storm Recurrence Interval (yrs)	Regression Peak Discharge (cfs)	Standard Error (%)	Lower Limit (cfs)	Upper Limit (cfs)	TR-20 Peak Discharge (cfs)
2	66.4	35.1%	43.1	89.7	90
5	150.1	28.5%	107.3	192.9	207
10	231.4	26.2%	170.8	292.1	335
50	543.2	27.7%	392.7	693.7	659
100	746.9	30.7%	517.6	976.2	810

Table 2.9 – Peak Discharge Results, SP 2

Storm Recurrence Interval (yrs)	Regression Peak Discharge (cfs)	Standard Error (%)	Lower Limit (cfs)	Upper Limit (cfs)	TR-20 Peak Discharge (cfs)
2	36.6	35.1%	23.7	49.4	58
5	83.5	28.5%	59.7	107.2	119
10	128.8	26.2%	95.0	162.5	181
50	302.3	27.7%	218.5	386.0	328
100	415.2	30.7%	287.7	542.6	396

Table 2.10 – Peak Discharge Results, SP 3

Storm Recurrence Interval (yrs)	Regression Peak Discharge (cfs)	Standard Error (%)	Lower Limit (cfs)	Upper Limit (cfs)	TR-20 Peak Discharge (cfs)
2	83.0	35.1%	53.9	112.1	114
5	186.8	28.5%	133.5	240.0	253
10	287.7	26.2%	212.3	363.1	394
50	674.1	27.7%	487.4	860.9	793
100	926.6	30.7%	642.2	1211.1	970

Table 2.11 – Peak Discharge Results, SP 4					
Storm Recurrence Interval (yrs)	Regression Peak Discharge (cfs)	Standard Error (%)	Lower Limit (cfs)	Upper Limit (cfs)	TR-20 Peak Discharge (cfs)
2	43.0	35.1%	27.9	58.1	26
5	98.0	28.5%	70.0	125.9	76
10	151.4	26.2%	111.7	191.1	136
50	357.0	27.7%	258.1	455.9	298
100	491.4	30.7%	340.5	642.2	379

Table 2.12 – Peak Discharge Results, SP 5					
Storm Recurrence Interval (yrs)	Regression Peak Discharge (cfs)	Standard Error (%)	Lower Limit (cfs)	Upper Limit (cfs)	TR-20 Peak Discharge (cfs)
2	115.7	35.1%	75.1	156.3	125
5	259.0	28.5%	185.2	332.8	285
10	398.8	26.2%	294.3	503.3	454
50	934.2	27.7%	675.4	1192.9	961
100	1284.8	30.7%	890.4	1679.2	1187

Table 2.13 – Peak Discharge Results, SP 6					
Storm Recurrence Interval (yrs)	Regression Peak Discharge (cfs)	Standard Error (%)	Lower Limit (cfs)	Upper Limit (cfs)	TR-20 Peak Discharge (cfs)
2	36.1	35.1%	23.4	48.7	29
5	82.5	28.5%	59.0	106.0	74
10	127.6	26.2%	94.1	161.0	124
50	301.2	27.7%	217.7	384.6	258
100	414.6	30.7%	287.3	541.9	317

Table 2.14 – Peak Discharge Results, SP 7					
Storm Recurrence Interval (yrs)	Regression Peak Discharge (cfs)	Standard Error (%)	Lower Limit (cfs)	Upper Limit (cfs)	TR-20 Peak Discharge (cfs)
2	148.4	35.1%	96.3	200.5	137
5	330.8	28.5%	236.5	425.1	308
10	509.0	26.2%	375.7	642.4	492
50	1191.6	27.7%	861.5	1521.7	1224
100	1639.3	30.7%	1136.0	2142.5	1521

Table 2.15 – Peak Discharge Results, SP 8					
Storm Recurrence Interval (yrs)	Regression Peak Discharge (cfs)	Standard Error (%)	Lower Limit (cfs)	Upper Limit (cfs)	TR-20 Peak Discharge (cfs)
2	16.4	35.1%	10.7	22.2	32
5	38.0	28.5%	27.2	48.9	52
10	58.8	26.2%	43.4	74.3	72
50	138.7	27.7%	100.3	177.2	126
100	190.6	30.7%	132.1	249.1	149

Table 2.16 – Peak Discharge Results, SP 9					
Storm Recurrence Interval (yrs)	Regression Peak Discharge (cfs)	Standard Error (%)	Lower Limit (cfs)	Upper Limit (cfs)	TR-20 Peak Discharge (cfs)
2	65.5	35.1%	42.5	88.5	70
5	148.2	28.5%	106.0	190.4	170
10	228.7	26.2%	168.8	288.6	286
50	537.6	27.7%	388.7	686.6	591
100	739.7	30.7%	512.6	966.8	731

Table 2.17 – Peak Discharge Results, SP 10					
Storm Recurrence Interval (yrs)	Regression Peak Discharge (cfs)	Standard Error (%)	Lower Limit (cfs)	Upper Limit (cfs)	TR-20 Peak Discharge (cfs)
2	40.1	35.1%	26.0	54.1	45
5	91.3	28.5%	65.3	117.3	103
10	141.1	26.2%	104.1	178.0	165
50	331.9	27.7%	240.0	423.9	321
100	456.5	30.7%	316.3	596.6	390

Table 2.18 – Peak Discharge Results, SP 11					
Storm Recurrence Interval (yrs)	Regression Peak Discharge (cfs)	Standard Error (%)	Lower Limit (cfs)	Upper Limit (cfs)	TR-20 Peak Discharge (cfs)
2	99.3	35.1%	64.4	134.1	110
5	222.9	28.5%	159.4	286.4	262
10	343.4	26.2%	253.4	433.4	407
50	805.6	27.7%	582.5	1028.8	913
100	1108.4	30.7%	768.1	1448.6	1130

Table 2.19 – Peak Discharge Results, SP 12					
Storm Recurrence Interval (yrs)	Regression Peak Discharge (cfs)	Standard Error (%)	Lower Limit (cfs)	Upper Limit (cfs)	TR-20 Peak Discharge (cfs)
2	206.2	35.1%	133.8	278.5	223
5	457.0	28.5%	326.8	587.2	512
10	702.5	26.2%	518.4	886.6	831
50	1641.8	27.7%	1187.0	2096.6	1820
100	1108.4	30.7%	768.1	1448.6	1130

Table 2.20 – Peak Discharge Results, SP 13					
Storm Recurrence Interval (yrs)	Regression Peak Discharge (cfs)	Standard Error (%)	Lower Limit (cfs)	Upper Limit (cfs)	TR-20 Peak Discharge (cfs)
2	224.4	35.1%	145.6	303.2	251
5	496.7	28.5%	355.1	638.2	573
10	763.3	26.2%	563.3	963.2	933
50	1782.9	27.7%	1289.1	2276.8	2033
100	2452.5	30.7%	1699.6	3205.5	2528

The calibrated TR-20 peak discharges for the study points fall within 1 standard error of the regional regression peak discharges for the majority of storm events. The calibrated TR-20 peak discharges for the 2-yr, 5-yr and 10-yr storm event are higher than the upper limit of the regional regression equations for study points SP 1, SP 2 and SP 3. Study point SP 8 peak discharges exceed the upper limit of the regional regression equations for the 2-yr and 5-yr storm event. The peak discharges for these study points exceed the upper limits of the regional regression equations because the drainage areas are highly impervious (24.7%, 43.7%, 29.3% and 38% respectively), where the remainder of the study point drainage areas have smaller amount of impervious area and an increased amount of forest cover. This leads to a skewing of the calibration when the drainage area characteristics vary widely within the same watershed. The difference between the upper limit of the regional regression equations and the drainage area peak discharges of the calibrated hydrologic model are within the bounds of sound engineering. Additionally, the peak discharges from the model for those storm events are not abnormal in their range. After careful review of the calibrated hydrologic model, it can be considered successfully calibrated for use in planning and analysis of the Foster Branch watershed, stream erosion rates and remediation concept development.

Chapter 3 Watershed Field Assessment

I. Field Studies for Foster Branch Watershed Assessment

A. Overview

Sediment source assessment methods should be selected based on a clear understanding of the dominant sediment-producing processes active in the watersheds of concern (USEPA, 1999). The assessment of Foster Branch included an evaluation of upland sources as well as in-channel sources. Based on preliminary field visits and anecdotal evidence from area residents it was assumed that the major source of sediment would be from in-channel sources.

1. Upland Sediment Source Assessment

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 existing annual pollutant loads for the upland areas of the Foster Branch watershed.

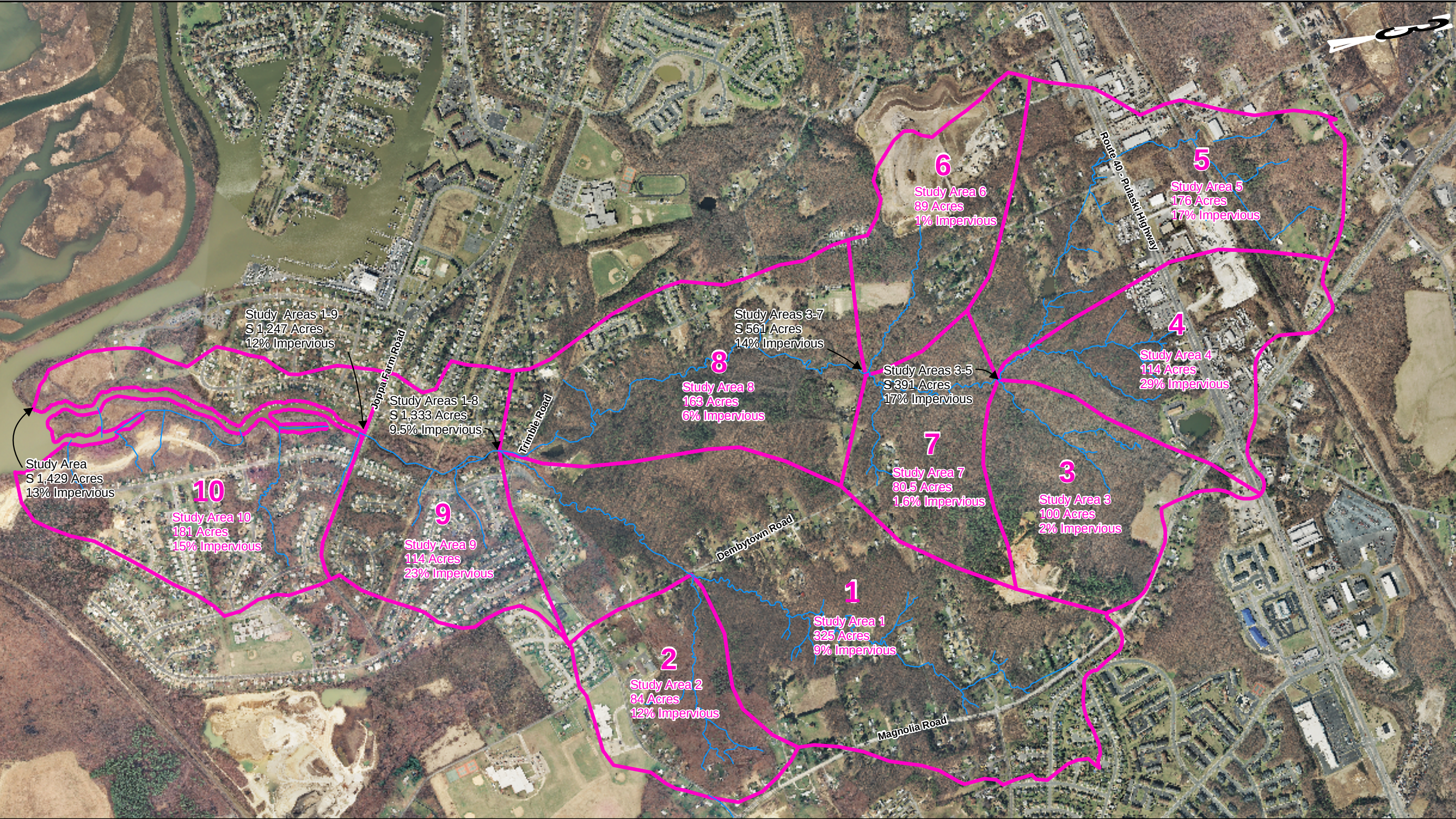
2. In-Channel Sediment Sources

Evaluating in-channel sediment sources should ideally include water quality monitoring over several years to develop estimates of suspended and bed load sediments. Because long-term monitoring is costly and resource intensive this approach was not practical for the Foster Branch watershed. A geomorphic-based assessment approach was utilized that included the channel stability assessment.

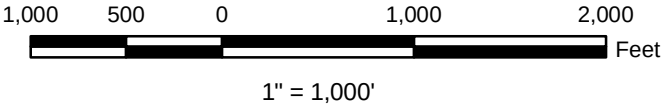
B. Pre-Assessment Office Preparation

The Foster Branch watershed was digitized on the County's GIS topographic maps. All properties that included a stream channel were identified and a list of property owners was developed. Letters were mailed to all property owners requesting permission to access the property in order to conduct the assessment. Any property whose owner denied permission to enter was marked on the maps.

To facilitate the field effort, the Foster Branch watershed was divided into 10 subshed study areas (Figure 3.1). 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 = 100 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.). The subshed areas were digitized onto the maps.



Notes:
1. Basemap Data from 2007 Harford County GIS.
2. Aerial Photography from Harford County GIS dated 2007.
3. Watershed and Storm Drain Features from 2010 Harford County GIS.



1 Study Area Boundary



Bayland
Consultants & Designers, Inc.
"Integrating Engineering and Environment"

1321 Mercedes Drive, Suite A
Hanover, Maryland 21076

Phone: (410) 694-9401
Fax: (410) 694-9405
bayland@baylandinc.com

Figure 3.1
Foster Branch
Subshed
Study Areas

C. Preliminary Subwatershed Inventory

A preliminary field reconnaissance was conducted along 45,601 linear feet of Foster Branch and its tributaries to identify and map potential sources of sediment throughout the watershed. Sources of sediment included in-channel sources such as streambank erosion; slope failure, headcuts and streambed degradation; and sediment depositional features such as point bars, mid-channel and lateral bars. In addition, upland sources of sediment were identified such as construction sites with poorly maintained sediment control measures or extensive areas with bare soil or minimal vegetation. Existing conditions were photographically documented. Teams of two people were assigned subsheds to survey. After the mapping survey had been completed, the reconnaissance maps were analyzed and the subsheds prioritized for a more intensive assessment.

D. Detailed Assessment

1. Field Data Collection

An intensive field reconnaissance was conducted of the ten (10) subsheds to identify, map and characterize sources of sediment throughout the watershed. One team of two people conducted the detailed assessment of all subsheds surveyed. Problem areas were mapped and photo-documented. Field measurements were recorded on data sheets. Field data collection included:

- a. Geomorphic mapping of all channel reaches including eroding banks, failing slopes, debris jams, sediment bars, head cuts, etc.
- b. Channel bankfull width and depth was measured along representative reaches of the channel and at locations where detailed information was collected.
- c. For eroding banks and failing slopes, data was collected that allowed a detailed characterization of individual bank/slope conditions and an evaluation of the degree of instability, potential for further erosion, and an estimated rate of erosion. The data included – bank/slope height and length, bank/slope angle, root depth and density, percent surface protection, bank material (e.g. silt/clay, sand, gravel, etc.) and stratification (e.g. presence or absence of differing layers of bank material), and an evaluation of near bank stress.
- d. For headcuts, the width of channel and height of head cut was measured.
- e. For sediment bars, an initial assessment was conducted to determine whether the bar was mobile or not. Bars that were vegetated were considered less likely to be mobilized during storm flows and no further evaluation was conducted. Those bars determined to be mobile were characterized by type of bar

- (e.g. point, mid-channel or lateral) and type of material (e.g. sand, gravel, sand and gravel, etc.). Measurements were taken to determine width, depth and linear feet of bar material.
- f. Obvious factors contributing to erosion and/or sediment deposition (e.g. storm drain outfalls, channel modification activities, etc.) were noted on the field maps.
- g. Potential stormwater retrofit sites and sediment retention sites were identified and mapped.

2. Data Management and Analysis

Field data collected on the topographic maps and data sheets was organized and tabulated by subshed and by problem type. The tabulated data was used for analysis and to develop various computations and estimates of sediment loadings from the in-channel sources. Geomorphic maps were compiled from the field mapping and were also used for the assessment and development of restoration reaches and projects (Appendix C).

a. Streambanks and Failing Slopes

Rosgen (1990, 1996, 2004) developed a methodology for predicting annual streambank erosion rates. The method involves collecting streambank field data and channel characteristics to calculate a Bank Erosion Hazard Index (BEHI) and Near Bank Stress (NBS) rating using the Bank Assessment for Non-Point Source Consequences of Sediment (BANCS). He demonstrated that significant relations exist between stress in the near-bank region (NBS), stream bank erosion potential (BEHI) and measured stream bank erosion rates. Utilizing this methodology he developed regional regressions relating BEHI and NBS ratings to measured bank erosion rates in the western United States. Regional regressions have also been developed for North Carolina (USDA-NRCS and NCSU, 2002, 2009).

This method has been used successfully to develop estimates of sediment loads from streambank erosion in Maryland, Pennsylvania, North Carolina and Arkansas (BayLand & Clear Creeks, 2002; BayLand & Clear Creeks, 2003; Buck Engineering, 2007; Clear Creeks and Skelly & Loy, 2006; Clear Creeks, 2001; Rosgen, 1999, 2001; USDA-NRCS and NCSU, 2009; and Van Eps, et. al., 2005).

This method has been incorporated into Watershed Assessment of River Stability and Sediment Supply (WARSS), a geomorphology-based procedure for quantifying the effects of land uses on sediment relations and channel stability (Rosgen, 2006).

As part of this study, field data on bank erosion potential (BEHI) and stress in the near-bank region (NBS) were collected for the eroding stream banks and slopes along Foster Branch and its tributaries (a sample Field Data Sheet is included in the Appendix D).

Utilizing the calculated BEHI and NBS ratings for the Foster Branch stream reaches and the regional regressions, it was possible to predict lateral erosion rates (feet/year) for the banks and slopes evaluated. Estimates for sediment loadings (cubic yards/year) were developed based on the existing bank/slope height, length of stream bank/slope evaluated and the predicted erosion rates (summary tables are included in Appendix D).

b. Headcuts

Sediment loading estimates (cubic yards) for headcuts was based on calculations using head cut height, width of channel, and the length of head ward migration required to reach a stable gradient of 0.008 ft/ft. It was assumed that complete head ward migration to reach a stable channel gradient would take 30 years. Therefore, rough estimates of annual sediment loading (cubic yards/year) were calculated by dividing the total loading by 30 (summary tables are included in Appendix D).

c. Sediment Bars

Sediment loading estimates (cubic yards) for mobile sediment bars included a straight forward calculation of sediment volume utilizing length, width and depth of sediment in the bar. It was assumed that complete mobilization and transport of the bar material would take 30 years. Therefore, rough estimates of annual sediment loading (cubic yards/year) were calculated by dividing the total loading by 30 (summary tables are included in Appendix D).

d. Total Sediment Load Versus Bed Load Sediment Load

Sediment is transported as suspended load (silt, clay and fine sands held in the water column above the bottom by turbulence) and bed load (medium to coarse sand, gravel and coarser material, like cobbles and boulders moved by rolling, sliding and bouncing along the streambed). The total sediment load is the sum of suspended load and bed load. Grains with sizes that cannot be found in the shifting parts of the bed in appreciable quantities are known as wash load which, in general, is a part of the suspended load. Whether an individual particle is transported as suspended load or as bed load depends on particle size, weight and shape, and on the ambient hydraulic conditions.

The sediment removed from the tidal portion of Foster Branch during successive dredging operations was composed of medium to coarse sands and small to large gravel. Analyses of the streambed material along the reaches evaluated during the current study indicates that the dominant particle size ranges from coarse sand to medium gravel with finer and coarser materials present in somewhat lesser quantities.

As a consequence, it appears that the bulk of the material dredged from the tidal creek was transported from the Foster Branch watershed as bed load. Although there

is no doubt that material transported in suspension contributes to the problem it appears that much of the finer material passes further downstream in fine layers and may pass through the creek and out into the Gunpowder River.

The sediment contributed from bank erosion, head cuts and sediment bars includes all size fractions from clay and silt to sand, gravel and cobble. Therefore the sediment loadings developed from the data collected for these sediment sources in Foster Branch were estimates of the total sediment loadings.

To facilitate the development of sediment abatement strategies focused on improving overall water quality, as well as reducing the need to routinely dredge the tidal creek, it was important to determine the percentage of the estimated total sediment load that could be attributed to the suspended and bed load sediment fractions. Because monitoring was not a component of this study it was necessary to rely on studies from other watersheds to guide a technically-based approach.

Clear Creeks (2006) conducted an assessment of Quittapahilla Creek Watershed in Lebanon County, Pennsylvania. The assessment included: field reconnaissance surveys, geomorphic stream assessments, in-stream habitat assessments, sampling of fish and macroinvertebrate communities, water quality monitoring, developing a sediment-discharge rating curve, and hydrologic and water quality modeling.

The water quality monitoring effort involved two major components. The first component included collecting surface water samples under base flow and storm flow conditions. In addition, continuous reading temperature data loggers were installed throughout the watershed to characterize in-stream temperature conditions over a one-year period. The second component was collecting bed load and suspended sediment samples under storm flow conditions and development of sediment-discharge rating curves to determine annual sediment loadings from different areas within the Quittapahilla Creek watershed (Clear Creeks and Skelly & Loy, 2005).

The water quality modeling effort was completed using the AVGWLF GIS-based watershed modeling tool developed by Penn State's Institutes of the Environment. This tool facilitates the use of the GWLF watershed model via GIS software (ArcView) interface, and is currently being used by the Pennsylvania Department of Environmental Protection to help support its ongoing TMDL projects within Pennsylvania. The model was refined to allow for more detailed analysis of pollutant loads in the Quittapahilla Creek watershed. In addition, the field data collected during the field reconnaissance and geomorphic assessment, as well as the sediment-discharge data, was used to calibrate the model to actual field conditions in the watershed. These refinements allowed more accurate modeling of local landscape conditions, streambank erosion rates, and sediment and nutrient loading rates (Evans, 2006).

The results of the water quality monitoring indicated sediment yield from Quittapahilla Creek watershed is 11,650 tons/year of which 10,485 tons (90%) is suspended sediment. The water quality modeling compared favorably with the

monitoring results indicating sediment yield from Quittapahilla Creek watershed is 10,065 tons/year. Results of the monitoring and modeling also indicated that between 20% to 31% is contributed from the urban subwatersheds of Upper Quittapahilla Creek. Interestingly, the upper 1/4 of the watershed may be contributing as much as 1/3 of the total sediment load.

As part of this current study, a search was conducted of the scientific literature to gather additional information. The literature indicates that the bed load fraction of the total sediment load can range from a few percent to as much as 60% in some watersheds. Watershed characteristics (e.g. watershed slope, stream power, soil cohesiveness and soil erodibility, and land use/land cover) are the major determinants in the percent each fraction represents of the total.

Numbers found most frequently in the literature are 10% to 20% bed load fraction of the total load (e.g. Simons & Senturk, 1977; Dietrich and Dunne, 1978; Holland, 1978; Summerfield & Hulton, 1994; Hay, 1998; Knighton, 1998; Basumallick & Mukherjee, 1999; Galy & France-Lanord, 2001; and Lave & Avouac, 2001). The lower percentage of the bed load fraction compares favorably with the results of the Quittapahilla Creek assessment where 10% of the total load was bed load.

For the Foster Branch study, a conservative value of 15% was used to represent the bed load fraction of the total sediment load. The final computations included determining the bed load sediment load by source type, as well as the total bed load sediment load for each of the Foster Branch subsheds. (Summary tables are included in Appendix D).

II. Findings of Watershed Assessment

Sediment enters watercourses from a variety of sources. Common upland sources include construction activities, agricultural operations and surface mining. In some watersheds one or all of these land use activities can contribute significant sediment loadings. Although not always obvious, in-channel sources of sediment such as, stream bank and streambed erosion can contribute as much, if not more sediment than upland sources. This is especially true in watersheds with highly erodible soils that are undergoing significant changes in hydrologic regime. The primary objective of the current study was to identify the most significant sources of sediment in the Foster Branch watershed.

A. Evaluation of Upland Conditions

1. Historic

As noted in the Watershed Characterization Section, the Foster Branch watershed is characterized by rolling to steep topography and highly erodible soils. Historic aerial photographs from 1957 to 1971 show that, prior to the 1966 land use in the watershed was predominantly forest and farm fields. The aerial photographs also

show two large sand and gravel mining areas within the watershed. Field observations indicate the presence of landforms such as irregular mounds, broad flats and shallow pits consistent with these types of operations. Active sand and gravel mining areas were likely sources of sediment to Foster Branch. The farm fields may also have contributed sediment to the creeks in the watershed. As the land use in the watershed was converted from forest and farm fields to residential and commercial development during the mid to late 1960's and 1970's, construction activities would have been a significant source of sediment to Foster Branch.

2. Current

Although the interior of the watershed is still predominantly forest, the high percent of imperviousness associated with the commercial uses along Pulaski Highway generate significant run-off in the upper Foster Branch watershed. The subsheds draining the eastern boundary of the watershed collect run-off from Magnolia Elementary School and the medium to high density residential development along Magnolia Road. The medium density residential subdivisions clustered along Trimble Road and Joppa Farm Road and secondary roads contribute run-off to the subsheds draining these areas. Two stormwater detention facilities located in the Woodbridge and Joppa Woods subdivisions provide some level of stormwater management. However, in general there is little control of runoff from the developed areas throughout the watershed.

Field observations indicate there was no active development in the watershed at the time of this study. However, mapping of previously approved subdivisions indicates that much of the currently forested interior will be converted to single family homes and cul-de-sacs when the housing market rebounds. This future development will no doubt present challenges for a watershed already experiencing channel stability and sedimentation problems.

The former sand and gravel mining areas are still evident. The site at the end of Oak Avenue is now Pappy's Inc., a rubble fill. A large sediment basin controls runoff from the site before it discharges into the tributary in Subshed 6 near the end of Pine Road. According to the Watershed Assessment Report prepared by Harford County DPW's Water Resources Engineering (1997) the site has an NPDES industrial discharge permit issued and enforced by Maryland Department of the Environment. The permit limits the discharge of total suspended solids. At the time that study was completed there had been no enforcement actions. Although much of the second site west of Magnolia Road has reverted to forest or old field, there is still a significant area that is bare soil or poorly vegetated. Field observations indicate the site has been recently graded. Perimeter berms and sediment basins had been constructed to contain runoff and trap sediments prior to discharging into the tributaries in Subshed 3.

B. Evaluation of In-Channel Conditions

1. Historic

There is no data to document the historic channel conditions along Foster Branch. However, the historic aerial photographs from 1957 to 1971 show that as recently as 1964 the tidal portion of the creek was a large tidal wetland with a narrow stream channel meandering through the wetland. The 1966 aerial photo shows Joppa Farm Road had been constructed, development was underway along Garnett Road and Kearney Drive, and the tidal creek had been dredged.

Harford County DPW Water Resources Engineering completed two stream stabilization projects in the Foster Knoll area during the late 1990's. These projects include the tributaries that drain the steep eastern ridge in subsheds 9 and 10 and are referred to as the Haverhill Road and Stillmeadow Drive projects, respectively. The Stillmeadow Drive project included the installation of two small sediment traps below Foster Knoll Road before the tributary empties into the tidal creek.

2. Current

Stream bank and streambed erosion along Foster Branch and its tributaries is currently the most significant source of sediment to the tidal portion of Foster Branch. The majority of the stream channels throughout the watershed are unstable characterized by extensive streambank erosion, sediment deposition, debris jams and headcuts. The altered hydrologic regime of the upper watershed and the steep erodible soils throughout the watershed are the most significant factors contributing to instability problems along the stream reaches.

The principal effect of the altered hydrologic regime is channel enlargement resulting from streambed and bank erosion to accommodate increased runoff volumes. Due to channel enlargement cross-sectional areas of stream channels impacted by urbanization may be 2 to 3 times greater than rural stream channels with the same watershed drainage areas (Hammer, 1972; Robinson, 1976; Wilkerson, et al. 1998; Powell, Pentz, and Gemmill, 1999).

The most accurate estimates of sediment loadings contributed by these channel adjustments would be provided by conducting a comprehensive, multi-year water quality monitoring effort. Unfortunately, this approach is resource intensive and very expensive. The detailed geomorphic assessment approach utilized for this study provided a cost-effective and reasonably reliable method for identifying sediment sources and estimating sediment loadings. In addition, the data collected and computations completed provide a basis for evaluating the benefits of implementing stream restoration/stabilization measures and best management practices designed to control runoff and trap sediment.

The following is a summary of the findings of that analysis as it relates to the current conditions within the Foster Branch subshed areas.

Subshed 1

Subshed 1 includes 13,695 linear feet of the East Branch of Foster Branch and its tributaries. Its subshed drains 325 acres of medium to high density residential land and is 9% impervious surfaces. Although there are two stormwater detention facilities located in the Woodbridge and Joppa Woods subdivisions the majority of the subwatershed has no stormwater controls.

With the exception of the most upstream reach and a few short stream reaches along the middle and lower sections of the subshed, channel conditions can be characterized as unstable C4, B4c and G4 stream reaches. The instability includes severe bank erosion and lateral migration, multiple debris jams and significant 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.

Conditions are particularly unstable along the upper section on the downstream side of Magnolia Road. This section of channel is deeply incised and undergoing severe bank erosion. The toe of the banks consists of clay deposits overlain by sandy and gravelly soils. Groundwater seepage is keeping the clay layer plastic and causing the banks to slump even when there is little or no storm flow. Approximately 200 linear feet is affected by these conditions. The middle section (between the private drive downstream of Hanson Road and Dembytown Road) is characterized by severe bank erosion and multiple slope failures. Multiple headcuts are common along the tributaries in the middle section. Dumping of trash and debris (e.g. concrete, shingles, tires, lumber, car parts, etc.) has caused severe aggradation, such that the channel is completely full of sediment. The lower section (between Dembytown Road and Trimble Road) has the highest percentage of unstable channel. At the upstream and downstream ends of the lower section the stream is eroding into high terraces in the rear yards of residences fronting on Dembytown Road and Falconbridge Road. The presence of large debris jams is forcing storm flows to undercut the terraces causing them to slump into the channel. Bank heights along these unstable reaches range from 3 to 13 feet in the upper section, 3 to 20 feet in the middle section, and 2.5 to 20 feet in the lower section.



Photos 3.1 and 3.2 – Eroding bank downstream side of Magnolia Road and plastic clay layer at toe of bank



Photo 3.3 – Failing slope along middle section



Photo 3.4 – Slope failure with dumped trash and debris in channel along middle section



Photo 3.5 – Bank erosion along lower section



Photo 3.6 – Debris jam and aggradation along lower section



Photo 3.7 – Bar deposition along lower section



Photo 3.8 – Bar deposition along lower section

Subshed 2

Subshed 2 includes 4,900 linear feet along a tributary to the East Branch of Foster Branch. Its subshed drains 84 acres of institutional land including the Magnolia Elementary School property and the John Wesley Methodist Church property along Trimble Road, as well as medium to high density residential land along Trimble Road and Magnolia Road and is 12% impervious surfaces. The subwatershed has no stormwater controls.

With the exception of the small tributaries in the northeast corner of the subshed, conditions can be characterized as unstable C4, B4c and G4 stream reaches. The instability includes severe bank erosion and lateral migration, multiple debris jams and significant aggradation. Multiple headcuts are common along the tributaries.

Conditions are particularly unstable along the upper section on the downstream side of Trimble Road where runoff from the Magnolia Elementary School property outfalls into the channel. This section of channel is deeply incised and undergoing severe bank erosion, with undercut and falling trees throughout. Bank heights along these unstable reaches range from 5 to 11.5 feet. The toe of the banks consists of clay deposits overlain by sandy and gravelly soils. Groundwater seepage is keeping the clay layer plastic and causing the banks to slump even when there is little or no storm flow. These conditions affect approximately 500 linear feet of stream channel.

The middle section is characterized by stable banks but heavy sedimentation throughout. Bank heights range from 3 to 7 feet. Debris and multiple headcuts are common along the middle section. Aggradation is so severe in the lower section of the subshed that there is no channel. Deposits of sediment have completely covered the forest floor and buried the base of trees to a depth 1 to 1.5 feet. Bank heights along this unstable reach range from 0 to 2.5 feet.



Photo 3.9 – Deeply incised upper section with eroding banks



Photo 3.10 – Deeply incised upper section with clay slumps at toe of banks



Photo 3.11 – Deeply incised upper section with undercut and falling trees



Photo 3.12 – Middle section with stable banks and heavy sedimentation



Photo 3.13 – Severe aggradation and channel avulsion in lower section



Photo 3.14 – Severe aggradation and channel avulsion in lower section

Subshed 3

Subshed 3 includes 3,549 linear feet along two tributaries to the West Branch of Foster Branch. Its subshed drains 100 acres of forest, old field and barren land and is 2% impervious surfaces. It includes the area of the old sand and gravel site west of Magnolia Road.

In spite of the current forest cover, the landscape over much of this subshed is similar to many old mined areas that have never been reclaimed. It is composed of irregular mounds and broad flats with shallow pits. The area is intersected by incising gullies. Although much of the site has reverted to forest or old field, there is still a significant area that is bare soil or poorly vegetated. At the time the field work was conducted it appeared that a large area of the site has been recently graded. Perimeter berms and sediment basins had been constructed to contain runoff and trap sediments prior to discharging into the drainage ways. With the exception of a few short sections of stable channel the majority of the drainage ways in this subshed are highly unstable with multiple headcuts and eroding side slopes. Head cuts range from 1 to 7 feet in height. Bank heights range from 3 to 30 feet.



Photo 3.15 – Recently graded off Magnolia Road



Photo 3.16 – Shallow wetland near outlet of graded area



Photo 3.17 – Typical 3.0 foot head cut



Photo 3.18 – Typical 4.0 foot head cut



Photo 3.19 – Large 7.0 foot head cut

Subshed 4

Subshed 4 includes 5,496 linear feet along several tributaries to the West Branch of Foster Branch. Its subshed drains 114 acres of commercial land along US Route 40 – Pulaski Highway and is 29% impervious surfaces. The subwatershed has five documented stormwater facilities.

The channels can be characterized as unstable G4, B4 and C4 stream reaches. The instability includes severe bank erosion and lateral migration, gully erosion, multiple debris jams and significant aggradation. Multiple headcuts are common along the tributaries.

Conditions are particularly unstable along the steep, upper section of the West Tributary on the downstream side of Route 40 adjacent to the car dealership. Stormwater runoff from the commercial properties along Route 40 outfalls into the channel. This section of channel is deeply incised and undergoing severe bank erosion, with undercut and falling trees throughout. Bank heights along these unstable reaches range from 4 to 18 feet. The toe of the slopes along the high terraces consists of clay deposits overlain by sandy and gravelly soils. Groundwater seepage is keeping the clay layer plastic and causing the slopes to slump even when there is little or no storm flow. These conditions affect approximately 500 linear feet of stream channel.

Runoff from the large car lot at the Castle Auto Outlet has created a deeply incised gully adjacent to the West Tributary. The gully enters the West Tributary from the right approximately 400 linear feet downstream of Route 40. This gully is migrating upstream along the drainage way at the rear of the car dealership. A small relatively stable tributary enters the West Tributary from the left approximately 600 linear feet downstream of Route 40.

The upper reach of the middle section of the West Tributary is characterized by stable banks but heavy sedimentation throughout. Bank heights range from 2 to 3 feet. The lower reach of the middle section of the West Tributary is characterized by bank erosion and sedimentation throughout. Bank heights range from 3 to 5.5 feet. The lower section of the West Tributary is characterized by bank erosion and sedimentation throughout. Bank heights range from 3 to 4 feet.

Conditions are also unstable along the steep, East Tributary downstream of Route 40 where it outfalls to the rear of the Super 8 Motel. Fill placed when the motel was constructed encroaches on the valley creating unstable side slopes along the upper section of this tributary. The unstable conditions include severe bank erosion and lateral migration, slope failures, and multiple head cuts throughout.



Photo 3.20 – Failing slope along West Tributary



Photo 3.21 – Failing slope along West Tributary



Photo 3.22 – Bank erosion along West Tributary



Photo 3.23 – Bank erosion along West Tributary

Subshed 5

Subshed 5 includes 1,665 linear feet along a tributary to the West Branch of Foster Branch. Its subshed drains 176 acres of low density residential along Route 7 – Philadelphia Road and Pine Road as well as the commercial land along US Route 40 – Pulaski Highway and is 17% impervious surfaces. With the exception of one small detention pond at the rear of the Muscle Car Garage at the corner of Pine Road. This subwatershed has five documented stormwater facilities.

The tributary originates at the rear of a commercial property fronting on Philadelphia Road. This section of the stream can be characterized as an unstable, deeply incised gully (G5 stream type) with eroding banks throughout its length. Bank heights along the gully range from 6 to 12 feet. Just before the tributary flows underneath the railroad it is joined by a small, first order tributary that originates at the outfall to a private pond on the property of a former nursery fronting on Philadelphia Road. This small stream starts as a well defined channel that carries a base flow, however, it quickly becomes a network of less well-defined ephemeral channels flowing through a forested wetland as it approaches the railroad tracks. After it flows beneath the railroad it flows across vacant land adjacent to the First Choice Automotive property along the north side of Route 40. The channel in this section can be characterized as a relatively stable B4c stream channel along the upper reach and a straightened, unstable G4 stream channel along the lower reach. The instability in the unstable reach includes localized bank erosion. Bank heights range from 2.5 to 5 feet.

Piped beneath Route 40 the tributary reemerges as an unstable G4 channel adjacent to the Muscle Car Garage on the south side of Route 40. The instability in this reach includes bank erosion and head cuts in the upper reach. Bank heights range from 4 to 5 feet. The lower reach is a relatively stable C4 channel with bank heights of 1.5 to 2.0 feet. Piped beneath Pine Road the tributary reemerges as a relatively stable, C4 channel that traverses private residential property before emptying into a one acre pond. Instability along this section is minor with localized bank erosion, bar deposition, and debris jams. Bank heights range from 1.5 to 2.0 feet. The large wetland created by the accumulation of sediment at the upstream end of the pond indicates that the unstable conditions in the upper subwatershed have existed for some time.

Three channels join at the outlet to the pond. The first is a small, unstable, ephemeral channel carrying runoff from Rayner Lane. Instability along this channel includes multiple head cuts ranging in height from 1 to 3 feet, and multiple debris jams with associated sediment deposition. Bank heights range from 1.5 to 3.5 feet. The second channel is an ephemeral gully carrying runoff from private driveways to the west of the pond. Instability along this channel includes bank erosion throughout and one active head cut 2.5 feet in height. Bank heights range from 1 to 3 feet. The third is the main channel which flows approximately 600 linear feet before it joins the West Tributary draining Subshed 4. The channel in this section can be characterized as an unstable B4c and F4 stream channel. The instability includes localized bank erosion and lateral migration, debris jams and bar deposition. Bank heights range from 5 to 7 feet.



Photo 3.24 – Relatively stable B4c channel downstream of railroad



Photo 3.25 – Unstable G4 channel upstream of Route 40



Photo 3.26 – Unstable G4 channel upstream of Route 40



Photo 3.27 – Armored channel downstream of Route 40



Photo 3.28 – Unstable G4 channel downstream of Route 40



Photo 3.29 – Relatively stable C4 channel upstream of Pine Road



Photo 3.30 – Debris jam along reach downstream of Pine Road



Photo 3.31 – Relatively stable C4 reach downstream of Pine Road



Photo 3.32 – Wetland at upstream end of pond



Photo 3.33 – Private pond along middle section of Subshed 5



Photo 3.34 – Outlet structure of pond



Photo 3.35 – Unstable outfall and channel downstream of pond



Photo 3.36 – Bank erosion along lower section



Photo 3.37 – Bank erosion and large gravel bar along lower section



Photo 3.38 – Bank erosion along lower section



Photo 3.39 – Tight meander bend along lower section

Subshed 6

Subshed 6 includes 2,065 linear feet along a tributary to the West Branch of Foster Branch. Its subshed drains 89 acres and is 1% impervious surfaces. Land use includes low density residential along Oak Avenue and Pine Road and Pappy's Inc., a rubble fill that was formerly a sand and gravel mining area at the end of Oak Avenue. The subwatershed has no stormwater controls.

The tributary originates at the outfall of a sediment basin at the rear of the Pappy's Inc. property and flows across the rear yards of residences at the end of Pine Road and Wiesser Court where it joins the West Branch at the downstream end of Subshed 7.

With the exception of a short section of stable B4c channel in the middle of the reach, the stream channel can be characterized as an unstable G4 stream. The instability includes gully erosion, bank erosion and lateral migration, debris jams and bar deposition. Multiple headcuts are common along the tributary. Head cut heights range from 2 to 4 feet. Bank heights range from 3 to 8.5 feet.



Photo 3.40 – Rubble landfill at Pappy's Inc. visible in background of photo



Photo 3.41 – Bank erosion along upper section



Photo 3.42 – Gully erosion and a 4 foot head cut along upper section



Photo 3.43 – Bank erosion along middle section



Photo 3.44 – Gully erosion and debris jam along middle section



Photo 3.45 – Bank erosion along lower section

Subshed 7

Subshed 7 includes 3,970 linear feet along a reach of the mainstem West Branch of Foster Branch and a tributary that drains the area to the south at the end of Dembytown Road. Its subshed drains 391 acres and is 17% impervious surfaces. Subshed 7 comprises the interior of the Foster Branch watershed and is completely surrounded by the subsheds along the boundaries of the watershed. Although the land cover in this subshed is predominantly forest it drains Subsheds 3 through 5 with their commercial land uses and uncontrolled stormwater runoff.

The mainstem channel can be characterized as unstable B4c and C4 stream reaches. The instability includes severe bank erosion and lateral migration, multiple debris jams and significant bar deposition. Bank heights range from 4 to 6 feet. The tight meander bends are contributing to the stress on the already unstable banks. The channel and floodplain in the upper section have been impacted by ATV trails.

The South Tributary channel can be characterized as unstable G4 and C4 stream reaches. The instability includes severe bank erosion and lateral migration, debris jams and significant bar deposition, and gully erosion. Bank heights range from 3 to 6 feet. Multiple headcuts are common. Head cut heights range from 1 to 4 feet.



Photo 3.46 – ATV trails along upper section



Photo 3.47 – ATV trails along upper section



Photo 3.48 – Bank erosion, debris jams and bar deposition along upper section



Photo 3.49 – Large bar deposits along upper section



Photo 3.50 – Large bar deposits along upper section



Photo 3.51 – Tight meander bend, bank erosion and falling tree along middle section

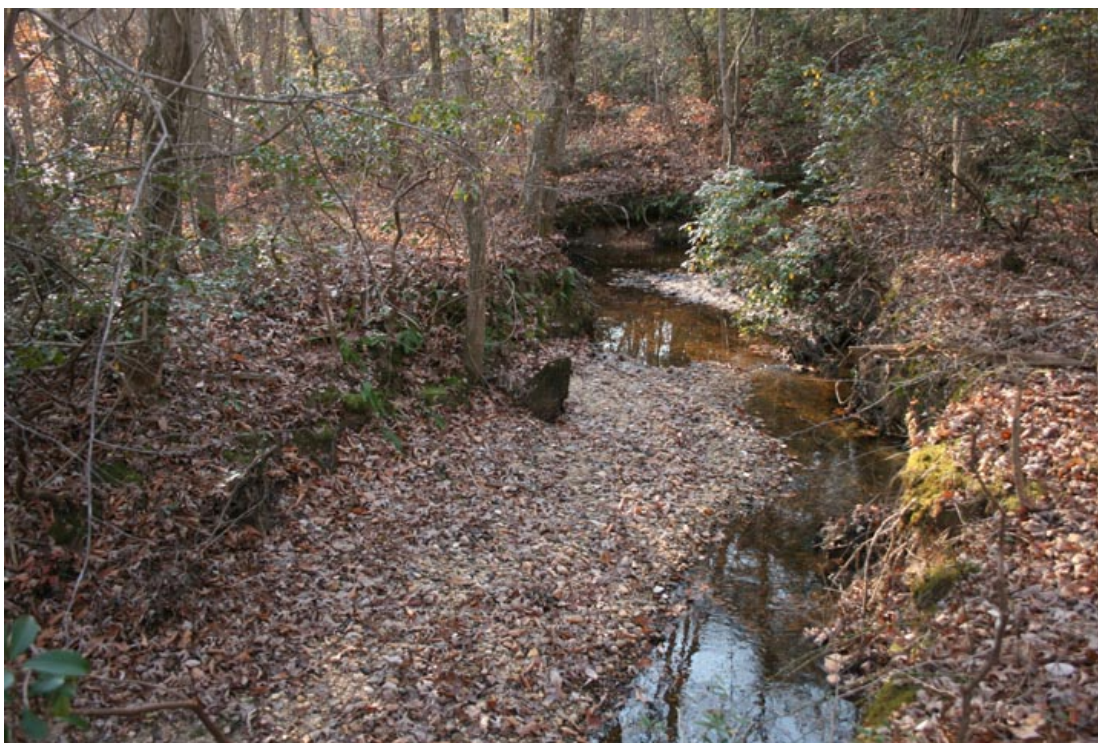


Photo 3.52 – Large bar deposit along middle section

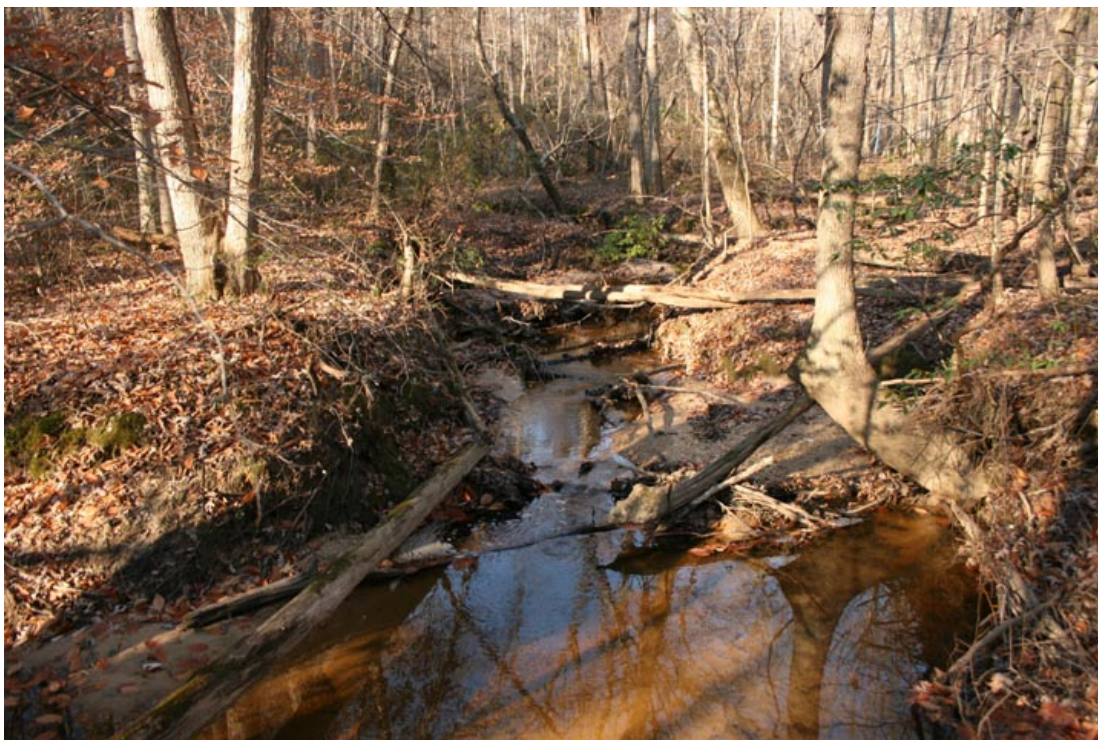


Photo 3.53 – Large debris jams along middle section



Photo 3.54 – Large bar deposits along lower section



Photo 3.55 – Large bar deposits along lower section



Photo 3.56 – Tight meander bend along lower section



Photo 3.57 – Incised upper section of South Tributary



Photo 3.58 – Bank erosion along upper section of South Tributary



Photo 3.59 – Bank erosion along middle section of South Tributary



Photo 3.60 – Debris in channel and junk cars in floodplain lower section of South Tributary

Subshed 8

Subshed 8 includes 5,825 linear feet along reaches of the mainstem West Branch of Foster Branch and two small tributaries. Its subshed drains 561 acres and is 14% impervious surfaces. Although the land cover in this subshed is predominantly forest it drains Subsheds 3 through 7 with the commercial land uses along Route 40 and the uncontrolled stormwater runoff. Although the majority of the stream in this subshed traverses private land, the most downstream portion flows through the Robert Copenhaver Park before it enters the culvert at Trimble Road.

The channels along the upper section can be characterized as unstable B4c and C4 stream reaches. The instability includes severe bank erosion, lateral migration, multiple debris jams and bar deposition, and headcuts ranging in height from 1 to 2.5 feet. Bank heights range from 4 to 10 feet along the upper section. In two locations the channel is eroding into the adjacent high terrace causing the slopes to fail. The tight meander bends are contributing to the stress on the already unstable banks and slopes.

Because access to several properties had been denied by the landowners, a short section of the lower reaches could not be directly assessed. However, observations were made from adjacent properties where access had been granted. With the exception of a short reach of relatively stable E4 stream channel, the channels along the lower section can be characterized as unstable C4, B4c, G4 and E4 stream reaches. The instability includes bank erosion and lateral migration with a chute cutoff forming on the tightest meander bends, debris jams and bar deposition. Bank heights range from 3 to 5.5 feet along the lower section.

The first tributary drains a small pond located on vacant land off Trimble Road in the northwest corner of Subshed 8. The secondary tributary originates at a culvert located off Trimble Road in the southwest corner of Subshed 8. Both tributaries are stable throughout their length.



Photo 3.61 – Bank erosion along upper section



Photo 3.62 – Bank erosion and bar deposition along upper section



Photo 3.63 – Tight meander bends and bank erosion along upper section



Photo 3.64 – Debris jams and bar deposition along middle section



Photo 3.65 – Bank erosion and bar deposition along middle section



Photo 3.66 – Bank erosion and bar deposition along lower section



Photo 3.67 – Bank erosion and bar deposition along lower section



Photo 3.68 – Debris jam and bar deposition along lower section



Photo 3.69 – Pond in Robert Copenhaver Park



Photo 3.70 – Straightened lower section in park upstream of Trimble Road

Subshed 9

Subshed 9 includes is 2,415 linear feet of stream that includes the East and West Branches of Foster Branch before they join downstream of Trimble Road, the mainstem Foster Branch after they do, and a small tributary that drains the east slope. Its subshed drains 1,333 acres and is 9.5% impervious surfaces. Because the land cover in this subshed is predominantly medium to high density residential it includes 23% impervious surfaces. However, because it drains Subsheds 1 through 8 with the mix of forest, old field, residential, commercial and institutional land uses throughout the watershed its cumulative impervious surface is much lower. The floodplain along this section of the mainstem is forest and is part of the Robert Copenhaver Park property.

The mainstem channels can be characterized as unstable F4 and C4 stream reaches. The instability includes bank erosion and bar deposition throughout. Bank heights range from 6 to 8 feet along the upper and middle mainstem section and 3 to 4 feet along the lower section. Two significant slope failures are occurring where the channel is eroding the 25 foot high terrace at the rear of a residence along Foster Knoll Road.

The tributary that drains the steep eastern ridge is one of the stream stabilization projects completed by Harford County DPW's Water Resources Engineering during the late 1990's. Referred to as the Haverhill Road project, it is very stable throughout most of its length.



Photo 3.71 – Robert Copenhaver Park along floodplain upstream and downstream of Trimble Road



Photo 3.72 – West Branch culvert downstream side of Trimble Road



Photo 3.73 – Armoring along left bank of West Branch downstream of Trimble Road



Photo 3.74 – Confluence of East and West Branches of Foster Branch



Photo 3.75 – Bank erosion and failing footbridge along upper section



Photo 3.76 – Bank erosion along upper section



Photo 3.77 – Bank erosion and failing footbridge along upper section



Photo 3.78 – Failing slope along middle section



Photo 3.79 – Failing slope along middle section



Photo 3.80 – Bank erosion along middle section



Photo 3.81 – Debris jam and bar deposition along lower section

Subshed 10

Subshed 10 is 2,030 linear feet of stream that includes the tidal portion of the mainstem Foster Branch and a small tributary that drains the east slope. Its subshed drains 1,429 acres and is 13% impervious surfaces. Because the land cover in this subshed is predominantly medium to high density residential it includes 15% impervious surfaces. However, because it drains Subsheds 1 through 9 with the mix of forest, old field, residential, commercial and institutional land uses throughout the watershed its cumulative impervious surface is somewhat lower.

The tributary that drains the steep eastern ridge is one of the stream stabilization projects completed by Harford County DPW's Water Resources Engineering during the late 1990's. Referred to as the Stillmeadow Drive project, it is currently experiencing stability problems throughout most of its length.

The channel can be characterized as unstable G4, B4 and C4 stream reaches. The instability includes severe bank erosion and lateral migration, and multiple headcuts. Bank heights range from 3 to 10 feet and the heights of the head cuts range from 1.5 to 3 feet.

Many of the stabilization structures installed as components of the stabilization project have failed and several are actually contributing to the instability. The material eroded from the unstable upper and middle sections is depositing along the lower section causing significant aggradation. The two small sediment traps installed below Foster Knoll Road as components of the stabilization project are nearly full of sediment transported from the unstable tributary.



Photo 3.82 – Tidal portion of creek downstream of Joppa Farm Road



Photo 3.83 – Gravel bar deposit along lower section of tributary



Photo 3.84 – Sediment traps downstream of Foster Knoll Road



Photo 3.85 – Sediment traps downstream of Foster Knoll Road

C. Analysis of In-Channel Sediment Sources

The results of the current study indicate that stream bank erosion, slope failures, head cuts, and sediment bars are contributing a significant volume of sediment annually.

1. Sediment Contribution by Source Type

As shown in Table 3.1, a total of 6,090 cubic yards (9,043,650 lbs) of sediment is contributed annually from in-channel sources. This equates to 1,025 cubic yards (1,522,719 lbs) of bed load material moving into the tidal creek each year.

Table 3.1 – Sediment Load by Source Type						
Subshed Area	Bank Erosion (cy/yr)	Head Cuts (cy/yr)	Bar Deposition (cy/yr)	Slope Failure (cy/yr)	Total Sediment (cy/yr)	Total Bed Load (cy/yr)
1	1,004	18	38	59	1,119	200.5
2	644	31	19	0	694	120.7
3	188	68	6	3	264	44.9
4	1,009	15	9	18	1,051	165.4
5	251	7	0	0	258	38.7
6	337	4	1	7	350	53.5

Table 3.1 – Sediment Load by Source Type						
Subshed Area	Bank Erosion (cy/yr)	Head Cuts (cy/yr)	Bar Deposition (cy/yr)	Slope Failure (cy/yr)	Total Sediment (cy/yr)	Total Bed Load (cy/yr)
7	655	20	11	2	688	112.5
8	700	4	23	6	734	130.0
9	637	0	17	19	672	115.0
10	248	5	6	0	260	44.2
Total Sediment (cy)	5,673	172	132	113	6,090	1025.4

Bank erosion contributes the largest volume of sediment, 5,673 cubic yards (8,424,405 lbs) of sediment annually. This equates to 245 lbs/linear foot of unstable channel. Although head cuts, bar deposition and slope failures contribute significantly less sediment, these in-channel sources contribute 417 cubic yards (619,245 lbs) annually.

2. Sediment Contribution by Subshed

Subsheds 1, 4, 8, 2, 7 and 9 are by far the biggest contributors adding 4,958 cubic yards (7,362,630 lbs) of total sediment and 744 cubic yards (1,104,840 lbs) of bed load or 81% of the total sediment contributed by the entire watershed (Figure 3.2).

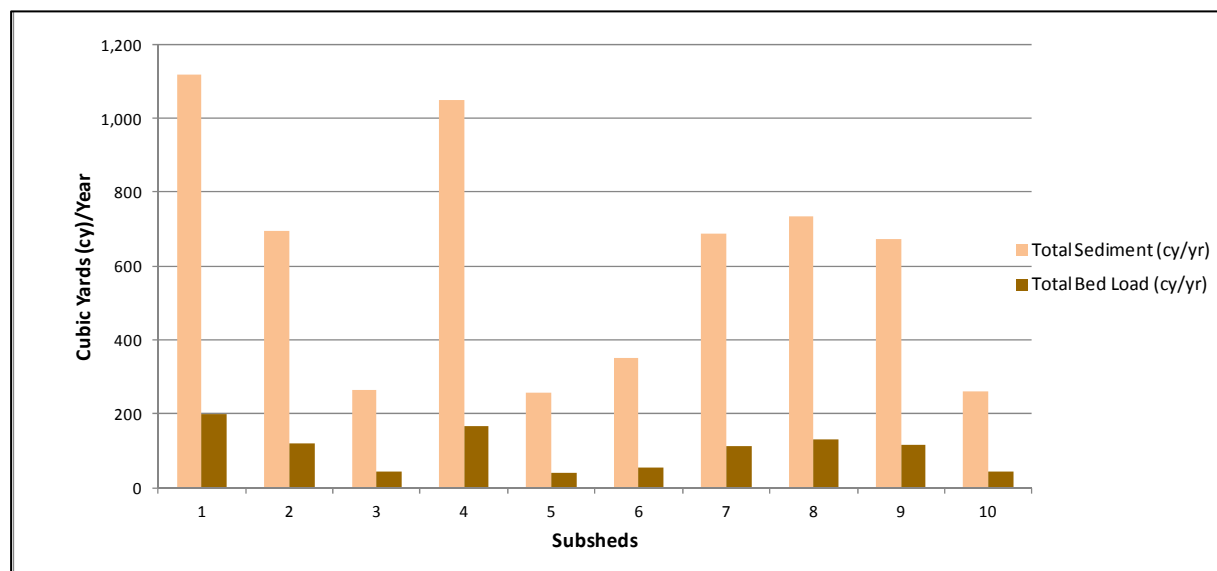


Figure 3.2 – Sediment Load by Subshed

3. Comparison of Foster Branch Sediment Loads to Other Watersheds

To evaluate the magnitude of sediment problem, the Foster Branch sediment loads were compared to the sediment loads measured in the Quittapahilla Creek Watershed Assessment previously referred to in the Assessment Methods Section of this Report, as well as two other watersheds. To evaluate sediment load from all sources, upland and in-channel sediment loads were combined and determined on a per acre basis. To keep the comparison relevant, the evaluation of sediment load from stream channel sources included only sediment loads from bank erosion and measured and modeled sediment loads from urban subsheds of Quittapahilla Creek.

Table 3.2 shows that when upland (from Chapter 5 – Table 5.3) and in-channel sediment loads are combined, the total sediment load for Foster Branch watershed is 9,173,506 lbs/yr. This equates to a sediment load of 6,431 lbs/acre. Measured sediment loads for the Quittapahilla Creek subsheds ranged from 267.6 to 489.6 lbs/acre. Evans (2004) found that in two impaired urban watersheds in Pennsylvania, sediment loadings ranged from 813 to 1,370 lbs/acre. The sediment loadings for Quittapahilla Creek fall below this range, while Foster Branch sediment loadings are much higher.

Table 3.2 – Comparison of Quittapahilla Creek and Foster Branch Watersheds Annual Sediment Load from All Sources					
Subshed	ID #	% Impervious	DA (Acres)	Total Sediment Load (lbs/yr)	Sediment Load (lbs/ac/yr)
Brandywine	15	20	2,213	592,263	267.6
Lebanon	16	85	7,291	3,293,829	451.7
Mid Quittie	12	20	3,767	1,844,483	489.6
Foster Branch	NA	11.9	1,429	9,173,506	6,431

Table 3.3 shows sediment loads from streambank erosion in Foster Branch watershed is 8,424,405 lbs/yr. This equates to a sediment load of 250 lbs/linear foot of unstable channel. Measured sediment loads for the Quittapahilla Creek subsheds ranged from 27.0 to 28.96 lbs/linear foot of unstable channel.

Table 3.3 – Comparison of Quittapahilla Creek and Foster Branch Watersheds Annual Sediment Load from Streambank Erosion					
Subshed	ID #	% Impervious	Sediment Load (lbs/yr)	Unstable Stream Length	Sediment Load (lbs/yr/lf)
Brandywine	15	20	246,960	9,095	27.2
Lebanon	16	85	125,685	4,650	27.0
Mid Quittie	12	20	527,877	18,225	28.96
Foster Branch	NA	13	8,424,405	34,360	250.0

In another study, Evans (2004) estimated that sediment from streambank erosion accounted for 61.8% and 78.6% of the total sediment load in the two urban Pennsylvania watersheds he evaluated. In the three Quittapahilla Creek subsheds sediment from streambank erosion accounted for 41.6%, 3.8% and 28.6% of the total sediment load. In Foster Branch, sediment from streambank erosion accounted for 91.8% of the total sediment load.

Information is not available on the characteristics of two urban watersheds evaluated by Evans. However, a comparison of Quittapahilla Creek and Foster Branch watersheds can provide perspective on the differences in total sediment load, as well as the sediment load from streambank erosion.

Quittapahilla Creek

Notwithstanding the significant amount of impervious area in its headwaters and the concrete flumes rapidly conveying storm flows to the natural sections of the channel, the creek is relatively stable. Several factors have contributed to Quittapahilla Creek's overall ability to withstand land use and channel alterations.

The limestone geology and rolling to gentle topography (slopes ranging from 3% to 8%) allow much of the runoff from non-urban areas to infiltrate into the soils. Channel gradient ranges from 0.002 to 0.005 feet/feet. The creek actually includes "losing reaches" where surface water goes subterranean. These characteristics tend to moderate the overall hydrologic regime of the watershed.

The cohesive nature of the silt clay banks along most reaches of the creek provides resistance to the erosive forces of storm flows. As a consequence, annual erosion rates along most of the creek are measured in tenths of feet per year as opposed streams with banks composed of sands and gravels where erosion rates are often measured in feet per storm event.

The nature of the creek bed has prevented it from incising as many creeks do in response to a changing hydrologic regime associated with urbanization. Although not always evident, the creek bed along most of its length rests on bedrock. Along many reaches a layer of gravel, sand and silt covers the bedrock. Where these finer materials have been removed by storm flows the bedrock is exposed as ledges, drops and chutes. A number of the upper reaches have sections composed of boulder and cobble riffles.

Bank heights are limited by the depth the stream can down cut before encountering bedrock or some other grade control mechanism. The relatively shallow depth to bedrock over much of the upper creek and along key sections throughout has kept bank heights relatively low.

Although much of the creek has been straightened, channel gradient is relatively flat. This factor in combination with low bank heights and broad floodplain keep stream

power (erosive capacity) low over a range of storm flows. This has contributed to overall lower bank erosion rates.

Although riparian buffers are lacking along many reaches, the significant length of the mainstem that has a woody riparian buffer is remarkable for a creek with the type of land use activities present along the Quittapahilla Creek corridor. The presence of mature trees and shrubs along significant lengths of the creek also contributes to overall lower bank erosion rates.

Foster Branch

The upper portion of the Foster Branch watershed is characterized by gentle to hilly topography. Narrow ridgelines drop over steep slopes ranging from 15% to 35% into relatively narrow stream valleys. Channel gradient ranges from 0.008 to 0.028 feet/feet. The middle watershed includes a central ridge that separates the West and East Branch. The side slopes of this ridge range from 15% to 30%. The tributaries dropping off the ridge have narrow valleys and are relatively steep.

In the lower watershed the main valleys broaden into wider, flatter floodplains. In these areas the channel gradient ranges from 0.002 to 0.008 feet/feet. The West and East Branch join just downstream of Trimble Road. In spite of a broader floodplain, Foster Branch in its lower watershed is still confined by adjacent ridges as it flows into tidal waters. The tributaries draining the ridge to the east are characterized by steep narrow valleys. The lower west ridge is drained predominantly by storm drain systems.

This region of Harford County is underlain by sedimentary deposits of sand, gravel, silt and clay. The dominant upland soils weathered from these rocks are silt loam, loamy sand, gravelly sandy loam, and loamy clayey soils on the ridges and side slopes of the watershed. These soils are characterized by rapid permeability and a severe erosion hazard. Loamy Clayey land consists of very old clay deposits overlain by more recent deposits of sandy loam, loam or silt loam. These soils are characterized by variable permeability. The clay is very plastic and sticky when wet. Its most important characteristic is its poor stability. Clay slides, slumps and flows are common where the soils have been disturbed. These conditions are particularly evident in Subsheds 1, 2 and 4.

The dominant land use in the upper Foster Branch watershed is commercial uses located along Pulaski Highway. The dominant land use in the interior of the middle watershed is forest. However, the eastern boundary of the watershed is characterized by medium to high density residential development. Magnolia Elementary School is situated along this boundary as well. The dominant land use in the lower watershed includes medium density residential subdivisions. The floodplain upstream and downstream of Trimble Road is public parkland.

The high percent imperviousness in the headwaters, steep topography, high stream power and highly erodible nature of the soils contribute to overall unstable

conditions throughout the watershed. More than 75% of the channels in the watershed are unstable. The worst channel conditions are in the headwater areas of Subsheds 1, 2 and 4.

4. Foster Branch Subsheds 1, 2 and 4 – Historic Sediment Loading Estimates Based on Channel Adjustments

A more detailed evaluation of these three subsheds will provide a final perspective on the estimates of sediment loads from streambank erosion in the Foster Branch watershed.

To determine how significant a contribution channel adjustments have been historically, an estimate of sediment loadings from in-channel sources was developed.

Historic aerial photographs from 1957 to 1971 show that, prior to 1966 land use in the watershed was predominantly forest and farm fields. Land use along Pulaski Highway and Magnolia Road in the subsheds draining Subsheds 1, 2 and 4 was converted from forest and farm fields to residential and commercial development during the mid to late 1960's and 1970's.

Assuming that prior to 1961 the cross-sectional area of the channels in the headwaters of Subsheds 1, 2 and 4, were typical of stable rural Coastal Plain streams, annual sediment loadings contributed from channel erosion can be determined as follows.

Subshed 1

Given:

Existing channel cross-sectional area in upper reach (EA) = 360 ft²

Existing channel cross-sectional area stable reach* (HA) = 4 ft²

Length of stream channel along the upper reach (SL) = 250 ft.

* Note drainage area same as upper reach

Cubic feet of sediment lost from channel erosion

$$(EA - HA) \times SL = (360 \text{ ft}^2 - 4 \text{ ft}^2) \times 250 \text{ ft.} = 89,000 \text{ ft}^3$$

Cubic feet (pounds) of sediment lost from channel erosion

$$89,000 \text{ ft}^3 \times 55 \text{ lbs/ft}^3 = 4,895,000 \text{ lbs}$$

Cubic feet (pounds) of sediment per linear foot of channel erosion

$$4,895,000 \text{ lbs}/250 \text{ ft} = 19,580 \text{ lbs/LF}$$

Annual sediment loadings from channel erosion

$$19,580 \text{ lbs/LF}/50 \text{ years} = 391.6 \text{ lbs/LF/year}$$

Subshed 2

Given:

Existing channel cross-sectional area in upper reach (EA) = 440 ft²

Existing channel cross-sectional area stable reach* (HA) = 4.5 ft²

Length of stream channel along the upper reach (SL) = 500 ft.

* Note drainage area same as upper reach

Cubic feet of sediment lost from channel erosion

$$(EA - HA) \times SL = (440 \text{ ft}^2 - 4.5 \text{ ft}^2) \times 500 \text{ ft.} = 217,750 \text{ ft}^3$$

Cubic feet (pounds) of sediment lost from channel erosion

$$217,750 \text{ ft}^3 \times 55 \text{ lbs/ft}^3 = 11,976,250 \text{ lbs}$$

Cubic feet (pounds) of sediment per linear foot of channel erosion

$$11,976,250 \text{ lbs}/500 \text{ ft} = 23,952.5 \text{ lbs/LF}$$

Annual sediment loadings from channel erosion

$$23,952.5 \text{ lbs/LF}/50 \text{ years} = 479 \text{ lbs/LF/year}$$

Subshed 4

Given:

Existing channel cross-sectional area in upper reach (EA) = 1080 ft²

Existing channel cross-sectional area stable reach* (HA) = 10 ft²

Length of stream channel along the upper reach (SL) = 500 ft.

* Note drainage area same as upper reach

Cubic feet of sediment lost from channel erosion

$$(EA - HA) \times SL = (1080 \text{ ft}^2 - 10 \text{ ft}^2) \times 500 \text{ ft.} = 535,000 \text{ ft}^3$$

Cubic feet (pounds) of sediment lost from channel erosion

$$535,000 \text{ ft}^3 \times 55 \text{ lbs/ft}^3 = 29,425,000 \text{ lbs}$$

Cubic feet (pounds) of sediment per linear foot of channel erosion

$$29,425,000 \text{ lbs}/500 \text{ ft} = 58,850 \text{ lbs/LF}$$

Annual sediment loadings from channel erosion

$$58,850 \text{ lbs/LF}/50 \text{ years} = 1,177 \text{ lbs/LF/year}$$

This evaluation shows that significant sediment loads (391.6 – 1,177 lbs/LF/year) can be contributed from relatively short reaches of stream (250 – 500 LF) adjusting to the altered hydrologic regime associated with urbanization.

5. Discussion

From the results of this Study, it is clear that the Foster Branch watershed is severely degraded. Although sediment loads from upland sources are relatively low compared to the other urban watersheds cited in this report, sediment loads from in-channel sources are significantly higher. These differences have been attributed to the high percent imperviousness in the headwaters, steep topography, high stream power, and highly erodible nature of the soils throughout the Foster Branch watershed. As a consequence, more than 75% of the channels in the watershed are unstable and present a significant source of sediment to the tidal portion of the creek.

Although watershed sediment loads have long been expressed as a unit weight per unit area per unit time (e.g. kilograms/hectare/year and pounds/acre/year), it is only recently that the term pounds/linear foot of stream channel/year has become a standard expression for sediment loads from in-channel sources. It provides a convenient means for comparing conditions along different stream systems. However, it is important to remember that even in a given watershed, conditions can vary considerably from reach to reach. A stable reach may contribute little or no sediment. Even along unstable reaches measured bank erosion can vary from 0.1 foot per year to as much as 6 to 10 feet in a single storm. During drought years a reach may contribute little sediment or a

significant amount during an unusually wet year. Therefore, annual rates are indicative of average contributions over a period of time with actual contributions varying from year to year. In addition, loading rates developed from data collected at a single or few point(s) along a stream system and applied to the entire stream system should be utilized with caution.

The assessment methodology utilized in the current Study involved the collection of data along all stream reaches in the watershed, thereby ensuring that the sediment load estimates developed represent the conditions throughout the Foster Branch watershed.

Chapter 4 Sediment Reduction Strategies

I. Environmental Need

A. Impacts of Increased Sediment Loadings on Aquatic Habitats and Biotic Communities

An increase in loading of suspended and bedded sediment to aquatic systems is now considered one of the greatest causes of water quality impairment in the Nation (U.S.EPA, 2003a).

Turbidity, suspended solids, sediment and siltation have been consistently listed in 305(b) Water Quality Reports in rivers and streams, lakes, reservoirs, ponds, wetlands and estuarine waters. In 1998, approximately 40% of assessed river miles in the U.S. had problems arising from sediment stress (U.S. EPA, 2000). The U.S. EPA's Office of Water is presently considering how to develop criteria for suspended and bedded sediment.

1. General

The biological effects of suspended and bedded sediment on estuarine environments were reviewed by Wilber and Clarke (2001). Excessive sediments in aquatic systems contribute to increased turbidity leading to altered light regimes which can directly impact primary productivity, species distribution, behavior, feeding, reproduction and survival of aquatic biota.

Reduced light can reduce production of phytoplankton and submerged aquatic vegetation. Reduced light and increased turbidity can also affect the feeding ability and movements of fish, especially larval fish. Larger fish may be able to reduce some of these effects by avoiding low visibility water.

Other direct effects of increased suspended and bedded sediment include physical abrasion and clogging of filtration and respiratory organs. In extreme cases, excess suspended and bedded sediment can cause burial and smothering of infaunal or epibenthic organisms. Most estuarine benthic organisms are adapted to living in an environment subject to periodic resuspension of sediment and can dig out from under a small amount of sediment (Maurer, 1986). Demersal eggs may be particularly vulnerable, however, as only a few millimeters of deposited sediment may prevent them from hatching (D. Nelson, personal communication).

Some of the most important indirect effects of suspended and bedded sediment in estuarine habitats relate to loss of primary and secondary production. Reductions in primary production affects primary consumers, which in turn affects secondary consumers and continues up the food chain. Eventually these effects reach even the top predators, such as eagles and humans.

The effects of suspended and bedded sediment in streams were reviewed by Waters (1995). Suspended and bedded sediment have two major avenues of action in streams and rivers: 1) direct effects on biota; and 2) direct effects on physical habitat, which results in indirect effects on biota. Examples of direct effects on biota include suppression of photosynthesis by shading primary producers; increased drifting of and consequent predation on benthic invertebrates; and shifts to turbidity-tolerant fish communities.

Indirect effects on biota will occur as the biotic assemblages that rely upon aquatic habitat for reproduction, feeding and cover are adversely affected by habitat loss or degradation of this habitat. An example of indirect effects of suspended and bedded sediment in streams and rivers is the loss of spawning habitat for fishes by an increase in embeddedness, caused by the entrapment of fine material in the gravel. Increased sedimentation can limit the amount of oxygen in the spawning beds which can reduce hatching success, or trap the fry in the sediment after hatching.

Suspended sediments contribute to turbidity and thus affect light transmission through the water column (Waters, 1995). Turbidity is an optical property of water resulting in a decrease in light transmission due to absorption and scattering. Consequently turbidity is a key water quality parameter in aquatic systems in that it has a predominant influence on the compensation point (the depth at which photosynthesis equals respiration in plants) and is therefore a critical determinant in the distribution of submerged aquatic vegetation (SAV) (Batuik, et al., 1992).

Various measurements are used for bedded sediments as well. These include depth of deposition within a given time period, percent fines, geometric mean diameter, and Fredle number (Caux et al., 1997). (Fredle number is an index of permeability that has been found to correlate well with survival-to-emergence of salmon and trout (Lotspeich and Everest, 1981).

2. Macroinvertebrates

Waters (1995) considers the effects of increased deposition of sediments on benthic invertebrates as one of the most important concerns within the sediment pollution issue, especially in regards to the dependence of freshwater fisheries on benthic productivity. Waters (1995) identifies three major relationships between benthic invertebrate communities and sediment deposition in streams: 1) correlation between abundance and substrate particle size; 2) embeddedness of substrate and loss of interstitial space; and 3) change in species composition with change in type of habitat (substrate composition).

Alteration in the quality and quantity of deposited sediments can affect the structure and function of benthic macroinvertebrate communities by increasing substrate embeddedness and altering substrate particle size distributions (Erman and Erman, 1984). Increased embeddedness can result in decreases in aquatic insect densities and small increases in siltation can directly affect caddisfly pupa survival.

3. Fish

There are three major effects of suspended and bedded sediment on fishes: 1) direct physiological effects of suspended sediment, such as suffocation; 2) effects due to decreases in water clarity; and 3) effects due to sediment deposition, leading to increased embeddedness or burial of eggs and larvae (Waters, 1995; Wilber and Clarke, 2001).

The effects of increased suspended and bedded sediment resulting in increased embeddedness on salmonids in particular, have been well documented (e.g. Waters, 1995). An increased supply of fine sediment to a stream can cause the gravel interstices of a stream bed to be filled in. This process can cause reduced hatching due to the reduction in flow through the stream bed and the resulting decrease in dissolved oxygen. It can also cause reduced larval survival because of armoring of the sediment surface which traps the larvae. Increased sedimentation in other habitats (e.g. estuaries) can cause burial of eggs (Wilber and Clarke, 2001). Even a small amount of deposited sediment can cause a problem. Winter flounder eggs, for example, will suffer reduced hatching success if buried to only one half an egg diameter (D. Nelson, NMFS, unpublished data).

4. Aquatic Macrophytes

Some populations of aquatic macrophytes have experienced dramatic losses over the past two decades, a decline largely attributed to changes in underwater light climate due to increases in suspended sediment concentrations (Best et al., 2001).

Turbidity limits the growth and distribution of aquatic plants by reducing available light. The large-scale declines of submerged aquatic vegetation (SAV) reported in the Chesapeake Bay are believed to be directly related to increasing amounts of nutrients and sediments entering the Bay (Batiuk et al., 1992, 2000; Dennison et al., 1993).

To address the unacceptable Bay-wide decline in SAV the U.S. EPA Chesapeake Bay Program office established water clarity criteria. Water clarity criteria are based on the light requirements for SAV growth and survival. The criteria take total suspended solids (particulate matter and chlorophyll a) into account, as well as, epiphytic growth and salinity regime. Water clarity criteria are used in the Chesapeake Bay because it is assumed that they will result in achievement of clarity/solids levels that would not impair other habitats/organisms (with the exception that the water clarity criteria may not fully protect "smothering" of bottom soft or hard bottom habitats with larger sized sediment particles from sources that "bypass"/don't influence shallow water habitats), since the SAV represent one of the components of the Chesapeake Bay ecosystem that is most sensitive to increases in suspended sediment. A detailed explanation of the derivation of Chesapeake Bay water clarity criteria can be found in U.S. EPA (2003b).

SAV are also subject to burial, although different species have different tolerances for sediment accretion and different sediment entrainment qualities (Fonseca and Fisher, 1986). These different tolerances can result in changes in species composition in addition to overall loss of SAV as a result of increased siltation (Terrados et al., 1998). It is not always possible to separate out the effects of burial from the other effects of increased sediment input, for example, reduced light penetration (Terrados et al., 1998).

B. Impacts on Recreational Boating

Sediment accumulation in navigation channels and actively boated waterways can have a considerable impact on recreational boating as well as secondary impacts on the aquatic environment. Initially, sediment accumulation may have little or no impact on boating. However, as the accumulation increases in depth, the available water column “under-keel” is reduced initially causing prop wash and repeated resuspension of bottom sediment during boating. As the accumulation increases, prop wash increases in frequency (e.g. a greater range of vessel drafts affected) and magnitude. This prop washing can have a profound and extended effect on tidal water quality as washed and resuspended sediment plumes are dragged and dispersed downstream by boating operations, as well as currents and tides. Since boating activities occur predominantly during warmer weather, key aquatic habitat and growth cycles can be affected such as the suppression of SAV and fish spawning. Eventually, as in the case of Foster Branch, the sediment accumulation can create unsafe navigation depths where compromised vessel operations can lead to damage to boat and engine parts and can create unsafe boating conditions.

In order to restore these sediment impacted waterways, the State of Maryland conducts maintenance dredging under its Waterway Improvement Program to restore boating access and associated economic and environmental benefits of unimpeded access to the Chesapeake Bay.



Photo 4.1 – Foster Branch Tidal Waterway - watershed sediment accumulation must be dredged every 10+/- years.

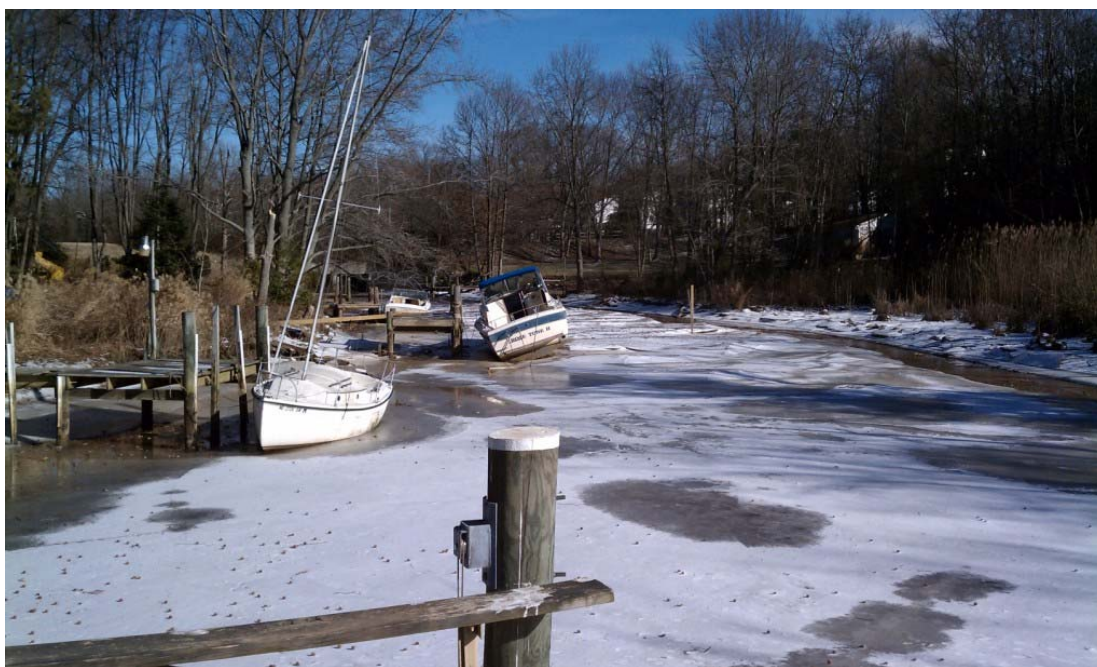


Photo 4.2 – Foster Branch Tidal Waterway - 2' to 5' of sediment accumulation in upper 600' reach

II. Identification of Sediment Abatement Strategies

A. Source Reduction Strategies

1. Identification of Channel Restoration / Stabilization Projects

Because unstable stream reaches are the primary source of sediment in the Foster Branch watershed, any successful long-term effort focused on reducing sediment loadings to the tidal creek must include channel restoration and stabilization.

Due to the widespread stability problems it would not be practical to implement restoration of all of the unstable stream reaches. Therefore, it was important to identify the most significant problem areas.

A comprehensive analysis was conducted to identify potential channel restoration and stabilization projects. The first part of this process was relatively straightforward and utilized the results of the sediment loadings analysis.

The stream reaches in those subsheds with the largest contribution of sediment were evaluated to determine their relative contribution to the sediment from their respective subshed. The evaluation included tabulating the contribution of sediment from individual eroding banks, slope failures, head cuts and bar deposition within a given reach. Those stream reaches determined to be the most significant contributors were set aside for further evaluation and ranking. Those stream reaches determined to have smaller contributions, that is, exhibiting minor and localized erosion or sedimentation, were not evaluated further.

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 to 350 linear feet (LF) in length and include stabilization of storm drain outfalls, stabilization of approaches to culverts and bridges, and localized gully or streambank stabilization. Large scale projects are usually implemented as individual Capital Improvement Projects. Typical large scale projects are 1,000 to 3,500 LF in length and include channel reconstruction and streambank stabilization along significant sections of the channel.

As shown in Table 4.1 the 19 stream reaches identified as potential stabilization / restoration projects vary in length from 50 to 1,315 LF. Only three reaches are greater than 1,000 LF in length. Nine reaches are from 350 to 1,000 LF in length and seven reaches are less than 350 LF.

Table 4.1 – Stream Stabilization/Restoration Projects				
Project ID	Project Type	Project Length (ft)	Sediment Load Reduction (cy/yr)	Bed Load Reduction (cy/yr)
SR 1-1	Stream Restoration	800	549	82
SR 1-2	Head Cut Stabilization	110	11	2
SR 1-3	Slope Stabilization	80	3	1
SR 1-4	Stream Restoration Head Cut Stabilization Bar Stabilization Slope Stabilization	600	26	4
SR 1-5	Stream Restoration Bar Stabilization Slope Stabilization	1,315	278	52
SR 1-6	Stream Restoration/Relocation Bar Stabilization Slope Stabilization	660	96	19
SR 2-1	Stream Restoration	600	479	88
SR 2-2	Head Cut Stabilization	50	10	2
SR 2-3	Stream Restoration	330	132	20
SR 2-4	Sediment Trap (Low Earthen Berm and Stable Outfall)		19	19
SR 3-1	Head Cut Stabilization	100	57	9
SR 3-2	Head Cut Stabilization	235	9	1
SR 4-1	Stream Restoration	700	482	72
SR 4-2	Stream Restoration Slope Stabilization	1,125	367	55
SR 6-1	Stream Restoration	750	199	30
SR 7-1	Stream Restoration	1,275	72	11
SR 8-1	Stream Restoration	635	372	62
SR 9-1	Stream Restoration Slope Stabilization	650	589	88
SR 10-1	Stream Restoration	985	253	38
Subtotal SR Projects		11,000	4,003	655

2. Recommended Approach to Stabilization and 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 floodwaters 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 (base flow, 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 Foster Branch 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; minimizing the effects of land use by installing storm water 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 photos of example projects that were designed utilizing a natural channel design approach and specific techniques that are directly applicable to the stability problems identified along Foster Branch and its tributaries.

GRADE CONTROL STRUCTURES

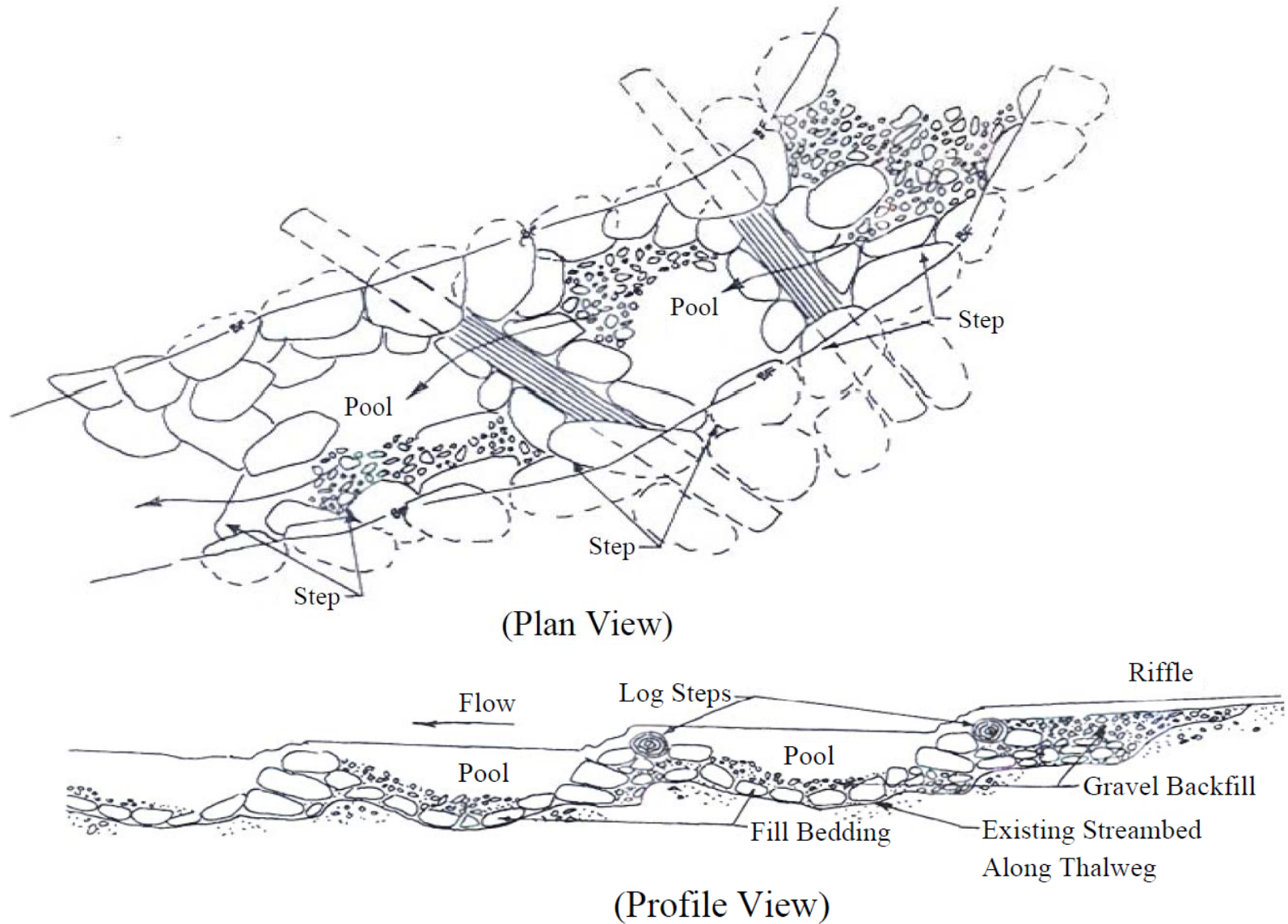


Figure 4.1 – Log/Boulder Step-Pools

GRADE CONTROL STRUCTURES

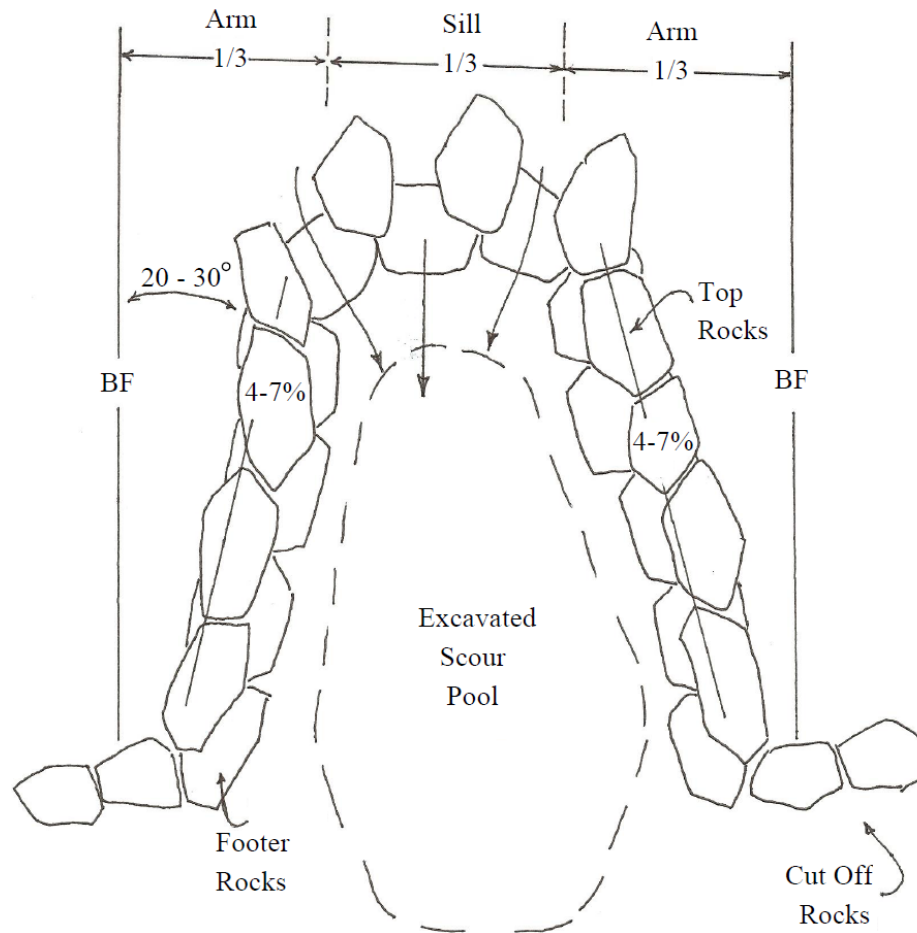


Figure 4.2 – Cross Vane

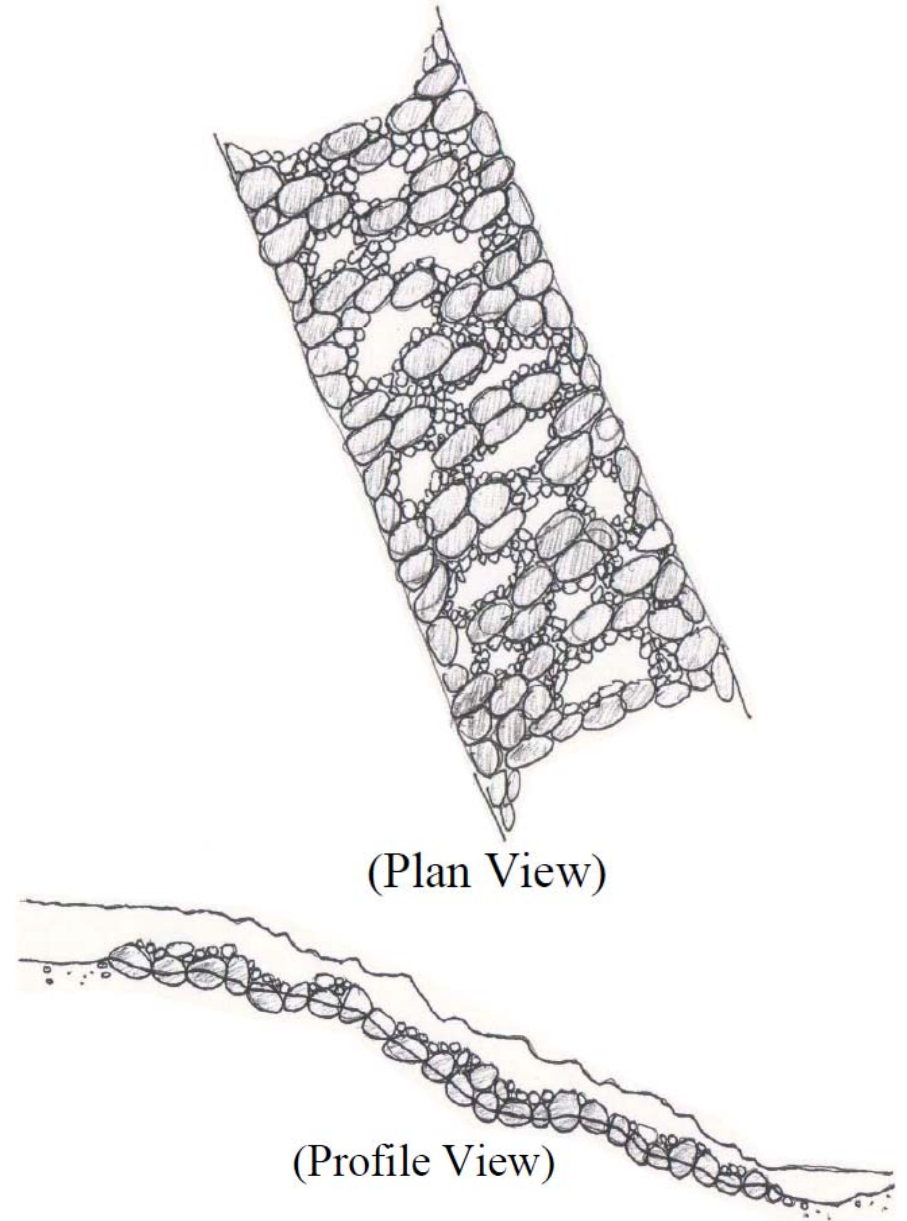


Figure 4.3 – Boulder Cascade

FLOW DIVERSION STRUCTURES

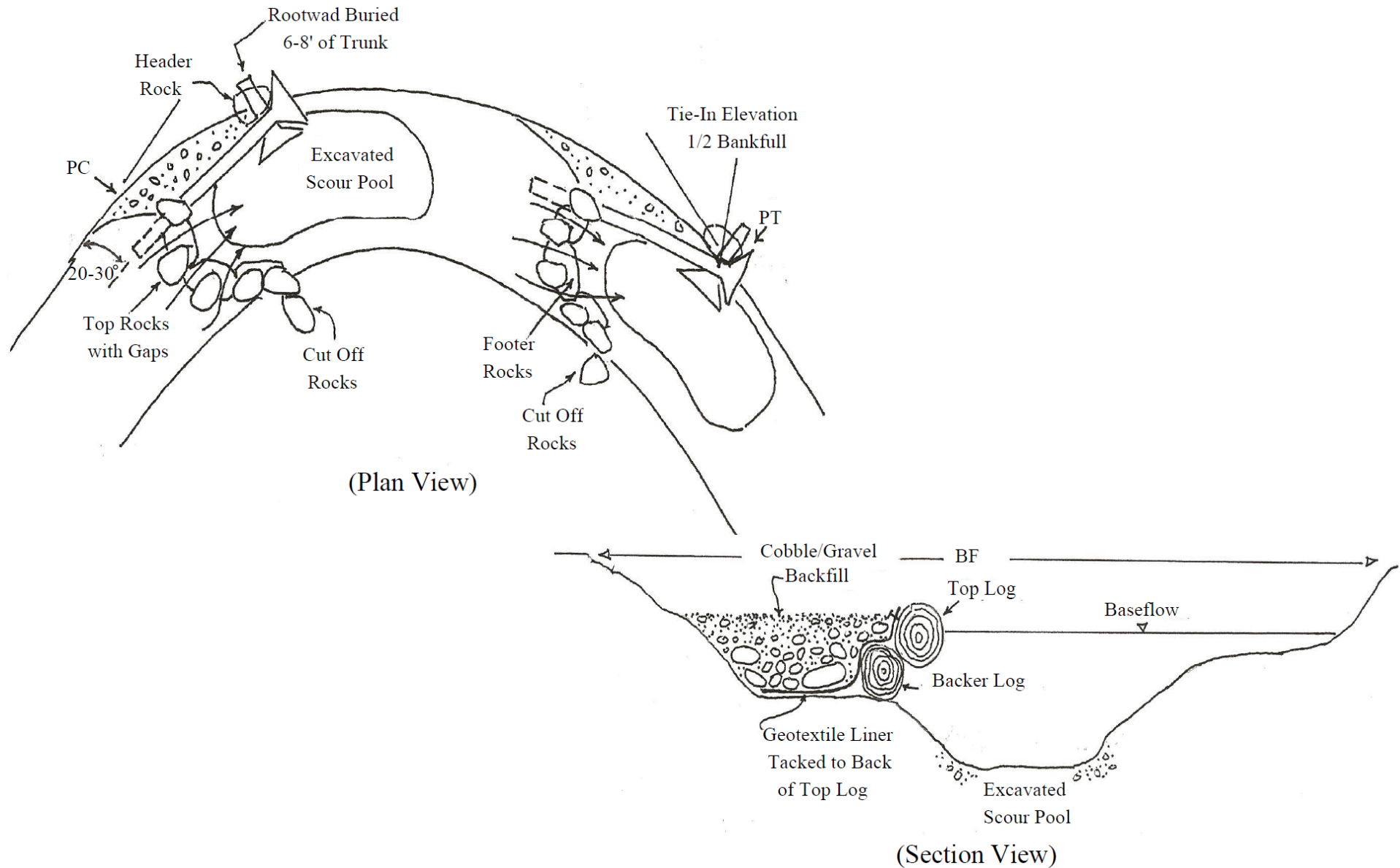


Figure 4.4 – Log Boulder J-Hook

FLOW DIVERSION STRUCTURES

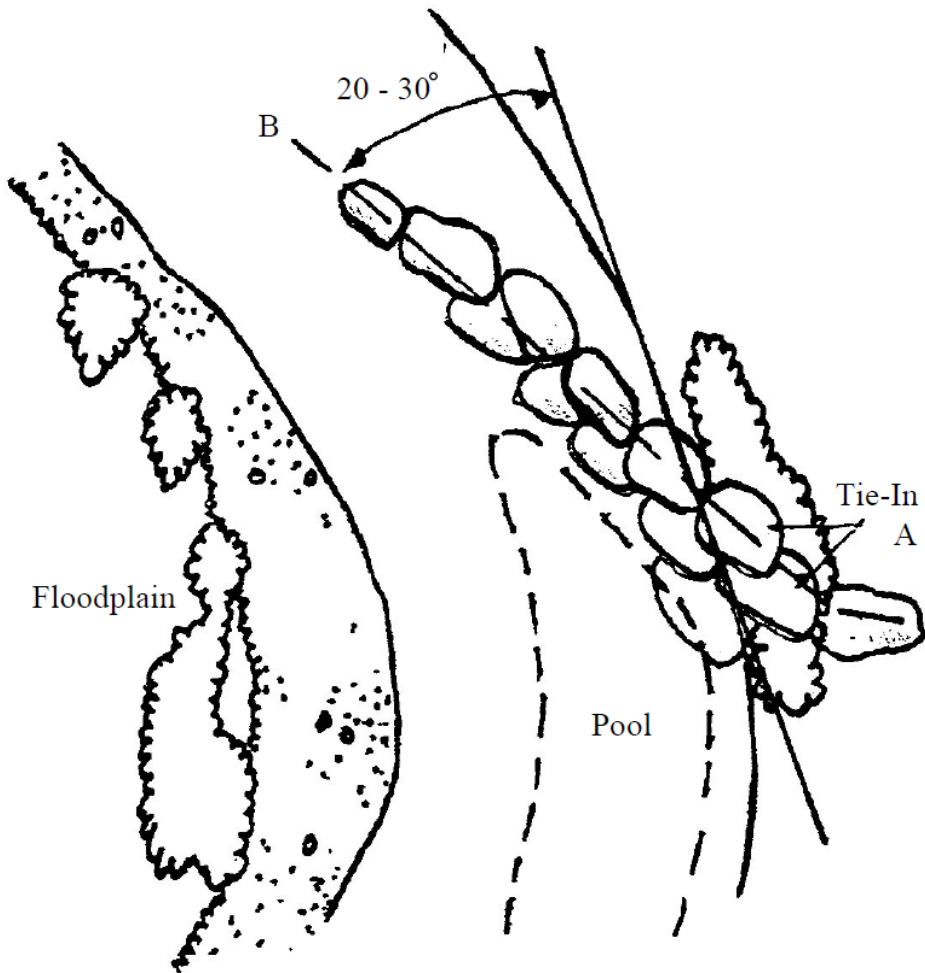


Figure 4.5 – Rock Vane

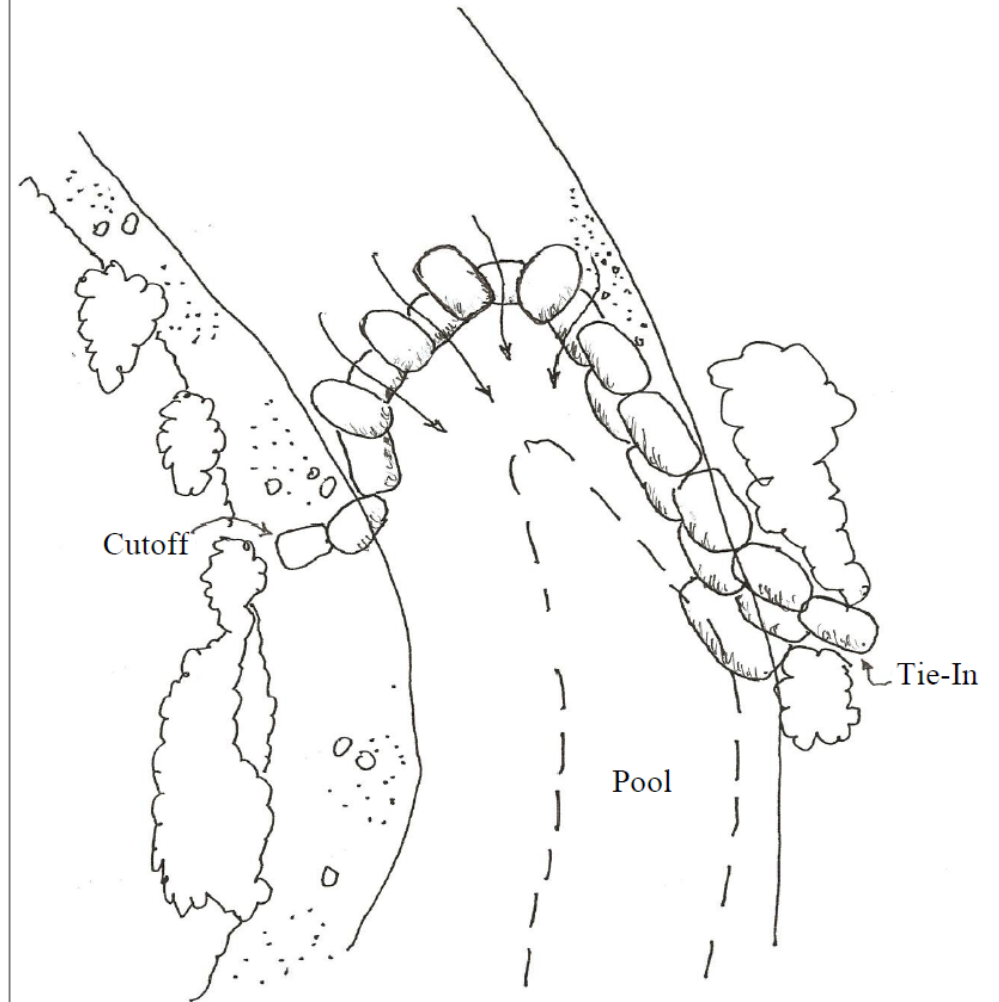


Figure 4.6 – Boulder J-Hook

BANK RECONSTRUCTION/STABILIZATION STRUCTURES

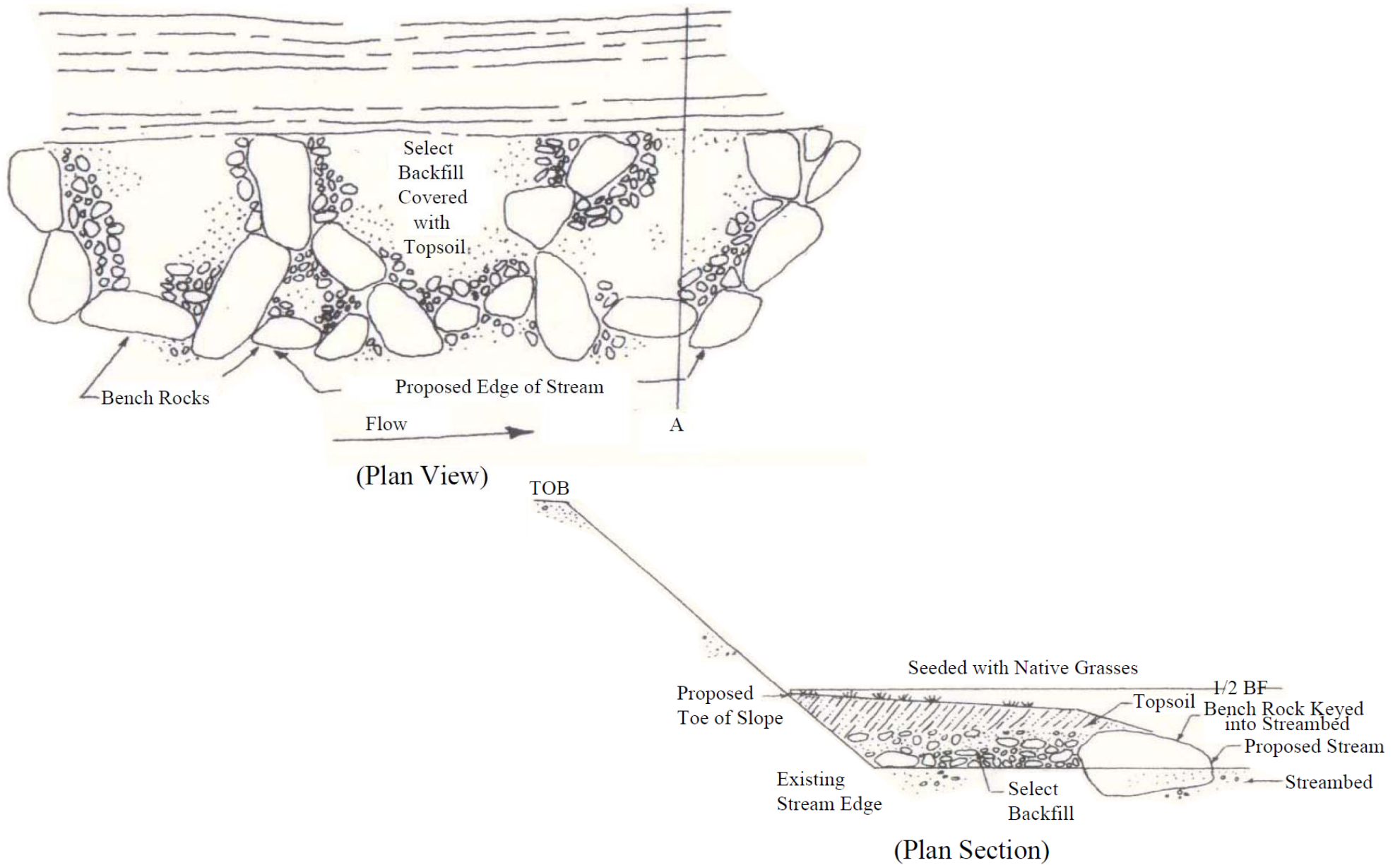


Figure 4.7 – Toe Benches

BANK RECONSTRUCTION/STABILIZATION STRUCTURES

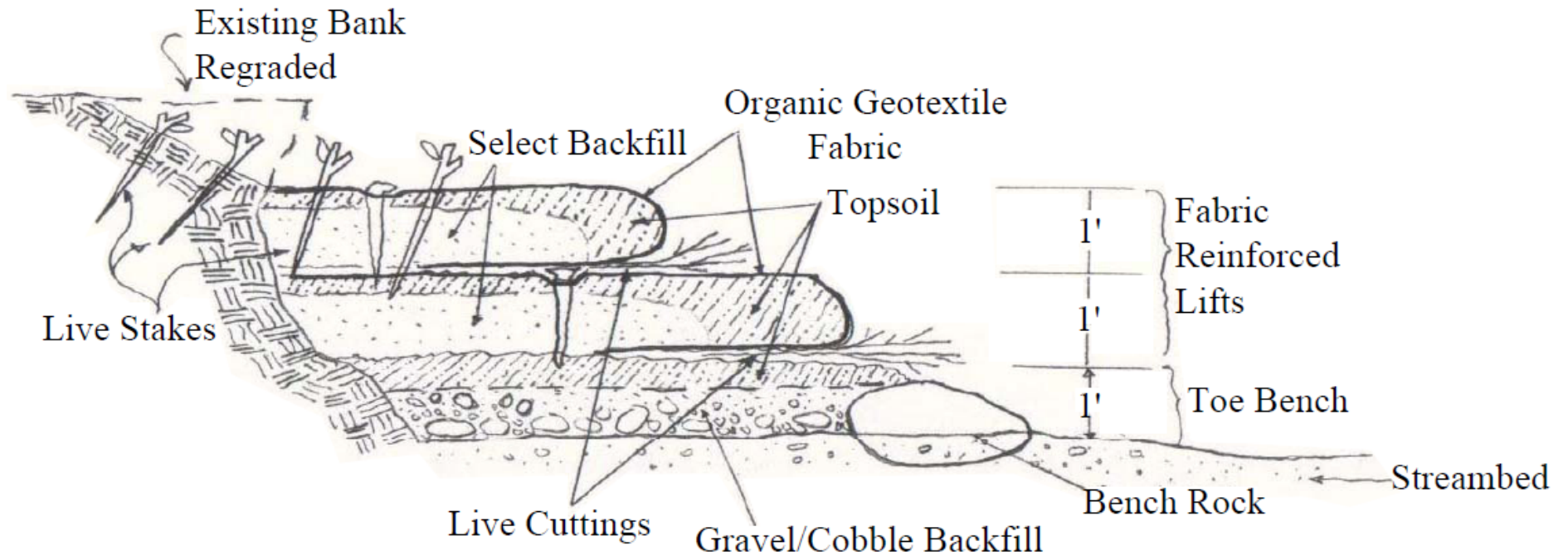


Figure 4.8 – Toe Benches and Soil Fabric Lifts

BANK STABILIZATION STRUCTURES

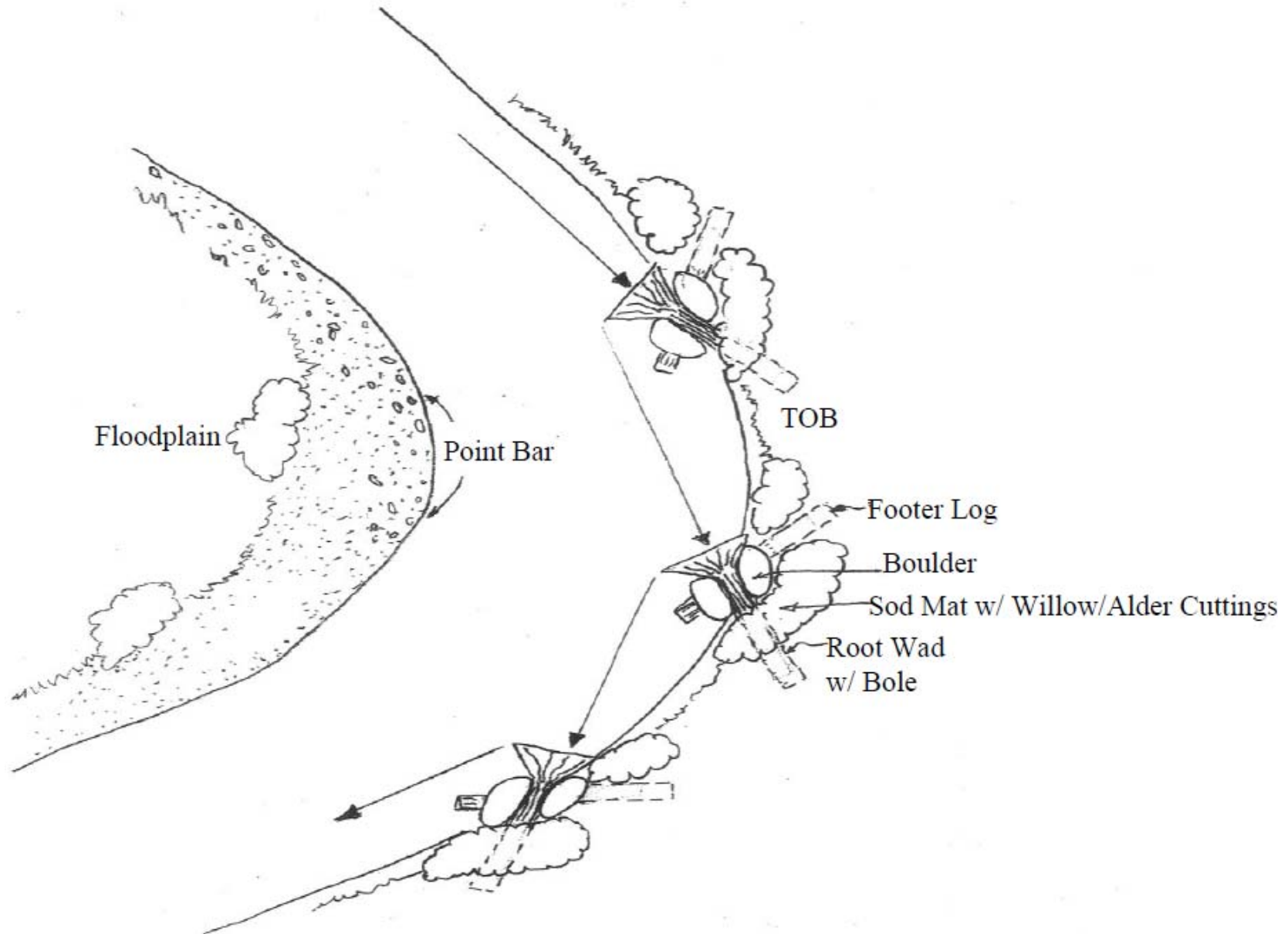


Figure 4.9 – Rootwad Revetment

BANK RECONSTRUCTION/STABILIZATION STRUCTURES

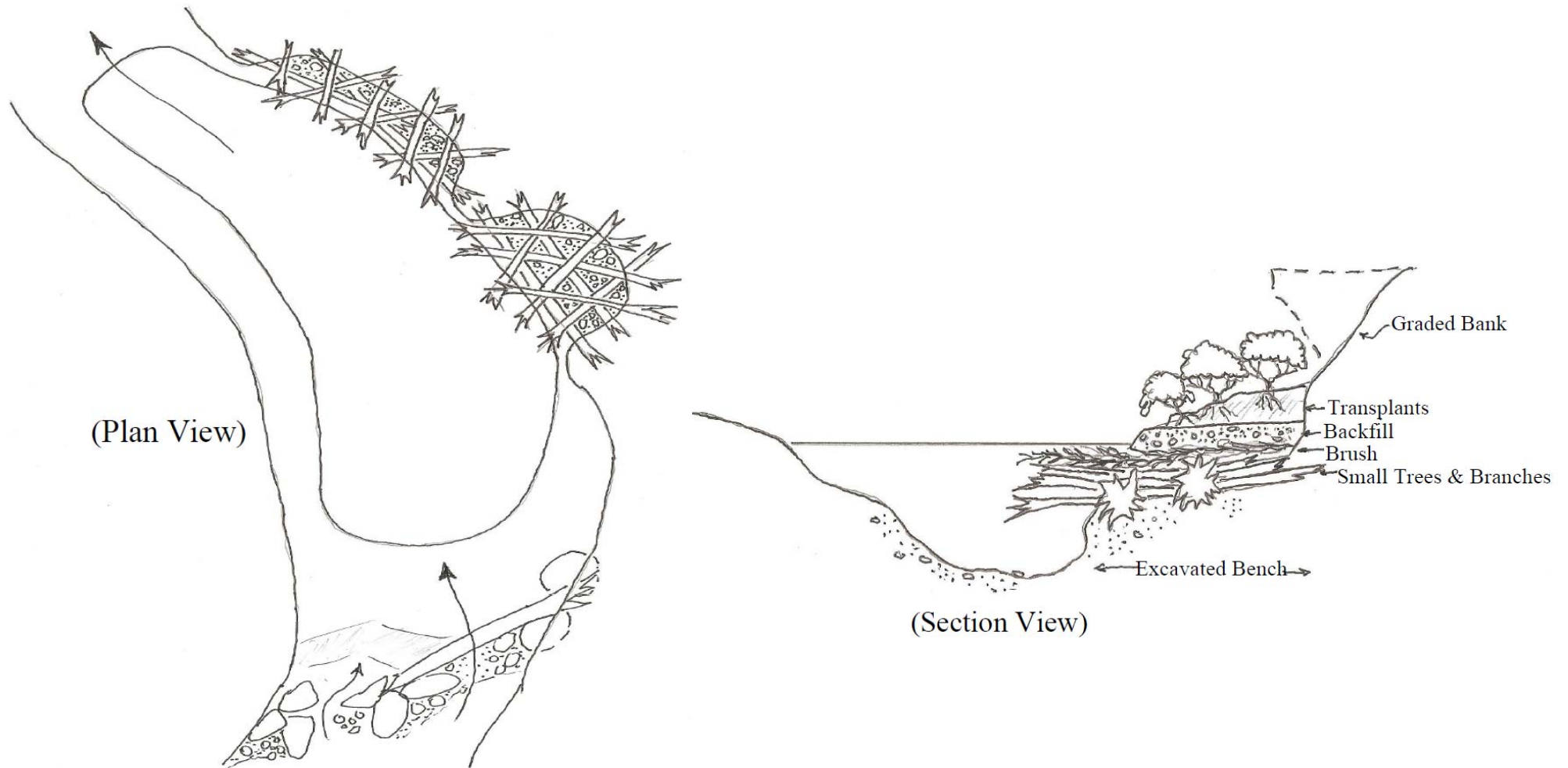


Figure 4.10 – Toe Wood Revetment

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. Stormwater Management and Sediment Collection/Retention Strategies

A. Stormwater Best Management Practices

1. Overview

A primary goal of this assessment is to reduce and manage the magnitude of sedimentation and associated cost and impacts to the tidal portion of Foster Branch. This historic and actively navigated channel has been dredged approximately every ten years in order to eliminate severe shoaling, unacceptable loss of water depth and related loss of boating access throughout the three-quarter mile waterway. Environmental impacts to the tidal waterway are also prevalent as deeper water habitat is rapidly converted to shallows and mud flats. These sediment loadings create negative impacts to tidal water quality and associated submerged flora and fauna. These conditions are exacerbated by secondary impacts from boater prop wash and prop dredging causing sediment resuspension, redistribution and added degradation of water quality and habitat.

The initial objective of the stormwater assessment was to assess management and conveyance systems in the urbanized portion of the watershed below Trimble Road. This portion of the watershed, Subsheds 9 and 10, surrounds the tidal waterway and was thought to contribute substantially to the tidal sedimentation and water quality degradation. However, as the watershed field assessment data was evaluated, it became clear that the bulk of the sediment source was further upstream within the watershed. The preliminary assessment of the stormwater infrastructure below Trimble Road also confirmed that sighting BMP's with less beneficial sediment removal or peak flow reduction capacity (channel protection volume) would be difficult or meaningless since the streams and drainage ways are shorter, flatter and generally more stable in this portion of the watershed.

It was decided that a more strategic stormwater management approach would benefit the tidal waterway and the watershed as a whole. The stormwater investigation would be expanded to focus on upstream areas particularly in the largest sediment producing subsheds, Subsheds 1, 4, 2, 8 and 7. The investigation would also focus on sighting facilities immediately upstream of severely degraded stream reaches to help attenuate peak flows and thereby reduce erosion and downstream sedimentation.

2. Desktop and Field Assessment

A strategic assessment of potential stormwater best management practices (BMPs) sites was conducted in order to identify opportunities to achieve measureable reductions in erosion, sedimentation and nutrient loading within the stream and tidal waterway. This BMP site selection process incorporated field observations and GIS analysis along with the data and findings from the stream assessment to develop a list of potential retrofit sites that would be cost effective and implementable to meet the expanded goals of this assessment. This process included prioritizing sites that met a

favorable combination of the following selection criteria: existing stormwater or sediment facilities; County owned sites; sites that have a drainage area with a high percentage of impervious area; sites with enough area to implement a project that would have quantifiable results; good construction access; minimum disturbance to existing woodland or sensitive areas; and favorable environmental constraints.

3. Candidate BMP Sites

This section describes the identified stormwater management BMP retrofit sites that exhibited a favorable combination of the selection criteria. The description of each potential BMP lists the site location, current property owner, drainage area and percent impervious, potential achievable combined storage (Wet and Dry), estimated construction cost, and a description of the potential retrofit project and associated benefits. All facilities are proposed to be retrofitted or constructed as wet ponds that would be cost effective and have high removal efficiencies for nutrients and sediments and would be easy to maintain.

Table 4.2 – Stormwater Management Facility 1	
Owner	Stancills, Inc
Location	1020 Oak Avenue Joppa, MD 21085
Drainage Area	40.7± Acres
% Impervious of Drainage Area	4.4±%
Type of BMP Proposed	Wet Pond
Achievable Facility Storage	4.7± ac-ft
Estimated Construction Cost	\$120,000
Description	Existing 0.88 acre sediment basin currently utilized for control of stormwater runoff from 40± acres of spoil stockpiles. Existing sediment basin, upon closure of industrial operations, could potentially be retrofitted to provide limited sediment capacity, reduce peak discharges and reduce downstream erosion, enhance water quality, incorporate wetland planting zones and habitat diversity for future use of the contributing drainage area.

Table 4.3 – Stormwater Management Facility 2	
Owner	Kenneth and Sylvia Day
Location	911 Pine Road Joppa. MD 21085
Drainage Area	185.5± Acres
% Impervious of Drainage Area	24.7±%
Type of BMP Proposed	Wet Pond
Achievable Facility Storage	4.6± ac-ft
Estimated Construction Cost	\$200,000
Description	An existing 0.86 acre in-stream private pond with permanent pool was created by construction of a 10 foot high embankment. This in-stream facility is currently acting as a sediment basin for upstream erosion sources from a large subwatershed and is gradually becoming filled. The existing pond could be retrofitted through dredging and reconstruction of the principal spillway to create additional sediment storage, reduce peak discharges and reduce downstream erosion, enhance water quality, incorporate wetland planting zones and habitat diversity.

Table 4.4 – Stormwater Management Facility 3	
Owner	C S P Associates
Location	914 Pulaski Highway Joppa, MD 21085
Drainage Area	26.4± Acres
% Impervious of Drainage Area	43.7±%
Type of BMP Proposed	Wet Pond
Achievable Facility Storage	1.1± ac-ft
Estimated Construction Cost	\$150,000
Description	A proposed new facility located immediately upstream of the Pulaski Highway culvert within the existing floodplain. The facility could be constructed to provide limited sediment capacity, peak discharge reduction and reduced downstream erosion, provide water quality treatment, and incorporate wetland planting zones and habitat diversity.

Table 4.5 – Stormwater Management Facility 4	
Owner	Woodbridge Homeowners Association
Location	Corner of Hanson Road and Magnolia Road
Drainage Area	33.0± Acres
% Impervious of Drainage Area	20.0±%
Type of BMP Proposed	Wet Pond
Achievable Facility Storage	4.4± ac-ft
Estimated Construction Cost	\$80,000
Description	The existing facility was constructed in 1987 as a dry detention stormwater management facility to provide stormwater management for the Woodbridge Residential Community. The facility currently provides 2-, 10- and 100-year management with a riser structure that has an 18" low flow pipe. The existing facility could be retrofitted with a new riser structure and excavation of a wet pool and wetland bench to provide limited additional sediment capacity, reduction of peak discharges and downstream erosion, enhance water quality, incorporate wetland planting zones and habitat diversity.

Table 4.6 – Stormwater Management Facility 5	
Owner	Harford County Board of Education – Magnolia Elementary and Middle School
Location	901 Trimble Road Joppa, MD 21085
Drainage Area	9.2± Acres
% Impervious of Drainage Area	35.0±%
Type of BMP Proposed	Wet Pond
Achievable Facility Storage	2.9± ac-ft
Estimated Construction Cost	\$175,000
Description	A proposed new facility located within the open space between Trimble Road and the school access loop. The facility could be constructed to provide limited sediment capacity, provide water quality and channel protection storage with wetland planting zones and habitat diversity. The facility could also be utilized to provide educational opportunities for Magnolia Elementary and Middle School students.

B. Discussion

Based upon their position in the landscape the stormwater BMP's would be effective at capturing suspended sediment and nutrient loads but would not address the bed load erosion that is a predominant impact factor for the Foster Branch tidal waterway as described in Chapter 3. The exception would be SWM Facility No. 2 which

is an existing in-line pond. This facility can capture significant sediment and pollutants from its 185.5 acre watershed but since it is in-line, also has the unique ability to capture approximately 35 cubic yards per year of upstream bed load material. The bed load reductions and storage summary is included in Table 4.7.

Table 4.7 – Bed Load Reductions and Storage Summary			
Project	Type	Storage (ac-ft)	Sediment Bed Load Reduction (cy/yr)
SWM-1	Retrofit of Existing Sediment Basin	4.7	-
SWM-2	Retrofit of Existing Private Pond	4.6	35
SWM-3	New SWM Facility	1.1	-
SWM-4	Retrofit of Existing SWM Facility	4.4	-
SWM-5	New SWM Facility	2.9	-
Total		17.7	35

Since SWM Facility 2 will accomplish superior pollutant load reductions and is able to reduce bed loads to the tidal creek it was selected for further development and implementation within the overall watershed plan.

C. Sediment Collection and Retention Strategies

1. Overview

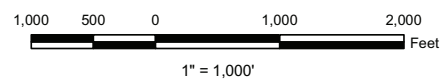
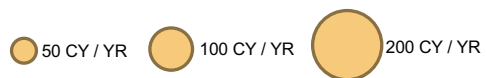
Nineteen stream restoration/stabilization projects were identified that would have a significant impact on reducing suspended sediment loads downstream and to the tidal waterway. If fully implemented, these projects would reduce suspended loads by approximately 66%. While this makes significant headway on overall pollutant reduction, the bed load filling of the upper tidal waterway would continue at a rate of 370 cubic yards per year. It was also recognized that funding and implementation of all 19 stream restoration projects would take more than a decade resulting in even greater annual bed load deposition.

Since a primary goal of this project is to make significant reductions in tidal impacts, additional sediment collection and retention strategies were investigated. The strategies investigated include in-line facilities, meaning facilities that would be located within the stream channel, and offline facilities that are located away from or adjacent to the stream. To facilitate favorable sighting of any sediment retention facility, a map was created showing the magnitude of bed load that is produced from each sub-watershed (Figure 4.11). This map along with previously discussed loading charts and tables were used to locate and size potential sediment retention facilities.



Notes:
1. Aerial Photography from Harford County Dated 2007.

1 Foster Branch Study Area
— Hydro/Streams



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Figure 4.11
Foster Branch
Stream Channel
Annual Bed Loads

2. In-line Facilities

In order to have the greatest impact on bed load, the stream channel downstream of Trimble Road was considered for an in-line sediment retention facility. This location was superior based on its position relative to the upstream bed load sources that could be captured from both the east and west stream branches. A desktop review was conducted that produced two candidate sites for locating an in-stream facility (Figure 4.12). The downstream candidate site would be located just upstream of the embankment of Joppa Farm Road using the embankment to create ponding and sediment retention. The width and topography of the floodplain would also allow excavation and/or creation of lower successive upstream embankments for additional ponding and sediment retention.

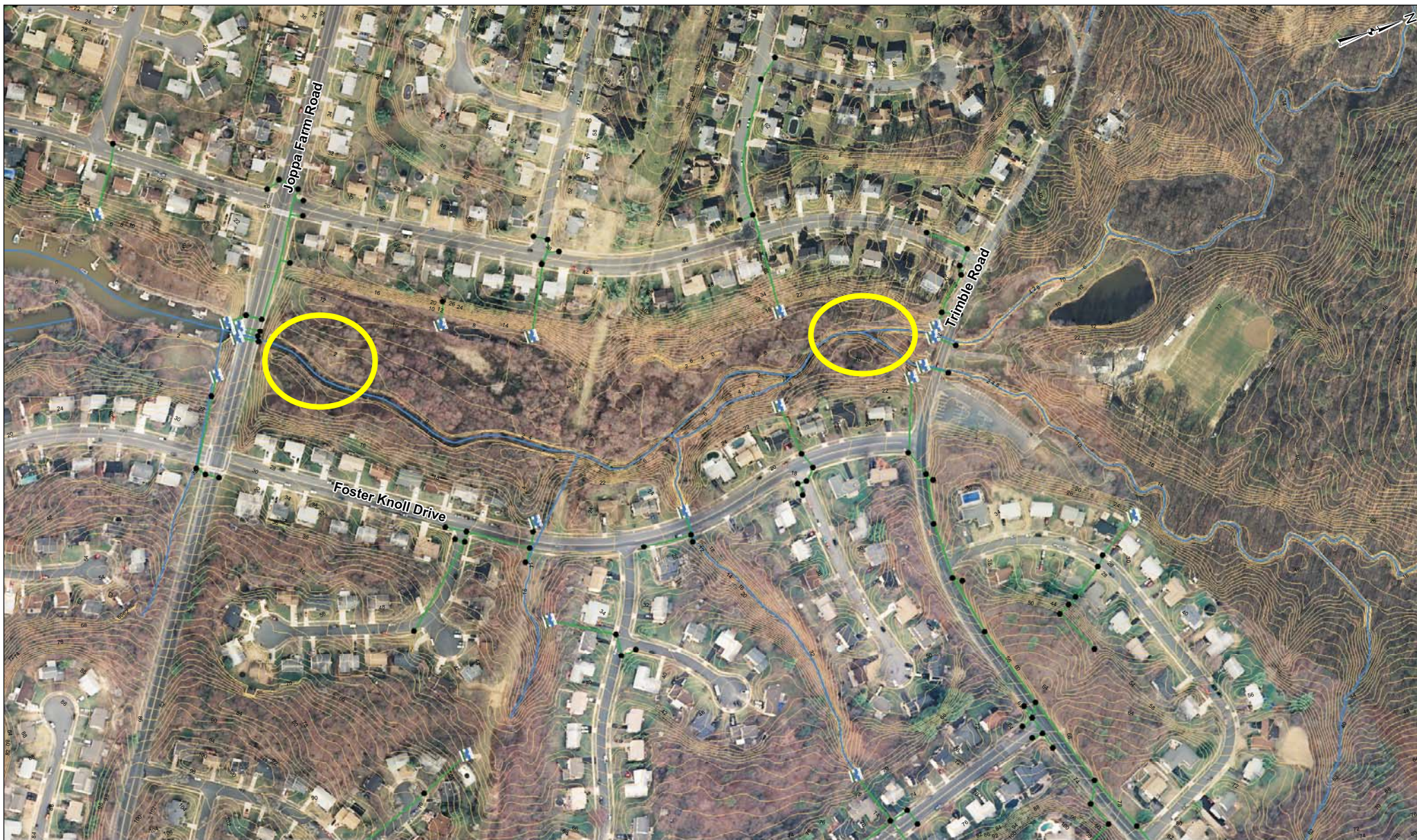
A second in-line site was considered just downstream of the Trimble Road culvert. This site also had sufficient floodplain width to allow excavated areas to serve as retention basins for the large volume of bed load that would be delivered from upstream reaches.

A site visit was conducted of both locations. Although significant area exists within the floodplain to construct in-line retention facilities the stream slope, local topography and site restrictions limited the magnitude of sediment storage available without significant excavation, cost and impacts to forested areas and the aquatic system. Based on the potential impacts, regulatory approval for use of the sites would be highly unlikely. The in-line sites were eliminated from further study.

3. Off-line Facilities

Off-line facilities were also considered in the downstream portion of the watershed where they would have the greatest opportunity to capture bed load sediment prior to entering the tidal waterway. Two sites were investigated just upstream of Trimble Road, one adjacent to the West Branch and one adjacent to the East Branch (Figure 4.13). Both sites are located within Robert Copenhaver Park, a County owned and operated facility.

A site visit was conducted of the existing man-made pond located on the West Branch and a similarly situated site on the East Branch. Both locations had favorable access and topography along the stream to allow placement of an off-line facility. The existing pond in particular presents opportunities to use previously created man-made features to minimize impacts to the environment. The pond could be enhanced and deepened to allow significant sediment capturing capacity while maintaining its aesthetic and recreational value as well.



Notes: 1. Aerial Photography 2007 2. Contours 2 ft interval	● Manhole Covers — Storm Drain Outfalls — Storm Drains	100 50 0 100 200 Feet 1" = 100'	Bayland Consultants & Designers, Inc. <i>"Integrating Engineering and Environment"</i> 1321 Mercedes Drive, Suite A Phone: (410) 694-9401 Hanover, Maryland 21076 Fax: (410) 694-9405 bayland@baylandinc.com baylandinc.com	Figure 4.12 Foster Branch In-line Sediment Collection Sites
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Notes: 1. Aerial Photography 2007 2. Contours 2 ft interval	● Manhole Covers — Storm Drain Outfalls — Storm Drains	100 50 0 100 200 Feet 1" = 100'	Bayland Consultants & Designers, Inc. <i>"Integrating Engineering and Environment"</i> 1321 Mercedes Drive, Suite A Phone: (410) 694-9401 Hanover, Maryland 21076 Fax: (410) 694-9405 bayland@baylandinc.com	Figure 4.13 Foster Branch Off-line Sediment Collection Sites
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The project team had experience with development of a highly successful off-line sediment entrainment system designed to capture bed load for the Big Creek Stream Restoration Project in Mt. Airy, North Carolina. The system incorporates a sediment vortex device that would lie within an upstream bed location allowing bed load that is transported during storm events to be captured and carried to an off-line pond or basin. A slotted pipe is placed at the channel bottom across most of the channel width while allowing base flow to bypass the slot and continue its course downstream. The slotted pipe carries sediment down-gradient into a pond or basin (Photo 4.3 and 4.4).



Photo 4.3 – Slotted vortex pipe



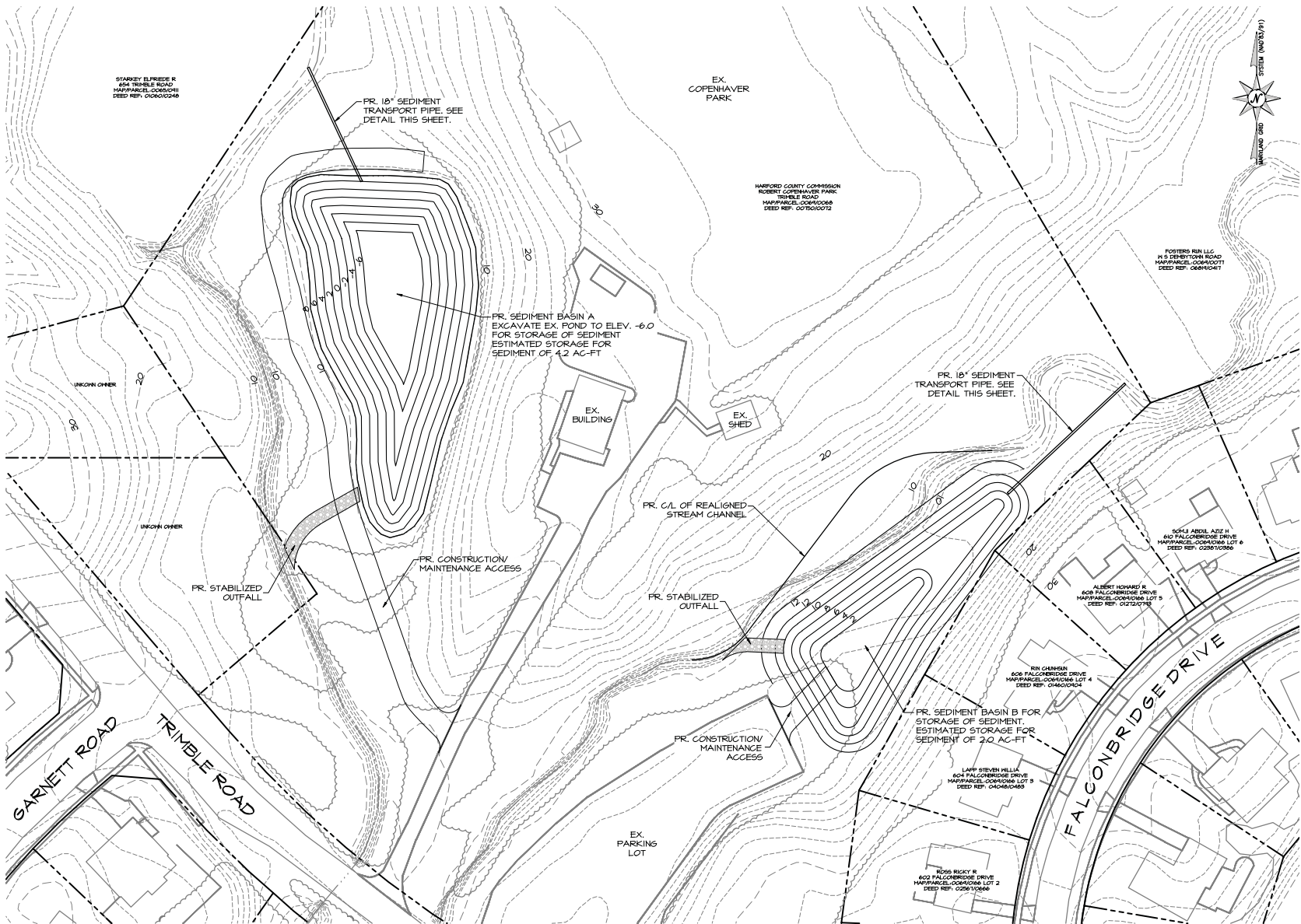
Photo 4.4 – Sediment basin located down-gradient of the slotted vortex pipe

Further research of the sediment vortex device was conducted to find that such devices are used more commonly for irrigation canals and channels that supply water for hydropower. Sediment vortex tube extractors can be a cost effective solution to remove a significant portion of the bed material sediments, sand or coarser material, with an extraction of only 10% to 20% of the base flow. Based on review of empirical testing data and field measurements of systems currently used, a trapping efficiency of 50% of the bed load material or greater can be expected for the sediment vortex tube extractor. Since the trapped materials would be sand and gravel, the water quality of the basin/pond would remain consistent with the stream water quality. In addition, the deposited sand and gravel would have value as construction material and may be used by the County or removed at nominal cost by local contractors or hauling operators.

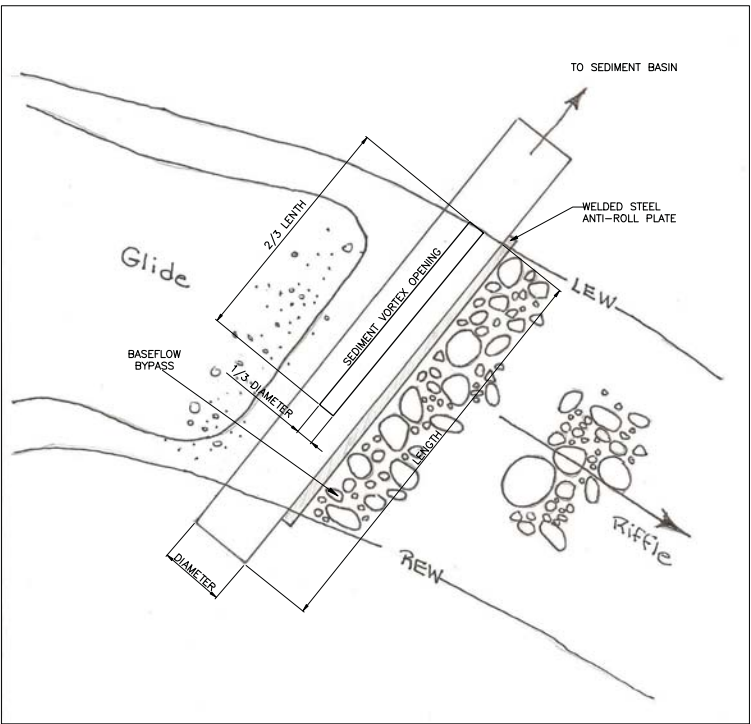
Upon review of the basic principles of the sediment collection system with the Harford County DPW and discussions of maintenance responsibilities for the pond and basins, it was determined that a concept design would be prepared for the sediment basin sites at Copenhaver Park (Figures 4.14 and 4.15).



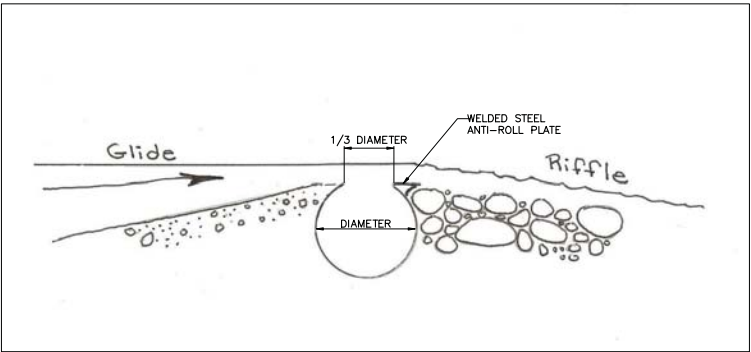
Figure 4.14 - Off-line Sediment Collection Concept Plan



PLAN VIEW
SCALE: 1" = 50'



SEDIMENT REMOVAL VORTEX PIPE PLAN VIEW
SCALE: NTS



SEDIMENT REMOVAL VORTEX PIPE SECTION VIEW
SCALE: NTS



SEDIMENT VORTEX LOOKING UPSTREAM
SCALE: NTS



SEDIMENT VORTEX DISCHARGE INTO BASIN
SCALE: NTS

SEDIMENT BASIN DETAILS

FACILITY	STORAGE AC-FT	STORAGE CF	STORAGE CY	50% STORAGE AC-FT	50% STORAGE CF	50% STORAGE CY	CLEANOUT ELEVATION @ 50% STORAGE
SEDIMENT BASIN A	4.2	182,952	6,776	2.1	91,476	3,338	3.5
SEDIMENT BASIN B	2.0	87,120	3,226	1.0	43,560	1,613	8.0

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BAYLAND JOB NO. 4_2804

Figure 4.15
Sediment Removal System Concept
Foster Branch Sediment Assessment

DATE		BY	REVISIONS	DESCRIPTION	SCALE: AS SHOWN	
					DRAWN BY: CJS	DATE: 09/07/11
					CHECKED BY: SB	DATE: 09/07/11
					SHEET NO. 1 OF 1	

Sediment bed loads developed in Chapter 3 were tabulated for the drainage areas above each of the two sediment basins. Using the 50% bed load trapping efficiency, sediment bed load reductions were calculated for each basin. If upstream restoration projects were implemented the magnitude of sediment bed load delivered to and removed by the basins would also be reduced as shown in Table 4.8.

Table 4.8 – Sediment Bed Load Reductions				
Project	Type	Storage (ac-ft)	Sediment Bed Load Reductions	
			No Restoration Projects Implemented (cy/yr)	All Upstream Restoration Projects Implemented (cy/yr)
SB-1	New Sediment Basin	4.2	273	152
SB-2	New Sediment Basin	2	161	26
Total		6.2	433	179

Based on the superior bed load reduction capabilities of Sediment Basins 1 and 2, these facilities were selected for further development and implementation within the Foster Branch Small Watershed Action Plan.

IV. Projects Prioritization

Ranking the stream restoration reaches involved two major criteria. The first criteria evaluated the reach based on its proximity to the tidal creek. Reaches closer to the tidal creek were considered more immediate contributors to the sedimentation problem. The second criteria utilized 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. The unstable stream reaches were then ranked in descending order from highest to lowest degree of instability. Several of the reaches that ranked 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.

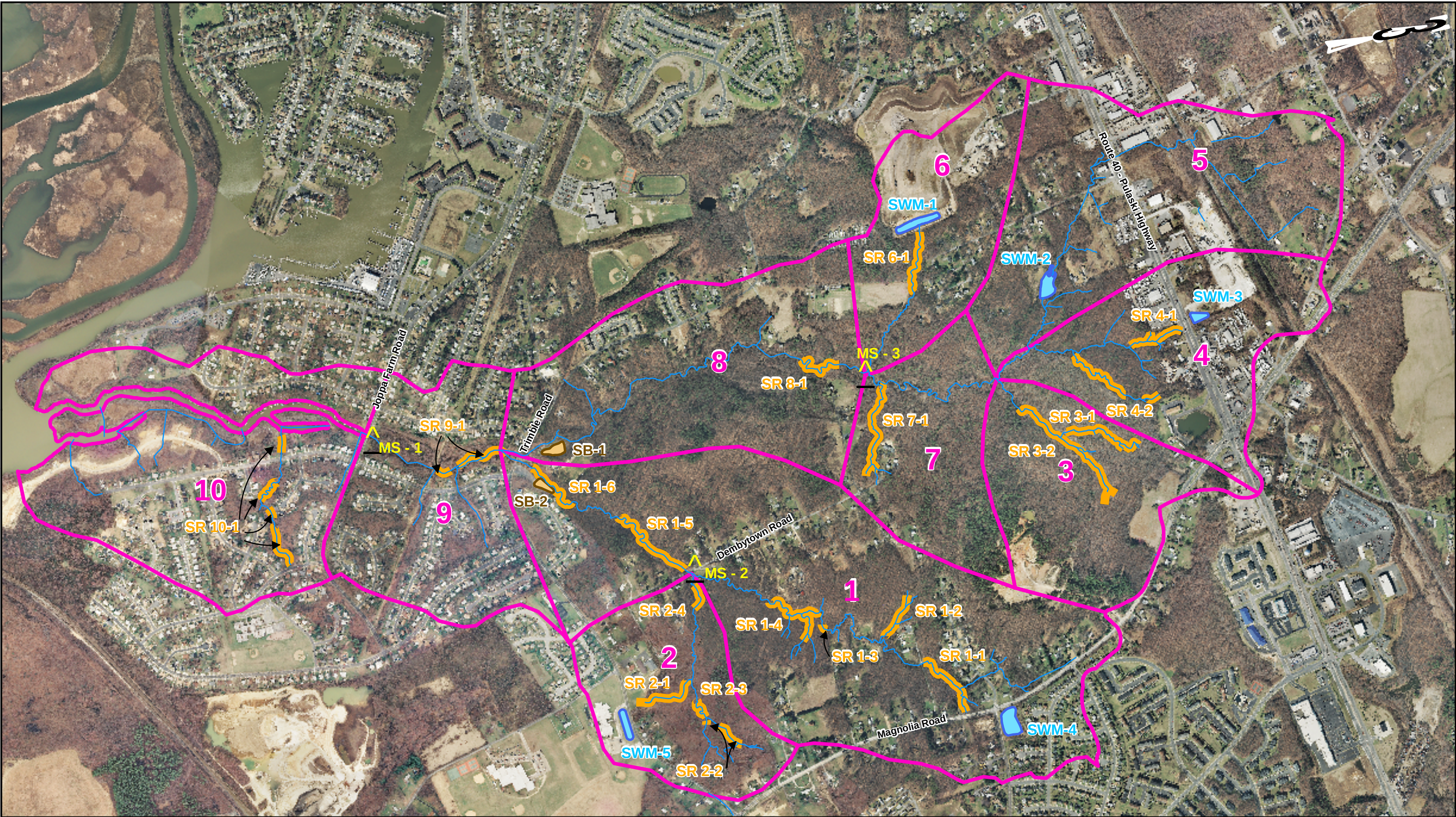
Ease of implementation was based on consideration of issues such as construction access (e.g. distance from public roads, terrain that must be traversed and/or vegetation that must be avoided, etc.); availability of staging and stockpile areas, special equipment and/or material needs, natural constraints (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 interrelated 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.

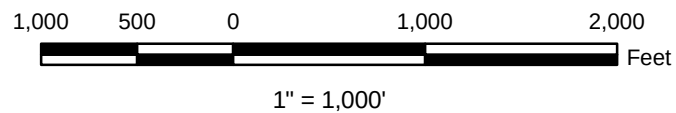
Upon completion of the stream restoration ranking, the stormwater retrofits and sediment retention basins were carried forward to be ranked with the stream restoration projects primarily based upon their bed load removal capacity and their effectiveness to improve both stream and tidal waterway water quality and habitat.

A map of all Foster Branch stabilization/restoration projects is provided in Figure 4.16.



Notes:
1. Aerial Photography from Harford County Dated 2007.

- 1 Foster Branch Study Area
- Hydro/Streams
- Stream Repair/Restoration Projects
- Storm Water Management Projects
- Sediment Basin Projects
- ^ In-Stream Monitoring Station



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Figure 4.16
Foster Branch
Sediment Reduction
Projects

Table 4.9 – Foster Branch Stabilization/Restoration Projects			
Priority	Project ID	Project Type	Project Length (ft)
1	SR 9-1	Stream Restoration	650
2	SR 10-1	Stream Restoration	985
3	SR 1-6	Stream Restoration	660
4	SB - 2	Sediment Basin	N/A
5	SB - 1	Sediment Basin	N/A
6	SR 1-5	Stream Restoration	1,315
7	SR 8-1	Stream Restoration	635
8	SR 1-4	Stream Restoration	600
9	SR 1-1	Stream Restoration	800
10	SR 4-1	Stream Restoration	700
11	SR 4-2	Stream Restoration	1,125
12	SR 2-1	Stream Restoration	600
13	SR 2-4	Sediment Trap	N/A
14	SR 2-3	Stream Restoration	330
15	SR 2-2	Head Cut Stabilization	50
16	SR 3-2	Head Cut Stabilization	235
17	SR 3-1	Head Cut Stabilization	100
18	SWM - 2	Stormwater Management	N/A
19	SR 7-1	Stream Restoration	1,275
20	SR 6-1	Stream Restoration	750
21	SR 1-2	Head Cut Stabilization	110
22	SR 1-3	Slope Stabilization	80
		Total	11,000

V. Preliminary Cost Estimates

Table 4.10 provides preliminary cost estimates for design, permitting and construction for all of the sediment reduction projects including the channel stabilization and restoration, stormwater retrofits, and sediment retention ponds presented in this study.

Design and permitting costs include: consultant's 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 Costs include: 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's professional fees for geotechnical studies; on-site construction management; or as-built surveys.

Table 4.10 – Foster Branch Stabilization / Restoration Projects						
Priority	Project ID	Project Type	Project Length (ft)	Design Cost	Construction Cost	Total Cost
1	SR 9-1	Stream Restoration	650	\$72,900	\$162,000	\$234,900
2	SR 10-1	Stream Restoration	985	\$88,650	\$197,000	\$285,650
3	SR 1-6	Stream Restoration	660	\$70,650	\$117,750	\$188,400
4	SB-2	Sediment Basin	N/A	\$85,000	\$115,000	\$200,000
5	SB-1	Sediment Basin	N/A	\$85,000	\$110,000	\$195,000
6	SR 1-5	Stream Restoration	1,315	\$127,350	\$212,250	\$339,600
7	SR 8-1	Stream Restoration	635	\$57,150	\$127,000	\$184,150
8	SR 1-4	Stream Restoration	600	\$85,050	\$141,750	\$226,800
9	SR 1-1	Stream Restoration	800	\$72,000	\$120,000	\$192,000
10	SR 4-1	Stream Restoration	700	\$63,000	\$175,000	\$238,000
11	SR 4-2	Stream Restoration	1,125	\$107,550	\$179,250	\$286,800
12	SR 2-1	Stream Restoration	600	\$54,000	\$120,000	\$174,000
13	SR 2-4	Sediment Trap	N/A	\$15,000	\$25,000	\$40,000
14	SR 2-3	Stream Restoration	330	\$29,700	\$49,500	\$79,200
15	SR 2-2	Head Cut Stabilization	50	\$5,000	\$8,000	\$13,000
16	SR 3-2	Head Cut Stabilization	235	\$5,000	\$23,500	\$28,500
17	SR 3-1	Head Cut Stabilization	100	\$5,000	\$10,000	\$15,000
18	SWM-2	Stormwater Management	N/A	\$70,000	\$200,000	\$270,000
19	SR 7-1	Stream Restoration	1,275	\$114,750	\$191,250	\$306,000
20	SR 6-1	Stream Restoration	750	\$67,500	\$75,000	\$142,500
21	SR 1-2	Head Cut Stabilization	110	\$5,000	\$11,000	\$16,000
22	SR 1-3	Slope Stabilization	80	\$16,000	\$16,000	\$32,000
		Total	11,000	\$1,301,250	\$2,386,250	\$3,687,500

The highest priority projects 1 through 6 would have a combined bed load reduction that would address over 60% of the bed load deposition to the tidal waterway and is therefore recommended to be implemented as Phase I of the Foster Branch Small Watershed Action Plan. Phase I has a total estimated cost of \$1,443,550 of the total \$3,687,500 restoration program.

Chapter 5 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 Foster Branch watershed and for each of the identified 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 is the Simple Method of calculating annual pollutant loads (lbs/yr) and Table 5.1 lists the input parameters utilized in the Simple Method to develop the annual pre-project annual pollutant loads.

$$\text{Equation 1: } L = [(P) (P_j) (R_v) / 12] (C) (A) (2.72) , \text{ where } R_v = [0.05 + (0.9 I_a)]$$

Table 5.1 – Simple Method Annual Pollutant Loading Model Input Parameters		
Parameter	Symbol	Input Value
Annul Precipitation (in/yr)	P	45.83
Fraction of Runoff Producing Events	P _j	0.9
Runoff Coefficient	R _v	Site Dependant
Drainage Area (Acres)	A	Site Dependant
Drainage Area Impervious (%)	I _a	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 5.2 delineates the watershed by current land use as per the hydrologic analysis methodology located in Chapter 2, Section III, E.

Table 5.2 – Watershed by Current Land Use		
Land Use	Amount (acres)	Land Use (%)
Impervious	251.1	17.6
Woods	738.0	51.8
Open Space	343.6	24.1
Meadow	36.0	2.5
Barren	55.0	3.9
Total	1423.7	100

Table 5.3 lists the annual pollutant loading for the watershed and the pre-project drainage areas. The Annual Pollutant Loading does not account for any pre-project pollutant loading that was compiled as part of the Foster Branch sediment assessment from in stream bank erosion within the watershed. The pollutant loading for Foster Branch Watershed does not account for any existing BMPs within the watershed. Initially watershed loadings were calculated based upon the entire 1,423.7 acre watershed and the associated 17.6% impervious area. Since the Simple Method is calibrated for stormwater runoff in urban areas, these loadings would likely be overstated due to the large forested areas within the watershed. Therefore non-urban areas were removed from the calculation and annual watershed pollutant loadings were recalculated using the actual 594.7 acres of urban area (impervious plus open space) and the 42.2% imperviousness of that area (see loadings for WS-U). This approach is thought to be a more reasonable use of the Simple Method and more accurate for estimating existing loading rates.

Table 5.3 – Annual Pollutant Loading for Pre-project Drainage Areas						
Project ID	Project Description	DA (Acres)	Imp. Area (%)	Annual Pollutant Loading		
				TN (lbs/yr)	TP (lbs/yr)	TSS (lbs/yr)
WS	Foster Branch Watershed	1,423.8	17.6	5,531.9	719.2	150,745.4
WS-U	Foster Branch Watershed (Urban)	594.7	42.2	4,765.4	619.5	129,855.9
1	Retrofit - Stancills, Inc	40.7	4.4	68.0	8.8	1,852.7
2	Retrofit - Kenneth and Sylvia Day	185.5	24.7	941.7	122.4	25,661.9
3	New Facility - C S P Associates	26.4	43.7	218.2	28.4	5,945.6
4	Retrofit - Woodbridge Homeowners Association	33	20.0	141.5	18.4	3,856.0
5	New Facility - Magnolia Elementary and Middle School	9.2	35.0	62.6	8.1	1,706.0
6	New Facility – Offline Sediment Vortex Facility	742.9	16.5	2,749.3	357.4	74,918.3
7	New Facility – Offline Sediment Vortex Facility	395	15.0	1,362.4	177.1	37,125.0

II. Pollutant Removal Efficiencies and Load Reductions

Current stormwater best management practices pollutant removal efficiencies as detailed in Section 6, Best Management Practices, 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 5.4 lists the efficiency effectiveness estimate used for each of the existing and proposed BMPs.

Table 5.4 – Chesapeake Bay Watershed Model Phase 5.3: Pollutant Removal Efficiency Effectiveness Estimate			
Urban Best Management Practice	Target Pollutant Removal Efficiencies		
	TN (%)	TP (%)	TSS (%)
Wet Pond and Wetlands	20	45	60
Dry Extended Detention Ponds	20	20	60
Dry Detention and Hydrodynamic Structures	5	10	10
Erosion and Sediment Control	25	40	40

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. If the existing facility was not designed as a stormwater management facility or other BMP, then it was considered to not function as a BMP and was not quantified as providing any sort of pollutant removal. For new BMP sites, the target pollutant removal efficiencies were assigned as previously defined in Table 5.4. Table 5.5 lists the target removal efficiencies for each of the proposed stormwater BMP projects.

Table 5.5 – Target Pollutant Removal Efficiency for the Proposed Stormwater BMP Projects				
Project ID	Project Description	Target Pollutant Removal Efficiencies		
		TN (%)	TP (%)	TSS (%)
1	Retrofit – Convert Sediment Basin to Wet Pond	-5	5	20
2	Retrofit- Convert existing in stream pond into Wet Pond	20	45	60
3	New Facility – Wet Pond	20	45	60
4	Retrofit - Convert Dry Detention Pond to Wet Pond	15	35	50
5	New Facility – Wet Pond	20	45	60
6	New Facility – Offline Vortex Sediment Removal Facility (Hydrodynamic Structure)	5	10	10
7	New Facility – Offline Vortex Sediment Removal Facility (Hydrodynamic Structure)	5	10	10

The proposed water quality benefits for each of the proposed projects were then normalized with the water quality volume as defined in the Maryland 2000 Stormwater Management Design Manual to produce an efficiency percentage as defined in Equation 2 and listed in Table 5.6.

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.

$$\text{Equation 3: } EP \times \text{Target Pollutant Removal Efficiency} \times \text{Annual Pre-project Pollutant Load} = \text{Potential Post-Project Annual Pollutant Removal}$$

Since the stormwater management facilities were not conceptualized for this report, the efficiency percentage has been estimated. For new facilities 1 and 5, the estimated pollutant removal efficiency was 100%. The conceptualized new offline vortex sediment removal facilities (Projects 6 and 7) are continuous hydrodynamic structures that will operate at the removal efficiency rate independent of the volume of storage provided in the settling basin. The efficiency percentage for the retrofit designs was developed from the current and potential achievable WQv storage volumes of the existing facility.

Table 5.6 – 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		
				TN (lbs/yr)	TP (lbs/yr)	TSS (lbs/yr)
1	0.3	0.3	100.0%	-3.4	0.4	370.5
2	4.2	4.0	95.0%	179.0	52.4	14,631.5
3	1.0	1.0	100.0%	43.6	12.8	3,567.4
4	0.6	0.6	100.0%	21.2	6.4	1,928.0
5	0.3	0.3	100.0%	12.5	3.7	1,023.6
6	N/A	N/A	100.0%	137.5	35.7	7,491.8
7	N/A	N/A	100.0%	68.1	17.7	3,712.5
Total				458.5	129.1	32,725.4

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 the 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. The Spring Branch watershed is located in Baltimore County, within the same geographical vicinity as the Foster Branch watershed. The monitored Spring Branch load reductions from the stream restoration project are shown in Table 5.7 and were used to estimate the potential load reductions for the Foster Branch proposed stream restoration projects.

Table 5.7 – Stream Restoration Pollutant Load Reductions			
Spring Branch Stream Restoration Load Reductions	Target Pollutant Load Reductions		
	TN (lbs/ft/yr)	TP (lbs/ft/yr)	TSS (lbs/ft/yr)
Stream Restoration Project	0.02	0.0035	2.55

Table 5.8 lists the potential annual pollutant load reductions for the proposed stream restoration projects.

Table 5.8 – Potential Annual Pollutant Load Reductions for Proposed Stream Restoration Projects				
Project ID	Reach Length (LF)	Potential Post-project Annual Pollutant Removal		
		TN (lbs/yr)	TP (lbs/yr)	TSS (lbs/yr)
1-1	800	16.0	2.8	2,040.0
1-2	100	2.0	0.4	255.0
1-3	60	1.2	0.2	153.0
1-4	600	12.0	2.1	1,530.0
1-5	1315	26.3	4.6	3,353.3
1-6	660	13.2	2.3	1,683.0
2-1	600	12.0	2.1	1,530.0
2-2	50	1.0	0.2	127.5
2-3	330	6.6	1.2	841.5
3-1	100	2.0	0.4	255.0
3-2	235	4.7	0.8	599.3
4-1	700	14.0	2.5	1,785.0
4-2	1125	22.5	3.9	2,868.8
6-1	750	15.0	2.6	1,912.5
7-1	1275	25.5	4.5	3,251.3
8-1	635	12.7	2.2	1,619.3
9-1	650	13.0	2.3	1,657.5
10-1	985	19.7	3.4	2,511.8
Total	10,970	219.4	38.4	27,973.5

III. Discussion

The Foster Branch watershed is a first order tributary to Gunpowder River and a second order tributary to the Chesapeake Bay. The 2017 municipal separate storm sewer system (MS4) pollution reduction target of the Phase I Chesapeake Bay Watershed Implementation Plan is equivalent to the retrofit of 30% of pre-1985 developed land. The proposed stormwater BMPs along with the proposed stream

restoration projects can achieve significant reductions in the pollutant loadings, including reductions in channel erosion that are not quantified within the pollutant loading calculations. These reductions will assist Harford County in meeting the goals of their MS4 permit while reducing the amount of sedimentation of Foster Branch headwaters and other downstream water bodies. The reduction in pollutant loadings for implementation of all projects is summarized below in Table 5.9.

Table 5.9 – Total Pollutant Load Reductions			
	TN lbs/yr	TP lbs/yr	TSS lbs/yr
All SWM Projects	458.5	129.1	32,725.4
All Stream Projects	219.4	38.4	27,973.5
Total Projects	677.9	167.5	60,698.9
Watershed (Pre Restoration Loadings)	4,765.4	619.5	129,855.9
% Reductions	14%	27%	47%

Chapter 6 Monitoring Plan

The County, restoration partners and the stakeholders all 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. Since sediment transport and deposition are creating significant aquatic impacts in both tidal and non-tidal waters, the monitoring plan for Foster Branch incorporates both tidal and in-stream monitoring components. The monitoring is structured in three phases that would follow the Restoration Implementation Schedule contained in Chapter 7. This phasing will allow for an adaptive management approach that would allow for changes to be made if regional or cumulative load reductions were above or below expected results.

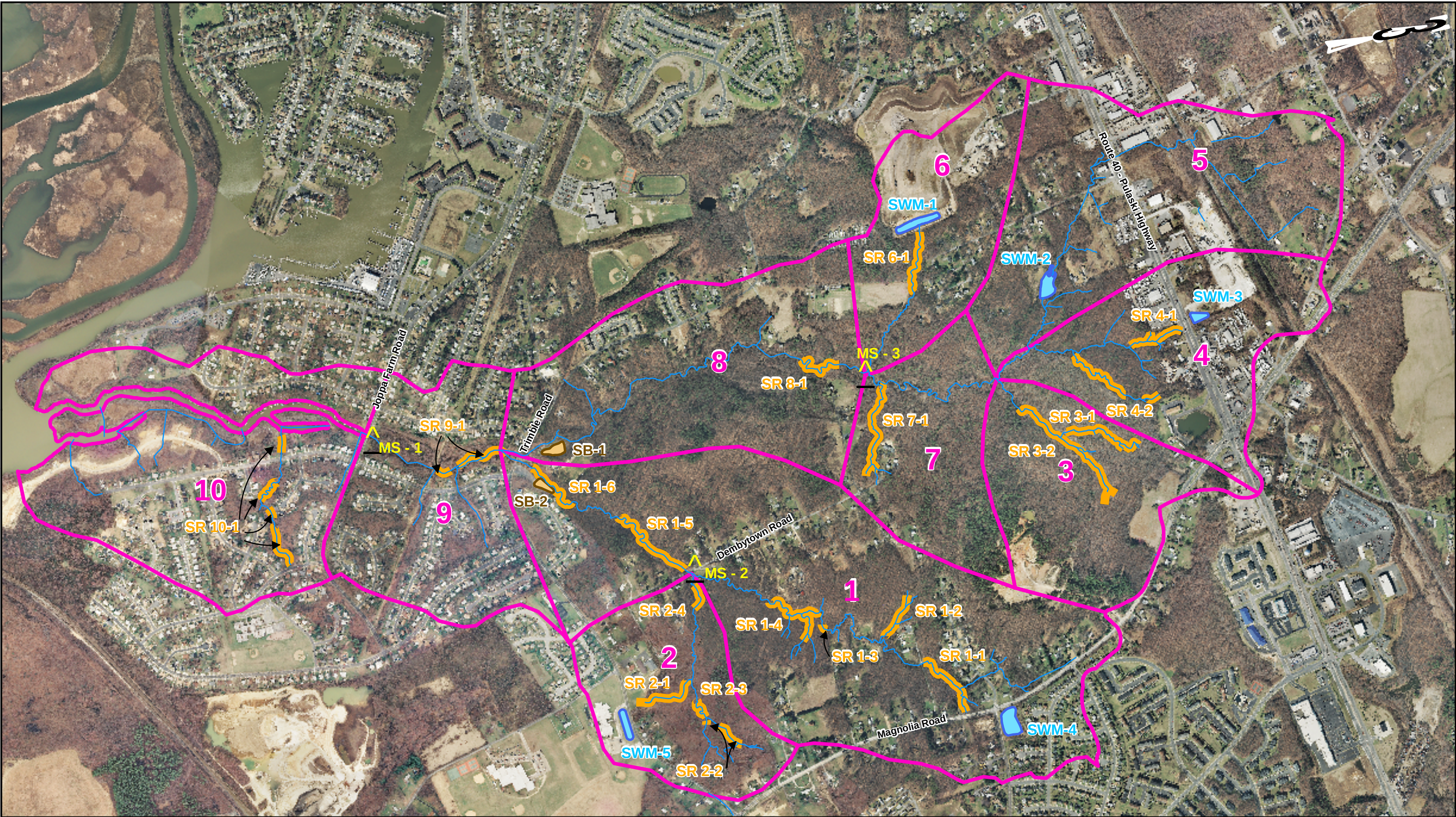
The tidal water monitoring consists of submerged aquatic vegetation (SAV) surveys and bathymetric surveys. The SAV surveys monitor the growth, species and density of the grasses which are an important habitat for fish and crabs, sustenance for waterfowl and capture suspended sediments from the watershed. SAV growth is dependent upon good water clarity. Harford County has previously monitored SAV in 2007, 2008 and 2011 and has contracted for the surveys to be performed in 2012 and 2013. Phase I restoration projects are expected to reduce tidal sediment loads by approximately 50%. Therefore, the monitoring plan includes Phase I post-restoration monitoring of SAV from 2019 to 2021.

Foster Branch is highly impaired from sedimentation not only from TSS but also from bed load. Bathymetric surveys of the tidal portion of Foster Branch will monitor the amount of sedimentation coming into the waterway. Each survey will track the progress of the restoration projects to measure if the amount of sedimentation is being reduced. The County dredged and surveyed the tidal waterway in 2011 and plans to resurvey at the end of Phase I and Phase II restoration in 2021 and 2026 respectively to monitor the incremental and overall success of the projects.

In stream monitoring will occur pre- and post-restoration by placing sentinel (fixed, long-term) monitoring stations in strategic locations to measure the trends of key indicators such as total suspended solids, nitrogen and phosphorous. The first station would be installed for Phase I in 2013 and placed near the stream outfall into tidal water at Joppa Farm Road. Pre-restoration monitoring would consist of data collection and preparing interpretive charts and graphs of the monitoring data from 2014-2016. Equipment would be routinely checked and calibrated. The post-restoration monitoring would start in 2017 and run through 2021 to ensure that data is collected consistently for three years after all of the Phase I projects are completed. Also included in the post-restoration monitoring are surveys/soundings of the sediment basins SB-1 and SB-2 that will be constructed during Phase I. These surveys will monitor the accumulation of sediment within the basins and the available remaining sediment capacity. The Phase II and Phase III in-stream monitoring will be similar to Phase I and follow the Restoration Implementation schedule as seen in Chapter 7. The monitoring station for Phase II will be set in 2017 at the stream crossing at Dembytown Road. The Phase III station is

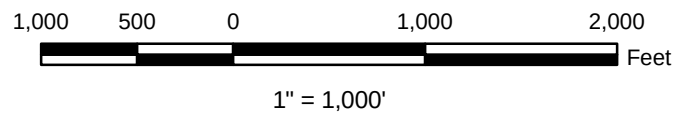
scheduled to be installed in 2021 at the confluence of Subsheds 6, 7 and 8. Monitoring station locations are shown on the Foster Branch Sediment Reduction Projects Map, Figure 6.1. Monitoring costs are detailed in the Restoration Implementation Schedule.

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 restoration projects progress, citizen initiatives and the results of the monitoring plan. Reports can easily be generated and shared to keep the County, restoration partners and the stakeholders informed of the restoration efforts and progress.



Notes:
1. Aerial Photography from Harford County Dated 2007.

- 1 Foster Branch Study Area
- Hydro/Streams
- Stream Repair/Restoration Projects
- Storm Water Management Projects
- Sediment Basin Projects
- ^ In-Stream Monitoring Station



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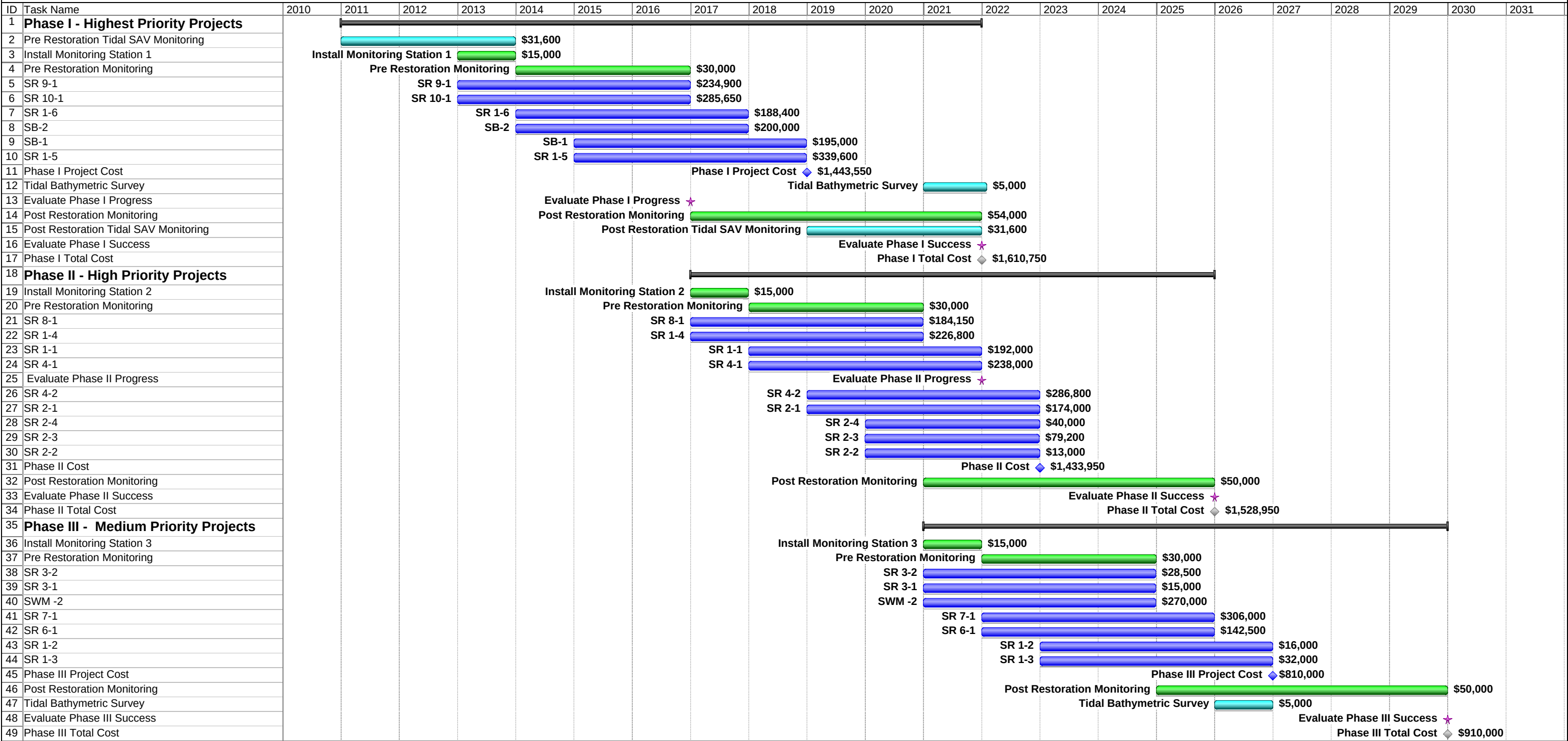
1321 Mercedes Drive, Suite A Phone: (410) 694-9401
Hanover, Maryland 21076 Fax: (410) 694-9405
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Figure 6.1
Foster Branch
Sediment Reduction
Projects

Chapter 7 Implementation Schedule

A schedule has been established on the next page to include a timeline of when each watershed restoration project should be implemented based on priority ranking. The restoration implantation is set up in three phases. Phase I includes the highest priority projects as defined previously in Chapter 4, Section 3. Phase II high priority projects would be implemented next, followed by Phase III medium priority projects. Each implementation phase will be monitored as shown on the schedule and would include annual reports and evaluation of the techniques used and projects implemented. This structuring allows for on-going analysis to allow for future projects and techniques to be adapted to changing conditions and to focus resources on the most successful techniques. The schedule includes pertinent milestones to highlight funding needs prior to implementation.

Foster Branch Watershed
Restoration Implementation Schedule



Legend

- Tidal Monitoring Task
- In-stream Monitoring Task
- Stream and Stormwater Restoration Project Implementation

Chapter 8 Watershed Goals and Public Outreach

I. Watershed Goals

Harford County DPW prioritizes restoration projects by evaluating opportunities identified in watershed plans. The Foster Branch Watershed Assessment was selected due to the continuing sedimentation to the tidal headwaters resulting in poor water quality of the tidal waterway, complaints by citizens and continued cost to maintain the waterway. Foster Branch drains to the tidal Foster Branch and then to the Gunpowder River. The tidal portion of Foster Branch must be consistently dredged on a 10-year cycle due to the massive amounts of sedimentation from the watershed. This watershed was prioritized due to the benefit to overall watershed health, public input and concerns for protection and preservation of the tidal waterway.

Harford County DPW has set the following goals to restore the Foster Branch watershed:

- Repair stream instability problems.
- Reduce sediment loadings.
- Control runoff from developed areas.
- Preserve recreational boating access to the Chesapeake Bay.
- Improve water quality of Foster Branch and Gunpowder River.

II. Public Outreach

The Foster Branch Small Watershed Action Plan arose from many concerns expressed by citizens living in the watershed. The first watershed study for Foster Branch was conducted in 1997. Since then concerned citizens have remained active and involved with the local County government urging them to protect the tidal waterway and to repair, restore and mitigate the ongoing erosion, sedimentation and degradation within the watershed. Updates on project status, funding and future restoration projects have been made through various public meetings, meetings with the Foster Branch Waterway Committee, letters and other communications to homeowners and through the Harford County DPW website. Examples of public outreach documents are included in Appendix E.

It is essential to have citizen participation in watershed restoration to provide support for funding and to assist with long term maintenance and water quality improvements that may not be possible otherwise. The County has established the following goals for public outreach in the Foster Branch watershed:

- **Promote the Development of a Watershed Group for Foster Branch –** The DPW, with strong landowners/stakeholders support, is promoting the development of a Foster Branch watershed organization. DPW is working to increase participation and is helping to evolve the existing tidal waterway committee membership to include additional members from around the watershed. Stakeholders have expressed interest in participating in a

watershed group and organizing stream clean-ups and tree plantings. This organization can facilitate community-based stewardship of the Foster Branch watershed. Eventually, this group could organize tree plantings, stream cleanups, environmental education programs and recreational activities.

- **Establish a Foster Branch SWAP Implementation Committee** – The purpose of the committee would be to coordinate implementation efforts between agencies and organizations, secure funding for implementation efforts, and track the success of the implementation. DPW would initially take the lead to organize the committee as the first order of business in implementing the plan.
- **Create a Website to Encourage Watershed Stewardship** – DPW currently provides a central location for citizens to access information about their watersheds and streams. The website provides information on watershed basics (e.g. what is a watershed?), locator watershed maps (e.g. what watershed do you live in?), and current projects in each watershed. Website enhancements under consideration include information to promote practices that citizens can do on an everyday basis to become better watershed stewards, and provide information on how to volunteer or become involved.
- **Target Areas for Reforestation** – DPW can conduct a GIS analysis to target residential lands for buffer awareness initiatives such as no-mow zones around streams and shorelines and encourage planting of trees. They should also investigate publically owned land for tree planting potential.
- **Citizen Education** – The County can raise awareness of common activities homeowners can exercise on their own yards to reduce inputs to nearby waterways. Through their website, mailings and community meetings information can be passed along to citizens relating to alternatives for chemical lawn treatment, increasing landscaping using native plants of the Chesapeake Bay watershed, and installing rain barrels and/or rain gardens.

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