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UniStar
NUCLEAR ENERGY

November 2, 2010

UN#10-262

Amanda Sigillito, Chief
Non-Tidal Wetlands and Waterways Division
Maryland Department of the Environment
Water Management Administration
1800 Washington Boulevard
Baltimore, Maryland 21230

Woody Francis, Project Manager
U.S. Army Corps of Engineers – Baltimore District
10 S. Howard Street
Baltimore, Maryland 21201

Subject: Draft Final Phase II Nontidal Wetland and Stream Mitigation Plan for Calvert Cliffs Nuclear Power Plant, Unit 3 in Calvert County, Maryland, MDE Project Number 08-WL-1462 (T), 09-NT-0191 (NT), USACE Tracking No. NAB-2007-08123-M05

References:
1) UN#10-037, Phase II Non-Tidal Wetlands and Stream Concept Plan and Tidal Wetlands Impacts for Calvert Cliffs Nuclear Power Plant, Unit 3, in Calvert County, Maryland, MDE Project Number 08-WL-1462 (T), 09-NT-0191 (NT), USACE Tracking No. NAB-2007-08123-M05, Dated March 18, 2010
2) UN#09-524, Summary - Conceptual Phase II Non-Tidal Wetland and Stream Mitigation Plan for Calvert Cliffs Nuclear Power Plant, Unit 3 in Calvert County, Maryland, MDE Project Number 08-WL-1462 (T), 09-NT-0191 (NT), USACE Tracking No. NAB-2007-08123-M05, dated December 17, 2009.

Enclosed for review and approval please find the Draft Final Phase II Nontidal Wetland and Stream Mitigation Plan dated October 2010, for the proposed Calvert Cliffs Nuclear Power Plant, Unit 3 in Calvert County, Maryland (Enclosure 1). The Draft Final Phase II Nontidal Wetland and Stream Mitigation Plan ("Draft Final Plan") incorporates the philosophy of the Phase II Non-Tidal Wetlands and Stream Concept Plan ("Conceptual Plan") forwarded by Reference 1 and provides the details for implementing/constructing the Conceptual Plan. As such, the Draft Final Plan makes up the complete Phase II Nontidal Wetland and Stream Mitigation Plan by presenting the objective/scope/goal of the plan and the implementation (construction detail) aspect of the plan. The enclosed Draft Final Plan incorporates comments received from the Maryland Department of the Environment (MDE).

Enclosure 2 provides an update to the summary of the Phase II Non-Tidal Wetland and Stream Mitigation Plan originally forwarded by Reference 2. UniStar understands that this summary document was the only outstanding item identified to the NRC that USACE needed to support the Final Environmental Impact Statement writing session scheduled for mid-November.

If you have any questions concerning the attached document, please call Mr. Jim Burkman at (410) 787-5130.

Sincerely,

Greg Gibson

Enclosures – 1) Calvert Cliffs Nuclear Power Plant, Unit 3 Draft Final Phase II Nontidal Wetland and Stream Mitigation Plan, October 2010
2) Calvert Cliffs Nuclear Power Plant, Unit 3 Summary – Draft Final Phase II Nontidal Wetland and Stream Mitigation Plan, October 2010

cc: Laura Quinn – NRC Project Manager, Environmental Projects Branch 2 (w/enclosure)
Susan Gray – Power Plant Research Program (w/enclosure)
Cheryl Kerr – MDE (w/enclosure)
Kelly Neff – MDE (w/enclosure)

UN#10-262

Enclosure 1

Calvert Cliffs Nuclear Power Plant, Unit 3
Draft Final Phase II Nontidal Wetland and Stream Mitigation Plan
October 2010

UN#10-262

Enclosure 2

Calvert Cliffs Nuclear Power Plant, Unit 3
Summary – Draft Final Phase II Nontidal Wetland and Stream Mitigation Plan
October 2010

Summary – Draft Final Phase II Nontidal Wetland and Stream Mitigation Plan
Calvert Cliffs Nuclear Power Plant, Unit 3
October 2010

The Draft Final Phase II Nontidal Wetland and Stream Mitigation Plan (henceforth referred to as the "Phase II Mitigation Plan") for the Calvert Cliffs Nuclear Power Plant (CCNPP), Unit 3 has been prepared in accordance with the Final Compensatory Mitigation Rule issued by the United States Army Corps of Engineers (USACE) and the Environmental Protection Agency (EPA), published 10 April 2008. This updated Phase II Mitigation Plan has been refined, in regard to expanding to provide more detail, from the Conceptual Phase II Mitigation Plan submitted to USACE and the Maryland Department of the Environment (MDE) in December 2009. The site vicinity is depicted in Figure 1.

The Phase II Mitigation Plan has been prepared in accordance with the Maryland Compensatory Mitigation Guidance (Interagency Mitigation Task Force [IMTF], 1994) and USACE Regulatory Guidance Letter (RGL) No. 08-03, dated 10 October 2008. The Plan addresses the 12 critical elements required by the Final Compensatory Mitigation Rule. The overall goal of the Phase II Mitigation Plan is to replace functions and values lost resulting from the proposed development, as well as to protect existing stream and wetland resources from potential impacts associated with changing land use from the Unit 3 expansion.

<u>Nontidal Wetland Mitigation</u>

The project proposes no more than 8,350 linear feet of stream impacts and no more than 11.72 acres of jurisdictional wetland and open water pond impacts. A comprehensive description of the impact sites has been provided in the wetland delineation report dated May 2007, Joint Permit Application (JPA) submitted on 16 May 2008, and subsequent revisions and addendums.

The limit of disturbance for the construction of the CCNPP Unit 3 facility has been designed to avoid and minimize impacts to natural resources to the greatest extent possible while still meeting the project needs. However, the construction of the project would not be possible without permanently impacting federally regulated wetlands and streams. To meet a "no net loss" goal for nontidal wetland mitigation, the mitigation strategy chosen for the CCNPP Unit 3 project proposes onsite, in-kind mitigation. This is accomplished through the creation or enhancement of several sites, depicted on Figure 2.

The proposed wetland creation and enhancement areas will be planted with native hydrophytic vegetation after excavation to final grades. The proposed species composition will be largely representative of the wetlands within the CCNPP property and native to the region. In addition, the plant material will include species that have been identified as suitable for installation on wetland mitigation projects by the Chesapeake Bay Critical Area Commission.

Dense stands of Phragmites have been observed in the sediment basins of the Lake Davies Dredged Material Disposal Area, Johns Creek, and other forested wetland areas on the CCNPP Unit 3 site. The control of Phragmites through herbicide application, mowing practices, and flooding of the sediment basins is proposed for the wetland creation and enhancement areas presently containing the invasive species. The following mitigation credit ratios and proposed total credits are proposed for the Phase II Mitigation Plan:

Wetland Mitigation Credit Summary

[illegible]	[illegible]	[illegible]	Mitigation Credit (acres)
Forested Creation	12.26	1:2	6.13
Emergent Creation	1.61	1:1	1.61
Wetland Enhancement	19.62	1:4	4.91
Total Impact Amount = 11.72 acres		**Total Credit Amount = 12.65 acres**	

<u>Stream Mitigation</u>

Stream mitigation credits will be achieved through various restoration and preservation techniques with the goal of protecting and improving aquatic resource functions and returning natural/historic functions to degraded aquatic resources. The Phase II Mitigation Plan includes 10,236 linear feet of stream restoration and 930 linear feet of stream preservation in order to obtain the required stream mitigation credits. This is measured based on valley distance and not sinuous length of channel. The Phase II Mitigation Plan is designed to reduce the potential of secondary impacts from proposed development and promote habitat and establishment of an American eel (*Anguilla rostrata*) population onsite. Stream impacts/credits are detailed below:

Stream Mitigation Credit Summary

Mitigation Type	Mitigation Amount (linear feet)	Mitigation Ratio	Mitigation Credit (linear feet)
Stream Restoration	10,236	1:1	10,236
Stream Preservation	930	1:2	465
Total Impact Length = 8,350 linear feet		**Total Credit Amount = 10,701 linear feet**	

Stream mitigation work is designed to meet the goals and objectives of this Phase II Mitigation Plan in accordance with the guidance provided by the regulatory and resource agencies. Several sites are proposed and depicted on Figure 2. In-channel work will be performed in accordance with an approved Erosion and Sediment Control Plan and performed by a qualified contractor, experienced in the field of stream and wetland restoration. Work will be performed with sufficient construction oversight to ensure the specifications of the design are met, disturbance is minimized, and any in-field changes which may occur are conducted and documented appropriately. The supervisory aspects of the design will include an onsite engineer working in coordination with a biologist/ecologist, providing oversight of the contractor on a day-to-day basis to ensure the design approaches are field-fit according to changing existing conditions while limiting disturbance to existing vegetation and natural resources.

The restoration design on the project site utilizes a combination of natural channel design (NCD) and regenerative stormwater conveyance (RSC) principles. NCD techniques, as pioneered by Dr. David Rosgen, are utilized to ensure that the riffle grade control techniques of RSC, thalweg grading, and low flow water surface facet creation are coordinated with stable reference systems onsite. Additionally, the reference criteria provide a basis for judging the success of the proposed dynamic sand-bedded systems.

RSC is a groundwater recharge, storage, floodplain reconnection, and infiltration practice that use a series of open channel, sand seepage step pools and riffle grade controls, through which stormwater flows are conveyed. The silty sand soils on this site are particularly suited to allow lateral infiltration from RSC storage and maximize floodplain contact, storage, and runoff quantity and quality attenuation. The purpose of these systems is to reduce the commonly seen erosion in ordinary stormwater conveyances and convert stormwater to shallow groundwater, mitigating nutrient pollution and thermal impacts to the receiving waters. The riffle grade controls within RSC systems are sized to resist transport of their underlying material in the 100-

year storm, accreting sediment over top of them at lower discharges, and flushing at higher discharges without transporting the underlying grade control material.

To ensure that the stream-wetland system is successful and diverse into the future, with fresh sources of woody debris, the mitigation design does not propose the removal or management of beaver, nor is a timber management plan proposed. In this way, it is intended that the stream system receives a diverse mix of large and small woody debris and leaf litter without the channel destabilizing and becoming entrenched.

Site Maintenance and Protection

The Phase II Mitigation Plan includes the creation and enhancement of nontidal wetlands, as well as the restoration and enhancement/preservation of nontidal stream channels. The compensatory mitigation is proposed to be onsite and areas where mitigation efforts have taken place on the property shall be protected long-term protections in perpetuity through the use of a Declaration of Restrictive Covenants, following the conclusion of the Site Maintenance and Monitoring program and regulatory agency sign-off on the mitigation efforts compliance with the permit requirements.

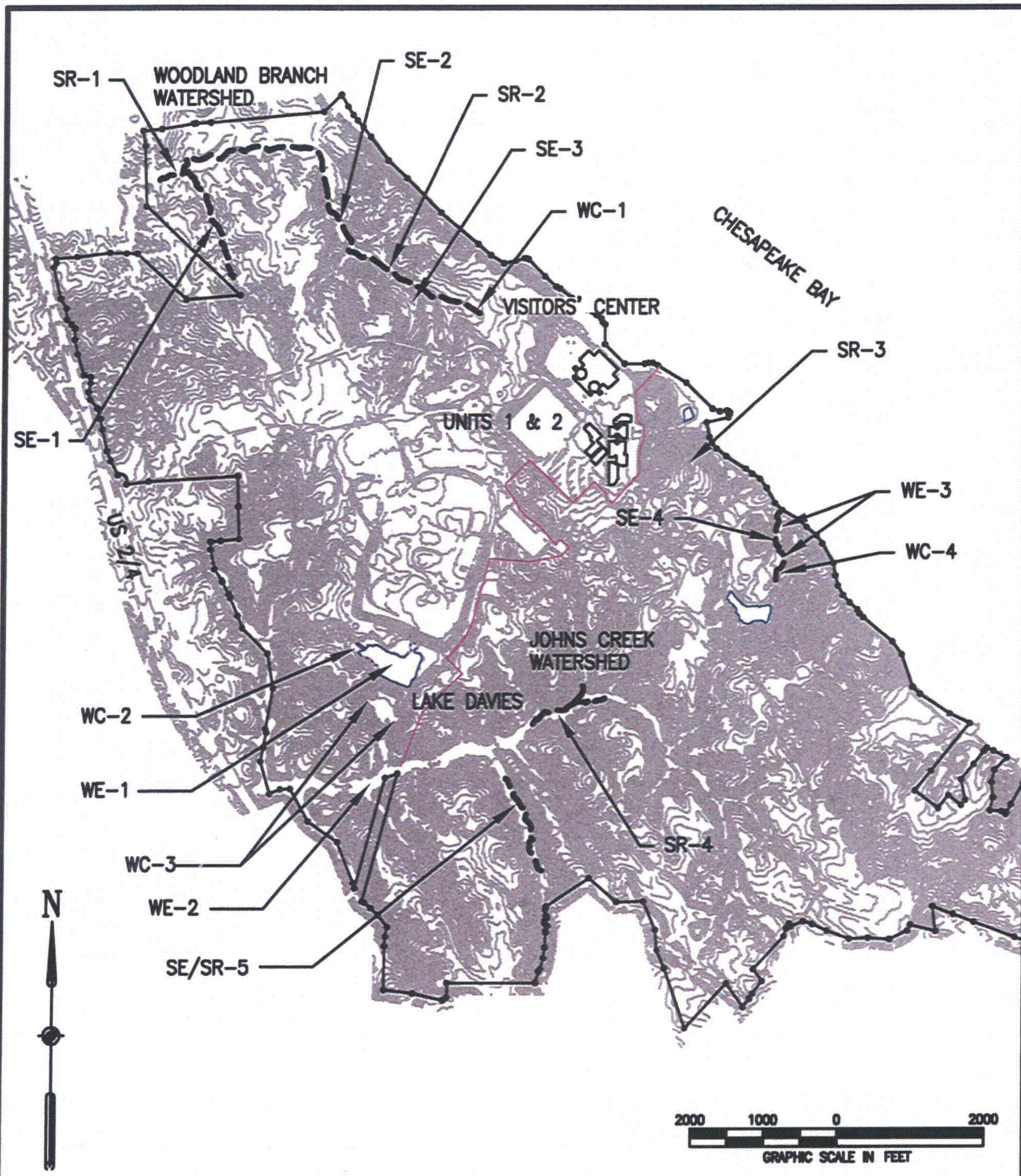
After the onsite wetland creation and enhancement activities are complete, a 5-year annual monitoring program will be implemented in accordance with the Maryland Compensatory Mitigation Guidance (IMTF, 1994), and the guidance provided in RGL No. 08-03 (USACE, October 2008). Performance standards for monitoring will be within accepted guidelines.

Monitoring of the stream channels proposed within the mitigation plan will be performed in an effort to compare post-construction conditions to pre-construction baseline data and within the specifications set forth in the plan and by regulating agencies.

EA Engineering, Science, and Technology, Inc.

Figure 1. Vicinity Map

Calvert Cliffs Nuclear Power Plant Wetland Delineation Addendum



FILE PATH: Q:\PROJECTS\1462103 - UNISTAR\MITIGATION DESIGN\FIGURE.DWG [LAYOUT1] 10/29/10

EA ENGINEERING, SCIENCE, AND TECHNOLOGY			UNISTAR NUCLEAR ENERGY CALVERT CLIFFS NUCLEAR POWER PLANT LUSBY, MARYLAND			FIGURE 2 – MITIGATION AREAS	
PROJECT MGR	DESIGNED BY	DRAWN BY	CHECKED BY	SCALE	DATE	PROJECT NO	FIGURE
RP	JJM/CJS	CJS	GAT	1"=2000'	OCT. 2010	1462103	2

Calvert Cliffs Nuclear Power Plant, Unit 3 Draft Final Phase II Nontidal Wetland and Stream Mitigation Plan Lusby, Maryland

Prepared for:

UniStar Nuclear Energy
Baltimore, Maryland

Prepared by:

EA Engineering, Science, and Technology, Inc.
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(410) 771-4950

October 2010 EA Project Number: 14621.03

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Calvert Cliffs Nuclear Power Plant, Unit 3
Draft Final Phase II Nontidal Wetland and Stream Mitigation Plan
Lusby, Maryland

Prepared for:

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Baltimore, Maryland

Prepared by:

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15 Loveton Circle
Sparks, Maryland 21152
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October 2010

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

EA	EA Engineering, Science, and Technology, Inc.
EPA	Environmental Protection Agency
CCNPP	Calvert Cliffs Nuclear Power Plant
COMAR	Code of Maryland Regulations
FGM	Fluvial Geomorphic
FIDS	Forest Interior Dwelling Species
ft	Foot or Feet
IMTF	Interagency Mitigation Task Force
JPA	Joint Permit Application
LOD	Limit of Disturbance
MBSS	Maryland Biological Stream Survey
MDE	Maryland Department of the Environment
MHW	Mean High Water
mm	Millimeter(s)
NCD	Natural Channel Design
NRC	Nuclear Regulatory Commission
O.C.	On Center
ORAM	Ohio Rapid Assessment Method
RBP	Rapid Bioassessment Protocols
RGL	Regulatory Guidance Letter
RSC	Regenerative Stormwater Conveyance
SE	Stream Enhancement
SR	Stream Restoration
SWM	Stormwater Management
UniStar	UniStar Nuclear Energy
USACE	U.S. Army Corps of Engineers
WC	Wetland Creation
WE	Wetland Enhancement

EXECUTIVE SUMMARY

The Draft Final Phase II Nontidal Wetland and Stream Mitigation Plan (henceforth referred to as the "Phase II Mitigation Plan") for the Calvert Cliffs Nuclear Power Plant (CCNPP), Unit 3 has been prepared in accordance with the Final Compensatory Mitigation Rule issued by the United States Army Corps of Engineers (USACE) and the Environmental Protection Agency (EPA), published 10 April 2008. This updated Phase II Mitigation Plan has been refined, in regard to expanding to provide more detail, from the Conceptual Phase II Mitigation Plan submitted to USACE and the Maryland Department of the Environment (MDE) in December 2009. The site vicinity is depicted in Figure 1.

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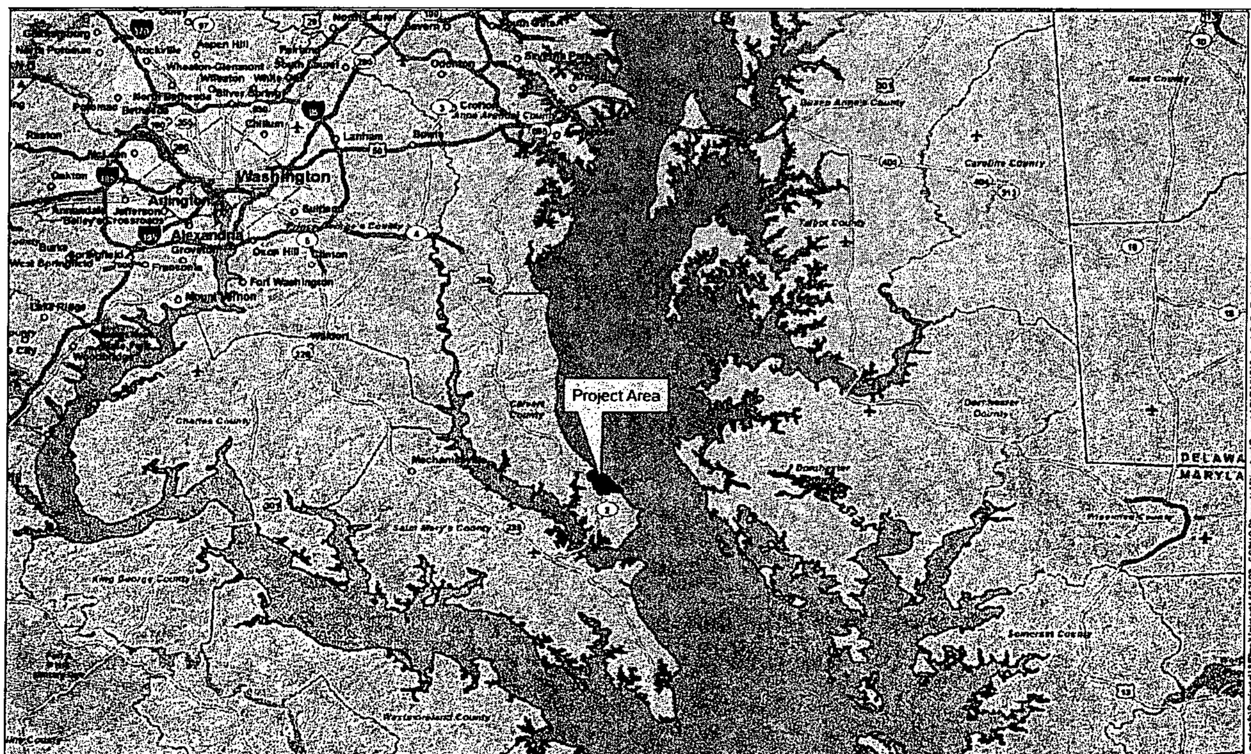
Monitoring of the stream channels proposed within the mitigation plan will be performed in an effort to compare post-construction conditions to pre-construction baseline data and within the specifications set forth in the plan and by regulating agencies.

1.0 INTRODUCTION

UniStar Nuclear Energy (UniStar) has proposed construction of a new nuclear power plant (Unit 3) at the project site known as the Calvert Cliffs Nuclear Power Plant (CCNPP), located in the Lusby area of Calvert County, Maryland, along the shoreline of the Chesapeake Bay, about 45 miles southeast of Washington D.C. (Figure 1). CCNPP is being proposed for expansion to provide additional energy service to meet the growing regional demand. A joint permit application and proposal for onsite mitigation of wetlands and streams has previously been submitted. EA Engineering, Science, and Technology, Inc. (EA) has been retained to develop the Phase II Final Nontidal Wetland and Stream Mitigation Plan (henceforth referred to as the "Phase II Mitigation Plan") in accordance with the Final Compensatory Mitigation Rule issued by the U.S. Army Corps of Engineers (USACE) and the Environmental Protection Agency



EA Engineering, Science, and Technology, Inc.

Figure 1. Vicinity Map
Calvert Cliffs Nuclear Power Plant Wetland Delineation Addendum

0 15 30 Miles

N W E S

(EPA), published 10 April 2008.

Federal and state regulations require that the losses be compensated through mitigation for activities that cause unavoidable losses of wetlands and streams. Wetland and stream mitigation is defined as the creation, restoration, enhancement, or preservation of wetlands or streams, to compensate for the wetlands and streams that will be lost. This document provides supporting details for the wetland and stream mitigation plan proposed for the Unit 3 project at CCNPP.

EA has prepared this Phase II Mitigation Plan to present the proposed design for the stream and wetland mitigation sites for review and approval by USACE and the Maryland Department of the Environment (MDE) in order to facilitate the final permit authorization for the proposed impacts to existing streams and wetlands as documented in the Joint Permit Application (JPA) submitted on 16 May 2008, and subsequent revisions and addendums. This Phase II Mitigation Plan has been developed from the Conceptual Phase II Nontidal Wetland and Stream Mitigation Plan, which was submitted to USACE and MDE on 8 December 2010 for review and comments. Prior to developing this Mitigation Plan, comments from MDE were received on the Conceptual Phase II Nontidal Wetland and Stream Mitigation Plan and have been addressed in this report.

The Phase II Mitigation Plan has been prepared in accordance with the *Maryland Compensatory Mitigation Guidance* (Interagency Mitigation Task Force [IMTF], 1994) and the USACE Regulatory Guidance Letter (RGL) No. 08-03, dated 10 October 2008, and documents the 12 critical elements as required by the Final Compensatory Mitigation Rule. The 12 critical elements include the following:

- Objectives
- Site selection criteria
- Site protection instruments
- Baseline information (for impact and compensation sites)
- Credit determination methodology
- Mitigation work plan
- Maintenance plan
- Ecological performance standards
- Monitoring requirements
- Long-term management plan
- Adaptive management plan
- Financial assurances

The 12 critical elements have been addressed throughout the Draft Phase II Mitigation Plan, and a summary of the 12 critical elements is included in Appendix A.

2.0 MITIGATION GOALS AND OBJECTIVES

As part of the planning process for proposed Unit 3 and associated facilities, steps were taken to ensure avoidance and minimization of impacts to Wetland and Stream resources to the maximum extent practicable. A detailed description of the Avoidance and Minimization procedure has been included in the JPA (Section 4-F) as well as within Section 6.0 of the previously submitted *Supplemental Environmental Resource Report*. However, due to numerous safety, operational, and engineering requirements and restraints, the anticipated development would result in unavoidable permanent impacts to wetlands and stream resources.

2.1 AQUATIC RESOURCE FUNCTIONS

The overall goal of the Phase II Mitigation Plan is to replace functions and values lost due to proposed development, as well as protect existing stream and wetland resources from potential impacts associated with changing land use from the Unit 3 expansion. The wetland and stream impacts on the CCNPP Unit 3 site occur within the same hydrologic units as the proposed wetland enhancement and creation areas and the stream enhancement and restoration areas; i.e., the Patuxent River Lower and West Chesapeake Bay hydrologic units. The geographic relationship between the areas of nontidal wetland and stream losses and the proposed mitigation sites provides an opportunity to mitigate impacts at an upper watershed level. The watershed approach used in the design of the compensatory mitigation plan for CCNPP Unit 3 is consistent with the ongoing natural resource management activities that have been conducted at CCNPP over the years. The mitigation activities are also compatible with comprehensive watershed management plans for CCNPP.

Mitigation credits are required to compensate for the unavoidable nontidal wetland impacts and stream impacts associated with the proposed project. The creation and enhancement of nontidal wetlands are being proposed to enhance water quality and habitat, as well as provide functional replacement for impacted wetlands. The stream mitigation credits will be achieved through restoration, enhancement, and preservation techniques with the goal of protecting and improving aquatic resource functions and returning natural/historic functions to former or degraded aquatic resources. Similarly, through the establishment of headwater wetland and infiltration practices in head-cut and upland situations, restoration of historical channel functions, historical groundwater elevations, and increases in base flow will be achieved.

2.2 PREVENTION OF SECONDARY IMPACTS

The proposed Phase II Mitigation Plan has been designed to account for proposed development and stormwater discharges in order to minimize their potential impacts on the existing aquatic resources. This is accomplished through the utilization of energy dissipation structures, re-connection of the channel with the existing floodplain, and appropriate channel sizing. The addition of infiltration practices and planting of riparian trees and shrubs is intended to increase base flow propagation in the watershed as well as reduce the potential for thermal impacts from stormwater discharges.

The mitigation design has been created to utilize construction techniques with minimal impact to existing water resources as well as existing vegetation. The design is intended to work with existing trees and shrubs to minimize canopy disturbance, and to utilize tree materials created through the clearing and grubbing phase of the construction of Unit 3.

Furthermore, the creation of headwater wetlands and infiltration practices are proposed to promote base flow, attenuate spikes in the hydrograph which may be erosive to stream channels, and compensate for existing and proposed impervious areas. These practices are proposed in order to have a successful mitigation outcome utilizing watershed approaches.

2.3 REDUCE IMPACTS TO THE AMERICAN EEL

The American eel has suffered extreme decline since European colonization of the region. The American eel is a catadromous species that begins its life by hatching from eggs in the Sargasso Sea, an area of the Atlantic Ocean north of the Bahamas. The eels then migrate to estuaries of the Atlantic Coast where they spend most of their lives before returning to the Sargasso Sea to spawn (Murdy et al. 1997). Historically, American eels were found throughout the East Coast streams, comprising more than 25 percent of the total fish biomass (Atlantic States Marine Fisheries Commission 2000]. As development of the rivers began and eel harvesting increased, the American eel populations began to decline throughout its range. During the upstream migration from the Sargasso Sea to the tributaries and estuaries of the Atlantic Ocean, American eels are forced to go through many obstacles in order to successfully reach their nursery grounds. Therefore, eels are susceptible to a variety of habitat, overfishing, and parasitic pressures. Changes in water quality and obstacles to fish passage present the two largest obstacles to their success in eastern freshwater streams. Eels mature in these freshwater streams for between 10 and 40 years. Since they live in a limited home range, the habitat must not be ephemeral (Ford and Mercer 1986).

American eel habitat enhancement and preservation has been identified as a priority for this project. This habitat includes undercut banks, crevices, hollow and overhanging logs, and sheltered areas. These areas coincide with roots, leaf mat, and partially and fully submerged woody debris in the channel.

The Phase II Mitigation Plan includes preservation of stream reaches identified as having known eel populations or potential habitat, and enhancements in other reaches to create suitable eel habitat. Enhancement of stream reaches to provide potential habitat for the American eel include placement of woody debris in the channel and work to raise the groundwater elevation to enhance base flow in the channels. At present, many channels exhibit excellent woody debris and cover elements; however, they lack base flow. Through enhancing base flow, additional habitat can be created for American eel. In addition, many reaches have head-cuts with large drops that may present migration barriers for American eel during their inland migration. These head cuts would be eliminated through creation of steps, or through other uplift techniques.

3.0 BASELINE INFORMATION FOR DEVELOPMENT AREA/IMPACTS

Jurisdictional wetlands and streams will be permanently impacted as a result of constructing the proposed Unit 3 project. The limit of disturbance (LOD) for the construction of the CCNPP Unit 3 facility has been designed to avoid and minimize impacts to natural resources to the greatest extent practical while still meeting the project needs. However, the construction of the project would not be possible without permanently impacting Waters of the United States, including federally regulated wetlands. The previously submitted permit application for the project proposes 8,350 linear feet of stream impacts and impacts to 11.72 acres of jurisdictional wetlands and open water ponds. A comprehensive description of the impact sites has been provided in the previously submitted wetland delineation report dated May 2007 and the JPA submitted on 16 May 2008.

3.1 NONTIDAL WETLANDS PROPOSED FOR IMPACT

The wetland areas to be impacted by the construction of Unit 3 include forested and emergent nontidal wetlands as well as open water ponds and are detailed in Table 1.

Table 1. Nontidal Wetland Impacts

Wetland Type	Area of Impact	Impact Type
Forested Wetland	7.88 acres	Permanent Grading/Fill
Emergent Wetland	1.21 acres	Permanent Grading/Fill
Open Water	2.63 acres	Permanent Grading/Fill
Total Area of Permanent Impacts = 11.72 acres		

Common functions of the impacted wetlands were previously determined to be groundwater recharge, groundwater discharge, flood flow alteration, sediment/shoreline stabilization, sediment/toxicant retention, nutrient removal/transformation, production export, aquatic diversity/abundance, and wildlife habitat diversity/abundance. Common values were also determined to be recreation, uniqueness/heritage, education/scientific value, and visual quality/aesthetics. The Ohio Rapid Assessment Method (ORAM), as outlined in the *Ohio Rapid Assessment Method for Wetlands* (Mack 2001) was used to quantify the functions and values of wetland communities on the CCNPP Unit 3 project site to determine the appropriate level of mitigation. This was performed as part of the Phase I Mitigation Plan as developed for Unistar by MACTEC in 2009. The areas assessed not only consisted of the wetlands that would be impacted by the proposed development, but included the wetlands not being impacted, in order to determine the viability of mitigation sites. A majority of the wetland systems proposed for impacts appear to be degraded and exhibited moderate functions and values. The detailed results of the wetland evaluation have been included in Section 5.0 of the *Supplemental Environmental Resource Report*, which was previously submitted with the JPA.

3.2 STREAM CHANNELS PROPOSED FOR IMPACT

Approximately 8,350 linear feet of jurisdictional (perennial and intermittent) stream channels were identified within the proposed LOD on the CCNPP Unit 3 site development project site which will be impacted as described in Table 2. The stream identification numbers listed in Table 2 correspond to the USACE identification system used during the Jurisdictional Determination site inspection and documented in the Phase I Mitigation Plan (MACTEC 2009).

Table 2. Stream Impact Summary

Stream Reach Identification	Impact Length (linear feet)
RA-I-A	729
RA-IVC-A	1,595
RA-IVN-A	102
RA-IVN-B	2,943
RA-IVN-C	555
RA-IVN-D	1,342
RA-VIIN-A	521
RA-VIIS-A	563
Total Impact Length = 8,350 linear feet	

An onsite evaluation of the stream channels using the Rapid Bioassessment Protocols (RBP) (U.S. EPA 1999) was conducted, as well as a benthic macro-invertebrate assessment using the Maryland Biological Stream Survey (MBSS) guidelines (Kazyak 2001). Most of the stream reaches proposed for impact received scores of suboptimal, as based on the RBP. Detailed results from these stream assessments were provided in Section 6.0 of the *Supplemental Environmental Resource Report*, which was included in the previously submitted JPA.

As part of the Phase II Mitigation Plan, EA has calculated the anticipated temporary impacts to wetlands and stream channels that will be impacted during the mitigation construction activities. In addition to the permanent impacts to 11.72 acres of wetlands and 8,350 linear feet of stream channels, the mitigation activities are anticipated to temporarily impact no more than 1.75 acres of wetlands and 590 linear feet of stream channels. These impacts associated with the mitigation activity are temporary and will be removed upon completion of the mitigation construction. The anticipated temporary impacts are proposed for construction access, temporary crossings, and other activities associated with ongoing construction activities. Fill material placed within the streams and wetlands will be removed and restored to original grade upon completion of the mitigation activities and re-planted with appropriate hardwood vegetation. Mitigation construction laydown areas are proposed be placed to minimize wetland and stream impacts. A detailed set of plans, including the proposed LOD are included in the Sediment and Erosion Control Plans and provided with the set of Draft Final Design Plans in Appendix B.

4.0 MITIGATION CREDIT ACCOUNTING

The LOD for the construction of the CCNPP Unit 3 facility has been designed to avoid and minimize impacts to natural resources to the greatest extent practical while still meeting the project needs. However, the construction of the project would not be possible without permanently impacting Waters of the United States, including federally regulated wetlands and streams.

To determine the required compensatory mitigation for wetland impacts, USACE–Baltimore District was consulted to determine the appropriate mitigation strategies for the project. The mitigation strategy chosen for the CCNPP Unit 3 project is onsite, in-kind mitigation. Therefore, no purchasing of mitigation bank credits is proposed to satisfy compensatory mitigation requirements. The Phase I Mitigation Plan (MACTEC 2009) was underway prior to issuance of the Final Compensatory Mitigation Rule issued by USACE and EPA and it was determined that there were no approved, State of Maryland, wetland/stream mitigation banks within the service area.

4.1 NONTIDAL WETLAND MITIGATION

To meet a "no net loss" goal of nontidal wetland mitigation, the 11.72 acres of nontidal wetland impacts caused by the construction of the proposed project must be mitigated by creating, restoring, or enhancing an equal area of nontidal wetlands. The Phase II Mitigation Plan for the Calvert Cliffs Unit 3 project includes the creation of new wetland areas onsite as well as enhancing existing wetlands. The wetland creation areas will include creation of both forested and emergent wetlands. A portion of open water creation is also proposed in order to replace functions and values lost from the impacted areas, as well as creating an ecologically diverse wetland mosaic within the mitigation area. The following mitigation credit ratios are proposed for the Phase II Mitigation Plan:

- Forested Wetland Creation = 1:2 credit ratio
- Wetland Enhancement = 1:4 credit ratio
- Emergent Wetland Creation = 1:1 credit ratio

Wetland enhancement will consist of the removal and control of common reed (*Phragmites australis*, commonly referred to as phragmites), along with planting of native bottomland hardwood species within existing wetlands where possible. Based on comments received by MDE on 2 December 2009, it has been determined that this technique will yield mitigation credits at a 1:4 ratio. A summary of wetland mitigation credits is described in Table 3.

Table 3. Wetland Mitigation Credit Summary

Mitigation Type	Mitigation Amount (acres)	Mitigation Ratio	Mitigation Credit (acres)
Forested Creation	12.26	1:2	6.13
Emergent Creation	1.61	1:1	1.61
Wetland Enhancement	19.62	1:4	4.91
Total Impact Amount = 11.72 acres		**Total Credit Amount = 12.65 acres**	

4.2 STREAM MITIGATION

As previously stated, the construction of the project would not be possible without permanently impacting 8,350 linear feet of jurisdictional stream. As stated in the approved Phase I Mitigation Plan, the amount of stream mitigation proposed is based on a mitigation ratio of 1:1 for linear feet of stream impacts. Therefore, the Phase II Mitigation Plan includes greater than the required 8,350 linear feet of stream mitigation credits through restoration and preservation techniques as described in Table 4.

Table 4. Stream Mitigation Credit Summary

Mitigation Type	Mitigation Amount (linear feet)	Mitigation Ratio	Mitigation Credit (linear feet)
Stream Restoration	10,236	1:1	10,236
Stream Preservation	930	1:2	465
			Total Credit Amount = 10,701 linear feet

Restoration

The mitigation proposed for the project consists of restoration of aquatic resources through the manipulation of the physical, chemical, or biological characteristics of resources with the goal of returning natural/historic functions to a former or degraded aquatic resource. For the purpose of tracking net gains in aquatic resource area, restoration is divided into two categories: re-establishment and rehabilitation. Re-establishment results in rebuilding a former aquatic resource and results in a gain in aquatic resource area and functions. Rehabilitation has the goal of repairing natural/historic functions to a degraded aquatic resource. Rehabilitation results in a gain in aquatic resource function, but does not result in a gain in aquatic resource area.

Preservation

Preservation will minimize the threat to, or prevent the decline of, aquatic resources by future actions. This includes the protection and maintenance of aquatic resources through the implementation of appropriate legal and physical mechanisms. Deed restrictions will be utilized as protection mechanisms for preservation of the aquatic resources.

Enhancement

Stream enhancement is defined by manipulating the physical, chemical, or biological characteristics of the aquatic resources to heighten, intensify, or improve a specific aquatic resource function(s). Enhancement strategies proposed in the Phase II Mitigation Plan were coupled with restoration practices onsite and, therefore, were not counted as a standalone practice. Enhancement practices include the addition of vegetation to floodplain and riparian areas, as well as invasive species removal and other management practices.

The Final Mitigation Rule that has been adopted by USACE states that enhancement differs from restoration, rehabilitation, and re-establishment because the objective of enhancement is usually to improve one or two functions, which may result in a decrease in the performance of other functions. Increasing those particular functions does not change the amount of area occupied by the aquatic resource. In contrast, re-establishment and rehabilitation (which are forms of restoration) are intended to return most, if not all, natural and/or historic functions to a former or degraded aquatic resource. If a compensatory mitigation activity results in an increase in aquatic resource area, in addition to increases in one or more aquatic resource functions, then it is appropriately classified as restoration.

4.3 ADDITIONAL MITIGATION CREDIT RESERVE

During the development of the Phase II Mitigation Plan, it was determined that the potential exists to obtain more mitigation credits onsite than is required for the proposed impacts. The impacts for the development of CCNPP require the mitigation of 11.72 acres of wetlands and 10,701 linear feet of stream channels. However, the conceptual Phase II Mitigation Plan anticipates 12.65 acres of wetland credits and 10,701 linear feet of stream credits, creating a surplus of 0.93 acres of wetland credits and 2,351 linear feet of stream credits.

UniStar Nuclear Energy has elected to include the additional mitigation areas into this Phase II Mitigation Plan in an effort to create a reserve of mitigation credits for potential future use for impacts that may arise for future projects onsite. The reserve of mitigation credits would not be sold or transferred to any project located offsite. The purpose of this proposed reserve is to provide compensatory mitigation for future unavoidable impacts to Waters of the United States, including nontidal wetlands that result from activities authorized under Section 404 of the Clean Water Act and the Maryland Nontidal Wetlands Protection Act, provided such use has met all applicable requirements and is authorized by the appropriate authority(s). The credit reserve would be used to comply with the special condition mitigation requirements of permitted projects by providing in-kind compensation for authorized wetlands losses and may only be used for future projects after all appropriate and practical steps to avoid and minimize adverse impacts to aquatic resources, including nontidal wetlands and streams, have been taken.

The mitigation credit reserve does not provide ultimate Federal and/or State authorization for specific future projects impacting Waters of the United States, exclude such future projects from any applicable statutory or regulatory requirements, or preauthorize the use of credits from the reserve for any particular project.

5.0 EXISTING CONDITIONS / BASELINE DATA / BASIS OF DESIGN

The subject property consists of approximately 2,070 acres located in the Lusby area of Calvert County, Maryland, along the shoreline of the Chesapeake Bay, about 45 miles southeast of Washington, D.C. The site is bound to the north and south by wooded land, to the east by the Chesapeake Bay, and to the west by Maryland State Highway 2/4. The proposed Unit 3 development is primarily sited on the southern portion of the subject property.

The current site conditions consist primarily of forested areas along the northern and southern portion of the site around the existing development. The topography of the site consists of gently rolling slopes within the center of the site and stream valleys with narrow floodplains, adjoined by steep side slopes located within the forested undeveloped portions of the site. The streams and wetlands on the site were identified as nontidal, as the steep shoreline cliffs prevent tidal influence from extending beyond the sandy beaches.

The areas of potential mitigation were selected during the development of the Phase I Mitigation Plan and further studied prior to the development of the Phase II Mitigation Plan. After reviewing the Phase I Mitigation Plan, EA conducted multiple site visits of the project site in order to verify the Phase I findings and collect additional data to support the Phase II design. EA conducted field reviews from August 2009 through October 2009 in order to: (1) complete the delineation of remaining streams and wetlands within the project area, (2) perform a detailed Fluvial Geomorphology Investigation of the proposed stream mitigation sites, (3) perform an assessment of the proposed wetland mitigation areas, and (4) conduct a Baseline Conditions Assessment of the existing streams.

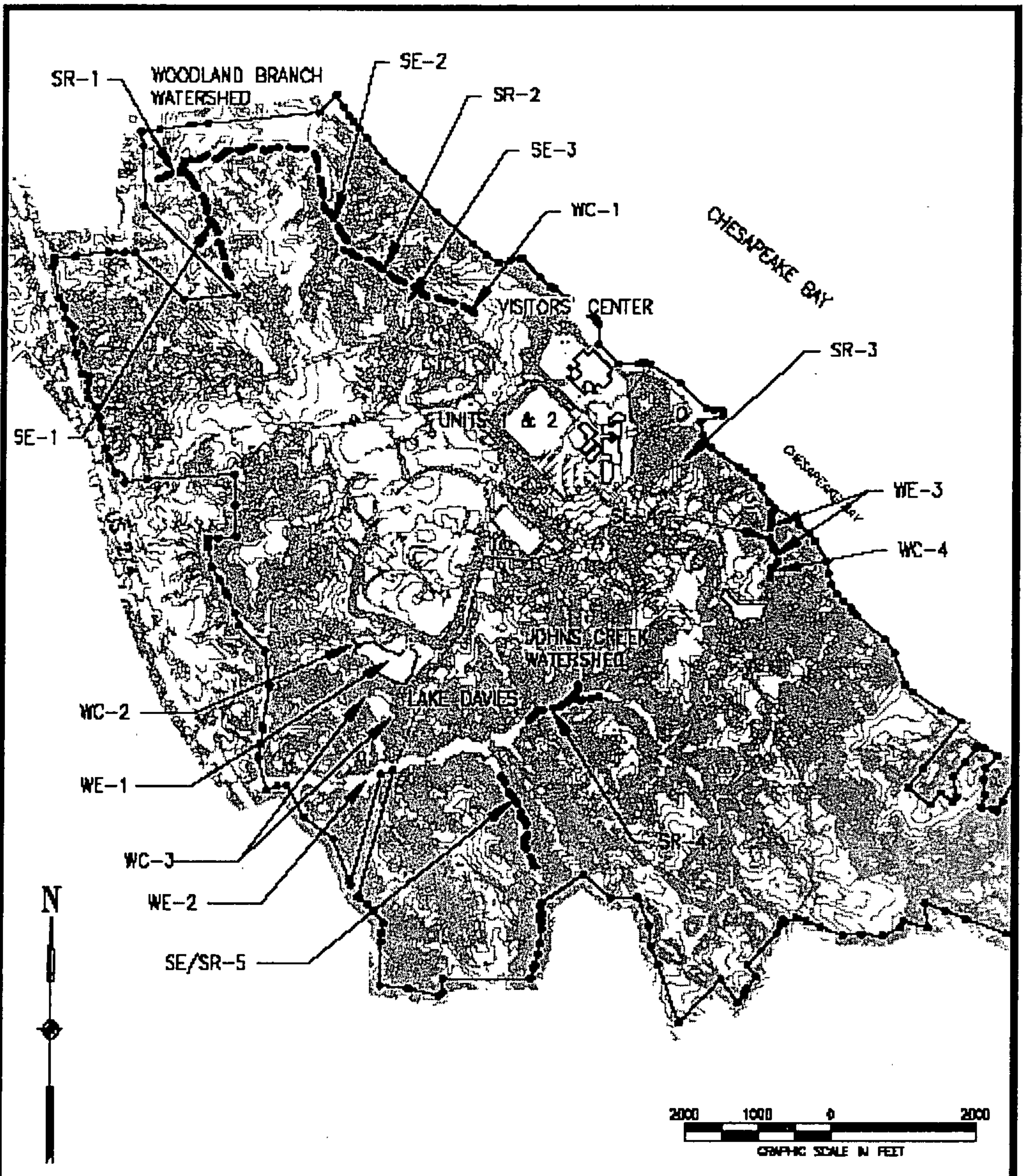
5.1 NONTIDAL WETLAND MITIGATION AREAS

Locations for potential wetland enhancement and wetland creation areas were identified within the approved Phase I Mitigation Plan (MACTEC 2009). These areas were determined after field reviews conducted in 2007 and 2008, in which specific locations were identified as having ecological lift potential for wetland enhancement or as being suitable for the creation of wetland communities from upland landscape. The Phase I concept included the creation and enhancement within the Lake Davies Disposal Area sediment basins (WC-2 and WE-1), the portion of Johns Creek to the south of the sediment basins (WE-2), as well as an upland grassed field at the Camp Conoy area (WC-1).

After review of the site conditions, and development layout, EA determined that the forested wetland creation area at Camp Conoy (previously WC-1 in the Phase I plan) may not be suitable for the previously proposed forested wetland. The area formerly proposed for WC-1 will be proposed for upland reforestation in order to close the canopy within the Critical Area and increase Forest Interior Dwelling Species (FIDS) habitat.

Additional changes were made to the proposed wetland mitigation areas from the Phase I Mitigation Plan. After review of existing data and field reconnaissance conducted by EA, some revisions to the locations for wetland creation have been proposed. The following is a list of the proposed wetland creation and wetland enhancement areas proposed to meet the mitigation requirements.

- WC-1 – Creation of forested head water wetland system at the head of Woodland Branch, near the open field north of the old visitor center. Associated with stream restoration stationing along Woodland Branch (WB 0+00 – 3+75).
- WC-2 – Creation of a forested/emergent wetland system with open water habitat, within the middle manmade sediment basin of the Lake Davies Disposal Area.
- WE-1 – Enhancement of an existing wetland located within a smaller manmade, abandoned, sediment basin within the Lake Davies Disposal Area.
- WC-3 – Creation of two small forested wetland areas adjacent to WE-1.
- WE-2 – Enhancement of a portion of Johns Creek and a linear drainage way extension occurring to the south of the Lake Davies Disposal Area.
- WE-3 and WC-4 –Creation and enhancement of forested wetlands in the location of the old open water ponds located below Camp Conoy Pond. This wetland is associated with the stream restoration proposed for SE-4 (SE-4 0+00 – 10+44).



EA ENGINEERING, SCIENCE, AND TECHNOLOGY		UNISTAR NUCLEAR ENERGY CALVERT CLIFFS NUCLEAR POWER PLANT LUSBY, MARYLAND			FIGURE 2 – MITIGATION AREAS		
PROJECT MGR RP	DESIGNED BY JJM/CJS	DRAWN BY CJS	CHECKED BY GAT	SCALE 1"=2000'	DATE OCT. 2010	PROJECT NO 1462103	FIGURE 2

Wetland Creation Area #1 (WC-1)

Mitigation Site WC-1 is located at the head of Woodland Branch, near the open field north of the old visitor center. The majority of the proposed mitigation site exists within the forested area along Woodland Branch with a small portion extending into the existing open grass field. The uppermost portion of Woodland Branch is highly incised and degraded, with a large head-cut located at the origin of the stream. The visitor's center onsite directs stormwater runoff from the adjacent impervious surface towards the stream channel and has contributed to the identified degradation; however, aerial photography has indicated that the adjacent field has been cleared or in agricultural use since at least 1938. The existing vegetation and the soil profile within the WC-1 site were examined during field reconnaissance.. The forested portion of this mitigation site consists predominantly of sweetgum (*Liquidambar styraciflua*), red maple (*Acer rubrum*), tulip poplar (*Liriodendron tulipifera*), white oak (*Quercus alba*), American beech (*Fagus grandifolia*), and American holly (*Ilex opaca*). Meanwhile, the nearby open grass field appears to be a warm seasonal grass meadow area that is maintained on a low level. The topography in this area drains down to Woodland Branch and receives runoff from the existing development.

Wetland Creation Area #2 (WC-2)

Mitigation Site WC-2 is located within the middle sediment basin of the Lake Davies Disposal Area, which was created during the construction of the existing development. The basin is surrounded by earthen berms on all sides, with an outlet on the western side that drains to Goldstein Branch. During the site evaluation, EA observed a dense stand of common reed (*Phragmites australis*) which dominates the entire sediment basin. Native vegetation was observed around the outer perimeter of the basin and consisted of red maple, tulip poplar, and black willow (*Salix nigra*). The underlying soils were observed during the site evaluation to identify the presence of hydric soils. The upper layer of the underlying soils appears to consist of material and sediment from the dredge spoils which have formed a dense clay layer containing an abundance of phragmites rhizomes. Below the dense clay layer, EA identified hydric soils with the presence of saturation, oxidized root channels, and extensive mottling.

Wetland Enhancement Area #1 (WE-1)

Mitigation Site WE-1 is located within the lower basin of the Lake Davies Disposal Area, which is also surrounded by large earthen berms on all sides. This lower basin contains two drains located on the southern end, which appear to drain the basin and convey flow to the lower drainageway located to the south (WE-2). Similar to WC-2, this basin is dominated by phragmites with native vegetation along the perimeter. A small pocket of native vegetation was also observed within the center of the basin. Dominant native vegetation within this mitigation area consists of red maple, black willow, tulip poplar, and small spike false nettle (*Boehmeria cylindrica*). The underlying soils were observed during the site evaluation to identify the presence of hydric soils. The soils within this basin were similar to the soils observed at WC-2, in which the upper layer contained a dense clay layer containing an abundance of phragmites rhizomes. Below the dense clay layer, EA identified hydric soils with the presence of saturation, oxidized root channels, and extensive mottling.

Wetland Creation Area #3 (WC-3)

Mitigation Site WC-3 consists of two small topographic low areas adjacent to the lower basin of the Lake Davies Disposal Area (WE-1). These two areas are currently not identified as existing wetlands as they lack the presence of wetland hydrology. Dominant native vegetation within these creation areas consist of red maple, sweetgum, and tulip poplar, with some phragmites extending into these areas. The soils within the two creation areas were similar to the soils observed at WE-1. However, the dense clay observed in the adjacent sediment basin was only a few inches deep in these areas, and contained a more natural underlying soil matrix. Wetland hydrology was not observed in these areas.

Wetland Enhancement Area #2 (WE-2)

Mitigation Site WE-2 includes the existing linear drainageway that conveys flow from the aforementioned lower basin of the Lake Davies Disposal Area (WE-1), down to Johns Creek and the lower portion of the stream valley along Johns Creek. The enhancement area along Johns Creek includes approximately 3,000 linear feet of stream valley dominated by phragmites. The portions of the Johns Creek reach that are not infested with phragmites consist of a bottomland hardwood forest community dominated by red maple, sweetgum, and black gum (*Nyssa sylvatica*) with New York fern (*Thelypteris noveboracensis*), sensitive fern (*Onoclea sensibilis*), soft rush (*Juncus effusus*), and lizard tail (*Saururus cernuus*) dominating the understory. The linear drainageway extending down from WE-1 is dominated by phragmites. Wetland hydrology and hydric soils were identified throughout the area of WE-2.

Wetland Enhancement Area #3 and Creation Area #4 (WE-3 and WC-4)

Mitigation Sites WC-4 and WE-3 are located along the stream channel downstream of the existing Camp Conoy Pond. The proposed mitigation area is within a forested area between the developed camp area and the Chesapeake Bay and consists of a series of open water ponds located in-line to the existing stream channel proposed for restoration. A large head cut is located at the downstream portion of the stream channel. During the site investigation, it appeared that the water elevation in Camp Conoy Pond had been lowered and the hydrology within the wetlands downstream has been affected. The existing vegetation and the soil profile within this area were examined during field reconnaissance. The forested portion of this mitigation site consists predominantly of red maple, sweetgum, tulip poplar, white oak, American beech, and American holly. Meanwhile, the open water ponds predominately contain false nettle along the edges. The topography in this area drains down to the Chesapeake Bay and receives runoff from the existing camp area. This area is proposed to receive increased discharges from the proposed SWM plan for Unit 3.

5.2 STREAM MITIGATION REACHES

Locations for potential stream restoration and enhancement areas were previously identified within the approved Phase I Mitigation Plan (MACTEC 2009) and are described in Table 5 and identified on the figure above. These lengths have been revised during the development of the Phase II Mitigation Plan, and names have been replaced with baseline stationing. The total linear feet of valley distance is used to determine the length of the mitigation reach, rather than the stationing which follows the approximate sinuous channel centerline.

Table 5. Proposed Stream Mitigation Reaches

Mitigation Area	Location	Length (linear feet)
SR-1 WB 36+75-57+50	Lower Woodland Branch	2,100
SR-2 WB 0+00-18+00	Upper Woodland Branch	1,700
SR-3	Chesapeake Bay Tributary 1	800
SR-4 JC 11+50-25+00	Johns Creek	1,150
SR-5 SE/R-5 0+00-17+50	UT Johns Creek	1,700
SE-1 SE-1 0+00-14+14	UT Lower Woodland Branch	1,520
SE-2 WB 18+00-36+75	Woodland Branch	900
SE-3 SE-3 0+00-2+19, & UT 0+00-2+86	UT Upper Woodland Branch	631
SE-4 SE-4 0+00-10+44	Chesapeake Bay Tributary 2	1,044
SE-5 SE/R-5 0+00-17+50	UT Johns Creek	1,700

5.2.1 Stream Mitigation Reach Descriptions

Descriptions of stream reaches are based upon segmented breaks identified through the Phase I assessment for the project, as well as changes in constraints, stream type or valley gradient. Since the reaches are varied and the lengths of channel are large, reaches are broken into general units and characterized on a macro scale in most instances, rather than breaking down individual sections of varying degrees of entrenchment, vegetation, bed material, etc. Therefore, multiple channel conditions are often within each reach. Their observed state is based on visual assessment as well as survey information, the process and site utilization of which is described in Section 5.2.2. These reaches have been further refined into general terms based on the average valley gradient within these reaches; similarly, reach characteristics are correlated with gradient of their respective valleys.

Upper Reach Woodland Branch – WB 0+00 – 18+00

The main stem of Woodland Branch originates at the open field north of the old visitors center. The upper reach of this stream corresponds to the proposed wetland creation site from WB 0+00 to WB 3+75, which consists of a highly incised and degraded gully, with a large head-cut located at the origin of the stream. The valley gradient is steep, varying from approximately 5-20% in portions of the reach. Channel depths exceed five feet throughout the reach. The visitor's center and adjoining parking areas direct stormwater runoff from the adjacent impervious surfaces towards an open field and stream channel and may contributed to the identified degradation. However, aerial photography has indicated that the adjacent field has been cleared or in agricultural use since at least 1938, so the majority of the long-term degradation in this reach likely began before the visitor center was constructed. The forested portion of this mitigation site consists predominantly of sweet gum, red maple, tulip poplar, white oak, American beech, and American holly. Meanwhile, the nearby open grass field appears to be a warm-season grass meadow area that is maintained periodically through mowing. The topography in this area drains down to Woodland Branch and receives runoff from the existing development. Incision and re-creation of a floodplain terrace within the channel has occurred within the stream banks from WB 0+00 – 18+00. However, the channel is not well connected to the historic floodplain and the banks exhibit dense vegetation growth, overhead cover, and root mass directly in the channel.

Middle Reach Woodland Branch – WB 18+00 – 36+75

The middle reach of the main stem of Woodland Branch (WB 18+00 – 36+75) was observed during minimal base flow. The lower portion of the reach is wide with a high width/depth ratio, and exhibits channels predominantly of clean, fine to medium sand. Numerous additional floodplain channels can be observed which are either abandoned or utilized only in high flow situations. The reach shows little evidence of significant erosion, block failures, or excessive shear stress. The valley gradient is approximately 1% and bank heights vary from 1-4' typically. Roots, logs, and leaf matter are present in the channel. The reach at its lower extent is controlled by an 18-inch metal pipe and stone fire road crossing which serves as grade control. At the lower extent of the reach there is evidence of connected wetlands and fresh sand on the floodplain, suggesting an aggradation situation; however, channel and wetland stability appears to be strong. Vegetation is dense, contributing to the floodplain and channel stability.

The upper half of this reach is characterized by a relatively stable sand channel, with high width/depth ratio, which emerges from an incised state at the top, and becomes slightly incised through the bottom portion before becoming a stable reach. Much of this reach is incised several feet and lacks habitat. There is less woody debris in the channel than is seen on other reaches; however, the channel contained base flow at the time of the assessment. The floodplain is largely unconnected to the channel, although abandoned channels in the floodplain are present and may be active at higher flow stages. The floodplain exhibits mature upland species primarily with small pockets of adjacent wetlands.

Lower Reach Woodland Branch – WB 36+75 – 57+50

The lower reach of Woodland Branch was separated into two distinct portions. The upper half of this reach begins below an 18-inch corrugated steel pipe culvert, which appears to have caused instability downstream including channel entrenchment. The upper portions are moderately entrenched, and poorly connected to the adjacent floodplain. The floodplain is dominated by upland species, indicating the incision and resulting lowered water table have been present for an extended period of time. The floodplain has several abandoned channels that have similar dimension to the reference reaches onsite. This channel has a gravel content that appears to be limestone from fire road maintenance activities. Although this stone is seen in bar features, it is not considered the bed load of the reach, as riffles are populated with fine to medium sands, with a veneer of silt over top. Channel banks are silt and sand materials, further supporting this assumption. Banks are vertical and erosive over much of the reach with little overhead cover and poor root mass. At the time of the survey, there was no base flow in the upper assessment reach.

The lower portion of this reach is more incised than the upper portion. Tree roots are contained on only the uppermost foot of the banks, leaving vertical, erosive silt banks exposed. This reach, when surveyed, was also without base flow. Channel substrate is sand with silt, similar to upper reaches.

UT Upper Woodland Branch – SE-3 0+00 – 2+19 and UT 0+00 – 2+86

One unnamed tributary located on the upper reach of Woodland Branch was also identified as part of the stream restoration area. This tributary begins as a wetland complex and degrades into an incised channel, with low width/depth ratio and an entrenchment ratio approaching a value of 1.

UT Lower Woodland Branch – SE 0+00 – 14+14

One unnamed tributary located on the lower reach of Woodland Branch was also identified as part of the stream restoration area. This tributary was assessed in three individual sections including a short reference reach in between two incised reaches.

The upper reach of this tributary begins at a 24-inch concrete pipe culvert under an existing logging road. The culvert causes destabilization of the channel, due to excess downstream velocity and maintenance activities for approximately 110 feet downstream of the culvert. The channel has exposed silt banks and evidence of erosion throughout, indicating the beginning stages of channel incision.

The middle reach of this tributary was identified as a reference reach and is characterized by small, connected floodplain channels. This reach is the basis for restoration design used along this tributary as well as other portions of Woodland Branch. This reach requires enhancement or restoration work in order to create transitions to impaired reach work areas as required at its upstream and downstream limits, and planting to create a continuous riparian buffer with the other restoration reaches.

The entrenched lower portion of this headwater tributary to Woodland Branch alternates between moderate to severe entrenchment with the occurrence of root wads and logs in the channel. The base flow of the channel becomes subsurface in several portions of the reach.

SR-3 – No Stationing

SR-3 was identified as having an abundance of American eels, which are targeted for preservation onsite. SR-3 is unique in that the majority of the entire reach is a hard-bottomed channel with imbricated fossilized *Chesapecten nefrens* scallops, now extinct, dating this geologic feature to approximately 12-15 millions years old. This consolidated clay layer serves as grade control of the reach, rendering it stable. Additionally, a gray consolidated clay layer is located above this layer, which is very stable and fairly resistant to erosion.

The upper portions of the reach are severely incised, with banks in excess of 10 vertical feet. The lower portions of the reach are less incised, with stable bench features and no visible grade control other than logs and root wads. Gravel beds are observed in the lower portions of the reach. The entire reach has large amounts of submerged and overhanging woody debris, undercut banks, and submerged roots. It appears that American eel heavily utilize these features for habitat.

SE-4 0+00 – 10+44

The SE-4 reach is located in the Camp Conoy area of the site and drains directly to the Chesapeake Bay. The reach is influenced by three impoundments. The watershed contains the present Camp Conoy Pond, and begins as the outfall from a pond, with another in-stream pond located immediately before a steep drop to the Chesapeake Bay. There is evidence in the reach that an additional in-stream pond once existed along the channel but was breached. The channel is fairly steep and moderately incised, with silt-sand bed and silt banks. There is little riparian vegetation but a fairly developed upland canopy over the site. At the time of the survey, the only water observed was in the ponds, and a minimal groundwater base flow in the portion of the reach which directly connects to the Chesapeake Bay. SE-4 is entrenched along its length, and as a result, flow does not regularly over top the stream bank inundating the floodplain under common flow events, nor is sediment regularly deposited onto the floodplain. Groundwater is shallow but normally below the invert of the existing channel, and base flow is usually absent from the reach in drier months. Additionally, the degree of entrenchment creates conditions of excess sediment transport, which result in deeper entrenchment through channel incision.

The lower portion of the reach cascades down a shear silt/clay bank onto a small stony beach adjacent to the Chesapeake Bay. The cliff face and incised channel banks are characterized by areas of bare earth and the presence of common reed as well as other invasive species, grasses, and small shrubs, all of which assist in partially stabilizing the slope.

SR-4 - JC 11+50 – 25+00

SR-4 is the main stem of Johns Creek. Prior to this restoration reach, the stream is considered to be a reference and becomes a highly connected wetland channel system with sparse trees and thick sedge floodplain and banks. The reach reference portion of the reach is extremely flat with little discernable movement of the water. Reference morphology is presented in Table 7 earlier in this report. Within the more channelized portion of the reference, slopes are approximately 1.1 percent with a sinuosity of approximately 1.5—the highest observed in the assessment of the site. Immediately downstream of the reference, the reach becomes deeply incised within approximately 50 channel feet, until uplifted through beaver activity backwatering in lower reaches. Evidence of abandoned floodplain channels is present within SR-4 floodplain areas, with the pattern and dimension of these abandoned channels matching closely with those of reference reaches. Below this reach, beaver have created additional wetlands and channel grade controls which have arrested channel incision, although wetlands are significantly impacted by phragmites.

SR-5/SE-5 0+00 – 17+50

The SE-5 and SR-5 reaches are a connected first order headwater tributary to Johns Creek. The reaches culminate in the Johns Creek Valley wetland complex with poorly defined channels. The reaches alternate between moderate and severe entrenchment, with many fluctuations between these states throughout. These reaches are incised with grade control provided by occasional logs or root sills. The reach at the time of assessment contained base flow throughout. The majority of the reach is low sinuosity, low slope, with the greatest amounts of slope occurring at log and root grade controls. Channel beds are fine to medium sand with silt components, most likely sourced from overland flow and stream bank erosion. The floodplain is moderately drained with upland and wetland species present.

5.2.2 FGM Investigation

EA performed a detailed Fluvial Geomorphologic Assessment during September and October 2009, in which approximately 2,900 linear feet of representative channel were surveyed utilizing differential leveling techniques to determine channel measurements and longitudinal profile in the formulation of the mitigation design. In addition, pebble counts, bar samples, cross sections, and protrusion measurements were utilized to quantify the key fluvial geomorphic (FGM) data to derive conclusions about the long-term stability of each reach. Total station survey along with field measurements were utilized to measure channel form factors such as radius of curvature, belt width, etc.

Survey of the site centered on channels which experience base flow conditions, and was taken not only in the context of the observed single-thread base flow channels, but how those channels interact with other channels within the valley of that base flow channel.

A longitudinal profile survey was conducted at locations that depicted the departure of the reach from stable to unstable conditions, comparing stable reference conditions in relation to upstream or downstream entrenchment or channel down-cutting conditions. Stable conditions were defined as those reaches which exhibited riparian vegetation and habitat which appeared to persist, in addition to channel depth conditions which demonstrated frequent access to the floodplain. Frequent access to the floodplain was often identified through visual observation of fresh sand deposits, wash lines and fresh floodplain scour. Unstable or degrading conditions were defined as those channels which have entrenched themselves and no longer exhibit evidence of frequent floodplain access, and additionally, are actively down-cutting. Degrading channels also offer poor habitat quality and an absence of riparian vegetation, or presence of invasive species. Cross sections were also surveyed for the channel depicting unstable / degrading conditions as well as reference conditions.

In reference reaches, cross sections of representative thalweg facet features (riffle, run, pool, and glide facets) were surveyed. A minimum of one of each of these facets was surveyed at the top and bottom of the reaches to identify how cross sectional area changed through the reach. Cross sections were also surveyed to account for the dimension of the valley in which the reaches reside. In degraded reaches, only cross sections of riffles and pools were surveyed. These are the most easily identified features in these degraded reaches, and the main purpose was to show the contrasting entrenchment conditions between these reaches and reference or stable reaches. Many reaches were surveyed during the absence of base flow due to the intermittent nature of the streams and time of year of the survey. Where base flow was available, water surface elevations were recorded in the longitudinal profile. Bars (point, mid-channel, and transverse), berms, and other in-channel features were identified in longitudinal profiles, along with abandoned floodplain channels, channel sinuosity, valley cross sections, and other contextual features. Reference reaches are identified on the design drawings and are proposed only for minor enhancement work (planting and woody debris placement), or will remain undisturbed with the exception of transitions to the restoration areas.

Particular attention during survey was given to log features in the channel. Logs and woody debris in the channel are the primary observed factor for channel self-recovery. As woody debris enters the channel thalweg, backwatering occurs and organic matter (leaves, twigs, etc.) accumulates behind the debris. This in turn causes a lifting of the base elevation of the thalweg, thus allowing for thalweg re-connection with the floodplain. Survey of these debris and log features provided a baseline understanding of how these features influence channel profile, and was seen as essential to providing a template of acceptable slopes, inverts, and methodologies to construct similar features in restoration reaches. Channel stability onsite was not evaluated based on the static condition of channel facets, but rather the dynamic condition of the systems as a whole throughout a reach in maintaining floodplain functions and values.

5.2.3 FGM Investigation Findings: General Findings and Reach Classification

Speaking generally about the streams on site, these streams consist of sand bedded, sinuous thalweg channels with minor periodic grade controls usually composed of woody debris, limbs, or root mat. Larger changes in grade are associated with beaver activity, backwater pools and aggregation, or channel degradation. Numerous "abandoned" (not exhibiting signs of frequent base flow) or dry channels exist throughout the floodplain, as well as wetland systems throughout the entire valley bottom. Abandoned terraces are rare; generally the valley bottoms are flat and transition sharply within only a few feet to upland conditions. In this way, floodplains are sinks for sediments with sediment sources generally supplied by upland areas.

Through the evaluation process, EA surveyed multiple reaches within the site, including reference reaches were surveyed in conjunction with the transition areas to incised, degraded reaches. The Calvert Cliffs sites exhibit many instances of systems in flux, with observable changes in reaches between entrenched systems and stream systems connected to their floodplains. Reference reaches are present and discussed in detail in Section 5.2.5, Basis of Design.

Rosgen Stream Classification was performed for the base flow thalweg channels on site. This was selected because this classification system is the most widely accepted system available. This system was also used in the Phase I report. However, this classification is qualitative in that it relates channel classification properties to a bankfull or channel forming discharge. A classic example of how this bankfull stage miss-identification can change the classification of a reach is how many F-classified reaches are mis-characterized as C-classified reaches because bankfull elevation is estimated too high. In fact, evaluation of the Phase I report by EA found this to be the case on many of the assessment and reference reached indentified by the previous consultants. These reaches were in fact entrenched, based on their depth, lack of floodplain access, and conflict with the basis of understanding that sand bedded channels transport sediment during significant runoff events of practically any magnitude, but are low energy in that they do not exhibit substantive excess shear stress that precludes the presence of depositional features.

Therefore, EA developed a modified classification scheme in order to provide useful data and a basis of comparison between reaches. EA first looked at discharges, via regional curves and TR-55 modeling in order to understand the magnitude of discharges occurring on site. The 1-year, 2-year, and an approximate estimate of the 1.5-year discharge were examined and compared with regional curves for the Maryland Coastal Plain.

The base flow thalweg of each valley was surveyed and classified. EA utilized this information to identify the slope of the existing base flow thalweg, and the cross sectional area associated with the "top of floodplain" elevation.

The strict relation with traditional bankfull, however, ends there. EA utilized its best judgment to determine if traditional bankfull made any sense as a channel-forming discharge each reach. In many cases where excessive channel incision had occurred, there was no connection with the floodplain for any range of discharges which could be associated with a bankfull; therefore the channel entrenchment ratio was approximately calculated as a value of 1, and the channel was judged to be entrenched. These reaches also did not engage any other thalwegs or abandoned channels in the floodplain and were also the base flow channel. They serve as single, entrenched channels.

Other reaches on the site, however, contained only a small amount of the modeled or regional curve-estimated discharge. These reaches were highly connected to the floodplain and exhibited log grade controls, dense roots on channel banks and stable habitat. These reaches may or may not engage additional well-defined thalwegs within the valley. These reaches were classified as according to the Rosgen classification system with the realization that discharges greater than top-of-bank stage engaged multiple channels in some cases, and therefore classification was related to a top of bank (single thread) condition, as well as a out of bank (multi-thread) condition. Additionally, EA realized that characterizing the top-of-bank condition would be useful in determining the acceptable parameters to with which to base proposed thalweg grading construction data upon.

Utilizing this methodology, the threshold for classification of majority of stream reaches requiring restoration classify as B5c channels with a low width/depth ratio (out of range of the typical B channels). Those channels classified in the B group are generally not so entrenched as prohibit self recovery, however channels classifying as F or G stream types are. B channels on site in many cases activate additional thalwegs in the valley, indicating that dedritic function had not been lost to channel incision. G and F channels exist on the site, and have lost all dendritic function and can be observed in the longitudinal profile series data, usually at the end of a profile, depicting departure from dendritic and otherwise stable channel states. A complete departure occurs in F and G thalwegs from any floodplain channels, meaning that multiple-thread channels degrade to single thread entrenched channels. These channels mimic the sinuosity of stable stream types in most cases; however, head cuts, block bank failures, disturbed vegetation, and silt veneer over sandy beds dominate. Entrenchment ratios approach a value of 1, and bank heights exceed one foot and can be up to fifteen feet. Overall, the majority of channels are dominated by sandy bed materials and silt/clay banks. Impaired reaches often display a veneer of silt over a bed material of fine to medium sand, which is indicative of stream bank erosion in these reaches.

Additionally, the presence of floodplain wetlands is not evident in degraded reaches. Upland species such as tulip poplar dominate the floodplain, also indicating a system-wide lowering of the shallow groundwater table. This demonstrates that channel incision not only leads to the formation of single-thread channel systems, but a widespread lowering the shallow groundwater table.

5.2.4 FGM Investigation Findings: Degraded Reaches and Factors Influencing Channel Departure and Recovery

There are several main features which are seen as causing channel departure on the site. The main indicator of reduced floodplain function and channel degradation observed on site is channel incision. While portions of incised channel demonstrate the potential for self recovery, as incision increases in depth this potential is not observed. Through analysis of the transitions between reference and degraded reaches, it was observed that woody debris when coupled with channel depths of approximately one foot to 18 inches had strong potential for self recovery through the introduction of woody debris as grade control, and channel depths in excess of 18 inches did not demonstrate significant accretion of sediments behind grade controls and continued to down cut and widen. Incision was measures as the maximum riffle depth from the adjacent floodplain elevation. Within Woodland Branch, incised surveyed reaches varied between 15' and 3.67' of maximum riffle depth, and Johns Creek surveyed reaches varied between 3.88' and 1.17'. Reach SE-4 had a incision range of 6.21' to 1.21'.

Breaks in the riparian canopy and lack of woody debris introduction into the channel appear to be significant factors in channel departure. These breaks in canopy were assessed visually. As the fine silt/sand soils and bed material of the reaches is highly erosive, in situations where the channel is not situated on a hard compacted clay footing, logs and woody debris provide the grade control that prevents channel incision. Similarly observed, after channel incision has occurred, channel recovery or partial recovery is initiated through logs, leaf matter, and roots creating partial blockages and channel roughness. Through natural occurrence or beaver activity, the continual introduction of woody debris into the channel is seen as essential for preserving stability. Similarly, a vigorous riparian buffer is seen as essential to channel restoration. In some reaches, deer that are present in large numbers may be removing riparian vegetation and causing instability.

Previous agricultural disturbance and logging activity may also contribute to the channel degradation onsite. Although many portions of the site have been untouched since the 1960s when the facility was first developed, the effects of agricultural and logging activity can still be observed onsite, including erosion in many old logging roads and general floodplain disturbance including mounds, potholes, and other excavation activity. These influences may explain channel incision and disturbance at some portions of the site. The most prominent example is the headwater on Woodland Branch, which drain the watershed that includes the visitor center, associated parking lot, and a large cleared field that has been planted in a warm-season grass mix. The cleared field has been disturbed for the entire known photographic record, back to 1938. Due to flow concentration and runoff from impervious surfaces and cleared land, this reach quickly degrades into a 10- to 15-foot-deep head cut. This reach also lacks a strong base flow, which may be caused by excessive runoff and lack of infiltration due to the watershed land use. Other similar headwater areas onsite do not exhibit these traits, leading to the conclusion that impervious area and lack of forest cover result in stream channel destabilization. Trenching, straightening, and other factors may have also contributed to channel destabilization.

5.2.5 FGM Investigation Findings: Reference Reaches and Basis of Design

Evaluation of the FGM data has been used to determined that stable, unconfined stream forms onsite consist of low bankfull width, low bankfull depth, high width/depth ratio, low gradient (channel slope and valley slope is approximately 1 percent or less), and sand-silt bedded streams with relatively low sinuosity between 1.2 and 1.5. Valleys may single or multiple thread channels, but regardless of dedritic function, the channels utilize the floodplain frequently and for discharges well below the 1-year, 2-year, and regional curve-estimated bankfull discharges. Channels are well connected to floodplains, with floodplain elevation being such that the flooding and inundation of the floodplain occurs frequently (multiple times per year) and is driven via "typical" storm events as well as snowmelt and rain-on-snow events. The valley bottom serves as the belt width and flood-prone width in most cases. Reaches are characterized by logs and roots providing grade control and forming short, steep run facet features, resulting in scour pools immediately downstream. Without logs or root features concentrating shear stress, pools are relatively shallow, found in backwater areas, or are a result of beaver activity. Leaf matter is abundant in the channel bed in many locations. Channel thalwegs by themselves would classify as Rosgen C5 type, but when accounting for valleys with multiple thalwegs, classify as D5, with potential to evolve increased sinuosity and floodplain connectivity to a E/D5 stream type (E systems in single-thread situations) over a prolonged time period through natural, stable states of erosion, accretion, and vegetation maturation. Not every valley has multiple thalwegs; headwater systems are C5 systems, although the potential exists for them to not be streams at all, but rather, vegetated wetland headwater seeps. A summary of Woodland Branch reference data, which was used as a basis of design, is presented in Table 6.

Table 6. Woodland Branch Reference Data

Woodland Branch Reference Sediment – Riffle (values in millimeters [mm])					
D16	D35	D50	D84	D95	D100
0.06	0.17	0.2	7.42	10.97	16.0
SE-1 Reference Bar Sample – 100% sand, no particles exceeding 2.0 mm					
Bankfull (Average) Channel Slope					1.1%
Thalweg Parameters			Minimum	Average	Maximum
Riffle Slope (Thalweg, Observed)			0.165%	0.783%	1.620%
Run Slope (Thalweg, Observed)			1.499%	4.327%	8.166%
Pool Slope (Thalweg, Observed)			~0.0% (backwater)	0.124%	0.337%
Glide Slope (Thalweg, Observed)			~0.0% (backwater)	0.134%	0.321%
Pool to Pool Spacing (Thalweg, Observed)			18.47 ft	29.82 ft	47.84 ft
Pool Maximum Depth (Relative to Floodplain)			0.85 ft	1.04 ft	1.30 ft
Riffle Maximum Depth (Relative to Floodplain)			0.56 ft	0.63 ft	0.87 ft

Johns Creek watersheds are similar in their reference characteristics, although at a slightly lower slope. These reaches are a flatter valley slope with a more prevalent gravel fraction, although the streams still classify as sand bed. A summary of Johns Creek reference data, which was used as a basis of design, is presented in Table 7.

Table 7. Johns Creek Reference Data

Johns Creek Reference Sediment – Riffle (values in millimeters [mm])					
D16	D35	D50	D84	D95	D100
0.08	0.17	0.23	0.76	0.98	5.70
SE-1 Reference Bar Sample – 92.78% sand, 7.22% gravel, D100 8 mm					
Bankfull (Average) Channel Slope					0.54%
Thalweg Parameters			Minimum	Average	Maximum
Riffle Slope (Thalweg, Observed)			0.135%	0.514%	0.945%
Run Slope (Thalweg, Observed)			2.651%	5.206%	12.129%
Pool Slope (Thalweg, Observed)			~0.0% (backwater)	0.015%	0.055%
Glide Slope (Thalweg, Observed)			0.149%	0.322%	0.496%
Pool to Pool Spacing (Thalweg, Observed)			10.37 ft	20.23 ft	35.53 ft
Pool Maximum Depth (Relative to Floodplain)			1.02 ft	1.53 ft	2.03 ft
Riffle Maximum Depth (Relative to Floodplain)			0.81 ft	0.90 ft	1.02 ft

5.2.6 Design Basis Discussion

The restoration methodology follows a combination of RSC and NCD principles. Some reaches follow a very close RSC methodology and others utilize the methodology only for the basic principles of design for riffle grade controls. The restoration basis of design utilizes reference data on site in the creation of riffle grade control facet slopes, the grading and shaping of thalweg features, and channel thalweg plan form parameters. The basis for design is discussed in full detail in section 6.2, however the portions relating to the reference conditions on site are discussed here.

Although several elements of natural channel design principles are not utilized for the design, reference parameters are utilized in the proposed design to develop parameters for thalweg grading, grade control slope design, and log structure size, slope, and spacing. Additionally, reference data is used in the development of the system-wide stability parameters which will gauge its long term stability through the mitigation monitoring period. Reference data is utilized to determine suitable connectivity and entrenchment ratios. Entrenchment of the system prevents the formation of any meaningful large-scale depositional zones, key to sequestering nutrients and fostering wetland habitat. Additionally, entrenchment creates a large scale lowering of the shallow groundwater table and reduction in the quantity and quality of floodplain wetlands. Arguably, the entire valley bottom of these systems should be the active channel, engaging single or multiple thalwegs and wetlands depending on woody debris present, the magnitude of the rain event and resulting runoff, or beaver activity within the floodplain.

5.2.7 Basis for Restoration Reach Selection

Given these observations of channel departure and its causes, the mitigation plan seeks to reduce channel incision within degraded reaches to acceptable levels of self recovery and channel connectivity with the floodplain, creating a large scale uplift of the shallow groundwater table and re-inundation of the floodplain with common runoff events. The mitigation plan identifies the reaches within the project site which have the best potential for restoration, and reaches in which restoration will arrest the migration of channel incision, protecting existing wetland and stream resources within the site. Additionally, the mitigation plan seeks to provide additional control of stormwater runoff from the proposed Unit 3 site development activities to reduce the potential for secondary impacts to existing wetland and stream resources on site.

Woodland Branch watershed is a proposed restoration reach because of the prevalence of incised stream resources within it. The restoration work here seeks to reverse three centuries of deforestation, agriculture, and site development which has incised its channels, drained its wetlands, and destroyed its benthic habitat. Similarly, the restoration work in Johns Creek seeks to create a continuum of connected floodplain / beaver wetlands from the intersection of MD Route 2/4 up to the discharges near the headwaters from the proposed site development, by removing phragmites, lifting incised portions of the channel, and preventing the migration of channel incision into sedge/rush floodplain wetlands already existing in the valley.

6.0 WORK PLAN

The proposed Draft Final Phase II Mitigation Plan accounts for proposed development and stormwater discharges in order to minimize their potential impacts on the existing aquatic resources. This is accomplished through the utilization of energy dissipation structures, re-connection of the channel with the existing floodplain, and appropriate channel sizing. The addition of infiltration practices and planting of riparian trees and shrubs is intended to increase base flow propagation in the watershed as well as reduce thermal impacts from stormwater discharges. EA has worked closely with the Unit 3 SWM design team in order to effectively design the Phase II Mitigation Plan to account for the changes in discharge locations and flows. The proposed wetland and stream mitigation concepts described below are proposed in accordance with our Goals and Objectives, as stated in Section 2.0.

6.1 NONTIDAL WETLAND MITIGATION

Onsite compensatory mitigation for unavoidable impacts to approximately 11.72 acres of jurisdictional, nontidal forested wetlands, emergent wetlands, and open water ponds is being proposed in order to meet a "no net loss" goal of nontidal wetland mitigation. The Phase II Mitigation for the CCNPP Unit 3 project includes the creation of new forested and emergent wetland areas onsite as well as enhancement of existing wetlands in areas previously described in Section 5.1 of this report. A portion of open water creation is also included in order to replace functions and values lost from the affected areas, as well as create a wetland mosaic within the mitigation area.

6.1.1 Wetland Mitigation Work Descriptions

WC-1: Upper Woodland Branch (WB 0+00 – 3+75 Drawings EX-1, G-1, and P-1)

Forested wetland creation is proposed for the upland areas at the origin of Woodland Branch, located north of the existing visitor's center. The existing head cut and incised stream channels at the head of Woodland Branch are unlikely to maintain stable conditions if proposed for restoration. Rather, EA has evaluated the potential to fill this head cut and replace it with headwater infiltration wetlands to enhance base flow, dissipate energy, promote stability, and allow for transition to the preservation reaches downstream.

The primary strategy for the creation of the headwater wetland is utilizing design techniques similar to regenerative stormwater conveyance (RSC) practices. RSC is an infiltration practice that uses a series of open channel, sand seepage step pools and riffle weirs, through which stormwater flows are conveyed. The purpose of these systems is to reduce the commonly seen erosion in ordinary stormwater conveyances and convert stormwater to shallow groundwater, mitigating nutrient pollution and thermal impacts to the receiving waters, while promoting base flow downstream.

Currently, Woodland Branch receives runoff from the surrounding development which would be utilized as a hydrology source for the created wetland system. Micropools and other microtopography features have been included in the system design to diversify habitat for wetland flora and fauna. This area will be planted with seedlings of native hydrophytic tree and shrub species to create a wetland hardwood forest community. Approximately 1.10 acres of forested wetlands will be created at a 1:2 mitigation credit ratio yielding approximately 0.55 acres of wetland credit. An increase in wetland function is anticipated through the creation of wildlife habitat, increase in groundwater recharge/discharge, and an increase in sediment retention and nutrient removal/uptake. This wetland is part of a larger restoration system described in further detail below as part of the Upper Woodland Branch Reach (WB 0+00 – 18+00).

WC-2: Lake Davies Upper Disposal Basin (Drawings EX-18, EX-19, EX-20, G-18, G-19, G-20, P-18, P-19, and P-20)

WC-2 consists of a wetland creation area proposed within the upper basin of the Lake Davies Disposal Area. Wetland creation will be established through the creation of three separate vegetative zones consisting of an interior open water pond planted with a minimal amount of aquatic species. The open water pond will be surrounded with an emergent fringe wetland that will be planted with herbaceous plant species. The remaining area will consist of a created bottomland hardwood forest with a system of low flow channels created from proposed outfall discharges.

Wetland fill material will be deposited within the sediment basin to create the different zones and provide microtopography features that will be included in the system design to diversify habitat for wetland flora and fauna. Soil material from the affected onsite wetland areas will be used for the WC-2 mitigation site; however, only wetlands that do not contain phragmites will be considered as a source of hydric soil material. A flow control structure will be utilized at the outfall point of the basin in order to manipulate and control hydrology within the wetland creation area. WC-2 will require the removal and control of phragmites prior to grading and planting the wetland creation area.

Through these mitigation activities, approximately 1.61 acres of emergent wetland will be created at a mitigation credit ratio of 1:1 and approximately 7.80 acres of forested wetland at a 1:2 credit ratio, yielding approximately 1.61 and 3.90 acres, respectively, of wetland credit. In addition, this design will include the creation of approximately 0.90 acres of open water habitat.

The creation of open water, emergent marsh, and bottomland hardwood forest will greatly increase wetland habitat diversity within this basin and be an improvement over the existing habitat conditions. Additionally, an increase in wetland function is anticipated through the increase in groundwater recharge/discharge, and an increase in sediment retention and nutrient removal/uptake.

WE-1: Lake Davies Lower Disposal Basin (Drawings EX-20, EX-21, G-20, G-21, P-20, and P-21)

WE-1 consists of a wetland enhancement area proposed within the lower basin of the Lake Davies Disposal Area. Enhancement of this area is proposed through the eradication of phragmites, by mowing and application of chemical herbicide, and the planting of native tree and shrub wetland species. The enhancement proposed in this area consists of approximately 2.57 acres of existing wetlands at a mitigation credit ratio of 1:4. Therefore, approximately 0.64 acres of wetland credit is anticipated for WE-1. It is anticipated that the planting of native woody species within the enhancement area, along with phragmites eradication, will provide an increase in wetland function (habitat improvement) and values (visual quality/aesthetics).

WC-3: Lake Davies Lower Disposal Basin (Drawings EX-20, EX-21, G-20,G-21, P-20, and P-21)

Mitigation Site WC-3 consists of two small topographic low areas adjacent to the lower basin of the Lake Davies Disposal Area (WE-1). Wetland creation will be established through the grading of these two pockets to an elevation equal to WE-1 and provide microtopography features that will diversify habitat for wetland flora and fauna through planting of native hardwood wetland species. WC-3 will also require the removal and control of phragmites prior to grading and planting the wetland creation area.

Through these mitigation activities, approximately 0.44 acres of forested wetland will be created at a mitigation credit ratio of 1:2, yielding approximately 0.22 acres of wetland credit. It is anticipated that the planting of native woody species within this area, along with phragmites eradication, will provide an increase in wetland function (habitat improvement) and values (visual quality/aesthetics).

WE-2: Johns Creek Lower Reach (Drawings EX-15, EX-16, EX-17, EX-21, G-15, G-16, G-17, G-21, P-15, P-16, P-17, and P-21)

Mitigation Site WE-2 includes the existing linear drainageway that conveys flow from the aforementioned lower basin of the Lake Davies Disposal Area (WE-1), down to Johns Creek and the lower portion of the stream valley along Johns Creek. Enhancement of this area is proposed through the eradication of phragmites, by the application of chemical herbicide, and the planting of native tree and shrub wetland species where possible. The enhancement proposed in this area consists of approximately 16.01 acres of existing wetlands at a mitigation credit ratio of 1:4. Therefore, approximately 4.0 acres of wetland credit is anticipated for WE-2. It is anticipated that the planting of native woody species within the enhancement area, along with phragmites eradication, will provide an increase in wetland function (habitat improvement) and values (visual quality/aesthetics).

WC-4: SE-4 (SE-4 0+00 – 10+44 Drawings EX-25, EX-26, G-25, G-26, P-25, and P-26)

Wetland creation and enhancement is proposed along SE-4, which is located downstream of the existing Camp Conoy Pond. The proposed mitigation area exists within a forested area between the developed camp area and the Chesapeake Bay and consists of a series of open water ponds located in-line with the existing stream channel proposed for restoration. This area is proposed to receive increased discharges from the proposed SWM plan. Enhancement of the open water areas and creation of additional forested wetland areas along the existing stream channel is proposed for this reach, in addition to Priority 1 stream restoration within the existing channel.

The primary strategy for the creation and enhancement of the wetland areas is to utilize design techniques similar to RSC practices.

Modifications to the existing earthen berms and placement of water control structures will be utilized to enhance open water areas to encompass emergent wetland features. Microtopography features will be included in the system design to diversify habitat for wetland flora and fauna. This wetland area will be planted with seedlings of native hydrophytic tree and shrub species to create a wetland hardwood forest community as well as emergent plantings in and around the open water ponds. Approximately 2.86 acres of forested wetlands will be created at a 1:2 mitigation credit ratio yielding approximately 1.43 acres of wetland credit, and approximately 1.08 acres of wetlands will be enhanced at a 1:4 mitigation credit ratio yielding approximately 0.27 acres of wetland credit. An increase in wetland function is anticipated through the creation of wildlife habitat, increase in groundwater recharge/discharge, and an increase in sediment retention and nutrient removal/uptake. This wetland mitigation area is part of a larger restoration system and is described in further detail below as part of the SE-4 stream restoration reach (SE-4 0+00 – 10+44). The secondary purpose of these systems is to reduce impacts to the existing aquatic resources from the proposed SWM discharges while promoting base flow back into the existing channel downstream.

The previously described wetland mitigation work plan includes 1.61 acres of emergent and 12.56 acres of forested nontidal wetlands that will be created, as well as 19.62 acres of forested wetland enhancement in order to obtain 13.01 credits for the required wetland mitigation. Table 8 summarize the wetland mitigation work plan.

Table 8. Summary of Wetland Mitigation Work Plan

	Mitigation Area	Type	Acreage	Ratio	Credit
Creation	WC-1	Forest	1.1	1:2	0.55
	WC-2	Forest	7.8	1:2	3.90
	WC-2	Emergent	1.61	1:1	1.61
	WC-2	Open water	0.9	**	**
	WC-3	Forest	0.5	1:2	0.25
	WC-4	Forest	2.86	1:2	1.43
Enhancement	WE-1	Forest	2.53	1:4	0.63
	WE-2	Forest	16.01	1:4	4.00
	WE-3	Emergent	1.08	1:4	0.27
				Total wetland credit =	**12.65**

** Open water creation is proposed to replace lost functions of existing impacts. However, it is understood that no credit for wetland acreage is credited for open water creation areas.

6.1.2 Wetland Mitigation Planting Plan

The proposed wetland creation and enhancement areas will be planted with native hydrophytic vegetation as detailed on the attached Plant List (Appendix C) and as shown on the attached Draft Final Design Plans (P-27) provided in Appendix B. After excavation and the establishment of bottom elevations, the wetland creation areas will be planted. Overall tree and shrub spacing proposed for Forested Wetlands and Upland/Riparian Zones is approx. 8 feet on center (O.C.) (681 per acre) with trees averaging 16 feet O.C. (170 per acre) intermingled with shrubs at 9 feet O.C. (538 per acre). Emergent herbaceous species will be planted 3 feet O.C. (4,800 per acre). Canopy trees, understory trees, evergreens, and native shrubs shall be randomly intermingled (unless otherwise noted for clustering) throughout appropriate Zonation Concentration Areas noted and installed at the overall Spacing Range listed for each layer.

Plant spacing was determined to allow for anticipated mortality from wildlife depredation and defoliation by insects during early seedling establishment. The plant material will be predominantly representative of the species composition of the wetlands within the CCNPP property and native to the region. In addition, the plant material will include species that have been identified as suitable for installation on wetland mitigation projects by the Chesapeake Bay Critical Area Commission. However, final selection of plant stock will be determined to some extent by availability. The selected tree species will consist of containerized and/or bare root stock protected by tree shelters. The tree shelters will provide protection from wildlife depredation, wind, or other damaging influences.

6.1.3 Phragmites Management Plan

Phragmites is a large, coarse, perennial grass that usually forms large, dense stands reducing the diversity of plant and wildlife species. These stands exist in various locations within the CCNPP property. Phragmites identified onsite has been observed to be more than 10 feet in height. Flowering and seed set occur between July and September. Germination occurs in spring on exposed moist soils. Vegetative spread by belowground rhizomes (roots) can result in dense patches with up to 20 stems per square foot. Phragmites is capable of vigorous vegetative reproduction and often forms dense, nearly monospecific stands, as have been observed in the sediment basins of the Lake Davies Disposal Area, Johns Creek, and other forested wetland areas on the CCNPP Unit 3 site.

Phragmites is best controlled by application of herbicide treatment followed by mechanical removal (cutting and/or mowing) along with annual maintenance in order to prevent regrowth while native plants begin to re-colonize. For large, dense areas, prescribed burns can provide additional control after the initial herbicide treatment, but should only be performed by trained individuals.

Chemical Control

Glyphosate and imazapyr have been shown, through research and field tests, to be the most effective for phragmites control as an initial treatment. Both are non-selective, affecting any plant they come in contact with. With proper application, following the manufacturer's instructions, impacts to native plants and animals can be minimized. Treatment in wetland areas requires the use of aquatic formulations. Use of a surfactant is recommended with aquatic treatment in order to increase effectiveness.

Imazapyr should be applied in early to late summer (June – September) or either glyphosate or a glyphosate/imazapyr mixture in late summer (August – September). Application methods vary depending on the size/density of the stand of phragmites and its location in the landscape. For small stands and scattered plants, methods include hand swiping, stem injections, or hand spraying. For large dense stands, the use of commercial equipment and a licensed or certified applicator will be necessary to meet safety requirements and to reduce impacts to native plants. According to the manufacturer's label, certification in pesticide application is required for use of imazapyr and recommended for use of glyphosate.

Mechanical Control

Mowing or cutting of the stand is the next step in phragmites control. It removes dead plant material after the herbicide treatment, encourages native plant growth, and allows for easier identification of phragmites regrowth, which can then be spot treated with herbicide.

Mowing or cutting should not be performed for at least 2 weeks after the herbicide treatment to allow for optimum plant exposure to the herbicide. Mowing or cutting should be done in late summer to fall (August – mid-November), but can be done in winter when the ground is frozen for wet sites. Mowing before treatment with herbicide or at the wrong time of year can actually stimulate growth of phragmites.

Hand cutting can be used for individual stems or small stands, whereas mowing with a brush cutter or flail-type mower is recommended for large, dense stands. Mowing should be done in two directions to adequately chop thatch. The cutting blades should be set to a mowing height greater than 4 inches to minimize impacts to small animals and native plants.

Equipment used to mow and cut phragmites should be cleared of all debris before removal from the site in order to reduce the chance of spreading seed to other sites. Plant material should be collected and bagged to control seed spread and also increase sunlight to the ground for the promotion of germination of native plants.

Long-Term Management

Phragmites will continue to re-establish from the existing seed bank and neighboring populations without annual maintenance. Follow-up spot treatments will most likely be required in order to allow native plants to successfully populate the wetland areas. Phragmites will be controlled and monitored for a length of time as described in Section 8.0, *Post-Construction Monitoring*, and Section 9.0, *Long-Term Management*, of this report.

6.2 STREAM MITIGATION

Stream mitigation work is designed to meet the goals and objectives of this Draft Final Phase II Mitigation Plan in accordance with the guidance provided by the regulatory and resource agencies. In-channel work will be performed in intermittent channels during periods of little or no base flow, and in all cases of flow, in accordance with an approved Erosion and Sediment Control Plan that allows for maintenance of stream flow during construction. Work will be performed by a qualified contractor, experienced in the field of stream and wetland restoration, with the specialized small and/or low ground-pressure equipment necessary to complete the job with minimal site disturbance. Work will be performed with sufficient construction oversight to ensure the specifications of the design are met and in-field changes which may occur are conducted and documented appropriately. Additionally, a strong construction supervision component of the design is proposed to minimize disturbance to existing vegetation, and relocate vegetation which can be practicably saved. The supervisory aspects of the design will include an onsite engineer working in coordination with a biologist/ecologist, providing oversight of the contractor on a day-to-day basis to ensure the design approaches are field-fit according to valley shape, profile, and existing vegetation, and that existing natural resources on site are impacted to the least extent possible.

6.2.1 Design Approach Methodology and Specifics

As discussed in Section 5.2.5, restoration design on the project site utilizes a combination of NCD and RSC principles. Section 5.2.5 discusses the reference data usage for the methodology and presents those design parameters. NCD techniques, as pioneered by Dr. David Rosgen, are utilized to ensure that the riffle grade control techniques of RSC, thalweg grading and low flow water surface facet creation are coordinated with stable reference systems onsite. Additionally, the reference criteria provide a basis for judging the success of the proposed dynamic sand-bedded systems.

Unlike gravel bed streams, the stream reaches which were used for the basis of design at the mitigation site, discussed in Section 5.2.5, do not follow the traditional "bankfull" channel design model of NCD, although some of the design principles are extremely similar. Bankfull-based NCD focuses on the net sediment flux through a reach being equal to zero, meaning that the amount of sediment delivered to the reach is equal to the amount transported away. These designs also focus on achieving a threshold critical shear stress. This is the shear stress value at which bed material of a certain size begins to move. Generally, significant amounts of bed material are not entrained below this value.

Traditional bankfull design also dictates that the vast majority of the sediment transport occurs during the bankfull discharge due to its magnitude and frequency. The bankfull discharge is often referred to as the "channel forming discharge" for this reason. Sand systems such as those found at the mitigation site apply these principles, but for a variety of discharges at which different channel thalwegs throughout the floodplain are engaged, therefore enabling the entire floodplain to become part of the active channel. Each thalweg within a reach has its own zone of shear stress concentration, with its own sediment regime. These systems, in their stable condition, entrain bedload material at nearly every discharge, including the average daily discharge (less than 1 cubic foot per second in the observed cases). This is because the threshold for the movement of sand is negligible compared to the shear stress evolved from discharges created in runoff events. This stable system characterization is supported through observation of the identified reference reaches on Woodland Branch and Johns Creek from 2009 to the present day. The result is a dynamic state in which pools and riffles may change position through aggradation and erosion, but the morphological parameters which characterize the reach as a whole remain consistent. When evaluating the system on a larger level over time, expansive areas of long-term stable sediment transport and deposition can be observed. This is particularly evident in beaver dam complexes where backwater pools form depositional areas for all discharges experienced on the reach, and breaches of dams or the high-gradient areas associated with dam breaches represent reaches with overall erosive tendencies.

Areas of non-zero sediment flux are not accounted for in traditional natural channel design. This is in direct contrast with traditional regulatory driven performance requirements governing gravel bed stream restoration efforts, where the migration of riffles and pools is viewed as a channel alteration and a failure of the restoration approach, a view which may or may not be justified depending on the system and local geology involved.

The restoration approach proposed for this project also uses riffle grade control practices, and RSC techniques proposed in combination throughout the project. RSC has been pioneered by the Anne Arundel County, Maryland, Department of Public Works and various Maryland engineering consultants, and guidance for the design of RSCs has been issued through Anne Arundel County. Riffle grade control sizing criteria and calculations for each drainage area in which riffle grade controls are proposed are presented in Appendix E.

RSC is a groundwater recharge, storage, floodplain reconnection, and infiltration practice that uses a series of open channel, sand seepage step pools and riffle grade controls, through which stormwater flows are conveyed. The silty sand soils on this site are particularly suited to allow lateral infiltration from RSC storage and maximize floodplain contact, storage, and runoff quality and quantity attenuation. The purpose of these systems is to reduce the commonly seen erosion in ordinary stormwater conveyances and convert stormwater to shallow groundwater, mitigating nutrient pollution and thermal impacts to the receiving waters. The riffle grade controls within RSC systems are sized to resist transport of their underlying material in the 100-year storm, accreting sediment over top of them at lower discharges, and flushing at higher discharges without transporting the underlying grade control material. This approach is similar to a Priority 1 stream restoration, which replaces an incised channel with a re-dimensioned channel at a higher elevation and new alignment. Priority 1 restoration techniques are employed in this restoration plan, usually in re-establishing flow to the abandoned floodplain channel thalweg between weirs, so long as that channel meets the pattern and entrenchment criteria appropriate for the reach.

The riffle grade control techniques proposed for this project, however, vary when compared to other installations that utilize these design methodologies. Anne Arundel County, Maryland, Department of Public Works specifications call for equal-sized riffles through the project for a given design discharge. Throughout the proposed project, multiple weir dimensions vary to accommodate different design discharges and natural variance in the floodplain and valley shape and slope. In order to limit disturbance and create a more natural system in appearance, the structures are designed to fit with the existing floodplain shape and grade where practicable. Although this presents an added level of complexity for the contractor and onsite engineer, it allows the installation to incorporate a higher degree of flow diversity into the project. Additionally, it is the intention of this mitigation plan to give the onsite engineer and the contractor the freedom to field-fit riffles and structures to meet existing conditions, so long as these changes meet the design criteria for the 100-year discharge, are documented fully in the as-built survey, are certified by the onsite engineer, and do not result in drastic alterations to the mitigation plan without the approval of the regulating agencies.

Additional deviation from accepted practices being proposed in this project includes allowing the contractor to substitute native topsoil and sod (i.e., sod mats) for mulch on the surfaces of riffle grade controls. As the riffle grade controls have a certain amount of excavation associated with them, this would result in a reuse of natural restoration materials which might otherwise be wasted. Additionally, if a source of riparian sedge/rush and shrub sod can be obtained, be it from site disturbance or from commercial sources, this material could be utilized to stabilize disturbed floodplain surfaces and re-establish floodplain wetland vegetation in areas of disturbance onsite.

RSC principles are employed in two distinct design situations at the mitigation site. Steep gradient reaches (those with floodplain gradients that exceed approximately 1 percent) employ weir/pool complexes with elevation drops as high as 1 foot through the riffles, and well defined deep pools immediately downstream. In low-gradient reaches, riffle grade control structures are installed for every 1 foot of fall, with between 3 and 6 inches of fall through each structure. The lowest upstream point of each riffle grade control structure is set at the approximate floodplain elevation at the structure location. No pools or pools with very minor depths are graded in between riffle structures. Reaches following each structure will be graded with a thalweg channel at negligible slope and with log grade controls making up the elevation difference between weir structures. These thalweg grading areas are designed to the same parameters, which are found in reference reach portions of the site. The log structures have small elevation drops across them, and over time they are intended to decay and be replaced by roots and other natural woody debris acting as grade control. It is anticipated that with new woody debris introduction, degradation of installed log grade controls, and establishment of vegetation, the low flow facet features will be free to move and self adjust between the stone riffle grade controls. The stone riffle grade controls therefore prevent large amounts of channel incision, and maintain any channel degradation within the tolerances for channel self-recovery.

The stone grade control structures are deployed to maintain grade as well as provide backwater areas, thus mimicking the function of natural beaver dam activity. In the coastal plain systems on site, there is no geologically present stone or cobble to act as grade control. Only small amounts of ferracrete are noted on site. The primary geologic and natural materials available for channel composition are silt, sand, clay in very deep formations, vegetation, and woody debris. Therefore, the only natural materials which would provide grade control on the site are woody debris and vegetation (root mat). One of the natural tools of grade control observed in nature in these types of systems is beaver dams, which are formed, breached, and rebuilt in stable complexes. Active beaver meadows and wetlands often display the presence of multiple dams, active and abandoned, inundated and exposed, but all contributing to grade control and widespread areas of deposition and floodplain wetlands.

Although the spacing of the riffle grade control structures is much closer than most observed active beaver dam activity, these stone structures intend to replace the grade control element that multiple beaver dam placements create over time, and replicate the depositional zones associated with them. Although it would be ideal to create these structures with woody material, the abundance of such material and construction techniques to create stable grade controls are not available to the restoration contractor at this time. Woody debris structures, such as beaver dams, also quickly fail without maintenance from beaver. The placement of the proposed woody debris also intends to add brush piles, drift lines, and other woody features at various states of inundation to enhance the habitat for wildlife value, and add organic carbon to the soil for the purposes of building both diverse aerobic and anaerobic wetland soil chemistry and a vibrant ecological community. This woody debris is not intended to be a grade control and is distinct from the log grade control structures discussed above.

Additionally, installation of defined pools and backwater areas behind riffle grade control structures allows a unique opportunity to manage stormwater quantity on the site, and lift groundwater elevations to create low energy areas and floodplain wetland creation. In this way, a large-scale manipulation of the groundwater table is proposed to create incidental connected floodplain wetlands. While no new impervious area is proposed in the Woodland Branch watershed for the CCNPP Unit 3 project, the practices proposed mitigate for existing unmanaged stormwater draining into the watershed from land use changes due to prior clearing and agricultural use and from the current visitor's center parking lot. As these wetlands have a certain dynamic element to them, the wetlands that may be created as a result of the stream mitigation plan are not counted toward the wetland mitigation credit accounting.

To ensure that the stream-wetland system is successful and diverse into the future, with fresh sources of woody debris, the mitigation design does not propose the removal or management of beaver, nor is a timber management plan proposed. In this way, it is intended that the stream system receives a diverse mix of large and small woody debris and leaf litter without the channel destabilizing and becoming entrenched.

Upper Reach Woodland Branch (WB 0+00 – 18+00) and UT Upper Woodland Branch (SE-3 0+00 – 2+19 and UT 0+00 – 2+86 Drawings EX-1, EX-2, G-1, G-2, P-1, and P-2)

This reach has experienced incision and the re-creation of a floodplain within the channel. Given the steep gradient of the reach, RSC approaches with well-defined pools are proposed for the majority of the reach. The existing channel is not well connected to the floodplain; however, the banks exhibit dense vegetation growth, overhead cover, and root mass directly in the channel. The existing thalweg can be kept and reconnected with the floodplain or abandoned and preserved in many areas as oxbow wetlands. Therefore, emphasis has been placed on expanding base flow through the reach and preserving the connection for localized fish movement within the reach and to other reaches.

The primary strategy for the stabilization of SE-3 is the installation of watershed practices, such as headwater wetland creation and extensive headwater wetland creation practices using RSC methodologies. The goal is to raise the water table and promote base flow in Woodland Branch. The contractor will install regenerative fill media in the existing channel for the purposes of filtration and site access, minimizing disturbance to existing vegetation.

Middle Reach Woodland Branch – WB 18+00 – 36+75 (Drawings EX-3, EX-4, EX-5, G-3, G-4, G-5, P-3, P-4 and P-5)

The upper portion of this reach (WB 18+00 – 27+25) is proposed as a restoration and enhancement reach. Portions of the reach, once uplifted through the installation of log structures and riffle grade controls, will only require installation of riparian vegetation in the floodplain for stabilization. More advanced restoration will be required at the upper and lower extremes, where transition must be made to preservation reaches which will prevent the migration of incision through those preserved reaches. Steeper portions of the reach utilize RSC practices with defined pools, while low-gradient portions utilize riffle grade controls coupled with log structures and thalweg grading. Meanwhile the lower portion of this reach (WB 27+75-36+75) has a degree of entrenchment which allows for natural self-recovery; therefore, no grading is proposed. The only exception would be minimal stabilization or enhancement required in the floodplain as determined during construction oversight, since there will be contractor access available through this reach.

Lower Reach Woodland Branch (WB 36+75 – 57+50 Drawings EX-6, EX-7, G-6, G-7, P-6, and P-7)

Given the abundance of abandoned channel features in the floodplain, Priority 1 restoration of the reach includes re-use of these floodplain channels through uplift of the channel using riffle grade controls. Existing channels are proposed to be incorporated into thalweg grading areas between weirs at their existing elevations, with minimal disturbance wherever possible. Use of these channels will require that log grade controls be installed; however, grading and pattern adjustment is minimal, and this alternative is seen as a low-impact restoration alternative. Existing channels would be filled or turned into oxbow wetlands.

This method of restoration is expected to significantly raise groundwater elevations throughout the reach and provide a degree of wetland creation and enhancement within the active floodplain.

UT Lower Woodland Branch – SE-1 0+00 – 14+14 (Drawings EX-7, EX-8, EX-9, G-7, G-8, G-9, P-7, P-8, and P-9)

The upper portion of this reach (SE-1 0+00-2+25) proposes a pre-formed scour pool and alternating logs sills and log/root structures to be utilized to provide energy dissipation and channel uplift in this reach, correcting the conditions created by the existing culvert. The floodplain has trees and canopy cover and requires only minor planting improvements. No significant floodplain grading is anticipated; however, channel fill will accompany uplift activities.

The lower portion of this reach (SE-1 2+25 – 14+14) will require channel grade control and uplift. There is potential to utilize existing abandoned floodplain channels to provide this uplift as new thalweg is coupled with riffle grade controls. Presently abandoned channels have the similar dimensions and patterns as nearby stable reference reaches. This would lead to creation of oxbow wetlands and infiltration areas in existing entrenched locations, and an uplift of the water table creating floodplain wetlands. Minor floodplain grading is proposed in this reach as associated with channel relocation and the installation of stream restoration structures. Replacement and augmentation of riparian vegetation is proposed for this reach.

Stream Preservation Reach SR-3 (Not depicted on site construction drawings)

SR-3, because of its superior eel habitat, is targeted for preservation to allow existing habitat elements to continue to exist as they are. It also has unique bed features which cannot be replicated through construction activities, creating unique habitat within the site. The permittee proposes to preserve 930 linear feet of stream channel through the use of a Declaration of Restrictions.

SE-4 (SE-4 0+00-10+44 Drawings EX-25, EX-26, G-25, G-26, P-25, and P-26)

Restoration goals for this reach include work to improve the utilization of SE-4 by American eels, reconnect the channel with its floodplain, create and enhance wetlands, and promote base flow conditions by raising the shallow groundwater table within the reach.

The SE-4 restoration design applies RSC methodology with natural channel design principles of riffle/pool grade controls and headwater wetland creation to dissipate flow energy, lift the existing channel to connect with the existing floodplain, and filter stormwater runoff through a sand and woodchip channel-fill media. Additionally, recognizing the nature of this coastal plain system, restoration techniques will utilize woody grade controls to capture sandy bed load, and strive to mimic the natural series of grade controls and impoundments found in beaver dam systems, as found nearby onsite and throughout the region.

This proposed design utilizes the existing ponds as stilling basins to reduce flow velocity, with grading and planting proposed to reduce open water habitat in favor of creating emergent wetland habitat which, through natural succession, will shift towards forested wetland habitat.

Below the lowest pond, a series of stone step pools is proposed to provide American eel passage, grade stability, and connection to the Chesapeake Bay. The step pools are designed to prevent vertical channel incision and maintain channel profile stability. Additionally, energy dissipation is provided through the pools, limiting peak velocity of the flows and allowing refuge for American eels that may use this tributary.

The banks above the proposed step pools are currently vegetated with phragmites. Proposed grading on the banks above these step pools would eliminate the invasive reed, and when graded would allow natural erosion from slope sloughing and corresponding sediment deposition at the cliff base (colluvial processes). This would mimic the slope of the existing eroding silt/sand cliff faces rather than the existing conditions that occur through erosion of the channel bed from stream flow. After restoration of SE-4, erosion of the sand cliff faces would be driven by natural processes such as wind, rain splash, freeze/thaw cycling, and natural slope instability, rather than through stream scour mechanisms.

While the Phase I plan proposed vegetative stabilization of the outfall of SE-4, the Draft Final Phase II plan does not include vegetative stabilization. The proposed design should result in enhancing the supply of sediment and, thus, potentially increasing available tiger beetle larval habitat in this area. Existing invasive and stabilizing plant species are proposed to be removed (through physical removal and limited chemical treatment) from the cliff vicinity and graded slopes. The graded and adjacent portions of the slope are designed to allow colluvial erosion and are not to be re-vegetated. In this way the design seeks to maintain a stable and natural erosion of sandy soils to mimic the specialized habitat critical to the life cycle of Puritan tiger beetles.

The step pool system would outfall to a small basin graded landward of the mean high water (MHW) line but graded to below the MHW elevation. The maximum width of the LOD in this area is less than 30 feet. This basin is designed to collect and flush sediment in accordance with existing near-shore sediment transport and wave action processes, and provide log habitat for American eel and other aquatic species.

Stream Restoration Reach SR-4 (Drawings EX-12, EX-13, G-12, G-13, P-12 and P-13, Construction Baseline Station JC 11+50 to JC 25+00)

The goals of SR-4 are to uplift the channel, replicating the floodplain wetlands observed upstream of the reach and also below the reach in the beaver dam influenced areas. A primary goal of the restoration is to arrest the incision occurring in this reach before it drains the reference reach and connected floodplain wetland areas upstream. Additionally, treatment using RSC practices at proposed stormwater outfalls to this reach and within the reach, as well as energy dissipation structures, are proposed to preserve stability within SR-4 and within the reference reach upstream.

Restoration practices throughout the reach include riffle grade control structures, log and root structures, Priority 1 restoration by introducing the channel into the abandoned floodplain, and planting of riparian and wetland species throughout the reach. As phragmites is observed adjacent to this reach, the Johns Creek restoration areas will require ongoing maintenance to control invasive species.

Stream Restoration Reach SR/SE-5 ,(Drawings EX-22, EX-23, EX-24, G-22, G-23, G-24, P-22, P-23, and P-24, Construction Baseline Station SE/SR-5 0+00 TO SE/SR-5 17+50)

Restoration practice throughout the reach includes riffle grade control / RSC systems, log and root structures, and planting of riparian and wetland species throughout the reach. RSC treatment in the upper portions of the reach are proposed to provide surface water infiltration and to support base flow within the reach.

The above stream mitigation work plan includes 10,236 linear feet of restoration and 930 linear of feet of stream preservation be performed on the existing stream channels (Table 9).

Table 9. Detailed Stream Mitigation by Reach

	Mitigation Area	L.F.
Restoration	Woodland Branch	4354
	SE-1	1376
	SE-4	1036
	Johns Creek	1525
	SR/SE-5	1649
	SE-3	296
	Total Restoration =	**10236**
Preservation	SR-3	930
	Total Preservation =	**930**
Total Stream Mitigation =		**11166**

The remainder of the stream restoration areas including the adjacent riparian areas will be re-vegetated using native seed mixtures as well as a mixture of plants identified in the attached Plant List for the wetland areas. Permanent seeding will be applied at a rate of approximately 15 pounds per acre and plants will be added as needed. Live stakes will also be placed along the disturbed stream banks, and the spacing and type of individual plantings will be determined based on the scale of disturbance, and the time of planting for successful establishment of the stage of development.

7.0 SITE PROTECTION INSTRUMENT

The Phase II Mitigation Plan includes the creation and enhancement of nontidal wetlands, as well as the restoration, enhancement, and preservation of nontidal stream channels. The compensatory mitigation is proposed to be onsite and shall be protected in perpetuity. Therefore, the mitigation areas will be protected in the future to prohibit activities including construction, grading, filling, excavating, ditching, draining, as well as the removal, cutting, mowing, burning, or harming of vegetation unless otherwise approved by USACE.

The permittee proposes to use a Declaration of Restrictive Covenants in order to ensure the protection of the streams and wetlands included in the Phase II Mitigation Plan. The protection document will allow for measures and accommodations required by the Nuclear Regulatory Commission (NRC) including but not limited to:

- The removal of dead and/or diseased trees,
- Management of wildlife, and
- Accommodation of possible future utility crossings.

Upon approval of the Final Phase II Mitigation Plan, the permittee will draft the appropriate protection document for approval by USACE prior to finalizing the document. Permits will generally require that the approved preservation mechanism be properly executed and recorded within 30 days of permit issuance unless the District exercises flexibility where it appears there is no immediate threat to the property; the terms of the preservation mechanism have been agreed to by necessary parties, and legitimate reasons for a limited extension of time exist.

In accordance with Code of Maryland Regulations (COMAR) 26.23.0403, the protection document utilized for the mitigation areas for the proposed project will also include language granting the recipient agency, or any successor agency, access to the mitigation sites for inspections during the monitoring period and for construction of the mitigation project. The protection documents will also include appropriate language to allow monitoring activities, as well as any remediation activities that may be required by the regulatory agencies. If the permittee or person conducting the proposed activity forfeits a bond and the recipient agency decides to complete construction of the mitigation project and shall also include language that the restriction is perpetual, binding on the grantor's personal representatives, heirs, successors, and assigns and runs with the land.

8.0 POST-CONSTRUCTION MONITORING AND PERFORMANCE STANDARDS

8.1 NONTIDAL WETLAND MONITORING

The permittee recognizes the concerns expressed by agencies that while the impacts proposed by the site development are permanent, the success of the mitigation areas in terms of their ecological functions and values is by no means certain in perpetuity.

Therefore, a comprehensive monitoring plan is proposed to monitor the implementation of this mitigation plan. After the onsite wetland creation and enhancement activities are complete, as-built design plans will be submitted to MDE and USACE within 120 days of completion and a monitoring program will be implemented for the project. The permittee is proposing a 5-year monitoring program in accordance with the *Maryland Compensatory Mitigation Guidance* (IMTF 1994), and the guidance provided in RGL No. 08-03 (USACE, October 2008). The mitigation monitoring effort will follow the MDE monitoring protocol for mitigation projects greater than ½ acre and include the collection of specific data for reporting, including the following:

- The growth and vitality of the planted hydrophytic species;
- Current site conditions at fixed photographic points;
- The species composition of recruited, desirable plant species;
- The species composition and areal cover of nuisance/non-native plant species;
- Wildlife utilization and depredation; and
- Measurements of surface inundation or groundwater.

The monitoring procedure will include a baseline monitoring event (Year 0), conducted immediately following the completion of the mitigation site construction activities and included in the submittal of the as-built design plans. Following the completion of the baseline monitoring event, a 5-year monitoring schedule will be conducted. Year 1 of the monitoring effort will be conducted during the fall of the same year of completion of the mitigation planting, unless the plantings are completed after July 1st. If the wetland mitigation areas are not completed prior to July 1st, the first year monitoring event will be performed the following year. Each monitoring event will be followed by an annual monitoring report which will be submitted before December 31st of each monitoring year.

Annual monitoring and sampling events will be performed in accordance with guidelines from the *Maryland Compensatory Mitigation Guidance* (IMTF 1994) between May and September of each year in order to appropriately measure vegetation. The success criteria for the monitoring program will include, at a minimum, the success of the planted vegetation, as measured through survivorship counts and observations of vitality and growth, and the existence of wetland hydrology for the created wetlands. Vegetation density measurement techniques outlined in the MDE guidance document will be utilized for both emergent and forested wetland mitigation areas and conducted during years 2, 3, and 5.

If success criteria have been satisfied at the completion of the 5-year monitoring program, a request for release from monitoring will be made to USACE and MDE.

If at any time the compensatory mitigation project cannot be maintained in accordance with the approved mitigation plan, it is the responsibility of the permittee to notify USACE and MDE.

8.2 STREAM CHANNEL MONITORING

Monitoring of the stream channels proposed within the mitigation plan will be performed in an effort to compare post-construction conditions and pre-construction baseline data, for the purposes of assessing the success of the mitigation project in relation to the mitigation plan goals and determine the degree of success the mitigation project has achieved in meeting the objectives of providing proper channel function and increased habitat quality. Success criteria will be gathered annually to document the success of the proposed mitigation plan to achieve its goals of no net loss of stream function. Mitigation reaches will be monitored annually for the duration of the monitoring period, which is proposed for 5 years. Monitoring reports will be submitted in accordance with the wetland mitigation monitoring requirements.

At the time of the as-built survey of the mitigation reaches, the project owner will survey and install monumented cross sections on the mitigation reaches as directed by the Contract Drawings and the Engineer. At a minimum, one cross section shall be installed per 300 linear feet of stream channel. Cross sections will capture the channel features at a maximum of 0.2-foot resolution and floodplain features at a minimum of 1-foot resolution. Cross sections should capture the thalweg and entire valley cross section. Thalweg facet features will be noted in the data collection. Monitoring reports will overlay these cross sections annually on a figure and annually calculate values of channel entrenchment, and note additional thalweg and wetland development, deposition or scour, and any associated notes or observations obtained through monitoring data collection. Cross sections will be collected for both restoration and portions of selected preservation reaches. Deposition and scour will be noted and expressed in terms to changes within the reach, with individual areas of deposition and scour not necessarily noted as failures so long as the reach maintains its new base level and floodplain connectivity.

Longitudinal profiles will be surveyed by the owner detailing the channel bed, water surface (if present), and floodplain elevation found on the restoration reaches. These survey areas will continue upstream and downstream of the reach for a minimum of 50 channel feet or until the limits of the restoration reach.

Wolman riffle pebble counts, point bar samples, and measurements of the largest and second largest particles found on the point bar surface will be collected annually from the restoration reaches. A minimum of one bar sample and one riffle pebble count will be obtained from each reach per year, and must be collected in the same approximate locations each monitoring year.

Furthermore, stone structures and treatments as identified on the as-built survey shall be monitored with photographs and evaluated for effectiveness annually. Monitors will note any noticeable failures or transport of structure material in the proximity of the structures. Installed riparian trees and shrubs will also be monitored for survival (85 percent survival of planted species required after 5 years). Wood structures and woody debris will not be monitored.

Annual monitoring reports will be prepared in accordance with the *Mitigation and Monitoring Guidelines* (USACE 2004), the protocols presented in the *Maryland Compensatory Mitigation Guidance* (IMTF 1994), and the guidance provided in RGL No. 08-03 (USACE, October 2008). The monitoring program will be conducted pursuant to the MDE mitigation monitoring guidelines and protocols, and monitoring reports will contain a discussion of any deviations from as-built and an evaluation of the significance of these deviations and whether they are indicative of a stabilizing or destabilizing situation. At a minimum each annual monitoring report will include the following:

- Identification of parties responsible for monitoring;
- Location of monitoring stations depicted on an 11-inch by 17-inch map;
- Description of methods used for data collection;
- Photo documentation;
- Discussion of observed ecological function and floodplain connectivity with the channel;
- Pebble count data to determine size of bed material, and changes in composition; and
- Documentation of any change from the as-built drawings and proposed remedies, if required.

8.3 PERFORMANCE STANDARDS

Compensatory mitigation plans are required to provide written performance standards for assessing whether mitigation is achieving planned goals. The performance standards will become part of individual permits as special conditions and be used for performance monitoring. Project performance evaluations will be performed by USACE, as specified in the permits or special conditions, based upon monitoring reports. Adaptive management activities may be required to adjust to unforeseen or changing circumstances, and responsible parties may be required to adjust mitigation projects or rectify deficiencies. The project performance evaluations will be used to determine whether the environmental benefits or "credit(s)" for the entire project equal or exceed the environmental impact(s) or "debit(s)" of authorized activities. Performance standards for compensatory mitigation sites will be based on quantitative or qualitative characteristics that can be practicably measured. The performance standards will be indicators that demonstrate that the mitigation is developing or has developed into the desired habitat.

The success criteria for the CCNPP Unit 3 wetland creation/enhancement sites will include:

- 85 percent wetland vegetation coverage of the mitigation site (planted and naturally regenerated/recruited stems);

- The appearance of positive growth indicators for planted species, such as height and/or ground level diameter;

- A value of no more than 10 percent areal cover of phragmites and other invasive species within the treated wetland mitigation sites; and

- The establishment of appropriate inundation conditions or saturated soil conditions during the growing season and under normal yearly climatological conditions for the wetland creation mitigation sites.

  - Emergent – saturated soil to the surface or presence of water on the surface for at least 21 consecutive days of the growing season.

  - Forested – saturated soil to the surface and evidence of groundwater table within 10 inches of the surface long enough to develop hydric characteristics.

The performance standards established for the stream systems are more complicated than the typical gravel bed stream restoration, where channel facets are relatively fixed in position. As described in the previous design narrative, the sand bed systems proposed for Woodland Branch and Johns Creek are dynamic and changing, with the goal of connecting the channel thalweg to the floodplain. Therefore, channel function can be measured through a few key elements:

- Channel Thalweg Entrenchment: Between the installed riffle weirs, channel thalweg depth should not exceed 1 foot, except in localized pool facets. This is equal to the maximum proposed amount of valley fall between riffle grade control structures. This is also within range for natural logs and woody debris to act as grade controls, lifting the base level of channels back to a state of floodplain connection.

- Thalweg dimension, other than depth and the required cross sections, shall not be monitored, as it must be allowed dynamically to adjust to debris, vegetation, sediment flux, and debris.

- Riffle Grade Control Integrity: Stone riffle grade controls, riffle weirs, and installed stone structures should be monitored for movement and transport of the structure material. Riffle grade controls shall preserve their throat inverts and not significantly down cut or move their D50 material. Deposition within riffle grade controls is acceptable, as is scour of the surface mulch or topsoil over the cobble structure. Riffle grade controls shall not be circumvented by the formation of a new thalweg, bypassing their function.

- Log thalweg grade control structures shall not be monitored, as it is anticipated that they will decompose, be buried, cut-around, or otherwise degrade as part of natural channel evolution. It is also anticipated that they will be replaced by roots, new logs, and other natural debris acting in a similar capacity. Similarly, log debris placed in pools or the floodplain shall not be monitored as performance criteria as they are intended to decompose over time.

- Thalweg absolute position shall not be monitored, although channel thalweg survey coupled with corresponding water surface and floodplain elevations shall be monitored. Besides being impractical over such an extent of restoration, the system is intended to shift and change thalweg position, engaging thalwegs at multiple different discharges, abandoning and reforming thalweg features, and adjusting facet position between the confines of riffle grade controls. Profile survey is proposed as a means of gauging absolute entrenchment. Similarly, the presence of a channel thalweg will not be required as success criteria, since the valley bottom shall be allowed to evolve into a wetland or a braided stream system while still preserving floodplain function.

- Channel and floodplain vegetation should be monitored for the success of plantings and modified according to the adaptive management plan to adjust species composition and placement.

- Beaver Activity: Beaver activity within the mitigation reach shall not be considered a failure or detriment. Backwatering through beaver impoundments does not merit a structure failure or loss of floodplain function. Vegetation shall be monitored for effects of beaver activity, with adequate action being taken through the adaptive management plan to meet the reforestation goals of the site.

- Reach photos shall be collected at the approximately same photo position and perspective annually, during the same season.

9.0 LONG-TERM MANAGEMENT RESPONSIBILITIES

Long-term management and maintenance of the wetland mitigation sites will be assured through the placement of a Declaration of Restrictive Covenants on the mitigation area. If the mitigation area should ever be sold, all appropriate protective mechanisms (which will have been recorded) will remain in effect and will remain with the site into perpetuity. The permittee proposes that a Performance Bond be provided for the mitigation effort (COMAR 26.24.05.02).

Appropriate measures to address deficiencies identified during monitoring will be developed by USACE in consultation with MDE and the permittee. These appropriate measures will be part of the adaptive management plan discussed in Section 10, will ensure that the modification of the mitigation project provides ecological resource functions comparable to the project objectives.

10.0 ADAPTIVE MANAGEMENT PLAN

Due to the extensive breadth of mitigation proposed and complex ecological and geomorphological functions attempting to be replicated, as well as the uniqueness of the site and variability of weather, the permittee recognizes that the mitigation may require more advanced management and modification in order to be viable. Therefore, the permittee proposes an adaptive management and monitoring plan for use at this site.

In accordance with Final Mitigation Rule 332.7(c)(4), the performance standards outlined in Section 8.3 of this report can be revised through the adaptive management procedure to take into account appropriate measures implemented to address deficiencies. The performance standards may also be modified to reflect changes in management strategies and objectives so long as the modifications lead to ecological benefits comparable to or superior to the approved compensatory mitigation project. For example, the tree protection used onsite may not prevent deer grazing on the new plants, preventing the vegetation from establishing. The adaptive management to replace the plants using a new method to reduce grazing may be utilized. Adaptive management procedure can be implemented under any circumstances in which the function of the impacted wetlands and streams are not being performed by the mitigation project and secondary impacts are not being prevented.

Adaptive management would be managed and implemented by USACE. In the event that monitoring or other information identifies a deficiency in the compensatory mitigation project, at any time during or following construction of the project, USACE is to be notified within a month of the discovery of the deficiency. USACE is to be notified through a letter and formal report documenting the deficiencies to be addressed. USACE then has 4 weeks to assess the deficiencies and determine whether the ecological functions of the project are comparable to the approved performance standards.

If it is found that the deficiencies have significantly impaired the progress of the compensatory mitigation project, then the participating parties will consult to produce appropriate measures in coordination with the permittee. USACE and MDE have final approval over the measure implemented to address the mitigation project deficiencies. The proposal of appropriate measures should take place within 8 weeks following the USACE decision that the deficiencies need to be addressed and the final course of action decided on within 4 weeks following the presentation of appropriate measures. During the 4 weeks following the presentation of appropriate measures, the consulting stake-holders will participate in a review and revision process until the plans are approved by USACE and MDE. Corrective action will be taken as soon as possible following the adaptive management decision, within the constraints of growing seasons, closure periods, the special conditions of the permit, and weather conditions.

11.0 FINANCIAL ASSURANCE

If success criteria are not met within the proposed mitigation area by the 5th (or otherwise determined final) year of the monitoring program, some additional replanting, re-grading, or hydrologic modification may be necessary at the mitigation site and mitigation monitoring may be extended. USACE may require financial assurances on a permit-by-permit basis to ensure the initiation and successful completion of required compensatory mitigation. If required by USACE as a special condition of the permit, sufficient funding for this potential activity will be provided in the form of a Performance Bond or Letter of Credit to be posted before construction authorized by the permit commences. The amount of the Performance Bond or Letter of Credit will be determined and justified based on the required land management strategies and activities required to achieve ecological success. If the mitigation area(s) are not successful (i.e., do not provide adequate compensatory mitigation for authorized impacts and causing a net loss in wetland function), some form of contingency would need to be in place to assure that remedial activities can be funded to bring the site into compliance. Financial guarantees provide assurances to the permitting agencies that monies will be available to perform remedial activities should they be required. The financial assurances for the proposed mitigation plan will be established in accordance with the USACE RGL No. 05-1 (14 February 2005) Guidance on the Use of Financial Assurances and may be provided in the form of a Performance Bond or Letter of Credit.

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Appendix A

12 Critical Elements Summary

12 CRITICAL ELEMENTS SUMMARY

1. Objectives

The primary objective of the plan is to replace functions and values of nontidal wetlands and stream channels lost due to proposed development. The creation and enhancement of nontidal wetlands are being proposed to promote base flow in the existing channels, enhance water quality, improve wildlife habitat, and increase groundwater recharge functions. The stream mitigation credits will be achieved through restoration, enhancement, and preservation techniques with the goal of protecting and improving aquatic resource functions and returning natural/historic functions to former or degraded aquatic resources.

The proposed Draft Final Phase II Mitigation Plan has been designed to account for proposed development and stormwater discharges in order to minimize their potential impacts on the existing aquatic resources. This is accomplished through the utilization of energy dissipation structures, re-connection of the channel with the existing floodplain, and appropriate channel sizing. The addition of infiltration practices and planting of riparian trees and shrubs is intended to increase base flow propagation in the watershed as well as reduce the potential for thermal impacts from stormwater discharges.

The Draft Final Phase II Mitigation Plan includes preservation of stream reaches identified as having known eel populations or potential eel habitat, and enhancements in other reaches to create suitable eel habitat.

2. Site Selection Criteria

The Phase I Mitigation Plan was underway prior to issuance of the Final Compensatory Mitigation Rule issued by the U.S. Army Corps of Engineers (USACE) and U.S. Environmental Protection Agency (EPA), and it was determined that there were no approved, State of Maryland, wetland/stream mitigation banks within the service area. Therefore the mitigation strategy chosen for the Calvert Cliffs Nuclear Power Plant (CCNPP) Unit 3 project is onsite, in-kind mitigation. The areas proposed for mitigation were selected during the development of the Phase I Mitigation Plan and further studied prior to the development of the Draft Final Phase II Mitigation Plan. EA conducted field reviews from August 2009 through October 2009 in order to: (1) complete the delineation of remaining streams and wetlands within the project area, (2) perform a detailed Fluvial Geomorphology Investigation of the proposed stream mitigation sites, (3) perform a detailed assessment of the proposed wetland mitigation areas, and (4) conduct a Baseline Conditions Assessment of the existing streams. Mitigation sites were finalized based on the results of these studies.

3. Site Protection Instruments

The permittee proposes to use a Declaration of Restrictive Covenants in order to ensure the protection of the streams and wetlands included in the Phase II Mitigation Plan. Mitigation areas will be protected in the future to prohibit activities including construction, grading, filling, excavating, ditching, draining, as well as the removal, cutting, mowing, burning, or harming of vegetation unless otherwise approved by USACE.

The protection document will allow for measures and accommodations required by the Nuclear Regulatory Commission (NRC), including, but not limited to:

- The removal of dead and/or diseased trees,
- Management of wildlife, and
- Accommodation of possible future utility crossings.

4. Baseline Information (for impact and compensation sites)

Existing

The wetland areas to be impacted by the construction of Unit 3 include forested and emergent nontidal wetlands as well as open water ponds.

Wetland Type	Area of Impact	Impact Type
Forested Wetland	7.88 acres	Permanent Grading/Fill
Emergent Wetland	1.21 acres	Permanent Grading/Fill
Open Water	2.63 acres	Permanent Grading/Fill
Total Area of Permanent Impacts = 11.72 acres		

Common functions of the impacted wetlands were previously determined to be groundwater recharge, groundwater discharge, flood flow alteration, sediment/shoreline stabilization, sediment/toxicant retention, nutrient removal/transformation, production export, aquatic diversity/abundance, and wildlife habitat diversity/abundance. A majority of the wetland systems proposed for impacts appear to be degraded and exhibited moderate functions and values.

In addition, 8,350 linear feet of streams are proposed for impact onsite. Most of the stream reaches proposed for impact received scores of suboptimal, as based on the Rapid Bioassessment Protocols (RBP, U.S. EPA 1999).

Proposed

Detailed descriptions of the baseline conditions of the proposed mitigation areas are provided in Section 6.0 of the Draft Final Phase II Mitigation Report and in the summary document.

5. Credit Determination Methodology

To meet a "no net loss" goal of nontidal wetland mitigation, the 11.72 acres of nontidal wetland impacts caused by the construction of the proposed project must be mitigated by creating, restoring, or enhancing an equal area of nontidal wetlands. Based on comments received by MDE on 2 December 2009, it has been determined that this technique will yield mitigation credits as detailed below:

Mitigation Type	Mitigation Amount (acres)	Mitigation Ratio	Mitigation Credit (acres)
Forested Creation	12.26	1:2	6.13
Emergent Creation	1.61	1:1	1.61
Wetland Enhancement	19.62	1:4	4.91
Total Impact Amount = 11.72 acres		**Total Credit Amount = 12.65 acres**	

Stream mitigation proposed is based on a mitigation ratio of 1:1 for linear feet of stream impacts. Therefore, the Phase II Mitigation Plan includes greater than the required 8,350 linear feet of stream mitigation credits through restoration and preservation techniques.

Mitigation Type	Mitigation Amount (linear feet)	Mitigation Ratio	Mitigation Credit (linear feet)
Stream Restoration	10,236	1:1	10,236
Stream Preservation	930	1:2	465
Total Impact Amount = 8,350 l.f.		**Total Credit Amount = 10,701 l.f.**	

6. Mitigation Work Plan

Section 7.0 of the Draft Final Phase II Mitigation Report and the associated Design Plans contains a detailed description of the Work Plan proposed for the mitigation project.

7. Maintenance Plan

Maintenance within all mitigated areas will include the removal of invasive species. If the amount of areal cover of invasive species exceeds 10 percent areal cover, invasive species will be removed.

Based on the annual monitoring program to measure the progress of the mitigation sites, new maintenance procedures can be implemented through an adaptive management plan. This may include additional planting in any of the mitigation sites.

8. Ecological Performance Standards

The success criteria for the CCNPP Unit 3 wetland creation/enhancement sites will include:

- 85 percent wetland vegetation coverage of the mitigation site
- The appearance of positive growth indicators for planted species and/or recruited, desirable plant species that make-up the 85 percent coverage

- A value of no more than 10 percent areal cover of phragmites and other invasive species
- The establishment of appropriate inundation conditions or saturated soil conditions

The performance standards established for the stream systems are more complicated than typical gravel bed stream restoration efforts, where channel facets are relatively fixed in position. Refer to Section 8.3 of the Draft Final Phase II Mitigation Plan Report for a detailed description of these performance standards.

9. Monitoring Requirements

The permittee is proposing a 5-year monitoring program in accordance with the *Maryland Compensatory Mitigation Guidance* (IMTF, 1994), and the guidance provided in RGL No. 08-03 (USACE, October 2008). The wetland mitigation monitoring efforts will follow the MDE monitoring protocol for mitigation projects greater than one-half acre and will include the collection of specific data for reporting, including the following:

- The growth and vitality of the planted hydrophytic species;
- Current site conditions at fixed photographic points;
- The species composition of recruited, desirable plant species;
- The species composition and areal cover of nuisance/non-native plant species;
- Wildlife utilization and depredation; and
- Measurements of surface inundation or groundwater.

The monitoring procedure will include a baseline monitoring event and subsequent annual monitoring followed by an annual monitoring report which will be submitted before December 31st of each monitoring year.

Monitoring of the stream channels proposed within the mitigation plan will be performed in an effort to compare post-construction conditions and pre-construction baseline data. Data will be used for the purposes of assessing the success of the mitigation project in relation to the mitigation plan goals, in order to determine the degree of success the mitigation project has achieved in meeting the objectives of providing proper channel function and increased habitat quality. Success criteria will be gathered annually to document the success of the proposed mitigation plan to achieve its goals of no net loss of stream function. Mitigation reaches will be monitored annually for the duration of the monitoring period which is proposed for 5 years. Monitoring reports will be submitted in accordance with the wetland mitigation monitoring requirements.

If success criteria have been satisfied at the completion of the 5-year monitoring program, a request for release from monitoring will be made to USACE and/or MDE.

10. Long-Term Management Plan

Long-term management and maintenance of the wetland mitigation sites will be assured through the placement of a Declaration of Restrictive Covenants on the mitigation area.

Appropriate measures to address deficiencies identified during monitoring will be developed by USACE in consultation with MDE and the permittee. These appropriate measures will ensure that the modification of the mitigation project provides ecological resource functions comparable to the project objectives.

11. Adaptive Management Plan

The permittee, in order to meet the potential need for changing mitigation strategies or meeting with unexpected site conditions, has developed an adaptive management plan to ensure that mitigation goals are met for the site. Adaptive management would be supervised by USACE. In the event that monitoring or other information identifies a deficiency in the compensatory mitigation project, at any time during or following construction of the project, USACE is to be notified by the permittee within a month of the discovery of the deficiency. USACE is to be notified through a letter and formal report documenting the deficiencies to be addressed. USACE will then assess the deficiencies and determine whether the ecological functions of the project are comparable to the approved performance standards.

If it is found that the deficiencies have significantly impaired the progress of the compensatory mitigation project, then the participating parties will consult to produce appropriate measures in coordination with the permittee. USACE and MDE have final approval over the measure implemented to address the mitigation project deficiencies. The proposal of appropriate measures should take place within 8 weeks following the USACE decision that the deficiencies need to be addressed and the final course of action decided on within 4 weeks following the presentation of appropriate measures. During the 4 weeks following the presentation of appropriate measures, the consulting stake-holders will participate in a review and revision process until the plans are approved by USACE and MDE. Corrective action will be taken as soon as possible following the adaptive management decision, within the constraints of growing seasons, closure periods, the special conditions of the permit, and weather conditions.

12. Financial Assurances

USACE may require financial assurances on a permit-by-permit basis to ensure the initiation and successful completion of required compensatory mitigation. If required by USACE as a special condition of the permit, sufficient funding for this potential activity will be provided in the form of a Performance Bond or Letter of Credit to be posted before construction authorized by the permit commences. The amount of the Performance Bond or Letter of Credit will be determined and justified based on the required land management strategies and activities required to achieve ecological success. If the mitigation area(s) are not successful (i.e., do not provide adequate compensatory mitigation for authorized impacts, thus causing a net loss in wetland or stream function), some form of contingency would need to be in place to assure that remedial activities can be funded to bring the site into compliance. The financial assurances for the proposed mitigation plan will be established in accordance with the USACE RGL No. 05-1 (14 February 2005) Guidance on the Use of Financial Assurances and may be provided in the form of a Performance Bond or Letter of Credit.

Appendix B

Draft Final Design Plans

Appendix C

Existing Conditions Hydrology Analysis Report

Existing Conditions Hydrology Analysis for the Calvert Cliffs Nuclear Power Plant, Unit 3 Phase II Nontidal Wetland and Stream Mitigation Plan Lusby, Maryland

Prepared for:

Unistar Nuclear Energy
Baltimore, Maryland

Prepared by:

EA Engineering, Science, and Technology, Inc.
15 Loveton Circle
Sparks, Maryland 21152
(410) 771-4950

October 2010 EA Project Number: 14621.03

TABLE OF CONTENTS

Page

LIST OF FIGURES

LIST OF TABLES

LIST OF ACRONYMS AND ABBREVIATIONS

cfs	Cubic Feet Per Second
CN	Curve Number
DA	Drainage Area
EA	EA Engineering, Science, and Technology, Inc.
ft	Foot or Feet
NRCS	Natural Resources Conservation Service
POI	Point of Interest
Tc	Time of Concentration

1.0 INTRODUCTION

EA Engineering, Science, and Technology, Inc. (EA) has completed the hydrologic analysis to estimate peak flows in Woodland Branch tributaries, Johns Creek tributaries, and un-named streams contributing to the Chesapeake Bay, in support of the steam restoration project associated with Unit 3 development (see Figure 1: Locations of Flow Estimates). The hydrologic analysis focuses on the existing conditions, prior to development, and peak flows associated with the 1-, 2-, 10-, and 100-yr storm events.

2.0 PROCEDURES

EA utilized the Natural Resources Conservation Service (NRCS) TR-55 software to conduct the flow estimates. The TR-55 software includes methodologies that provide peak flow estimates resulting from drainage area characteristics in pre-development conditions and channel and reservoir routing to transfer the resulting flows from the drainage area to a location downstream, which are necessary computation procedures to conduct the analysis.

Drainage Area: Peak Flow Estimate

Drainage area characteristics required for TR-55 computation are listed as follows:

A. Size of drainage area in Acres (sources: Unistar topography and U.S. Geological Survey 2009 topography);

B. Land use (source: Google aerial photography [Google Imagery 2010 / Terrametrics Map Data 2010);

C. Soils type (source: Department of Agriculture, NRCS, web soil survey, http://websoilsurvey.nrcs.usda.gov/app/WebSoilSurvey.aspx);

D. Time of concentration (sources: same as size drainage area); and

E. Rainfall (source: TR-55, Calvert County of Maryland, type II).

EA delineated drainage areas contributing to the locations identified in the stream channel (see Figure 1), which are points of interest (POIs) using the topography (listed by Item A). Estimated peak flows from TR-55 are expected to occur at POIs. Topography was also used to determine time of concentration (Tc) path. Specific Tc data required include flow length and slope-related sheet and shallow concentrated flows. The land use characteristic for all delineated drainage areas was identified to be forested type in good condition. The hydrologic soil group (HSG) for the drainage areas were identified using NRCS soils data as referenced in Item C (see Appendix C for identified soil types). Rainfall data were provided by TR-55. The following Tables 1 and 2 show data utilized for TR-55 coding.

Table 1. Woodland Branch, TR-55 Drainage Area Characteristics Data

Drainage Area Identification	Area	Curve Number (CN)	Time of Concentration
	(acres)	(no units)	(hrs)
1	28.69	55	0.275
2	48.10	55	0.517
3	67.59	55	0.356
4	38.86	55	0.467
5	71.35	55	0.451
6	36.68	55	0.475
7	16.05	55	0.228
8	29.65	55	0.377

Table 2. Johns Creek and Chesapeake Bay Stream, TR-55 Drainage Area Characteristics Data

Drainage Area Identification	Area	Curve Number (CN)	Time of Concentration
	(acres)	(no units)	(hrs)
9	20.72	55	0.282
10	192.35	55	0.688
11	380.23	55	0.993
12	65.81	55	0.394
13	61.4	55	0.754

Channel and Reservoir Routing Procedures

Six POIs in Woodland Branch and Johns Creek required channel routing, which are POIs 1, 3, 4, 5, 6, 7, and 9. POIs 2, 8, 10, 11, and 13 did not require channel or reservoir routing. Only POI 12 required both channel and reservoir routing.

Channel routing methodology in TR-55 requires input data such as reach length, manning's coefficient, friction slope, and channel geometry (bottom width and side slope). Channel cross-sectional area is assumed to be trapezoidal.

For reservoir routing, TR-55 requires spillway or pipe data from principal channels. Specifically, the spillway data requires pond surface area and vertical distance above spillway crest and associated surface area. Pipe principal channel requires surface area information similarly to spillway data with an additional input which is pipe vertical distance from the invert elevation to the spillway crest. Tables 3 and 4 illustrate channel and reservoir data.

Table 3. Woodland Branch, Channel Routing Data

Channel Identification	Reach Length	Manning's n	Friction Slope	Bottom Width	Side Slope
(from upstream POI to downstream POI)	(ft)	no units	(ft/ft)	(ft)	H (ft):V (ft)
2-1	1464	0.125	0.0200	110	4:1
8-7	155	0.125	0.0010	20	5:1
7-6	426	0.125	0.0164	20	4:1
6-5	1352	0.125	0.0081	35	4:1
5-4	1295	0.125	0.0077	100	8:1
4-3	1759	0.125	0.0068	210	5:1

Table 4. Johns Creek and Chesapeake Bay Streams, Channel Routing Data

Channel Identification	Reach Length	Manning's n	Friction Slope	Bottom Width	Side Slope
(from upstream POI to downstream POI)	(ft)	no units	(ft/ft)	(ft)	H (ft):V (ft)
10-9	1116	0.015	0.0094	135	2:1
12a-12b	1000	0.025	0.001	20	2:1
12b-12c	800	0.025	0.01	20	2:1
12c-12d	500	0.025	0.02	10	1:1

Note: DA 12 has two channels (12a-12b and 12b-12c) connecting three reservoirs and one channel (12c-12d) discharging to the Chesapeake Bay.

Channel and reservoir routing schematics are provided in Appendix A.

3.0 CONCLUSIONS

EA utilized NRCS TR-55 software to estimate peak flows at established POIs for the 1-, 2-, 10-, and 100-yr storm events. The results are shown in Table 5 below.

Table 5. Flow Results at Woodland Branch, Johns Creek, and Chesapeake Bay Streams Points of Interest (POIs)

	Flows (cfs)			
POI	1-yr	2-yr	10-yr	100-yr
1	2.18	8.19	47.50	122.03
2	1.44	6.07	38.54	98.31
3	6.31	20.57	138.64	390.85
4	5.07	18.01	130.68	363.67
5	4.26	16.16	118.47	321.46
6	2.48	10.65	72.54	186.56
7	1.37	5.86	42.65	111.00
8	0.96	4.55	29.27	73.58
9	5.74	21.47	129.70	334.80
10	5.28	20.46	126.12	324.21
11	9.30	32.74	191.16	492.52
12	1.22	3.89	22.09	44.82
13	1.64	6.19	37.72	97.07

See Appendix B for TR-55 outputs.

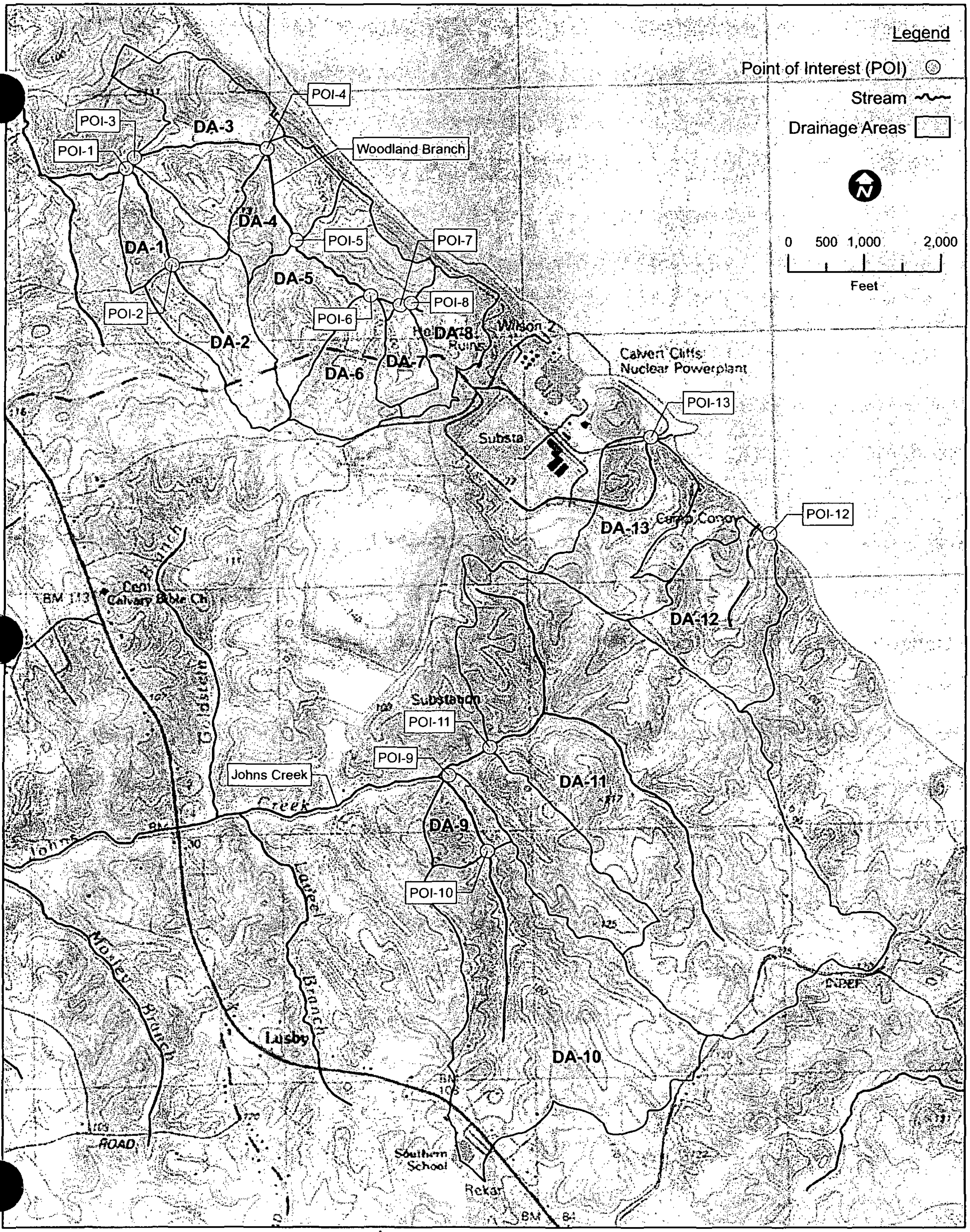


Figure 1. Locations of Flow Estimates

Appendix A
TR-55 Channel and Reservoir Routing Schematics

Woodland Branch TR-55 Channel Routing Schematic

Reach Flow Path

Reach Flow Path

Project (Unistar, Calvert Cliffs) Flow Path

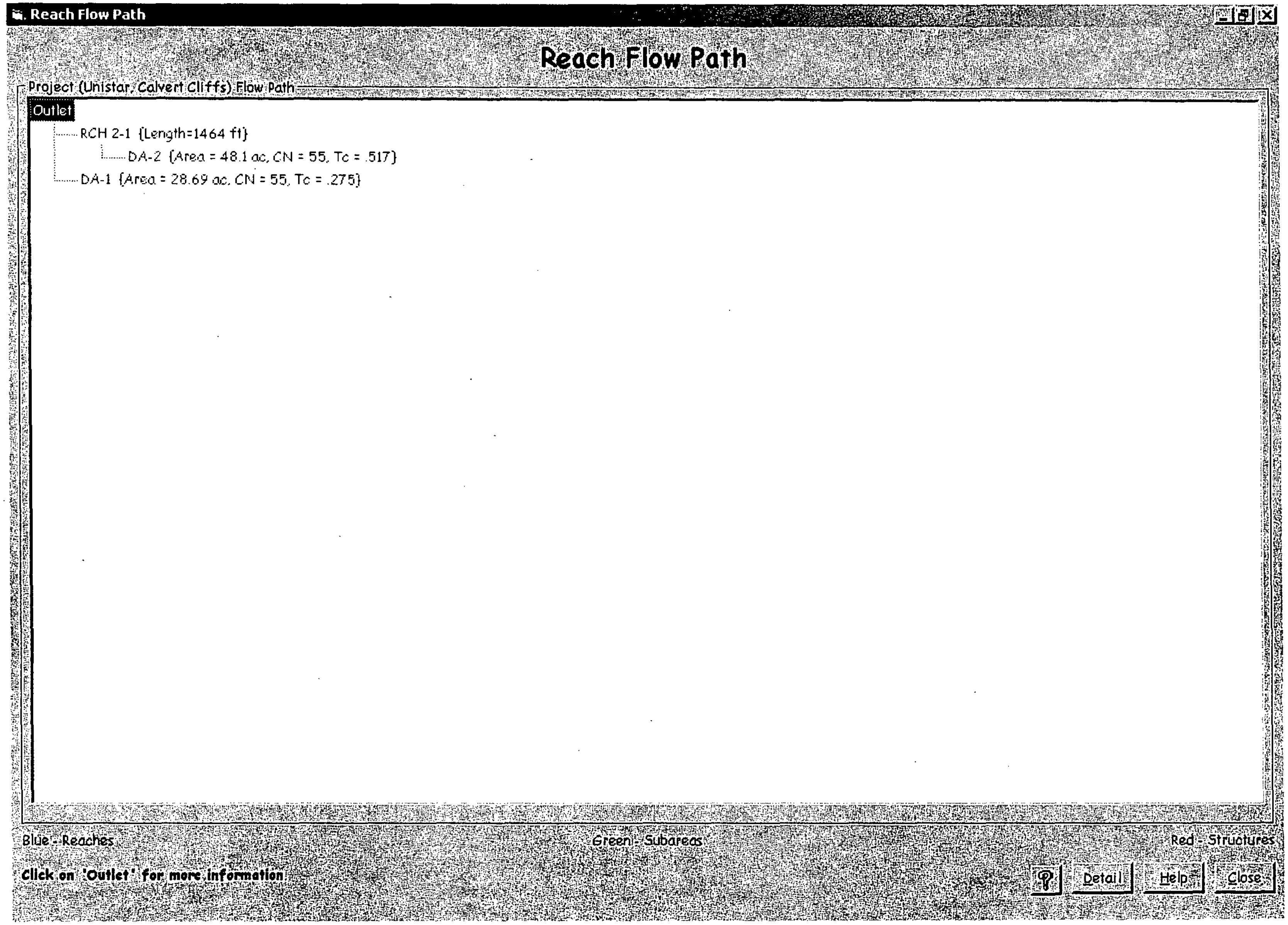
- Outlet
  - RCH 4-3 {Length=1759 ft}
    - RCH 5-4 {Length=1295 ft}
      - RCH 6-5 {Length=1352 ft}
        - RCH 7-6 {Length=426 ft}
          - RCH 8-7 {Length=155 ft}
            - DA-8 {Area = 29.65 ac, CN = 55, Tc = .377}
          - DA-7 {Area = 16.05 ac, CN = 55, Tc = .228}
        - DA-6 {Area = 36.68 ac, CN = 55, Tc = 0.475}
      - DA-5 {Area = 71.35 ac, CN = 55, Tc = .451}
    - DA-4 {Area = 36.86 ac, CN = 55, Tc = 0.467}
  - DA-3 {Area = 67.59 ac, CN = 55, Tc = 0.356}

Blue - Reaches | Green - Subareas | Red - Structures

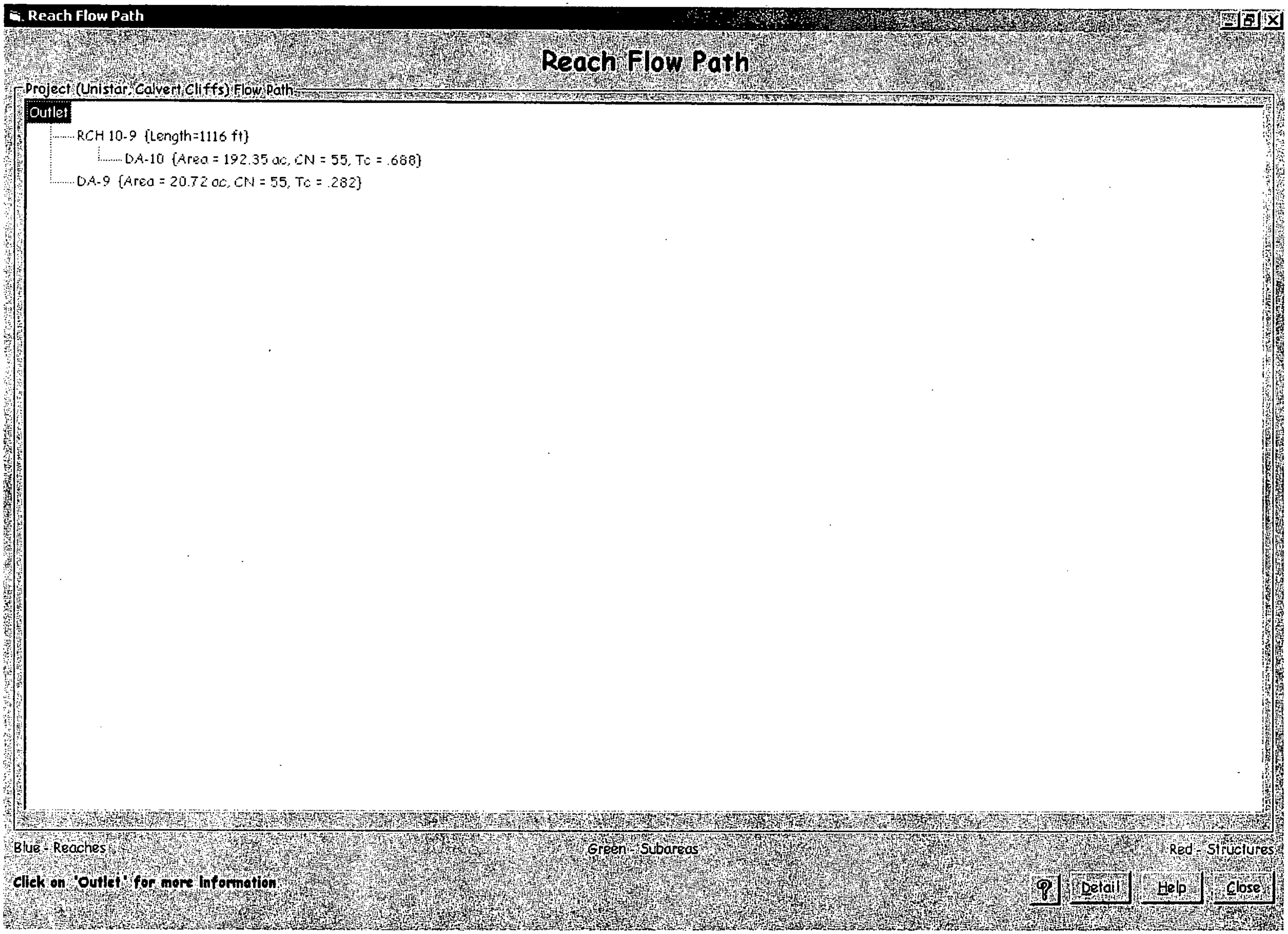
Click on 'Outlet' for more information

? | Detail | Help | Close

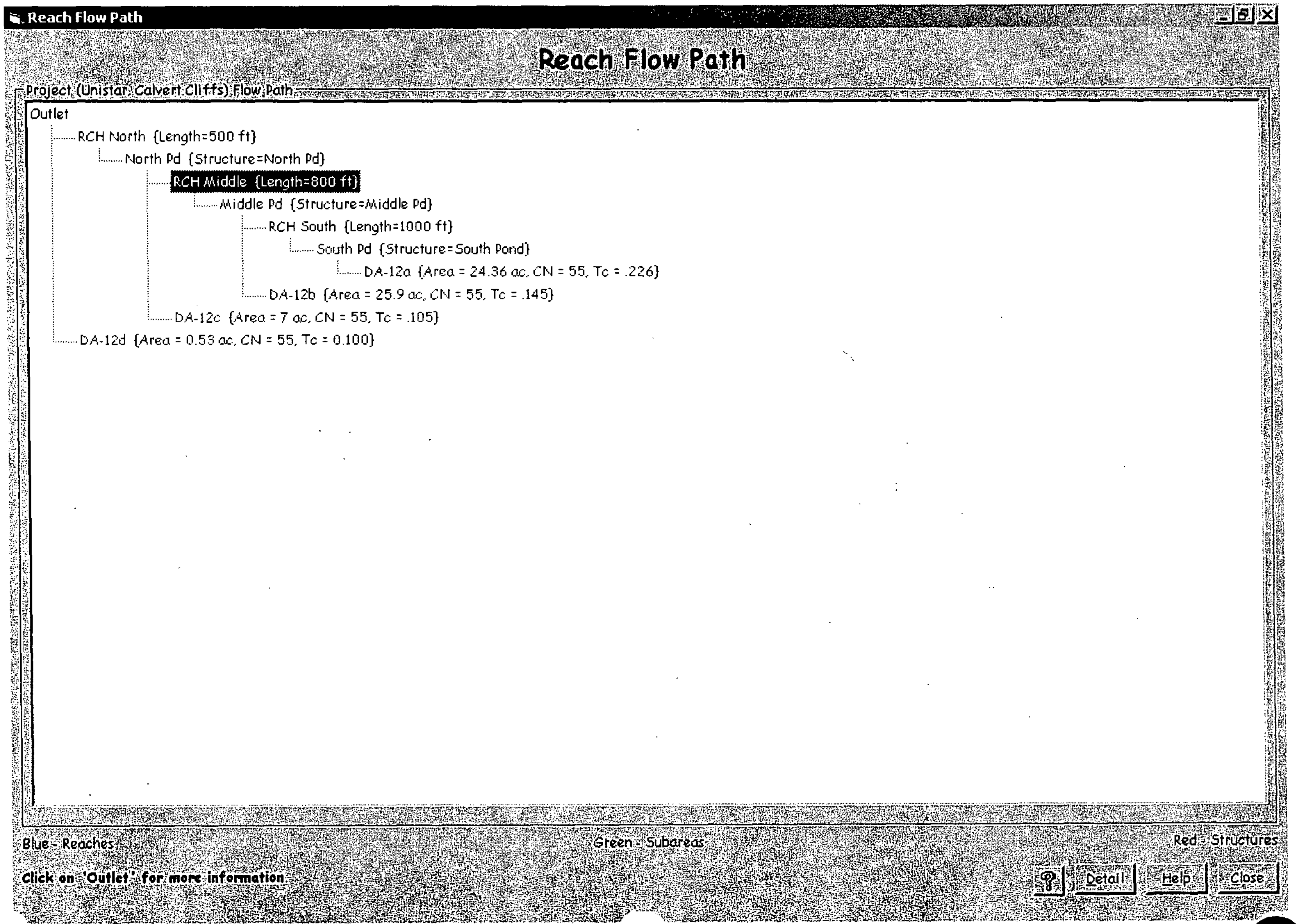
Woodland Branch TR-55 Channel Routing Schematic



Johns Creek TR-55 Channel Routing Schematic



Johns Creek TR-55 Reservoir Routing Schematic



Appendix B

TR-55 Results for POIs 1-13
(for 1-, 2-, 10-, and 100-yr storm events)

Woodland Branch

WinTR-55 Current Data Description

--- Identification Data ---

User: qn   Date: 9/27/2010
Project: Unistar, Calvert Cliffs   Units: English
SubTitle: Flow estimate at designated points   Areal Units: Acres
State: Maryland
County: Calvert
Filename: C:\Documents and Settings\qnguyen\My Documents\Unistar\Report\Existing Conditions\TR-55

--- Sub-Area Data ---

Name	Description	Reach	Area(ac)	RCN	Tc
DA-1		Outlet	28.69	55	.275
DA-2		RCH 2-1	48.1	55	.517

Total area: 76.79 (ac)

--- Storm Data --

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.4	4.4	5.3	6.1	6.7	7.6	2.8

Storm Data Source: Calvert County, MD (NRCS)
Rainfall Distribution Type: Type II
Dimensionless Unit Hydrograph: <standard>

Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Storm Data

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.4	4.4	5.3	6.1	6.7	7.6	2.8

Storm Data Source: Calvert County, MD (NRCS)
Rainfall Distribution Type: Type II
Dimensionless Unit Hydrograph: <standard>

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Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Watershed Peak Table

Sub-Area or Reach Identifier	ANALYSIS: (cfs)	Peak Flow by Rainfall Return Period 10-Yr (cfs)	100-Yr (cfs)	1-Yr (cfs)
SUBAREAS				
DA-1	5.40	33.86	83.51	1.04
DA-2	6.07	38.54	98.31	1.44
REACHES				
RCH 2-1	6.07	38.54	98.31	1.44
Down	6.03	38.19	97.47	1.44
OUTLET	8.19	47.50	122.03	2.18

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Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Hydrograph Peak/Peak Time Table

Sub-Area or Reach Identifier	Peak Flow and Peak Time (hr) by Rainfall Return Period ANALYSIS: (cfs) (hr)	10-Yr (cfs) (hr)	100-Yr (cfs) (hr)	1-Yr (cfs) (hr)
SUBAREAS				
DA-1	5.40	33.86	83.51	1.04
	12.13	12.09	12.07	12.21
DA-2	6.07	38.54	98.31	1.44
	12.33	12.22	12.20	12.47
REACHES				
RCH 2-1	6.07	38.54	98.31	1.44
	12.33	12.22	12.20	12.47
Down	6.03	38.19	97.47	1.44
	12.56	12.49	12.40	12.67
OUTLET	8.19	47.50	122.03	2.18

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Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Sub-Area Summary Table

Sub-Area Identifier	Drainage Area (ac)	Time of Concentration (hr)	Curve Number	Receiving Reach	Sub-Area Description
DA-1	28.69	0.275	55	Outlet	
DA-2	48.10	0.517	55	RCH 2-1	

Total Area: 76.79 (ac)

qn

Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Reach Summary Table

Reach Identifier	Receiving Reach Identifier	Reach Length (ft)	Routing Method
RCH 2-1	Outlet	1464	CHANNEL

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Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Sub-Area Time of Concentration Details

Sub-Area Identifier/	Flow Length (ft)	Slope (ft/ft)	Mannings's n	End Area (sq ft)	Wetted Perimeter (ft)	Velocity (ft/sec)	Travel Time (hr)
DA-1							
SHEET	100	0.0878	0.150				0.088
SHALLOW	153	0.1691	0.050				0.006
SHALLOW	616	0.0608	0.050				0.043
CHANNEL	1242					2.500	0.138
				Time of Concentration			.275
DA-2							
SHEET	100	0.0165	0.150				0.171
SHALLOW	592	0.0219	0.050				0.069
CHANNEL	1997					2.000	0.277
				Time of Concentration			.517

qn

Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Sub-Area Land Use and Curve Number Details

Sub-Area Identifier	Land Use		Hydrologic Soil Group	Sub-Area Area (ac)	Curve Number
DA-1	Woods	(good)	B	28.687	55
	Total Area / Weighted Curve Number			28.69	55
				=====	==
DA-2	Woods	(good)	B	48.098	55
	Total Area / Weighted Curve Number			48.1	55
				====	==

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Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Reach Channel Rating Details

Reach Identifier	Reach Length (ft)	Reach Manning's n	Friction Slope (ft/ft)	Bottom Width (ft)	Side Slope
RCH 2-1	1464	0.125	0.02	110	4 :1

Reach Identifier	Stage (ft)	Flow (cfs)	End Area (sq ft)	Top Width (ft)	Friction Slope (ft/ft)
RCH 2-1	0.0	0.000	0	110	0.02
	0.5	58.572	56	114	
	1.0	187.043	114	118	
	2.0	601.313	236	126	
	5.0	2888.808	650	150	
	10.0	9913.166	1500	190	
	20.0	36794.913	3800	270	

WinTR-55 Current Data Description

--- Identification Data ---

User:	qn	Date:	9/27/2010
Project:	Unistar, Calvert Cliffs	Units:	English
SubTitle:	Flow estimate at designated points	Areal Units:	Acres
State:	Maryland		
County:	Calvert		
Filename:	C:\Documents and Settings\qnguyen\My Documents\Unistar\Report\Existing Conditions\TR-55		

--- Sub-Area Data ---

Name	Description	Reach	Area(ac)	RCN	Tc
DA-5		RCH 5-4	71.35	55	.451
DA-6		RCH 6-5	36.68	55	0.475
DA-7		RCH 7-6	16.05	55	.228
DA-8		RCH 8-7	29.65	55	.377
DA-4		RCH 4-3	36.86	55	0.467
DA-3		Outlet	67.59	55	0.356

Total area: 258.18 (ac)

--- Storm Data --

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.4	4.4	5.3	6.1	6.7	7.6	2.8

Storm Data Source: Calvert County, MD (NRCS)
Rainfall Distribution Type: Type II
Dimensionless Unit Hydrograph: <standard>

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Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Storm Data

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.4	4.4	5.3	6.1	6.7	7.6	2.8

Storm Data Source: Calvert County, MD (NRCS)
Rainfall Distribution Type: Type II
Dimensionless Unit Hydrograph: <standard>

Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Watershed Peak Table

Sub-Area or Reach Identifier	ANALYSIS: (cfs)	Peak Flow by Rainfall Return Period 10-Yr (cfs)	100-Yr (cfs)	1-Yr (cfs)
SUBAREAS				
DA-5	9.79	62.76	158.84	2.20
DA-6	4.87	31.15	78.96	1.12
DA-7	3.39	20.62	50.25	0.63
DA-8	4.55	29.27	73.58	0.96
DA-4	4.95	31.61	80.55	1.13
DA-3	10.77	68.97	173.24	2.23
REACHES				
RCH 8-7	4.55	29.27	73.58	0.96
Down	3.59	25.47	67.18	0.90
RCH 7-6	5.86	42.65	111.00	1.37
Down	5.84	42.45	110.32	1.37
RCH 6-5	10.65	72.54	186.56	2.48
Down	10.31	69.54	179.40	2.47
RCH 5-4	16.16	118.47	321.46	4.26
Down	15.93	114.91	311.37	4.26
RCH 4-3	18.01	130.68	363.67	5.07
Down	17.83	126.06	350.99	5.07
OUTLET	20.57	138.64	390.85	6.31

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Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Hydrograph Peak/Peak Time Table

Sub-Area or Reach Identifier	Peak Flow and Peak Time (hr) by Rainfall Return Period ANALYSIS: (cfs) (hr)	10-Yr (cfs) (hr)	100-Yr (cfs) (hr)	1-Yr (cfs) (hr)
SUBAREAS				
DA-5	9.79	62.76	158.84	2.20
	12.26	12.20	12.18	12.40
DA-6	4.87	31.15	78.96	1.12
	12.29	12.20	12.17	12.43
DA-7	3.39	20.62	50.25	0.63
	12.10	12.06	12.04	12.15
DA-8	4.55	29.27	73.58	0.96
	12.22	12.15	12.13	12.32
DA-4	4.95	31.61	80.55	1.13
	12.28	12.19	12.18	12.42
DA-3	10.77	68.97	173.24	2.23
	12.20	12.14	12.12	12.30
REACHES				
RCH 8-7	4.55	29.27	73.58	0.96
	12.22	12.15	12.13	12.32
Down	3.59	25.47	67.18	0.90
	12.29	12.18	12.13	12.56
RCH 7-6	5.86	42.65	111.00	1.37
	12.15	12.11	12.08	12.49
Down	5.84	42.45	110.32	1.37
	12.24	12.15	12.13	12.57
RCH 6-5	10 65	72.54	186.56	2.48
	12.27	12.18	12.14	12.55
Down	10.31	69.54	179.40	2.47
	12.66	12.37	12.29	12.91
RCH 5-4	16.16	118.47	321.46	4.26
	12.61	12.31	12.24	12.82
Down	15.93	114.91	311.37	4.26
	12.97	12.54	12.40	13.18
RCH 4-3	18.01	130.68	363.67	5.07
	12.97	12.51	12.37	13.16
Down	17.83	126.06	350.99	5.07
	13.46	12.87	12.62	13.65
OUTLET	20.57	138.64	390.85	6.31

qn

Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Sub-Area Summary Table

Sub-Area Identifier	Drainage Area (ac)	Time of Concentration (hr)	Curve Number	Receiving Reach	Sub-Area Description
DA-5	71.35	0.451	55	RCH 5-4	
DA-6	36.68	0.475	55	RCH 6-5	
DA-7	16.05	0.228	55	RCH 7-6	
DA-8	29.65	0.377	55	RCH 8-7	
DA-4	36.86	0.467	55	RCH 4-3	
DA-3	67.59	0.356	55	Outlet	

Total Area: 258.18 (ac)

qn

Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Reach Summary Table

Reach Identifier	Receiving Reach Identifier	Reach Length (ft)	Routing Method
RCH 8-7	RCH 7-6	155	CHANNEL
RCH 7-6	RCH 6-5	426	CHANNEL
RCH 6-5	RCH 5-4	1352	CHANNEL
RCH 5-4	RCH 4-3	1295	CHANNEL
RCH 4-3	Outlet	1759	CHANNEL

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Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Sub-Area Time of Concentration Details

Sub-Area Identifier/	Flow Length (ft)	Slope (ft/ft)	Mannings's n	End Area (sq ft)	Wetted Perimeter (ft)	Velocity (ft/sec)	Travel Time (hr)
DA-5							
SHEET	100	0.0174	0.150				0.167
SHALLOW	612	0.0238	0.050				0.068
CHANNEL	1631					2.100	0.216
				Time of Concentration			.451
DA-6							
SHEET	100	0.0100	0.150				0.209
SHALLOW	413	0.0422	0.050				0.035
CHANNEL	1748					2.100	0.231
				Time of Concentration			0.475
DA-7							
SHEET	100	0.1645	0.150				0.068
SHALLOW	603	0.0492	0.050				0.047
CHANNEL	816					2.000	0.113
				Time of Concentration			.228
DA-8							
SHEET	100	0.0813	0.150				0.090
SHALLOW	90	0.1297	0.050				0.004
SHALLOW	568	0.0314	0.050				0.055
CHANNEL	1211					2.000	0.168
CHANNEL	431					2.000	0.060
				Time of Concentration			.377
DA-4							
User-provided							0.467
				Time of Concentration			0.467
DA-3							
User-provided							0.356
				Time of Concentration			0.356

Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Sub-Area Land Use and Curve Number Details

Sub-Area Identifier	Land Use		Hydrologic Soil Group	Sub-Area Area (ac)	Curve Number
DA-5	Woods	(good)	B	71.349	55
	Total Area / Weighted Curve Number			71.35	55
				=====	==
DA-6	Woods	(good)	B	36.684	55
	Total Area / Weighted Curve Number			36.68	55
				=====	==
DA-7	Woods	(good)	B	16.052	55
	Total Area / Weighted Curve Number			16.05	55
				=====	==
DA-8	Woods	(good)	B	29.655	55
	Total Area / Weighted Curve Number			29.65	55
				=====	==
DA-4	Woods	(good)	B	36.86	55
	Total Area / Weighted Curve Number			36.86	55
				=====	==
DA-3	CN directly entered by user		-	67.59	55
	Total Area / Weighted Curve Number			67.59	55
				=====	==

qn

Unistar, Calvert Cliffs
Flow estimate at designated points
Calvert County, Maryland

Reach Channel Rating Details

Reach Identifier	Reach Length (ft)	Reach Manning's n	Friction Slope (ft/ft)	Bottom Width (ft)	Side Slope
RCH 8-7	155	0.125	0.001	20	5 :1
RCH 7-6	426	0.125	0.0164	20	4 :1
RCH 6-5	1352	0.125	0.0081	35	4 :1
RCH 5-4	1295	0.125	0.0077	100	8 :1
RCH 4-3	1759	0.125	0.0068	210	5 :1

Reach Identifier	Stage (ft)	Flow (cfs)	End Area (sq ft)	Top Width (ft)	Friction Slope (ft/ft)
RCH 8-7	0.0	0.000	0	20	0.001
	0.5	2.477	11.3	25	
	1.0	8.286	25	30	
	2.0	29.363	60	40	
	5.0	182.508	225	70	
	10.0	843.488	700	120	
	20.0	4385.437	2400	220	
RCH 7-6	0.0	0.000	0	20	0.0164
	0.5	9.921	11	24	
	1.0	32.778	24	28	
	2.0	113.425	56	36	
	5.0	670.295	200	60	
	10.0	2967.613	600	100	
	20.0	14890.805	2000	180	
RCH 6-5	0.0	0.000	0	35	0.0081
	0.5	12.014	18.5	39	
	1.0	38.949	39	43	
	2.0	129.525	86	51	
	5.0	692.072	275	75	
	10.0	2761.774	750	115	
	20.0	12540.670	2300	195	
RCH 5-4	0.0	0.000	0	100	0.0077
	0.5	33.310	52	108	
	1.0	107.344	108	116	
	2.0	352.024	232	132	
	5.0	1801.646	700	180	
	10.0	6798.966	1800	260	
	20.0	28916.689	5200	420	
RCH 4-3	0.0	0.000	0	210	0.0068
	0.5	65.086	106.3	215	
	1.0	207.436	215	220	
	2.0	663.948	440	230	
	5.0	3140.583	1175	260	
	10.0	10476.928	2600	310	
	20.0	36929.770	6200	410	

Johns Creek

WinTR-55 Current Data Description

--- Identification Data ---

User: qn
Project: Unistar, Calvert Cliffs
SubTitle:
State: Maryland
County: Calvert
Filename: C:\Documents and Settings\qnguyen\My Documents\Unistar\Report\Existing Conditions\TR-55

Date: 9/27/2010
Units: English
Areal Units: Acres

--- Sub-Area Data ---

Name	Description	Reach	Area(ac)	RCN	Tc
DA-9		Outlet	20.72	55	.282
DA-10		RCH 10-9	192.35	55	.688

Total area: 213.07 (ac)

--- Storm Data --

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.4	4.4	5.3	6.1	6.7	7.6	2.8

Storm Data Source: Calvert County, MD (NRCS)
Rainfall Distribution Type: Type II
Dimensionless Unit Hydrograph: <standard>

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Unistar, Calvert Cliffs

Calvert County, Maryland

Storm Data

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.4	4.4	5.3	6.1	6.7	7.6	2.8

Storm Data Source: Calvert County, MD (NRCS)
Rainfall Distribution Type: Type II
Dimensionless Unit Hydrograph: <standard>

qn

Unistar, Calvert Cliffs

Calvert County, Maryland

Watershed Peak Table

Sub-Area or Reach Identifier	ANALYSIS: (cfs)	Peak Flow by Rainfall Return Period 10-Yr (cfs)	100-Yr (cfs)	1-Yr (cfs)
SUBAREAS				
DA-9	3.84	24.15	59.68	0.74
DA-10	20.46	126.12	324.21	5.28
REACHES				
RCH 10-9	20.46	126.12	324.21	5.28
Down	20.35	124.44	319.83	5.27
OUTLET	21.47	129.70	334.80	5.74

qn

Unistar, Calvert Cliffs

Calvert County, Maryland

Hydrograph Peak/Peak Time Table

Sub-Area or Reach Identifier	Peak Flow and Peak Time (hr) by Rainfall Return Period ANALYSIS: (cfs) (hr)	10-Yr (cfs) (hr)	100-Yr (cfs) (hr)	1-Yr (cfs) (hr)
SUBAREAS				
DA-9	3.84	24.15	59.68	0.74
	12.14	12.08	12.07	12.22
DA-10	20.46	126.12	324.21	5.28
	12.49	12.34	12.31	12.66
REACHES				
RCH 10-9	20.46	126.12	324.21	5.28
	12.49	12.34	12.31	12.66
Down	20.35	124.44	319.83	5.27
	12.79	12.56	12.44	12.96
OUTLET	21.47	129.70	334.80	5.74

Unistar, Calvert Cliffs

Calvert County, Maryland

Sub-Area Summary Table

Sub-Area Identifier	Drainage Area (ac)	Time of Concentration (hr)	Curve Number	Receiving Reach	Sub-Area Description
DA-9	20.72	0.282	55	Outlet	
DA-10	192.35	0.688	55	RCH 10-9	

Total Area: 213.07 (ac)

Unistar, Calvert Cliffs

Calvert County, Maryland

Reach Summary Table

Reach Identifier	Receiving Reach Identifier	Reach Length (ft)	Routing Method
RCH 10-9	Outlet	1116	CHANNEL

Unistar, Calvert Cliffs

Calvert County, Maryland

Sub-Area Time of Concentration Details

Sub-Area Identifier/	Flow Length (ft)	Slope (ft/ft)	Mannings's n	End Area (sq ft)	Wetted Perimeter (ft)	Velocity (ft/sec)	Travel Time (hr)
DA-9							
SHEET	100	0.0863	0.150				0.088
SHALLOW	526	0.1045	0.050				0.028
CHANNEL	1197					2.000	0.166
				Time of Concentration			.282
DA-10							
SHEET	100	0.0264	0.150				0.142
SHALLOW	1111	0.0324	0.050				0.106
SHALLOW	977	0.0220	0.050				0.113
CHANNEL	2351					2.000	0.327
				Time of Concentration			.688

qn

Unistar, Calvert Cliffs

Calvert County, Maryland

Sub-Area Land Use and Curve Number Details

Sub-Area Identifier	Land Use		Hydrologic Soil Group	Sub-Area Area (ac)	Curve Number
DA-9	Woods	(good)	B	20.72	55
	Total Area / Weighted Curve Number			20.72	55
				=====	==
DA-10	Woods	(good)	B	192.35	55
	Total Area / Weighted Curve Number			192.35	55
				======	==

qn

Unistar, Calvert Cliffs

Calvert County, Maryland

Reach Channel Rating Details

Reach Identifier	Reach Length (ft)	Reach Manning's n	Friction Slope (ft/ft)	Bottom Width (ft)	Side Slope
RCH 10-9	1116	0.15	0.0094	135	2 :1

Reach Identifier	Stage (ft)	Flow (cfs)	End Area (sq ft)	Top Width (ft)	Friction Slope (ft/ft)
RCH 10-9	0.0	0.000	0	135	0.0094
	0.5	40.897	68	137	
	1.0	130.027	137	139	
	2.0	414.098	278	143	
	5.0	1928.075	725	155	
	10.0	6261.012	1550	175	
	20.0	20983.014	3500	215	

WinTR-55 Current Data Description

--- Identification Data ---

User:	qn	Date:	9/27/2010
Project:	Unistar, Calvert Cliffs	Units:	English
SubTitle:		Areal Units:	Acres
State:	Maryland		
County:	Calvert		

Filename: C:\Documents and Settings\qnguyen\My Documents\Unistar\Report\Existing Conditions\TR-55

--- Sub-Area Data ---

Name	Description	Reach	Area(ac)	RCN	Tc
DA-11		Outlet	380.23	55	.993

Total area: 380.23 (ac)

--- Storm Data --

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.4	4.4	5.3	6.1	6.7	7.6	2.8

Storm Data Source:	Calvert County, MD (NRCS)
Rainfall Distribution Type:	Type II
Dimensionless Unit Hydrograph:	<standard>

qn Unistar, Calvert Cliffs

Calvert County, Maryland

Storm Data

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.4	4.4	5.3	6.1	6.7	7.6	2.8

Storm Data Source: Calvert County, MD (NRCS)
Rainfall Distribution Type: Type II
Dimensionless Unit Hydrograph: <standard>

qn

Unistar, Calvert Cliffs

Calvert County, Maryland

Watershed Peak Table

Sub-Area or Reach Identifier	ANALYSIS: (cfs)	Peak Flow by Rainfall Return Period 10-Yr (cfs)	100-Yr (cfs)	1-Yr (cfs)
SUBAREAS				
DA-11	32.74	191.16	492.52	9.30
REACHES				
OUTLET	32.74	191.16	492.52	9.30

qn Unistar, Calvert Cliffs

Calvert County, Maryland

Hydrograph Peak/Peak Time Table

Sub-Area or Reach Identifier	Peak Flow and Peak Time (hr) by Rainfall Return Period ANALYSIS: (cfs) (hr)	10-Yr (cfs) (hr)	100-Yr (cfs) (hr)	1-Yr (cfs) (hr)
SUBAREAS				
DA-11	32.74 12.71	191.16 12.61	492.52 12.52	9.30 12.98
REACHES				
OUTLET	32.74	191.16	492.52	9.30

qn

Unistar, Calvert Cliffs

Calvert County, Maryland

Sub-Area Summary Table

Sub-Area Identifier	Drainage Area (ac)	Time of Concentration (hr)	Curve Number	Receiving Reach	Sub-Area Description
DA-11	380.23	0.993	55	Outlet	

Total Area: 380.23 (ac)

Unistar, Calvert Cliffs

Calvert County, Maryland

Sub-Area Time of Concentration Details

Sub-Area Identifier/	Flow Length (ft)	Slope (ft/ft)	Mannings's n	End Area (sq ft)	Wetted Perimeter (ft)	Velocity (ft/sec)	Travel Time (hr)
DA-11							
SHEET	100	0.0922	0.150				0.086
SHALLOW	1062	0.0224	0.050				0.122
CHANNEL	5653					2.000	0.785
					Time of Concentration		.993

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Unistar, Calvert Cliffs

Calvert County, Maryland

Sub-Area Land Use and Curve Number Details

Sub-Area Identifier	Land Use		Hydrologic Soil Group	Sub-Area Area (ac)	Curve Number
DA-11	Woods	(good)	B	380.225	55
	Total Area / Weighted Curve Number			380.23	55
				======	==

Streams Discharging to Chesapeake Bay

WinTR-55 Current Data Description

--- Identification Data ---

User: qn
Project: Unistar, Calvert Cliffs
SubTitle:
State: Maryland
County: Calvert
Filename: C:\Documents and Settings\qnguyen\My Documents\Unistar\Report\Existing Conditions\TR-55

Date: 9/27/2010
Units: English
Areal Units: Acres

--- Sub-Area Data ---

Name	Description	Reach	Area(ac)	RCN	Tc
DA-12b		Middle Pd	25.9	55	.145
DA-12c		North Pd	7	55	.105
DA-12a		South Pd	24.36	55	.226
DA-12d		Outlet	0.53	55	0.100

Total area: 57.79 (ac)

--- Storm Data --

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.4	4.4	5.3	6.1	6.7	7.6	2.8

Storm Data Source: Calvert County, MD (NRCS)
Rainfall Distribution Type: Type II
Dimensionless Unit Hydrograph: <standard>

Unistar, Calvert Cliffs

Calvert County, Maryland

Storm Data

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.4	4.4	5.3	6.1	6.7	7.6	2.8

Storm Data Source: Calvert County, MD (NRCS)
Rainfall Distribution Type: Type II
Dimensionless Unit Hydrograph: <standard>

Unistar, Calvert Cliffs

Calvert County, Maryland

Watershed Peak Table

Sub-Area or Reach Identifier	ANALYSIS: (cfs)	Peak Flow by Rainfall Return Period 10-Yr (cfs)	100-Yr (cfs)	1-Yr (cfs)
SUBAREAS				
DA-12b	6.98	38.09	90.41	1.32
DA-12c	2.15	10.71	25.92	0.43
DA-12a	5.17	31.43	76.58	0.97
DA-12d	0.17	0.82	1.99	.00
REACHES				
South Pd	5.17	31.43	76.58	0.97
Down	4.22	26.96	67.16	0.83
Middle Pd	6.98	47.09	125.77	1.62
Down	3.59	21.00	34.12	1.08
North Pd	3.95	22.61	49.77	1.22
Down	3.89	22.00	44.05	1.22
RCH South	4.22	26.96	67.16	0.83
Down	3.94	23.68	60.58	0.83
RCH Middle	3.59	21.00	34.12	1.08
Down	3.59	20.99	34.12	1.08
RCH North	3.89	22.00	44.05	1.22
Down	3.89	22.00	44.04	1.22
OUTLET	3.89	22.09	44.82	1.22

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Unistar, Calvert Cliffs

Calvert County, Maryland

Hydrograph Peak/Peak Time Table

Sub-Area or Reach Identifier	Peak Flow and Peak Time (hr) by Rainfall Return Period ANALYSIS: (cfs)	(hr)	10-Yr (cfs)	(hr)	100-Yr (cfs)	(hr)	1-Yr (cfs)	(hr)
SUBAREAS								
DA-12b	6.98	12.05	38.09	12.02	90.41	11.99	1.32	12.07
DA-12c	2.15	12.03	10.71	12.01	25.92	11.95	0.43	12.05
DA-12a	5.17	12.09	31.43	12.06	76.58	12.04	0.97	12.15
DA-12d	0.17	12.03	0.82	12.01	1.99	11.94	.00	n/a
REACHES								
South Pd	5.17	12.09	31.43	12.06	76.58	12.04	0.97	12.15
Down	4.22	12.17	26.96	12.12	67.16	12.10	0.83	12.27
Middle Pd	6.98	12.05	47.09	12.04	125.77	12.04	1.62	12.38
Down	3.59	12.65	21.00	12.44	34.12	12.52	1.08	13.12
North Pd	3.95	12.66	22.61	12.45	49.77	12.04	1.22	13.12
Down	3.89	12.80	22.00	12.57	44.05	12.08	1.22	13.24
RCH South	4.22	12.17	26.96	12.12	67.16	12.10	0.83	12.27
Down	3.94	12.34	23.68	12.23	60.58	12.19	0.83	12.45
RCH Middle	3.59	12.65	21.00	12.44	34.12	12.52	1.08	13.12
Down	3.59	12.69	20.99	12.48	34.12	12.55	1.08	13.15
RCH North	3.89	12.80	22.00	12.57	44.05	12.08	1.22	13.24
Down	3.89	12.81	22.00	12.59	44.04	12.09	1.22	13.26
OUTLET	3.89		22.09		44.82		1.22	

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Unistar, Calvert Cliffs

Calvert County, Maryland

Structure Output Table

Reach Identifier / Structure Identifier	ANALYSIS:	10-Yr	100-Yr	1-Yr
Reach: South Pd				
Weir : South Pond				
250(ft)				
PF (cfs)	4.22	26.96	67.16	0.83
SV (ac ft)	.03	.18	.44	.01
STG (ft)	.01	.05	.14	.00
Reach: Middle Pd				
Pipe : Middle Pd				
24(in)				
PF (cfs)	3.59	21.00	34.12	1.08
SV (ac ft)	.17	1.00	3.18	.05
STG (ft)	.12	.70	2.13	.04
Reach: North Pd				
Weir : North Pd				
24(ft)				
PF (cfs)	3.89	22.00	44.05	1.22
SV (ac ft)	.03	.19	.32	.01
STG (ft)	.08	.46	.73	.03

Peak Flow (PF), Storage Volume (SV), Stage (STG) by Rainfall Return Period

Unistar, Calvert Cliffs

Calvert County, Maryland

Sub-Area Summary Table

Sub-Area Identifier	Drainage Area (ac)	Time of Concentration (hr)	Curve Number	Receiving Reach	Sub-Area Description
DA-12b	25.90	0.145	55	Middle Pd	
DA-12c	7.00	0.105	55	North Pd	
DA-12a	24.36	0.226	55	South Pd	
DA-12d	.53	0.100	55	Outlet	

Total Area: 57.79 (ac)

Unistar, Calvert Cliffs

Calvert County, Maryland

Reach Summary Table

Reach Identifier	Receiving Reach Identifier	Reach Length (ft)	Routing Method
South Pd	RCH South		STRUCTURE(South Pond)
Middle Pd	RCH Middle		STRUCTURE(Middle Pd)
North Pd	RCH North		STRUCTURE(North Pd)
RCH South	Middle Pd	1000	CHANNEL
RCH Middle	North Pd	800	CHANNEL
RCH North	Outlet	500	CHANNEL

Unistar, Calvert Cliffs

Calvert County, Maryland

Sub-Area Time of Concentration Details

Sub-Area Identifier/	Flow Length (ft)	Slope (ft/ft)	Mannings's n	End Area (sq ft)	Wetted Perimeter (ft)	Velocity (ft/sec)	Travel Time (hr)
DA-12b							
SHEET	100	0.0675	0.150				0.097
SHALLOW	725	0.0675	0.050				0.048
					Time of Concentration		.145
DA-12c							
SHEET	100	0.0675	0.150				0.097
SHALLOW	125	0.0675	0.050				0.008
					Time of Concentration		.105
DA-12a							
SHEET	100	0.0187	0.150				0.163
SHALLOW	957	0.0675	0.050				0.063
					Time of Concentration		.226
DA-12d							
User-provided							0.100
					Time of Concentration		0.100

Unistar, Calvert Cliffs

Calvert County, Maryland

Sub-Area Land Use and Curve Number Details

Sub-Area Identifier	Land Use		Hydrologic Soil Group	Sub-Area Area (ac)	Curve Number
DA-12b	Woods	(good)	B	25.9	55
	Total Area / Weighted Curve Number			25.9 ====	55 ==
DA-12c	Woods	(good)	B	7	55
	Total Area / Weighted Curve Number			7 =	55 ==
DA-12a	Woods	(good)	B	24.36	55
	Total Area / Weighted Curve Number			24.36 =====	55 ==
DA-12d	CN directly entered by user		-	.53	55
	Total Area / Weighted Curve Number			.53 ===	55 ==

Unistar, Calvert Cliffs

Calvert County, Maryland

Reach Channel Rating Details

Reach Identifier	Reach Length (ft)	Reach Manning's n	Friction Slope (ft/ft)	Bottom Width (ft)	Side Slope
South Pd	(This reach is a structure: South Pond)				
Middle Pd	(This reach is a structure: Middle Pd)				
North Pd	(This reach is a structure: North Pd)				
RCH South	1000	0.025	0.001	20	2 :1
RCH Middle	800	0.025	0.01	20	1 :1
RCH North	500	0.025	0.02	10	1 :1

Reach Identifier	Stage (ft)	Flow (cfs)	End Area (sq ft)	Top Width (ft)	Friction Slope (ft/ft)
South Pd	(This reach is a structure: South Pond)				
Middle Pd	(This reach is a structure: Middle Pd)				
North Pd	(This reach is a structure: North Pd)				
RCH South	0.0	0.000	0	20	0.001
	0.5	11.968	10.5	22	
	1.0	38.518	22	24	
	2.0	126.407	48	28	
	5.0	655.022	150	40	
	10.0	2532.097	400	60	
	20.0	11132.421	1200	100	
RCH Middle	0.0	0.000	0	20	0.01
	0.5	37.281	10.3	21	
	1.0	118.067	21	22	
	2.0	374.712	44	24	
	5.0	1764.961	125	30	
	10.0	6026.666	300	40	
	20.0	22726.289	800	60	
RCH North	0.0	0.000	0	10	0.02
	0.5	26.296	5.3	11	
	1.0	83.458	11	12	
	2.0	268.211	24	14	
	5.0	1342.287	75	20	
	10.0	5061.705	200	30	
	20.0	21844.051	600	50	

Unistar, Calvert Cliffs

Calvert County, Maryland

Structure Description - User Entered

Reach Identifier	Surface Area @ Crest (ac)	Height Above Crest (ft)	Surface Area @ Ht Above (ac)	Pipe Diameter (in)	Head on Pipe (ft)	Weir Length (ft)
South Pd	3.1	5	5.88			250
Middle Pd	1.4	2	1.57	24	4	
North Pd	.4	2	.57			24

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Unistar, Calvert Cliffs

Calvert County, Maryland

Structure Rating Details - Computed

Reach Idendifier	Stage (ft)	Pool Storage (ac ft)	Flows (cfs) @ Weir Length: Length #1 250ft	Length #2 ft	Length #3 ft
South Pond	0	0.00	0.000		
	0.5	1.62	247.487		
	1	3.38	700.000		
	2	7.31	1979.899		
	5	22.45	7826.238		
	10	58.80	22135.944		
	20	173.20	62609.903		

Reach Idendifier	Stage (ft)	Pool Storage (ac ft)	Flows (cfs) @ Pipe Diameter: Dia #1 24in	Dia #2 in	Dia #3 in
Middle Pd	0	0.00	0.000		
	1	1.44	30.159		
	2	2.97	33.719		
	4	6.28	39.897		
	10	18.25	54.370		
	20	45.00	72.319		

Reach Idendifier	Stage (ft)	Pool Storage (ac ft)	Flows (cfs) @ Weir Length: Length #1 24ft	Length #2 ft	Length #3 ft
North Pd	0	0.00	0.000		
	0.5	0.21	23.759		
	1	0.44	67.200		
	2	0.97	190.070		
	5	3.06	751.319		
	10	8.25	2125.051		
	20	25.00	6010.551		

WinTR-55 Current Data Description

--- Identification Data ---

User: qn
Project: Unistar, Calvert Cliffs
SubTitle:
State: Maryland
County: Calvert
Filename: C:\Documents and Settings\qnguyen\My Documents\Unistar\Report\Existing Conditions\TR-55

Date: 9/27/2010
Units: English
Areal Units: Acres

--- Sub-Area Data ---

Name	Description	Reach	Area(ac)	RCN	Tc
DA-13		Outlet	61.4	55	.754

Total area: 61.40 (ac)

--- Storm Data --

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.4	4.4	5.3	6.1	6.7	7.6	2.8

Storm Data Source: Calvert County, MD (NRCS)
Rainfall Distribution Type: Type II
Dimensionless Unit Hydrograph: <standard>

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Unistar, Calvert Cliffs

Calvert County, Maryland

Storm Data

Rainfall Depth by Rainfall Return Period

2-Yr (in)	5-Yr (in)	10-Yr (in)	25-Yr (in)	50-Yr (in)	100-Yr (in)	1-Yr (in)
3.4	4.4	5.3	6.1	6.7	7.6	2.8

Storm Data Source: Calvert County, MD (NRCS)
Rainfall Distribution Type: Type II
Dimensionless Unit Hydrograph: <standard>

Unistar, Calvert Cliffs

Calvert County, Maryland

Watershed Peak Table

Sub-Area or Reach Identifier	ANALYSIS: (cfs)	10-Yr (cfs)	100-Yr (cfs)	1-Yr (cfs)
	Peak Flow by Rainfall Return Period			
SUBAREAS				
DA-13	6.19	37.72	97.07	1.64
REACHES				
OUTLET	6.19	37.72	97.07	1.64

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Unistar, Calvert Cliffs

Calvert County, Maryland

Hydrograph Peak/Peak Time Table

Sub-Area or Reach Identifier	Peak Flow and Peak Time (hr) by Rainfall Return Period ANALYSIS: (cfs) (hr)	10-Yr (cfs) (hr)	100-Yr (cfs) (hr)	1-Yr (cfs) (hr)
SUBAREAS				
DA-13	6.19 12.55	37.72 12.41	97.07 12.37	1.64 12.73
REACHES				
OUTLET	6.19	37.72	97.07	1.64

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Unistar, Calvert Cliffs

Calvert County, Maryland

Sub-Area Summary Table

Sub-Area Identifier	Drainage Area (ac)	Time of Concentration (hr)	Curve Number	Receiving Reach	Sub-Area Description
DA-13	61.40	0.754	55	Outlet	

Total Area: 61.40 (ac)

Unistar, Calvert Cliffs

Calvert County, Maryland

Sub-Area Time of Concentration Details

Sub-Area Identifier/	Flow Length (ft)	Slope (ft/ft)	Mannings's n	End Area (sq ft)	Wetted Perimeter (ft)	Velocity (ft/sec)	Travel Time (hr)
DA-13							
SHEET	100	0.0026	0.150				0.358
SHALLOW	857	0.0576	0.050				0.061
CHANNEL	2411					2.000	0.335
					Time of Concentration		.754

Unistar, Calvert Cliffs

Calvert County, Maryland

Sub-Area Land Use and Curve Number Details

Sub-Area Identifier	Land Use		Hydrologic Soil Group	Sub-Area Area (ac)	Curve Number
DA-13	Woods	(good)	B	61.401	55
	Total Area / Weighted Curve Number			61.4	55
				====	==

Appendix C

Soils Type

Map Unit Symbol	Map Unit Name	Acres in AOI	Percent of AOI
BlB2	Beltsville silt loam, 2 to 5 percent slopes, moderately eroded	17	0.30%
W	Water	1,726.50	25.90%
SrE	Sassafras and Westphalia soils, steep	1,711.60	25.70%
ErE	Eroded land, steep	448.6	6.70%
MnB2	Matapeake silt loam, 2 to 5 percent slopes, moderately eroded	388.7	5.80%
My	Mixed alluvial land	341.6	5.10%
ReD	Rumford-Evesboro gravelly loamy sands, 12 to 20 percent slopes	248.3	3.70%
SaB2	Sassafras loamy fine sand, 2 to 5 percent slopes, moderately eroded	229.2	3.40%
ShC3	Sassafras fine sandy loam, 5 to 10 percent slopes, severely eroded	227.2	3.40%
ShD3	Sassafras fine sandy loam, 10 to 15 percent slopes severely eroded	180.9	2.70%
MnC3	Matapeake silt loam, 5 to 10 percent slopes, severely eroded	172	2.60%
ReC	Rumford-Evesboro gravelly loamy sands, 6 to 12 percent slopes	144.2	2.20%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
BlB2	Beltsville silt loam, 2 to 5 percent slopes, moderately eroded	Moderately well drained	1.2	0.00%
SrE	Sassafras and Westphalia soils, steep	Well drained	809.6	30.20%
W	Water		334.9	12.50%
MnB2	Matapeake silt loam, 2 to 5 percent slopes, moderately eroded	Well drained	241.6	9.00%
ErE	Eroded land, steep	Well drained	228.9	8.50%
My	Mixed alluvial land	Poorly drained	169.7	6.30%
MnC3	Matapeake silt loam, 5 to 10 percent slopes, severely eroded	Well drained	144.3	5.40%
ReD	Rumford-Evesboro gravelly loamy sands, 12 to 20 percent slopes	Well drained	123.2	4.60%
ReC	Rumford-Evesboro gravelly loamy sands, 6 to 12 percent slopes	Well drained	80.6	3.00%
MnD3	Matapeake silt loam, 10 to 15 percent slopes, severely eroded	Well drained	74.8	2.80%
ShC3	Sassafras fine sandy loam, 5 to 10 percent slopes, severely eroded	Well drained	67.7	2.50%
SaC2	Sassafras loamy fine sand, 5 to 10 percent slopes, moderately eroded	Well drained	64.6	2.40%

Map unit symbol	Map unit name	Rating	Acres in AOI	Percent of AOI
BlB2	Beltsville silt loam, 2 to 5 percent slopes, moderately eroded	C	1.2	0.00%
SrE	Sassafras and Westphalia soils, steep	B	809.6	30.20%
W	Water		334.9	12.50%
MnB2	Matapeake silt loam, 2 to 5 percent slopes, moderately eroded	B	241.6	9.00%
ErE	Eroded land, steep	B	228.9	8.50%
My	Mixed alluvial land	D	169.7	6.30%
MnC3	Matapeake silt loam, 5 to 10 percent slopes, severely eroded	B	144.3	5.40%
ReD	Rumford-Evesboro gravelly loamy sands, 12 to 20 percent slopes	A	123.2	4.60%
ReC	Rumford-Evesboro gravelly loamy sands, 6 to 12 percent slopes	B	80.6	3.00%
MnD3	Matapeake silt loam, 10 to 15 percent slopes, severely eroded	B	74.8	2.80%
ShC3	Sassafras fine sandy loam, 5 to 10 percent slopes, severely eroded	B	67.7	2.50%
SaC2	Sassafras loamy fine sand, 5 to 10 percent slopes, moderately eroded	B	64.6	2.40%

ShB2	Sassafras fine sandy loam, 2 to 5 percent slopes, moderately eroded	114.2	1.70%	SaB2	Sassafras loamy fine sand, 2 to 5 percent slopes, moderately eroded	Well drained	55.9	2.10%	SaB2	Sassafras loamy fine sand, 2 to 5 percent slopes, moderately eroded	B	55.9	2.10%
SaC2	Sassafras loamy fine sand, 5 to 10 percent slopes, moderately eroded	80.1	1.20%	ShD3	Sassafras fine sandy loam, 10 to 15 percent slopes severely eroded	Well drained	41.7	1.60%	ShD3	Sassafras fine sandy loam, 10 to 15 percent slopes severely eroded	B	41.7	1.60%
MnD3	Matapeake silt loam, 10 to 15 percent slopes, severely eroded	75.9	1.10%	ShB2	Sassafras fine sandy loam, 2 to 5 percent slopes, moderately eroded	Well drained	29	1.10%	ShB2	Sassafras fine sandy loam, 2 to 5 percent slopes, moderately eroded	B	29	1.10%
Co	Coastal beaches	65.9	1.00%	RdD2	Rumford loamy sand, 10 to 15 percent slopes, moderately eroded	Well drained	27.6	1.00%	RdD2	Rumford loamy sand, 10 to 15 percent slopes, moderately eroded	B	27.6	1.00%
BtB2	Butlertown silt loam, 2 to 5 percent slopes, moderately eroded	50.9	0.80%	BtB2	Butlertown silt loam, 2 to 5 percent slopes, moderately eroded	Well drained	25.3	0.90%	BtB2	Butlertown silt loam, 2 to 5 percent slopes, moderately eroded	C	25.3	0.90%
MnC2	Matapeake silt loam, 5 to 10 percent slopes, moderately eroded	51.9	0.80%	MnC2	Matapeake silt loam, 5 to 10 percent slopes, moderately eroded	Well drained	24.7	0.90%	MnC2	Matapeake silt loam, 5 to 10 percent slopes, moderately eroded	B	24.7	0.90%
Sx	Swamp	48.1	0.70%	ShD2	Sassafras fine sandy loam, 10 to 15 percent slopes moderately eroded	Well drained	24.9	0.90%	ShD2	Sassafras fine sandy loam, 10 to 15 percent slopes moderately eroded	B	24.9	0.90%
ShC2	Sassafras fine sandy loam, 5 to 10 percent slopes, moderately eroded	38.9	0.60%	Co	Coastal beaches	Poorly drained	19.2	0.70%	Co	Coastal beaches	D	19.2	0.70%
ShD2	Sassafras fine sandy loam, 10 to 15 percent slopes moderately eroded	39.2	0.60%	HoB2	Howell fine sandy loam, 2 to 6 percent slopes, moderately eroded	Well drained	13.2	0.50%	HoB2	Howell fine sandy loam, 2 to 6 percent slopes, moderately eroded	C	13.2	0.50%
Tm	Tidal marsh	35.6	0.50%	Ma	Made land		13.9	0.50%	Ma	Made land		13.9	0.50%
RdD2	Rumford loamy sand, 10 to 15 percent slopes, moderately eroded	29.4	0.40%	Es	Escarpments	Well drained	9.8	0.40%	Es	Escarpments	B	9.8	0.40%
EvB	Evesboro loamy sand, 0 to 6 percent slopes	17.2	0.30%	EvB	Evesboro loamy sand, 0 to 6 percent slopes	Excessively drained	10.3	0.40%	EvB	Evesboro loamy sand, 0 to 6 percent slopes	A	10.3	0.40%
HoB2	Howell fine sandy loam, 2 to 6 percent slopes, moderately eroded	18.5	0.30%	EvE	Evesboro loamy sand, 12 to 35 percent slopes	Excessively drained	7.5	0.30%	EvE	Evesboro loamy sand, 12 to 35 percent slopes	A	7.5	0.30%

BtC3	Butlertown silt loam, 5 to 10 percent slopes, severely eroded	13.1	0.20%
Es	Escarpments	14.6	0.20%
HoD2	Howell fine sandy loam, 12 to 20 percent slopes, moderately eroded	10.9	0.20%
HwB2	Howell silt loam, 2 to 6 percent slopes, moderately eroded	11.4	0.20%
HyD3	Howell clay loam, 12 to 20 percent slopes, severely eroded	10.8	0.20%
Ma	Made land	13.9	0.20%
ReB	Rumford-Evesboro gravelly loamy sands, 2 to 6 percent slopes	14.2	0.20%
EvE	Evesboro loamy sand, 12 to 35 percent slopes	9.8	0.10%
HoC2	Howell fine sandy loam, 6 to 12 percent slopes, moderately eroded	8.3	0.10%
HyC3	Howell clay loam, 6 to 12 percent slopes, severely eroded	5.5	0.10%
MlB2	Marr fine sandy loam, 2 to 6 percent slopes, moderately eroded	3.5	0.10%
SlB2	Sassafras loam, 2 to 5 percent slopes, moderately eroded	4.9	0.10%
SlC3	Sassafras loam, 5 to 10 percent slopes, severely eroded	5.1	0.10%
WoA	Woodstown fine sandy loam, 0 to 2 percent slopes	6.6	0.10%

HwB2	Howell silt loam, 2 to 6 percent slopes, moderately eroded	Well drained	8.2	0.30%
Tm	Tidal marsh	Very poorly drained	8.3	0.30%
HyC3	Howell clay loam, 6 to 12 percent slopes, severely eroded	Well drained	5.5	0.20%
SlC3	Sassafras loam, 5 to 10 percent slopes, severely eroded	Well drained	4.2	0.20%
BtC3	Butlertown silt loam, 5 to 10 percent slopes, severely eroded	Well drained	1.7	0.10%
EvC	Evesboro loamy sand, 6 to 12 percent slopes	Excessively drained	2.7	0.10%
ReB	Rumford-Evesboro gravelly loamy sands, 2 to 6 percent slopes	Well drained	2.5	0.10%
ImB	Iuka fine sandy loam, local alluvium, 2 to 5 percent slopes	Moderately well drained	0.6	0.00%
WaD3	Westphalia fine sandy loam, 12 to 20 percent slopes severely eroded	Well drained	0.5	0.00%
WoA	Woodstown fine sandy loam, 0 to 2 percent slopes	Moderately well drained	0.9	0.00%
WoB	Woodstown fine sandy loam, 2 to 5 percent slopes	Moderately well drained	2.2	0.10%
Totals for Area of Interest			2,681.30	100.00%

HwB2	Howell silt loam, 2 to 6 percent slopes, moderately eroded	C	8.2	0.30%
Tm	Tidal marsh	D	8.3	0.30%
HyC3	Howell clay loam, 6 to 12 percent slopes, severely eroded	C	5.5	0.20%
SlC3	Sassafras loam, 5 to 10 percent slopes, severely eroded	B	4.2	0.20%
BtC3	Butlertown silt loam, 5 to 10 percent slopes, severely eroded	C	1.7	0.10%
EvC	Evesboro loamy sand, 6 to 12 percent slopes	A	2.7	0.10%
ReB	Rumford-Evesboro gravelly loamy sands, 2 to 6 percent slopes	B	2.5	0.10%
ImB	Iuka fine sandy loam, local alluvium, 2 to 5 percent slopes	C	0.6	0.00%
WaD3	Westphalia fine sandy loam, 12 to 20 percent slopes severely eroded	B	0.5	0.00%
WoA	Woodstown fine sandy loam, 0 to 2 percent slopes	C	0.9	0.00%
WoB	Woodstown fine sandy loam, 2 to 5 percent slopes	C	2.2	0.10%
Totals for Area of Interest			2,681.30	100.00%

WoB	Woodstown fine sandy loam, 2 to 5 percent slopes	5.5	0.10%
BlC3	Beltsville silt loam, 5 to 10 percent slopes, severely eroded	1.4	0.00%
Ek	Elkton silt loam	2.9	0.00%
EvC	Evesboro loamy sand, 6 to 12 percent slopes	2.7	0.00%
ImB	Iuka fine sandy loam, local alluvium, 2 to 5 percent slopes	1.9	0.00%
MlC3	Marr fine sandy loam, 6 to 12 percent slopes, severely eroded	0.5	0.00%
OcB	Ochlockonee fine sandy loam, local alluvium, 2 to 5 percent slopes	3.1	0.00%
OtB	Othello silt loam, 2 to 5 percent slopes	1.6	0.00%
ShA	Sassafras fine sandy loam, 0 to 2 percent slopes	0.1	0.00%
WaD3	Westphalia fine sandy loam, 12 to 20 percent slopes severely eroded	0.5	0.00%
Totals for Area of Interest		6,654.00	100.00%

Appendix D

Fluvial Geomorphic Assessment Data

SE 1

Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

Stream:	**Calvert Cliffs, Reach - Woodland SE-1**				
Basin:	**Woodland Branch**	Drainage Area:	**48** acres	**0.075**	mi^2
Location:	**Calvert Cliffs Nuclear Plant**				
Twp.&Rge:	**Lusby;**	Sec.&Qtr.: ;			
Cross-Section Monuments (Lat./Long.):	**0 Lat / 0 Long**			Date:	**10/01/09**
Observers:	**Jim Morris, Tom King**			Valley Type:	IX

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**5.86**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.38**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**2.25**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**15.42**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**0.89**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**75**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**12.8**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.18**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.01104**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.2**	

Stream Type → **C 5** ← (See **Figure 2-14**)

RIVERMORPH PROFILE SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SE-1
Profile Name: Refference Only
Survey Date: 10/01/2009

Survey Data

DIST	CH	WS	BKF	P1	P2	P3	P4
96	6.74	6.66	6.11				
97	7.29	6.79					
98	7.09	6.81	6.03				
102	6.99	6.82	6.22				
105	6.94	6.82	6.19				
109	6.98	6.85	6.14				
111	6.99	6.85					
113.5	7.14	6.89					
115	7.26	6.87	6.33				
118	7.17	6.89					
120	6.98	6.89	6.09				
123	7.03	6.91					
128	7.06	6.92	6.32				
134	7.06	6.96	6.27				
137	7.08	6.97	6.47				
140	7.09	6.96					
145	7.1	6.98	6.43				
147	7.38	6.97					
148.6	7.13	6.97	6.43	6.38			
150	7.09	6.97					
151.5	7.06	6.98	6.49				
154	7.24	7.09	6.39				
158	7.25	7.12	6.55				
163	7.28	7.12					
169	7.29	7.18	6.56				
173	7.43	7.23					
176	7.71	7.3					
178	7.97	7.49					
179	7.6	7.51					
182	7.71	7.67	7.04				
184	7.77	7.67					
187	7.84	7.68					
189	7.94	7.69					
191	8.03	7.74					
194	8	7.75					
195	8.12	7.82					
197	8.1	7.89	7.14	7.09			

200	8.39	7.94	7.12
202	8.25	7.93	
206	8.29	7.93	
209	8.27	7.92	
216	8.29	7.92	
226	8.27	7.92	
231	8.32	7.92	
233	8.34	7.99	7.32
235	8.62	8.27	
238	8.56	8.29	7.38
240	8.45	8.29	7.38
246	8.4	8.3	7.54
250	8.42	8.31	
255	8.45	8.31	
264	8.47	8.37	
267	8.67	8.4	7.91
271	8.64	8.43	
275	8.57	8.46	
280	8.6	8.45	
283	8.99	8.45	
288	8.82	8.43	
293	9.1	8.77	
297	8.94	8.74	
300	8.98	8.75	8.42
305	6.44	6.06	5.61
312	6.33	6.11	5.76
315	6.38	6.14	
319	6.21	6.13	5.72

Cross Section / Bank Profile Locations

Name	Type	Profile Station
Riffle 20	Other XS	20
Glide 150	Glide XS	150
Riffle 158	Riffle XS	158
Run 233	Run XS	233
Pool 235	Pool XS	235
Valley at 445	Riffle XS	445
Depart Riffle at 364	Riffle XS	364
Entrenched Riffle at 486	Riffle XS	486

Measurements from Graph

Bankfull Slope: 0.01104

Variable	Min	Avg	Max
S riffle	0.00165	0.00783	0.0162
S pool	0	0.00124	0.00337
S run	0.01499	0.04327	0.08166
S glide	0	0.00134	0.00321
P - P	18.47	29.82	47.84

Pool length	4.23	12.46	28.71
Riffle length	7.57	18.87	30.93
Dmax riffle	0.56	0.63	0.7
Dmax pool	0.85	1.04	1.3
Dmax run	0.73	0.9	1.01
Dmax glide	0.59	0.77	0.87
Low bank ht	0.2	0.2	0.2

Length and depth measurements in feet, slopes in ft/ft.

RIVERMORPH PROFILE SUMMARY

Notes

River Name: Calvert Cliffs
Reach Name: Woodland SE-1
Profile Name: Refference Only
Survey Date: 10/01/2009

DIST	Note
96	left / begin ref
98	left
102	right
105	left
109	right
111	Run
113.5	Pool
115	mid pool
118	Glide
120	Riffle
128	right
134	left
137	right
145	left
148.6	Glide L/R
151.5	right
154	left
158	Riffle (left)
169	RIGHT
182	right
197	right/left
200	left
233	Run Right
238	right
240	right
246	left
267	right
280	large downed tree
293	DEBRIS JAM AT 292
300	RIGHT BANK
305	left bank
312	left bank

319 left - end of refference

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SE-1
Cross Section Name: Riffle 158
Survey Date: 09/23/2009

Cross Section Data Entry

BM Elevation: 99 ft
Backsight Rod Reading: 1 ft

TAPE	FS	ELEV	NOTE
-25	6.4	93.6	
-7	6.62	93.38	
0	6.56	93.44	LEP
2	6.45	93.55	
3	6.45	93.55	
4	6.46	93.54	BKF
5	6.61	93.39	
5.3	7.1	92.9	LEW
5.7	7.18	92.82	
6	7.24	92.76	
6.5	7.35	92.65	
7	7.21	92.79	
7.4	7.09	92.91	REW
8	6.76	93.24	
9	6.49	93.51	
11	6.42	93.58	
18	6.82	93.18	
50	6.4	93.6	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	94.43	94.43	94.43
Bankfull Elevation (ft)	93.54	93.54	93.54
Floodprone Width (ft)	75	-----	-----
Bankfull Width (ft)	5.86	5.13	2.93
Entrenchment Ratio	12.8	-----	-----
Mean Depth (ft)	0.38	0.5	0.27
Maximum Depth (ft)	0.89	0.89	0.77
Width/Depth Ratio	15.42	10.26	10.85
Bankfull Area (sq ft)	2.25	1.46	0.79
Wetted Perimeter (ft)	6.33	4.03	3.84
Hydraulic Radius (ft)	0.36	0.36	0.2

Begin BKF Station	1.8	1.8	6.93
End BKF Station	9.86	6.93	9.86

Entrainment Calculations

Entrainment Formula: Shields Curve

	Channel	Left Side	Right Side
Slope	0.011	0.011	0.011
Shear Stress (lb/sq ft)	0.25	0.25	0.14
Movable Particle (mm)	13.7	13.7	8.6

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SE-1
Cross Section Name: Pool 235
Survey Date: 09/23/2009

Cross Section Data Entry

BM Elevation: 99 ft
Backsight Rod Reading: 1 ft

TAPE	FS	ELEV	NOTE
0	7.48	92.52	LEP
3	7.32	92.68	
4	7.41	92.59	BKF
5	7.64	92.36	
5.5	8.29	91.71	LEW
6	8.42	91.58	
7	8.82	91.18	
7.5	8.75	91.25	
8	8.57	91.43	vertical bank
8.3	7.67	92.33	
9	7.41	92.59	
11	7.31	92.69	
13	7.38	92.62	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	94	94	94
Bankfull Elevation (ft)	92.59	92.59	92.59
Floodprone Width (ft)	13	-----	-----
Bankfull Width (ft)	5	2.5	2.5
Entrenchment Ratio	2.6	-----	-----
Mean Depth (ft)	0.74	0.57	0.91
Maximum Depth (ft)	1.41	1.21	1.41
Width/Depth Ratio	6.76	4.39	2.75
Bankfull Area (sq ft)	3.69	1.42	2.27
Wetted Perimeter (ft)	6.17	4.11	4.48
Hydraulic Radius (ft)	0.6	0.35	0.51
Begin BKF Station	4	4	6.5
End BKF Station	9	6.5	9

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SE-1
Cross Section Name: Run 233
Survey Date: 09/23/2009

Cross Section Data Entry

BM Elevation: 99 ft
Backsight Rod Reading: 1 ft

TAPE	FS	ELEV	NOTE
0	7.41	92.59	LEP
2	7.4	92.6	
4	7.42	92.58	bkf
4.2	7.99	92.01	LEW
5	8.06	91.94	
5.5	8.06	91.94	
6	8.02	91.98	
6.5	8.04	91.96	
7	7.99	92.01	REW
7.5	7.71	92.29	
8	7.61	92.39	
9	7.35	92.65	
13	7.34	92.66	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	93.22	93.22	93.22
Bankfull Elevation (ft)	92.58	92.58	92.58
Floodprone Width (ft)	13	-----	-----
Bankfull Width (ft)	4.73	2.37	2.36
Entrenchment Ratio	2.75	-----	-----
Mean Depth (ft)	0.46	0.59	0.33
Maximum Depth (ft)	0.64	0.64	0.62
Width/Depth Ratio	10.28	4.02	7.15
Bankfull Area (sq ft)	2.18	1.4	0.78
Wetted Perimeter (ft)	5.25	3.39	3.08
Hydraulic Radius (ft)	0.41	0.41	0.25
Begin BKF Station	4	4	6.37
End BKF Station	8.73	6.37	8.73

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SE-1
Cross Section Name: Glide 150
Survey Date: 09/23/2009

Cross Section Data Entry

BM Elevation: 99 ft
Backsight Rod Reading: 1 ft

TAPE	FS	ELEV	NOTE
-7	6.19	93.81	
0	6.34	93.66	LEP
2	6.28	93.72	
3	6.33	93.67	
4	6.46	93.54	
4.8	7.06	92.94	LEW
5	7.15	92.85	
5.5	7.16	92.84	
6	7.05	92.95	
6.5	7.05	92.95	
7	6.99	93.01	
7.5	6.53	93.47	
8	6.55	93.45	
9	6.39	93.61	BKF
12	6.42	93.58	
18	6.7	93.3	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	94.38	94.38	94.38
Bankfull Elevation (ft)	93.61	93.61	93.61
Floodprone Width (ft)	25	-----	-----
Bankfull Width (ft)	6.54	1.52	5.02
Entrenchment Ratio	3.82	-----	-----
Mean Depth (ft)	0.33	0.29	0.35
Maximum Depth (ft)	0.77	0.75	0.77
Width/Depth Ratio	19.82	5.24	14.34
Bankfull Area (sq ft)	2.19	0.44	1.75
Wetted Perimeter (ft)	6.98	2.49	5.99
Hydraulic Radius (ft)	0.31	0.18	0.29
Begin BKF Station	3.46	3.46	4.98
End BKF Station	10	4.98	10

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH REACH SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SE-1

Stream Type	Valley Type	D50(mm)	Val Slope	BKF Q(cfs)	DA(sq mi)
C 5	IX	0.18	0.0132	5.2	0.075

Dimension Summary

Database based on the following Cross Sections:

Variable	Min	Avg	Max
Floodprone Width (ft)	75	75	75
Riffle Area (Sq ft)	2.25	2.25	2.25
Max Riffle Depth (ft)	0.89	0.89	0.89
Mean Riffle Depth (ft)	0.38	0.38	0.38
Riffle Width (ft)	5.86	5.86	5.86
Pool Area (Sq ft)	3.69	3.69	3.69
Max Pool Depth (ft)	1.41	1.41	1.41
Mean Pool Depth (ft)	0.74	0.74	0.74
Pool Width (ft)	5	5	5
Run Area (Sq ft)	2.18	2.18	2.18
Max Run Depth (ft)	0.64	0.64	0.64
Mean Run Depth (ft)	0.46	0.46	0.46
Run Width (ft)	4.73	4.73	4.73
Glide Area (Sq ft)	2.19	2.19	2.19
Max Glide Depth (ft)	0.77	0.77	0.77
Mean Glide Depth (ft)	0.33	0.33	0.33
Glide Width (ft)	6.54	6.54	6.54

Pattern Summary

Variable	Min	Avg	Max
Sinuosity	1.2		
Meander Wavelength (ft)	36	49.25	66
Radius of Curvature (ft)	3	6.65	9.5
Belt Width (ft)	50	55	70

Profile Summary

Data Based on the following:

Variable	Min	Avg	Max
S riffle (ft/ft)	0.00165	0.00783	0.0162
S pool (ft/ft)	0	0.00124	0.00337

S run (ft/ft)	0.01499	0.04327	0.08166
S glide (ft/ft)	0	0.00134	0.00321
P - P (ft)	18.47	29.82	47.84
Pool length (ft)	4.23	12.46	28.71
Riffle length (ft)	7.57	18.87	30.93
Dmax riffle (ft)	0.89	0.89	0.89
Dmax pool (ft)	1.41	1.41	1.41
Dmax run (ft)	0.64	0.64	0.64
Dmax glide (ft)	0.77	0.77	0.77
Low bank ht start-end (ft)	0.2	0.2	0.2
Bankfull slope (ft/ft)		0.01104	

Hydraulic Summary

Variable	Min	Avg	Max
Discharge (cfs)		5.2	
Velocity (fps)		2.31	
Hyd Radius (ft)	0.36	0.36	0.36

Worksheet 5-4. Morphological relations, including dimensionless ratios of river reach sites (Rosgen and Silvey, 2005).

Stream: **Calvert Cliffs, Reach - Woodland SE-1** Location: **Calvert Cliffs Nuclear Plant**

Observers: **Jim Morris, Tom King** Date: **10/01/09** Valley Type: **IX** Stream Type: **C 5**

River Reach Summary Data

Channel Dimension

Mean Riffle Depth (d_{bkf})	0.38	ft	R				25	ft^2
Mean Pool Depth (d_{bkfp})	0.74	ft	Pool Width (W_{bkfp})	5	ft	Pool Area (A_{bkfp})	3.69	ft^2
Mean Pool Depth/Mean Riffle Depth	1.95	d_{bkfp}/d_{bkf}	Pool Width/Riffle Width	0.85	W_{bkfp}/W_{bkf}	Pool Area / Riffle Area	1.64	A_{bkfp}/A_{bkf}
Max Riffle Depth (d_{maxrif})	0.89	ft	Max Pool Depth (d_{maxp})	1.41	ft	Max Riffle Depth/Mean Riffle Depth	2.342	
Max Pool Depth/Mean Riffle Depth	3.711		Point Bar Slope	0	ft/ft	Inner Berm Width (W_{ib})	0	ft
Inner Berm Depth (d_{ib})	0	ft	Inner Berm Width/Depth Ratio	0	W_{ib}/d_{ib}	Inner Berm Area (A_{ib})	0	ft^2
Streamflow: Estimated Mean Velocity at Bankfull Stage (u_{bkf})				2.31	ft/s	Estimation Method		
Streamflow: Estimated Discharge at Bankfull Stage (Q_{bkf})				5.2	cfs	Drainage Area	0.075	mi^2

Channel Pattern

Geometry	Mean	Min	Max		Dimensionless Geometry Ratios	Mean	Min	Max
Meander Wavelength (L_m)	49.3	36	66	ft	Meander Length Ratio (L_m/W_{bkf})	8.40	6.14	11.26
Radius of Curvature (R_c)	6.65	3	9.5	ft	Radius of Curvature/Riffle Width (R_c/W_{bkf})	1.13	0.51	1.62
Belt Width (W_{blt})	55	50	70	ft	Meander Width Ratio (W_{blt}/W_{bkf})	9.39	8.53	11.95
Individual Pool Length	12.5	4.23	28.7	ft	Pool Length/Riffle Width	2.13	0.72	4.90
Pool to Pool Spacing	29.8	18.5	47.8	ft	Pool to Pool Spacing/Riffle Width	5.09	3.15	8.16
Riffle Length	18.9	7.57	30.9	ft	Riffle Length/Riffle Width	3.22	1.29	5.28

Channel Profile

Valley Slope (VS)	0.0132	ft/ft	Average Water Surface Slope (S)	0.01104	ft/ft	Sinuosity (VS/S)	1.2
Stream Length (SL)	0	ft	Valley Length (VL)	0	ft	Sinuosity (SL/VL)	

Low Bank Height (LBH)				Max Riffle Depth				Bank-Height Ratio (BHR) (LBH/Max Riffle Depth)		
	start	0.2	ft		start	0	ft		start	
	end	0.2	ft		end	0	ft		end	

Facet Slopes	Mean	Min	Max		Dimensionless Slope Ratios	Mean	Min	Max
Riffle Slope (S_{rif})	0.008	0.002	0.016	ft/ft	Riffle Slope/Average Water Surface Slope (S_{rif} / S)	0.709	0.149	1.467
Run Slope (S_{run})	0.043	0.015	0.082	ft/ft	Run Slope/Average Water Surface Slope (S_{run} / S)	3.919	1.358	7.397
Pool Slope (S_p)	0.001	0.000	0.003	ft/ft	Pool Slope/Average Water Surface Slope (S_p / S)	0.112	0.000	0.305
Glide Slope (S_g)	0.001	0.000	0.003	ft/ft	Glide Slope/Average Water Surface Slope (S_g / S)	0.121	0.000	0.291

Feature Midpoint[a]	Mean	Min	Max		Dimensionless Depth Ratios	Mean	Min	Max
Max Riffle Depth (d_{maxrif})	0.89	0.89	0.89	ft	Max Riffle Depth/Mean Riffle Depth (d_{maxrif} / d_{bkf})	2.34	2.34	2.34
Max Run Depth (d_{maxrun})	0.64	0.64	0.64	ft	Max Run Depth/Mean Riffle Depth (d_{maxrun} / d_{bkf})	1.68	1.68	1.68
Max Pool Depth (d_{maxp})	1.41	1.41	1.41	ft	Max Pool Depth/Mean Riffle Depth (d_{maxp} / d_{bkf})	3.71	3.71	3.71
Max Glide Depth (d_{maxg})	0.77	0.77	0.77	ft	Max Glide Depth/Mean Riffle Depth (d_{maxg} / d_{bkf})	2.03	2.03	2.03

	Reach[b]	Riffle[c]	Bar		Reach[b]	Riffle[c]	Bar	Protrusion Height[d]	
% Silt/Clay	35.71	16	0	D_{16}	0.03	0.06	0	0	mm
% Sand	42.86	58	100	D_{35}	0.06	0.17	0	0	mm
% Gravel	21.43	26	0	D_{50}	0.18	0.2	0	0	mm
% Cobble	0	0	0	D_{84}	3.14	7.42	0	0	mm
% Boulder	0	0	0	D_{95}	5.64	10.97	0	0	mm
% Bedrock	0	0	0	D_{100}	11.3	16	2	0	mm

[a] Max, mean depths are ave. mid-point values except pools: taken at deepest part of pool.
[b] Composite sample of riffles and pools within the designated reach.
[c] Active bed of a riffle.
[d] Height of roughness feature above bed.

SR 1 Imp

Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

Stream: **Calvert Cliffs, Reach - Woodland Top of SR-1 Uplift**	
Basin:	Drainage Area: **0** acres **0** mi^2
Location:	
Twp.&Rge: **;**	Sec.&Qtr.: **;**
Cross-Section Monuments (Lat./Long.): **0 Lat / 0 Long**	Date: **10/05/09**
Observers:	Valley Type: IX

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**5.25**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.46**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**2.43**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**11.41**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**0.56**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**8.06**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**1.54**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.13**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.0124**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.1**	

Stream Type **B 5c** (See **Figure 2-14**)

RIVERMORPH PROFILE SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland Top of SR-1 Uplift
Profile Name: Main Reach
Survey Date: 10/02/2009

Survey Data

DIST	CH	WS	BKF	P1	P2	P3	P4
1	7.14		5				
5	7.04	6.94					
8	7.04	6.94					
12	7.28	7.03	5.22				
17	7.55						
19	7.72						
23	7.77		5.36	5.28			
27	7.49		5.49		6.92		
30	7.28						
33	7.13	7.03	5.46		6.83		
36	7.13	7.03					
40	7.22	7.07					
45	7.42	7.29	5.97				
47	7.5	7.37	6.07				
51	7.78	7.37	5.57		6.61		
53	7.72	7.37					
57	8.09		5.78		7.55		
61	8.15						
64	7.52		5.46	5.67			
67	7.47	7.37					
71	7.54	7.39	5.46	5.78			
76	7.55	7.45					
78	7.69						
81	7.73	7.61	6.03	6.23			
83	8.16	7.62					
84	7.77	7.62					
86	7.98						
89	7.87						
91	7.92						
93	7.87	7.77	6.32	6.22			
95	8.44						
97	8.44	8.16					
100	8.48	8.16	6.3				
103	8.3	8.16					
106	8.28	8.17					
108	8.4		6.24				
111	8.44		6.27				

115	8.38				
119	8.35				
122	8.4				
125	8.29	8.19	6.65	6.62	
128	8.32				
133	8.35		6.69	6.58	
138	8.38		6.87	6.84	7.44
142	8.39				
146	8.33	8.23	7.02		
149	8.44				
150	8.53				
152	8.57				
154	8.43				
156	8.39		6.9		
159	8.61		6.7	6.9	
163	8.53				
166	8.44				
170	8.57		6.95	6.84	
174	8.47				
176	8.35	8.25			
177	8.6				
179	8.47				
182	8.47				
185	8.45	8.35	7.49	7.02	
190	8.74				
193	8.62	8.52			
197	8.67				
199	8.71				
202	8.84		7.58	7.36	
205	8.73				
208	8.66	8.56			
211	8.69	8.59			
213	8.76	8.66	7.86		
216	8.91	8.76			
218	9	8.76	7.73	7.76	

Cross Section / Bank Profile Locations

Name	Type	Profile Station
Pool at 21	Pool XS	21
Riffle 142	Riffle XS	142
Abandonned Riffle at 11	Riffle XS	11
Abandonned Pool at 60	Pool XS	60

Measurements from Graph

Bankfull Slope: 0.0124

Variable	Min	Avg	Max
S riffle	0	0	0
S pool	0	0	0

S run	0	0	0
S glide	0	0	0
P - P	0	0	0
Pool length	0	0	0
Riffle length	0	0	0
Dmax riffle	0	0	0
Dmax pool	0	0	0
Dmax run	0	0	0
Dmax glide	0	0	0
Low bank ht	0	0	0

Length and depth measurements in feet, slopes in ft/ft.

RIVERMORPH PROFILE SUMMARY

Notes

River Name: Calvert Cliffs
Reach Name: Woodland Top of SR-1 Uplift
Profile Name: Main Reach
Survey Date: 10/02/2009

DIST	Note
1	left- note - entire reach shot in the dry!
8	gravel bar present
12	left
23	left/right
27	left, inner berm
33	left, inner berm
40	mid riffle
45	left
51	right / top bar
57	left / top berm
71	left/right
81	l/r - lots of woody debris
93	l/r
100	left
108	right
111	left
125	right/left
133	right/left
138	r/l tw of ab channel start at 153
146	left
156	right
159	right/left
170	RIGHT/LEFT
182	start gravel bar
185	left/right
202	left/right
213	right
218	right/left

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland Top of SR-1 Uplift
Cross Section Name: Riffle 142
Survey Date: 10/02/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	6.28	93.72	LEP
2	6.86	93.14	
3	7.07	92.93	
3.5	7.21	92.79	
3.88	0	92.2	BKF
4	8.01	91.99	
4.5	8.21	91.79	
5	8.24	91.76	
6	8.36	91.64	
7	8.36	91.64	
8	8.34	91.66	
9	8.1	91.9	
9.5	6.96	93.04	
10	6.84	93.16	
11	7.01	92.99	
12	7.17	92.83	
12.5	7.39	92.61	
13	7.42	92.58	
14	7.29	92.71	
15	7.15	92.85	
16	6.78	93.22	
18	6.44	93.56	
20	6.26	93.74	
22	6.13	93.87	
24	6.07	93.93	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	93.92	93.92	93.92
Bankfull Elevation (ft)	92.78	92.78	92.78
Floodprone Width (ft)	23.67	-----	-----
Bankfull Width (ft)	8.27	3	7.99

Entrenchment Ratio	2.86	-----	-----
Mean Depth (ft)	0.72	0.93	0.6
Maximum Depth (ft)	1.14	1.14	1.14
Width/Depth Ratio	11.49	3.23	13.32
Bankfull Area (sq ft)	5.94	2.8	3.14
Wetted Perimeter (ft)	9.4	4.63	7.06
Hydraulic Radius (ft)	0.63	0.6	0.44
Begin BKF Station	3.51	3.51	6.51
End BKF Station	14.5	6.51	14.5

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland Top of SR-1 Uplift
Cross Section Name: Pool at 21
Survey Date: 10/02/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	5.33	94.67	LEP
2	5.33	94.67	
4	5.32	94.68	
5	5.37	94.63	
6	5.85	94.15	
7	6.04	93.96	BKF
8	6.7	93.3	
10	7.53	92.47	
11	7.82	92.18	
12	7.8	92.2	
13	7.19	92.81	vertical
13.2	5.53	94.47	
15	5.24	94.76	
18	4.98	95.02	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	95.74	95.74	95.74
Bankfull Elevation (ft)	93.96	93.96	93.96
Floodprone Width (ft)	18	-----	-----
Bankfull Width (ft)	6.14	3.07	3.07
Entrenchment Ratio	2.93	-----	-----
Mean Depth (ft)	1.21	0.84	1.58
Maximum Depth (ft)	1.78	1.51	1.78
Width/Depth Ratio	5.07	3.65	1.94
Bankfull Area (sq ft)	7.42	2.59	4.83
Wetted Perimeter (ft)	7.73	4.95	5.81
Hydraulic Radius (ft)	0.96	0.52	0.83
Begin BKF Station	7	7	10.07
End BKF Station	13.14	10.07	13.14

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH REACH SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland Top of SR-1 Uplift

Stream Type	Valley Type	D50(mm)	Val Slope	BKF Q(cfs)	DA(sq mi)
B 5c	IX	0.13	0.0136	0	0

Dimension Summary

Database based on the following Cross Sections:

Variable	Min	Avg	Max
Floodprone Width (ft)	8.06	8.06	8.06
Riffle Area (Sq ft)	2.43	2.43	2.43
Max Riffle Depth (ft)	0.56	0.56	0.56
Mean Riffle Depth (ft)	0.46	0.46	0.46
Riffle Width (ft)	5.25	5.25	5.25
Pool Area (Sq ft)	7.42	7.42	7.42
Max Pool Depth (ft)	1.78	1.78	1.78
Mean Pool Depth (ft)	1.21	1.21	1.21
Pool Width (ft)	6.14	6.14	6.14
Run Area (Sq ft)	0	0	0
Max Run Depth (ft)	0	0	0
Mean Run Depth (ft)	0	0	0
Run Width (ft)	0	0	0
Glide Area (Sq ft)	0	0	0
Max Glide Depth (ft)	0	0	0
Mean Glide Depth (ft)	0	0	0
Glide Width (ft)	0	0	0

Pattern Summary

Variable	Min	Avg	Max
Sinuosity	1.1		
Meander Wavelength (ft)	0	0	0
Radius of Curvature (ft)	0	0	0
Belt Width (ft)	0	0	0

Profile Summary

Data Based on the following:

Variable	Min	Avg	Max
S riffle (ft/ft)	0	0	0
S pool (ft/ft)	0	0	0

S run (ft/ft)	0	0	0
S glide (ft/ft)	0	0	0
P - P (ft)	0	0	0
Pool length (ft)	0	0	0
Riffle length (ft)	0	0	0
Dmax riffle (ft)	0	0.56	0
Dmax pool (ft)	1.78	1.78	1.78
Dmax run (ft)	0	0	0
Dmax glide (ft)	0	0	0
Low bank ht start-end (ft)	0	0	0
Bankfull slope (ft/ft)		0.0124	

Hydraulic Summary

Variable	Min	Avg	Max
Discharge (cfs)		0	
Velocity (fps)		0	
Hyd Radius (ft)	0.43	0.43	0.43

RIVERMORPH PROFILE SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland Top of SR-1 Uplift
Profile Name: Abandoned Channel
Survey Date: 10/02/2009

Survey Data

DIST	CH	WS	BKF	P1	P2	P3	P4
2	6.46						
5	6.55	5.83	5.93				
8	6.65						
11	6.75	5.95					
13	6.77	6.01	5.96				
16	6.93						
18	6.8						
21	6.87	5.95	6.4				
23	6.84						
25	6.84						
28	6.84						
30	6.87						
32	6.95						
36	7.08						
38	7.12						
40	7.14						
42	7.29						
44	7.22						
46	7.29						
48	7.33						
50	7.38						
52	7.26						
54	7.31						
56	7.37						
58	7.54						
60	7.53	6.58					
62	7.47						
64	7.45						
66	7.5						
68	7.58						
70	7.58						
72	7.67						
74	7.71						
76	7.69						
78	7.68						
80	7.62						
82	7.57						

84	7.59	
86	7.53	
88	7.66	
90	7.77	
92	8.91	7.02

Cross Section / Bank Profile Locations

Name	Type	Profile Station
Pool at 21	Pool XS	21
Riffle 142	Riffle XS	142
Abandonned Riffle at 11	Riffle XS	11
Abandonned Pool at 60	Pool XS	60

Measurements from Graph

Bankfull Slope: 0

Variable	Min	Avg	Max
S riffle	0	0	0
S pool	0	0	0
S run	0	0	0
S glide	0	0	0
P - P	0	0	0
Pool length	0	0	0
Riffle length	0	0	0
Dmax riffle	0	0	0
Dmax pool	0	0	0
Dmax run	0	0	0
Dmax glide	0	0	0
Low bank ht	0	0	0

Length and depth measurements in feet, slopes in ft/ft.

RIVERMORPH PROFILE SUMMARY

Notes

River Name: Calvert Cliffs
Reach Name: Woodland Top of SR-1 Uplift
Profile Name: Abandoned Channel
Survey Date: 10/02/2009

DIST	Note
5	l/r
13	right/left
21	left/right
92	bottom of main channel at end

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland Top of SR-1 Uplift
Cross Section Name: Abandonned Riffle at 11
Survey Date: 10/02/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	5.98	94.02	BKF
1	6.18	93.82	
1.5	6.43	93.57	
2	6.63	93.37	
2.5	6.74	93.26	
3	6.72	93.28	
3.5	6.72	93.28	
4	6.63	93.37	
5	6.48	93.52	
6	6.14	93.86	
7	5.95	94.05	
8	5.89	94.11	
9	5.94	94.06	
10	5.95	94.05	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	94.78	94.78	94.78
Bankfull Elevation (ft)	94.02	94.02	94.02
Floodprone Width (ft)	10	-----	-----
Bankfull Width (ft)	6.84	3.42	3.42
Entrenchment Ratio	1.46	-----	-----
Mean Depth (ft)	0.43	0.46	0.4
Maximum Depth (ft)	0.76	0.76	0.74
Width/Depth Ratio	15.91	7.43	8.55
Bankfull Area (sq ft)	2.95	1.58	1.38
Wetted Perimeter (ft)	7.06	4.29	4.25
Hydraulic Radius (ft)	0.42	0.37	0.32
Begin BKF Station	0	0	3.42
End BKF Station	6.84	3.42	6.84

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland Top of SR-1 Uplift
Cross Section Name: Abandonned Pool at 60
Survey Date: 10/02/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	6.97	93.03	
2	6.93	93.07	
5	6.79	93.21	
8	6.59	93.41	
10	6.59	93.41	
11	6.59	93.41	
12	6.66	93.34	BKF
14	7.26	92.74	
15	7.44	92.56	
15.5	7.46	92.54	
16	7.5	92.5	
16.5	7.5	92.5	
17	7.39	92.61	
18	6.97	93.03	
19	6.59	93.41	
20	6.42	93.58	REP

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	94.18	94.18	94.18
Bankfull Elevation (ft)	93.34	93.34	93.34
Floodprone Width (ft)	20	-----	-----
Bankfull Width (ft)	6.82	3.41	3.41
Entrenchment Ratio	2.93	-----	-----
Mean Depth (ft)	0.52	0.47	0.57
Maximum Depth (ft)	0.84	0.8	0.84
Width/Depth Ratio	13.12	7.26	5.98
Bankfull Area (sq ft)	3.55	1.61	1.94
Wetted Perimeter (ft)	7.08	4.31	4.36
Hydraulic Radius (ft)	0.5	0.37	0.45
Begin BKF Station	12	12	15.41
End BKF Station	18.82	15.41	18.82

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

SR 1 Middle Imp

Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

Stream: **Calvert Cliffs, Reach - Woodland SR-1 Middle**			
Basin:	Drainage Area: **0** acres	**0**	mi^2
Location:			
Twp.&Rge: ;	Sec.&Qtr.: ;		
Cross-Section Monuments (Lat./Long.): **0 Lat / 0 Long**		Date: **10/15/09**	
Observers:		Valley Type: IX	

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**7**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**1.01**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**7.06**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**6.93**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**1.6**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**8.5**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**1.21**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.12**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00395**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.12**	

Stream Type **G 5c** (See **Figure 2-14**)

RIVERMORPH PROFILE SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SR-1 Middle
Profile Name: Reach SR-1 Mid
Survey Date: 10/15/2009

Survey Data

DIST	CH	WS	BKF	P1	P2	P3	P4
0	8.34	8.24		5.35			
4	8.33	8.23					
8	8.36	8.26		5.09			
11	8.39	8.29					
15	8.47	8.33		5.18			
17	8.43	8.33					
19	8.46	8.36					
22	8.46	8.36		5.17			
25	8.47	8.37					
31	8.49	8.39					
34	8.54	8.44					
37	8.59	8.45					
40	8.55	8.45					
43	8.56	8.46					
45	8.56	8.46					
48	8.85	8.62					
50	8.72	8.62					
59	8.9	8.76		5.58			
62	8.9	8.76					
64	8.97	8.75					
68	8.87	8.75					
71	8.85	8.75					
73	8.9	8.8					
75	8.93	8.83					
77	8.94	8.84					
80	8.97	8.87					
83	8.97	8.87					
86	8.97	8.87	7.74	5.34			
87	9.1	8.93					
89	9.06	8.93					
91	9.03	8.93					
93	9.11	8.93					
95	9.03	8.93					
97	9.05	8.95					
101	9.09	8.99		5.68			
103	9.17	9.06					
105	9.29	9.06					

109	9.37	9.06		
113	9.16	9.06		
117	9.19	9.09		
122	9.24	9.14		
125	9.35	9.17		5.7
132	9.4	9.17		
134	9.29	9.17		
137	9.49	9.17	7.94	
139	9.64	9.17		
140	9.78	9.17		
143	9.81	9.17		5.26
148	9.51	9.17		
151	9.27	9.17		
155	9.28	9.18		
158	9.38	9.28		
162	9.39	9.29		5.59
168	9.42	9.29		
172	9.38	9.29		
178	9.32	9.29		5.67
182	9.5	9.29		
185	9.35	9.29		
188	9.37	9.3		
195	9.51	9.36		
198	9.41	9.35		
203	9.39	9.33		5.93
212	9.43	9.36		
215	9.55	9.45		
217	9.55	9.45		
220	9.57	9.47		6.23
224	9.62	9.5		
228	9.79	9.54		
231	9.6	9.53		6.62
234	9.65	9.55		
237	9.61	9.54		
241	9.61	9.54		
244	9.66	9.56		6.57
248	9.67	9.57		
252	9.67	9.57		
255	9.74	9.64		
257	9.82	9.7		

Cross Section / Bank Profile Locations

Name	Type	Profile Station
POOL AT 140	Pool XS	140
RIFFLE AT 75	Riffle XS	75

Measurements from Graph

Bankfull Slope: 0.00395

Variable	Min	Avg	Max

S riffle	0.00407	0.00733	0.00998
S pool	0	0.00044	0.00084
S run	0.00808	0.02179	0.05075
S glide	0	0.0013	0.00234
P - P	34.98	59.9	84.65
Pool length	2.67	12.11	26.17
Riffle length	10.68	18.1	41.92
Dmax riffle	1	1.2	1.36
Dmax pool	1.24	1.46	1.85
Dmax run	1.02	1.24	1.35
Dmax glide	1.21	1.37	1.53
Low bank ht	3.26	3.37	3.49

Length and depth measurements in feet, slopes in ft/ft.

RIVERMORPH PROFILE SUMMARY

Notes

River Name: Calvert Cliffs
Reach Name: Woodland SR-1 Middle
Profile Name: Reach SR-1 Mid
Survey Date: 10/15/2009

DIST	Note
0	LEFT
4	THIS REACH WAS SHOT DRY
8	RIGHT
15	LEFT
59	LEFT
75	RIFFLE SECTION HERE
86	BENCH / HIGH LEFT BANK
101	LEFT
125	LEFT
137	LEFT
140	POOL SECTION HERE
143	LEFT
162	LEFT
178	LEFT
203	LEFT
220	LEFT
231	LEFT
244	LEFT
257	END OF PROFILE

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SR-1 Middle
Cross Section Name: RIFFLE AT 75
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	5.39	94.61	LEP
1	5.51	94.49	
4	5.5	94.5	
8	5.47	94.53	
10	5.46	94.54	
11	5.28	94.72	
12	5.17	94.83	
13	5.47	94.53	
14	5.57	94.43	
15	5.59	94.41	
17	5.31	94.69	
19	5.24	94.76	
21	5.22	94.78	
22	5.49	94.51	
23	5.97	94.03	
24.5	7.14	92.86	
25	7.92	92.08	
26	8.21	91.79	
27	8.75	91.25	
28	8.95	91.05	
29	8.91	91.09	
30	8.65	91.35	
31	7.7	92.3	BKF
32	5.48	94.52	
35	5.27	94.73	
39	5.33	94.67	
44	5.39	94.61	
50	5.59	94.41	
53	5.23	94.77	
59	5.36	94.64	
61	5.33	94.67	
66	4.17	95.83	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	93.55	93.55	93.55
Bankfull Elevation (ft)	92.3	92.3	92.3
Floodprone Width (ft)	7.95	-----	-----
Bankfull Width (ft)	6.14	3.07	3.07
Entrenchment Ratio	1.29	-----	-----
Mean Depth (ft)	0.83	0.72	0.94
Maximum Depth (ft)	1.25	1.24	1.25
Width/Depth Ratio	7.4	4.26	3.27
Bankfull Area (sq ft)	5.1	2.22	2.87
Wetted Perimeter (ft)	6.87	4.62	4.72
Hydraulic Radius (ft)	0.74	0.48	0.61
Begin BKF Station	24.86	24.86	27.93
End BKF Station	31	27.93	31

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SR-1 Middle
Cross Section Name: POOL AT 140
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	5.95	94.05	LEP
3	6.14	93.86	
5	6.09	93.91	
7	5.85	94.15	
8	5.78	94.22	
9	5.86	94.14	
9.5	7.73	92.27	
10	8.21	91.79	BKF
11	8.83	91.17	
12	9.43	90.57	
13.5	9.81	90.19	
14	9.78	90.22	
15	9.39	90.61	
16	9.17	90.83	
17	8.21	91.79	
18	5.93	94.07	
19	5.74	94.26	
20	5.56	94.44	
25	5.66	94.34	
29	5.72	94.28	
35	5.59	94.41	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	93.39	93.39	93.39
Bankfull Elevation (ft)	91.79	91.79	91.79
Floodprone Width (ft)	8.5	-----	-----
Bankfull Width (ft)	7	3.5	3.5
Entrenchment Ratio	1.21	-----	-----
Mean Depth (ft)	1.01	0.96	1.06
Maximum Depth (ft)	1.6	1.6	1.6
Width/Depth Ratio	6.93	3.65	3.3

Bankfull Area (sq ft)	7.06	3.35	3.72
Wetted Perimeter (ft)	7.87	5.49	5.58
Hydraulic Radius (ft)	0.9	0.61	0.67
Begin BKF Station	10	10	13.5
End BKF Station	17	13.5	17

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH REACH SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SR-1 Middle

Stream Type	Valley Type	D50(mm)	Val Slope	BKF Q(cfs)	DA(sq mi)
G 5c	IX	0.12	0.0056	0	0

Dimension Summary

Database based on the following Cross Sections:

Variable	Min	Avg	Max
Floodprone Width (ft)	7.95	7.95	7.95
Riffle Area (Sq ft)	5.1	5.1	5.1
Max Riffle Depth (ft)	1.25	1.25	1.25
Mean Riffle Depth (ft)	0.83	0.83	0.83
Riffle Width (ft)	6.14	6.14	6.14
Pool Area (Sq ft)	7.06	7.06	7.06
Max Pool Depth (ft)	1.6	1.6	1.6
Mean Pool Depth (ft)	1.01	1.01	1.01
Pool Width (ft)	7	7	7
Run Area (Sq ft)	0	0	0
Max Run Depth (ft)	0	0	0
Mean Run Depth (ft)	0	0	0
Run Width (ft)	0	0	0
Glide Area (Sq ft)	0	0	0
Max Glide Depth (ft)	0	0	0
Mean Glide Depth (ft)	0	0	0
Glide Width (ft)	0	0	0

Pattern Summary

Variable	Min	Avg	Max
Sinuosity	1.12		
Meander Wavelength (ft)	0	0	0
Radius of Curvature (ft)	0	0	0
Belt Width (ft)	0	0	0

Profile Summary

Data Based on the following:

Variable	Min	Avg	Max
S riffle (ft/ft)	0.00407	0.00733	0.00998
S pool (ft/ft)	0	0.00044	0.00084

S run (ft/ft)	0.00808	0.02179	0.05075
S glide (ft/ft)	0	0.0013	0.00234
P - P (ft)	34.98	59.9	84.65
Pool length (ft)	2.67	12.11	26.17
Riffle length (ft)	10.68	18.1	41.92
Dmax riffle (ft)	0	1.6	0
Dmax pool (ft)	1.6	1.6	1.6
Dmax run (ft)	0	0	0
Dmax glide (ft)	0	0	0
Low bank ht start-end (ft)	3.26	3.37	3.49
Bankfull slope (ft/ft)		0.00395	

Hydraulic Summary

Variable	Min	Avg	Max
Discharge (cfs)		0	
Velocity (fps)		0	
Hyd Radius (ft)	0.74	0.74	0.74

SE 2 Imp

Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

Stream: **Calvert Cliffs, Reach - Woodland SE-2, Low SR-2**				
Basin:	Drainage Area: **0**	acres	**0**	mi^2
Location:				
Twp.&Rge: ;	Sec.&Qtr.: ;			
Cross-Section Monuments (Lat./Long.): **0 Lat / 0 Long**			Date: **12/15/09**	
Observers:			Valley Type: IX	

Parameter	Value	Unit
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**11.78**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.47**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**5.56**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**25.06**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**0.77**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**37**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**3.14**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.17**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00384**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.1**	

Stream Type → **C 5** ← (See **Figure 2-14**)

RIVERMORPH PROFILE SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SE-2, Low SR-2
Profile Name: SE-2 Reach
Survey Date: 10/06/2009

Survey Data

DIST	CH	WS	BKF	P1	P2	P3	P4
0	6.4	6.32	4.67				
3	6.4	6.33					
6	6.45	6.35	4.8				
10	6.42	6.37					
17	6.42	6.37					
20	6.42	6.37					
23	6.43	6.39	5.1				
25	6.51	6.4					
28	6.51	6.42					
31	6.49	6.43	4.64				
34	6.49	6.46					
36	6.53	6.46	4.86				
40	6.55	6.54					
45	6.59	6.58	5.16				
55	6.67	6.59		5.79			
62	6.73	6.69					
64	6.85	6.73					
67	6.8	6.73					
70	7.37	6.73					
73	7.32	6.73					
76	6.99	6.73					
79	7.44						
82	7.21		5.31	6.37			
85	6.83						
90	6.83	6.73					
93	6.81	6.73					
96	6.8	6.73					
99	6.82	6.73	5.48				
102	6.78	6.73					
107	6.87	6.8					
113	6.93	6.81					
115	7.07	6.93					
117	7.61	6.87					
120	7.18	6.87					
123	7.25	6.89					
127	7.03	6.85					
131	6.99	6.83	5.69				

136	6.99	6.88			
140	6.91	6.85			
142	6.9	6.88			
144	7.59	6.88			
148	7.09				
150	6.97	6.9			
154	6.95	6.92	5.96		
165	7.04	6.96			
172	7.06	6.96			
177	7.08	6.99			
183	7.11	7.04			
189	7.14	7.08	6.15		
193	7.13	7.1			
197	7.3	7.12			
200	7.68	7.12			
203	7.72	7.12	6.13		
219	7.29	7.21			
225	7.32	7.25		6.37	
227	7.55	7.26			
231	8.11	7.26			
238	7.56	7.21			
240	7.27	7.2			
245	7.24	7.2			
253	7.6	7.24			
256	7.38	7.26			
265	5.89	5.86	4.95		
270	5.95	5.89			
275	5.98	5.91			
279	6	5.91			
286	5.97	5.92			
292	6.03	5.96			
300	6.05	5.93			
311	6.05	5.99	5.15	5.72	
321	6.13	6.07			
328	6.15	6.09	5.42	5.25	
333	6.19	6.17			
337	6.23	6.17			
343	6.25	6.17			
350	6.25	6.19	5.62	5.53	
356	6.29	6.26			
365	6.34	6.29	5.68	5.72	
372	6.41	6.35	5.84		
377	6.45	6.37			
381	6.49	6.43			
386	6.52	6.44	5.94		5.51
395	6.57	6.53	6.02		6.52
400	6.66	6.57	5.57	6.07	5.55
407	6.79	6.69	5.75	6.2	5.58
415	6.88	6.73	5.86		
421	6.89	6.83			
425	7.01	6.87	6.32		

Cross Section / Bank Profile Locations

Name	Type	Profile Station
Entr Riffle at 14	Riffle XS	14
Entr Pool at 73	Pool XS	73
Glide at 208.5	Glide XS	208.5
Pool at 233	Riffle XS	233
Run at 249	Run XS	249
Riffle at 300	Riffle XS	300

Measurements from Graph

Bankfull Slope: 0.00384

Variable	Min	Avg	Max
S riffle	0.00354	0.0048	0.00643
S pool	0	0.00205	0.0025
S run	0.00602	0.00995	0.01606
S glide	0.00281	0.00468	0.00562
P - P	26.26	40.95	60.08
Pool length	8.9	16.29	24.92
Riffle length	21.81	34.72	47.18
Dmax riffle	0.65	1.05	1.39
Dmax pool	1.22	1.72	2.1
Dmax run	1.19	1.34	1.47
Dmax glide	0.92	1.24	1.46
Low bank ht	0.6	1	1.45

Length and depth measurements in feet, slopes in ft/ft.

RIVERMORPH PROFILE SUMMARY

Notes

River Name: Calvert Cliffs
Reach Name: Woodland SE-2, Low SR-2
Profile Name: SE-2 Reach
Survey Date: 10/06/2009

DIST	Note
0	right
6	right
23	right
31	right
36	right
45	right
55	r bank bench
62	log
82	6.37 = top of bar
99	right
131	left

142	log
154	left
189	left
203	left
225	top of point bar
265	left
337	big tree
386	high bank
395	high bank
415	block failure right bank

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SE-2, Low SR-2
Cross Section Name: Entr Riffle at 14
Survey Date: 10/14/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	4.52	95.48	lep
2	4.8	95.2	
3	5.03	94.97	
4	5.29	94.71	BKF
4.5	5.73	94.27	
5	6.38	93.62	
5.2	6.46	93.54	
5.8	6.36	93.64	lew
7	6.32	93.68	
9	6.15	93.85	
10	6.12	93.88	
10.5	5.48	94.52	
11	5.08	94.92	
11.5	4.98	95.02	
13	4.9	95.1	
15	4.9	95.1	
16	4.52	95.48	
17	4.32	95.68	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	95.88	95.88	95.88
Bankfull Elevation (ft)	94.71	94.71	94.71
Floodprone Width (ft)	17	-----	-----
Bankfull Width (ft)	6.74	3.37	3.37
Entrenchment Ratio	2.52	-----	-----
Mean Depth (ft)	0.84	0.9	0.78
Maximum Depth (ft)	1.17	1.17	1
Width/Depth Ratio	8.02	3.74	4.32
Bankfull Area (sq ft)	5.66	3.03	2.64
Wetted Perimeter (ft)	7.63	4.88	4.75
Hydraulic Radius (ft)	0.74	0.62	0.56

Begin BKF Station	4	4	7.37
End BKF Station	10.74	7.37	10.74

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SE-2, Low SR-2
Cross Section Name: Entr Pool at 73
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	4.5	95.5	LEP
3	4.62	95.38	
4	4.75	95.25	
6	5.2	94.8	
6.5	6.7	93.3	
7	6.88	93.12	
8	7.02	92.98	
9	7.22	92.78	
10	7.46	92.54	
11	7.29	92.71	
12	6.93	93.07	
12.5	6.7	93.3	REW
13	6	94	BKF
13.4	5.95	94.05	
14	5.32	94.68	
15	5.18	94.82	
17	5.18	94.82	
18	5.34	94.66	
21	5.01	94.99	
24	4.6	95.4	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	95.46	95.46	95.46
Bankfull Elevation (ft)	94	94	94
Floodprone Width (ft)	23	-----	-----
Bankfull Width (ft)	6.73	3.36	3.37
Entrenchment Ratio	3.42	-----	-----
Mean Depth (ft)	1.03	1	1.07
Maximum Depth (ft)	1.46	1.37	1.46
Width/Depth Ratio	6.53	3.36	3.15
Bankfull Area (sq ft)	6.95	3.36	3.59

Wetted Perimeter (ft)	7.82	5.32	5.24
Hydraulic Radius (ft)	0.89	0.63	0.69
Begin BKF Station	6.27	6.27	9.63
End BKF Station	13	9.63	13

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SE-2, Low SR-2
Cross Section Name: Run at 249
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 93.66 ft
Backsight Rod Reading: 4.93 ft

TAPE	FS	ELEV	NOTE
0	4.97	93.62	LEP
1	5.07	93.52	
2	5.26	93.33	
3	5.51	93.08	
3.4	5.83	92.76	LEW
4	5.86	92.73	
5	5.75	92.84	
6	5.54	93.05	
7	5.58	93.01	
8	5.61	92.98	
9	5.75	92.84	
10	5.69	92.9	
11	5.58	93.01	
12	5.51	93.08	
13	5.36	93.23	
15	5.32	93.27	
18	5.23	93.36	
21	5.19	93.4	
25	5.18	93.41	BKF
29	4.97	93.62	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	94.09	94.09	94.09
Bankfull Elevation (ft)	93.41	93.41	93.41
Floodprone Width (ft)	29	-----	-----
Bankfull Width (ft)	23.42	11.71	11.71
Entrenchment Ratio	1.24	-----	-----
Mean Depth (ft)	0.24	0.42	0.06
Maximum Depth (ft)	0.68	0.68	0.17
Width/Depth Ratio	97.58	27.88	195.17
Bankfull Area (sq ft)	5.53	4.87	0.66

Wetted Perimeter (ft)	23.63	12.1	11.89
Hydraulic Radius (ft)	0.23	0.4	0.06
Begin BKF Station	1.58	1.58	13.29
End BKF Station	25	13.29	25

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SE-2, Low SR-2
Cross Section Name: Glide at 208.5
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 93.66 ft
Backsight Rod Reading: 4.93 ft

TAPE	FS	ELEV	NOTE
0	4.93	93.66	LEP
2	4.74	93.85	
3	4.85	93.74	
4	5.08	93.51	
5	5.35	93.24	
6	5.16	93.43	
7	5.38	93.21	
8	5.51	93.08	
8.5	5.63	92.96	LEW
9	5.68	92.91	
10	5.69	92.9	
11	5.63	92.96	
12	5.49	93.1	
13	5.4	93.19	
14	5.35	93.24	
15	5.51	93.08	
16	5.45	93.14	
16.5	5.08	93.51	BKF
18	4.76	93.83	
20	4.65	93.94	
27	4.65	93.94	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	94.12	94.12	94.12
Bankfull Elevation (ft)	93.51	93.51	93.51
Floodprone Width (ft)	27	-----	-----
Bankfull Width (ft)	12.5	6.25	6.25
Entrenchment Ratio	2.16	-----	-----
Mean Depth (ft)	0.37	0.34	0.39
Maximum Depth (ft)	0.61	0.61	0.59
Width/Depth Ratio	33.78	18.38	16.03

Bankfull Area (sq ft)	4.57	2.15	2.41
Wetted Perimeter (ft)	12.76	6.95	7
Hydraulic Radius (ft)	0.36	0.31	0.34
Begin BKF Station	4	4	10.25
End BKF Station	16.5	10.25	16.5

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SE-2, Low SR-2
Cross Section Name: Riffle at 300
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 93.66 ft
Backsight Rod Reading: 4.93 ft

TAPE	FS	ELEV	NOTE
0	5.13	93.46	LEP
2	5.24	93.35	
3	5.21	93.38	
4	5.27	93.32	BKF
4.2	5.64	92.95	
5	5.93	92.66	LEW.
6.2	6.04	92.55	
7	5.97	92.62	
8	5.96	92.63	
9	5.81	92.78	
11	5:76	92.83	
13	5.68	92.91	
14	5.43	93.16	
16	5.25	93.34	
17	5.29	93.3	
19	5.58	93.01	
20	5.72	92.87	
21	5.82	92.77	
22	5.72	92.87	
23	5.46	93.13	
24	5.3	93.29	
26	5.37	93.22	
28	5.46	93.13	
31	5.27	93.32	
34	5.09	93.5	
37	4.92	93.67	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	94.09	94.09	94.09
Bankfull Elevation (ft)	93.32	93.32	93.32
Floodprone Width (ft)	37	-----	-----

Bankfull Width (ft)	11.78	5.71	6.07
Entrenchment Ratio	3.14	-----	-----
Mean Depth (ft)	0.47	0.63	0.33
Maximum Depth (ft)	0.77	0.77	0.52
Width/Depth Ratio	25.06	9.06	18.39
Bankfull Area (sq ft)	5.56	3.58	1.98
Wetted Perimeter (ft)	12.11	6.52	6.63
Hydraulic Radius (ft)	0.46	0.55	0.3
Begin BKF Station	4	4	9.71
End BKF Station	15.78	9.71	15.78

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Woodland SE-2, Low SR-2
Cross Section Name: Pool at 233
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 93.66 ft
Backsight Rod Reading: 4.93 ft

TAPE	FS	ELEV	NOTE
0	4.93	93.66	LEP
2	4.91	93.68	
5	4.88	93.71	
6	4.93	93.66	
7	5.38	93.21	
8	5.7	92.89	LEW
9	6.15	92.44	
10	6.42	92.17	
11	6.28	92.31	
12	6.31	92.28	
13	5.98	92.61	
13.5	5.17	93.42	BKF
18	4.95	93.64	
25	4.85	93.74	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	94.67	94.67	94.67
Bankfull Elevation (ft)	93.42	93.42	93.42
Floodprone Width (ft)	25	-----	-----
Bankfull Width (ft)	6.97	3.49	3.48
Entrenchment Ratio	3.59	-----	-----
Mean Depth (ft)	0.83	0.66	0.99
Maximum Depth (ft)	1.25	1.25	1.25
Width/Depth Ratio	8.4	5.29	3.52
Bankfull Area (sq ft)	5.77	2.31	3.46
Wetted Perimeter (ft)	7.71	4.96	5.24
Hydraulic Radius (ft)	0.75	0.47	0.66
Begin BKF Station	6.53	6.53	10.02
End BKF Station	13.5	10.02	13.5

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

SR 3 Lower Imp

Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

Stream: **Calvert Cliffs, Reach - SR-3 Lower Reach**			
Basin:	Drainage Area: **27.52** acres	**0.043**	mi^2
Location:			
Twp.&Rge: ;	Sec.&Qtr.: ;		
Cross-Section Monuments (Lat./Long.): **0 Lat / 0 Long**		Date: **10/06/09**	
Observers:		Valley Type: VIII	

Parameter	Value	Units
Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**8.53**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.72**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**6.14**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**11.85**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**0.88**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**17.14**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**2.01**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**9.65**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00843**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.1**	

Stream Type → **B 4c** ← (See **Figure 2-14**)

RIVERMORPH PROFILE SUMMARY

River Name: Calvert Cliffs
Reach Name: SR-3 Lower Reach
Profile Name: Lower
Survey Date: 10/05/2009

Survey Data

DIST	CH	WS	BKF	P1	TOB	P3	P4
0	5.1	4.86					
3	5.1	4.86					
8	5.1	4.85	3.73				
13	5.08	4.92					
20	5.08	4.97					
22		4.21					
25	5.37	4.98					
30	5.48	5.04					
33	5.44	5.08					
37	5.28	5.09					
41	5.26	5.11	4.57	2.23			
46	5.39	5.16					
51	5.46	5.26					
55	5.39	5.3	4.47	2.5			
57	5.82	5.42					
63	5.93	5.42					
77	5.62	5.42					
81	5.57	5.44					
88	5.63	5.47					
93	5.6	5.47					
96	5.56	5.47	4.61				
100	5.64	5.47					
107	5.66	5.59					
108		4.82	3.69				
114	5.72	5.59					
120		5.02	4.21				
121	5.8	5.67					
127	5.86	5.73					
133	5.94	5.78					
136		5.22	4.31	3.77			
138	6.21	5.79					
143	6.06	5.81					
149	5.94	5.78					
153	5.99	5.89	3.66				
157	6.07	5.91	4.67				
160	6.12	5.92					
165	6.07	5.92					

171	6.17	6.12			
171.3	6.82				
172	6.84	6.46			
178	6.88	6.45			
189	7.05	6.45			
194	6.96	6.46			
201	6.75	6.52			
205	6.63	6.5	5.92	3.59	3.3
212	6.64	6.5			
220	6.73	6.62			
226	6.85	6.72			
233	6.96	6.77	5.92	3.73	

Cross Section / Bank Profile Locations

Name	Type	Profile Station
Riffle at 96	Riffle XS	0
Pool at ~172	Pool XS	0

Measurements from Graph

Bankfull Slope: 0.00843

Variable	Min	Avg	Max
S riffle	0.00243	0.00906	0.01497
S pool	0	0.00485	0.01453
S run	0.00657	0.03665	0.07862
S glide	0.0025	0.00625	0.00946
P - P	33.64	53.09	74.62
Pool length	6.91	14.31	22.72
Riffle length	8.24	17.43	33.64
Dmax riffle	0.73	0.87	1
Dmax pool	1.03	1.26	1.45
Dmax run	0.71	0.85	0.96
Dmax glide	0.74	0.94	1.04
Low bank ht	0.73	0.87	1

Length and depth measurements in feet, slopes in ft/ft.

RIVERMORPH PROFILE SUMMARY

Notes

River Name: Calvert Cliffs
Reach Name: SR-3 Lower Reach
Profile Name: Lower
Survey Date: 10/05/2009

DIST Note

8	small log
22	right bank
41	left/right
46	start eel habitat
96	RIGHT BANK
108	LEFT/RIGHT
120	LEFT/RIGHT
127	lod at 129
157	RIGHT/LEFT
171	log present
205	tob l/r
233	l/l fence

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: SR-3 Lower Reach
Cross Section Name: Riffle at 96
Survey Date: 10/06/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	2.67	97.33	LEP
3	3.02	96.98	
5	3.72	96.28	
7	4	96	
9	4.02	95.98	
9	4.44	95.56	
11	4.57	95.43	
13	4.68	95.32	BKF
14	5.21	94.79	
14.5	5.45	94.55	LEW
15	5.5	94.5	
17	5.56	94.44	
19	5.49	94.51	
21	5.43	94.57	REW
22	4.02	95.98	
35	0	100	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	96.2	96.2	96.2
Bankfull Elevation (ft)	95.32	95.32	95.32
Floodprone Width (ft)	17.14	-----	-----
Bankfull Width (ft)	8.53	4.27	4.26
Entrenchment Ratio	2.01	-----	-----
Mean Depth (ft)	0.72	0.68	0.75
Maximum Depth (ft)	0.88	0.88	0.87
Width/Depth Ratio	11.85	6.28	5.68
Bankfull Area (sq ft)	6.14	2.92	3.21
Wetted Perimeter (ft)	9.11	5.33	5.52
Hydraulic Radius (ft)	0.67	0.55	0.58
Begin BKF Station	13	13	17.27
End BKF Station	21.53	17.27	21.53

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: SR-3 Lower Reach
Cross Section Name: Pool at ~172
Survey Date: 10/06/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	1.83	98.17	LEP
2	2.92	97.08	
5	6.47	93.53	LEW
6	7.02	92.98	
7	6.86	93.14	
8	6.73	93.27	
9	6.47	93.53	
10	6.02	93.98	
12	5.59	94.41	BKF
13	5.2	94.8	
19	3.07	96.93	
27	2.4	97.6	
30	1.6	98.4	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	95.84	95.84	95.84
Bankfull Elevation (ft)	94.41	94.41	94.41
Floodprone Width (ft)	12.88	-----	-----
Bankfull Width (ft)	7.74	3.87	3.87
Entrenchment Ratio	1.66	-----	-----
Mean Depth (ft)	0.79	1.08	0.5
Maximum Depth (ft)	1.43	1.43	1.11
Width/Depth Ratio	9.8	3.58	7.74
Bankfull Area (sq ft)	6.13	4.18	1.95
Wetted Perimeter (ft)	8.49	5.56	5.15
Hydraulic Radius (ft)	0.72	0.75	0.38
Begin BKF Station	4.26	4.26	8.13
End BKF Station	12	8.13	12

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

SR 3 Lower Imp

Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

Stream: **Calvert Cliffs, Reach - SR-3 Upper Reach**				
Basin:	Drainage Area:	**0** acres	**0**	mi^2
Location:				
Twp.&Rge: ;	Sec.&Qtr.: ;			
Cross-Section Monuments (Lat./Long.): **0 Lat / 0 Long**			Date: **10/05/09**	
Observers:			Valley Type: IV	

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**7.42**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.95**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**7.02**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**7.81**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**1.23**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**10.19**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**1.37**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**8**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.01606**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.1**	

Stream Type **G 4/1c** (See **Figure 2-14**)

RIVERMORPH PROFILE SUMMARY

River Name: Calvert Cliffs
Reach Name: SR-3 Upper Reach
Profile Name: Upper SR-3
Survey Date: 10/05/2009

Survey Data

DIST	CH	WS	BKF	P1	P2	P3	P4
0	3.65	3.53					
4	3.68	3.63					
6	3.74	3.63					
8	3.74	3.68					
10	4.21	4.04					
13	4.4	4.15					
15	4.22	4.13					
17	4.4	4.14					
20	4.33	4.17					
24	4.52	4.29					
26			3.87				
27	4.62						
29	4.55	4.33					
30		4.33					
32	4.47	4.33					
34	4.38	4.33					
37	4.55	4.33					
41	4.58	4.48					
45	4.73	4.48					
52	4.54	4.44					
57	4.68	4.47					
62	4.65	4.48					
66	4.65	4.48					
73	4.62	4.48					
77	4.57	4.48					
82	4.65	4.56					
83	5.45	5.23					
85	5.45	5.26					
88	5.48	5.4					
90	6.42	6.26					
93	7.56	7.44					
96		7.44	6.26				
98	8.02	7.44					
104	8.06	7.47					
108	7.74	7.48					
110			6.88	7.13			
114	7.59	7.49					

118	7.63	7.49	6.31
124	7.78	7.57	6.18
127	7.74	7.58	6.34
132			6.65
136	7.79	7.63	6.74
143	7.79	7.65	6.5
148	8	7.77	
155	8.16	7.91	
158	8.09	7.94	
162	8.56	8.24	
165	8.64	8.28	
171	8.54	8.4	
175	8.96	8.52	
178	8.82	8.54	
182	9.03	8.87	
185	9.37	9.15	

Cross Section / Bank Profile Locations

Name	Type	Profile Station
XS Pool Upper 104	Pool XS	104
XS Riffle Top 127	Riffle XS	127

Measurements from Graph

Bankfull Slope: 0.01606

Variable	Min	Avg	Max
S riffle	0.00059	0.00351	0.00642
S pool	0.00198	0.00432	0.00803
S run	0.02944	0.09676	0.24944
S glide	0.00321	0.00446	0.00642
P - P	2.67	22.21	61.24
Pool length	2.49	7	15.13
Riffle length	17.09	21.01	24.92
Dmax riffle	1.28	1.32	1.35
Dmax pool	0.74	1.07	1.69
Dmax run	1.7	1.7	1.7
Dmax glide	1.32	1.51	1.7
Low bank ht	3.16	4.39	5.61

Length and depth measurements in feet, slopes in ft/ft.

RIVERMORPH PROFILE SUMMARY

Notes

River Name: Calvert Cliffs
Reach Name: SR-3 Upper Reach
Profile Name: Upper SR-3

Survey Date: 10/05/2009

DIST	Note
13	mid pool
30	LOD
90	shell layer elevation
96	begin shell layer
104	pool section here
110	top point bar / bench
118	bench
124	bench
127	riffle section
132	top of shells
143	left

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: SR-3 Upper Reach
Cross Section Name: XS Riffle Top 127
Survey Date: 10/05/2009

Cross Section Data Entry

BM Elevation: 100 ft
Backsight Rod Reading: 3.2 ft

TAPE	FS	ELEV	NOTE
0	2.23	100.97	LEP
6	3.43	99.77	
8	4.65	98.55	
10	6.98	96.22	
11.5	9.44	93.76	BNKPN
13	9.73	93.47	BKF
14	10.68	92.52	
15	10.76	92.44	LEW
16	10.81	92.39	
18	10.96	92.24	
19	10.84	92.36	REW
19.5	10.78	92.42	
20.5	9.64	93.56	TOP OF SHELLS
24	3.14	100.06	
26	2.45	100.75	
29	1.82	101.38	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	94.7	94.7	94.7
Bankfull Elevation (ft)	93.47	93.47	93.47
Floodprone Width (ft)	10.19	-----	-----
Bankfull Width (ft)	7.42	3.77	3.65
Entrenchment Ratio	1.37	-----	-----
Mean Depth (ft)	0.95	0.89	1
Maximum Depth (ft)	1.23	1.14	1.23
Width/Depth Ratio	7.81	4.24	3.65
Bankfull Area (sq ft)	7.02	3.37	3.65
Wetted Perimeter (ft)	8.3	5.29	5.28
Hydraulic Radius (ft)	0.85	0.64	0.69
Begin BKF Station	13	13	16.77
End BKF Station	20.42	16.77	20.42

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: SR-3 Upper Reach
Cross Section Name: XS Pool Upper 104
Survey Date: 10/05/2009

Cross Section Data Entry

BM Elevation: 100 ft
Backsight Rod Reading: 3.19 ft

TAPE	FS	ELEV	NOTE
0	1.91	101.28	LEP
5	2.65	100.54	
6	3.03	100.16	
7	3.45	99.74	
8	6.87	96.32	
8.5	8.58	94.61	top of shells
9.5	10.69	92.5	lew
11	10.84	92.35	
12	11.15	92.04	
13	11.29	91.9	
14.5	11.13	92.06	
16	10.72	92.47	
18	10.64	92.55	rew
18.5	10.42	92.77	
19	9.66	93.53	BKF - top of shells
22	2.78	100.41	
25	1.55	101.64	
27	0.07	103.12	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	95.16	95.16	95.16
Bankfull Elevation (ft)	93.53	93.53	93.53
Floodprone Width (ft)	11.37	-----	-----
Bankfull Width (ft)	9.99	4.24	5.75
Entrenchment Ratio	1.14	-----	-----
Mean Depth (ft)	1.17	1.23	1.13
Maximum Depth (ft)	1.63	1.63	1.6
Width/Depth Ratio	8.54	3.45	5.09
Bankfull Area (sq ft)	11.69	5.21	6.48
Wetted Perimeter (ft)	11.23	6.56	7.87
Hydraulic Radius (ft)	1.04	0.79	0.82

Begin BKF Station	9.01	9.01	13.25
End BKF Station	19	13.25	19

Entrainment Calculations

Entrainment Formula: Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

SE 4 Lower Imp

RIVERMORPH PROFILE SUMMARY

River Name: Calvert Cliffs
Reach Name: Bay SE-4 Bottom
Profile Name: Headcut to Beach
Survey Date: 09/23/2009

Survey Data

DIST	CH	WS	BKF	P1	P2	P3	P4
0	8.65	8.2					
9	8.78						
16	8.8	8.35					
23	9.06	8.3					
30	8.95						
49	9.1	8.65					
58	9.48						
62	9.74						
69	10.7						
70	14.8						
78	14.53						
85	15.04						
90	15.64						
103	16.1						
112	16.5						
120	17.78						
135	18.52						
142	18.72						
148	18.83						
156	20.25						
169	21.95						
172	23.22						
175	27.2						
185	28.41						

Cross Section / Bank Profile Locations

Name	Type	Profile Station
XS-3 @ 0+75	Riffle XS	0

Measurements from Graph

Bankfull Slope: 0

Variable Min Avg Max

S riffle	0	0	0
S pool	0	0	0
S run	0	0	0
S glide	0	0	0
P - P	0	0	0
Pool length	0	0	0
Riffle length	0	0	0
Dmax riffle	0	0	0
Dmax pool	0	0	0
Dmax run	0	0	0
Dmax glide	0	0	0
Low bank ht	0	0	0

Length and depth measurements in feet, slopes in ft/ft.

RIVERMORPH PROFILE SUMMARY

Notes

River Name: Calvert Cliffs
Reach Name: Bay SE-4 Bottom
Profile Name: Headcut to Beach
Survey Date: 09/23/2009

DIST	Note
0	theo bkf
16	right tob
23	right tob
30	channel is 5' wide here
49	theo bkf
175	upper beach elevation
185	beach added in office

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Bay SE-4 Bottom
Cross Section Name: XS-3 @ 0+75
Survey Date: 09/23/2009

Cross Section Data Entry

BM Elevation: 96.41 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	5.54	90.87	
7	6.06	90.35	
18	7.4	89.01	
20	8.3	88.11	
21	11.8	84.61	
23.2	14.15	82.26	
26	14.4	82.01	
29	14.08	82.33	
30.5	12.43	83.98	
31	8.43	87.98	
37	7.38	89.03	
43	5.15	91.26	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	99.99	99.99	99.99
Bankfull Elevation (ft)	91	91	91
Floodprone Width (ft)	43	-----	-----
Bankfull Width (ft)	42.3	21.15	21.15
Entrenchment Ratio	1.02	-----	-----
Mean Depth (ft)	3.05	1.31	4.8
Maximum Depth (ft)	8.99	6.55	8.99
Width/Depth Ratio	13.87	16.15	4.41
Bankfull Area (sq ft)	129.19	27.74	101.45
Wetted Perimeter (ft)	51.12	30.83	33.38
Hydraulic Radius (ft)	2.53	0.9	3.04
Begin BKF Station	0	0	21.15
End BKF Station	42.3	21.15	42.3

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

SE 4 Upper Imp

Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

Stream:	**Calvert Cliffs, Reach - Bay SE-4 Top**			
Basin:	**SE-4**	Drainage Area: **70.4** acres	**0.11**	mi^2
Location:				
Twp.&Rge: ;		Sec.&Qtr.: ;		
Cross-Section Monuments (Lat./Long.):	**0 Lat / 0 Long**		Date: **09/15/09**	
Observers:			Valley Type: VIII	

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**2.38**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.42**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**1.01**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**5.67**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**0.56**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**4.24**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**1.78**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.19**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.01178**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.1**	

Stream Type → **B 5c** ← (See **Figure 2-14**)

RIVERMORPH PROFILE SUMMARY

River Name: Calvert Cliffs
Reach Name: Bay SE-4 Top
Profile Name: Top
Survey Date: 09/16/2009

Survey Data

DIST	CH	WS	BKF	P1	P2	P3	P4
0	7.32	7.32					
4	7.35		6.39				
6	7.27						
10	7.37						
14	7.41		6.69				
19	7.52						
25	7.55						
27			5.87				
35	7.78						
42	7.91						
46	7.89						
51	7.96						
56	8.19	7.34					
59	8.25						
62	8.24						
65	8.3						
74	8.34						
78	8.34	7.66					
83	8.41						
88	8.47	7.78					
92	8.69						
97	8.88						
101	8.74						
104	8.74						
108	8.88	8.16					
113	9.02						
119	9.27	8.36					
125	9.36						
131	9.4						
137	9.47		6.99				
141	9.39						
148	9.7						
153	9.75	8.93	7				
162	9.69						
167	9.73						
171	9.71	8.9					
179	9.79						

186	9.95		
189	10		
193	10.03	9.14	7.89
199	10.1		
205	10.19		
209	10.21	9.51	
215	10.42		
219	10.34		8.75
226	10.3		
231	10.43	9.57	
237	10.45		
240	10.5		
242	10.47		
244	10.61		
250	10.71		8.7
256	10.72		
261	10.81		
264	10.99		
269	11		
274	11.07		
278		9.77	
284	11.24		
289	11.15		
292	11.32		
296		10.27	
330	11.37		

Cross Section / Bank Profile Locations

Name	Type	Profile Station
Riffle 231	Riffle XS	0
Pool 219	Pool XS	0

Measurements from Graph

Bankfull Slope: 0

Variable	Min	Avg	Max
S riffle	0	0	0
S pool	0	0	0
S run	0	0	0
S glide	0	0	0
P - P	0	0	0
Pool length	0	0	0
Riffle length	0	0	0
Dmax riffle	0	0	0
Dmax pool	0	0	0
Dmax run	0	0	0
Dmax glide	0	0	0
Low bank ht	0	0	0

Length and depth measurements in feet, slopes in ft/ft.

RIVERMORPH PROFILE SUMMARY

Notes

River Name: Calvert Cliffs
Reach Name: Bay SE-4 Top
Profile Name: Top
Survey Date: 09/16/2009

DIST	Note
4	tob left
14	bench
27	tob right
51	pool
56	bench
62	riffle
65	riffle
78	bench
92	log
108	bench
137	left bank
153	tob right
215	p
231	r
242	run
244	run

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Bay SE-4 Top
Cross Section Name: Riffle 231
Survey Date: 09/23/2009

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	100	
0	8.4	91.6	LEP
3	8.72	91.28	
8	8.79	91.21	
10	8.98	91.02	
11	9.21	90.79	
11.5	9.35	90.65	
11.7	10.25	89.75	
12.2	10.36	89.64	
13	10.44	89.56	TW
13.6	10.28	89.72	
14	9.88	90.12	BKF
14.6	9.63	90.37	
16	9.21	90.79	
29	8.1	91.9	
50	0	100	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	90.68	90.68	90.68
Bankfull Elevation (ft)	90.12	90.12	90.12
Floodprone Width (ft)	4.24	-----	-----
Bankfull Width (ft)	2.38	1.19	1.19
Entrenchment Ratio	1.78	-----	-----
Mean Depth (ft)	0.42	0.45	0.4
Maximum Depth (ft)	0.56	0.54	0.56
Width/Depth Ratio	5.67	2.64	2.97
Bankfull Area (sq ft)	1.01	0.54	0.47
Wetted Perimeter (ft)	2.88	2.05	1.92
Hydraulic Radius (ft)	0.35	0.26	0.25
Begin BKF Station	11.62	11.62	12.81
End BKF Station	14	12.81	14

Entrainment Calculations

Entrainment Formula: Shields Curve

	Channel	Left Side	Right Side
Slope	0.01178	0	0
Shear Stress (lb/sq ft)	0.26		
Movable Particle (mm)	14.2		

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Bay SE-4 Top
Cross Section Name: Pool 219
Survey Date: 09/23/2009

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	8.4	91.6	LEP
4	8.5	91.5	
9	8.3	91.7	
13	8.64	91.36	
14	8.9	91.1	
14.5	9.1	90.9	BKF
15.7	10.11	89.89	
16.4	10.29	89.71	
17	10.31	89.69	
17.4	10.31	89.69	TW
18	10.27	89.73	
18.2	9.29	90.71	
19	8.76	91.24	
24	8.5	91.5	
34	8.4	91.6	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	92.11	92.11	92.11
Bankfull Elevation (ft)	90.9	90.9	90.9
Floodprone Width (ft)	34	-----	-----
Bankfull Width (ft)	3.99	1.99	2
Entrenchment Ratio	8.53	-----	-----
Mean Depth (ft)	0.87	0.75	0.99
Maximum Depth (ft)	1.21	1.19	1.21
Width/Depth Ratio	4.59	2.65	2.02
Bankfull Area (sq ft)	3.46	1.48	1.97
Wetted Perimeter (ft)	5.24	3.57	4.05
Hydraulic Radius (ft)	0.66	0.41	0.49
Begin BKF Station	14.5	14.5	16.49
End BKF Station	18.49	16.49	18.49

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

SR 4 Imp

Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

Stream: **Calvert Cliffs, Reach - Johns SR-4**			
Basin:	Drainage Area: **0** acres	**0** mi^2	
Location:			
Twp.&Rge: ;	Sec.&Qtr.: ;		
Cross-Section Monuments (Lat./Long.): **0 Lat / 0 Long**		Date: **10/15/09**	
Observers:		Valley Type: IX	

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**8.5**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.58**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**4.96**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**14.66**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**1.09**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or ($2 \times d_{mbkf}$) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**25**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**2.94**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.23**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.0054**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.54**	

Stream Type	**C 5**	(See **Figure 2-14**)

RIVERMORPH PROFILE SUMMARY

River Name: Calvert Cliffs
Reach Name: Johns SR-4
Profile Name: Reference
Survey Date: 11/02/2009

Survey Data

DIST	CH	WS	BKF	P1	P2	P3	P4
0	6.61	6.37		6.25			
3	6.42	6.37	5.72				
5	6.4	6.38	5.49				
9	6.45	6.39	5.71				
11	6.53	6.41					
13	6.56	6.43	5.28		5.78		
15	6.6	6.42					
18	6.68	6.42					
21	6.53	6.43	5.62				
24	6.47	6.44	5.62				
26	6.65	6.49					
29	6.59	6.51					
31	6.75	6.61					
32	6.89	6.67					
35	6.98	6.71	6.04				
37	7.29	6.68					
39	7.78	6.68					
41	7.73	6.68					
42	7.45	6.68					
43	7.15	6.69	6.03				
45	7.01	6.69					
47	6.78	6.7					
48	6.88	6.71					
50	7	6.79					
51	7.73	6.79					
52	7.75	6.79					
53	7.21	6.79					
57	7.23	6.78	5.98		5.98		
60	7.15						
62	7.13						
64	7.11		5.81		6.14		
65	7.03	6.78					
67	6.89	6.78					
69	6.94		5.94				
70	7.2						
71	7.53						
72	7.3						

74	7.03	6.79	6.07	6.63
77	7.02			
79	7.02		5.63	
82	6.95	6.79		
84	6.93			
85	7.12		6.07	
88	7.09	6.79		
91	6.97		5.79	
94	6.89	6.79		
100	6.88	6.8	5.82	
103	6.99	6.81		
107	6.97	6.85		
110	7.02	6.87	6.19	
115	6.99	6.86	5.83	
118	6.95	6.86		
120	7.15	6.89		
121	7.24	6.99		
122	7.31			
125	7.12		6.13	
129	7.02	6.97		
130	7.13	6.99		
131	7.29	7.04		
132	7.42			
134	7.25			
135	7.19	7.01		
138	7.15	7.02	6.28	
140	7.26		6.22	
144	7.18	7.03		
147	7.1	7.04		
150	7.39	7.1		
152	7.24	7.11		
155	7.31	7.13		
156	7.47	7.25		
158	7.56	7.27		
160	7.71		6.26	
161	7.58	7.29		
163	7.34	7.29		
165	7.41		6.7	
167	7.4	7.29		
170			6.52	
173	7.38	7.31		
174	7.52	7.37		
178	7.5	7.39		
180	7.45		6.76	

Cross Section / Bank Profile Locations

Name	Type	Profile Station
Pool at 38	Pool XS	38
Glide at 44	Glide XS	44
Valley Run at 49	Run XS	49
Riffle at 100	Riffle XS	100
Riffle at 220	Riffle XS	220

Pool at 238	Pool XS	238	
Riffle Valley 100	Riffle XS	0	

Measurements from Graph

Bankfull Slope: 0.0054

Variable	Min	Avg	Max
S riffle	0.00135	0.00514	0.00945
S pool	0	0.00156	0.00559
S run	0.02651	0.05206	0.12129
S glide	0.00149	0.00322	0.00496
P - P	10.37	20.23	35.53
Pool length	3.41	10.35	16.34
Riffle length	3.13	7.5	10.23
Dmax riffle	0.81	0.9	1.02
Dmax pool	1.02	1.53	2.03
Dmax run	0.83	0.99	1.16
Dmax glide	0.87	1.02	1.23
Low bank ht	0.83	0.89	0.97

Length and depth measurements in feet, slopes in ft/ft.

RIVERMORPH PROFILE SUMMARY

Notes

River Name: Calvert Cliffs
Reach Name: Johns SR-4
Profile Name: Reference
Survey Date: 11/02/2009

DIST	Note
0	GLIDE
3	RIGHT
5	LEFT
9	RIGHT
13	GLIDE
21	RIGHT
24	RIGHT
35	RIGHT
37	POOL
39	POOL SECTION
45	GLIDE SECTION
48	RUN SECTION
79	LEFT
91	RIGHT
100	RIGHT
110	RIFFLE SECTION
125	LEFT

140	LEFT
160	RIGHT
180	RIGHT

RIVERMORPH PROFILE SUMMARY

River Name: Calvert Cliffs
Reach Name: Johns SR-4
Profile Name: reach
Survey Date: 10/15/2009

Survey Data

DIST	CH	WS	BKF	BAR	BENCH	P3	P4
0	6.61	6.37	6.25				
3	6.42	6.37	5.72				
5	6.4	6.38	5.49				
9	6.45	6.39	5.71				
11	6.53	6.41					
13	6.56	6.43	5.28	5.78			
15	6.6	6.42					
18	6.68	6.42					
21	6.53	6.43	5.62				
24	6.47	6.44	5.62				
26	6.65	6.49					
29	6.59	6.51					
31	6.75	6.61					
32	6.89	6.67					
35	6.98	6.71	6.04				
37	7.29	6.68					
39	7.78	6.68					
41	7.73	6.68					
42	7.45	6.68					
43	7.15	6.69	6.03				
45	7.01	6.69					
47	6.78	6.7					
48	6.88	6.71					
50	7	6.79					
51	7.73	6.79					
52	7.75	6.79					
53	7.21	6.79					
57	7.23	6.78	5.98	5.98			
60	7.15						
62	7.13						
64	7.11		5.81	6.14			
65	7.03	6.78					
67	6.89	6.78					
69	6.94		5.94				
70	7.2						
71	7.53						
72	7.3						

74	7.03	6.79	6.07	6.63	
77	7.02				
79	7.02		5.63		
82	6.95	6.79			
84	6.93				
85	7.12		6.07		
88	7.09	6.79			
91	6.97		5.79		
94	6.89	6.79			
100	6.88	6.8	5.82		
103	6.99	6.81			
107	6.97	6.85			
110	7.02	6.87	6.19		
115	6.99	6.86	5.83		
118	6.95	6.86			
120	7.15	6.89			
121	7.24	6.99			
122	7.31				
125	7.12		6.13		
129	7.02	6.97			
130	7.13	6.99			
131	7.29	7.04			
132	7.42				
134	7.25				
135	7.19	7.01			
138	7.15	7.02	6.28		
140	7.26		6.22		
144	7.18	7.03			
147	7.1	7.04			
150	7.39	7.1			
152	7.24	7.11			
155	7.31	7.13			
156	7.47	7.25			
158	7.56	7.27			
160	7.71		6.26		
161	7.58	7.29			
163	7.34	7.29			
165	7.41		6.7		
167	7.4	7.29			
170			6.52		
173	7.38	7.31			
174	7.52	7.37			
178	7.5	7.39			
180	7.45		6.76		
181	7.74	7.37			
184	7.63	7.37	6.77		
186	7.47		6.68		
189	7.48	7.38			
192	7.55	7.41			
192.5	7.63	7.58			
194	7.78	7.6	6.43		
200	7.73	7.73	6.46		6.09
201	10.08	9.78			
202	11.43	9.78			

204	11.38	9.78			
210	10.03				
213	10.07	9.78	6.66		
218	9.86				
224	10.07				
230	10.01	9.78			
236	9.8	9.8	6.8		
236.2	10.68	9.9			
237	10.55	9.9			
241	10.22	9.9			
242	10.02	9.94	7.2		
246	10.23	9.96			9.17
253	10.22	10.08	6.91		
258	10.17	10.08			
262	10.22	10.09			
265	10.6	10.11			
270	10.44	10.15	6.87	5.3	

Cross Section / Bank Profile Locations

Name	Type	Profile Station
Pool at 38	Pool XS	38
Glide at 44	Glide XS	44
Valley Run at 49	Run XS	49
Riffle at 100	Riffle XS	100
Riffle at 220	Riffle XS	220
Pool at 238	Pool XS	238
Riffle Valley 100	Riffle XS	0

Measurements from Graph

Bankfull Slope: 0

Variable	Min	Avg	Max
S riffle	0	0	0
S pool	0	0	0
S run	0	0	0
S glide	0	0	0
P - P	0	0	0
Pool length	0	0	0
Riffle length	0	0	0
Dmax riffle	0	0	0
Dmax pool	0	0	0
Dmax run	0	0	0
Dmax glide	0	0	0
Low bank ht	0	0	0

Length and depth measurements in feet, slopes in ft/ft.

RIVERMORPH PROFILE SUMMARY

Notes

River Name: Calvert Cliffs
Reach Name: Johns SR-4
Profile Name: reach
Survey Date: 10/15/2009

DIST	Note
0	GLIDE
3	RIGHT
5	LEFT
9	RIGHT
13	GLIDE
21	RIGHT
24	RIGHT
35	RIGHT
37	POOL
39	POOL SECTION
45	GLIDE SECTION
48	RUN SECTION
79	LEFT
91	RIGHT
100	RIGHT
110	RIFFLE SECTION
125	LEFT
140	LEFT
160	RIGHT
180	RIGHT
184	RIGHT
236	LEFT
242	LEFT
253	LEFT
270	benchmark at ele 5.3

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Johns SR-4
Cross Section Name: Riffle at 100
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	6.07	93.93	
2	5.94	94.06	
5	5.85	94.15	
5.6	5.79	94.21	lep
8	5.8	94.2	BKF
9	6.01	93.99	
10	6.58	93.42	
10.4	6.8	93.2	
11	6.88	93.12	
12	6.89	93.11	
12.5	6.77	93.23	
13	6.74	93.26	
14	6.61	93.39	
14.5	6.08	93.92	
15	5.88	94.12	
16	5.82	94.18	
18	5.97	94.03	
20	6.18	93.82	
22	5.99	94.01	
24	5.68	94.32	
25	5.71	94.29	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	95.29	95.29	95.29
Bankfull Elevation (ft)	94.2	94.2	94.2
Floodprone Width (ft)	25	-----	-----
Bankfull Width (ft)	15.23	0.79	14.44
Entrenchment Ratio	1.64	-----	-----
Mean Depth (ft)	0.42	0.08	0.44
Maximum Depth (ft)	1.09	0.17	1.09
Width/Depth Ratio	36.26	9.88	32.82

Bankfull Area (sq ft)	6.37	0.07	6.31
Wetted Perimeter (ft)	15.79	0.97	15.15
Hydraulic Radius (ft)	0.4	0.07	0.42
Begin BKF Station	8	8	8.79
End BKF Station	23.23	8.79	23.23

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Johns SR-4
Cross Section Name: Pool at 38
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	5.43	94.57	
2.5	5.49	94.51	lep
4	5.72	94.28	
5	5.87	94.13	
6	6.16	93.84	
7	6.47	93.53	
7.5	6.69	93.31	LEW
8	7.68	92.32	
8.8	7.71	92.29	
9.5	7.63	92.37	
10	7	93	
10.2	6.71	93.29	
10.5	6.22	93.78	
12	5.98	94.02	BKF
14	5.91	94.09	
20	5.69	94.31	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	95.75	95.75	95.75
Bankfull Elevation (ft)	94.02	94.02	94.02
Floodprone Width (ft)	20	-----	-----
Bankfull Width (ft)	6.62	2.97	3.65
Entrenchment Ratio	3.02	-----	-----
Mean Depth (ft)	0.76	0.64	0.86
Maximum Depth (ft)	1.73	1.71	1.73
Width/Depth Ratio	8.71	4.64	4.24
Bankfull Area (sq ft)	5.02	1.89	3.13
Wetted Perimeter (ft)	8.1	5.41	6.12
Hydraulic Radius (ft)	0.62	0.35	0.51
Begin BKF Station	5.38	5.38	8.35
End BKF Station	12	8.35	12

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Johns SR-4
Cross Section Name: Glide at 44
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	5.4	94.6	
2	5.35	94.65	
3	6.07	93.93	
4	5.94	94.06	lep
5	5.82	94.18	
5.5	6.12	93.88	
6	6.26	93.74	
7	6.6	93.4	
7.3	6.77	93.23	
7.6	6.9	93.1	
8	6.95	93.05	
8.5	6.9	93.1	
9	6.75	93.25	
9.5	6.58	93.42	
10	6.14	93.86	
11	5.92	94.08	
13	5.68	94.32	BKF
15	5.62	94.38	
45	5.62	94.38	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	95.59	95.59	95.59
Bankfull Elevation (ft)	94.32	94.32	94.32
Floodprone Width (ft)	45	-----	-----
Bankfull Width (ft)	10.54	5.33	5.21
Entrenchment Ratio	4.27	-----	-----
Mean Depth (ft)	0.53	0.5	0.55
Maximum Depth (ft)	1.27	1.24	1.27
Width/Depth Ratio	19.89	10.66	9.47
Bankfull Area (sq ft)	5.54	2.66	2.88
Wetted Perimeter (ft)	11.17	6.95	6.71

Hydraulic Radius (ft)	0.5	0.38	0.43
Begin BKF Station	2.46	2.46	7.79
End BKF Station	13	7.79	13

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Johns SR-4
Cross Section Name: Riffle at 220
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	6.9	93.1	LEP
2	6.81	93.19	
3	6.91	93.09	
3.5	7.16	92.84	
4	8.93	91.07	BKF
5	9.15	90.85	
5.5	9.85	90.15	
6	9.9	90.1	
7	9.85	90.15	LEW
8	9.82	90.18	
9	9.83	90.17	
10	9.67	90.33	
11	7.75	92.25	
12	6.94	93.06	
13	6.6	93.4	
15	6.54	93.46	
17	6.72	93.28	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	92.04	92.04	92.04
Bankfull Elevation (ft)	91.07	91.07	91.07
Floodprone Width (ft)	7.16	-----	-----
Bankfull Width (ft)	6.39	3.19	3.2
Entrenchment Ratio	1.12	-----	-----
Mean Depth (ft)	0.72	0.62	0.81
Maximum Depth (ft)	0.97	0.97	0.91
Width/Depth Ratio	8.88	5.15	3.95
Bankfull Area (sq ft)	4.58	1.99	2.59
Wetted Perimeter (ft)	7.24	4.49	4.57
Hydraulic Radius (ft)	0.63	0.44	0.57
Begin BKF Station	4	4	7.19

End BKF Station	10.39	7.19	10.39

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Johns SR-4
Cross Section Name: Pool at 238
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	7.04	92.96	lep
1	7.17	92.83	
2	7.42	92.58	
3	7.57	92.43	
5	8.46	91.54	BKF
5.8	10	90	LEW
7	10.39	89.61	
8	10.55	89.45	
9	10	90	REW
10	9.86	90.14	
11	7.35	92.65	
11.5	7.32	92.68	
12	7.16	92.84	
13	7.04	92.96	
17	6.82	93.18	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	93.63	93.63	93.63
Bankfull Elevation (ft)	91.54	91.54	91.54
Floodprone Width (ft)	17	-----	-----
Bankfull Width (ft)	5.56	2.78	2.78
Entrenchment Ratio	3.06	-----	-----
Mean Depth (ft)	1.51	1.53	1.49
Maximum Depth (ft)	2.09	2.05	2.09
Width/Depth Ratio	3.68	1.82	1.87
Bankfull Area (sq ft)	8.38	4.25	4.13
Wetted Perimeter (ft)	7.67	5.84	5.94
Hydraulic Radius (ft)	1.09	0.73	0.7
Begin BKF Station	5	5	7.78
End BKF Station	10.56	7.78	10.56

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Johns SR-4
Cross Section Name: Riffle Valley 100
Survey Date: 12/18/2009

Cross Section Data Entry

BM Elevation: 0 ft
Backsight Rod Reading: 0 ft

TAPE	FS	ELEV	NOTE
0	0	96.53	
4	0	95.06	
7	0	94.93	
15	0	94.96	
20	0	95.11	
22	0	95.21	
24	0	95.07	
27	0	94.89	
33	0	94.87	
36	0	95.06	
39	0	94.95	
44	0	94.75	
47	0	94.76	
50	0	94.94	
51	0	94.85	
52	0	94.3	
54	0	94.21	
56.4	0	94.2	BKF
57.4	0	93.99	
58.4	0	93.42	
58.8	0	93.2	
59.4	0	93.12	
60.4	0	93.11	
60.9	0	93.23	
61.4	0	93.26	
62.4	0	93.39	
62.9	0	93.92	
63.4	0	94.12	
64.4	0	94.18	
66.4	0	94.03	
68.4	0	93.82	
70.4	0	94.01	
72.4	0	94.32	
73.4	0	94.29	
108.4	0	94.29	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	95.29	95.29	95.29
Bankfull Elevation (ft)	94.2	94.2	94.2
Floodprone Width (ft)	105.03	-----	-----
Bankfull Width (ft)	15.23	7.61	7.62
Entrenchment Ratio	6.9	-----	-----
Mean Depth (ft)	0.42	0.65	0.19
Maximum Depth (ft)	1.09	1.09	0.38
Width/Depth Ratio	36.26	11.71	40.11
Bankfull Area (sq ft)	6.37	4.93	1.44
Wetted Perimeter (ft)	15.79	8.18	7.7
Hydraulic Radius (ft)	0.4	0.6	0.19
Begin BKF Station	56.4	56.4	64.01
End BKF Station	71.63	64.01	71.63

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Johns SR-4
Cross Section Name: Valley Run at 49
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	3.75	96.25	
4	5.22	94.78	
7	5.35	94.65	
15	5.32	94.68	
20	5.17	94.83	
22	5.07	94.93	
24	5.21	94.79	
27	5.39	94.61	
33	5.41	94.59	
36	5.22	94.78	
39	5.33	94.67	
44	5.53	94.47	
47	5.52	94.48	
50	5.34	94.66	
51	5.43	94.57	
52	5.98	94.02	
54	6.07	93.93	LEP
55	6.09	93.91	
55.8	6.39	93.61	LEW
56	6.6	93.4	
57	6.72	93.28	
58	6.84	93.16	
58.8	6.78	93.22	
59.5	6.75	93.25	
61	5.89	94.11	
62	5.89	94.11	
65	5.64	94.36	
73	5.4	94.6	BKF
82	5.42	94.58	
90	5.23	94.77	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	96.04	96.04	96.04
Bankfull Elevation (ft)	94.6	94.6	94.6
Floodprone Width (ft)	89.43	-----	-----
Bankfull Width (ft)	32.18	7.16	25.01
Entrenchment Ratio	2.78	-----	-----
Mean Depth (ft)	0.37	0.77	0.25
Maximum Depth (ft)	1.44	1.42	1.44
Width/Depth Ratio	86.97	9.3	100.04
Bankfull Area (sq ft)	11.88	5.53	6.35
Wetted Perimeter (ft)	32.73	8.89	26.68
Hydraulic Radius (ft)	0.36	0.62	0.24
Begin BKF Station	50.67	50.67	57.83
End BKF Station	82.84	57.83	82.84

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

SE-R 5 Imp

Worksheet 5-3. Field form for Level II stream classification (Rosgen, 1996; Rosgen and Silvey, 2005).

Stream: **Calvert Cliffs, Reach - Johns SR-5**	
Basin:	Drainage Area: **0** acres **0** mi^2
Location:	
Twp.&Rge: **;**	Sec.&Qtr.: **;**
Cross-Section Monuments (Lat./Long.): **0 Lat / 0 Long**	Date: **10/15/09**
Observers:	Valley Type: **IX**

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**6.1**	ft
Bankfull DEPTH (d_{bkf}) Mean DEPTH of the stream channel cross-section, at bankfull stage elevation, in a riffle section ($d_{bkf} = A / W_{bkf}$).	**0.4**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**2.45**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**15.25**	ft/ft
Maximum DEPTH (d_{mbkf}) Maximum depth of the bankfull channel cross-section, or distance between the bankfull stage and Thalweg elevations, in a riffle section.	**0.49**	ft
WIDTH of Flood-Prone Area (W_{fpa}) Twice maximum DEPTH, or (2 x d_{mbkf}) = the stage/elevation at which flood-prone area WIDTH is determined in a riffle section.	**7.45**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**1.22**	ft/ft
Channel Materials (Particle Size Index) D_{50} The D_{50} particle size index represents the mean diameter of channel materials, as sampled from the channel surface, between the bankfull stage and Thalweg elevations.	**0.2**	mm
Water Surface SLOPE (S) Channel slope = "rise over run" for a reach approximately 20–30 bankfull channel widths in length, with the "riffle-to-riffle" water surface slope representing the gradient at bankfull stage.	**0.00626**	ft/ft
Channel SINUOSITY (k) Sinuosity is an index of channel pattern, determined from a ratio of stream length divided by valley length (SL / VL); or estimated from a ratio of valley slope divided by channel slope (VS / S).	**1.08**	

Stream Type **F 5** (See **Figure 2-14**)

RIVERMORPH PROFILE SUMMARY

River Name: Calvert Cliffs
Reach Name: Johns SR-5
Profile Name: Reach
Survey Date: 10/15/2009

Survey Data

DIST	CH	WS	BKF	P1	P2	P3	P4
0	7.31	7.06	5.43				
1	7.55	7.08					
4	7.79	7.08	5.92				
7	7.8	7.09					
11	8.08	7.09	5.83				
14	7.98	7.1	5.83				
17	7.41		5.68				
19	7.28	7.1					
22	7.26		5.58				
27	7.45	7.1	6.13				
30	8.18	7.1	5.93				
32	7.97	7.1					
36	7.76	7.1					
38	7.65		6.01				
41	7.71	7.1					
46	7.66						
48	7.34	7.1					
50	7.19	7.1	6.63				
52	7.36	7.26					
53	7.88	7.88					
54	8.16	8.16					
54.1	9.92						
55	10.67	8.34					
63	8.72		5.66	7.75			
68		8.22					
71	8.58	8.22					
74	8.69	8.22					
78	8.48	8.22					
79	9.43	8.55					
86	9.46		6.26	7.32			
90	8.87						
94	8.7	8.52					
96	8.83	8.55					
100	8.75						
102	9.06	8.56					
106	9.17	8.56	6.87	8.17	6.73		
111	8.71	8.56					

115	8.81	8.57		
120	8.77	8.57	6.77	
123	9.29			
134	8.99	8.58	6.35	
138	8.75	8.58		
142	8.7	8.58		
146	8.7	8.59		
150	8.7	8.6		
153	9.45	8.61		
165	8.81	8.61		
168	8.8	8.62	6.5	6.13
170	8.87	8.62		

Cross Section / Bank Profile Locations

Name	Type	Profile Station
Pool at 29	Pool XS	29
Riffle at 144	Riffle XS	144

Measurements from Graph

Bankfull Slope: 0.00626

Variable	Min	Avg	Max
S riffle	0.00383	0.00753	0.01424
S pool	0	0.00083	0.00153
S run	0.27228	0.28546	0.29863
S glide	0.00134	0.00293	0.00586
P - P	19.58	23.97	29.73
Pool length	12.28	14.67	18.69
Riffle length	6.59	9.61	12.46
Dmax riffle	1.39	2.06	2.44
Dmax pool	2.25	2.94	4.54
Dmax run	1.58	2	2.33
Dmax glide	1.31	2.06	2.55
Low bank ht	0.96	1.6	2.12

Length and depth measurements in feet, slopes in ft/ft.

RIVERMORPH PROFILE SUMMARY

Notes

River Name: Calvert Cliffs
Reach Name: Johns SR-5
Profile Name: Reach
Survey Date: 10/15/2009

DIST Note

30	pool section
32	large log
48	glide
63	bar
146	riffle section

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Johns SR-5
Cross Section Name: Riffle at 144
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	6.43	93.57	LEP
2	6.38	93.62	
3	6.56	93.44	
4	6.93	93.07	
6	7.95	92.05	
6.3	0	91.81	BKF - office estimate
7	8.55	91.45	LEW
8	8.68	91.32	
9	8.65	91.35	
10	8.65	91.35	
11	8.67	91.33	
12	8.55	91.45	
13	7.66	92.34	
14	7.39	92.61	
15	6.99	93.01	
16	6.7	93.3	
22	6.26	93.74	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	92.3	92.3	92.3
Bankfull Elevation (ft)	91.81	91.81	91.81
Floodprone Width (ft)	7.45	-----	-----
Bankfull Width (ft)	6.1	3.11	2.99
Entrenchment Ratio	1.22	-----	-----
Mean Depth (ft)	0.4	0.39	0.41
Maximum Depth (ft)	0.49	0.49	0.48
Width/Depth Ratio	15.25	7.97	7.29
Bankfull Area (sq ft)	2.45	1.21	1.23
Wetted Perimeter (ft)	6.34	3.67	3.6
Hydraulic Radius (ft)	0.39	0.33	0.34
Begin BKF Station	6.3	6.3	9.41

End BKF Station	12.4	9.41	12.4

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

RIVERMORPH CROSS SECTION SUMMARY

River Name: Calvert Cliffs
Reach Name: Johns SR-5
Cross Section Name: Pool at 29
Survey Date: 10/15/2009

Cross Section Data Entry

BM Elevation: 98 ft
Backsight Rod Reading: 2 ft

TAPE	FS	ELEV	NOTE
0	5.48	94.52	lep
2	5.65	94.35	
3	5.84	94.16	
4	6.28	93.72	BKF
4.5	7.21	92.79	LEW
5	7.36	92.64	
6	7.75	92.25	
7	7.68	92.32	
8	8.01	91.99	
9	7.75	92.25	
9.5	6.25	93.75	
10	5.78	94.22	
12	5.35	94.65	
13	5.26	94.74	

Cross Sectional Geometry

	Channel	Left	Right
Floodprone Elevation (ft)	95.45	95.45	95.45
Bankfull Elevation (ft)	93.72	93.72	93.72
Floodprone Width (ft)	13	-----	-----
Bankfull Width (ft)	5.49	2.75	2.74
Entrenchment Ratio	2.37	-----	-----
Mean Depth (ft)	1.27	1.12	1.42
Maximum Depth (ft)	1.73	1.47	1.73
Width/Depth Ratio	4.32	2.46	1.93
Bankfull Area (sq ft)	6.97	3.09	3.88
Wetted Perimeter (ft)	7.29	4.82	5.3
Hydraulic Radius (ft)	0.96	0.64	0.73
Begin BKF Station	4	4	6.75
End BKF Station	9.49	6.75	9.49

Entrainment Calculations

Entrainment Formula: Rosgen Modified Shields Curve

	Channel	Left Side	Right Side
Slope	0	0	0
Shear Stress (lb/sq ft)			
Movable Particle (mm)			

Appendix E

Calculations for Weir Design

OBJECTIVE:

Determine the dimensions and materials for the riffle grade control structures utilized for the Woodland Branch regenerative stormwater conveyance and riffle grade control practices.

ASSUMPTIONS:

For Woodland Branch, the watershed and upland areas are protected as reforestation areas, or part of the Chesapeake Bay Critical Area. Therefore, there is no additional planned impervious area to be introduced into the watershed. The design assumes that the existing discharges are conservative estimates reflecting future land use. Only the existing discharges are utilized for the weir design.

Flores, Hala, (2009). *Step Pool Storm Conveyance Design Calculator.* Anne Arundel County Department of Public Works, Annapolis, Maryland.

Flores, Markusic, McMonigle, and Underwood (2009). *Step Pool Storm Conveyance.* Anne Arundel County Department of Public Works, Annapolis, Maryland.

PROCEDURE:

From TR-55, determine the pre- and post- development discharges for the 1, 10 and 100 year storm and associated time of concentration. For Woodland Branch, Pre and Post development discharges are equal:

Drainage Area	Tc (hours)	100yr (CFS)	1yr (CFS)	10yr (CFS)
1	0.275	122.03	2.18	47.50
2	0.517	98.31	1.44	38.54
3	0.356	363.7	5.1	130.7
5	0.451	321.46	4.26	118.47
6	0.475	78.96	1.12	31.15
7	0.228	50.25	0.63	20.62
8	0.377	73.58	0.96	29.27

Utilizing the site map, determine the length of conveyance areas and elevation drop through them. Calculate the desired number of weirs for the site based on the elevation drop through the weirs. **For Woodland Branch, MDE comment in August 2010 requested a stone grade control structure for every foot of elevation drop**, with woody grade controls in between. Woodland Branch utilizes pools with zero slope on steep gradients and thalweg grading areas with negligible slope in low gradient valleys (approximately 1% slope).

Elevation drop through the weir is chosen to work with site conditions and existing reference reach data and is an iterative process. Excessive loss of elevation through the weirs will result in a backwatering situation behind them or an entrenched channel situation. For steep slopes, a maximum of

1' per weir is utilized. In situations where valley gradient is approximately 1% or less, 6" or less drop through the weir is utilized.

The Step Pool Design Conveyance Calculator from Anne Arundel County Department of Public Works is utilized in this calculation. This calculator is modified to achieve the desired number elevation drop through the weirs coupled with the desired design discharges. Spreadsheets are attached to this calculation.

The water quality component (pool and media bed design) of the Step Pool Design Conveyance Calculator was not utilized for Woodland Branch designs, as no proposed development is occurring in this watershed. The design focuses on riffle stability in lifting the channel bed elevation to reconnect it with the floodplain, with water quality and quantity effects being a secondary to the goals of changing shallow groundwater elevation.

RESULTS:

Weir designs are summarized below:

Drainage Area	Cobble Size (Inches)	Width (Feet)	Depth (Feet)	Slope
DA-1	6	50	1.2	3.00%
DA-2	6	21	1.5	4.00%
DA-2	6	45	1	4.20%
DA-3	6	120	1.5	1.80%
DA-5	6	14	3	2.20%
DA-5	6	27	2	1.80%
DA-5	6	45	2.2	2.20%
DA-6	6	22	1.5	2.50%
DA-7	6	25	1.5	3.60%
DA-8	6	12	1.6	6.80%
DA-8	6	20	1.5	6.80%
DA-8	6	27	1	6.80%

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Input values shaded in Grey "Required"
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Check parameters in bold

Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.28	
Pre development discharge (cfs)	Q_{pre}	122.0	2.2	47.5
Post development design discharge (cfs)	Q_{post}	122.0	2.2	47.5
Total available length (ft)	L	909	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	14.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.02	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	33	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	14	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	33	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	50.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	1.2	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_t	1.5	**ok**	
Enter Desired Pool Depth (ft)	h_p	2.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**20.8**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.6**		
Computed Roughness	n	0.05		
Riffle Cross Section Area (ft2), for parabola	A	40.00		
Theta - Intermediate step for solving	θ	0.10		
Riffle Hydraulic Perimeter (ft), for parabola	P	50.08		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	0.80		
Calculated Flow for design parameters (cfs)	Q	137.21		
Check Riffle Velocity (ft/sec)	V	3.43		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**14**
Provided total pool depth (ft) =	**28**
hydraulic power for return period 100 year storm is satisfied	

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	50.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	1.20
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	15.25
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	9
The area is for a semi parabola	A_{out}	92
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	1.42
Hydraulic Perimeter (ft), for semi parabola	P_{out}	33
Hydraulic Radius, using Chow 1959	R_h	2.81
Darcy Weisbach friction factor expressed in terms of L_{add}, v_{out},	f	0.21
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		0.00

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	1794		
Volume provided in voids (ft3)	10908		
Provided Volume of Storage (excludes infiltration) (ft3)	**13702**		
Infiltration Volume (ft3)	1000		

Peak Management of 100 year storm is satisfied
Peak Management of 1 year storm is satisfied
Peak Management of 10 year storm is satisfied

Checking Quality Management		
Site Drainage Area (Acres)	A	68
Contributory Impervious Area (Acres)	I	35
Volumetric Runoff Coefficient	Rv	0.53
Water Quality Volume, ft3	WQv	113692
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\ (Average\ of\ Pool\ and\ Riffle)}$	5.0
Width of sand filter (ft)	W_{sand}	8
Length of sand filter, where slope < = 5% (ft)	L_{sand}	909
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**7272**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	2.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**4168**

Water quality requirement is satisfied in SPSC

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Check parameters in bold

Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100		10
Time of Concentration in minutes (Before Development)	t_c		0.52	
Pre development discharge (cfs)	Q_{pre}	98.3	1.4	38.5
Post development design discharge (cfs)	Q_{post}	98.3	1.4	38.5
Total available length (ft)	L	500	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	10.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.02	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	12	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	21	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	12	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	21.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	1.5	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_t	2.0	**ok**	
Enter Desired Pool Depth (ft)	h_t	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		7.0		
Check the Froude Number to ensure Subcritical Flow Conditions		0.7		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	21.00		
Theta - intermediate step for solving	θ	0.28		
Riffle Hydraulic Perimeter (ft), for parabola	P	21.28		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	0.99		
Calculated Flow for design parameters (cfs)	Q	99.64		
Check Riffle Velocity (ft/sec)	**V**	**4.74**		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**21**
Provided total pool depth (ft) =	**63**

hydraulic power for return period 100 year storm is satisfied

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	21.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	1.50
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	**11.64**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	12
The area is for a semi parabola	A_{out}	93
protection volume	L_{add}	0
Theta - Intermediate step for solving	θ	1.32
Hydraulic Perimeter (ft), for semi parabola	P_{out}	27
Hydraulic Radius, using Chow 1959	R_h	3.42
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out}	f	0.20
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**0.00**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)		9075	
Volume provided in voids (ft3)		3000	
Provided Volume of Storage (excludes infiltration) (ft3)		**13075**	
Infiltration Volume (ft3)		1000	

Peak Management of 100 year storm is satisfied

Peak Management of 1 year storm is satisfied

Peak Management of 10 year storm is satisfied

Checking Quality Management

Water quality requirement is satisfied in SPSC

Site Drainage Area (Acres)	**A**	**48**
Contributory Impervious Area (Acres)	**I**	**0**
Volumetric Runoff Coefficient	Rv	0.05
Water Quality Volume, ft3	WQv	7841
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\ (\text{Average of Pool and Riffle})}$	**2.0**
Width of sand filter (ft)	W_{sand}	**10**
Length of sand filter, where slope <= 5% (ft)	L_{sand}	500
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**5000**
coefficient of permeability of filer media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**402**

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Check parameters in bold

Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood				
Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.52	
Pre development discharge (cfs)	Q_{pre}	98.3	1.4	38.5
Post development design discharge (cfs)	Q_{post}	98.3	1.4	98.5
Total available length (ft)	L	500	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	10.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.02	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	12	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	21	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	12	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	**0.50**	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	45.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	1.0	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_t	1.5	**ok**	
Enter Desired Pool Depth (ft)	h_i	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**22.5**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.6**		
Computed Roughness	n	0.05		
Riffle Cross Section Area (ft2), for parabola	A	30.00		
Theta - intermediate step for solving	θ	0.09		
Riffle Hydraulic Perimeter (ft), for parabola	P	45.06		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	0.67		
Calculated Flow for design parameters (cfs)	Q	98.82		
Check Riffle Velocity (ft/sec)	**V**	**3.29**	**Required Number of Pools**	**21**
			Provided total pool depth (ft) =	**63**

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

hydraulic power for return period 100 year storm is satisfied

Checking Quantity Management		
USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	45.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm.	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	1.00
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	**11.06**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	9
The area is for a semi parabola	A_{out}	86
protection volume	L_{add}	0
Theta - Intermediate step for solving	θ	1.37
Hydraulic Perimeter (ft), for semi parabola	P_{out}	25
Hydraulic Radius, using Chow 1959	R_h	2.69
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out}	f	0.22
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**0.00**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	9075		
Volume provided in voids (ft3)	3000		
Provided Volume of Storage (excludes infiltration) (ft3)	**13075**		
Infiltration Volume (ft3)	**1000**		

Peak Management of 100 year storm is satisfied

Peak Management of 1 year storm is satisfied

Peak Management of 10 year storm is satisfied

Checking Quality Management

Water quality requirement is satisfied in SPSC

Site Drainage Area (Acres)	**A**	**48**
Contributory Impervious Area (Acres)	**I**	**0**
Volumetric Runoff Coefficient	Rv	0.05
Water Quality Volume, ft3	WQv	7841
Average Sand filter bed depth (ft) minimum 18 inches	d_f (Average of Pool and Riffle)	**2.0**
Width of sand filter (ft)	W_{sand}	**10**
Length of sand filter, where slope < = 5% (ft)	L_{sand}	500
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**5000**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days); MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**402**

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Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.36	
Pre development discharge (cfs)	Q_{pre}	383.7	5.1	130.7
Post development design discharge (cfs)	Q_{post}	363.7	5.1	130.7
Total available length (ft)	L	1849	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	16.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.01	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	14	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	66	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	14	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	120.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	1.5	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_r	1.5	**ok**	
Enter Desired Pool Depth (ft)	h_p	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		40.0		
Check the Froude Number to ensure Subcritical Flow Conditions		0.5		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	120.00		
Theta - Intermediate step for solving	θ	0.05		
Riffle Hydraulic Perimeter (ft), for parabola	P	120.05		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.00		
Calculated Flow for design parameters (cfs)	Q	377.75		
Check Riffle Velocity (ft/sec)	V	3.15		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**66**
Provided total pool depth (ft) =	**198**
Run Solver	

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	120.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	1.50
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	17.01
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	9
The area is for a semi parabola	A_{out}	102
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	1.44
Hydraulic Perimeter (ft), for semi parabola	P_{out}	36
Hydraulic Radius, using Chow 1959	R_h	2.84
Darcy Weisbach friction factor expressed in terms of L_{add}, v_{out},	f	0.21
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		0.46

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	28521		
Volume provided in voids (ft3)	22188		
Provided Volume of Storage (excludes infiltration) (ft3)	51709		
Infiltration Volume (ft3)	1000		
Run Solver			
Run Solver			
Run Solver			

Checking Quality Management		
Site Drainage Area (Acres)	A	66
Contributory Impervious Area (Acres)	I	35
Volumetric Runoff Coefficient	Rv	0.53
Water Quality Volume, ft3	WQv	113692
Average Sand filter bed depth (ft) minimum 18 inches	d_f (Average of Pool and Riffle)	5.0
Width of sand filter (ft)	W_{sand}	8
Length of sand filter, where slope < = 5% (ft)	L_{sand}	1849
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**14792**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**3647**

Water quality requirement is satisfied in SPSC

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Anne Arundel County Government
Department of Public Works
Bureau of Engineering
Watershed and Ecosystem Services and Restoration
Watershed Assessment and Planning

ANNE ARUNDEL COUNTY
M A R Y L A N D

Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Input values shaded in Grey "Required"
Calculated values are noted with dotted pattern
Check parameters in bold

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.45	
Pre-development discharge (cfs)	Q_{pre}	321.5	4.3	118.5
Post development design discharge (cfs)	Q_{post}	321.5	4.3	118.5
Total available length (ft)	L	1555	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	18.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.01	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	18	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	46	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	18	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	45.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	2.2	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_f	2.0	**ok**	
Enter Desired Pool Depth (ft)	h	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**10.2**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.6**		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	66.00		
Theta - Intermediate step for solving	θ	0.19		
Riffle Hydraulic Perimeter (ft), for parabola	P	45.29		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.46		
Calculated Flow for design parameters (cfs)	Q	322.51		
Check Riffle Velocity (ft/sec)	V	**4.89**		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**46**
Provided total pool depth (ft) =	**138**
Run Solver	

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	45.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	2.20
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	**21.23**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	12
The area is for a semi parabola	A_{out}	170
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	1.43
Hydraulic Perimeter (ft), for semi parabola	P_{out}	45
Hydraulic Radius, using Chow 1959	R_h	3.76
Darcy Weisbach friction factor expressed in terms of L_{add}, v_{out},	f	0.19
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		-0.89

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	19878		
Volume provided in voids (ft3)	19860		
Provided Volume of Storage (excludes infiltration) (ft3)	**40738**		
Infiltration Volume (ft3)	1000		
Run Solver			
Run Solver			
Run Solver			

Checking Quality Management		
Site Drainage Area (Acres)	A	68
Contributory Impervious Area (Acres)	I	35
Volumetric Runoff Coefficient	Rv	0.53
Water Quality Volume, ft3	WQv	113692
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\ (Average\ of\ Pool\ and\ Filter)}$	5.0
Width of sand filter (ft)	W_{sand}	8
Length of sand filter, where slope < = 5% (ft)	L_{sand}	1655
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**13240**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**3647**

Water quality requirement is satisfied in SPSC

Contact

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ANNE ARUNDEL COUNTY
M A R Y L A N D

Input values shaded in Grey "Required"
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Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.45	
Pre development discharge (cfs)	Q_{pre}	321.5	4.3	118.5
Post development design discharge (cfs)	Q_{post}	321.5	4.3	118.5
Total available length (ft)	L	1655	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	18.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.01	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	18	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	46	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	18	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	**0.50**	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	100.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	1.5	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_r	**1.5**	**ok**	
Enter Desired Pool Depth (ft)	h_l	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**33.3**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.5**		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	100.00		
Theta - Intermediate step for solving	θ	0.06		
Riffle Hydraulic Perimeter (ft), for parabola	P	100.06		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.00		
Calculated Flow for design parameters (cfs)	Q	352.87		
Check Riffle Velocity (ft/sec)	V	3.53		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**46**
Provided total pool depth (ft) =	**138**
hydraulic power for return period 100 year storm is satisfied	

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	100.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	1.50
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	**19.52**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	9
The area is for a semi parabola	A_{out}	117
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	1.46
Hydraulic Perimeter (ft), for semi parabola	P_{out}	41
Hydraulic Radius, using Chow 1959	R_h	2.87
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out},	f	0.21
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		0.00

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	19878		
Volume provided in voids (ft3)	19860		
Provided Volume of Storage (excludes infiltration) (ft3)	**40738**		
Infiltration Volume (ft3)	1000		

Peak Management of 100 year storm is satisfied
Peak Management of 1 year storm is satisfied
Peak Management of 10 year storm is satisfied

Checking Quality Management		
Site Drainage Area (Acres)	A	68
Contributory Impervious Area (Acres)	I	35
Volumetric Runoff Coefficient	Rv	0.53
Water Quality Volume, ft3	WQv	113692
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\ (Average\ of\ Pool\ and\ Riffle)}$	5.0
Width of sand filter (ft)	W_{sand}	8
Length of sand filter, where slope < = 5% (ft)	L_{sand}	1655
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**13240**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**3647**

Water quality requirement is satisfied in SPSC

Contact

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ANNE ARUNDEL COUNTY
MARYLAND

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Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.45	
Pre development discharge (cfs)	Q_{pre}	158.8	2.2	62.8
Post development design discharge (cfs)	Q_{post}	158.8	2.2	62.8
Total available length (ft)	L	1655	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	18.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.01	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	15	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	55	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	15	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	**0.50**	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	14.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	3.0	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_f	**3.0**	**ok**	
Enter Desired Pool Depth (ft)	h_p	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**2.3**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.6**		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	28.00		
Theta - Intermediate step for solving	θ	0.71		
Riffle Hydraulic Perimeter (ft), for parabola	P	15.56		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.80		
Calculated Flow for design parameters (cfs)	Q	165.11		
Check Riffle Velocity (ft/sec)	V	**5.90**		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**55**
Provided total pool depth (ft) =	**165**

hydraulic power for return period 100 year storm is satisfied

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	14.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	3.00
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	**21.22**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	18
The area is for a semi parabola	A_{out}	255
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	1.36
Hydraulic Perimeter (ft), for semi parabola	P_{out}	48
Hydraulic Radius, using Chow 1959	R_h	5.34
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out},	f	0.17
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**0.00**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	23767		
Volume provided in voids (ft3)	19860		
Provided Volume of Storage (excludes infiltration) (ft3)	**44627**		
Infiltration Volume (ft3)	1000		

Peak Management of 100 year storm is satisfied

Peak Management of 1 year storm is satisfied

Peak Management of 10 year storm is satisfied

Checking Quality Management		
Site Drainage Area (Acres)	A	68
Contributory Impervious Area (Acres)	I	35
Volumetric Runoff Coefficient	Rv	0.53
Water Quality Volume, ft3	WQv	113692
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\ (Average\ of\ Pool\ and\ Riffle)}$	5.0
Width of sand filter (ft)	W_{sand}	8
Length of sand filter, where slope < = 5% (ft)	L_{sand}	1655
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**13240**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**3647**

Water quality requirement is satisfied in SPSC

Contact

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Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood				
Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.45	
Pre development discharge (cfs)	Q_{pre}	158.8	2.2	62.8
Post development design discharge (cfs)	Q_{post}	158.8	2.2	62.8
Total available length (ft)	L	1655	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	18.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.01	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	18	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	46	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	18	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	27.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	2.0	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_f	2.0	**ok**	
Enter Desired Pool Depth (ft)	h_r	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**6.8**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.6**		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	36.00		
Theta - Intermediate step for solving	θ	0.29		
Riffle Hydraulic Perimeter (ft), for parabola	P	27.39		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.31		
Calculated Flow for design parameters (cfs)	Q	161.48		
Check Riffle Velocity (ft/sec)	V	**4.49**	**Required Number of Pools**	**46**
			Provided total pool depth (ft) =	**138**

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

hydraulic power for return period 100 year storm is satisfied

Checking Quantity Management		
USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	27.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	2.00
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	**20.13**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	12
The area is for a semi parabola	A_{out}	161
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	1.42
Hydraulic Perimeter (ft), for semi parabola	P_{out}	43
Hydraulic Radius, using Chow 1959	R_h	3.74
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out},	f	0.19
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**0.00**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	19878		
Volume provided in voids (ft3)	19860		
Provided Volume of Storage (excludes infiltration) (ft3)	**40738**		
Infiltration Volume (ft3)	1000		

Peak Management of 100 year storm is satisfied

Peak Management of 1 year storm is satisfied

Peak Management of 10 year storm is satisfied

Checking Quality Management		
Site Drainage Area (Acres)	A	68
Contributory Impervious Area (Acres)	I	35
Volumetric Runoff Coefficient	Rv	0.53
Water Quality Volume, ft3	WQv	113692
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\ (Average\ of\ Pool\ and\ Riffle)}$	5.0
Width of sand filter (ft)	W_{sand}	8
Length of sand filter, where slope < = 5% (ft)	L_{sand}	1655
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**13240**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**3647**

Water quality requirement is satisfied in SPSC

Contact

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Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.48	
Pre development discharge (cfs)	Q_{pre}	79.0	1.1	31.2
Post development design discharge (cfs)	Q_{post}	79.0	1.1	31.2
Total available length (ft)	L	170	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	2.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.01	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	20	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	4	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	20	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	22.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	1.5	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_f	1.0	**ok**	
Enter Desired Pool Depth (ft)	h_r	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**7.3**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.5**		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	22.00		
Theta - Intermediate step for solving	θ	0.27		
Riffle Hydraulic Perimeter (ft), for parabola	P	22.27		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	0.99		
Calculated Flow for design parameters (cfs)	Q	80.12		
Check Riffle Velocity (ft/sec)	V	3.64	**Required Number of Pools**	**4**
			Provided total pool depth (ft) =	**12**

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Checking Quantity Management

hydraulic power for return period 100 year storm is satisfied

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.04
The width at the entrance riffle	W_{in}	22.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	1.50
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	3.35
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	6
The area is for a semi parabola	A_{out}	13
protection volume.	L_{add}	0
Theta - intermediate step for solving	θ	1.15
Hydraulic Perimeter (ft), for semi parabola	P_{out}	9
Hydraulic Radius, using Chow 1959	R_h	1.42
Darcy Weisbach friction factor expressed in terms of L_{add}, v_{out},	f	0.34
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		0.00

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	1729		
Volume provided in voids (ft3)	2040		
Provided Volume of Storage (excludes infiltration) (ft3)	**4769**		
Infiltration Volume (ft3)	1000		

Peak Management of 100 year storm is satisfied
Peak Management of 1 year storm is satisfied
Peak Management of 10 year storm is satisfied

Checking Quality Management		
Site Drainage Area (Acres)	A	68
Contributory Impervious Area (Acres)	I	35
Volumetric Runoff Coefficient	Rv	0.53
Water Quality Volume, ft3	WQv	113692
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\,(Average\ of\ Pool\ and\ Riffle)}$	6.0
Width of sand filter (ft)	W_{sand}	8
Length of sand filter, where slope < = 5% (ft)	L_{sand}	170
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**1360**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**3647**

More Water Quality Treatment is needed

Contact

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Anne Arundel County Government
Department of Public Works
Bureau of Engineering
Watershed and Ecosystem Services and Restoration
Watershed Assessment and Planning

ANNE ARUNDEL COUNTY
M A R Y L A N D

Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Input values shaded in Grey, Required
Calculated values are noted with dotted pattern
Check parameters in bold

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.23	
Pre development discharge (cfs)	Q_{pre}	50.3	0.6	20.6
Post development design discharge (cfs)	Q_{post}	50.3	0.6	20.6
Total available length (ft)	L	500	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	9.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.02	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	14	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	18	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	14	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	25.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	1.0	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_t	1.5	**ok**	
Enter Desired Pool Depth (ft)	h_p	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		12.5		
Check the Froude Number to ensure Subcritical Flow Conditions		0.5		
Computed Roughness	n	0.05		
Riffle Cross Section Area (ft2), for parabola	A	16.67		
Theta - Intermediate step for solving	θ	0.16		
Riffle Hydraulic Perimeter (ft), for parabola	P	25.11		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	0.66		
Calculated Flow for design parameters (cfs)	Q	51.98		
Check Riffle Velocity (ft/sec)	V	3.12	**Required Number of Pools**	**18**
			Provided total pool depth (ft) =	**54**
			hydraulic power for return period 100 year storm is satisfied	

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	25.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	1.00
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	**10.06**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	9
The area is for a semi parabola	A_{out}	60
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	1.35
Hydraulic Perimeter (ft), for semi parabola	P_{out}	23
Hydraulic Radius, using Chow 1959	R_h	2.64
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out},	f	0.23
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**0.00**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	7778		
Volume provided in voids (ft3)	3000		
Provided Volume of Storage (excludes infiltration) (ft3)	**11778**		
Infiltration Volume (ft3)	1000		

Peak Management of 100 year storm is satisfied
Peak Management of 1 year storm is satisfied
Peak Management of 10 year storm is satisfied

Checking Quality Management		
Site Drainage Area (Acres)	A	48
Contributory Impervious Area (Acres)	I	0
Volumetric Runoff Coefficient	Rv	0.05
Water Quality Volume, ft3	WQv	7841
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\ (Average\ of\ Pool\ and\ Riffle)}$	2.0
Width of sand filter (ft)	W_{sand}	10
Length of sand filter, where slope < = 5% (ft)	L_{sand}	500
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**5000**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**402**

Water quality requirement is satisfied in SPSC

Contact

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Watershed Assessment and Planning

ANNE ARUNDEL COUNTY
M A R Y L A N D

Input values shaded in Grey "Required"
Calculated values are noted with dotted pattern
Check parameters in bold

Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c	0.38		
Pre development discharge (cfs)	Q_{pre}	73.6	1.0	29.3
Post development design discharge (cfs)	Q_{post}	73.6	1.0	29.3
Total available length (ft)	L	452	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	15.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.03	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	20	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	11	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	20	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	**0.50**	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	12.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	1.6	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_f	**2.0**	**ok**	
Enter Desired Pool Depth (ft)	h	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**3.8**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.9**		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	12.80		
Theta - Intermediate step for solving	θ	0.49		
Riffle Hydraulic Perimeter (ft), for parabola	P	12.55		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.02		
Calculated Flow for design parameters (cfs)	Q	81.10		
Check Riffle Velocity (ft/sec)	V	**6.34**		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**11**
Provided total pool depth (ft) =	**33**
hydraulic power for return period 100 year storm is satisfied	

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	12.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	1.60
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	**16.83**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	12
The area is for a semi parabola	A_{out}	135
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	1.39
Hydraulic Perimeter (ft), for semi parabola	P_{out}	37
Hydraulic Radius, using Chow 1959	R_h	3.66
Darcy Weisbach friction factor expressed in terms of L_{add}, v_{out},	f	0.19
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**0.00**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	4753		
Volume provided in voids (ft3)	2712		
Provided Volume of Storage (excludes infiltration) (ft3)	**8465**		
Infiltration Volume (ft3)	1000		

Peak Management of 100 year storm is satisfied

Peak Management of 1 year storm is satisfied

Peak Management of 10 year storm is satisfied

Checking Quality Management		
Site Drainage Area (Acres)	A	48
Contributory Impervious Area (Acres)	I	0
Volumetric Runoff Coefficient	Rv	0.05
Water Quality Volume, ft3	WQv	7841
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\,(Average\ of\ Pool\ and\ Riffle)}$	2.0
Width of sand filter (ft)	W_{sand}	10
Length of sand filter, where slope < = 5% (ft)	L_{sand}	452
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**4520**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**402**

Water quality requirement is satisfied in SPSC

Contact

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Anne Arundel County Government
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Bureau of Engineering
Watershed and Ecosystem Services and Restoration
Watershed Assessment and Planning

ANNE ARUNDEL COUNTY
MARYLAND

Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Input values shaded in Grey "Required"
Calculated values are noted with dotted pattern
Check parameters in bold

Checking the Channel Conveyance for the design flood				
Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.38	
Pre development discharge (cfs)	Q_{pre}	73.6	1.0	29.3
Post development design discharge (cfs)	Q_{post}	73.6	1.0	29.3
Total available length (ft)	L	452	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	15.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.03	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	20	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	11	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	20	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	20.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	1.5	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_f	2.0	**ok**	
Enter Desired Pool Depth (ft)	h_l	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		6.7		
Check the Froude Number to ensure Subcritical Flow Conditions		0.9		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	20.00		
Theta - Intermediate step for solving	θ	0.29		
Riffle Hydrauhc Perimeter (ft), for parabola	P	20.30		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	0.99		
Calculated Flow for design parameters (cfs)	Q	122.12		
Check Riffle Velocity (ft/sec)	V	6.11		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**11**
Provided total pool depth (ft) =	**33**
hydraulic power for return period 100 year storm is satisfied	

Checking Quantity Management		
USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	20.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	1.50
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	16.59
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	12
The area is for a semi parabola	A_{out}	133
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	1.39
Hydraulic Perimeter (ft), for semi parabola	P_{out}	36
Hydraulic Radius, using Chow 1959	R_h	3.65
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out},	f	0.19
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		0.00

Required Volume of Storage (Rational Hydrograph)			
	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	4753		
Volume provided in voids (ft3)	2712		
Provided Volume of Storage (excludes Infiltration) (ft3)	**8465**		
Infiltration Volume (ft3)	1000		
Peak Management of 100 year storm is satisfied			
Peak Management of 1 year storm is satisfied			
Peak Management of 10 year storm is satisfied			

Checking Quality Management		
Site Drainage Area (Acres)	A	48
Contributory Impervious Area (Acres)	I	0
Volumetric Runoff Coefficient	Rv	0.05
Water Quality Volume, ft3	WQv	7841
Average Sand filter bed depth (ft) minimum 18 inches	d_f (Average of Pool and Riffle)	2.0
Width of sand filter (ft)	W_{sand}	10
Length of sand filter, where slope < = 5% (ft)	L_{sand}	452
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**4520**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**402**

Water quality requirement is satisfied in SPSC

Contact

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ANNE ARUNDEL COUNTY
MARYLAND

Input values shaded in Grey "Required"
Calculated values are noted with dotted pattern
Check parameters in bold

Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood				
Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.38	
Pre development discharge (cfs)	Q_{pre}	73.8	1.0	29.3
Post development design discharge (cfs)	Q_{post}	73.8	1.0	29.3
Total available length (ft)	L	452	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	15.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.03	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	20	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	11	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	20	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	27.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	1.0	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_r	1.5	**ok**	
Enter Desired Pool Depth (ft)	h_r	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**13.5**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.7**		
Computed Roughness	n	0.05		
Riffle Cross Section Area (ft2), for parabola	A	18.00		
Theta - Intermediate step for solving	θ	0.15		
Riffle Hydraulic Perimeter (ft), for parabola	P	27.10		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	0.66		
Calculated Flow for design parameters (cfs)	Q	76.26		
Check Riffle Velocity (ft/sec)	V	4.24		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**11**
Provided total pool depth (ft) =	**33**
hydraulic power for return period 100 year storm is satisfied	

Checking Quantity Management		
USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	27.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	1.00
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	**16.11**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	9
The area is for a semi parabola	A_{out}	97
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	1.43
Hydraulic Perimeter (ft), for semi parabola	P_{out}	34
Hydraulic Radius, using Chow 1959	R_h	2.83
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out},	f	0.21
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**0.00**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	4753		
Volume provided in voids (ft3)	2712		
Provided Volume of Storage (excludes infiltration) (ft3)	**8465**		
Infiltration Volume (ft3)	1000		

Peak Management of 100 year storm is satisfied

Peak Management of 1 year storm is satisfied

Peak Management of 10 year storm is satisfied

Checking Quality Management		
Site Drainage Area (Acres)	A	48
Contributory Impervious Area (Acres)	I	0
Volumetric Runoff Coefficient	Rv	0.05
Water Quality Volume, ft3	WQv	7841
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\ (Average\ of\ Pool\ and\ Riffle)}$	2.0
Width of sand filter (ft)	W_{sand}	10
Length of sand filter, where slope < = 5% (ft)	L_{sand}	452
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**4520**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**402**

Water quality requirement is satisfied in SPSC

OBJECTIVE:

Determine the dimensions and materials for the riffle grade control structures utilized for the SE-4 Reach (Unnamed Tributary to the Chesapeake Bay) regenerative stormwater conveyance practices.

ASSUMPTIONS:

The SE-4 reach is proposed to receive stormwater from the planned Unit 3 site development. Proposed condition design discharges for this reach were obtained from the Bechtel Corporation in October of 2009.

The design assumes that no additional stormwater will be routed through this reach and that the proposed conditions are a conservative estimate of the ultimate watershed condition.

PROCEDURE:

Flores, Hala, (2009). *Step Pool Storm Conveyance Design Calculator.* Anne Arundel County Department of Public Works, Annapolis, Maryland.

Flores, Markusic, McMonigle, and Underwood (2009). Step Pool Storm Conveyance. Anne Arundel County Department of Public Works, Annapolis, Maryland.

From TR-55, determine the pre- and post- development discharges for the 1, 10 and 100 year storm and associated time of concentration. For SE-4, Pre and Post development discharges are not equal since a large amount of stormwater from the site development is routed through the reach:

Drainage Area	Tc (hours)	100yr (CFS)	1yr (CFS)	10yr (CFS)
SE-4 Reach Pre-Development	0.321	169.0	10.0	101.1
SE-4 Reach Post-Development	0.321	395.2	23.0	236.7

As the valley width varies between the upper and lower portions of the site, two appropriate weir designs were utilized for the design.

Utilizing the site map, determine the length of conveyance areas and elevation drop through them. Calculate the desired number of weirs for the site based on the elevation drop through the weirs. **For SE-4, the reach is designed according to Anne Arundel County Specifications with 1' of drop per riffle and no slope on pools, with the reach having a regular riffle-pool distribution. Therefore all elevation change occurs within riffles.**

Two separate riffle widths were selected to meet site conditions, one each for the upper and lower portions of the reach.

The Step Pool Design Conveyance Calculator from Anne Arundel County Department of Public Works is utilized in this calculation. This calculator is modified to achieve the desired number elevation drop through the weirs coupled with the desired design discharges. Spreadsheets are attached to this calculation.

The water quality component was utilized for SE-4 designs. Water quality and quantity criteria are met in the storage in the sand filter and regenerative pools.

RESULTS:

Weir designs are summarized below:

Drainage Area	Cobble Size (Inches)	Width (Feet)	Depth (Feet)	Slope
SE-4 Upper	6	45	2.0	5.0%
SE-4 Lower	6	30	3.0	3.3%

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Date: 21-Dec-09

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c	19.30		
Pre development discharge (cfs)	Q_{pre}	169.0	10.0	101.0
Post development design discharge (cfs)	Q_{post}	395.2	23.0	236.7
Total available length (ft)	L	200	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	6.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.03	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	20	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	5	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	20	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	45.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	2.0	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
pools of the SPSC (ft)	h_r	3.0	**ok**	
Enter Desired Pool Depth (ft)	h_r	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**11.3**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.9**		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	60.00		
Theta - Intermediate step for solving	θ	0.18		
Riffle Hydraulic Perimeter (ft), for parabola	P	45.24		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.33		
Calculated Flow for design parameters (cfs)	Q	449.72		
Check Riffle Velocity (ft/sec)	V	7.50		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**5**
Provided total pool depth (ft) =	**15**

hydraulic power for return period 100 year storm is satisfied

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.04
The width at the entrance riffle	W_{in}	45.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	2.00
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be	D_{out}	**6.57**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	18
The area is for a semi parabola	A_{out}	79
protection volume.	L_{add}	268
Theta - Intermediate step for solving	θ	0.97
Hydraulic Perimeter (ft), for semi parabola	P_{out}	23
Hydraulic Radius, using Chow 1959	R_h	3.41
v_{out}, and d_{out}	f	0.22
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as		**0.00**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	261925	15053	157132
Volume provided in pools (ft3)	2161		
Volume provided in voids (ft3)	5400		
Provided Volume of Storage (excludes Infiltration) (ft3)	**8561**		
Infiltration Volume (ft3)	1000		

Peak Management of 100 year storm is not satisfied
Peak Management of 1 year storm is not satisfied
Peak Management of 10 year storm is not satisfied

Checking Quality Management

Water quality requirement is satisfied in SPSC

Site Drainage Area (Acres)	A	116
Contributory Impervious Area (Acres)	I	16.6
Volumetric Runoff Coefficient	Rv	0.18
Water Quality Volume, ft3	WQv	67758
Average Sand filter bed depth (ft) minimum 18 inches	d_f (Average of Pool and Riffle)	3.0
Width of sand filter (ft)	W_{sand}	30
Length of sand filter, where slope < = 5% (ft)	L_{sand}	200
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**6000**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00

design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\,Required}$	**2898**

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Check parameters in bold

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		19.30	
Pre development discharge (cfs)	Q_{pre}	169.0	10.0	101.0
Post development design discharge (cfs)	Q_{post}	395.2	23.0	236.7
Total available length (ft)	L	300	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	5.03	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.02	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	30	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	5	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	30	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	30.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	3.0	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
pools of the SPSC (ft)	h_r	4.0	**ok**	
Enter Desired Pool Depth (ft)	h_r	4.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		5.0		
Check the Froude Number to ensure Subcritical Flow Conditions		0.8		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	60.00		
Theta - Intermediate step for solving	θ	0.38		
Riffle Hydraulic Perimeter (ft), for parabola	P	30.78		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.95		
Calculated Flow for design parameters (cfs)	Q	462.00		
Check Riffle Velocity (ft/sec)	V	7.70	**Required Number of Pools**	5
			Provided total pool depth (ft) =	20

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Checking Quantity Management

hydraulic power for return period 100 year storm is satisfied

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.04
The width at the entrance riffle	W_{in}	30.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	3.00
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be	D_{out}	7.35
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	24
The area is for a semi parabola	A_{out}	118
protection volume.	L_{add}	402
Theta - Intermediate step for solving	θ	0.89
Hydraulic Perimeter (ft), for semi parabola	P_{out}	29
Hydraulic Radius, using Chow 1959	R_h	4.04
V_{out}, and d_{out}	f	0.20
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as		0.00

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	261925	15053	157132
Volume provided in pools (ft3)		5120	
Volume provided in voids (ft3)		8100	
Provided Volume of Storage (excludes infiltration) (ft3)		13220	
Infiltration Volume (ft3)			

Peak Management of 100 year storm is not satisfied
Peak Management of 1 year storm is not satisfied
Peak Management of 10 year storm is not satisfied

Checking Quality Management

Water quality requirement is satisfied in SPSC

Site Drainage Area (Acres)	A	116
Contributory Impervious Area (Acres)	I	16.6
Volumetric Runoff Coefficient	Rv	0.18
Water Quality Volume, ft3	WQv	67758
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\,(Average\ of\ Pool\ and\ Riffle)}$	3.0
Width of sand filter (ft)	W_{sand}	30
Length of sand filter, where slope < = 5% (ft)	L_{sand}	300
Area of sand filter provided (ft2)	$A_{f\,Provided}$	9000
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	4.00

design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\,Required}$	**2484**

OBJECTIVE:

Determine the dimensions and materials for the riffle grade control structures utilized for regenerative stormwater conveyance practices at Johns Creek stations JC 4+60 and JC 12+00 through 25+00.

ASSUMPTIONS:

The Johns Creek Valley at stations JC 4+60 and JC 12+00 through 25+00 is proposed to receive stormwater from the planned Unit 3 site development. Proposed condition design discharges for this reach were calculated by EA in October 2010.

SE/SR-5 reach is undeveloped and it is assumed that the pre=development conditions will persist into the future.

The design assumes that no additional stormwater will be routed through these reaches and that the proposed conditions for JC 4+60 and JC 12+00 through 25+00 are a conservative estimate of the ultimate watershed condition. The design further assumes that the pre-development condition is a suitable estimate of the watershed condition for SE/SR-5 since there is no proposed development to the drainage area of this reach.

Flores, Hala, (2009). *Step Pool Storm Conveyance Design Calculator*. Anne Arundel County Department of Public Works, Annapolis, Maryland.

Flores, Markusic, McMonigle, and Underwood (2009). Step Pool Storm Conveyance. Anne Arundel County Department of Public Works, Annapolis, Maryland.

PROCEDURE:

From TR-55, determine the design discharges for the 1, 10 and 100 year storm and associated time of concentration. EA developed design discharges from the site development utilizing information from Bechtel from 2009-2010, and developed the SE/SR-5 discharges through a TR-55 model:

Drainage Area	Tc (hours)	100yr (CFS)	1yr (CFS)	10yr (CFS)
SE/SR-5 Reach DA-9	0.28	324.2	5.3	126.1
SE/SR-5 Reach DA-10	0.69	126.1	0.7	24.2
B2 Outfall Post-Development	0.11	265.9	3.9	29.0
JNC 11B Outfall Post-Development	0.14	595.2	12.2	182.8
JNC 11CD Reach Outfall Post-Development	0.11	388.2	7.9	149.8
T-4 Outfall Post-Development	0.26	147.7	2.4	21.9

Utilizing the site map, determine the length of conveyance areas and elevation drop through each reach individually. Calculate the desired number of weirs for the site based on the elevation drop through the weirs.

For B2, the reach is designed according to Anne Arundel County Specifications with 1' of drop per riffle and no slope on pools, with the reach having a regular riffle-pool distribution. Therefore all elevation change occurs within riffles. **For the main stem of Johns Creek, MDE comment in August 2010 requested a stone grade control structure for every foot of elevation drop, with woody grade controls in between.**

The riffle weirs are therefore designed to have 3-4" of drop per riffle.

Reaches with proposed work included only those needed for discharges for the B2 reach, SE/SR-5, and the main stem of Johns Creek using JNC11CD.

The Step Pool Design Conveyance Calculator from Anne Arundel County Department of Public Works is utilized in this calculation. This calculator is modified to achieve the desired number elevation drop through the weirs coupled with the desired design discharges. Spreadsheets are attached to this calculation.

RESULTS:

As the valley width varies within the reaches, multiple weir designs were utilized for each reach assessed.
Weir designs are summarized below:

Drainage Area	Cobble Size (Inches)	Width (Feet)	Depth (Feet)	Slope
B2	6	63	1.5	3.5%
JNC11CD	6	100	2.2	1.2%
JNC11CD	6	80	2.5	1.2%
JNC11B	6	100	2.1	1.2%
JNC11B	6	130	2.0	1.2%
DA-9	6	100	1.5	2.1%
DA-9	6	57	2.0	2.1%
DA-10	6	62	2.0	1.7%

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Checking the Channel Conveyance for the design flood				
Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.23	
Pre development discharge (cfs)	Q_{pre}	265.9	3.9	29.0
Post development design discharge (cfs)	Q_{post}	265.9	3.9	29.0
Total available length (ft)	L	190	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	3.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.02	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	C_{riffle}	14	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	7	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	14	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	63.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	1.5	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_f	**2.0**	**ok**	
Enter Desired Pool Depth (ft)	h_i	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**21.0**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.6**		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	63.00		
Theta - Intermediate step for solving	θ	0.09		
Riffle Hydraulic Perimeter (ft), for parabola	P	63.10		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.00		
Calculated Flow for design parameters (cfs)	Q	267.69		
Check Riffle Velocity (ft/sec)	V	4.25		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**7**
Provided total pool depth (ft) =	**21**
hydraulic power for return period 100 year storm is satisfied	

Checking Quantity Management		
USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.04
The width at the entrance riffle	W_{in}	63.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	1.50
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	**4.19**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	12
The area is for a semi parabola	A_{out}	34
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	0.95
Hydraulic Perimeter (ft), for semi parabola	P_{out}	15
Hydraulic Radius, using Chow 1959	R_h	2.21
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out},	f	0.28
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**0.00**

Required Volume of Storage (Rational Hydrograph)	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	3025		
Volume provided in voids (ft3)	1140		
Provided Volume of Storage (excludes infiltration) (ft3)	5165		
Infiltration Volume (ft3)	1000		
Peak Management of 100 year storm is satisfied			
Peak Management of 1 year storm is satisfied			
Peak Management of 10 year storm is satisfied			

Checking Quality Management		
Site Drainage Area (Acres)	A	48
Contributory Impervious Area (Acres)	I	0
Volumetric Runoff Coefficient	Rv	0.05
Water Quality Volume, ft3	WQv	7841
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\,(\text{Average of Pool and Riffle})}$	2.0
Width of sand filter (ft)	W_{sand}	10
Length of sand filter, where slope < = 5% (ft)	L_{sand}	190
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**1900**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**402**

Water quality requirement is satisfied in SPSC

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Check parameters in bold

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Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.28	
Pre development discharge (cfs)	Q_{pre}	59.7	0.7	24.2
Post development design discharge (cfs)	Q_{post}	334.8	5.7	129.7
Total available length (ft)	L	853	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	9.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.01	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	16	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	27	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	16	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	57.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	2.0	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_i	2.0	**ok**	
Enter Desired Pool Depth (ft)	h_p	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**14.3**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.6**		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	76.00		
Theta - Intermediate step for solving	θ	0.14		
Riffle Hydraulic Perimeter (ft), for parabola	P	57.19		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.33		
Calculated Flow for design parameters (cfs)	Q	338.27		
Check Riffle Velocity (ft/sec)	V	**4.45**		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**27**
Provided total pool depth (ft) =	**81**
Run Solver	

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	57.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	2.00
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	**13.20**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	12
The area is for a semi parabola	A_{out}	106
protection volume.	L_{add}	3932
Theta - Intermediate step for solving	θ	1.35
Hydraulic Perimeter (ft), for semi parabola	P_{out}	30
Hydraulic Radius, using Chow 1959	R_h	3.51
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out},	f	0.20
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		-6.28

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	4655	85	1786
Volume provided in pools (ft3)	11668		
Volume provided in voids (ft3)	10236		
Provided Volume of Storage (excludes infiltration) (ft3)	**22904**		
Infiltration Volume (ft3)	1000		
Run Solver			
Run Solver			
Run Solver			

Checking Quality Management		
Site Drainage Area (Acres)	A	68
Contributory Impervious Area (Acres)	I	35
Volumetric Runoff Coefficient	Rv	0.53
Water Quality Volume, ft3	WQv	113692
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\,(Average\ of\ Pool\ and\ Riffle)}$	5.0
Width of sand filter (ft)	W_{sand}	8
Length of sand filter, where slope < = 5% (ft)	L_{sand}	853
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**6824**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**3647**

Water quality requirement is satisfied in SPSC

Contact

2662 Riva Road
Annapolis, MD 21401
Phone 410 222 4241

Anne Arundel County Government
Department of Public Works
Bureau of Engineering
Watershed and Ecosystem Services and Restoration
Watershed Assessment and Planning

ANNE ARUNDEL COUNTY
MARYLAND

Input values shaded in Grey "Required"
Calculated values are noted with dotted pattern
Check parameters in bold

Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.28	
Pre development discharge (cfs)	Q_{pre}	59.7	0.7	24.2
Post development design discharge (cfs)	Q_{post}	334.8	5.7	129.7
Total available length (ft)	L	853	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	9.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.01	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	16	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	27	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	16	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	100.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	1.5	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_t	1.5	**ok**	
Enter Desired Pool Depth (ft)	h_r	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**33.3**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.5**		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	100.00		
Theta - Intermediate step for solving	θ	0.06		
Riffle Hydraulic Perimeter (ft), for parabola	P	100.06		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.00		
Calculated Flow for design parameters (cfs)	Q	347.55		
Check Riffle Velocity (ft/sec)	**V**	**3.48**		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**27**
Provided total pool depth (ft) =	**81**
Run Solver	

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.03
The width at the entrance riffle	W_{in}	100.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	1.50
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	**13.20**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	9
The area is for a semi parabola	A_{out}	79
protection volume.	L_{add}	3932
Theta - Intermediate step for solving	θ	1.40
Hydraulic Perimeter (ft), for semi parabola	P_{out}	29
Hydraulic Radius, using Chow 1959	R_h	2.76
Darcy Weisbach friction factor expressed in terms of L_{add}, v_{out},	f	0.22
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**-10.72**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	4655	85	1786
Volume provided in pools (ft3)	11668		
Volume provided in voids (ft3)	10236		
Provided Volume of Storage (excludes infiltration) (ft3)	**22904**		
Infiltration Volume (ft3)	1000		

Run Solver

Run Solver

Run Solver

Checking Quality Management		
Site Drainage Area (Acres)	A	68
Contributory Impervious Area (Acres)	I	35
Volumetric Runoff Coefficient	Rv	0.53
Water Quality Volume, ft3	WQv	113692
Average Sand filter bed depth (ft) minimum 18 inches	d_f (Average of Pool and Riffle)	5.0
Width of sand filter (ft)	W_{sand}	8
Length of sand filter, where slope < = 5% (ft)	L_{sand}	853
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**6824**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**3647**

Water quality requirement is satisfied in SPSC

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MARYLAND

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Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c	[illegible]	0.69	[illegible]
Pre development discharge (cfs)	Q_{pre}	324.2	5.3	126.1
Post development design discharge (cfs)	Q_{post}	324.2	5.3	126.1

Total available length (ft)	L	726	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	6.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.01	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	20	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	18	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	20	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose > 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	62.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	2.0	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_r	**2.0**	**ok**	
Enter Desired Pool Depth (ft)	h_p	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**15.5**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.5**		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	82.67		
Theta - Intermediate step for solving	θ	0.13		
Riffle Hydraulic Perimeter (ft), for parabola	P	62.17		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.33		
Calculated Flow for design parameters (cfs)	Q	325.97		
Check Riffle Velocity (ft/sec)	V	**3.94**	**Required Number of Pools**	**18**
			Provided total pool depth (ft) =	**54**
			hydraulic power for return period 100 year storm is satisfied	

Isbash curve for Stone Density = 165 lb/ft3

Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.04
The width at the entrance riffle	W_{in}	62.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	2.00
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	7.93
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	12
The area is for a semi parabola	A_{out}	63
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	1.21
Hydraulic Perimeter (ft), for semi parabola	P_{out}	21
Hydraulic Radius, using Chow 1959	R_h	3.05
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out},	f	0.22
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**0.00**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	7778		
Volume provided in voids (ft3)	4350		
Provided Volume of Storage (excludes infiltration) (ft3)	**13128**		
Infiltration Volume (ft3)	1000		

Peak Management of 100 year storm is satisfied
Peak Management of 1 year storm is satisfied
Peak Management of 10 year storm is satisfied

Checking Quality Management		
Site Drainage Area (Acres)	A	193
Contributory Impervious Area (Acres)	I	0
Volumetric Runoff Coefficient	Rv	0.05
Water Quality Volume, ft3	WQv	31527
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\ (Average\ of\ Pool\ and\ Riffle)}$	2.0
Width of sand filter (ft)	W_{sand}	10
Length of sand filter, where slope < = 5% (ft)	L_{sand}	725
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**7250**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**1618**

Water quality requirement is satisfied in SPSC

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ANNE ARUNDEL COUNTY
M A R Y L A N D

Input values shaded in Grey "Required"
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Check parameters in bold

Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood				
Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.23	
Pre development discharge (cfs)	Q_{pre}	595.2	12.2	182.8
Post development design discharge (cfs)	Q_{post}	595.3	12.2	182.8
Total available length (ft)	L	900	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	9.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.01	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	15	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	30	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	15	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	100.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	2.1	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_f	**2.0**	**ok**	
Enter Desired Pool Depth (ft)	Δh	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**23.8**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.5**		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	140.00		
Theta - Intermediate step for solving	θ	0.08		
Riffle Hydraulic Perimeter (ft), for parabola	P	100.12		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.40		
Calculated Flow for design parameters (cfs)	Q	633.03		
Check Riffle Velocity (ft/sec)	V	**4.52**	**Required Number of Pools**	**30**
			Provided total pool depth (ft) =	**90**
			#NUM!	

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Checking Quantity Management		
USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	#NUM!
The width at the entrance riffle	W_{in}	100.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	2.10
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	-34.68
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	12
The area is for a semi parabola	A_{out}	-277
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	-1.48
Hydraulic Perimeter (ft), for semi parabola	P_{out}	71
Hydraulic Radius, using Chow 1959	R_h	-3.89
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out},	f	#NUM!
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**#NUM!**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	1	0	0
Volume provided in pools (ft3)	12964		
Volume provided in voids (ft3)	5400		
Provided Volume of Storage (excludes infiltration) (ft3)	**19364**		
Infiltration Volume (ft3)	1000		
#NUM!			
#NUM!			
#NUM!			

Checking Quality Management		
Site Drainage Area (Acres)	A	48
Contributory Impervious Area (Acres)	I	0
Volumetric Runoff Coefficient	Rv	0.05
Water Quality Volume, ft3	WQv	7841
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\ (Average\ of\ Pool\ and\ Riffle)}$	2.0
Width of sand filter (ft)	W_{sand}	10
Length of sand filter, where slope < = 5% (ft)	L_{sand}	900
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**9000**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**402**

Water quality requirement is satisfied in SPSC

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ANNE ARUNDEL COUNTY
M A R Y L A N D

Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Input values shaded in Grey "Required"
Calculated values are noted with dotted pattern
Check parameters in bold

Checking the Channel Conveyance for the design flood				
Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.23	
Pre development discharge (cfs)	Q_{pre}	595.2	12.2	182.8
Post development design discharge (cfs)	Q_{post}	595.3	12.2	182.8
Total available length (ft)	L	900	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	9.0	Design Width (ft)	
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.01	A	0.00
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	15	θ	#DIV/0!
Number of Riffle Segments for Project	N_{riffle}	30	P	#DIV/0!
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	#DIV/0!
Required Length of Pool Segments (ft)	L_{pool}	15	Design Velocity (ft/sec)	#DIV/0!
Cobble d50 size (ft) - choose - 6 inches	d50	0.50	Conveyed Q (cfs)	#DIV/0!
Top width of SPSC riffle channel (ft)	W	130.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	1.8	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	#DIV/0!
of the SPSC (ft)	h_r	**2.0**	**ok**	
Enter Desired Pool Depth (ft)	h_p	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**36.1**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.5**		
Computed Roughness	n	0.04		
Riffle Cross Section Area (ft2), for parabola	A	156.00		
Theta - Intermediate step for solving	θ	0.06		
Riffle Hydraulic Perimeter (ft), for parabola	P	130.07		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.20		
Calculated Flow for design parameters (cfs)	Q	618.94		
Check Riffle Velocity (ft/sec)	V	**3.97**		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**30**
Provided total pool depth (ft) =	**90**
#NUM!	

Checking Quantity Management		
USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	#NUM!
The width at the entrance riffle	W_{in}	130.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	1.80
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	-29.94
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	12
The area is for a semi parabola	A_{out}	-240
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	-1.47
Hydraulic Perimeter (ft), for semi parabola	P_{out}	62
Hydraulic Radius, using Chow 1959	R_h	-3.86
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out},	f	#NUM!
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**#NUM!**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	1	0	0
Volume provided in pools (ft3)	12964		
Volume provided in voids (ft3)	5400		
Provided Volume of Storage (excludes infiltration) (ft3)	**19364**		
Potential Infiltration Volume (ft3)	1000		
#NUM!			
#NUM!			
#NUM!			

Checking Quality Management		
Site Drainage Area (Acres)	A	48
Contributory Impervious Area (Acres)	I	0
Volumetric Runoff Coefficient	Rv	0.05
Water Quality Volume, ft3	WQv	7841
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\,(Average\ of\ Pool\ and\ Riffle)}$	2.0
Width of sand filter (ft)	W_{sand}	10
Length of sand filter, where slope < = 5% (ft)	L_{sand}	900
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**9000**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**402**

Water quality requirement is satisfied in SPSC

Contact

2662 Riva Road
Annapolis, MD 21401
Phone 410 222 4241

Anne Arundel County Government
Department of Public Works
Bureau of Engineering
Watershed and Ecosystem Services and Restoration
Watershed Assessment and Planning

ANNE ARUNDEL COUNTY
MARYLAND

Input values shaded in Grey "Required"
Calculated values are noted with dotted pattern
Check parameters in bold

Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.23	
Pre development discharge (cfs)	Q_{pre}	388.2	7.9	149.8
Post development design discharge (cfs)	Q_{post}	388.2	7.9	149.8
Total available length (ft)	L	1015	**Cascade Design (maximum 5 ft drop per segment)**	
Elevation drop over length (ft)	delta E	6.0	Design Width (ft)	40.00
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00	Design Depth (ft)	10.00
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50	Roughness	0.05
Water Quality slope (ft/ft)	Slope	0.01	A	266.67
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	28	θ	0.79
Number of Riffle Segments for Project	N_{riffle}	18	P	45.91
Number of Cascade Segments for Project	$N_{cascade}$	0	R_h	5.81
Required Length of Pool Segments (ft)	L_{pool}	28	Design Velocity (ft/sec)	68.09
Cobble d50 size (ft) - choose 12 inches	**d50**	**1.00**	Conveyed Q (cfs)	18156.55
Top width of SPSC riffle channel (ft)	W	100.0	**No Cascade is Needed**	
Depth of SPSC riffle channel (ft)	D	2.2	Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	82.00
of the SPSC (ft)	h_f	**2.0**	**ok**	
Enter Desired Pool Depth (ft)	h	3.0	**subcritical/ok**	
Check Riffle Side Slope, Must be > 2H:1V		**22.7**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.3**		
Computed Roughness	n	0.05		
Riffle Cross Section Area (ft2), for parabola	A	146.67		
Theta - Intermediate step for solving	θ	0.09		
Riffle Hydraulic Perimeter (ft), for parabola	P	100.13		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.46		
Calculated Flow for design parameters (cfs)	Q	406.58		
Check Riffle Velocity (ft/sec)	V	2.77		

Isbash curve for Stone Density = 165 lb/ft3		
Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	**18**
Provided total pool depth (ft) =	**54**
hydraulic power for return period 100 year storm is satisfied	

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.04
The width at the entrance riffle	W_{in}	100.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	2.20
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	7.99
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	12
The area is for a semi parabola	A_{out}	64
protection volume.	L_{add}	0
Theta - Intermediate step for solving	θ	1.21
Hydraulic Perimeter (ft), for semi parabola	P_{out}	21
Hydraulic Radius, using Chow 1959	R_h	3.06
Darcy Weisbach friction factor expressed in terms of L_{add}, V_{out},	f	0.32
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**0.00**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	7778		
Volume provided in voids (ft3)	6090		
Provided Volume of Storage (excludes infiltration) (ft3)	14868		
Infiltration Volume (ft3)	1000		

Peak Management of 100 year storm is satisfied

Peak Management of 1 year storm is satisfied

Peak Management of 10 year storm is satisfied

Checking Quality Management		
Site Drainage Area (Acres)	**A**	**48**
Contributory Impervious Area (Acres)	[illegible]	**0**
Volumetric Runoff Coefficient	Rv	0.05
Water Quality Volume, ft3	WQv	7841
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\,(Average\ of\ Pool\ and\ Riffle)}$	**2.0**
Width of sand filter (ft)	W_{sand}	**10**
Length of sand filter, where slope < = 5% (ft)	L_{sand}	1015
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**10150**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days), MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**402**

Water quality requirement is satisfied in SPSC

Contact

2662 Riva Road
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Bureau of Engineering
Watershed and Ecosystem Services and Restoration
Watershed Assessment and Planning

ANNE ARUNDEL COUNTY
M A R Y L A N D

Input values shaded in Grey "Required"
Calculated values are noted with dotted pattern
Check parameters in bold

Developed by: Hala Flores, P.E.
Date: 21-Dec-09

Checking the Channel Conveyance for the design flood

Design Return Period (Yr)	T	100	1	10
Time of Concentration in minutes (Before Development)	t_c		0.23	
Pre development discharge (cfs)	Q_{pre}	388.2	7.9	149.8
Post development design discharge (cfs)	Q_{post}	388.2	7.9	149.8
Total available length (ft)	E	1015		
Elevation drop over length (ft)	delta E	6.0		
Total Cascade Length for Project (ft)	$L_{cascade}$	0.00		
Maximum Cascade Slope (ft/ft)	$Slope_{cascade}$	0.50		
Water Quality slope (ft/ft)	Slope	0.01		
Average Length of Riffle Segments (ft), Minimum 10 ft	L_{riffle}	28		
Number of Riffle Segments for Project	N_{riffle}	18		
Number of Cascade Segments for Project	$N_{cascade}$	0		
Required Length of Pool Segments (ft)	L_{pool}	28		
Cobble d50 size (ft) - choose - 12 inches	d50	1.00		
Top width of SPSC riffle channel (ft)	W	80.0		
Depth of SPSC riffle channel (ft)	D	2.5		
of the SPSC (ft)	h_t	2.0	ok	
Enter Desired Pool Depth (ft)	h_p	3.0	subcritical/ok	
Check Riffle Side Slope, Must be > 2H:1V		**16.0**		
Check the Froude Number to ensure Subcritical Flow Conditions		**0.3**		
Computed Roughness	n	0.05		
Riffle Cross Section Area (ft2), for parabola	A	133.33		
Theta - intermediate step for solving	θ	0.12		
Riffle Hydraulic Perimeter (ft), for parabola	P	80.21		
Riffle Hydraulic Radius (ft), using Chow 1959	R_h	1.66		
Calculated Flow for design parameters (cfs)	Q	415.73		
Check Riffle Velocity (ft/sec)	**V**	**3.12**		

Cascade Design (maximum 5 ft drop per segment)

Parameter	Value
Design Width (ft)	40.00
Design Depth (ft)	10.00
Roughness	0.05
A	266.67
θ	0.79
P	45.91
R_h	5.81
Design Velocity (ft/sec)	68.09
Conveyed Q (cfs)	18156.55

No Cascade is Needed

Minimum Pool Depth "Use 3 pools" following each cascade segment (ft)	82.00

Isbash curve for Stone Density = 165 lb/ft3

Cobble d50 size	Allowable Velocity (Supercritical)	Allowable Velocity (Subcritical)
[inches]	[ft/sec]	[ft/sec]
4	5.1	7.1
5	5.7	8.0
6	6.3	8.7
7	6.8	9.4
8	7.2	10.1
9	7.7	10.7
10	8.1	11.3
11	8.5	11.8
12	8.8	12.3
15	9.9	13.8
18	10.8	15.1

Adequate conveyance of design storm

Selected Cobble Size is Adequate for 100 year storm

Subcritical Flow is Predominant

Required Number of Pools	18
Provided total pool depth (ft) =	**54**

hydraulic power for return period 100 year storm is satisfied

Checking Quantity Management

USDA 2006, n expressed in terms of d_{out} and d_{50} = 8 inches	n	0.04
The width at the entrance riffle	W_{in}	60.00
The velocity at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	V_{in}	7.57
The depth at the entrance riffle is calculated using Manning formula calculator and Q_{post} for the 1 year storm	D_{in}	2.50
Enter Trial Value : The total pool depth needed to render the power equivalent to 100-year predevelopment/desired levels. This should be compared against the total	D_{out}	**8.32**
This is the typical top width of the dead storage pool parabolic areas, 10:1 side slope	W_{out}	12
The area is for a semi parabola	A_{out}	67
protection volume	L_{add}	0
Theta - intermediate step for solving	θ	1.22
Hydraulic Perimeter (ft), for semi parabola	P_{out}	21
Hydraulic Radius, using Chow 1959	R_h	3.10
Darcy Weisbach friction factor expressed in terms of L_{add}, v_{out}	f	0.31
Solved using Solver equation: Bernoulli equation rewritten in terms of d_{out} as the		**0.00**

Required Volume of Storage (Rational Hydrograph)

	100 Yr	1 Yr	10 Yr
Required Volume of Storage (ft3)	0	0	0
Volume provided in pools (ft3)	7778		
Volume provided in voids (ft3)	6090		
Provided Volume of Storage (excludes infiltration) (ft3)	**14868**		
Infiltration Volume (ft3)	1000		

Peak Management of 100 year storm is satisfied

Peak Management of 1 year storm is satisfied

Peak Management of 10 year storm is satisfied

Checking Quality Management

Water quality requirement is satisfied in SPSC

Site Drainage Area (Acres)	A	48
Contributory Impervious Area (Acres)	[illegible]	0
Volumetric Runoff Coefficient	Rv	0.05
Water Quality Volume, ft3	WQv	7841
Average Sand filter bed depth (ft) minimum 18 inches	$d_{f\,(Average\ of\ Pool\ and\ Riffle)}$	2.0
Width of sand filter (ft)	W_{sand}	10
Length of sand filter, where slope <= 5% (ft)	L_{sand}	1015
Area of sand filter provided (ft2)	$A_{f\ Provided}$	**10150**
coefficient of permeability of filter media (ft/day)	k	3.50
height of water above filter bed- pool depth (ft)	h_f	3.00
design filter bed drain time (days); MDE recommended value	t_f	1.67
Required filter bed area (ft2)	$A_{f\ Required}$	**402**

Appendix F

List of Plan Details and Standard Specifications

PLAN DETAILS AND SPECIFICATION LIST
DRAFT FINAL PHASE II NONTIDAL WETLAND AND STREAM MITIGATION PLAN
CALVERT CLIFFS NUCLEAR POWER PLANT, UNIT 3

GENERAL REQUIREMENTS
SUMMARY OF WORK
SUBMITTAL PROCEDURES
CONTRACTOR HEALTH AND SAFETY PLAN
ENVIRONMENTAL MANAGEMENT
TEMPORARY CONSTRUCTION FACILITIES AND CONTROLS
EROSION AND SEDIMENT CONTROL
CLOSEOUT PROCEDURES

EARTHWORK
EARTHWORK AND DEWATERING
CLEARING AND GRUBBING

RESTORATION TECHNIQUE SPECIFICATIONS
REGENERATIVE STORMWATER CONVEYANCE (AA CO. SPEC)

TEMPORARY INSTREAM CONSTRUCTION MEASURES
MGWC 1.2: PUMP-AROUND PRACTICE

STREAM CROSSINGS
MGWC 4.1: FORD CROSSING

SLOPE PROTECTION AND STABILIZATION TECHNIQUES
MGWC 2.2: IMBRICATED RIPRAP
MGWC 2.4: LIVE STAKES
MGWC 2.5: LIVE FACINES
MGWC 2.7: BRUSH LAYERING
MGWC 2.10: ROOT WADS
MGWC 2.11: TOE PROTECTION

CHANNEL STABILIZATION AND REHABILITATION TECHNIQUES
MGWC 3.1: BOULDER PLACEMENT
MGWC 3.2: LOG VANES
MGWC 3.3: ROCK VANES
MGWC 3.4: J-HOOK VANES
MGWC 3.8: CROSS VANES
MGWC 3.9: STEP POOLS
LOG CHANNEL CUT-OFF STRUCTURES
ROOT WAD/LOG VANE STRUCTURES

SPECIAL EXCAVATION
WETLAND EXCAVATION
STREAM CHANNEL EXCAVATION AND FILL
TIDAL EXCAVATION

SPECIAL ENVIRONMENTAL CONTROLS
CONTRACTOR POLLUTION CONTROL PLAN

CONSERVATION PLANTING AND SEEDING
PLUG/CONTAINER PLANTING DETAIL
TREE PLANTING 1" CAL. TREE DETAIL
TREE/SHRUB PLANTING DETAIL
SOD MATS
CONSERVATION PLANTS AND SEEDING

WATER QUALITY MONITORING (DURING CONSTRUCTION)

Appendix G

RSC Specification

REGENERATIVE STORMWATER CONVEYANCE SPECIFICATION
(Formerly "Coastal Plains Outfall")

GEOTEXTILE

02550.01 GENERAL

A. Description

Geotextile shall be placed over the prepared surface after The Engineer has approved the excavation as shown on the drawings or as directed by The Engineer.

B. Related Work Included Elsewhere

Not applicable.

C. Quality Assurance

The engineer will inspect all materials prior to and/or after installation to ensure compliance with the Contract Documents.

D. Submittals

None.

02550.02 MATERIALS

A. Materials Furnished by the County

The County will not furnish any materials for geotextile.

B. Contractor's Options

Not applicable.

C. Detailed Material Requirements

1. Fabric shall be furnished in accordance with Section 02295.02. Paragraph 4.

02550.03 EXECUTION

All materials and construction techniques shall be inspected and approved by The Engineer prior to installation.

After the Engineer has approved the excavation, the Contractor shall install the geotextile fabric over the prepared surface. Securing pins shall be used to anchor the fabric in place. Where fabric overlaps are necessary, the minimum overlap shall at least 12 inches.

Geotextile fabric under the cobble weirs will not be required; however, the Contractor shall place geotextile under the sandstone boulders and exercise care in the placement of boulders to prevent puncture of the geotextile. If geotextile is punctured, the boulders shall be fully removed for at least three feet outside the limits of the fabric puncture and a new geotextile patch with minimum overlap, shall be securely fastened over the puncture with securing pins. No payment will be made for work involved in the repair of Contractor damaged geotextile.

The Contractor shall be responsible for disposal of all trash and any materials incidental to the project and disposing of them off-site.

02550.04 METHOD OF MEASUREMENT

Measurement for geotextile will be made of the surface area measured in place and acceptably installed.

02550.04 BASIS OF PAYMENT

Geotextile shall be measured and paid for at the Contract unit price per square yard of fabric installed. Payment for geotextile will be full compensation for furnishing and installing all materials, labor, equipment, tools and incidentals necessary to complete the work as specified in these special provisions and as on the plans.

BANK RUN GRAVEL AND SAND

02551.01 GENERAL

A. Description

The contractor shall furnish all labor, material and equipment required to install bank run gravel and sand as fill material as described in these Special Provisions and shown on the plans. This work shall consist of transporting, installing and maintaining bank run gravel and sand materials within the channel and on the floodplain, as specified on the plans or as directed by The Engineer.

B. Related Work Included Elsewhere

Not applicable.

C. Quality Assurance

The engineer will inspect all materials prior to and/or after installation to ensure compliance with the Contract Documents.

D. Submittals

The Contractor will locate potential sources for the bank run gravel and sand. The Contractor and the Engineer will jointly visit the sites to determine whether the sand and bank run gravel meets the specified requirements. The Contractor will not be granted an extension of time or extra compensation due to delay caused by sampling, testing, approval or disapproval of stone protection material under the requirements of these specifications.

02551.02 MATERIALS

A. Materials Furnished by the County

The County will not furnish any materials for bank run gravel and sand.

B. Contractor's Options

Not applicable.

C. Detailed Material Requirements

1. Sand shall meet the requirements of AASHTO C-33 size, #57, Section 02621.02.
2. Bank-run gravel shall be BRG base in accordance with Section 02621.02.
3. Wood chips and mulch shall be in accordance with Section 02860.02.

The Contractor will locate potential sources for the bank run gravel and sand. The Contractor and the Engineer will jointly visit the sites to determine whether the sand and bank run gravel meets the specified requirements. The Contractor will not be granted an extension of time or extra compensation due to delay caused by sampling, testing, approval or disapproval of stone protection material under the requirements of these specifications.

02551.03 EXECUTION

The Contractor shall install the bank run gravel and sand in accordance with Construction Drawings and these Special Provisions.

All remaining fill areas along the edges, ends of the placed cobble, and the underlying sand bed shall be backfilled with a soil mix comprised of masonry or concrete sand, containing less than 10 percent silt and / or clay, mixed and evenly blended with 20% wood chips or stump grindings, by volume. This material shall be placed to blend in with contiguous slopes, swales, or existing ground or used to form pool bottom.

Bank run gravel and sand shall be placed by mechanical or other acceptable methods with a minimum of voids. The bank run gravel and sand shall be placed to form a neat and uniform surface area. No mortar is permitted.

02551.04 METHOD OF MEASUREMENT

Measurement for bank run gravel and sand will be made of the volume measured in place, in cubic yards, and acceptably installed.

02551.04 BASIS OF PAYMENT

Payment for bank run gravel and sand shall be paid on per cubic yard of sand and bank run gravel installed. Payment will be full compensation for all materials, excavation and installation of sand and bank run gravel and for all material, labor, equipment, tools, and incidentals necessary to complete the work as specified in these special provisions and on the plans.

COBBLE

02552.01 GENERAL

A. Description

The contractor shall furnish all labor, material and equipment required to install cobble structures as described in these Special Provisions and shown on the plans. This work shall consist of transporting, installing and maintaining cobble materials within the channel, as specified on the plans or as directed by The Engineer.

B. Related Work Included Elsewhere

Not applicable.

C. Quality Assurance

The engineer will inspect all materials prior to and/or after installation to ensure compliance with the Contract Documents.

D. Submittals

The contractor will locate potential sources for rock. The contractor shall obtain from the quarry and submit to the Engineer a certificate verifying the rock size, weight per cubic foot, specifications, and weight range of rock being supplied. A representative rock sample and sieve analysis will be submitted to the Engineer for approval prior to delivery to the site. The rock will be accepted upon visual inspection at the point of usage.

02552.02 MATERIALS

A. Materials Furnished by the County

The County will not furnish any materials for cobble.

B. Contractor's Options

Not applicable.

C. Detailed Material Requirements

The stone shall be silica cobbles and shall meet the following requirements as specified.

Grading by Class

Class I Cobble: contain individual pieces between 3 and 12 inches in diameter. The total weight of cobble shall contain not more than 10% of the pieces smaller than 1 inch in diameter.

Grading by D_{50} Size

Cobble shall be composed of a well-graded mixture of stone size so that 50% of the pieces, by weight, shall be larger than the d_{50} size determined by using charts prepared by the US Department of Agriculture, Soil Conservation Service. A well graded mixture as used herein is defined as a mixture composed primarily of larger stone sizes but with a sufficient mixture of other sizes to fill the large voids between the stones. The diameter of the largest stone size in such a mixture shall be 1.5 times the d_{50} size (e.g., 8" * 1.5 = 12").

Sandstone Grizzly

This material is often referred to as "tailings" which are generated as a result of conventional sand mining operations in the coastal plain or piedmont regions. Sands and gravels that are mined in this region are typically screened prior to being washed to remove these large particles.

Sandstone grizzly shall contain individual pieces between 6 and 24 inches in length (10 - 50lbs). The total weight of boulders shall contain not more than 10% of the pieces smaller than 8 inches in diameter. This material can be used to expand the d_{50} in weirs where engineered sizes require stone larger than silica cobble (listed above).

The Contractor will locate potential sources for the rocks. The Contractor and the Engineer will jointly visit the sites to determine whether the stone meets the specified requirements. The Contractor will not be granted an extension of time or extra compensation due to delay caused by sampling, testing, approval or disapproval of stone protection material under the requirements of these specifications.

02552.03 EXECUTION

The Contractor shall install the cobble in accordance with Construction Drawings and these Special Provisions for cobble weirs. Cobble shall be placed by mechanical or other acceptable methods. The cobble shall be placed to form a neat and uniform surface area. No mortar is permitted.

Cobble shall be graded from the smallest to the largest pieces as specified above and will be controlled by visual inspection. The thickness of the cobble layer shall be 1.5 x 1.5 times the d50 (18" in depth). Sandstone grizzly may be utilized in critical areas as determined by The Engineer during construction and shall contain individual pieces between 6 and 24 inches in length (20 - 50lbs).

02552.04 METHOD OF MEASUREMENT

Measurement for cobble will be made of the volume measured in place, in cubic yards, and acceptably installed.

02552.04 BASIS OF PAYMENT

Payment for cobble shall be paid on per cubic yard of cobble installed. Payment will be full compensation for all materials, excavation and installation of cobble, and resetting of cobbles, and for all material, labor, equipment, tools, and incidentals necessary to complete the work as specified in these special provisions and on the plans.

SANDSTONE BOULDERS

02553.01 GENERAL

A. Description

Sandstone (aka, bog iron, ferracrete) is the only large type of boulder found on the coastal plain in Anne Arundel County. It is irregular and generally tabular in shape and neutral or acidic in pH.

The contractor shall furnish all labor, material and equipment required to install sandstone boulders as described in these Special Provisions and shown on the plans. This work shall consist of transporting, installing and maintaining sandstone boulder materials within the channel, as specified on the plans or as directed by The Engineer.

B. Related Work Included Elsewhere

Not applicable.

C. Quality Assurance

The engineer will inspect all materials prior to and/or after installation to ensure compliance with the Contract Documents.

D. Submittals

The contractor will locate potential sources for rock. The contractor shall obtain from the quarry and submit to the Engineer a certificate verifying the rock size, weight per cubic foot, specifications, and weight range of rock being supplied. A representative rock sample and sieve analysis will be submitted to the Engineer for approval prior to delivery to the site. The rock will be accepted upon visual inspection at the point of usage.

02553.02 MATERIALS

A. Materials Furnished by the County

The County will not furnish any materials for sandstone boulders.

B. Contractor's Options

Not applicable.

C. Detailed Material Requirements

Grading by Weight/Size

Sandstone boulders shall contain individual pieces between 2 and 6 feet in length (500 - 6,000lbs). The total weight of boulders shall contain not more than 10% of the pieces smaller than 15 inches in diameter.

The Contractor will locate potential sources for the sandstone boulders. The Contractor and the Engineer will jointly visit the sites to determine whether the stone meets the specified requirements. The Contractor will not be granted an extension of time or extra compensation due to delay caused by sampling, testing, approval or disapproval of stone protection material under the requirements of these specifications.

02553.03 EXECUTION

The Contractor shall install the sandstone boulders in accordance with Construction Drawings and these Special Provisions for sandstone boulders. Geotextile shall be placed at grade under the sandstone boulders as per the construction detail on the plans or as directed by The Engineer. Sandstone boulders shall be placed by mechanical or other acceptable methods with a minimum of voids. The sandstone boulders shall be placed to form a neat and uniform surface area. If necessary, sandstone can be chiseled or broken to achieve improved contact between stones. No mortar is permitted.

02553.04 METHOD OF MEASUREMENT

Measurement for sandstone boulders will be made of the volume measured in place and acceptably installed.

02553.04 BASIS OF PAYMENT

Payment for sandstone boulders shall be paid on per cubic yard of sandstone boulder installed. Payment will be full compensation for all materials, excavation and installation of sandstone boulders, and resetting of sandstone boulders, and for all material, labor, equipment, tools, and incidentals necessary to complete the work as specified in these special provisions and on the plans.

COMPOST

02554.01 GENERAL

A. Description

The contractor shall furnish all labor, material and equipment required to install compost as described in these Special Provisions and shown on the plans. This work shall consist of transporting, installing and maintaining compost material within the project area, as specified on the plans or as directed by The Engineer.

B. Related Work Included Elsewhere

Not applicable.

C. Quality Assurance

The engineer will inspect all materials prior to and/or after installation to ensure compliance with the Contract Documents.

D. Submittals

None.

02554.02 MATERIALS

A. Materials Furnished by the County

The County will not furnish any materials for compost.

B. Contractor's Options

Not applicable.

C. Detailed Material Requirements

Compost shall have a pH between 5.0 and 7.0. It shall be stable and not reheat upon restacking. Compost shall have a moisture content between 30 and 55 percent, a particle size of .5" or less.

Compost shall be of the following type:
Source-Separated Compost (Type B). Source-separated compost will be approved by the Maryland Department of the Agriculture (MDA). Compost shall be produced by an MDA certified compost operator. Compost shall have a soluble salt concentration not to exceed 5 ds (mmhos/cm).

Source-separated compost shall be one of the following types:
Tree leaf compost.

Non-tree leaf compost. When compost is from lawn clippings, it shall be tested for contaminant in conformance with COMAR 15.18.04.05.

The Contractor will locate, arrange, and coordinate visits to potential sources for the compost. The Contractor and the Engineer will jointly visit the sites to determine whether the compost meets the specified requirements. Compost shall be screened, and subject to approval by the Engineer. The Contractor will not be granted an extension of time or extra compensation due to delay caused by sampling, testing, approval or disapproval of compost material under the requirements of these specifications.

02554.03 EXECUTION

The Contractor shall install compost materials by mechanically blowing the compost into place at depths as specified on the construction drawings.

02554.04 METHOD OF MEASUREMENT

Measurement for compost will be made of the volume, in cubic yards, delivered to the site and acceptably installed.

02554.04 BASIS OF PAYMENT

Payment for compost shall be paid on per cubic yard of compost installed. Payment will be full compensation for all materials, excavation and installation of compost and for all material, labor, equipment, tools, and incidentals necessary to complete the work as specified in these special provisions and on the plans.

INVERTED ROOTWAD

02555.01 GENERAL

A. Description

The contractor shall furnish all labor, material and equipment required to install each inverted rootwad as described in these Special Provisions and shown on the plans. This work shall consist of harvesting, transporting, installing and maintaining inverted rootwad material within the project area, as specified on the plans or as directed by The Engineer.

B. Related Work Included Elsewhere

Not applicable.

C. Quality Assurance

The engineer will inspect all materials prior to and/or after installation to ensure compliance with the Contract Documents.

D. Submittals

None.

02555.02 MATERIALS

A. Materials Furnished by the County

The County will not furnish any materials for inverted rootwads.

B. Contractor's Options

Not applicable.

C. Detailed Material Requirements

Inverted rootwads shall consist of the root fan and trunk of a hardwood or pine tree with a trunk diameter at breast height (DBH) of 6 inches to 24 inches. Root fans shall be oblong to circular in shape and have a minimum spread of 2 feet as measured at its narrowest axis and covering an area a minimum of 16 square feet. The attached trunk shall be a minimum of 6 feet in length.

Inverted rootwads to be used for this construction can be salvaged from the project site provided that they meet the above requirements, are within the limits of grading, and are clearly flagged for clearing and grubbing. No live trees shall be harvested for the sole purpose of providing materials for this item. If sufficient materials meeting the above requirements are not available from the project site, the Contractor shall then obtain off site material meeting specified requirements.

02555.03 EXECUTION

Inverted rootwads shall be harvested by pushing over trees, leaving as much of the root fan and accompanying sod and soil clumps intact as possible. Care shall be taken in transporting rootwads to the construction site to minimize breakage of the root fan and loss of sod and soil.

Inverted rootwads are located in shallow aquatic pools at locations shown on the profile. Either push the trunk (stem side down) into soil or excavate the trench for the inverted rootwad and place in the trench so that the inverted rootwad sits with the root mass upward in the shallow aquatic pools, and backfill to secure. Placement of the inverted rootwads shall be verified by The Engineer to ensure that the inverted rootwads are secure.

02555.04 METHOD OF MEASUREMENT

Measurement for inverted rootwards will be made per rootwad placed and acceptably installed.

02555.04 BASIS OF PAYMENT

Payment for inverted rootwads shall be measured and paid at the Contract unit price per each inverted rootwad installed. Payment will be full compensation for the harvest and transport of all materials, excavation, installation and resetting of inverted rootwads all materials, excavation and installation of inverted rootwads and for all material, labor, equipment, tools, and incidentals necessary to complete the work as specified in these special provisions and on the plans.

PLANTS AND PLANTING

02556.01 GENERAL

A. Description

Contractor shall furnish all labor, material, equipment required to install plantings as specified on the plans or directed by the Engineer.

All requirements of Section 02860 Furnish and Plant Trees, Shrubs, Vines, Groundcovers and Seedling Stock of the Standard Specifications shall apply except as herein modified or as directed by the Engineer.

B. Related Work Included Elsewhere

Not applicable.

C. Quality Assurance

All requirements of Section 02860 Furnish and Plant Trees, Shrubs, Vines, Groundcovers and Seedling Stock of the Standard Specifications shall apply except as herein modified or as directed by the Engineer.

D. Submittals

None.

02556.02 MATERIALS

A. Materials Furnished by the County

The County will not furnish any materials for plants and planting.

B. Contractor's Options

Not applicable.

C. Detailed Material Requirements

Plants – All planting material shall be native to the Atlantic Coastal Plain region, and should be planted in appropriate wetness zones, as determined by designer, on the site.

The Contractor shall notify the Engineer of the plant deliver date(s), in writing, two (2) weeks prior to delivery.

02556.03 EXECUTION

All requirements of Section 02860 Furnish and Plant Trees, Shrubs, Vines, Groundcovers and Seedling Stock of the Standard Specifications shall apply except as herein modified or as directed by the Engineer.

After 3 years, the planted species must have an 85% survival, or the site must be 85% covered with native, non-invasive species. The pool bottoms must be 85% vegetated with native, non-invasive, wetland plants or aquatic vegetation.

02556.04 METHOD OF MEASUREMENT

All requirements of Section 02860 Furnish and Plant Trees, Shrubs, Vines, Groundcovers and Seedling Stock of the Standard Specifications shall apply except as herein modified or as directed by the Engineer.

02556.04 BASIS OF PAYMENT

All requirements of Section 02860 Furnish and Plant Trees, Shrubs, Vines, Groundcovers and Seedling Stock of the Standard Specifications shall apply except as herein modified or as directed by the Engineer.