U.S. Fish & Wildlife Service

Navy Dairy Farm Tributary Stream Restoration

Gambrills, Anne Arundel County, Maryland

Project Summary and Design Report Methodology

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NAVY DAIRY FARM STREAM RESTORATION, ANNE ARUNDEL COUNTY, MARYLAND: FUNCTION-BASED PROJECT SUMMARY AND DESIGN REPORT

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Stream Habitat Assessment and Restoration Program
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EXECUTIVE SUMMARY

The Maryland Department of Natural Resources (MDNR), Anne Arundel County (County), The Chesapeake Bay Foundation (CBF) and the US Fish and Wildlife Service (Service) are working cooperatively on nutrient/sediment reduction and habitat restoration project on the Naval Academy Dairy Farm in Gambrills, MD. The Navy Dairy Farm covers 857 acres and is leased by the Navy to Anne Arundel County. The farming operation is sub-leased from the County to Maryland Sunrise Farm, LLC. Maryland Sunrise Farm produces organically raised grains, hay and grass fed beef on the farm.

Approximately 750 acres of the farm drains to Towser's Branch (Little Patuxent River watershed). Most of the drainage enters Towser's Branch through an unnamed ephemeral stream that is significantly impaired and will be the subject of restoration work. The remaining acres of the farm drain to Jabez Branch, which is in the Severn River watershed. Jabez Branch is the last known stream with eastern brook trout in Maryland's Coastal Plain.

The programmatic goals of the Navy Dairy Farm stream restoration differ among the three main agencies involved with the restoration. The funds for the project were provided by the MDNR Bay Trust Fund, whose goal is to focus funds on the most cost-effective, innovative approaches within an efficient and logical location to improve the health of Maryland watershed lands, streams and non-tidal rivers. CBF's goal is to reduce sediment and nutrient pollution coming from the adjacent farmlands and streams in order to improve the water quality of the Chesapeake Bay Watershed. The Service's goals are to create riparian habitat for Eastern Wood-Peewee, Red-Shoulder Hawk and Acadian Flycatcher; to create wetland habitat for Spotted Salamander, Gray Tree Frog and Northern Green Frog; and to improve and preserve downstream habitat for American Eel and other aquatic species through stream restoration.

The Service conducted a rapid assessment to determine the restoration potential of the proposed site and if it was an appropriate site for restoration. The area had been impacted by agriculture practices, specifically row crops and livestock grazing, which has led to unstable stream banks, disconnected floodplain, poor bed-form diversity, streambed siltation, little to no riparian vegetation or buffer, and increased water temperatures. The Service, CBT and the County felt (based on a preliminary site visit) that many, if not all of these impacts could be restored. Additionally, the Service reviewed the recommendations of the Navy's Integrated Natural Resources Management Plans (INRMP) 2011 for the Navy Dairy Farm, which recommended habitat restoration and best management practices. Given the potential restoration lift and the INRMP recommendations, the Service and CBT felt that the proposed site would be an excellent candidate for reducing sedimentation and nutrients while providing a functional riparian buffer.

The project process used for this project follows the approach outlined in *A Function-Based Framework for Stream Assessment and Restoration Projects* (SFPF) (Harman et al., 2012). The SFPF is based on the premise of a hierarchal relationship among stream functions where lower-level functions support higher-level functions and that they are all influenced by local geology and climate, which underlies the Pyramid. The SFPF was integrated throughout the entire project process to ensure the most appropriate design approach would be selected. The project process

consists of the following steps: *Programmatic/Project Goals, Watershed Assessment, Reach-Scale Function-based Assessment, Restoration Potential, Design, Design Alternatives Analysis, Design Development,* and *Monitoring Plan*.

The focus of the watershed assessment was to determine the influence of the watershed health on the proposed project area. Specifically, watershed characteristics were evaluated to document hydrology (i.e., flow regime), sediment transport load (i.e., sources and amount), water quality (i.e., types and sources) and biology (i.e., locations and health). By understanding watershed conditions, we are able to determine if programmatic goals are achievable and determine the restoration potential of our project reach. The stream is ephemeral; however, the existing stream was most likely not a channel in the past but a swale, given its location in the watershed (headwaters) and the small drainage area. The watershed has a flashy flow regime due to existing land uses (i.e., primarily agriculture), poor soil conditions and concentrated flows. The existing soils are highly erodible and have very slow infiltration rates. The sediment supply of the project area consists primarily of suspended sediments. A total of 847 tons/year of sediment is eroded and of that, 347 tons/year is delivered to the stream, which is considered excessive.

The water quality being delivered to the project area is poor because of agriculture practices, highly erodible soils and point source discharges. There is no stream system upstream of the project area, therefore, there is no aquatic life upstream of the project.

The purpose of the reach level function-based assessment is to establish the existing functional condition, determine stressors, and identify constraints at the proposed project site. All existing critical functions, on every level of the pyramid were assessed so that potential changes in functions could be evaluated for each proposed design alternative. Additionally, critical functions supporting the project goals were also assessed.

The following assessment parameters, by pyramid level, were evaluated:

Level 1 - Hydrology – concentrated flows, land use changes, and flashiness (flow regime)
Level 2 - Hydraulics – floodplain connectivity and floodplain drainage
Level 3 - Geomorphology – lateral stability and riparian vegetation
Level 4 - Physicochemical – overall water quality
Level 5 - Biology – macroinvertebrate communities and fish communities

Each assessment parameter had at least one measurement method to quantify the existing function-based condition. Then, each measurement method value was rated as either functioning (F), functioning-at-risk (FAR), or not functioning (NF) based on set performance standards.

The Service identified two distinct reaches within the project area based on existing functionality and stream type. Reach 1 had an overall function-based condition of ***Functioning-at-Risk*** and Reach 2 had an overall function-based condition of ***Not Functioning.*** Both reaches are trending towards future instability before equilibrium can be reached.

The restoration potential is the highest level of restoration or functional lift that can be achieved given the watershed health, reach-level function-based condition, stressors and constraints.

(Harman et al., 2012). Based on these factors, the Service determined that for both Reach 1 and 2, pyramid Levels 2 - Hydraulics and 3 - Geomorphology can be restored to fully functional and pyramid Levels 1 - Hydrology and 4 – Physicochemical can have partial functional uplift. Since the project area is an ephemeral stream and baseline assessments indicated no or limited biological function, it is unlikely that there would be any potential uplift for level 5 – Biology.

The Service generated design objectives based on project goals, constraints and the restoration potential of the proposed project area. Design objectives should be quantifiable and describe how the proposed project will be implemented (Harman et al., 2012). There are common design objectives for both Reaches 1 and 2. There are some varying design objectives between the two reaches, based on their restoration potential. Table 1 below outlines the design objectives. The varying objectives are identified by either *"Reach 1 or Reach 2"* being written adjacent to the objective. The design objectives will also be used as monitoring performance standards.

Table 1 - Navy Dairy Farm - Design Objectives

Level and Category	Parameters	Design Objectives
Level 1- Hydrology	1. Flow Regime 2. Concentrated Flows	1. Reduce hydrograph peaks and increase duration compared to existing conditions (*Reach 2)* 2. Eliminate Concentrated Flows
Level 2 - Hydraulics	1. Floodplain Connectivity 2. Floodplain Storage	1a. Create floodplain connection at no greater than 1 yr storm event (*Reach 2)*. 1b. Create floodplain connection by BHR of 1.0 to 1.2 and ER of 1.4 to 2.2. (*Reach 1*) 2. Store flood flows up to a 5 yr storm event (*Reach 2*)
Level 3 - Geomorphology	1. Lateral Stability 2. Sediment/Reduction and Trapping 3. Riparian Buffer	1. Reduce stream bank erosion rates to match reference erosion rates (bank migration/lateral stability) 2. Decrease sediment loads leaving the project to loads less than entering loads entering the project 3. Create native riparian buffer for Eastern Wood-Peewee, Red-Shoulder Hawk, and Acadian Flycatcher
Level 4 - Physicochemical	1. Sediment Supply 2. Nutrient Levels	1. Refer to Level 3 sediment reduction and trapping objectives 2. Reduce nutrient levels compared to existing conditions

The Service conducted a design alternatives analysis to select the best restoration design approach that would meet the project goals, design objectives and the restoration potential of the site. It focused on how a specific design approach could influence stream functions (i.e., highest functional lift), impacts to existing functions, costs and risk.

There is a variety of design approaches available to restore stream functions of highly degraded stream systems. Typical design approaches used in Maryland include Natural Channel Design (NCD), Valley Restoration Design (VR), Analytical Design (AD) and Regenerative Storm Conveyance Design (RSC). The Service evaluated the strengths and limitations of each of these design approaches for the project area. Since flood flow storage and infiltration were priority design objectives, the Service focused on design approaches that were most effective in meeting these objectives. The Service recommended RSC for Reach 2 but not for Reach 1. The valley width was too narrow in Reach 1 to achieve any appreciable storage and filtration. Therefore, the Service recommended NCD for Reach 1. It is important to note that while the RSC design approach was the selected alternative for Reach 2, it is the functions produced by this approach (e.g., flood flow storage, increase attenuation and infiltration rather than conveyance) that the Services recommends. Therefore, the Service refers to this design approach as Storage and Infiltration System Design (SISD).

The proposed design stream type for Reach 1 is a Rosgen B4c. This stream type dissipates stream energy vertically through the use of grade control structures and close pool to pool spacing. The stream will be reconnected to the floodplain by gradually lifting the bed elevation through the use of grade control j-hooks and cross vanes. Additionally the banks will be graded back to increase the flood prone area to achieve an entrenchment ratio of at least 1.4. The banks will then be planted with native plant species. This design will allow the Service to achieve the Level 2 - Hydraulic design objectives of returning the bank height ratio to 1.0 through floodplain reconnection. Level 3 - Geomorphology design objectives of lateral stability will be achieved through the use of in-stream structures and riparian plantings.

The proposed design for Reach 2 involves a multi-tiered, stepped-pool system with a low width to depth ratio to dissipate energy laterally across the valley and vertically through the pools, as well as to attenuate storm flows. It consists of excavated pools, cobble weirs, sand/woodchip fill material and floodplain grade control structures. The existing channel will be filled with a sand/woodchip media, and then the pools will be excavated. The pools will hold water while it percolates vertically and longitudinally through the placed media as well as through the native soil. The cobble weirs were sized for a 5-year storm occurrence and the cobble material within the weirs were sized for a 100-year storm occurrence. The floodplain area will then be planted with native plant species. The excavation of pool areas and placement of infiltration media will enable the Service to achieve the Level 1 – Hydrology design objectives of storing and infiltrating flood flow, and Level 2 - Hydraulic design objective of reconnecting with the floodplain. Level 3 - Geomorphology design objectives of lateral stability will be achieved through the use of in-stream structures and riparian plantings. Level 4 – Physicochemical design objectives will be achieved through the storage created by the excavated pool areas.

Implementation of the NCD and SISD approaches typically involves channel realignment and extensive grading. Since the stream is ephemeral, the only potential impacts to existing

conditions would be to the existing riparian vegetation. However, since the existing riparian vegetation was rated as ***Not Functioning***, any potential realignment or grading will not adversely affect the existing riparian vegetation. Additionally, some temporary affects may occur during construction. These affects are typical of stream restoration projects regardless of which design approach is implemented and generally include increases in turbidity. Again, the stream is ephemeral, therefore, increases of turbidity during construction is greatly reduced. Erosion and sediment best management practices will be in place to reduce turbidity in the event that wet conditions occur.

The Service and CBF have also developed a monitoring plan based on the project goals and design objectives outlined in the report to evaluate the performance of the stream restoration project. The monitoring plan will include as-built surveys, rapid/visual geomorphic monitoring, monumented geomorphic surveys and biological surveys. As-built surveys will be used to confirm that the project was built to design standards and will also provide baseline data for future monitoring. The rapid/visual geomorphic surveys will follow the methodologies outlined in the *Rapid Stream Restoration Monitoring Protocols* (Davis et al., 2014) developed by the Service.

This report documents the findings of the function-based watershed assessment, function-based reach-scale assessment and design development process used by the Service to develop the restoration plan for the Navy Dairy Farm Stream Restoration Project.

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I. INTRODUCTION

The United States Navy (Navy), Maryland Department of Natural Resources (MDNR), Anne Arundel County (County), the Chesapeake Bay Foundation (CBF) and the US Fish and Wildlife Service (Service) are working cooperatively on a stream restoration project on the Navy Dairy Farm in Gambrills, MD. The project goals are to reduce nutrients and sediment through trapping and infiltration, as well as to improve stream and riparian habitat. The Navy acquired the property in 1913 to provide milk and food for the Naval Academy. In the 1990s, Federal legislation allowed the Navy to cease dairy operation and specified that the property remain in a "rural and agricultural nature."

The Navy Dairy Farm covers 857 acres and is now leased by the Navy to Anne Arundel County. The 30-year lease plans to convert 176 acres into a public park and keep the remaining acres as farm lands. Currently the farming operation is sub-leased from the County to Maryland Sunrise Farm, LLC. Maryland Sunrise Farm produces organically raised grains, hay and grass fed beef on the farm. The County's vision for the site is "Preservation, Utilization, Recreation, and Education."

Of the 857 acres, approximately 750 acres of the farm drains to Towser's Branch (Little Patuxent River watershed). Most of the drainage enters Towser's Branch through an unnamed ephemeral tributary that is significantly impaired and will be the subject of restoration work. The remaining acres of the farm drain to Jabez Branch, which is in the Severn River watershed. Jabez Branch is the last known stream with eastern brook trout in Maryland's Coastal Plain (Maryland Department of Natural Resources Fisheries Service, 2006). This project will draw on the experience and expertise of Federal, state and county agencies, non-governmental organizations and local volunteers to design, construct, monitor and maintain the restored area.

This report documents the findings of the function-based watershed assessment, function-based reach-scale assessment and design development process used by the Service to develop the restoration plan for the Navy Dairy Farm Stream Restoration.

II. SITE SELECTION

The Service has helped develop and approve the Navy's Integrated Natural Resources Management Plans for the Navy Dairy Farm for the last 20 years. The Navy Dairy Farm is one of a few large acre properties allocated to nature and agriculture within a relatively developed area. With increasing development, it is essential to preserve and restore these types of lands to their highest natural potential state in order to sustain growing anthropogenic stresses. The current plan recommends habitat restoration and best management practices, yet funding for any sort of project was not available.

In 2011, CBF approached the Service with Atlantic Coastal Bays Trust Fund (Bay Trust Fund) appropriations that were ear marked for restoration activities on public lands. With this in mind, the Service suggested the Navy Dairy Farm property. The Service, CBF, Navy, the County and

MD Sunrise Farms visited the site and determined that the Navy Dairy Farm offered an ideal location for water quality improvement projects on public lands. At that time, the Service proceeded to prioritize water quality projects throughout the entire property. The 5,000 linear foot ephemeral channel (Tributary 1) on the property was identified as a main source of sediment and nutrients and was prioritized for restoration.

Throughout its 5,000 lft entirety, Tributary 1 shows signs of lateral and vertical deteriorations. These deteriorations are likely the effect of land clearing, current farm practices and past cattle access for grazing. The Service identified reach breaks throughout the valley, which resulted in specific design objectives based on the valley's natural and anthropogenic constraints. This report is only for Reaches 1 and 2 (Phase 1), which are located in the first 1,075 lft of Tributary 1 (Figure 1). Subsequent reports (Phase 2) will be produced for the remaining reaches at a later date.

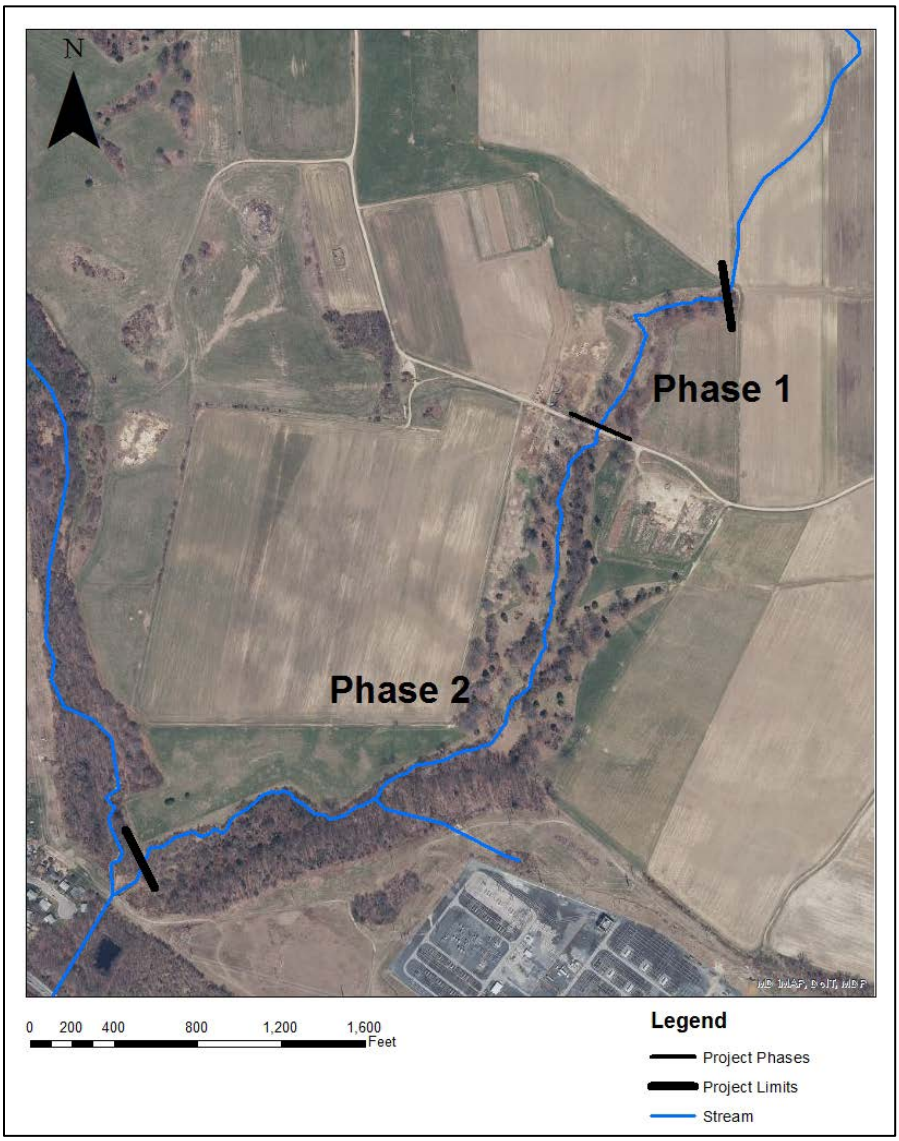

Figure 1: Navy Dairy Farm Stream Restoration Project Extent

III. PROJECT AND ASSESSMENT METHODOLOGY

A. PROJECT PROCESS

The Service used *"A Function-Based Framework for Stream Assessment and Restoration Projects"* (Harman, et al., A Function Based Framework for Stream Assessment and Restoration Projects, 2012) throughout the entire project process to ensure selection of the most appropriate design approach. This document is based on the premise of a hierarchal relationship of stream functions where lower-level functions support higher-level functions and that they are all influenced by local geology and climate, which underlies the Pyramid (Figure 2). The Pyramid consists of five critical categories that evaluate stream functions. The framework of the Streams Functions Pyramid (commonly called SFPF) is shown below in Figure 3. The Broad-Level View is the Stream Functions Pyramid graphic that was discussed above and shown in Figure 2. The remainder of the framework is a "drilling down" approach that provides more detailed forms of analysis and quantification of functions. The function-based parameters describe and support the functional statements within each functional category. The "measurement methods" are specific tools, equations, assessment methods, etc. that are used to quantify the function-based parameter. There can be more than one measurement method for a single function-based parameter. How the SFPF is specifically applied to the watershed and reach-level assessments is described below.

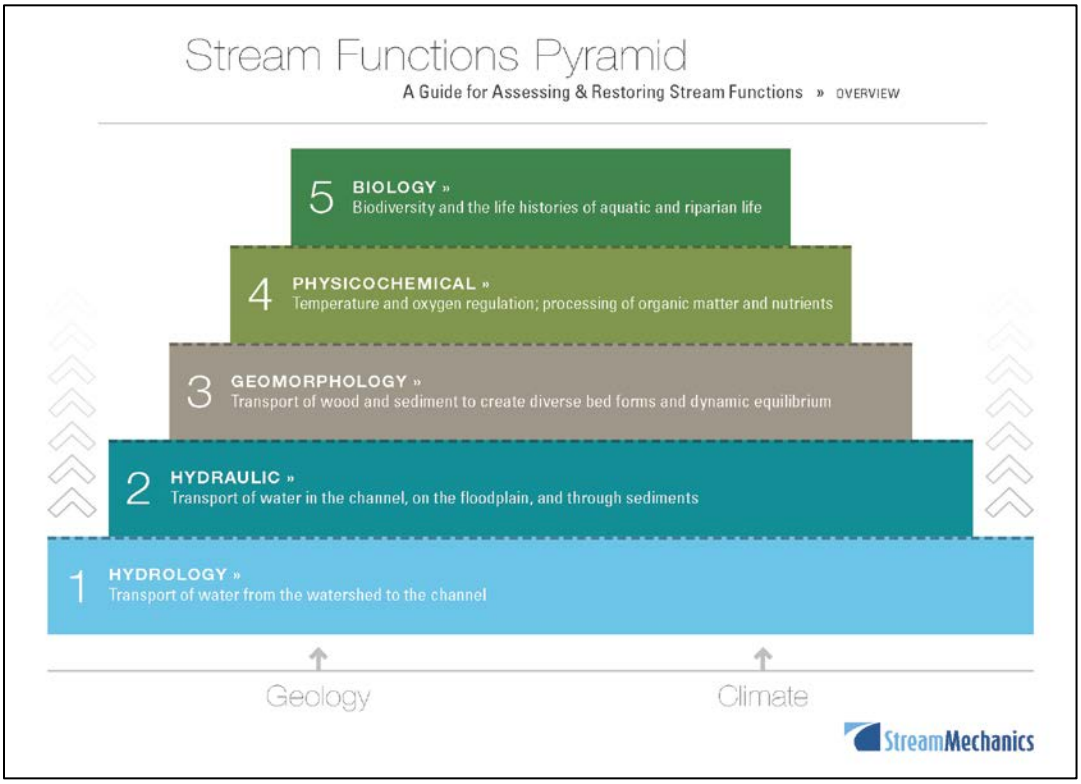

Figure 2: Stream Function Pyramid (Harman et all., 2012)

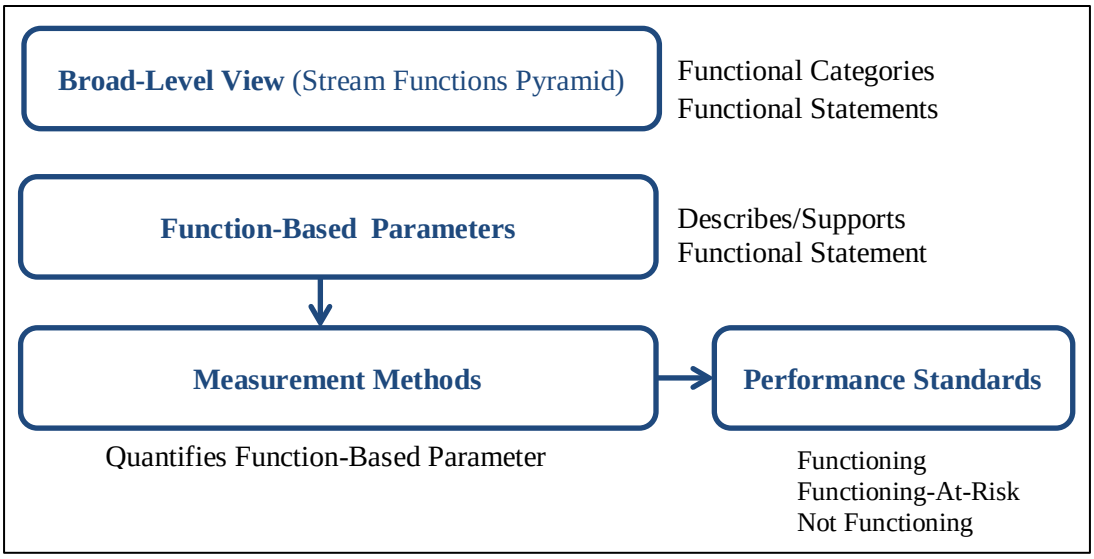

Figure 3: Stream Functions Pyramid Framework (Harman et al., 2012)

The SFPF project process consists of the following steps:

Programmatic/Project Goals – Documents what is driving the project and why the project is being proposed.

Watershed Assessment – Determines the health of the watershed and its influence on the proposed project area.

Reach-Scale Function-based Assessment – Establishes the existing function-based condition, determines stressors, identifies constraints and determines channel functional evolution.

Restoration Potential – Determines the highest level of restoration that can be achieved given the watershed conditions, function-based assessment results, stressors and constraints. Also, it is at this point that the actual amount of potential functional lift will be determined.

Design Objectives – Establishes design objectives based on the project goals, results of the watershed and reach-scale function-based assessment, constraints and restoration potential. Design objectives define how the project is going to be completed.

Design Alternatives Analysis – Determines the restoration design approach that best meets the project goals, objectives and restoration potential of the site. The focus is on how a design approach can change stream functions.

Design Development – Documents the design development process, ensures project feasibility, determines project implementation costs and produces a constructible design set along with specifications and materials.

Monitoring Plan – Determines if the quantifiable project objectives are achieved and that existing functioning parameters remain functioning.

B. WATERSHED ASSESSMENT

The purpose of the watershed assessment is to determine the influence of the watershed health on the proposed project area. Specifically, watershed characteristics are evaluated to document hydrology (i.e., flow regime), sediment transport load (i.e., sources and amount), water quality (i.e., types and sources) and biology (i.e., locations and health). By understanding watershed conditions, it can be determined if programmatic goals are achievable, as well as the restoration potential of the project reach.

The watershed assessment involved two levels of assessment: stream-based assessment and land-based assessment. The stream-based assessment involved a visual assessment of stream character and stability condition upstream and downstream of the project area. The fluvial geomorphic conditions observed included channel dimensions, pattern, profile, substrate material, vertical and lateral stability, sediment supply potential, Rosgen stream type and channel evolution. The land-based assessment analyzed land use/land cover patterns, soils, geology, hydrology, valley type, existing water quality and biological data, and watershed development.

C. REACH LEVEL ASSESSMENT

The purpose of the reach level function-based assessment is to establish the existing functional condition, determine stressors and identify constraints at the proposed project site. The Service conducted a function-based assessment of the Navy Dairy Farm Tributary 1 based on the SFPF. All existing critical functions on every level of the pyramid were assessed so that potential changes in functions could be evaluated for each proposed design alternative. Additionally, critical functions supporting the project goals were assessed.

The following assessment parameters, by pyramid level, were evaluated:

Level 1 - Hydrology – concentrated flows, land use changes, and flashiness (flow regime)
Level 2 - Hydraulics – floodplain connectivity and floodplain drainage
Level 3 - Geomorphology – lateral stability and riparian vegetation
Level 4 - Physicochemical – overall water quality
Level 5 - Biology – macroinvertebrate communities and fish communities

Each assessment parameter had at least one measurement method to quantify the existing function-based condition. Then, each measurement method value was rated as either functioning (F), functioning-at-risk (FAR), or not functioning (NF) based on set performance standards. Specific measurements for each assessment parameter can be found in Appendices F-I and the results of the assessment are described below.

IV. PROGRAMMATIC/PROJECT GOALS

The programmatic goals of the Navy Dairy Farm stream restoration differ among the three main agencies involved with the restoration. The funds for the project were provided by the MDNR Bay Trust Fund, whose goal is to focus funds on the most cost-effective, innovative approaches within an efficient and logical location to improve the health of Maryland watershed lands, streams and non-tidal rivers. CBF's goal is to reduce sediment and nutrient pollution coming from the adjacent farmlands and streams in order to improve the water quality of the Chesapeake Bay Watershed. The Service's goals are to create riparian habitat for Eastern Wood-Peewee, Red-Shoulder Hawk and Acadian Flycatcher; to create wetland habitat for Spotted Salamander, Gray Tree Frog and Northern Green Frog; and to improve and preserve downstream habitat for American Eel and other aquatic species through stream restoration.

The successful completion of the Navy Dairy Farm stream restoration project will satisfy strategic objectives put in place by the President's Chesapeake Bay Initiative, as well as the Service strategic plan for trust species.

V. WATERSHED AND REACH ASSESSMENT

A. WATERSHED ASSESSMENT

This section includes a summary of the watershed findings. Reference Appendices A-D for detailed watershed data.

The watershed drainage area is 0.55 sqmi (Figure 4) and the stream within the project area is currently ephemeral. However, the existing stream was most likely not a channel in the past, but a swale given its location in the watershed (headwaters) and the small drainage area. The development of a channel probably formed as a result of land uses changes. Now the watershed has a flashy flow regime. The current flow regime is influenced by existing land uses, soil conditions and concentrated flows. The majority of the watershed consists of the Navy Dairy Farm. Therefore, the primary land use is agriculture (84%). Eighty-five percent of the soils are classified as hydrologic soil group C and the other fifteen percent are group B. Both of these soil groups are primarily silt loam underlain by fine sand loam. They are highly erodible and have very slow infiltration rates. Their runoff rates are similar to watersheds with high impervious surfaces. Lastly, there is a network of drain tiles, from the adjacent crop fields, that feed storm runoff flows directly to the stream, which also contributes to the flashy flow regime.

The soils affect ground water recharge. Ground water recharge is reduced because of the slow infiltration rates associated with the existing soils. This was confirmed by a series of floodplain boring samples taken by a certified soil scientist throughout the project area. The borings did not show any signs of redox occurring except at the downstream end of the project area, which is approximately 3,000 feet downstream from Reach 2. Additionally, stream channel borings showed that there is a gravelly, sandy soil horizon approximately 24 inches below the stream bottom. This further supports the extensive disconnect of the channel to any potential groundwater.

The sediment supply of the project area consists primarily of suspended sediments. It consists of silts and fine sands that come from the adjacent crop fields via storm flow runoff. Generally, sediment supply consists of bedload and suspended sediments. Bedload sediments within the coastal plain physiographic region typically come from within the channel (Gellis et al 2006). However, since there is no stream network upstream of the project area, there is no source of bedload sediments.

The amount of soil loss associated with runoff was calculated by the Natural Resource Conservation Service (NRCS) using the RUSLE equation (US Department of Agriculture , 2013). A total of 847 tons/year of sediment is eroded and of that, 347 tons/year is delivered to the stream. This equates to 2.5 tons/year/acre being delivered to the stream, which is considered excessive. Since the sediment supply is primarily silt, it is easily entrained in the water column and can be transported long distances before settling out.

The water quality being delivered to the project area is poor. While no physical data were collected, watershed variables such as land use, soils and point and non-point discharges can be used to predict water quality conditions. The project area watershed is primarily agriculture, has highly erodible soils, point source discharges and a flashy flow regime. Under these conditions there will be an excessive sediment supply and frequent flooding and drying events which can cause rapid and adverse changes in pH, dissolved oxygen, conductivity, nitrogen, phosphorus, siltation levels, and concentrations of ions, toxins or pollutants (Williams, 1996) within the reach.

The project area has limited, if any, aquatic biology because it is an ephemeral stream. Ephemeral streams are generally considered to be either completely lacking in aquatic invertebrates, or to have a limited number of adventitious species that can complete their life cycles rapidly before the stream dries (Dieterich, 1992). A visual assessment of the project area by the Service, resulted in finding no aquatic life.

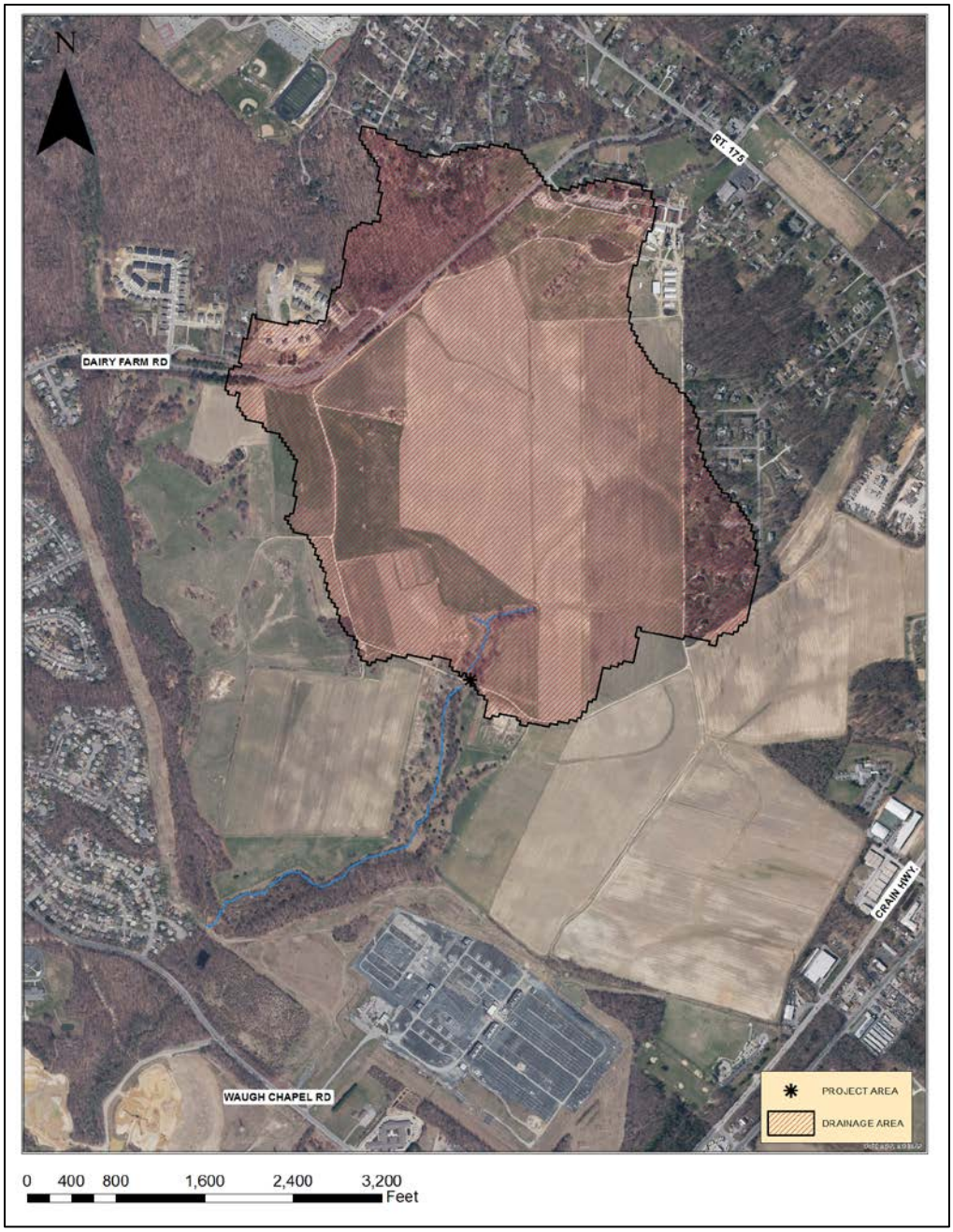

Figure 4: Project Drainage Area (Shaded in Red)

B. BASE MAPPING

The Service conducted a baseline survey and produced 1-foot ground survey information to accurately map (Appendix E) and represent the project area. The Service used this information to assess baseline conditions and to develop and illustrate a restoration design plan. Plan form, longitudinal profile and topographic information are represented.

C. REACH LEVEL FUNCTION-BASED ASSESSMENT

The Service identified two distinct stream reaches within the project area that have different function-based conditions (Figure 5). This section includes a summary of the reach level assessment findings of these two reaches. Reference Appendices F-I for detailed reach level data.

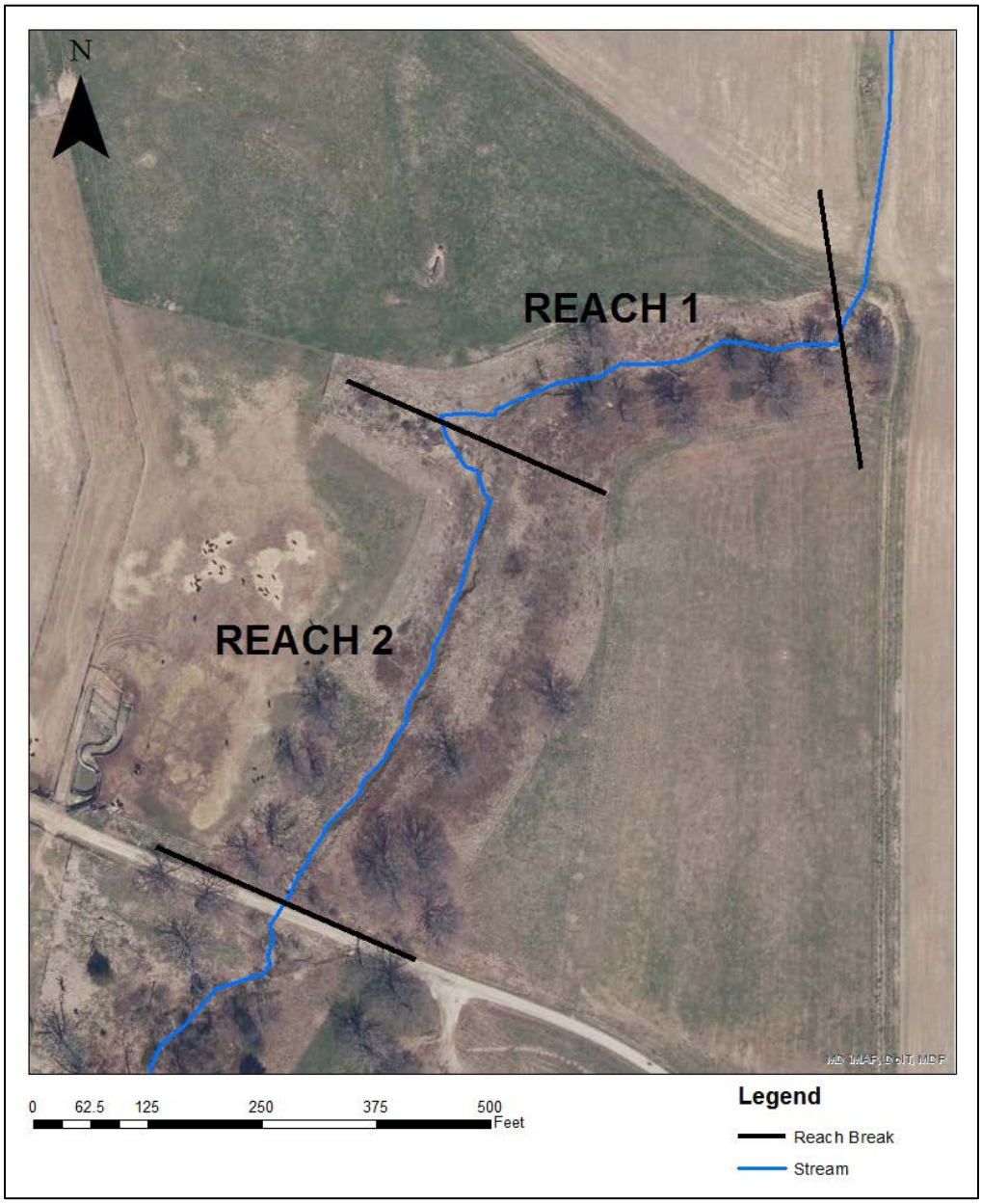

Figure 5: Project Reach Breaks

1. Reach 1

The Service determined that the overall function-based condition of Reach 1 is ***Functioning at Risk*** and is trending towards stability (Table 1). It is ephemeral and classified as a Rosgen B4/1. The stream channel most likely formed in the recent past because of land use changes and concentrated flows. The origins of this reach is from an outfall which drains the adjacent crop fields. The reach is disconnected from its floodplain except during large flood events. The floodplain valley slope is relatively low (0.004 ft/ft). However, it is constrained by its narrow width and thus has a limited area to store and retain flood flows. It has downcut to bedrock in some locations, but is likely no longer downcutting. The majority of stream banks are actively eroding due to increased stream energy associated with a disconnected floodplain and concentrated flows. The materials eroding from the streambanks are contributing to an already excessive sediment load. The riparian buffer is narrow and in poor condition. It consists primarily of small invasive pear trees and herbaceous plants. Bedform diversity is lacking but this is typical for ephemeral streams because stream flows are infrequent and bedload sediments needed to develop bed features is limited. Water quality is poor due to the agricultural activities and biology does not exist or is extremely limited, again, because the stream is ephemeral.

2. Reach 2

The Service determined that the overall function-based condition of Reach 2 is ***Not Functioning*** and is trending towards stability (Table 2). It is very similar to Reach 1. It is ephemeral, but classified as a ***Rosgen F4***. The stream channel most likely formed in the recent past because of land use changes and concentrated flows. The reach is disconnected from its floodplain, ***including*** during large flood events. The floodplain valley slope is relatively low (0.004 ft/ft). It is ***less*** constrained because the valley is ***wider*** than Reach 1 and has the ability to store and retain flood flows. It has also downcut but ***not*** to bedrock. However, it is likely no longer downcutting because the stream grade is controlled at the downstream end by a road-crossing culvert. The majority of stream banks are actively eroding due to increased stream energy associated with a disconnected floodplain. The materials eroding from the streambanks are contributing to an already excessive sediment load. The riparian buffer is narrow and in poor condition. It consists primarily of small invasive pear trees and herbaceous plants. Bedform diversity is lacking but this is typical for ephemeral streams because stream flows are infrequent and bedload sediments needed to develop bed features is limited. Water quality is poor due to the agricultural activities and biology does not exist or is extremely limited, again, because the stream is ephemeral.

Navy Dairy Farm Tributary Reach 1- Function-based Assessment Existing Conditions						
Level and Category	**Parameter**	**Measurement Method**	**Pre-Restoration Condition**			
			Value	**Rating**	**Overall by Level**	**Overall Reach**
1 - Hydrology	Concentrated Flows	USFWS Function-based Rapid Assessment	Concentrated flows from drain tiles	NF	**NF**	**FAR**
	Land Use Change	USFWS Function-based Rapid Assessment	> 70% Agriculture	NF		
	Flashiness	USFWS Function-based Rapid Assessment	Flashy Flow regime	NF		
2 - Hydraulics	Floodplain Connectivity	Bank Height Ratio	1.4	FAR	**FAR**	
		Entrenchment Ratio	1.6	F		
	Floodplain Drainage	USFWS Function-based Rapid Assessment	Concentrated flows, Hill slopes < 40 ft. from stream, extensive gully and rill erosion	NF		
3 - Geomorphology	Riparian Vegetation	Buffer Width from Meander Belt Width (Stability)	B4/1 Stream Type	N/A	**FAR**	
		Average Buffer Width From Top of Bank (Water Quality)	75ft buffer width, dominated by invasive species,, no brush layer	FAR		
	Lateral Stability	Lateral Erosion Rate - High to Very High BEHI Curve	Moderate to Extreme NBS	NF		
4 - Physicochemical	Water Quality	USFWS Function-based Rapid Assessment	Primarily agriculture land use	FAR	FAR	
5 - Biology	Macro and Fish Communities	USFWS Function-based Rapid Assessment	Ephemeral	N/A	N/A	

Table 1: Navy Dairy Farm Tributary Reach 1 - Function-based Assessment Existing Conditions

Navy Dairy Farm Tributary Reach 2- Function-based Assessment Existing Conditions						
Level and Category	**Parameter**	**Measurement Method**	**Pre-Restoration Condition**			
			Value	**Rating**	**Overall by Level**	**Overall Reach**
1 - Hydrology	Concentrated Flows	USFWS Function-based Rapid Assessment	Concentrated flows from drain tiles	NF	**NF**	**NF**
	Land Use Change	USFWS Function-based Rapid Assessment	> 70% Agriculture	NF		
	Flashiness	USFWS Function-based Rapid Assessment	Flashy Flow regime	NF		
2 - Hydraulics	Floodplain Connectivity	Bank Height Ratio	2.27	NF	**NF**	
		Entrenchment Ratio	1.3	NF		
	Floodplain Drainage	USFWS Function-based Rapid Assessment	Some concentrated flow, hill slopes 50-100ft from stream, minimal debris	FAR		
3 - Geomorphology	Riparian Vegetation	Buffer Width from Meander Belt Width (Stability)	3.5 times bankfull width and >15 ft from meander bend	F	**FAR**	
		Average Buffer Width From Top of Bank (Water Quality)	120 ft buffer width, dominated by invasive species,, little to no brush layer	FAR		
	Lateral Stability	Lateral Erosion Rate - Moderate BEHI Curve	Low to High NBS	FAR		
4 - Physicochemical	Water Quality	USFWS Function-based Rapid Assessment	Primarily agriculture land use	FAR	FAR	
5 - Biology	Macro and Fish Communities	Observation	Ephemeral	N/A	N/A	

Table 2: Navy Dairy Farm Tributary Reach 2 - Function-based Assessment Existing Conditions

3. Channel Evolution

Reach 1 and 2 are at different stages of evolution (Table 3). However, the ability of both reaches to evolve back to some level of quasi-equilibrium is unlikely to occur anytime in the near future without intervention. The geomorphic functions are still undergoing significant adjustment. Lateral erosion will continue to occur until a new stable floodplain is developed. During this time, riparian vegetation needs to establish and mature in order to assist in slowing down lateral erosion rates. Given the current stability condition and limited stream flows, the recovery of the stream within these two reaches could take several years or even possibly decades to occur and during this time could adversely affect downstream resources.

Navy Dairy Farm Tributary - Function-based Assessment Summary and Channel Evolution				
Reach	**Reach Length (ft)**	**Rosgen Stream Type**	**Channel Evolution**	**Reach Level Function-based Rating**
1	525	B4/1	B4/1 → G → F_b → B	FAR
2	535	F4	F4 → C	NF

Table 3: Navy Dairy Farm Tributary Function-based Assessment Summary and Channel Evolution

VI. PRELIMINARY DESIGN

This section presents the restoration potential, project constraints, design objectives, design alternatives analysis, design criteria and monitoring strategies involved in the Navy Dairy Farm Stream Restoration.

A. CONSTRAINTS

Constraints are man-made features that have the potential to influence the restoration potential of a stream restoration project. The Service identified a variety of constraints that will influence the final design solution for the proposed project area. While they are relatively minor, these constraints had to be addressed throughout the design phase and had to be considered when developing design goals and objectives.

The first constraint is an outfall at the farthest upstream end of the project area. The outfall is where the open channel drainage network originates for the watershed. It is connected to a terra-cotta drainage network that drains the adjacent crop fields. The outfall creates concentrated flows and increased stream energy. The outfall and drainage network must remain and therefore, design must be adapted to begin at that point.

The project reach also passes through a road culvert at the end of the project area. Like the outfall pipe upstream, this culvert cannot be removed, so the design had to accommodate the culvert. In this particular instance, the backwater generated by this culvert helped reduce energy

across the floodplain. As a precaution, the hydraulic model was run with and without the culvert in an effort to model the "worst case scenario".

The drainage area's main land use (i.e., agricultural) is a limiting factor as well. With the upper watershed being row cropped, establishment of permanent vegetation will likely not occur. This will result in the delivery of excessive runoff and sediment supply and poor water quality.

B. RESTORATION POTENTIAL

Restoration potential is the highest level of restoration or functional uplift that can be achieved given the watershed health, reach-level function-based condition, stressors and constraints. (Harman et al., 2012). Based on these factors, the Service determined that for both Reach 1 and 2, pyramid Levels 2 - Hydraulics and 3 - Geomorphology can be restored to fully functional and pyramid Level 4 – Physicochemical can be restored to partial functional uplift (Table 4). Restoration of Levels 2 and 3 functions are typically the easiest to achieve since it involves direct, physical manipulation of stream channel dimension, pattern and profile. Stream channel parameters such as beltwidth, bank heights, floodplain width, facet feature lengths, slopes and depths can be constructed to specifications considered functioning.

There is also the potential for partial uplift for pyramid Level 1 - Hydrology. Both Reach 1 and 2 can have partial uplift through the elimination and/or reduction of concentrated flows. All of the lateral sources of concentrated flows can be addressed. However, the outfall at the headwaters of the project cannot be eliminated. Reach 2 also has the potential to alter the flow regime. Specifically, peak flow floods can be reduced and flow duration can be increased through floodplain storage. This is possible for Reach 2, but not Reach 1 because of existing valley widths. Reach 1 has such a narrow valley width that there is not enough area to store flood flows that would influence the flow regime. However, there is enough valley width in Reach 2 to influence the flow regime.

The Service determined that there is a potential for partial uplift for Level 4 – Physicochemical. Sediment load sources and nutrient sources from the eroding streambanks can be eliminated. Sediment loads and nutrient levels from upstream runoff can also be potentially trapped and stored. However, it is unlikely that a significant amount of sediment loads and nutrients levels can be reduced because of the limited valley widths. This is why there is only a potential for partial uplift for Level 4 – Physicochemical.

Since the project area is an ephemeral stream and baseline assessments indicated no or limited biological function, it is unlikely that there would be any potential uplift for Level 5 – Biology.

Navy Dairy Farm - Restoration Potential				
Level and Category	**Parameter**	**Reach**	**Existing Conditions**	**Restoration Potential**
1 - Hydrology	Concentrated Flows	1	**NF**	**FAR***
		2	**NF**	**FAR***
	Land Use Change	1	**NF**	**NF**
		2	**NF**	**NF**
	Flashiness	1	**NF**	**NF**
		2	**NF**	**FAR***
2 - Hydraulics	Floodplain Connectivity	1	**FAR**	**F**
		2	**NF**	**F**
	Floodplain Drainage	1	**NF**	**F**
		2	**FAR**	**F**
3 - Geomorphology	Riparian Vegetation	1	**FAR**	**F**
		2	**FAR**	**F**
	Lateral Stability	1	**NF**	**F**
		2	**FAR**	**F**
4 - Physicochemical	Water Quality	1	**FAR**	**FAR***
		2	**FAR**	**FAR***
Note: "*" indicates partial uplift.				

Table 4: Restoration Potential

C. DESIGN OBJECTIVES

Design objectives are based on project goals and project area restoration potential. The objectives reflect the project goals but state specifically how the project will be completed. Thus, design objectives are quantifiable and measureable. The goals of the study are to improve water quality through sediment and nutrient reduction, create native riparian habitat for Eastern Wood-Peewee, Red-Shoulder Hawk and Acadian Flycatcher, and improve and preserve downstream habitat for American Eel and other aquatic species through stream restoration.

The Service developed, in coordination with CBF, design objectives to address the programmatic goals. There are common design objectives for both Reaches 1 and 2. There are some varying design objectives between the two reaches, based on their restoration potential. Table 5 below outlines the design objectives. The varying objectives are identified by either *"Reach 1 or Reach 2"* being written adjacent to the objective.

Navy Dairy Farm - Design Objectives		
Level and Category	**Parameters**	**Design Objectives**
Level 1- Hydrology	3. Flow Regime 4. Concentrated Flows	3. Reduce hydrograph peaks and increase duration compared to existing conditions (*Reach 2)* 4. Eliminate Concentrated Flows
Level 2 - Hydraulics	3. Floodplain Connectivity 4. Floodplain Storage	1a. Create floodplain connection at no greater than 1 yr storm event (*Reach 2)*. 1b. Create floodplain connection by BHR of 1.0 to 1.2 and ER of 1.4 to 2.2. (*Reach 1*) 2. Store flood flows up to a 5 yr storm event (*Reach 2*)
Level 3 - Geomorphology	4. Lateral Stability 5. Sediment/Reduction and Trapping 6. Riparian Buffer	4. Reduce stream bank erosion rates to match reference erosion rates (bank migration/lateral stability) 5. Decrease sediment loads leaving the project to loads less than entering loads entering the project 6. Create native riparian buffer for Eastern Wood-Peewee, Red-Shoulder Hawk, and Acadian Flycatcher
Level 4 - Physicochemical	3. Sediment Supply 4. Nutrient Levels	3. Refer to Level 3 sediment reduction and trapping objectives 4. Reduce nutrient levels compared to existing conditions

Table 5: Navy Dairy Farm Tributary – Design Objectives.

D. DESIGN ALTERNATIVES ANALYSIS

The purpose of design alternatives analysis is to select the best restoration design approach that meets the project goals and design objectives based on watershed and reach conditions, restoration potential and constraints. It focuses on how a specific design approach could influence existing stream functions (both potential uplift and loss), implementation costs and risk.

There is a variety of design approaches available to restore stream functions of highly degraded stream systems. Typical design approaches used in Maryland include Natural Channel Design (NCD), Valley Restoration Design (VR), Analytical Design (AD), and Regenerative Storm Conveyance Design (RSC). The Service evaluated the strengths and limitations of each of these design approaches for the project area.

1. Reach 1

Based on the watershed assessment, reach level assessment, restoration potential and constraints, the two most significant limitations of Reach 1 in achieving the project goals and design objectives is the existing valley characteristics and potential implementation costs. The valley width in Reach 1 is very narrow. With limited valley width, the effectiveness of VR and RSC design approaches is limited. It is not wide enough to reduce floodplain shear stresses to less than 2 lbs/ft^2 during flood events, which is a typical criterion for VR. Furthermore, the valley

width significantly limits any appreciable storage of flood flows, without significant implementation costs, that could provide potential sediment and nutrient reductions, which is a typical design objective of RSC designs and is one of the design objectives for this project.

Both VR and RSC design approaches would have best met the flood flow storage and sediment and nutrient loads reduction design objectives. However, since they are not appropriate design approaches for Reach 1, they have been eliminated from further consideration.

The two remaining design approaches that are not limited by any existing site conditions are the NCD and AD approaches. Both use similar analytical methods to evaluate potential design stability. However, the NCD approach uses reference reaches to design stream form and the AD approach typically does not. Therefore, the Service ultimately selected the NCD approach for Reach 1.

The NCD approach will result in function uplift through Level 4 – Physicochemical. Functions in Level 2 - Hydraulics and Level 3 – Geomorphology will be fully functional, while functions in Level 4 – Physicochemical will remain functioning-at-risk but have partial functional uplift. As was stated in the restoration potential section, restoration of Levels 2 and 3 functions are typically the easiest to achieve since it involves direct, physical manipulation of stream channel dimension, pattern and profile. Functional uplift for Level 4 functions cannot be constructed and rely on the functionality of lower level functions and watershed health. The expected level 4 uplift will be associated with sediment and nutrient reductions coming from streambank erosion and floodplain reconnection.

Implementation of the NCD approach typically involves channel realignment and extensive grading. Since the stream is ephemeral, the only potential impacts to existing conditions would be to the existing riparian vegetation. However, since the existing riparian vegetation was rated as ***Not Functioning***, any potential realignment or grading will not adversely affect the existing riparian vegetation. Additionally, some temporary affects may occur during construction. These affects are typical of stream restoration projects regardless of which design approach is implemented and generally include increases in turbidity. Again, the stream is ephemeral, therefore, increases of turbidity during construction is greatly reduced. Erosion and sediment best management practices will be in place to reduce turbidity in the event that wet conditions occur.

2. <u>Reach 2</u>

Reach 2 existing conditions are very similar to Reach 1, except the valley width is wider. This now enables the RSC design approach to be effective but not the VR design approach. The valley width has increased enough to have appreciable flood flow storage and potentially reduce sediment and nutrient loads. However, it is not wide enough to produce floodplain shear stresses of less than 2 lbs/ft^2 using the valley restoration design approach. Both the NCD and AD approaches are also still suitable for this reach. However, both of these approaches would result in less functional uplift in flood flow storage and sediment and nutrient loads reduction. Therefore, the Service selected the RSC design approach for Reach 2.

It is important to note that while the RSC design approach is the selected alternative, it is the functions produced by this approach (e.g., flood flow storage, increase attenuation and infiltration rather than conveyance) that the Services recommends. Therefore, the Service refers to this design approach as Storage and Infiltration System Design (SISD). The design methods and restoration activities that are associated with a SISD project will vary from the design standards outlined in the *Design Guidelines for Step Pool Storm Conveyance* (Flores et al., 2012). Specifics of how they vary are addressed below in Section E Design Development. Variation in design methods were made to reduce overall project risks and implementation costs.

The SISD design approach will result in function uplift through Level 4 – Physicochemical. Functions in Level 2 - Hydraulics and Level 3 – Geomorphology will be fully functional while functions in Level 1 – Hydrology and Level 4 – Physicochemical will remain functioning-at-risk but have partial functional uplift. The expected Level 1 uplift will be associated with storage of flood flows. It is possible that this design could change the flow regime by reducing peak flood flows and increasing the duration of base flows within the stream channel. The expected Level 4 uplift will be associated with sediment and nutrient reductions coming from streambank erosion and floodplain reconnection, like Reach 1, but additional reductions will occur through the increased flood flow storage, attenuation and infiltration that the design will create.

Implementation of the SISD design approach typically involves channel realignment and extensive grading. Like Reach 1, Reach 2 is ephemeral, and therefore, the only potential impacts to existing conditions would be to the existing riparian vegetation. The existing riparian vegetation was also rated as ***Not Functioning***, thus any potential realignment or grading will not adversely affect the existing riparian vegetation. The potential temporary effects that may occur during construction for Reach 1 are the same for Reach 2 and will be addressed the same.

E. DESIGN DEVELOPMENT

The valley required the use of two separate design techniques to achieve the project design objectives and to ensure the system maximized storage, increased infiltration, eliminated lateral degradation and functioned properly. Since different design techniques were used, the design development section will speak to each of these techniques individually designating them by reach. NCD was used for Reach 1 and SISD was used for Reach 2. NCD uses form and process to develop stream restoration designs. Form is the structural features of a stream and includes channel dimensions, pattern and profile. It is based on reference stream conditions that are the same stream type, valley type, vegetation type and bed material. Process is the analytical assessment of a design. Hydraulic and sediment calculations are conducted to determine the potential stability of the design. Adjustments are made to the design based on the results of the analytical assessment and then the design is re-assessed. This iterative process continues until the analytical assessment shows that the design will be self-maintaining and that the channel dimensions, pattern and profile match reference conditions. SISD has a different approach and while form and process are still used in design criteria, SISD aims to maximize storage, increase attenuation and infiltration and create a stable system for a variety of storm flows. This method requires an appropriate valley width section to adequately store and convey storm flows and maintain low overbank shear stresses.

In this section, the Service documents how the NCD and SISD processes were applied to the project area. It contains design criteria, proposed plan, in-stream structures, hydrologic and hydraulic assessment, sediment transport assessment and the proposed re-vegetation plan.

1. Design Criteria

a. Natural Channel Design

Design criteria for the NCD portion of the design was compiled by standardizing existing channel plan, profile and dimension of design criteria developed by the Service and other sources (Harman, et al., 2011). In addition, the Service was also able to locate a stable riffle within the project reach to model the design geometry criteria. The measurements from this cross section were verified and extrapolated using the regional curve calculations, resistance equations and natural channel design reference ratios for B4 stream type channels, described below in Section E4 Hydrology and Hydraulics. The Tables 6 and 7 below show reference geometry as well as summarize reference ratios and design criteria.

Navy Dairy Farm- Bankfull Riffle Characteristics		
Bankfull Characteristics	**Reference Cross Section**	**Design Cross Section**
Area (sq. ft)	7.49	7.36
Width (ft)	13.53	10.00
Depth (ft)	0.55	0.80
Velocity (ft/s)	2.66	3.27
Discharge (cfs)	19.90	24.07
Characteristics in the Coastal Plain Hydrologic Region regional curves (McCandless 2003)		

Table 6. Bankfull Riffle Characteristics

Stream Name	Navy Dairy Farm – Reach 1				
Drainage Area	0.4mi				
Stream Type	B4c				
#	**Variable**	**Symbol**	**Units**		**Value**
1	**Riffle Bankfull width**	W_{bkf}	**feet**	**Mean**	10
				Range	
2	**Riffle Bankfull mean depth**	d_{bkf}	**feet**	**Mean**	0.80
				Range	
3	**Width depth ratio**	**W/d**		**Mean**	12.5
				Range	12.0 - 18.0
4	**Riffle Bankfull cross sectional area**	A_{bkf}	ft_2	**Mean**	7.36
				Range	
5	**Bankfull mean velocity**	V_{bkf}	**ft/sec**	**Mean**	4.5
				Range	3.0 – 6.0
6	**Bankfull discharge**	Q_{bkf}	**cfs**	**Mean**	24.07
				Range	
7	**Riffle Bankfull maximum depth**	d_{max}	**feet**	**Mean**	1.04
				Range	0.96 – 1.12
8	**Max Riffle depth/ Mean riffle depth**	d_{riff}/d_{bkf}		**Mean**	1.3
				Range	1.2 - 1.4
9	**Low bank height to max d_{bkf} ratio**			**Mean**	1.05
				Range	1.0 - 1.1
10	**Width of flood prone area**	W_{fpa}	**feet**	**Mean**	18
				Range	14 - 22
11	**Entrenchment Ratio**	W_{fpa}/W_{bkf}		**Mean**	1.8
				Range	1.4 - 2.2
12	**Meander Length**	L_m	**feet**	**Mean**	N/A
				Range	N/A
13	**Ratio of meander length to bankfull width**	L_m/W_{bkf}		**Mean**	N/A
				Range	N/A
14	**Radius of curvature**	R_c	**feet**	**Mean**	N/A
				Range	N/A
15	**Ratio: Radius of curvature to bankfull width**	R_c/W_{bkf}		**Mean**	N/A
				Range	N/A

Table 7 continued					
16	**Belt Width**	W_{blt}	**feet**	**Mean**	N/A
				Range	N/A
17	**Meander width ratio**	W_{blt}/W_{bkf}		**Mean**	N/A
				Range	N/A
18	**Sinuosity**	**K**		**Mean**	1.2
				Range	1.1 - 1.3
19	**Valley Slope**	S_{val}	**ft/ft**		0.004
21	**Average Water Surface Slope**	S_{avg}	**ft/ft**	**Mean**	0.004
				Range	N/A
21	**Pool Water Surface Slope**	S_{pool}	**ft/ft**	**Mean**	0.0008
				Range	0 – 0.0016
22	**Pool WS slope / Average WS slope**	S_{pool}/S_{avg}		**Mean**	0.2
				Range	0 – 0.4
23	**Riffle Water Surface slope**	**Sriff**	**ft/ft**	**Mean**	0.0058
				Range	0.0044 - 0.0072
24	**Riffle WS slope / Average WS slope**	S_{rifF}/S_{avg}		**Mean**	1.45
				Range	1.1 - 1.8
25	**Run WS Slope**	S_{run}/S_{avg}	**ft/ft**	**Mean**	N/A
				Range	N/A
26	**Run WS slope / Average WS slope**	S_{run}/S_{avg}	**ft/ft**	**Mean**	N/A
				Range	N/A
27	**Glide WS Slope**	S_{glide}		**Mean**	0.0016
				Range	0.0012 - 0.002
28	**Glide WS slope / Average WS slope**	S_{glide}/S_{avg}	**ft/ft**	**Mean**	0.4
				Range	0.3 - 0.5
29	**Maximum pool depth**	d_{pool}	**feet**	**Mean**	2.2
				Range	1.6 – 2.8
30	**Ratio of max pool depth to average bankfull depth**	d_{pool}/d_{bkf}		**Mean**	2.75
				Range	2.0 - 3.5
31	**Max Run Depth**	d_{run}	**feet**	**Mean**	N/A
				Range	N/A
32	**Ratio of max run depth to average bankfull depth**	d_{run}/d_{bkf}		**Mean**	N/A
				Range	N/A
33	**Max Glide Depth**	d_{glide}	**feet**	**Mean**	N/A
				Range	N/A

Table 7 continued					
34	**Ratio of max glide depth to average bankfull depth**	d_{glide}/d_{bkf}	**feet**	**Mean**	N/A
				Range	N/A
35	**Pool width**	W_{pool}	**feet**	**Mean**	13
				Range	11 - 15
36	**Ratio of pool width to bankfull width**	W_{pool}/W_{bkf}		**Mean**	1.3
				Range	1.1 - 1.5
37	**Ratio of pool area to bankfull area**	A_{pool}/A_{bkf}		**Mean**	
				Range	
38	**Point bar slope**	S_{pb}		**Mean**	N/A
				Range	N/A
39	**Pool to pool spacing**	**p-p**	**feet**	**Mean**	37.5
				Range	15 - 60
40	**Ratio of pool to pool spacing to bankfull width**	$p\text{-}p/W_{bkf}$		**Mean**	3.75
				Range	1.5 - 6.0

Table 7: Navy Dairy Farm Design Criteria

b. <u>Storage and Infiltration System Design</u>

Design targets for the SISD portion of the project were compiled by examining the Regenerative Step Pool Storm Conveyance (SPSC) methodology developed by Anne Arundel County Department of Public Works, Bureau of Engineering as well as other sources. While this methodology does not require specific reference geometry for design, it does require the use of specific hydraulic calculations and not-to-exceed thresholds. Due to the specificity of these values, the majority of the design considerations for the SISD portion of this project will be discussed in the Section E4 Hydrology and Hydraulics.

2. Proposed Design

a. Reach 1

The Reach 1 design is a standard NCD approach. The proposed design stream type is a Rosgen B4c. This stream type dissipates stream energy vertically through the use of grade control structures and close pool to pool spacing. The project begins directly downstream of the existing bedrock portion of Reach 1. The stream will be reconnected to the floodplain by gradually lifting the bed elevation through the use of grade control j-hooks and cross vanes. Additionally, the banks will be graded back to increase the flood prone area to achieve an entrenchment ratio of at least 1.4. The banks will then be planted with native plant species. This design will allow the Service to achieve the Level 2 - Hydraulic design objectives of returning the bank height ratio to 1.0 through floodplain reconnection. Level 3 – Geomorphology design objectives of lateral stability will be achieved through the use of in-stream structures and riparian plantings.

b. Reach 2

The Reach 2 design is a SISD approach that has been designed as a multi-tiered, stepped-pool system with a low width to depth ratio to dissipate energy laterally across the valley and vertically through the pools, as well as to attenuate storm flows. It consists of excavated pool, cobble weirs, sand/woodchip fill material and floodplain grade control structures. In order to maximize storage and filtration, pools will be excavated between each cobble weir. The cobble weirs were designed and placed to allow no more than a 1-foot drop over the upstream cobble weir. The existing channel will be filled with a sand/woodchip media, and then the pools will be excavated. The pools will hold water while it percolates vertically and longitudinally through the placed media as well as native soil. The weirs, pools and floodplain have been designed to maximize flood flow storage based on the existing valley width and can store flood flows up to a 5-year storm occurrence. While the weirs dimensions were sized for a 5-year storm occurrence, the cobble within the weirs were sized for a 100-year storm occurrence. The floodplain area will then be planted with native plant species.

The excavation of pool areas and placement of infiltration media will enable the Service to achieve the Level 1 – Hydrology design objectives of storing and infiltrating flood flow and Level 2 - Hydraulic design objective of reconnecting with the floodplain. Level 3 - Geomorphology design objectives of lateral stability will be achieved through the use of in-stream structures and riparian plantings. Level -4 – Physicochemical design objectives will be achieved through the storage created by the excavated pool areas. The pools will provide nearly 750 tons of sediment storage, which will reduce downstream sedimentation and nutrient loadings.

Detailed of proposed plans can be found in Appendix J.

3. In-Stream Structures

Rock and log structures are in-stream structures made of natural materials used to divert erosive stream flows away from stream banks and maintain streambed elevations. The most typical rock and log structures used in-stream restoration are cross-vanes, j-hooks, log-rollers and toe wood. The rock and log structures provide streambed and bank stability and allow the streambed to naturally armor and the riparian vegetation to establish.

The Service has determined that j-hooks and cross-vanes are only required in Reach 1 to effectively "step down" storm flows before they enter Reach 2. Due to the channel's infrequent ephemeral flow, the Service has also determined that the j-hooks and cross-vanes should be built from rock boulders, to ensure the structures longevity. The locations of these structures were determined by matching the naturally occurring pool-to-pool spacing and strategically placing them in areas that would exhibit higher shear stress values during high flow events.

While in-stream structures mentioned above are common in the NCD approach, these specific structures are not required in Reach 2. Since the flow will be spread across the floodplain in Reach 2, the only required structure will be a cobble weir structure to transition the flow from one pool area to the next. As a precautionary measure, valley grade control sills will also be installed on the upstream and downstream sides of the cobble weirs ensuring storm flows will not erode transitional areas. The locations of these structures were determined by following the naturally occurring valley fall, and strategically placing them in areas that would limit vertical elevation changes greater than one foot. By accurately sizing the weir geometry, shear stress values, velocities and scour potential should be manageable during high flow events.

a. Cross-Vane

The cross-vane (Figure 6) will establish grade control, reduce bank erosion, create a stable width/depth ratio and maintain channel capacity, while maintaining sediment transport capacity, and sediment competence. The cross-vane also provides for the proper natural conditions of secondary circulation patterns commensurate with channel pattern, but with high velocity gradients and boundary stress shifted from the near-bank region. The cross-vane is also a stream habitat improvement structure due to: 1) an increase in bank cover as a result to a differential raise of the water surface in the bank region; 2) the creation of holding and refuge cover during both high and low flow periods in the deep pool; 3) the development of feeding lanes in the flow separation zones (the interface between fast and slow water) due to the strong down welling and upwelling forces in the center of the channel; and 4) the creation of spawning habitat in the tail-out or glide portion of the pool (Rosgen, 2010).While the figure below shows a structure consisting of large boulders, the cross-vane can be constructed using other materials such as logs and rootwads.

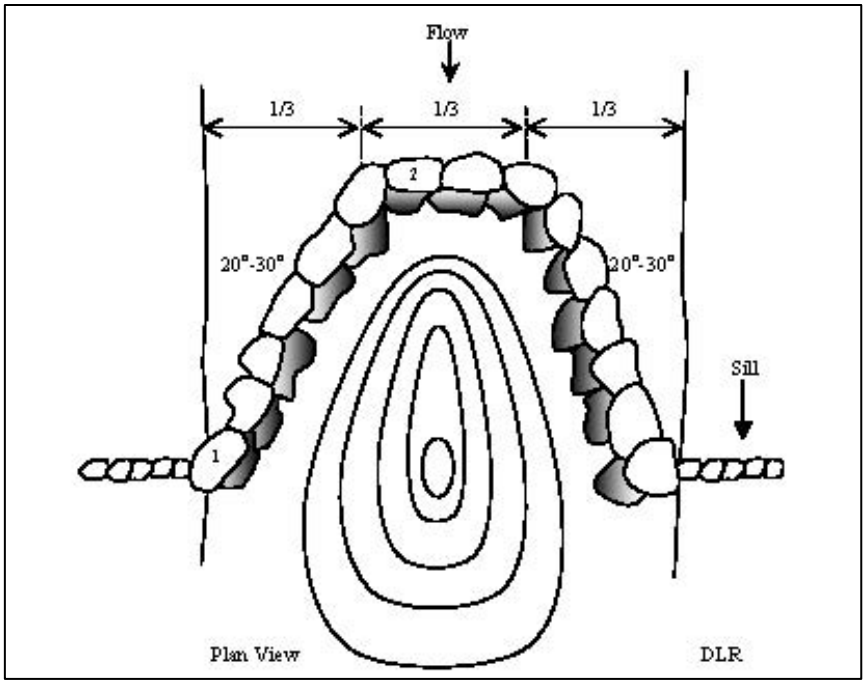

Figure 6. Cross Vane in Plan View

b. **J-Hook Vane**

The j-hook vane is an upstream directed, gently sloping structure composed of natural materials. The structure can include a combination of boulders, logs and root wads (Figure 7) and is located on the outside of stream bends where strong down welling and upwelling currents, high boundary stress and high velocity gradients generate high stress in the near-bank region. The structure is designed to reduce bank erosion by reducing near-bank slope, velocity, velocity gradient, stream power and shear stress. Redirection of the secondary cells from the near-bank region does not cause erosion due to back-eddy re-circulation. The vane portion of the structure occupies 1/3 of the bankfull width of the channel, while the hook occupies the center 1/3 as shown in Figure 7 (Rosgen, 2010).

Maximum velocity, shear stress, stream power and velocity gradients are decreased in the near-bank region and instead redirected towards the center of the channel. Sediment transport competence and capacity can be maintained as a result of the increased shear stress and stream power in the center of the channel. Backwater is created only in the near-bank region, reducing active bank erosion (Rosgen, 2010). While the figure below shows a structure consisting of large boulders, the j-hook vane can be constructed using other materials such as logs and root wads.

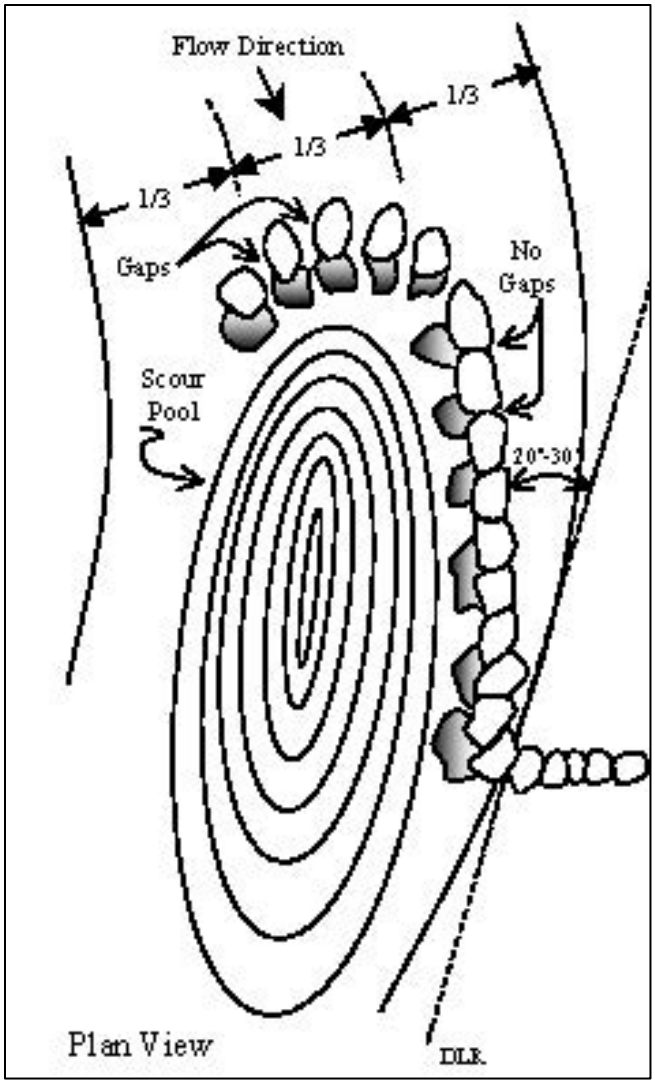

Figure 7. J-Hook Vane in Plan View

c. **<u>Cobble Weir</u>**

The cobble weir structure is an alternative to hardened riffles. These structures act as a grade control, but instead of holding the grade of a glide feature as seen in NCD, they instead hold the water surface elevation of the preceding pool. The cobble weirs consists of a design specific sized cobble silica stone that are placed at low grades in a parabolic cross section shape reinforced by larger footer stones downstream. This is done in an effort to adequately convey a designed storm discharge down valley without adverse degradation to the system. The structure is typically used frequently in this design approach as they are effective in generating aeration and increased dissolved oxygen concentration by creating hydraulic rises and falls while still directing energy. Figure 8 shows a typical drawing for a cobble weir.

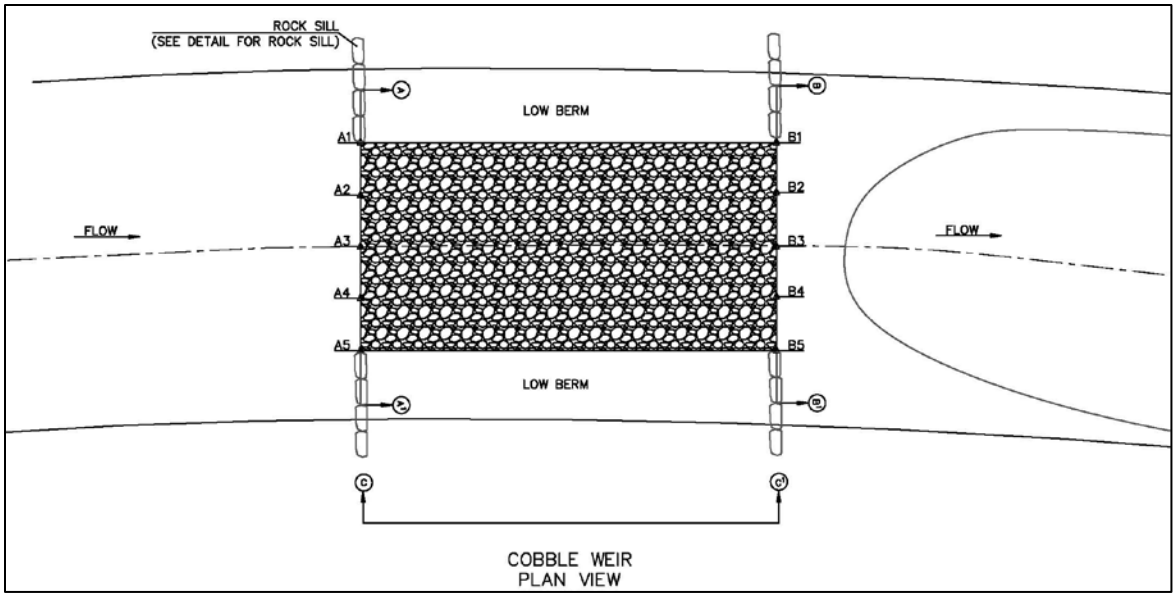

Figure 8. Cobble Weir Structure in Plan View

d. **<u>Rock Sill</u>**

The rock sill structures act as a grade control, but instead of holding the grade of a specific structure or channel elevation, they instead hold the elevation of the valley grade. The rock sill consists of a design specific sized boulder that is placed at the upstream and downstream ends of the cobble weirs and extend laterally across the valley until they tie in at the toe of slope. The sills have only one level of rock that is installed so that the top of the rock is flush with the proposed surface grades and underlain and backed with a non-woven filter fabric to eliminate the possibility of piping. This structure is placed as added insurance to maintain valley grades while the project area re-vegetates after construction as well as to ensure the valley will not be degraded during larger storm events. It is done in an effort to adequately convey a designed storm discharge down valley without adverse degradation to the system. Figure 9 shows a typical drawing for a rock sill.

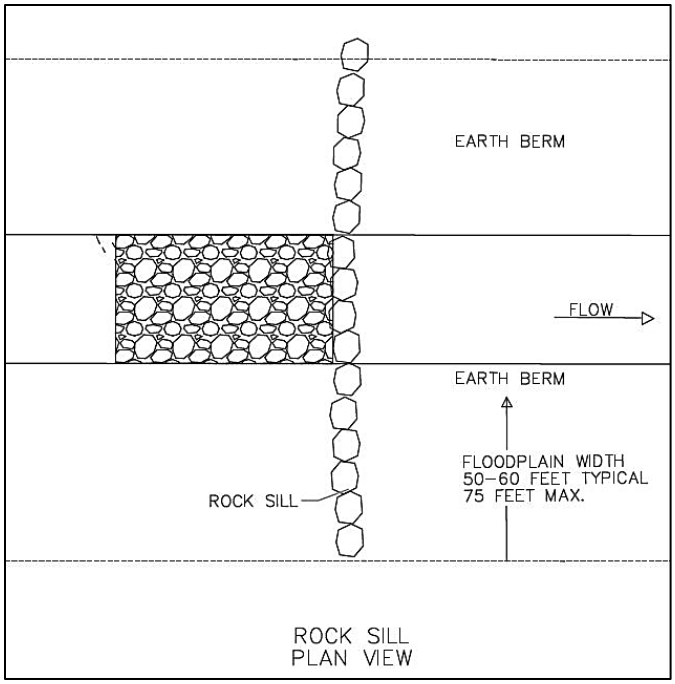

Figure 9. Rock Sill in Plan View

4. Hydrology & Hydraulics Analysis

Evaluating the hydraulics of a stream system is an important component to any assessment because it gives a better understanding of how water and sediment are transported through the channel and its associated floodplain. Since one of the design approaches used for this project was NCD, bankfull validation is required before conducting the hydraulic analysis. Detailed results of the hydrology and hydraulic assessment can be found in Appendices K and L.

a. Bankfull Validation

Bankfull discharge characterizes the range of discharges that is effective in shaping and maintaining a stream. Over time, geomorphic processes adjust the stream capacity and shape to accommodate the bankfull discharge within the stream. Bankfull discharge is strongly correlated to many important stream morphological features (e.g., bankfull width, drainage area, etc.) and is a critical piece of data used for several assessment parameters. Bankfull discharge is also used in natural channel design procedures as a scale factor to convert morphological parameters from a stable reach of one size to a disturbed reach of another size. The Service used *Regional Relationships* as well as *Resistance Relationships* to determine the bankfull discharge and channel dimension at the Navy Dairy Farm.

b. Geomorphic Indicators

During the Navy Dairy Farm assessment, the Service identified bankfull stage using geomorphic indicators formed by the stream as described by McCandless (2003). Figure 10 depicts significant geomorphic indicators typically found in the Mid-Atlantic. Based on these indicators, the Service identified a consistent geomorphic feature at the Navy Dairy Farm. This geomorphic

indicator was typically a significant slope break or back of bench found throughout the project area. A stable riffle was located within the project and surveyed to calculate stable channel dimensions (i.e., width, depth and area) associated with this geomorphic indicator. The riffle cross dimensions were then compared to the Bankfull Discharge and Channel Characteristics in the Coastal Plain Hydrologic Region regional curves (McCandless, 2003). Details of this comparison are described below in Section E4c. – Resistance Relationships.

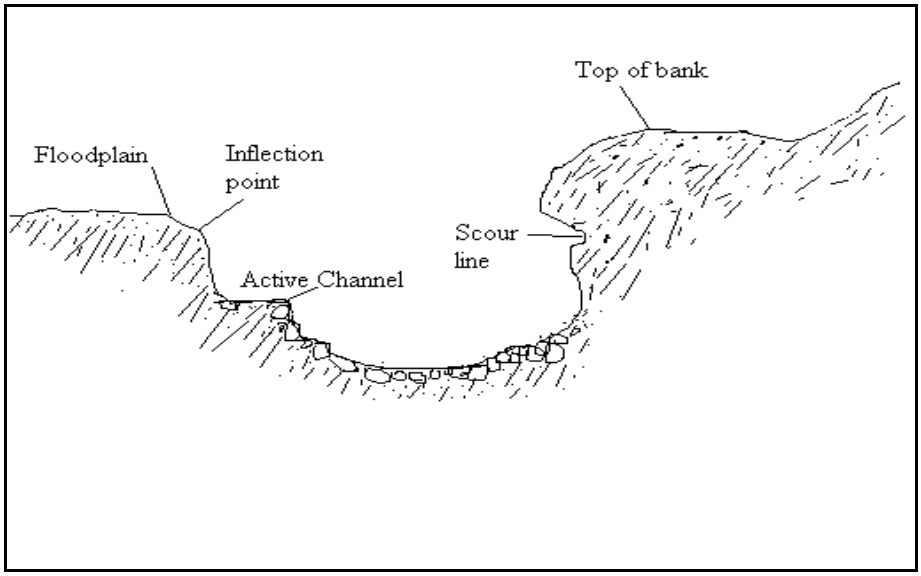

Figure 10: Typical Bankfull Indicators (McCandless, 2003)

c. Resistance Relationships

There are several methods to estimate bankfull discharge and velocity using resistance relationships. These methods typically make use of the cross sectional area, flow depth, representative particle size of channel substrate, channel slope and a determined roughness coefficient, or "friction factor". The Service used the Roughness Coefficient equation to determine discharge. This equation, $\boldsymbol{u = 1.49 * R^{2/3} * S^{1/2}/n}$, uses the hydraulic radius of the representative cross section, the channel slope and a known Manning's *n* (based on stream type) to determine velocity and discharge values. This method closely matched the back calculated roughness coefficient and was in agreement with the regional relationship findings and proved to be an appropriate estimate for bankfull discharge. A summary can be found in Table 8 and detailed information can be found on the "Proposed Design Conditions Plan Set Computations of Velocity and Bankfull Discharge Using Various Methods " worksheet in Appendix K.

Design and Regional Curve Bankfull Characteristics				
Bankfull Characteristics	**Reference Cross Section**	**Design Cross Section**	**Regional Curve (2003)**	**USGS StreamStats 1.25 RI**
Area (sq. ft)	7.49	7.36	8.19	-
Width (ft)	13.53	10.00	9.57	-
Depth (ft)	0.55	0.80	0.84	-
Velocity (ft/s)	2.66	3.49	-	-
Discharge (cfs)	19.90	24.02	26.97	24.9
	Characteristics in the Coastal Plain Hydrologic Region regional curves (McCandless 2003)			

Table 8: Design and Regression Bankfull Characteristics

d. Regional Relationships

The regional curve estimates channel discharge based on a linear regression equation derived from gaged sites across the same physiographic region with similar characteristics. Using only the drainage area, the Service was able to derive the estimated channel width, depth, cross sectional area and discharge using the Bankfull Discharge and Channel Characteristics in the Coastal Plain Hydrologic Region regional curves (McCandless, 2003) (Table 8). This information was then compared to the field measured riffle cross section to validate bankfull dimension and discharge.

e. Bankfull Validation

Based on the bankfull analysis, the Service determined that the bankfull or channel forming flow for Navy Dairy Farm ranges between 20 and 25 cfs. This discharge range generally corresponds well with the regional curve. More importantly, is how closely the surveyed cross section channel dimensions correspond with the regional curve. Estimating discharge has a higher range of error due to the sensitivity of the factors used in calculating discharge. Measurement of cross section area is more precise and a better indicator for validating bankfull.

f. Hydraulic Assessment

The Service conducted two hydraulic analyses to test the stream stability of the proposed design. The first was with the HEC-RAS model to evaluate stream channel and floodplain stability. The second was with the step-pool storm conveyance design calculator (Flores, et al., 2012) to evaluate the stability of the cobble weirs. Detailed results of the hydraulic assessment can be found in Appendix L.

The HEC-RAS model used thirty-two separate cross sections to compare the existing and proposed hydraulic conditions. The model was run using a bankfull flow of 24.9 cfs, a 2-Year flow of 63.90 cfs, a 5-Year flow of 148 cfs, a 10-Year flow of 233 cfs and a 100-Year flow of 755 cfs. These flows were derived from the resistance relationship using existing and design channel and valley geometry. A Manning's roughness coefficient of 0.035 was used for in-channel roughness, which is common among low gradient streams and an overbank roughness of 0.045 was used as a worst-case scenario, lightly vegetated roughness. The HEC-RAS model run showed that all flows through the proposed design would have channel velocities between 0.00 and 2.16 ft/s (Table 9). While the highest velocity is 9.56 ft/s, the majority of the high velocities are in four locations. The first is at the upstream outfall where the stream begins. Here the stream has already downcut to bedrock and will not present a stability problem. The other three locations are at instream structures (i.e., one grade control j-hook and two cobble weirs). At these locations, the proposed construction material (i.e., cobble and boulders) have been designed to withstand these velocities. It should also be noted that these higher velocities are all associated with the 100-year storm event. Therefore, the frequency of occurrence is low.

There are several locations where channel velocities are below 2 ft/s (Table 9). Creating these low velocities was intentional and needed to meet the design objective of trapping sediments and reducing peak flood flows. All of the locations with low velocities are located in the excavated pool areas. Lastly, the HEC-RAS model showed that all shears stresses in the floodplain, up to a 100-year storm event, stay below $2 lb/ft^2$, which is required in order to avoid floodplain erosion.

Sizing of the cobble weirs were based on managing flood flows up a 5-year storm event and withstanding shear stresses up to a 100-year storm event. The HEC-RAS model was used to design the correct weir dimensions so that it could pass the 5-year storm event. The step-pool storm conveyance design calculator results showed that the proposed weir dimensions and cobble size would withstand shear stresses associated with a 100-year storm event.

Navy Dairy Farm- HEC-RAS Model Results			
Bankfull Characteristics	**Storm Event**	**Existing Conditions**	**Design Conditions**
Overbank Shear Stress (lbs/ft2)	**Bankfull**	0.00 – 0.22	0.00 – 0.12
	2 year	0.00 – 0.43	0.00 – 0.29
	5 year	0.00 – 0.83	0.00 – 0.50
	10 year	0.00 – 1.08	0.01 – 0.59
	50 year	0.00 – 2.09	0.02 – 1.01
	100 year	0.00 – 0.82	0.03 – 1.21
Channel Velocity (ft/s)	**Bankfull**	1.83 – 4.86	0.19 – 4.21
	2 year	2.15 – 6.10	0.40 – 5.14
	5 year	2.59 – 7.28	0.80 – 6.08
	10 year	2.87 – 8.13	1.13 – 6.76
	50 year	4.17 – 12.18	2.03 – 8.57
	100 year	4.50 – 16.66	2.39 – 9.56

Table 9. HEC-RAS Model Results

5. Sediment Analysis

As stated in the *Watershed Level Assessment*, the sediment supply of the project area consists primarily of suspended sediments. This is because there is no stream network upstream of the project area and as a result, no source of bedload sediments.

The amount of soil loss from runoff was calculated by the NRCS using the RUSLE equation (US Department of Agriculture , 2013). A total of 847 tons/year of sediment is eroded and of that, 347 tons/year is delivered to the stream. This equates to 2.5 tons/year/acre being delivered to the stream, which is considered excessive. Since the sediment supply is primarily silt, it is easily entrained in the water column and can be transported long distances before settling out.

The available storage area of all the proposed pools can contain approximately 750 tons of sediment. Based on the annual amount of sediment being delivered, it is possible that the pool storage areas could be filled within two years. However, the actual rate of deposition is difficult to predict for a variety of reasons. First, silt sediments can remain entrained in the water column for long periods and as a result, be transported through the project area before settling out. Second, annual precipitation totals, frequency and magnitudes will influence the amount of sediment delivered to the project area. Furthermore, how the landscape is managed upstream of the project will influence sediment delivery amounts. Regardless of the actual rate of deposition, the pool storage areas will eventually be filled with silt and lose their sediment trapping capability. At this point, the Service recommends that the pools be re-excavated. Since the

stream system is ephemeral and does not support aquatic life, there should be limited to no adverse impacts to aquatic life when the pools are re-excavated.

It should be noted that in addition to this project, the Service plans to install a sediment basin upstream of this project in the near future to limit sediments delivered to the site. This will result in increasing the longevity of the pool trapping capability.

6. Vegetation Design

A significant riparian forest buffer will be restored in the valley of this ephemeral stream. This riparian buffer is an integral part of the stream ecosystem, providing bank stability and nutrient uptake, serving as a food source for aquatic organisms downstream of the project area and providing terrestrial habitat and migration corridors for wildlife. Many species of wildlife will benefit including migratory birds, amphibians, reptiles, small mammals and pollinating insects. Shading from the buffer will moderate stream temperature and prevent excessive algal growth. The riparian vegetation will help increase infiltration and evapotranspiration, which will benefit stream base flow in lower stream sections and help reduce erosive velocities of runoff. Large woody debris derived from the buffer is an important component of aquatic habitat.

The riparian planting has two distinct zones; the valley slopes and the floodplain. The valley slopes will be planted with trees and shrubs. The floodplain will also be planted with trees and shrubs except for the constructed pools which will be planted with herbaceous plants. The planting plan for the pools will be developed post construction after determining how the hydrology fluctuates. Native plants found in Maryland's Coastal Plain physiographic province in will be used in all planting areas.

Monitoring plant survival and management of invasive species, especially Callery Pear, will be important to the evolution of a fully functioning, self-sustaining buffer. The detailed planting plan can be found in Appendix M.

VII. MAINTENANCE AND MONITORING PLANS

A. MAINTENANCE PLAN

The Service will collaborate with CBF, the County and the Navy to develop a maintenance plan that will ensure the success of the restoration objectives and goals. Plan duration and responsible parties will also be determined at that time.

B. MONITORING PLAN

The Service will conduct an as-built survey directly following completion of the restoration. This survey will be used to confirm that the project was built to design standards and will serve as baseline data for future monitoring. The Service will compare this data to the design criteria and produce a brief report summarizing any implementation adjustments or discrepancies.

A well-developed post-restoration monitoring plan will allow the partners to determine the success of the project, and address any problems that may arise. The Service, CBF and the County have developed a monitoring plan based on the restoration goals and objectives outlined in Section 4C to evaluate the performance of the stream restoration project. This will take place after the successful completion of the Navy Dairy Farm Tributary 1 Restoration.

A Rapid Monitoring Protocol (RMP), developed by the Service, will be used to monitor the physical characteristics of the restoration projects. The RMP is a tiered approach for rapid restoration assessment that visually evaluates the stability and qualitative functional success of the restoration project. If there are indications of potential failure, the methodology requires that the project evaluators conduct a more intensive monitoring survey, which is the second tier survey. However, if a severe problem is identified (*e.g.* complete structure failure, excessive bank erosion, vertical incision > 1.3) the second tier may be skipped to go directly to the third tier – remediation/repair. During the second tier survey, project evaluators take measurements of the existing stream conditions and compare them to the proposed design criteria and reference data, to determine if remediation is required. If remediation/repair is required, the evaluators will perform a third tier survey that includes restoration design and implementation. The success of the riparian buffer plantings will also be monitored by visually quantifying bare areas, invasive species distribution, native recruitment and survivability of planted species. The Service will monitor the stream 1, 3, 5 and 7 years post restoration and provide a brief monitoring summary report for each year of monitoring.

VIII. PERMIT REQUIREMENTS

The permit requirements for Tributary 1 were unique for two distinct reasons. First, the Navy, a Federal entity, owns the property, which excludes the project from County grading permit requirements. Second, the tributary was found to be ephemeral with no adjacent wetlands, which excludes it from some state permitting.

A Joint Permit Application will be submitted to the Maryland Department of Environment (MDE) Waterway Construction Division as well as the U.S. Army Corps of Engineers (Corps). Once deemed ephemeral by MDE, with no adjacent wetlands, the project will be exempt from Non-Tidal waterway permitting; however, the Corps Nationwide Permit 27 will be required for project implementation. Additionally, since there is no regulated 100-yr FEMA floodplain in this area, no floodplain elevation review is required.

Since this project was exempt from County grading permits, Erosion and Sediment Control Plan approval will be sought from MDE Water Management Administration.

In order to simplify plan review for these agencies, the Service has prepared the Function-based Stream Restoration Project Process Review Checklist (Appendix N), the Natural Channel Design Review Checklist (Appendix O) and the Regenerative Storm Conveyance Design Review Checklist (Appendix P).

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APPENDIX A

Watershed Assessment

I. Geology and Soils

The Navy Dairy Farm Tributary 1 watershed lies completely in the western part of the Atlantic Coastal Plain. The Coastal Plain is defined geologically by the under-lying of unconsolidated sediments including gravel, sand, silt and clay from fluvial-deltaic and marine systems. This overlaps the rocks of the eastern Piedmont along an irregular line of contact known as the Fall Zone.

The sediments of the Coastal Plain dip eastward at a low angle, generally less than one degree, and range in age from Triassic to Quaternary (Maryland Geological Survey).

The Navy Dairy Farm watershed primarily consists of three types of soils: Mattapex-Butlertown complex 2 to 5% slope, Mattapex-Butlertown complex 5 to 10% slope, and Woodstown sandy loam 0 to 2% slope comprising 77.8% of the watershed. A more detailed soils report can be referenced in Appendix B.

The Mattapex-Butlertown complex 2 to 5% slope consist of two map units. Mattapex and similar soils represent 40%, and Bultertown and similar soils is approximately 35% and the final 25% are minor components. The complex is moderately well drained and located in fluviomarine terraces, interfluves, and broad insterstream divides. Although these soils have moderate draining, this complex is classified as a D hydrologic soil group representing very slow infiltration rates and high runoff potential. This corresponds with the typical profile of 0 to 42 inches of silt loam before a fine sandy loam or loamy sand layer is present. Permeability is moderately low ranging from 0.06 to 0.57 in/hr and has limited capacity of approximately 8.3 inches. Slopes range from 2 to 5 percent. Mean annual precipitation is about 40-50 inches, and mean annual temperature is about 52-57 degrees F.

The Mattapex-Butlertown complex 5 to 10% slope is very similar to the 2 to 5% slope. Precipitation, temperature, soil profile, drainage and capacity are the same as above but this complex is steeper and consist of Mattapex and similar soils represent 50%, and Bultertown and similar soils is approximately 30% and the final 20% are minor components.

The Woodstown sandy loam consists of moderately well drained soils and typically located in drainhead complexes, swales and depressions. Permeability is 0.20 to 2.0 in/hr with a limited capacity of 8.9 inches. The soil profile is more sandy then silt compared to the Mattapex-Butlertown, its hydrologic soil group is classified as a C still having low infiltration rates but low runoff potential. Slopes range from 0 to 2 percent. Mean annual precipitation is about 40 - 50 inches, and mean annual temperature is about 50 - 58 degrees F.

The majorities of the soils in the watershed are moderately well drained; have low infiltration rates and high runoff potential. These three factors likely reduce the amount of ground water recharge and limits the amount of ground water available to the stream which supports the reason the Navy Dairy Farm Tributary 1 is ephemeral.

II. Existing Land use/Land cover.

The Service used aerial photographs, and USGS StreamStats for Maryland (U.S. Geological Survey, 2012) to estimate the land use/land cover percentages for the Navy Dairy Farm watershed. Based on Maryland Department of Planning data from 2010, the primary land use in the watershed is agricultural practices, accounting for 84 percent of the coverage majority being cropland. Low Density Residential and Forest make up the remaining 16 percent. A more detailed distribution can be found in Table 1.

Based on the 2009 Anne Arundel County Comprehensive Land Use Plan, the land use distributions of this watershed will remain mostly unchanged with continue plans for low and medium residential development through 2020. Currently, the watershed consists of 2.3 percent impervious surfaces.

Currently, the project area consists of 84 percent tilled cropland and pasture, which likely contributes to the degraded stream bank conditions because it increase the rate and intensity of flows due to the limited vegetation. Cattle access have caused sheer banks and sloughing increasing sediment erosion.

While this current land use presents stability challenges if left unaltered, the proposed restoration plan aims to fence off cattle, establish a dense riparian buffer, and create basins to trap and redistribute sediment before entering Towser's Branch.

Navy Dairy Land Use Values			
Land Use	**Land Use Code**	**Acreage**	**% Watershed Covered**
Low Density Residential	11	26.89	7.69%
Cropland	21	170.50	48.75%
Pasture	22	113.75	32.52%
Row and Garden Crops	25	10.20	2.92%
Deciduous Forest	41	21.23	6.07%
Mixed Forest	43	7.18	2.05%
Source: Maryland Department of Planning, 2010			

Table 1: Navy Dairy Farm Land Use Values

III. Hydrology & Hydraulics

The Navy Dairy Farm watershed is a sub-watershed of the Little Patuxent River, which is the largest tributary of the Patuxent River. The Navy Dairy Farm watershed is small, broad basin covering 0.55 square miles at the project location and is in Coastal Plain hydrologic region.

The project area can be broken into two sections: Reach 1 is the upper section from the inlet to upstream of the wetland swale confluence and Reach 2 is downstream of the confluence to the farm road crossing. The entire project area is gravel-dominated (4) tending towards the smaller size range, with a two different of valley and stream types.

Reach 1's valley type is Confined Alluvial Fluvial Deposition (C-AL-FD) with a narrow floodplain (Rosgen D., 2012). This valley is narrow and restrained floodplain due to natural pinch points with less than 5 percent slope. The stream is consistent, as defined by Rosgen (1996), with a stream type B4/1. B type exhibits a slope range of 0.02-0.039 ft/ft, a moderate sinuosity of greater than 1.2, width to depth ratio of greater than 12, and entrenched ratio of 1.4-2.0. Sediment instream is gravel but within this section the stream is directly influenced by bedrock. B4 stream types have banks are relatively steep and generally composed of unconsolidated, heterogeneous, non-cohesive, alluvial materials that are finer than the gravel-dominated bed material.

Continuing downstream, Reach 2's valley type is Unconfined Alluvial Fluvial Deposition (U-AL-FD) (Rosgen D., 2012). This valley is wide, gentle with less than 3 percent slope and a well-developed floodplain adjacent to river terraces. These alluvial floodplains are maintained by the river and are dynamic in form. In this section, the stream is classified as a F4 stream type. The streambed has down cut as far as it can due to the upstream bedrock constraints and the man-made culvert constraint downstream. It is no longer connected to the floodplain, however in a few places benches have been created from sloughing to due to cattel activity or cattle crossing narrowing the stream and providing some velocity relief. F stream types have a less than 1.4 entrenchment ratio, greater than 12 width to deep ratio meaning that the stream has over widened and confined within the channel unable to access its floodplain during a bankfull event.

Rates of lateral adjustment are influenced by the presence and condition of riparian vegetation (Rosgen D., 2012). The Navy Dairy Farm Tributary 1 has little to no riparian buffer and with limited access to the floodplain the stream is susceptible to accelerated bank erosion.

The Navy Dairy Farm Tributary 1 exhibits a flow regime of an ephemeral channel. There is no groundwater entering the channel and was confirmed by a certified soil scientist with the NRCS/Service. 72" samples were throughout the entire 5,000 linear feet of the Tributary 1, taken 10' to 15' from the stream channel. Only at the end of the Tributary 1 were any signs of redox occurring. The sharp boundary of iron concentrations with the soil matrix indicates that the redox features were relict features due to surface water ponding (in contemporary hydric soils, the boundaries between the concentrations and the matrix are diffuse). There was likely a mill dam or beaver pond on Towser's Branch that caused water to back up in the Tributary 1, inundating the adjacent floodplain and resulting in redox indicators in the soil. Additional 48" borings were

done in the channel (approx. 1' below the existing stream bed) and no water table or free water was encountered.

Soil borings completed in the stream channel showed a gravelly, sandy soil horizon found at 24" below the stream bottom. Ground water was evident at 24-30" below the stream bottom further supporting the extensive disconnection to the water table.

Precipitation amounts for the bankfull 1.5 year storm event, twenty-four hour rain event are 3.24 inches, which deliver as much as 46.7 cfs to our site in 1.2 hours of time using the SCS LagEquation (National Oceanic and Atmospheric Adminstration, 2015).

This data suggests that the watershed is "flashy" based on comparisons of like sized rural watersheds with similar basin relief. The watershed receives an average 44.0 inches of precipitation annually (U.S. Geological Survey, 2012), most runoff is not absorbed into the soils, due to the pool soil hydrology.

While knowing the hydrology of a watershed is important, it usually cannot be manipulated. However, the watershed hydrology must be understood in order to develop a sound restoration plan. The Navy Dairy Farm Tributary 1 is ephemeral at the project area and The Service included storage basins in the design criteria and riparian wetlands to help infiltrate the runoff from adjacent lands. Some of these storage basin may hold water for a short time, but regaining base flow is not likely.

IV. Geomorphology

The Navy Dairy Farm watershed contains a few distinguishable valley and stream type transitions from its start at the inlet of subsurface drainage tile to its terminus at the farm road crossing. Reach 1 of the watershed consists confined valley and a stable B4/1 stream type (Rosgen D., 2012) channel in a high relief basin with bedrock control. Without this bedrock, the increased runoff from the concentrated flows of the drain tile would cause an incised channel to develop with vertical eroding banks as evidenced further downstream.

Reach 2 is has an unconfined valley and a F4 stream type with lower relief and a gravel, sand and silt mix substrate. While the upper portion of the watershed was observed to be stable, the lower portion of the watershed shows areas of vertical instability and widespread lateral instability. Localized vertical instability was observed in the form of poorly defined pools, glides and riffles. Widespread lateral instability was observed in the form of eroding stream banks and sparsely vegetated vertical banks and riparian corridors.

The current channel conveys storm water and provides very little processing of nutrients or sediments coming off the farm fields. The entire channel downstream of the bedrock is a sediment source due to the vertical eroding banks. Bank heights range from 1' to 4'. Watershed-wide observations support that there is a large available sediment source from adjacent cropland and stream bank erosion that must be addressed through the system, as evidenced by depositional features such an inner berm feature. Through the RUSLE equation (US Department of Agriculture, 2013) total soil loss coming off adjacent field upstream of the

inlet was 890.34 tons/year with 347.23 tons/year being delivered to the Tributary 1. More detailed map and calculations can be referenced in Appendix C. This watershed-scale sediment source plays a critical role in determining and selecting the correct design methodology.

V. Physicochemical and Biology

Physicochemical functions include the interaction of physical and chemical processes to create the basic water quality of the stream (including temperature, dissolved oxygen, conductivity, pH and turbidity), as well as to facilitate nutrient and organic carbon processes. These parameters provide both direct and indirect indications of stream condition and its ability to support biological conditions (Harman et al., 2012).

The Navy Dairy Farm watershed has a number of influential factors that must be considered in order to determine if the reach-scale restoration can have any impact on the existing physicochemical functions or if these variables cannot be influenced. Point source and non-point source contributions, effects of land-use change and climate factors all influence physicochemical function.

With the majority of the watershed consisting of the farm, this land is required to stay as agriculture as part of the Navy contract. Current agricultural practice is having large negative impacts on the water quality of the Tributary 1. With Organic farming, all croplands are tilled for weed control leaving acres of raw soil to be eroded and carried into the Tributary 1. Best management practices are being made around the farm, the most crucial for stream stabilization was fencing the cattle from access the stream and floodplain.

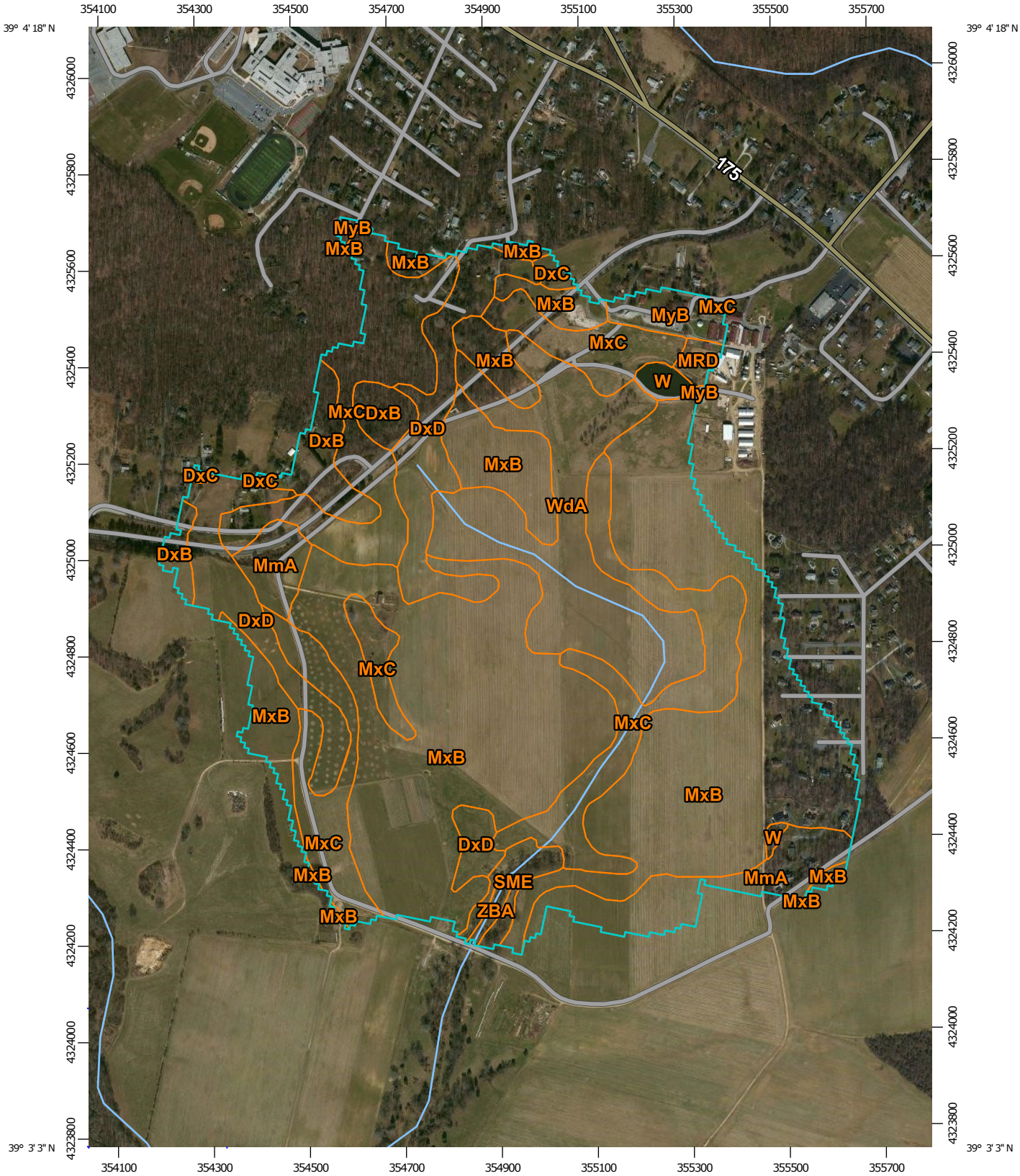
The SFPF (Harman et al., 2012) suggests that the ability of the lotic system to support biological processes is dependent upon the hydrology, hydraulic, geomorpholgy and physicochemical functions. A disruption in any one of the previously mentioned functions would result in loss of biologic diversity and abundance.

The most limiting condition for biology is that the stream is ephemeral and will not sustain aquatic life. No biological data was collected due to these conditions. With the water table exceedingly disconnected there is very little to no potential of returning base flow condition to the stream.

APPENDIX B

Project Area Soil Map

Soil Map—Anne Arundel County, Maryland
(Navy Dairy Farm Watershed)



Map Scale: 1:11,300 if printed on A portrait (8.5" x 11") sheet.

N

Meters: 0 150 300 600 900

Feet: 0 500 1000 2000 3000

Map projection: Web Mercator Corner coordinates: WGS84 Edge tics: UTM Zone 18N WGS84

Map Unit Legend

Anne Arundel County, Maryland (MD003)			
Map Unit Symbol	**Map Unit Name**	**Acres in AOI**	**Percent of AOI**
DxB	Downer-Phalanx complex, 2 to 5 percent slopes	12.1	3.5%
DxC	Downer-Phalanx complex, 5 to 10 percent slopes	1.5	0.4%
DxD	Downer-Phalanx complex, 10 to 15 percent slopes	32.2	9.2%
MmA	Matapeake silt loam, 0 to 2 percent slopes	17.9	5.1%
MRD	Matapeake and Mattapex soils, 10 to 15 percent slopes	1.6	0.5%
MxB	Mattapex-Butlertown complex, 2 to 5 percent slopes	160.8	46.0%
MxC	Mattapex-Butlertown complex, 5 to 10 percent slopes	71.6	20.5%
MyB	Mattapex-Butlertown-Urban land complex, 0 to 5 percent slopes	5.3	1.5%
SME	Sassafras and Croom soils, 15 to 25 percent slopes	4.0	1.2%
W	Water	2.1	0.6%
WdA	Woodstown sandy loam, 0 to 2 percent slopes	39.5	11.3%
ZBA	Zekiah and Issue soils, 0 to 2 percent slopes, frequently flooded	1.0	0.3%
Totals for Area of Interest		**349.8**	**100.0%**

APPENDIX C

RUSLE Data for Project Area

SEDIMENT DELIVERY
Dairy Farm

Drainage Area		Soil Loss	Total Soil Loss
1a,1b,1c	122.83 Ac	6.7 Tons/Ac/Yr	822.961 Tons/Yr
1	7.96 Ac	3.5 Tons/Ac/Yr	27.86 Tons/Yr
2a	2.03 Ac	9.4 Tons/Ac/Yr	19.082 Tons/Yr
8d	3.35 Ac	6.1 Tons/Ac/Yr	20.435 Tons/Yr
	136.17 Ac		890.338 Tons/Yr

Total Soil Loss	890.34 Tons/Yr		
Sediment Delivery Ratio	0.39		
Soil Delivered to Pond	347.23 Tons/Yr		
Pond Surface	0 Ac		
Pond Depth	0 ft		
Estimated Storage	0 Ac/ft	0 CY	
Annual Inflow	170.21 Ac/ft		
Ratio	0.000		
Trap Efficiency	0.5 %		
Soil Trapped by Pond	173.62 Tons/Yr	or	135 CY/Yr

With an available volume of 0 CY

Cleanout at 2/3 full, pond will need cleanout every 0.0 Years

Assisted By: David Scheler

CONSERVATION PLAN MAP

Farm 936 Tract 988

Customer(s): MD SUNRISE FARM LLC

District: ANNE ARUNDEL SCD

Approximate Acres: 878.65

ACCT# 020400005952000
WS# 021311050947

Date: 6/5/2015

Practices (polygons)

Practice name

- Wetland Creation
- Grassed Waterway
- existing fence
- Resource Inventory (Point)

Approved
JUN 1 2015
AASCD

ALL ACRES AND BOUNDARIES ARE APPROXIMATE

800 0 800 1,600 2,400 3,200 Feet

N

APPENDIX D

StreamStats Hydrology

StreamStats Version 3.0

Inlet Basin Characteristics Ungaged Site Report

Date: Tues Jan 12, 2016 3:49:01 PM GMT-5
Study Area: Maryland
NAD 1983 Latitude: 39.0568 (39 03 25)
NAD 1983 Longitude: -76.6751 (-76 40 31)

Label	Value	Units	Definition
DRNAREA	0.31	square miles	Area that drains to a point on a stream
FOREST	11.4	percent	Percentage of area covered by forest
STATSGOA	57.1	percent	Percentage of area of Hydrologic Soil Type A from STATSGO
STATSGOD	3.3	percent	Percentage of area of Hydrologic Soil Type D from STATSGO
PRECIP	43.8	inches	Mean Annual Precipitation
ADJCOEFF	0	dimensionless	Coefficient to adjust estimates for percentage of carbonate rock in Western Maryland
IMPERV	3.06	percent	Percentage of impervious area
FOREST_MD	14.2	percent	Percent forest from Maryland 2010 land-use data
SSURGOA	0	percent	Percentage of area of Hydrologic Soil Type A from SSURGO
SOILCorD	85.7	percent	Percentage of area of Hydrologic Soil Type C or D from SSURGO
LIME	0	percent	Percentage of area of limestone geology
BSLDEM10ff	0.0308	feet per foot	Mean basin slope computed from 10 m DEM in feet per foot
LC11IMP	1.63	percent	Percentage of impervious area determined from NLCD 2011 impervious dataset
LC11DEV	12.4	percent	Percentage of land-use from NLCD 2011 classes 21-24

StreamStats Version 3.0

Inlet Flow Statistics Ungaged Site Report

Date: Tues Jan 12, 2016 3:50:03 PM GMT-5
Study Area: Maryland
NAD 1983 Latitude: 39.0568 (39 03 25)
NAD 1983 Longitude: -76.6751 (-76 40 31)
Drainage Area: 0.31 mi2

Peak Flows Region Grid Basin Characteristics			
100% Peak Western Coastal Plain 2010 AHMMD (0.31 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	0.31 (below min value 0.41)	0.41	349.6
Percent SSURGO Soil Type C or D (percent)	85.7 (above max value 74.7)	13	74.7
Percent Impervious (percent)	3.06	0	36.8

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

Urban Flows Region Grid Basin Characteristics
100% Undefined Region (0.31 mi2)

The selected watershed is entirely in an area for which flow equations were not defined.

Low Flows Region Grid Basin Characteristics
100% Undefined Region (0.31 mi2)

The selected watershed is entirely in an area for which flow equations were not defined.

Peak Flows Region Grid Statistics						
Statistic	**Value**	**Unit**	**Prediction Error (percent)**	**Equivalent years of record**	**90-Percent Prediction Interval**	
					Min	**Max**
PK1 25	24.9	ft3/s				
PK1 5	34.7	ft3/s				
PK2	47.6	ft3/s				
PK5	111	ft3/s				
PK10	176	ft3/s				
PK25	298	ft3/s				

PK50	423	ft3/s				
PK100	592	ft3/s				
PK200	820	ft3/s				
PK500	1230	ft3/s				

http://www.gishydro.umd.edu/HydroPanel/hydrology_panel_report_3rd_edition_final.pdf (http://www.gishydro.umd.edu/HydroPanel/hydrology_panel_report_3rd_edition_final.pdf)
Thomas_ Jr._ W.O. and Moglen_ G.E._ 2010_ An Update of Regional Regression Equations for Maryland_ Appendix 3 in Application of Hydrologic Methods in Maryland_ Third Edition_ September 2010: Maryland State Highway Administration and Maryland Department of the Environment_ 38 p.

StreamStats Version 3.0

Outlet Basin Characteristics Ungaged Site Report

Date: Tues Dec 29, 2015 10:20:17 AM GMT-5
Study Area: Maryland
NAD 1983 Latitude: 39.0546 (39 03 16)
NAD 1983 Longitude: -76.6774 (-76 40 39)

Label	Value	Units	Definition
DRNAREA	0.57	square miles	Area that drains to a point on a stream
FOREST	8.02	percent	Percentage of area covered by forest
STATSGOA	57.1	percent	Percentage of area of Hydrologic Soil Type A from STATSGO
STATSGOD	3.3	percent	Percentage of area of Hydrologic Soil Type D from STATSGO
PRECIP	43.9	inches	Mean Annual Precipitation
ADJCOEFF	0	dimensionless	Coefficient to adjust estimates for percentage of carbonate rock in Western Maryland
IMPERV	2.3	percent	Percentage of impervious area
FOREST_MD	9.42	percent	Percent forest from Maryland 2010 land-use data
SSURGOA	0	percent	Percentage of area of Hydrologic Soil Type A from SSURGO
SOILCorD	78.1	percent	Percentage of area of Hydrologic Soil Type C or D from SSURGO
LIME	0	percent	Percentage of area of limestone geology
BSLDEM10ff	0.0316	feet per foot	Mean basin slope computed from 10 m DEM in feet per foot
LC11IMP	1.4	percent	Percentage of impervious area determined from NLCD 2011 impervious dataset
LC11DEV	10.9	percent	Percentage of land-use from NLCD 2011 classes 21-24

StreamStats Version 3.0

Outlet Flow Statistics Ungaged Site

Report Date: Tues Dec 29, 2015 10:20:54 AM GMT-5
Study Area: Maryland
NAD 1983 Latitude: 39.0546 (39 03 16)
NAD 1983 Longitude: -76.6774 (-76 40 39)
Drainage Area: 0.57 mi2

Peak Flows Region Grid Basin Characteristics			
100% Peak Western Coastal Plain 2010 AHMMD (0.57 mi2)			
Parameter	**Value**	**Regression Equation Valid Range**	
		Min	**Max**
Drainage Area (square miles)	0.57	0.41	349.6
Percent SSURGO Soil Type C or D (percent)	78.1 (above max value 74.7)	13	74.7
Percent Impervious (percent)	2.3	0	36.8

Warning: Some parameters are outside the suggested range. Estimates will be extrapolations with unknown errors.

Urban Flows Region Grid Basin Characteristics
100% Undefined Region (0.57 mi2)

The selected watershed is entirely in an area for which flow equations were not defined.

Low Flows Region Grid Basin Characteristics
100% Undefined Region (0.57 mi2)

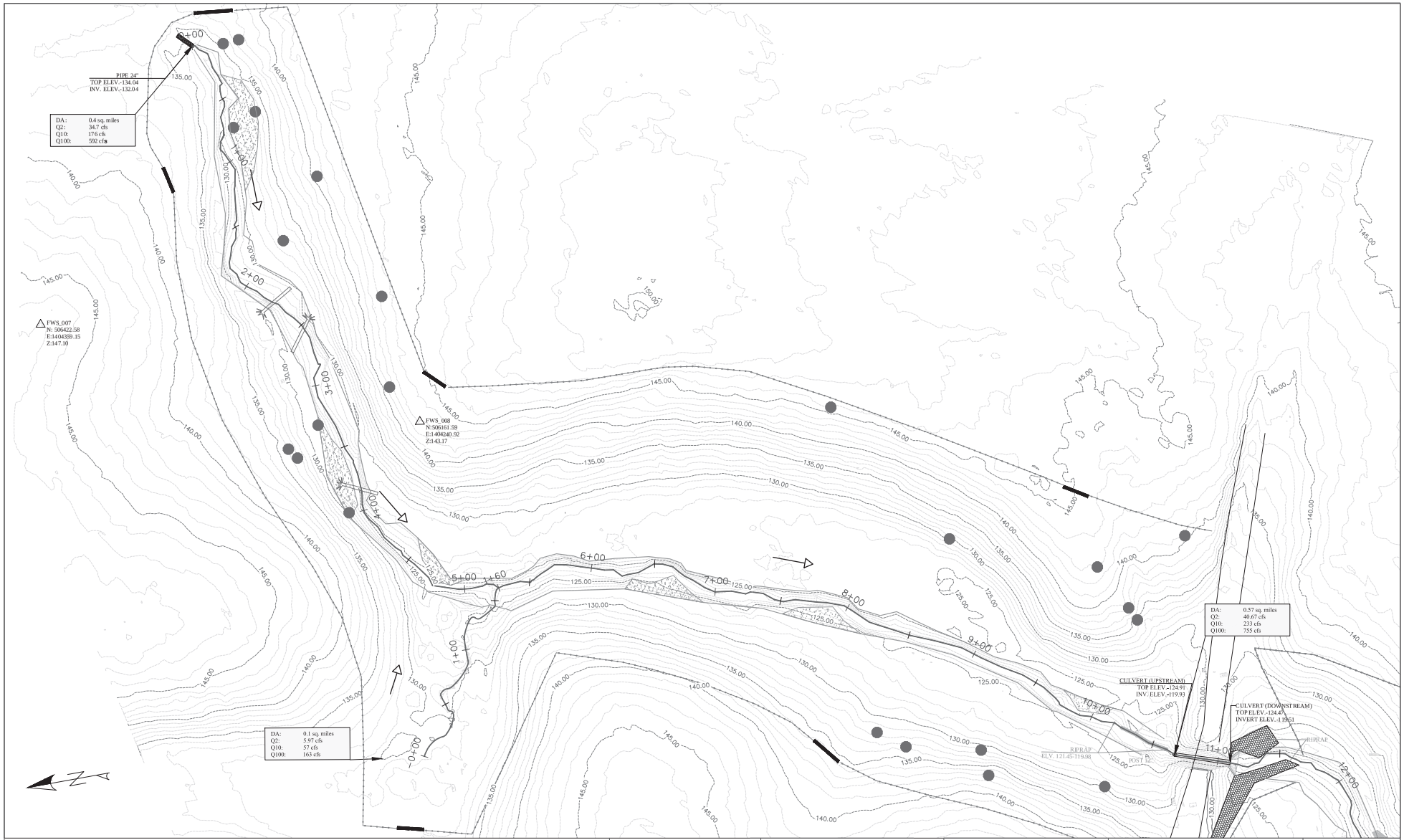
The selected watershed is entirely in an area for which flow equations were not defined.

Peak Flows Region Grid Statistics						
Statistic	**Value**	**Unit**	**Prediction Error (percent)**	**Equivalent years of record**	**90-Percent Prediction Interval**	
					Min	**Max**
PK1 25	33.8	ft3/s				
PK1 5	46.7	ft3/s				
PK2	63.9	ft3/s				
PK5	148	ft3/s				
PK10	233	ft3/s				
PK25	389	ft3/s				
PK50	545	ft3/s				
PK100	755	ft3/s				
PK200	1040	ft3/s				
PK500	1530	ft3/s				

http://www.gishydro.umd.edu/HydroPanel/hydrology_panel_report_3rd_edition_final.pdf
(http://www.gishydro.umd.edu/HydroPanel/hydrology_panel_report_3rd_edition_final.pdf)
Thomas_ Jr._ W.O. and Moglen_ G.E._ 2010_ An Update of Regional Regression Equations for Maryland_ Appendix 3 in Application of Hydrologic Methods in Maryland_ Third Edition_ September 2010: Maryland State Highway Administration and Maryland Department of the Environment_ 38 p.

APPENDIX E

Existing Condition Plan Set



CONTOUR INTERVAL = 1.0 FOOT

Not to Scale:

Professional Certification
I hereby certify that these document were prepared or approved by me, and that I am a duly licensed professional engineer under the laws of the State of Maryland, License No. 20346, Expiration Date: 2017-01-21

(Signature) (Date)

STATE OF MARYLAND
BRIAN HOLLAND
PROFESSIONAL ENGINEER

FREDERICK SEIBERT & ASSOCIATES, INC. © 2011

CIVIL ENGINEERS SURVEYORS LANDSCAPE ARCHITECTS LAND PLANNERS
128 SOUTH POTOMAC STREET, HAGERSTOWN, MARYLAND 21740
20 WEST BALTIMORE STREET, GREENCASTLE, PENNSYLVANIA 17225
(301) 739-5400 FAX (301) 739-0474 (717) 597-1987 FAX (717) 709-4036

U.S. FISH & WILDLIFE SERVICE

U.S. Fish & Wildlife Service
Chesapeake Bay Field Office
Stream Habitat Assessment and Restoration Program

177 Admiral Cochrane Drive
Annapolis, Maryland 21401

Tel. (410) 573-4581

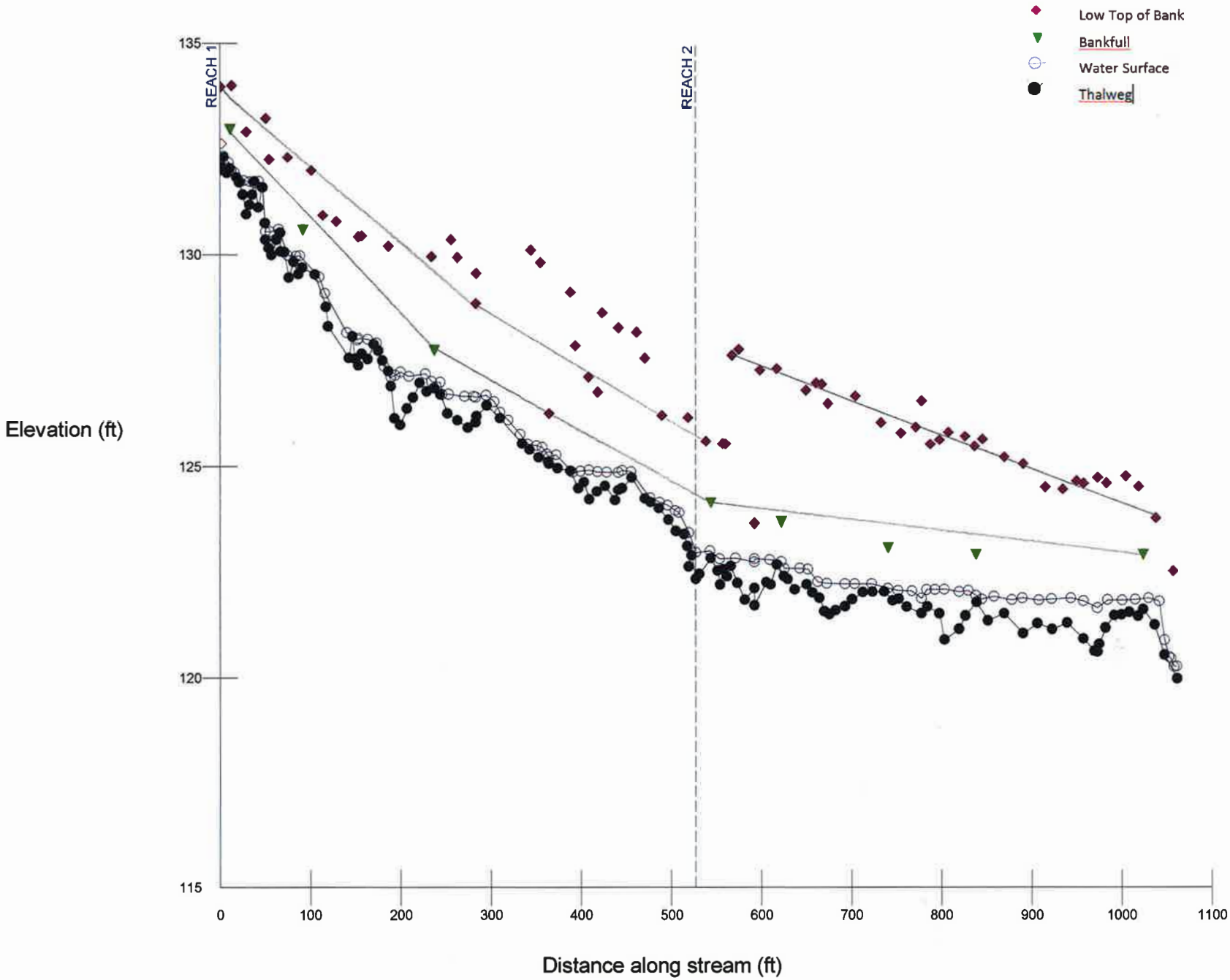
NAVY DAIRY FARM
ANNE ARUNDEL CO, MD

REVISIONS		EXISTING CONDITIONS	
DATE	BY		
		PROJECT MANAGER: BH	DRAFTING: CAC
		DESIGN: BH	CHECKED BY: KM
		DATE: 02/11/2016	SCALE: AS SHOWN

SHEET
3 of 12

EC - 1

Existing Profile



APPENDIX F

Stream Classification Worksheets

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

Stream:	**Navy Dairy Farm Tributary Reach 1**			
Basin:	Drainage Area:	acres	**.4**	mi^2
Location:				
Twp.&Rge: **;**	Sec.&Qtr.: **;**			
Cross-Section Monuments (Lat./Long.):	**0 Lat / 0 Long**	Date: **05/09/14**		
Observers: **BH, CC**	Valley Type: II			

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**10.52**	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}).	**0.56**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**5.86**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**18.79**	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**	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.	**16.78**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**1.6**	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.	**25**	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.	**0.02091**	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**	

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

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

Stream:	**Navy Dairy Farm Tributary- Reach 2**			
Basin:	Drainage Area:	acres	**0.55**	mi^2
Location:				
Twp.&Rge: **;**	Sec.&Qtr.: **;**			
Cross-Section Monuments (Lat./Long.):	**0 Lat / 0 Long**		Date:	**08/22/14**
Observers:			Valley Type:	VIII(c)

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**11.65**	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}).	**0.81**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**9.47**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**14.38**	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.	**1.75**	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.	**15.16**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**1.3**	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.	**7.01**	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.	**0.01788**	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**	

Stream Type **F 4** (See **Figure 2-14**)

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

Stream:	**Navy Dairy Farm- Reference**				
Basin:	Drainage Area:	**256**	acres	**0.4**	mi^2
Location:					
Twp.&Rge: **;**	Sec.&Qtr.: **;**				
Cross-Section Monuments (Lat./Long.):	**0 Lat / 0 Long**			Date:	**08/22/14**
Observers: **BH, CC**				Valley Type:	II

Bankfull WIDTH (W_{bkf}) WIDTH of the stream channel at bankfull stage elevation, in a riffle section.	**13.53**	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}).	**0.55**	ft
Bankfull X-Section AREA (A_{bkf}) AREA of the stream channel cross-section, at bankfull stage elevation, in a riffle section.	**7.49**	ft^2
Width/Depth Ratio (W_{bkf} / d_{bkf}) Bankfull WIDTH divided by bankfull mean DEPTH, in a riffle section.	**24.6**	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.	**1.17**	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.	**20.14**	ft
Entrenchment Ratio (ER) The ratio of flood-prone area WIDTH divided by bankfull channel WIDTH (W_{fpa} / W_{bkf}) (riffle section).	**1.49**	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.	**24**	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.	**0.01785**	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**	

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

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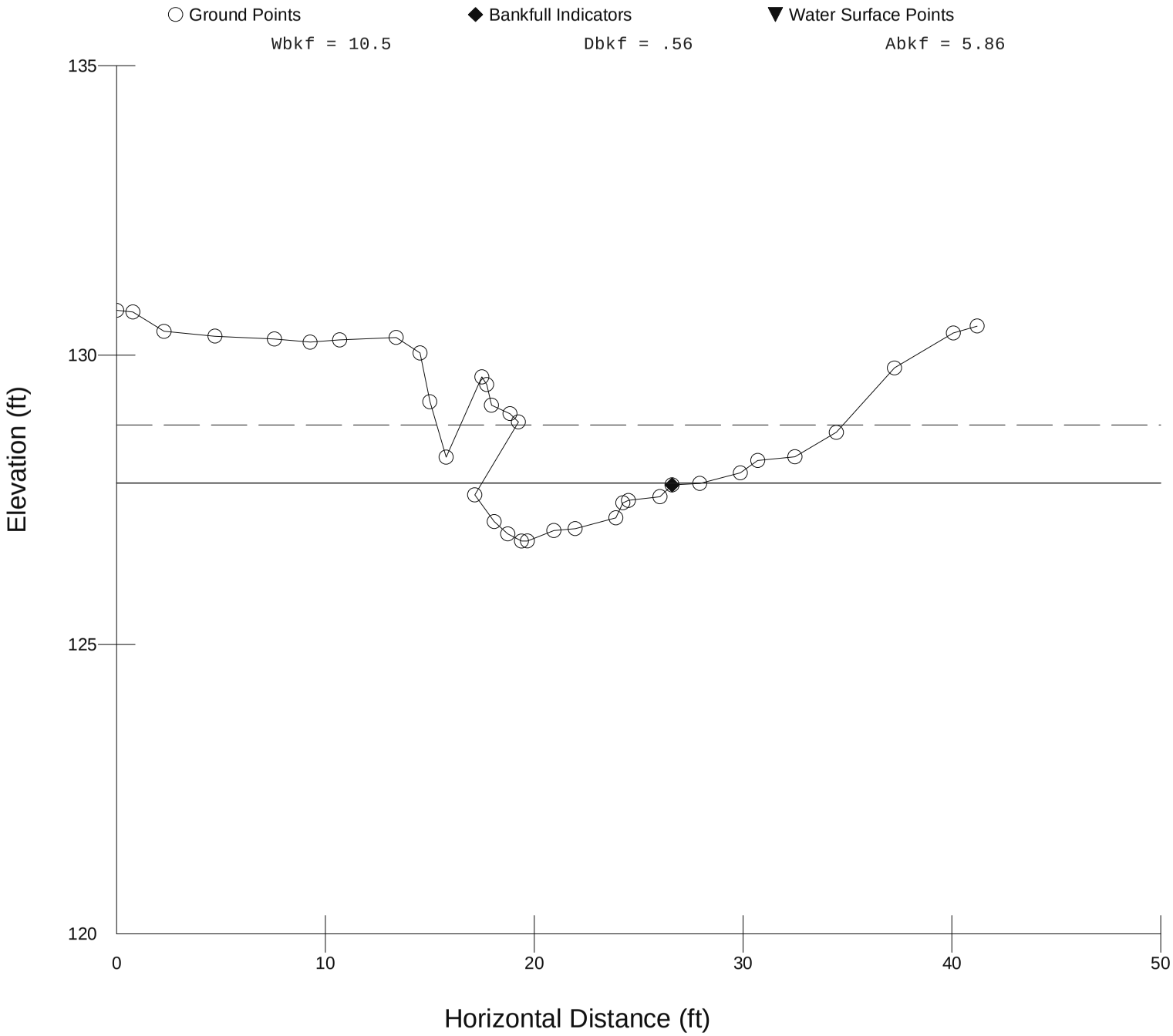
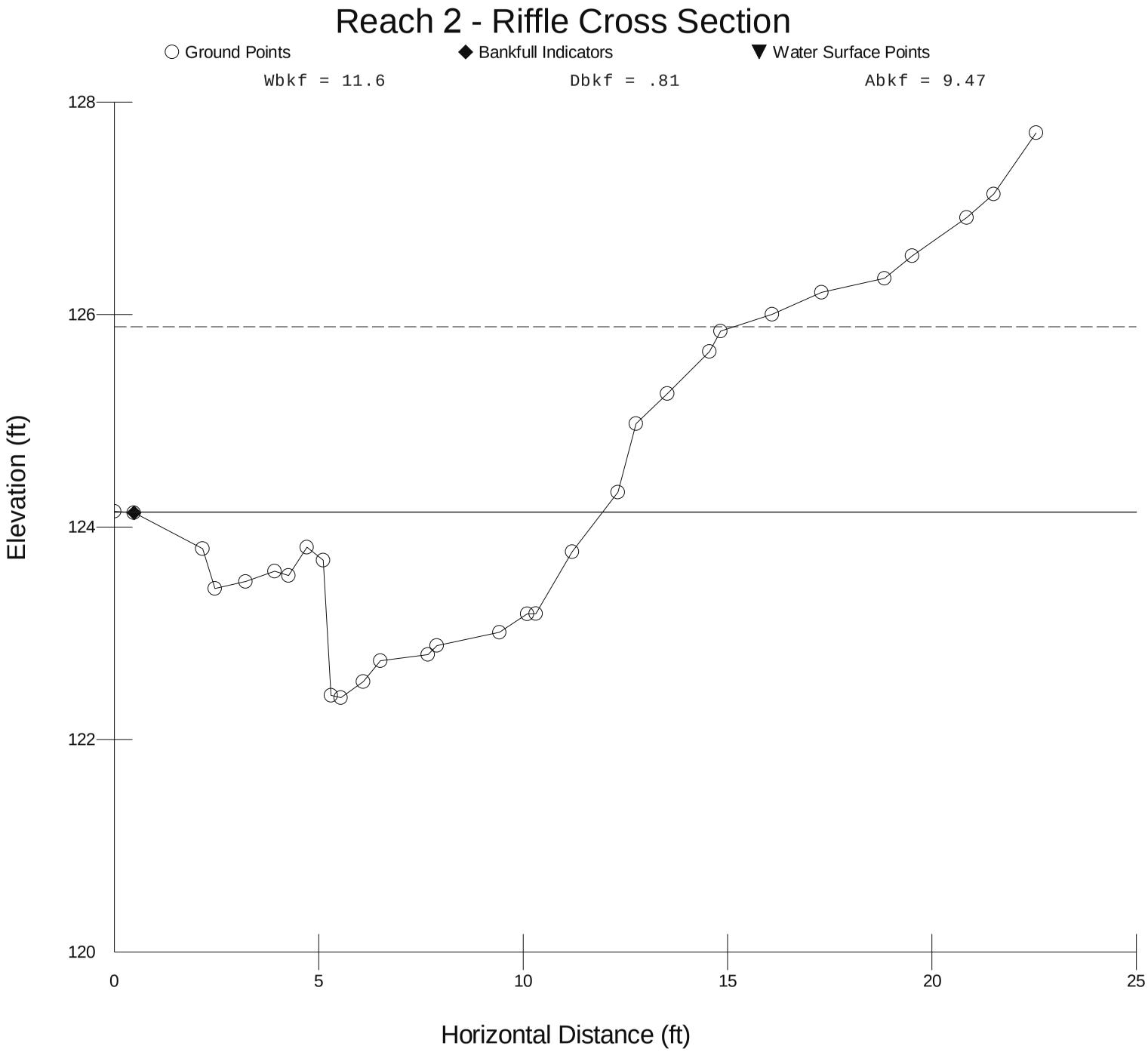
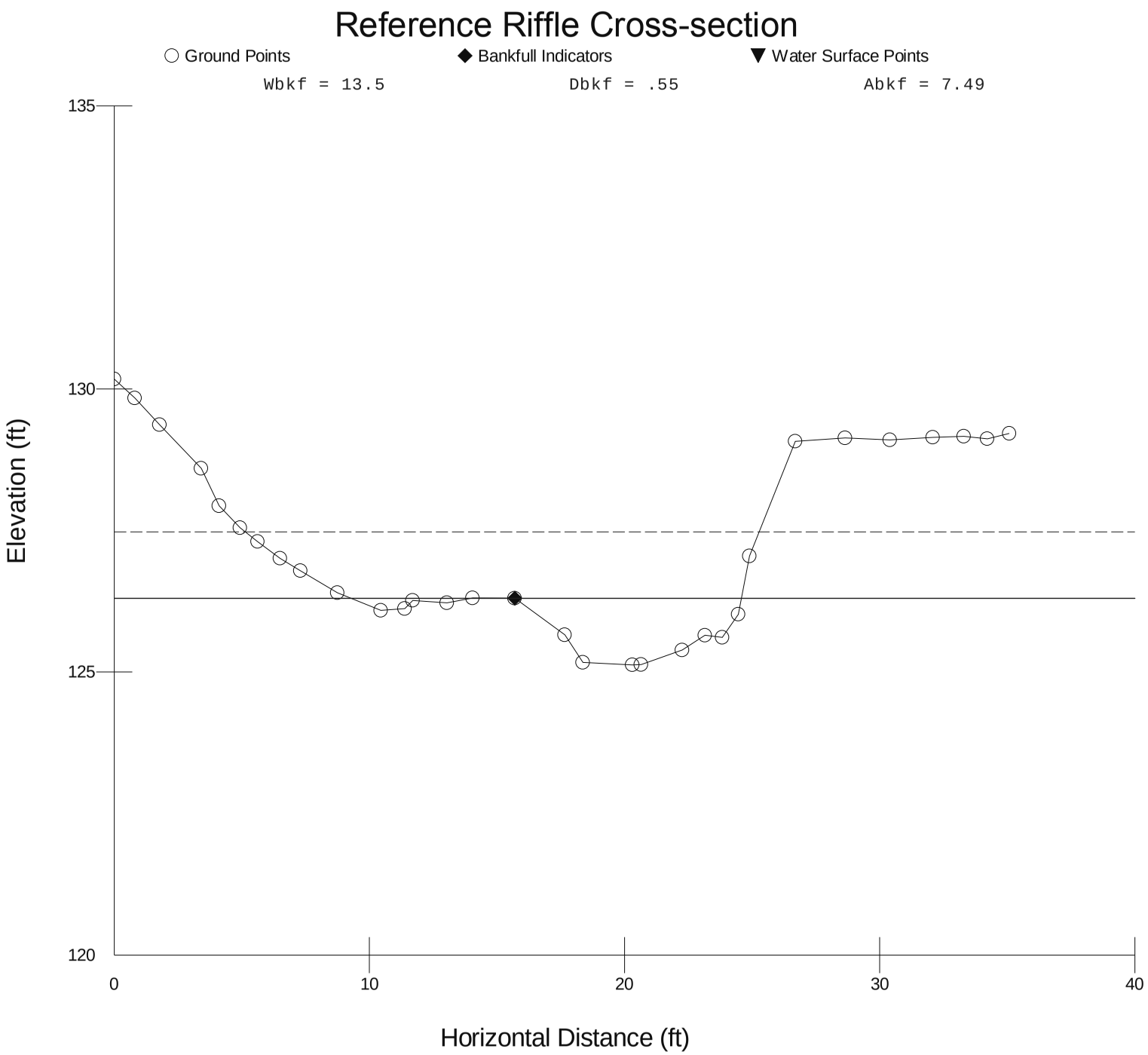
APPENDIX G

Existing Cross-Sections

Reach 1 - Riffle Cross Section




Reach 2 - Riffle Cross Section
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 11.6
Dbkf = .81
Abkf = 9.47
128
126
124
122
120
Elevation (ft)
0
5
10
15
20
25
Horizontal Distance (ft)


Reference Riffle Cross-section
Ground Points
Bankfull Indicators
Water Surface Points
Wbkf = 13.5
Dbkf = .55
Abkf = 7.49
135
130
125
120
Elevation (ft)
0
10
20
30
40
Horizontal Distance (ft)

APPENDIX H

Stream Bank Erosion Summary

Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**UT1, Reach - Reach 1**			Location:			
Graph Used:		Total Stream Length (ft): **1050**				Date: **5/9/2014**	
Observers:	**BH, CC**		Valley Type: **II**			Stream Type: **B 4/1**	
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (ft/yr)**	**Length of bank (ft)**	**Study bank height (ft)**	**Erosion subtotal [(4)×(5)×(6)] (ft^3/yr)**	**Erosion Rate (tons/yr/ft) {[(7)/27] × 1.3 / (5)}**
1. **Bank 1**	**Very High**	**Very High**	**0.872**	**50.0**	**5.0**	**218.00**	**0.21000**
2. **Bank 2**	**Moderate**	**Moderate**	**0.253**	**50.0**	**2.0**	**25.30**	**0.02440**
3. **Bank 3**	**High**	**High**	**0.575**	**45.0**	**1.0**	**25.87**	**0.02770**
4. **Bank 4**	**High**	**Very High**	**0.872**	**60.0**	**1.0**	**52.32**	**0.04200**
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							
13.							
14.							
15.							
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**321.49**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**11.91**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**15.48**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Unit Erosion Rate (tons/yr/ft)**	**0.0147**	

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Worksheet 3-13. Summary form of annual streambank erosion estimates for various study reaches.

Stream:	**UT1, Reach - Reach 2**			Location:			
Graph Used:		Total Stream Length (ft): **1050**				Date: **8/22/2014**	
Observers:			Valley Type: **XIV**			Stream Type: **F 4**	
(1)	**(2)**	**(3)**	**(4)**	**(5)**	**(6)**	**(7)**	**(8)**
Station (ft)	**BEHI rating (Worksheet 3-11) (adjective)**	**NBS rating (Worksheet 3-12) (adjective)**	**Bank erosion rate (Figure 3-9 or 3-10) (ft/yr)**	**Length of bank (ft)**	**Study bank height (ft)**	**Erosion subtotal [(4)×(5)×(6)] (ft^3/yr)**	**Erosion Rate (tons/yr/ft) {[(7)/27] × 1.3 / (5)}**
1. **Bank 5**	**High**	**Moderate**	**0.380**	**35.0**	**1.0**	**13.30**	**0.01830**
2. **Bank 6**	**Moderate**	**Moderate**	**0.253**	**510.0**	**1.2**	**154.84**	**0.01460**
3. **Bank 7**	**Moderate**	**Moderate**	**0.253**	**510.0**	**1.2**	**154.84**	**0.01460**
4.							
5.							
6.							
7.							
8.							
9.							
10.							
11.							
12.							
13.							
14.							
15.							
Sum erosion subtotals in Column (7) for each BEHI/NBS combination					**Total Erosion (ft^3/yr)**	**322.97**	
Convert erosion in ft^3/yr to yds^3/yr {divide Total Erosion (ft^3/yr) by 27}					**Total Erosion (yds^3/yr)**	**11.96**	
Convert erosion in yds^3/yr to tons/yr {multiply Total Erosion (yds^3/yr) by 1.3}					**Total Erosion (tons/yr)**	**15.55**	
Calculate erosion per unit length of channel {divide Total Erosion (tons/yr) by total length of stream (ft) surveyed}					**Unit Erosion Rate (tons/yr/ft)**	**0.0148**	

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APPENDIX I

Function-Based Data Collection Form

RAPID WATERSHED ASSESSMENT DATA SHEET

Watershed: Towsers

Stream: NDF Trib Reach 1 & 2

Photo(s): _____

Rater(s): URS

Date: _____

Overall Watershed Condition Good Fair Poor

WATERSHED ASSESSMENT

	Category / Parameter / Measurement Method	Description of Watershed Condition: Good	Fair	Poor	Rating (G/F/P)
1	Hydrology / Runoff / Watershed Impoundments	No impoundment upstream of project area	No impoundment within 1 mile upstream of project area OR impoundment does not adversely affect hydrology or fish passage	Impoundment(s) located within 1 mile upstream of project area and/or has an adverse effect on hydrology and/or fish passage	G
2	Hydrology / Runoff / Concentrated Flow	No potential for concentrated flow/impairments from adjacent land use	Some potential for concentrated flow/impairments to reach restoration site, however, measures are in place to protect resources	Potential for concentrated flow/impairments to reach restoration site and no treatments are in place	P
3	Hydrology / Runoff / Land Use Change	Rural communities/slow growth or primarily forested (>70%)	Single family homes/suburban development occurring or active agricultural practices occurring, or commercial and/or industrial development starting, forested area 20 - 70%	Rapidly urbanizing/urban or primarily active agricultural practices (> 70%), forested area <20%	P
4	Hydrology / Runoff / Distance to Roads	No roads in or adjacent to site. No proposed major roads in or adjacent to site in 10 year DOT plans	No roads in or adjacent to site. No more than one major road proposed in 10 year DOT plans	Roads located in or adjacent to site boundary and/or major roads proposed in 10 year DOT plans	F
5	Hydrology / Runoff / Flashiness	Non-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover less than 6%	Semi-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover 7%- 15%	Flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover greater than 15%	P
6	Geomorphology / Riparian Vegetation	>80% of contributing stream length has >25 ft corridor width	50 - 80% of contributing stream length has >25 ft corridor width	<50% of contributing stream length has >25 ft corridor width	P
7	Geomorphology / Sediment Supply	Low sediment supply. Upstream bank erosion and bed load supply is minimal. There are few bars present in the channel	Moderate sediment supply from upstream bank erosion and bed load supply. There are some point bars and small lateral bars	High sediment supply from upstream bank erosion and bed load supply. There are numerous alternating point bars, transverse bars and/or mid-channel bars	P
8	Physicochemical / Water Quality / 303(d) List	Very clear, or clear but tea-colored; objects visible at depth 3 to 6 ft (less if slightly colored); no oil sheen on surface; no noticeable film on submerged objects or rocks. Clear water along entire reach; diverse aquatic plant community includes low quantities of many species of macrophytes; little algal growth present. Not on 303d list	Considerable cloudiness most of the time; objects visible to depth 0.5 to 1.5 ft; slow sections may appear pea-green; bottom rocks or submerged objects covered with green or olive-green film; or moderate odor of ammonia or rotten eggs. Greenish water along entire reach; overabundance of lush green macrophytes; abundant algal growth, especially during warmer months. On or downstream of 303d list and TMDL/WS Mgmt plan addressing deficiencies	Very turbid or muddy appearance most of the time; objects visible at depth< 0.5 ft; slow moving water maybe bright green; other obvious water pollutants; floating algal mats, surface scum, sheen or heavy coat of foam on surface; or strong odor of chemicals, oil, sewage, or other pollutants. Pea-green, gray, or brown water along entire reach; dense stands of macrophytes clogging stream; severe algal blooms creating thick algal mats in stream. On or downstream of 303d list and no TMDL/WS mgmt plan to address deficiencies	P
9	Biology / Landscape Connectivity	Channel upstream and downstream of project area has native bed and bank materials and is not impaired	Channel upstream and downstream of project area has native bed and bank materials but is impaired	Channel upstream and downstream of project area is concrete piped, or hardened	P

EXISTING and PROPOSED REACH LEVEL STREAM FUNCTION-BASED RAPID ASSESSMENT FIELD DATA SHEET

Watershed: Towsers
Stream: NOF Trib Reach 1
Reach Length:
Photo(s):
Reach ID:

Rater(s): RBS
Date:
Latitude:
Longitude:

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category: Functioning	Functioning-at-Risk	Not Functioning
Stream Function Pyramid Level 1 Hydrology				
Runoff	1. Concentrated Flow	No potential for concentrated flow/impairments from adjacent land use	Some potential for concentrated flow/impairments to reach restoration site, however, measures are in place to protect resources	Potential for concentrated flow/impairments to reach restoration site and no treatments are in place
	Existing Condition			X
	Restoration Potential		X	
	Proposed Condition			
	2. Flashiness	Non-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover less than 6%	Semi-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover 7 - 15%	Flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover greater than 15%
	Existing Condition			X
	Restoration Potential		X	
	Proposed Condition			
	If existing runoff is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			

	F	FAR	NF
Runoff Overall EXISTING Condition	F	FAR	(NF)
Runoff Overall Restoration Potential	F	(FAR)	NF
Runoff Overall PROPOSED Condition	F	FAR	NF

	F	FAR	NF
Stream Function Pyramid Level 1 Hydrology Overall EXISTING Condition	F	FAR	(NF)
Stream Function Pyramid Level 1 Hydrology Overall Restoration Potential	F	(FAR)	NF
Stream Function Pyramid Level 1 Hydrology Overall PROPOSED Condition	F	FAR	NF

Assessment Parameter	Measurement Method	Functioning	Functioning-at-Risk	Not Functioning
Stream Function Pyramid Level 2 Hydraulics				
Floodplain Connectivity (Vertical Stability)	3. Bank Height Ratio (BHR)	<1.20	1.21 - 1.50	>1.50
	Existing Condition			X
	Restoration Potential	X		
	Proposed Condition			
	4a. Entrenchment (Meandering streams in alluvial valleys or Rosgen C, E, DA Streams)	>2.2	2.1 - 1.4	<1.4
	Existing Condition	X	X	X
	Restoration Potential	X		
	Proposed Condition			
	4b. Entrenchment (Non meandering streams in colluvial valleys or Rosgen B Streams)	>1.4	1.3 - 1.1	<1.1
	Existing Condition	X		
	Restoration Potential	X		
	Proposed Condition			
	5. Floodplain Drainage	no concentrated flow; runoff is primarily sheet flow; hillslopes < 10%; hillslopes >200 ft from stream; ponding or wetland areas and litter or debris jams are well represented	runoff is equally sheet and concentrated flow (minor gully and rill erosion occurring); hillslopes 10 - 40%; hillslopes 50 - 200 ft from stream; ponding or wetland areas and litter or debris jams are minimally represented	concentrated flows present (extensive gully and rill erosion); hillslopes >40%; hillslopes <50 ft from stream; ponding or wetland areas and litter or debris jams are not well represented or absent
	Existing Condition			X
	Restoration Potential		X	
	Proposed Condition			

Reach ID:	

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category: Functioning	Category: Functioning-at-Risk	Category: Not Functioning
	6. Vertical Stability Extent	Stable	Localized Instability	Widespread Instability
	Existing Condition			X
	Restoration Potential	X		
	Proposed Condition			
	If existing floodplain connectivity is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			

Floodplain Connectivity Overall EXISTING Condition	F	(FAR)	NF
Floodplain Connectivity Overall Restoration Potential	(F)	FAR	NF
Floodplain Connectivity Overall PROPOSED Condition	F	FAR	NF

Stream Function Pyramid Level 2 Hydraulics Overall EXISTING Condition F (FAR) NF

Stream Function Pyramid Level 2 Hydraulics Overall Restoration Potential (F) FAR NF

Stream Function Pyramid Level 2 Hydraulics Overall PROPOSED Condition F FAR NF

Stream Function Pyramid Level 3 Geomorphology

Riparian Vegetation

7. Riparian Vegetation Zone (EPA, 1999, modified)	Riparian zone extends to a width of >100 feet; good vegetation community diversity and density; human activities do not impact zone; invasive species not present or sparse	Riparian zone extends to a width of 25-100 feet; species composition is dominated by 2 or 3 species; human activities greatly impact zone; invasive species well represented and alter the community	Riparian zone extends to a width of <25 feet; little or no riparian vegetation due to human activities; majority of vegetation is invasive
Left Bank Existing			X
Left Bank Restoration Potential	X		
Left Bank Proposed			
Right Bank Existing			X
Right Bank Restoration Potential	X		
Right Bank Proposed			
If existing riparian vegetation is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			

Riparian Vegetation Overall EXISTING Condition	F	FAR	(NF)
Riparian Vegetation Overall Restoration Potential	(F)	FAR	NF
Riparian Vegetation Overall PROPOSED Condition	F	FAR	NF

ateral Stability

8. Dominant Bank Erosion Rate Potential	Dominate bank erosion rate potential is low or BEHI/NBS Rating: L/VL, L/L, L/M, L/H, L/VH, M/VL	Dominate bank erosion rate potential is moderate or BEHI/NBS Rating: M/L, M/M, M/H, L/Ex, H/L, M/VH, M/Ex, H/L, H/M, VH/VL, Ex/VL	Dominate bank erosion rate potential is high or BEHI/NBS Rating: (H/H), H/Ex, VH/H, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex
Existing Condition (Right bank)			X
Restoration Potential (Right Bank)	X		
Proposed Condition (Right Bank)			
Existing Condition (Left bank)			X
Restoration Potential (Left Bank)	X		
Proposed Condition (Left Bank)			

Reach ID:	

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category: Functioning	Category: Functioning-at-Risk	Category: Not Functioning
La	9. Lateral Stability Extent	Stable	Localized Instability	Widespread Instability
	Existing Condition			X
	Restoration Potential	X		
	Proposed Condition			
	If existing lateral stability is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			
	Lateral Stability Overall EXISTING Condition	F	FAR	NF
	Lateral Stability Overall Restoration Potential	F	FAR	NF
	Lateral Stability Overall PROPOSED Condition	F	FAR	NF

Bedform Diversity (Do not complete if stream is ephemeral)

10. Shelter for Fish and Macroinvertebrates (EPA 1999)	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, rubble, gravel, cobble and large rocks, or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient)	20-70% mix of stable habitat; suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of new fall, but not yet prepared for colonization (may rate at high end of scale)	Less than 20% mix of stable habitat; lack of habitat availability less than desirables obvious; substrate unstable or lacking
Existing Condition			
Restoration Potential			
Proposed Condition			
11a. Pool-to-Pool Spacing Ratio (Watersheds < 10 mi^2)	4.0 - 5.0	3.0 - 4.0 *or* 5.0 - 7.0	< 3.0 *or* >7.0
Existing Condition			
Restoration Potential			
Proposed Condition			
11b. Pool-to-Pool Spacing Ratio (Watersheds > 10 mi^2)	5.0 - 7.0	3.5 - 5.0 *or* 7.0 - 8.0	<3.5 *or* >8.0
Existing Condition			
Restoration Potential			
Proposed Condition			
12a. Pool Max Depth Ratio/Depth Variability (Gravel Bed Streams)	>1.5	1.2 - 1.5	<1.2
Existing Condition			
Restoration Potential			
Proposed Condition			
12b. Pool Max Depth Ratio/Depth Variability (Sand Bed Streams)	>1.2	1.1 - 1.2	<1.1
Existing Condition			
Restoration Potential			
Proposed Condition			

Moderate Gradient Perennial Streams in Colluvial Valleys

versity (Do not complete if stream is ephemeral)

11. Pool-to-Pool Spacing Ratio (3-5% Slope)	2.0 - 4.0	4.0 - 6.0	>6.0
Existing Condition			
Restoration Potential			
Proposed Condition			
12. Pool Max Depth Ratio/Depth Variability	>1.5	1.2 - 1.5	<1.2
Existing Condition			
Restoration Potential			
Proposed Condition			

Reach ID:	

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category: Functioning	Functioning-at-Risk	Not Functioning
Bedform Di	If existing bedform diversity is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason	N/A		

Bedform Diversity Overall EXISTING Condition	F	FAR	NF
Bedform Diversity Overall Restoration Potential	F	FAR	NF
Bedform Diversity Overall PROPOSED Condition	F	FAR	NF

Stream Function Pyramid Level 3 Geomorphology Overall EXISTING Condition F (FAR) NF

Stream Function Pyramid Level 3 Geomorphology Overall Restoration Potential (F) FAR NF

Stream Function Pyramid Level 3 Geomorphology Overall PROPOSED Condition F FAR NF

Stream Function Pyramid Level 4 Physicochemical

Water Quality and Nutrients (Do not complete if stream is ephemeral)

	Functioning	Functioning-at-Risk	Not Functioning
13. Water Appearance and Nutrient Enrichment (USDA 1999)	Very clear, or clear but tea-colored; objects visible at depth 3 to 6 ft (less if slightly colored); no oil sheen on surface; no noticeable film on submerged objects or rocks. Clear water along entire reach; diverse aquatic plant community includes low quantities of many species of macrophytes; little algal growth present	Frequent cloudiness especially after storm events; objects visible to depth 0.5 to 3.0 ft; may have slight green color; no oil sheen on water surface. Fairly clear or slightly greenish water along entire reach; moderate algal growth on stream substrate	Very turbid or muddy appearance most of the time; objects visible at depth< 0.5 ft; slow moving water maybe bright green; other obvious water pollutants; floating algal mats, surface scum, sheen or heavy coat of foam on surface; or strong odor of chemicals, oil, sewage, or other pollutants. Pea-green, gray, or brown water along entire reach; dense stands of macrophytes clogging stream; severe algal blooms creating thick algal mats in stream
Existing Condition		X	
Restoration Potential		X	
Proposed Condition			
14. Detritus (Petersen, 1992)	Mainly consisting of leaves and wood without sediment covering it	Leaves and wood scarce; fine organic debris without sediment	Fine organic sediment - black in color and foul odor (anaerobic) or detritus absent
Existing Condition		X	
Restoration Potential		X	
Proposed Condition			
If existing water quality is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			

Stream Function Pyramid Level 4 Physicochemical Overall EXISTING Condition F (FAR) NF

Stream Function Pyramid Level 4 Physicochemical Overall Restoration Potential F (FAR) NF

Stream Function Pyramid Level 4 Physicochemical Overall PROPOSED Condition F FAR NF

Stream Function Pyramid Level 5 Biology

Biology (mplete if stream is ephemeral)

	Abundant	Rare	Not present
15. Macroinvertebrate			
Existing Condition			
Restoration Potential			
Proposed Condition			
16. Macroinvertebrate Tolerance	Abundant intolerant species	Limited intolerant species	Only tolerant species
Existing Condition			
Restoration Potential			
Proposed Condition			
17. Fish Presence	Abundant	Rare	Not present
Existing Condition			
Restoration Potential			
Proposed Condition			

N/A

Reach ID:	

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category: Functioning	Functioning-at-Risk	Not Functioning
(Do not cc	If existing biology is FAR or NF, provide description of cause (s) and stability trend and if F can not be potentially achieved, provide reason	N/A		
Stream Function Pyramid Level 5 Biology Overall EXISTING Condition		F	FAR	NF
Stream Function Pyramid Level 5 Biology Overall Restoration Potential		F	FAR	NF
Stream Function Pyramid Level 5 Biology Overall PROPOSED Condition		F	FAR	NF

Bankfull Determination and Rosgen Stream Classification

Rosgen Stream Type (Observation)	B4/1				
Regional Curve (circle one):	Piedmont	Coastal Plain	Allegheny Plateau/Ridge and Valley	Urban	Karst
DA (sqmi)	.55		Rosgen Valley Type		II
BF Width (ft)	9.57		BF Area (sqft)		8.19
BF Depth (ft)	0.84		Percent Impervious (%)		1.4%

Field Measurements

Parameter	Measurements and Ratios			
Water surface to geomorphic feature elevation difference				
Riffle Mean Depth at Bankfull Stage (dbkf)				
Riffle Width at Bankfull Stage (Wbkf)				
Riffle XS Area at Bankfull Stage (Abkf = dbkf*Wbkf)				
Floodprone Area Width (Wfpa) (Wfpa=Width at elevation determined by 2xDmax)				
Entrenchment Ratio (ER) (ER=Wfpa/Wbkf)				
Low Bank Height (LBH)				
Riffle Maximum Depth at Bankfull Stage (Dmax)				
Bank Height Ratio (BHR) (BHR=LBH/Dmax)				
BEHI/NBS Ratings and Lengths				
Pool to Pool Spacing (P-P)				
Pool to Pool Spacing Ratio (P-P Ratio) (P-P Ratio=P-P/Wbkf)				
Pool Maximum Depth at Bankfull Stage (Dmbkfp)				
Pool Depth Ratio (Dmbkfp Ratio) (Dmbkfp Ratio=Dmbkfp/dbkf)				
Macroinvertebrate Species Observed				

Reach ID:	Reach 1

Rapid Assessment Summary

Overall Watershed Condition	Good	Fair	Poor

Overall EXISTING Reach Level Stream Condition F FAR NF

LEVEL 1 - F FAR NF	LEVEL 2 - F FAR NF	LEVEL 3 - F FAR NF	LEVEL 4 - F FAR NF	LEVEL 5 - F FAR NF
				N/A

If existing overall condition is FAR or NF, provide description of cause(s)	

	Functioning	Functioning-at-Risk: Trending Towards Functioning	Functioning-at-Risk: Trending Towards Not Functioning	Not Functioning
Channel Evolution Trend (Rosgen, 1996)	Little or no presence of active vertical or lateral stream adjustment; floodplain and/or flood prone area well developed, vegetated, and hydrologically connected to stream. Simon Stage 1 & 6. Rosgen Stream type E, C, B, A, & DA	Presence of localized vertical or lateral stream adjustment; floodplain well developed, vegetated and hydrologically connected to stream (floodplain can be newly formed within a channel that shows past active vertical or lateral stream adjustments). Simon Stage 5. Rosgen Stream type F→C, D→C, F→Bc, & G→B	Channel shows past evidence of active vertical downcutting and lateral widening but is currently rebuilding a new floodplain; presence of moderately defined riffles and pools; moderate aggradation occurring; width/depth ratio 12-40. Rosgen Stream type C→F, C→D, Bc→F, E→Gc, B→G & C→Gc	Channel has widespread active vertical downcutting and lateral widening; floodplain not hydrologically connected (abandoned floodplain); lack of well defined riffles and pools; incision ratio > 2.1; and for laterally meandering stream a sinuosity ratio < 1.2; entrenchment < 1.4. Simon Stage 2, 3, 4, & 5. Rosgen Stream type F, D, Gc, & G
If existing channel evolution is FAR or NF, provide description of cause(s)				

Constraints

List all man-made features that have the potential to limit design solutions	outfall at u/s end of project road crossing culvert at d/s end of project

Restoration POTENTIAL Level 1 2 3 4 5 Functioning

Provide reason(s) for restoration potential prediction	full lift for Levels 2 & 3 partial for levels 1 & 4

Overall PROPOSED Reach Level Stream Condition

LEVEL 1 - F FAR NF	LEVEL 2 - F FAR NF	LEVEL 3 - F FAR NF	LEVEL 4 - F FAR NF	LEVEL 5 - F FAR NF

If any Pyramid Level proposed condition cannot potentially achieve F, provide reason(s)	

EXISTING and PROPOSED REACH LEVEL STREAM FUNCTION-BASED RAPID ASSESSMENT FIELD DATA SHEET

Watershed: Towsers
Stream: NDF Trib Reach 2
Reach Length:
Photo(s):
Rater(s): PRS
Date:
Latitude:
Longitude:

Reach ID:

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category: Functioning	Functioning-at-Risk	Not Functioning
Stream Function Pyramid Level 1 Hydrology				
Runoff	1. Concentrated Flow	No potential for concentrated flow/impairments from adjacent land use	Some potential for concentrated flow/impairments to reach restoration site, however, measures are in place to protect resources	Potential for concentrated flow/impairments to reach restoration site and no treatments are in place
	Existing Condition			X
	Restoration Potential		X	
	Proposed Condition			
	2. Flashiness	Non-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover less than 6%	Semi-flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover 7 - 15%	Flashy flow regime as a result of rainfall patterns, geology, and soils, impervious cover greater than 15%
	Existing Condition			X
	Restoration Potential		X	
	Proposed Condition			
	If existing runoff is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			
	Runoff Overall EXISTING Condition	F	FAR	NF
	Runoff Overall Restoration Potential	F	FAR	NF
	Runoff Overall PROPOSED Condition	F	FAR	NF
Stream Function Pyramid Level 1 Hydrology Overall EXISTING Condition		F	FAR	NF
Stream Function Pyramid Level 1 Hydrology Overall Restoration Potential		F	FAR	NF
Stream Function Pyramid Level 1 Hydrology Overall PROPOSED Condition		F	FAR	NF
Stream Function Pyramid Level 2 Hydraulics				
Floodplain Connectivity (Vertical Stability)	3. Bank Height Ratio (BHR)	<1.20	1.21 - 1.50	>1.50
	Existing Condition			X
	Restoration Potential			
	Proposed Condition	X		
	4a. Entrenchment (Meandering streams in alluvial valleys or Rosgen C, E, DA Streams)	>2.2	2.1 - 1.4	<1.4
	Existing Condition			
	Restoration Potential			
	Proposed Condition			
	4b. Entrenchment (Non meandering streams in colluvial valleys or Rosgen B Streams)	>1.4	1.3 - 1.1	<1.1
	Existing Condition		X	
	Restoration Potential	X		
	Proposed Condition			
	5. Floodplain Drainage	no concentrated flow; runoff is primarily sheet flow; hillslopes < 10%; hillslopes >200 ft from stream; ponding or wetland areas and litter or debris jams are well represented	runoff is equally sheet and concentrated flow (minor gully and rill erosion occurring); hillslopes 10 - 40%; hillslopes 50 - 200 ft from stream; ponding or wetland areas and litter or debris jams are minimally represented	concentrated flows present (extensive gully and rill erosion); hillslopes >40%; hillslopes <50 ft from stream; ponding or wetland areas and litter or debris jams are not well represented or absent
	Existing Condition			X
	Restoration Potential		X	
	Proposed Condition			

Reach ID:	

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category: Functioning	Functioning-at-Risk	Not Functioning
	6. Vertical Stability Extent	Stable	Localized Instability	Widespread Instability
	Existing Condition			X
	Restoration Potential	X		
	Proposed Condition			
	If existing floodplain connectivity is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			

Floodplain Connectivity Overall EXISTING Condition	F	FAR	NF
Floodplain Connectivity Overall Restoration Potential	F	FAR	NF
Floodplain Connectivity Overall PROPOSED Condition	F	FAR	NF

Stream Function Pyramid Level 2 Hydraulics Overall EXISTING Condition F FAR NF

Stream Function Pyramid Level 2 Hydraulics Overall Restoration Potential F FAR NF

Stream Function Pyramid Level 2 Hydraulics Overall PROPOSED Condition F FAR NF

Stream Function Pyramid Level 3 Geomorphology

Riparian Vegetation

	7. Riparian Vegetation Zone (EPA, 1999, modified)	Riparian zone extends to a width of >100 feet; good vegetation community diversity and density; human activities do not impact zone; invasive species not present or sparse	Riparian zone extends to a width of 25-100 feet; species composition is dominated by 2 or 3 species; human activities greatly impact zone; invasive species well represented and alter the community	Riparian zone extends to a width of <25 feet; little or no riparian vegetation due to human activities; majority of vegetation is invasive
	Left Bank Existing			X
	Left Bank Restoration Potential	X		
	Left Bank Proposed			
	Right Bank Existing			X
	Right Bank Restoration Potential	X		
	Right Bank Proposed			
	If existing riparian vegetation is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			

Riparian Vegetation Overall EXISTING Condition	F	FAR	NF
Riparian Vegetation Overall Restoration Potential	F	FAR	NF
Riparian Vegetation Overall PROPOSED Condition	F	FAR	NF

teral Stability

	8. Dominant Bank Erosion Rate Potential	Dominate bank erosion rate potential is low or BEHI/NBS Rating: L/VL, L/L, L/M, L/H, L/VH, M/VL	Dominate bank erosion rate potential is moderate or BEHI/NBS Rating: M/L, M/M, M/H, L/Ex, H/L, M/VH, M/Ex, H/L, H/M, VH/VL, Ex/VL	Dominate bank erosion rate potential is high or BEHI/NBS Rating: H/H, H/Ex, VH/H, Ex/M, Ex/H, Ex/VH, VH/VH, Ex/Ex
	Existing Condition (Right bank)			X
	Restoration Potential (Right Bank)	X		
	Proposed Condition (Right Bank)			
	Existing Condition (Left bank)			X
	Restoration Potential (Left Bank)	X		
	Proposed Condition (Left Bank)			

Reach ID:	

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category: Functioning	Functioning-at-Risk	Not Functioning
Lat	9. Lateral Stability Extent	Stable	Localized Instability	Widespread Instability
	Existing Condition			
	Restoration Potential	X		
	Proposed Condition			X
	If existing lateral stability is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			
	Lateral Stability Overall EXISTING Condition	F	FAR	NF
	Lateral Stability Overall Restoration Potential	F	FAR	NF
	Lateral Stability Overall PROPOSED Condition	F	FAR	NF

Assessment Parameter	Measurement Method	Functioning	Functioning-at-Risk	Not Functioning
Bedform Diversity (Do not complete if stream is ephemeral)	10. Shelter for Fish and Macroinvertebrates (EPA 1999)	Greater than 70% of substrate favorable for epifaunal colonization and fish cover; mix of snags, submerged logs, undercut banks, rubble, gravel, cobble and large rocks, or other stable habitat and at stage to allow full colonization potential (i.e., logs/snags that are not new fall and not transient)	20-70% mix of stable habitat; suited for full colonization potential; adequate habitat for maintenance of populations; presence of additional substrate in the form of new fall, but not yet prepared for colonization (may rate at high end of scale)	Less than 20% mix of stable habitat; lack of habitat availability less than desirables obvious; substrate unstable or lacking
	Existing Condition			
	Restoration Potential			
	Proposed Condition			
	11a. Pool-to-Pool Spacing Ratio (Watersheds < 10 mi^2)	4.0 - 5.0	3.0 - 4.0 *or* 5.0 - 7.0	< 3.0 *or* >7.0
	Existing Condition			
	Restoration Potential			
	Proposed Condition			
	11b. Pool-to-Pool Spacing Ratio (Watersheds > 10 mi^2)	5.0 - 7.0	3.5 - 5.0 *or* 7.0 - 8.0	<3.5 *or* >8.0
	Existing Condition			
	Restoration Potential			
	Proposed Condition			
	12a. Pool Max Depth Ratio/Depth Variability (Gravel Bed Streams)	>1.5	1.2 - 1.5	<1.2
	Existing Condition			
	Restoration Potential			
	Proposed Condition			
	12b. Pool Max Depth Ratio/Depth Variability (Sand Bed Streams)	>1.2	1.1 - 1.2	<1.1
	Existing Condition			
	Restoration Potential			
	Proposed Condition			
	Moderate Gradient Perennial Streams in Colluvial Valleys			
	11. Pool-to-Pool Spacing Ratio (3-5% Slope)	2.0 - 4.0	4.0 - 6.0	>6.0
	Existing Condition			
	Restoration Potential			
	Proposed Condition			
	12. Pool Max Depth Ratio/Depth Variability	>1.5	1.2 - 1.5	<1.2
	Existing Condition			
	Restoration Potential			
	Proposed Condition			

N/A

Reach ID:	

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category: Functioning	Functioning-at-Risk	Not Functioning
Bedform Di	If existing bedform diversity is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason	N/A		

Bedform Diversity Overall EXISTING Condition	F	FAR	NF
Bedform Diversity Overall Restoration Potential	F	FAR	NF
Bedform Diversity Overall PROPOSED Condition	F	FAR	NF

Stream Function Pyramid Level 3 Geomorphology Overall EXISTING Condition F (FAR) NF

Stream Function Pyramid Level 3 Geomorphology Overall Restoration Potential (F) FAR NF

Stream Function Pyramid Level 3 Geomorphology Overall PROPOSED Condition F FAR NF

Stream Function Pyramid Level 4 Physicochemical

Water Quality and Nutrients (Do not complete if stream is ephemeral)

	Functioning	Functioning-at-Risk	Not Functioning
13. Water Appearance and Nutrient Enrichment (USDA 1999)	Very clear, or clear but tea-colored; objects visible at depth 3 to 6 ft (less if slightly colored); no oil sheen on surface; no noticeable film on submerged objects or rocks. Clear water along entire reach; diverse aquatic plant community includes low quantities of many species of macrophytes; little algal growth present	Frequent cloudiness especially after storm events; objects visible to depth 0.5 to 3.0 ft; may have slight green color; no oil sheen on water surface. Fairly clear or slightly greenish water along entire reach; moderate algal growth on stream substrate	Very turbid or muddy appearance most of the time; objects visible at depth< 0.5 ft; slow moving water maybe bright green; other obvious water pollutants; floating algal mats, surface scum, sheen or heavy coat of foam on surface; or strong odor of chemicals, oil, sewage, or other pollutants. Pea-green, gray, or brown water along entire reach; dense stands of macrophytes clogging stream; severe algal blooms creating thick algal mats in stream
Existing Condition		X	
Restoration Potential		X	
Proposed Condition			
14. Detritus (Petersen, 1992)	Mainly consisting of leaves and wood without sediment covering it	Leaves and wood scarce; fine organic debris without sediment	Fine organic sediment - black in color and foul odor (anaerobic) or detritus absent
Existing Condition		X	
Restoration Potential		X	
Proposed Condition			
If existing water quality is FAR or NF, provide description of cause(s) and stability trend and if F can not be potentially achieved, provide reason			

Stream Function Pyramid Level 4 Physicochemical Overall EXISTING Condition F (FAR) NF

Stream Function Pyramid Level 4 Physicochemical Overall Restoration Potential F (FAR) NF

Stream Function Pyramid Level 4 Physicochemical Overall PROPOSED Condition F FAR NF

Stream Function Pyramid Level 5 Biology

Biology (Do not complete if stream is ephemeral)

15. Macroinvertebrate	Abundant	Rare	Not present
Existing Condition			
Restoration Potential			
Proposed Condition			
16. Macroinvertebrate Tolerance	Abundant intolerant species	Limited intolerant species	Only tolerant species
Existing Condition			
Restoration Potential			
Proposed Condition			
17. Fish Presence	Abundant	Rare	Not present
Existing Condition			
Restoration Potential			
Proposed Condition			

N/A

Reach ID:	

Function-based Rapid Reach Level Stream Assessment

Assessment Parameter	Measurement Method	Category		
		Functioning	Functioning at-Risk	Not Functioning
(Do not co	If existing biology is FAR or NF, provide description of cause (s) and stability trend and if F can not be potentially achieved, provide reason	N/A		
	Stream Function Pyramid Level 5 Biology Overall EXISTING Condition	F	FAR	NF
	Stream Function Pyramid Level 5 Biology Overall Restoration Potential	F	FAR	NF
	Stream Function Pyramid Level 5 Biology Overall PROPOSED Condition	F	FAR	NF

Bankfull Determination and Rosgen Stream Classification

Rosgen Stream Type (Observation)	F4				
Regional Curve (circle one):	Piedmont	Coastal Plain	Allegheny Plateau/Ridge and Valley	Urban	Karst
DA (sqmi)	1.55			Rosgen Valley Type	II
BF Width (ft)	9.57			BF Area (sqft)	8.19
BF Depth (ft)	0.84			Percent Impervious (%)	1.41

Field Measurements

Parameter	Measurements and Ratios			
Water surface to geomorphic feature elevation difference				
Riffle Mean Depth at Bankfull Stage (dbkf)				
Riffle Width at Bankfull Stage (Wbkf)				
Riffle XS Area at Bankfull Stage (Abkf = dbkf*Wbkf)				
Floodprone Area Width (Wfpa) (Wfpa=Width at elevation determined by 2xDmax)				
Entrenchment Ratio (ER) (ER=Wfpa/Wbkf)				
Low Bank Height (LBH)				
Riffle Maximum Depth at Bankfull Stage (Dmax)				
Bank Height Ratio (BHR) (BHR=LBH/Dmax)				
BEHI/NBS Ratings and Lengths				
Pool to Pool Spacing (P-P)				
Pool to Pool Spacing Ratio (P-P Ratio) (P-P Ratio=P-P/Wbkf)				
Pool Maximum Depth at Bankfull Stage (Dmbkfp)				
Pool Depth Ratio (Dmbkfp Ratio) (Dmbkfp Ratio=Dmbkfp/dbkf)				
Macroinvertebrate Species Observed				

Reach ID:	Reach 2

Rapid Assessment Summary

Overall Watershed Condition	Good	Fair	Poor

Overall EXISTING Reach Level Stream Condition	F	FAR	NF

LEVEL 1 - F FAR NF	LEVEL 2 - F FAR NF	LEVEL 3 - F FAR NF	LEVEL 4 - F FAR NF	LEVEL 5 - F FAR NF
				N/A

If existing overall condition is FAR or NF, provide description of cause(s)	

	Functioning	Functioning-at-Risk		Not Functioning
		Trending Towards Functioning	Trending Towards Not Functioning	
Channel Evolution Trend (Rosgen, 1996)	Little or no presence of active vertical or lateral stream adjustment; floodplain and/or flood prone area well developed, vegetated, and hydrologically connected to stream. Simon Stage 1 & 6. Rosgen Stream type E, C, B, A, & DA	Presence of localized vertical or lateral stream adjustment; floodplain well developed, vegetated and hydrologically connected to stream (floodplain can be newly formed within a channel that shows past active vertical or lateral stream adjustments). Simon Stage 5. Rosgen Stream type F→C, D→C, F→Bc, & G→B	Channel shows past evidence of active vertical downcutting and lateral widening but is currently rebuilding a new floodplain; presence of moderately defined riffles and pools; moderate aggradation occurring; width/depth ratio 12-40. Rosgen Stream type C→F, C→D, Bc→F, E→Gc, B→G & C→Gc	Channel has widespread active vertical downcutting and lateral widening; floodplain not hydrologically connected (abandoned floodplain); lack of well defined riffles and pools; incision ratio > 2.1; and for laterally meandering stream a sinuosity ratio < 1.2; entrenchment < 1.4. Simon Stage 2, 3, 4, & 5. Rosgen Stream type F, D, Gc, & G

If existing channel evolution is FAR or NF, provide description of cause(s)	

Constraints

List all man-made features that have the potential to limit design solutions	u/s outfall d/s road crossing culvert

Restoration POTENTIAL Level	1	2	3	4	5	Functioning

Provide reason(s) for restoration potential prediction	full lift for LWLS 2 & 3 Partial lift for LWLS 1 & 4

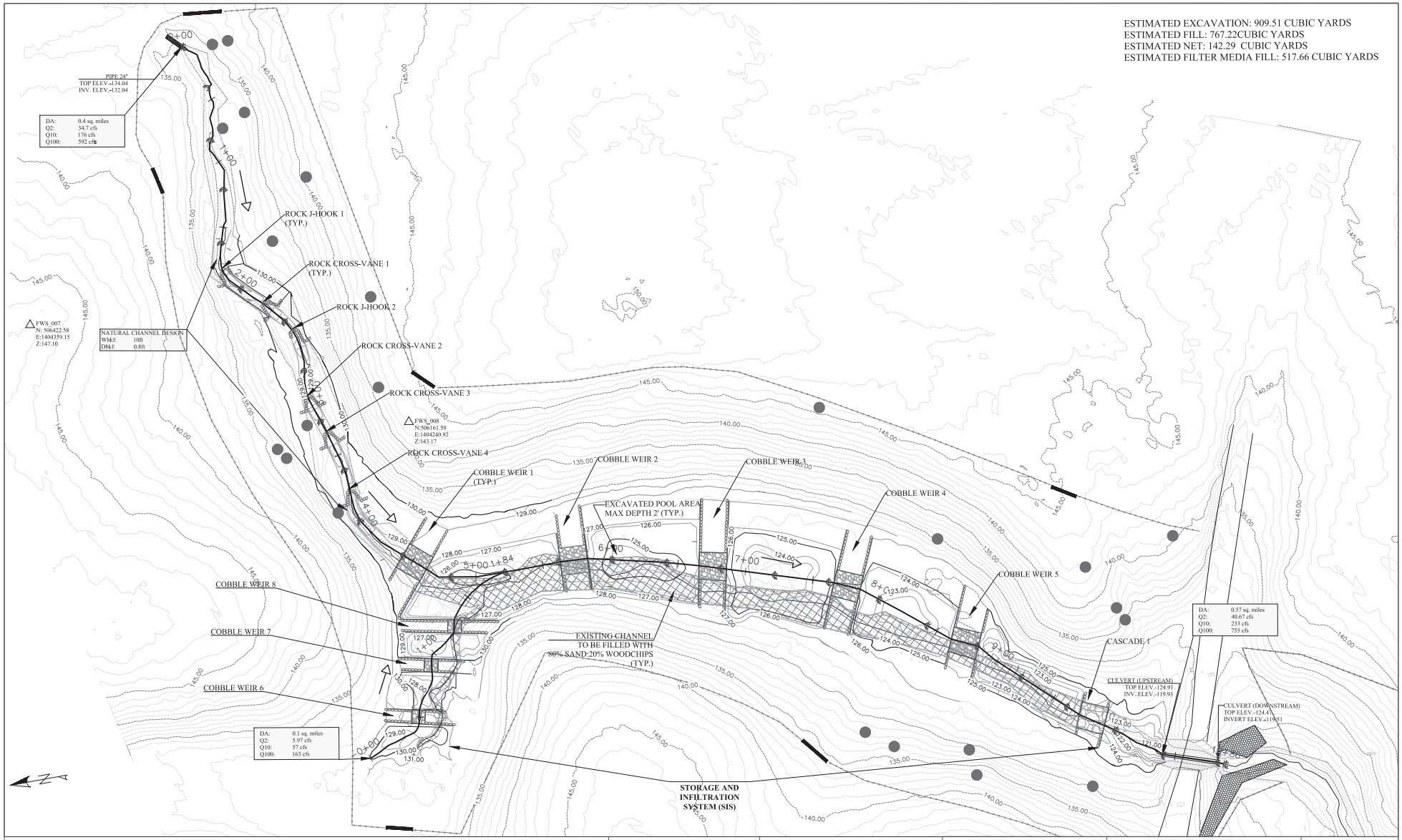
Overall PROPOSED Reach Level Stream Condition				
LEVEL 1 - F FAR NF	LEVEL 2 - F FAR NF	LEVEL 3 - F FAR NF	LEVEL 4 - F FAR NF	LEVEL 5 - F FAR NF
		N/A		

If any Pyramid Level proposed condition cannot potentially achieve F, provide reason(s)	

APPENDIX J

Proposed Design Conditions Plan Set

ESTIMATED EXCAVATION: 909.51 CUBIC YARDS
ESTIMATED FILL: 767.22CUBIC YARDS
ESTIMATED NET: 142.29 CUBIC YARDS
ESTIMATED FILTER MEDIA FILL: 517.66 CUBIC YARDS



CONTOUR INTERVAL = 1.0 FOOT

Not to Scale

Professional Certification
I hereby certify that these document were prepared or approved by me, and that I am a duly licensed professional engineer under the laws of the State of Maryland, License No. 20346, Expiration Date: 2017-01-27

(Signature) (Date)

STATE OF MARYLAND PROFESSIONAL ENGINEER

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U.S. FISH & WILDLIFE SERVICE

U.S. Fish & Wildlife Service
Chesapeake Bay Field Office
Stream Habitat Assessment and Restoration Program

177 Admiral Cochrane Drive
Annapolis, Maryland 21401

Tel. (410) 573-4581

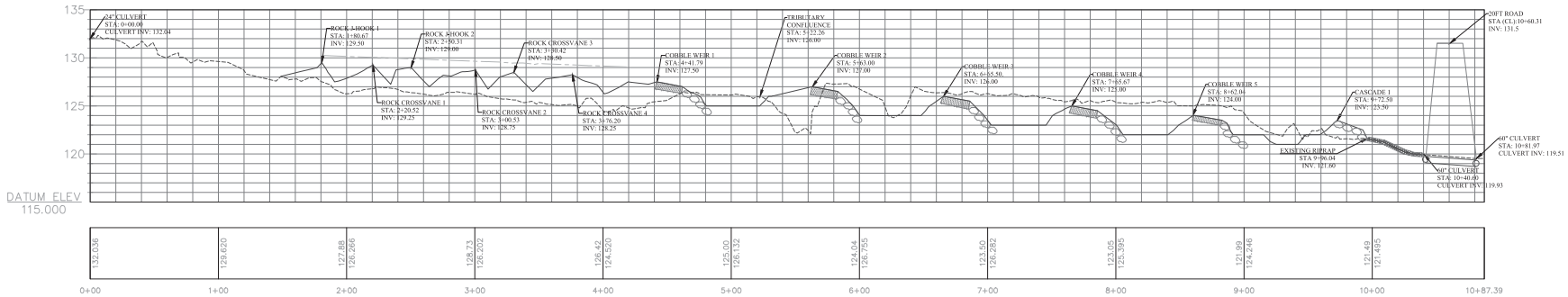
NAVY DAIRY FARM
ANNE ARUNDEL CO, MD

REVISIONS DATE	BY	PROPOSED CONDITIONS	
		PROJECT MANAGER: BH	DRAFTING: CAC
		DESIGN: BH	CHECKED BY: KM
		DATE: 02/11/2016	SCALE: AS SHOWN

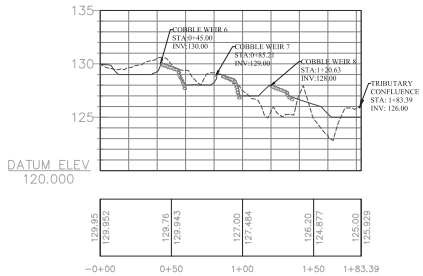
SHEET
4 of 12

PC - 1

CENTERLINE



TRIBUTARY



J-Hook Structure Table

Structure	Vane Data				A - J-Hook Invert			B_L - Left End Cross Over			B_R - Right End Cross Over			C - Plunge Pool		D - Crest Second Crossover		E - End Second Crossover						F - Maximum Pool		G - End Vane Bankfull Tie-in		
														Centerline		Centerline		E_L - Left Station			E_R - Right Station			Centerline				
	Side	Pitch	Length	Angle from Bank	Station	Offset	Elevation	Station	Offset	Elevation	Station	Offset	Elevation	Station	Elevation	Station	Elevation	Station	Offset	Elevation	Station	Offset	Elevation	Station	Elevation	Station	Offset	Elevation
J-Hook 1	RIGHT	5.0%	10.40	22°	1+80.67	0.00	129.50	NA	NA	NA	1+84.17	5.00	129.50	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	1+90.66	127.50	1+90.67	5.00	130.02
J-Hook 2	LEFT	5.0%	10.40	22°	2+50.31	0.00	129.00	2+53.81	-5.00	129.00	NA	NA	NA	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	2+64.49	127.00	2+60.31	-5.00	129.52

Cross Vane Structure Table

Structure	Vane Data						A - Cross Over						B - Plunge Pool		C - Crest Second Crossover		D - Second Crossover Tie-in								E - Max. Pool and Vane Tie-in						
	Left Vane			Right Vane			Centerline		A_L - Left End Cross Over		A_R - Right End Cross Over		Centerline		Centerline		D_L - Second Crossover Tie-in			D_R - Second Crossover Tie-in			Max. Pool Centerline			Left Bank Tie-in		Right Bank Tie-in	
	Length VL	Pitch	Angle from Bank	Length VR	Pitch	Angle from Bank	Station	Offset	Elevation	Offset	Elevation	Offset	Elevation	Station	Elevation	Station	Elevation	Station	Offset	Elevation	Station	Offset	Elevation	Station	Offset	Elevation	Offset	Elevation	Offset	Elevation
Cross Vane 1	10.40	5.0%	22.00	10.40	5.0%	22°	2+20.31	0.00	129.25	-1.00	129.25	1.00	129.25	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	2+34.35	0.00	127.25	-5.00	127.25	5.00	127.25
Cross Vane 2	10.40	5.0%	22.00	10.40	5.0%	22°	3+00.5	0.00	128.75	-1.00	128.75	1.00	128.75	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3+16.32	0.00	126.75	-5.00	126.75	5.00	126.75
Cross Vane 3	10.40	5.0%	22.00	10.40	5.0%	22°	3+30.42	0.0	128.50	-1.00	128.50	1.00	128.50	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	3+45.26	0.00	126.50	-5.00	126.50	5.00	126.50
Cross Vane 4	10.40	5.0%	22.00	10.40	5.0%	22°	3+76.20	0.0	128.25	-1.00	128.25	1.00	128.25	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	n/a	4+00.99	0.00	128.25	-5.00	128.25	5.00	128.25

Cobble Weir Structure Table

Structure	A1			A2			A3			A4			A5			B1			B2			B3			B4			B5		
	Centerline			Centerline			Centerline			Centerline			Centerline			Centerline			Centerline			Centerline			Centerline			Centerline		
	Station	Offset	Elevation	Station	Offset	Elevation	Station	Offset	Elevation	Station	Offset	Elevation	Station	Elevation	Station	Station	Elevation	Station	Elevation	Station	Offset	Elevation	Station	Offset	Elevation	Station	Elevation	Station	Offset	Elevation
Weir 1	4+41.79	-10.00	129.00	4+41.79	-7.00	128.00	4+41.79	0.00	127.50	4+41.79	7.00	128.00	4+41.79	10.00	129.00	4+61.79	-10.00	128.50	4+61.79	-7.00	127.50	4+61.79	0.00	127.00	4+61.79	7.00	127.50	4+61.79	10.00	128.50
Weir 2	5+63.00	-10.00	128.00	5+63.00	-7.00	127.50	5+63.00	0.00	127.00	5+63.00	7.00	127.50	5+63.00	10.00	128.00	5+83.00	-10.00	127.50	5+63.00	-7.00	127.00	5+83.00	0.00	126.50	5+83.00	7.00	127.00	5+83.00	10.00	127.50
Weir 3	6+65.50	-10.00	127.00	6+65.50	-7.00	126.50	6+65.50	0.00	126.00	6+65.50	7.00	126.50	6+65.50	10.00	127.00	6+85.50	-10.00	126.50	6+65.50	-7.00	126.00	6+85.50	0.00	125.50	6+85.50	7.00	126.00	6+85.50	10.00	126.50
Weir 4	7+85.67	-10.00	126.00	7+85.67	-7.00	125.50	7+85.67	0.00	125.00	7+85.67	7.00	125.50	7+85.67	10.00	126.00	7+85.67	-10.00	125.50	7+85.67	-7.00	124.00	7+85.67	0.00	124.50	7+85.67	7.00	124.00	7+85.67	10.00	125.50
Weir 5	8+62.04	-10.00	125.00	8+62.04	-7.00	124.50	8+62.04	0.00	124.00	8+62.04	7.00	124.50	8+62.04	10.00	125.00	8+82.04	-10.00	124.50	8+62.04	-7.00	124.00	8+82.04	0.00	123.50	8+82.04	7.00	124.00	8+82.04	10.00	124.50
Cascade 1	9+72.50	-10.00	124.50	9+72.50	-7.00	124.00	9+72.50	0.00	123.50	9+72.50	7.00	124.00	9+72.50	10.00	124.50	9+92.50	-10.00	123.50	9+92.50	-7.00	123.00	9+92.50	0.00	122.50	9+92.50	7.00	123.00	9+92.50	10.00	123.50
Weir 6 (Trib)	TRIB 0+45.00	-10.00	131.00	TRIB 0+45.00	-7.00	130.50	TRIB 0+45.00	0.00	130.00	TRIB 0+45.00	7.00	130.50	TRIB 0+45.00	10.00	131.00	TRIB 0+55.00	-10.00	130.50	TRIB 0+55.00	-7.00	130.00	TRIB 0+55.00	0.00	129.50	TRIB 0+55.00	7.00	130.00	TRIB 0+55.00	10.00	130.50
Weir 7 (Trib)	TRIB 0+85.21	-10.00	130.00	TRIB 0+85.21	-7.00	129.50	TRIB 0+85.21	0.00	129.00	TRIB 0+85.21	7.00	129.50	TRIB 0+85.21	10.00	130.00	TRIB 0+95.21	-10.00	129.50	TRIB 0+95.21	-7.00	129.00	TRIB 0+95.21	0.00	128.50	TRIB 0+95.21	7.00	129.00	TRIB 0+95.21	10.00	129.50
Weir 8 (Trib)	TRIB 1+20.63	-10.00	129.00	TRIB 1+20.63	-7.00	128.50	TRIB 1+20.63	0.00	128.00	TRIB 1+20.63	7.00	128.50	TRIB 1+20.63	10.00	129.00	TRIB 1+30.63	-10.00	128.50	TRIB 1+30.63	-7.00	128.00	TRIB 1+30.63	0.00	127.50	TRIB 1+30.63	7.00	128.00	TRIB 1+30.63	10.00	128.50

Not to Scale

Legend

Existing CL — — — Proposed CL ——— Proposed Bankfull — · —

Verticle Scale 1"=4'

Professional Certification
I hereby certify that these document were prepared or approved by me, and that I am a duly licensed professional engineer under the laws of the State of Maryland, License No. 20345, Expiration Date: 201 7-01-21.

(Signature) (Date)

STATE OF MARYLAND PROFESSIONAL ENGINEER

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U.S. FISH & WILDLIFE SERVICE

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Chesapeake Bay Field Office
Stream Habitat Assessment and Restoration Program

177 Admiral Cochrane Drive
Annapolis, Maryland 21401

Tel. (410) 573-4581

NAVY DAIRY FARM
ANNE ARUNDEL CO, MD

REVISIONS

DATE	BY

LONGITUDINAL PROFILE

PROJECT MANAGER: BH	DRAFTING: CAC
DESIGN: BH	CHECKED BY: KM
DATE: 02/11/2016	SCALE: AS SHOWN

SHEET
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LP - 1

APPENDIX K

Computations of Velocity and Bankfull Discharge Using Various Methods

Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY & DISCHARGE Estimates

Stream:	**Navy Dairy Farm Tributary**	Location:	**Reach - Reach 1**
Date:		Stream Type: **B4/1**	Valley Type: **II**
Observers:	**BH, CC**	HUC:	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Riffle Cross-Sectional AREA	**5.86**	A_{bkf} (ft^2)	Bankfull Riffle Mean DEPTH	**0.56**	d_{bkf} (ft)
Bankfull Riffle WIDTH	**10.52**	W_{bkf} (ft)	Wetted PERMIMETER ~ $(2 * d_{bkf}) + W_{bkf}$	**11.56**	W_p (ft)
D_{84} at Riffle	**112.17**	**Dia.** (mm)	D_{84} (mm) / 304.8	**0.37**	D_{84} (ft)
Bankfull SLOPE	**0.0209**	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	**0.51**	**R** (ft)
Gravitational Acceleration	**32.2**	g (ft / sec^2)	Relative Roughness R(ft) / D_{84} (ft)	**1.39**	**R / D_{84}**
Drainage Area	**0.4**	**DA** (mi^2)	Shear Velocity $u^* = (gRS)^{½}$	**0.586**	**u*** (ft/sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [\,2.83 + 5.66 * Log\{R / D_{84}\}\,]\,u^*$	**2.11**	ft / sec	**12.38**	cfs
2. Roughness Coefficient: a) Manning's *n* from Friction Factor / Relative Roughness (Figs. 2-18, 2-19) $u = 1.49*R^{2/3}*S^{1/2}/n$ $n =$ **0.0551**	**2.48**	ft / sec	**14.53**	cfs
2. Roughness Coefficient: b) Manning's *n* from Stream Type (Fig. 2-20) $u = 1.49*R^{2/3}*S^{1/2}/n$ $n =$ **0.056**	**2.44**	ft / sec	**14.30**	cfs
2. Roughness Coefficient: c) Manning's *n* from Jarrett (USGS): $u = 1.49*R^{2/3}*S^{1/2}/n$ $n = 0.39*S^{0.38}*R^{-0.16}$ **Note:** This equation is applicable to **steep, step/pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for Stream Types A1, A2, A3, B1, B2, B3, C2 & E3 $n =$ **0.100**	**1.37**	ft / sec	**8.01**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) **Darcy-Weisbach (Leopold, Wolman and Miller)**	**2.38**	ft / sec	**13.95**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) **Chezy C**	**0.00**	ft / sec	**0.00**	cfs
4. Continuity Equations: a) Regional Curves $u = Q / A$ **Return Period for Bankfull Discharge** $Q =$ **0.0** **year**	**0.00**	ft / sec	**0.00**	cfs
4. Continuity Equations: b) USGS Gage Data $u = Q / A$	**0.00**	ft / sec	**0.00**	cfs

Protrusion Height Options for the D_{84} Term in the Relative Roughness Relation (R/D_{84}) – Estimation Method 1

Option 1.	For **sand-bed** channels: Measure 100 **"protrusion heights"** of sand dunes from the downstream side of feature to the top of feature. Substitute the D_{84} sand dune protrusion height in ft for the D_{84} term in method 1.
Option 2.	For **boulder-dominated** channels: Measure 100 **"protrusion heights"** of boulders on the sides from the bed elevation to the top of the rock on that side. Substitute the D_{84} boulder protrusion height in ft for the D_{84} term in method 1.
Option 3.	For **bedrock-dominated** channels: Measure 100 **"protrusion heights"** of rock separations, steps, joints or uplifted surfaces above channel bed elevation. Substitute the D_{84} bedrock protrusion height in ft for the D_{84} term in method 1.
Option 4.	For **log-influenced** channels: Measure "**protrustion heights**" proportionate to channel width of log diameters or the height of the log on upstream side if embedded. Substitute the D_{84} protrusion height in ft for the D_{84} term in method 1.

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Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY & DISCHARGE Estimates

Stream:	**Navy Dairy Farm Tributary**			Location:	**Reach - Reach 2**
Date:		Stream Type:	**F4**	Valley Type:	**VIII**
Observers:	**BH, CC**			HUC:	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Riffle Cross-Sectional AREA	**9.47**	**A_{bkf}** (ft^2)	Bankfull Riffle Mean DEPTH	**0.81**	**d_{bkf}** (ft)
Bankfull Riffle WIDTH	**11.65**	**W_{bkf}** (ft)	Wetted PERMIMETER ~ $(2 * d_{bkf}) + W_{bkf}$	**13.43**	**W_p** (ft)
D_{84} at Riffle	**78.86**	**Dia.** (mm)	D_{84} (mm) / 304.8	**0.26**	**D_{84}** (ft)
Bankfull SLOPE	**0.0179**	**S_{bkf}** (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	**0.70**	**R** (ft)
Gravitational Acceleration	**32.2**	g (ft / sec^2)	Relative Roughness R(ft) / D_{84} (ft)	**2.70**	**R / D_{84}**
Drainage Area	**0.0**	**DA** (mi^2)	Shear Velocity $u^* = (gRS)^{½}$	**0.635**	**u*** (ft/sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [\,2.83 + 5.66 * Log\{R / D_{84}\}\,]\,u^*$	**3.37**	ft / sec	**31.95**	cfs
2. Roughness Coefficient: a) Manning's *n* from Friction Factor / Relative Roughness (Figs. 2-18, 2-19) $u = 1.49*R^{2/3}*S^{1/2}/n$ $n =$ **0.0416**	**3.79**	ft / sec	**35.84**	cfs
2. Roughness Coefficient: b) Manning's *n* from Stream Type (Fig. 2-20) $u = 1.49*R^{2/3}*S^{1/2}/n$ $n =$ **0.041**	**3.84**	ft / sec	**36.37**	cfs
2. Roughness Coefficient: c) Manning's *n* from Jarrett (USGS): $u = 1.49*R^{2/3}*S^{1/2}/n$ $n = 0.39*S^{0.38}*R^{-0.16}$ **Note:** This equation is applicable to **steep, step/pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for Stream Types A1, A2, A3, B1, B2, B3, C2 & E3 $n =$ **0.089**	**1.76**	ft / sec	**16.68**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) **Darcy-Weisbach (Leopold, Wolman and Miller)**	**3.88**	ft / sec	**36.70**	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) **Chezy C**	**0.00**	ft / sec	**0.00**	cfs
4. Continuity Equations: a) Regional Curves $u = Q / A$ **Return Period for Bankfull Discharge** $Q =$ **0.0** **year**	**0.00**	ft / sec	**0.00**	cfs
4. Continuity Equations: b) USGS Gage Data $u = Q / A$	**0.00**	ft / sec	**0.00**	cfs

Protrusion Height Options for the D_{84} Term in the Relative Roughness Relation (R/D_{84}) – Estimation Method 1

Option 1.	For **sand-bed** channels: Measure 100 **"protrusion heights"** of sand dunes from the downstream side of feature to the top of feature. Substitute the D_{84} sand dune protrusion height in ft for the D_{84} term in method 1.
Option 2.	For **boulder-dominated** channels: Measure 100 **"protrusion heights"** of boulders on the sides from the bed elevation to the top of the rock on that side. Substitute the D_{84} boulder protrusion height in ft for the D_{84} term in method 1.
Option 3.	For **bedrock-dominated** channels: Measure 100 **"protrusion heights"** of rock separations, steps, joints or uplifted surfaces above channel bed elevation. Substitute the D_{84} bedrock protrusion height in ft for the D_{84} term in method 1.
Option 4.	For **log-influenced** channels: Measure "**protrustion heights**" proportionate to channel width of log diameters or the height of the log on upstream side if embedded. Substitute the D_{84} protrusion height in ft for the D_{84} term in method 1.

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Worksheet 2-2. Computations of velocity and bankfull discharge using various methods (Rosgen, 2006b; Rosgen and Silvey, 2007).

Bankfull VELOCITY & DISCHARGE Estimates

Stream:	**Navy Dairy Farm Tributary**	Location:	**Reach - Reach 1 Reference**
Date:		Stream Type: **B4**	Valley Type: **II**
Observers:	**BH, CC**	HUC:	

INPUT VARIABLES			OUTPUT VARIABLES		
Bankfull Riffle Cross-Sectional AREA	7.49	A_{bkf} (ft^2)	Bankfull Riffle Mean DEPTH	0.55	d_{bkf} (ft)
Bankfull Riffle WIDTH	13.53	W_{bkf} (ft)	Wetted PERMIMETER ~ $(2 * d_{bkf}) + W_{bkf}$	14.20	W_p (ft)
D_{84} at Riffle	88.38	Dia. (mm)	D_{84} (mm) / 304.8	0.29	D_{84} (ft)
Bankfull SLOPE	0.0179	S_{bkf} (ft / ft)	Hydraulic RADIUS A_{bkf} / W_p	0.53	R (ft)
Gravitational Acceleration	32.2	g (ft / sec^2)	Relative Roughness R(ft) / D_{84} (ft)	1.83	R / D_{84}
Drainage Area	0.4	DA (mi^2)	Shear Velocity $u^* = (gRS)^{1/2}$	0.552	u* (ft/sec)

ESTIMATION METHODS	Bankfull VELOCITY		Bankfull DISCHARGE	
1. Friction Factor / Relative Roughness $u = [\,2.83 + 5.66 * Log\{R / D_{84}\}\,]\,u^*$	2.37	ft / sec	17.74	cfs
2. Roughness Coefficient: a) Manning's *n* from Friction Factor / Relative Roughness (Figs. 2-18, 2-19) $u = 1.49*R^{2/3}*S^{1/2}/n$ $n =$ 0.0488	2.66	ft / sec	19.90	cfs
2. Roughness Coefficient: b) Manning's *n* from Stream Type (Fig. 2-20) $u = 1.49*R^{2/3}*S^{1/2}/n$ $n =$ 0.056	2.32	ft / sec	17.34	cfs
2. Roughness Coefficient: c) Manning's *n* from Jarrett (USGS): $u = 1.49*R^{2/3}*S^{1/2}/n$ $n = 0.39*S^{0.38}*R^{-0.16}$ **Note:** This equation is applicable to **steep, step/pool, high boundary roughness, cobble- and boulder-dominated stream systems**; i.e., for Stream Types A1, A2, A3, B1, B2, B3, C2 & E3 $n =$ 0.094	1.39	ft / sec	10.37	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Darcy-Weisbach (Leopold, Wolman and Miller)	2.49	ft / sec	18.64	cfs
3. Other Methods (Hey, Darcy-Weisbach, Chezy C, etc.) Chezy C	0.00	ft / sec	0.00	cfs
4. Continuity Equations: a) Regional Curves $u = Q / A$ Return Period for Bankfull Discharge Q = 0.0 year	0.00	ft / sec	0.00	cfs
4. Continuity Equations: b) USGS Gage Data $u = Q / A$	0.00	ft / sec	0.00	cfs

Protrusion Height Options for the D_{84} Term in the Relative Roughness Relation (R/D_{84}) – Estimation Method 1

Option 1.	For **sand-bed** channels: Measure 100 **"protrusion heights"** of sand dunes from the downstream side of feature to the top of feature. Substitute the D_{84} sand dune protrusion height in ft for the D_{84} term in method 1.
Option 2.	For **boulder-dominated** channels: Measure 100 **"protrusion heights"** of boulders on the sides from the bed elevation to the top of the rock on that side. Substitute the D_{84} boulder protrusion height in ft for the D_{84} term in method 1.
Option 3.	For **bedrock-dominated** channels: Measure 100 **"protrusion heights"** of rock separations, steps, joints or uplifted surfaces above channel bed elevation. Substitute the D_{84} bedrock protrusion height in ft for the D_{84} term in method 1.
Option 4.	For **log-influenced** channels: Measure "**protrustion heights**" proportionate to channel width of log diameters or the height of the log on upstream side if embedded. Substitute the D_{84} protrusion height in ft for the D_{84} term in method 1.

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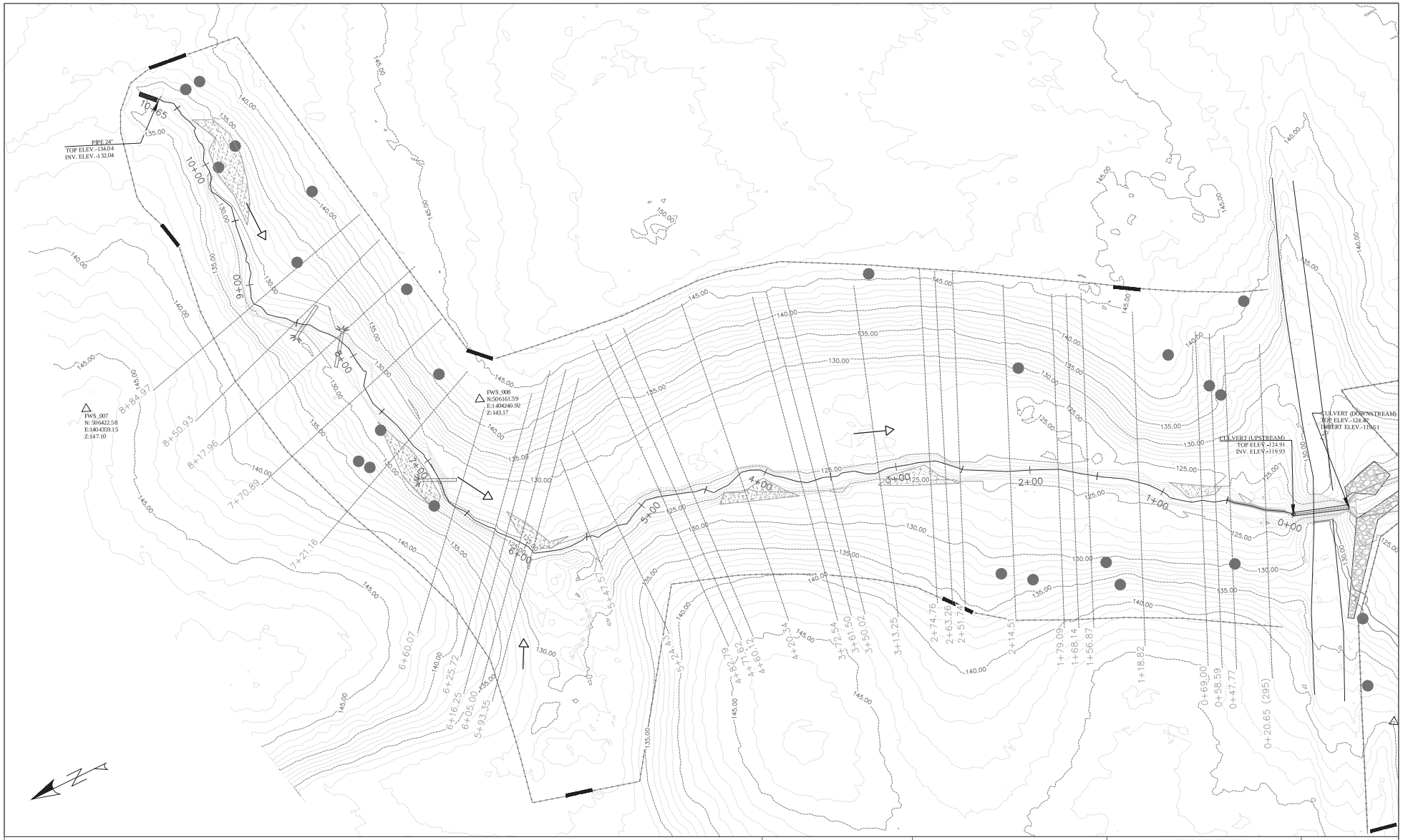
APPENDIX L

Existing vs. Proposed H&H Results



CONTOUR INTERVAL = 1.0 FOOT

Not to Scale

Professional Certification
I hereby certify that these documents were prepared or approved by me, and that I am a duly licensed professional engineer under the laws of the State of Maryland, License No. 20945, Expiration Date: 2015-08-21.

(Signature) (Date)

STATE OF MARYLAND
BRIAN HOWARD
No. 20945
PROFESSIONAL ENGINEER

U.S. FISH & WILDLIFE SERVICE

U.S. Fish & Wildlife Service
Chesapeake Bay Field Office
Stream Habitat Assessment and Restoration Program

177 Admiral Cochrane Drive
Annapolis, Maryland 21401

Tel. (410) 573-4581

NAVY DAIRY FARM
ANNE ARUNDEL CO, MD

REVISIONS		EXISTING CONDITIONS	
DATE	BY		
		PROJECT MANAGER: BH	DRAFTING: CAC
		DESIGN: BH	CHECKED BY:
		DATE: 12/2015	SCALE: AS SHOWN

SHEET
3 of 11

EC - 1

HEC-RAS Plan: NDF_Ex_Plan1 River: EX_HEC_NDF Reach: EX_HEC_CL

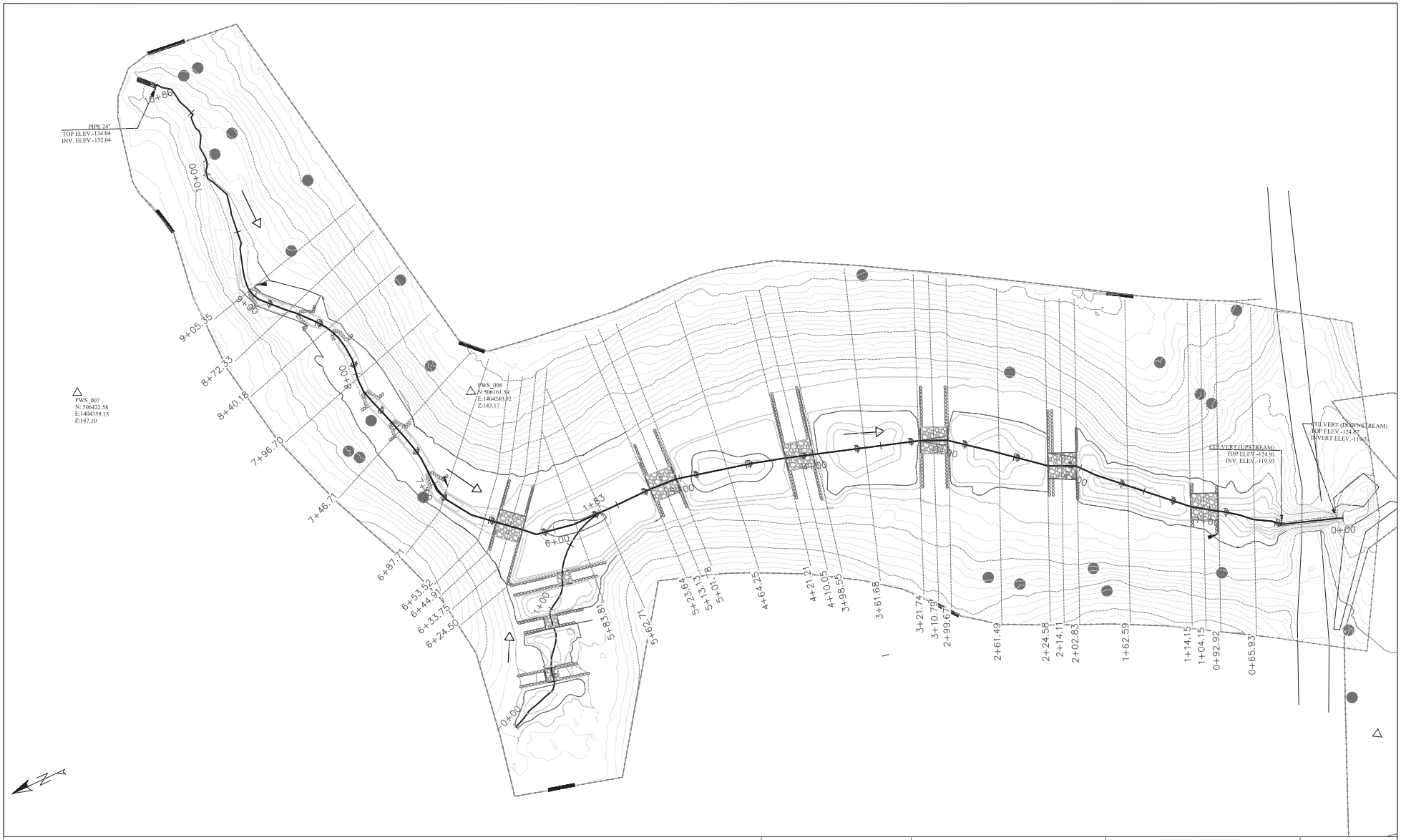
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear LOB	Shear ROB
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
EX_HEC_CL	884.97	BKF	24.90	127.47	128.38	128.38	128.69	0.016799	4.43	5.62	9.37	1.01	0.60		
EX_HEC_CL	884.97	2 YR	63.90	127.47	128.93	128.93	129.39	0.014727	5.41	11.82	13.18	1.01	0.78		
EX_HEC_CL	884.97	5 YR	148.00	127.47	129.64	129.64	130.31	0.011511	6.62	23.37	19.57	0.96	1.00		0.21
EX_HEC_CL	884.97	10 YR	233.00	127.47	130.17	130.17	130.97	0.010016	7.35	34.88	23.99	0.93	1.13		0.36
EX_HEC_CL	884.97	50 YR	545.00	127.47	131.50	131.50	132.48	0.007732	8.60	79.83	41.30	0.87	1.34		0.56
EX_HEC_CL	884.97	100 YR	755.00	127.47	132.44		133.24	0.005201	8.07	121.56	48.81	0.73	1.10		0.56
EX_HEC_CL	850.93	BKF	24.90	126.67	127.86		127.95	0.005169	2.51	9.92	14.29	0.53	0.19		
EX_HEC_CL	850.93	2 YR	63.90	126.67	128.49		128.64	0.004274	3.14	20.38	18.82	0.52	0.26		0.02
EX_HEC_CL	850.93	5 YR	148.00	126.67	129.46		129.66	0.002834	3.69	42.11	24.91	0.47	0.29	0.01	0.12
EX_HEC_CL	850.93	10 YR	233.00	126.67	130.13		130.39	0.002481	4.21	59.74	27.73	0.46	0.35	0.02	0.15
EX_HEC_CL	850.93	50 YR	545.00	126.67	131.65		132.07	0.002377	5.59	121.75	51.20	0.48	0.52	0.11	0.23
EX_HEC_CL	850.93	100 YR	755.00	126.67	132.61		133.02	0.001873	5.70	174.37	58.41	0.44	0.51	0.16	0.25
EX_HEC_CL	817.96	BKF	24.90	126.32	127.58		127.74	0.007836	3.22	7.73	11.86	0.70	0.31		
EX_HEC_CL	817.96	2 YR	63.90	126.32	128.24		128.47	0.005609	3.89	16.43	14.57	0.65	0.38		
EX_HEC_CL	817.96	5 YR	148.00	126.32	129.22		129.54	0.004253	4.52	32.76	18.62	0.60	0.44		
EX_HEC_CL	817.96	10 YR	233.00	126.32	129.87		130.28	0.004164	5.09	45.79	21.31	0.61	0.52		
EX_HEC_CL	817.96	50 YR	545.00	126.32	131.25		131.94	0.004403	6.82	88.99	44.15	0.67	0.82	0.17	0.14
EX_HEC_CL	817.96	100 YR	755.00	126.32	132.38		132.93	0.002591	6.35	145.72	54.39	0.54	0.65	0.22	0.19
EX_HEC_CL	770.89	BKF	24.90	126.38	127.30		127.43	0.005306	2.91	8.56	11.34	0.59	0.24		
EX_HEC_CL	770.89	2 YR	63.90	126.38	128.03		128.24	0.004105	3.69	17.31	12.84	0.56	0.32		0.00
EX_HEC_CL	770.89	5 YR	148.00	126.38	128.99		129.34	0.003854	4.87	32.25	18.41	0.57	0.48		0.12
EX_HEC_CL	770.89	10 YR	233.00	126.38	129.60		130.08	0.003920	5.74	46.75	28.14	0.60	0.62	0.08	0.19
EX_HEC_CL	770.89	50 YR	545.00	126.38	131.11		131.74	0.003476	7.17	104.03	45.03	0.61	0.83	0.26	0.37
EX_HEC_CL	770.89	100 YR	755.00	126.38	132.31		132.81	0.002191	6.69	163.65	54.71	0.50	0.67	0.25	0.34
EX_HEC_CL	721.16	BKF	24.90	125.32	126.82		127.08	0.009605	4.04	6.16	7.51	0.79	0.46		
EX_HEC_CL	721.16	2 YR	63.90	125.32	127.48	127.33	127.93	0.009011	5.35	12.27	11.59	0.82	0.68	0.09	0.08
EX_HEC_CL	721.16	5 YR	148.00	125.32	128.26	128.25	129.02	0.008978	7.27	23.68	17.92	0.89	1.08	0.30	0.29
EX_HEC_CL	721.16	10 YR	233.00	125.32	128.88	128.88	129.77	0.007955	8.13	36.35	23.22	0.87	1.24	0.41	0.41
EX_HEC_CL	721.16	50 YR	545.00	125.32	130.41	130.41	131.47	0.006239	9.71	85.17	41.39	0.83	1.52	0.54	0.58
EX_HEC_CL	721.16	100 YR	755.00	125.32	132.23		132.69	0.002024	7.02	173.24	53.89	0.50	0.71	0.33	0.32
EX_HEC_CL	660.07	BKF	24.90	124.25	125.96	125.93	126.33	0.015670	4.86	5.12	6.44	0.96	0.68		
EX_HEC_CL	660.07	2 YR	63.90	124.25	126.64	126.64	127.22	0.014704	6.10	10.50	9.33	1.00	0.94		0.05
EX_HEC_CL	660.07	5 YR	148.00	124.25	127.58	127.58	128.39	0.011462	7.28	21.49	15.11	0.95	1.15		0.27
EX_HEC_CL	660.07	10 YR	233.00	124.25	128.27	128.27	129.14	0.009640	7.77	33.82	20.72	0.91	1.22		0.42
EX_HEC_CL	660.07	50 YR	545.00	124.25	129.77	129.77	130.80	0.006701	9.08	81.65	39.81	0.82	1.40	0.25	0.55
EX_HEC_CL	660.07	100 YR	755.00	124.25	132.23	130.32	132.55	0.001271	5.52	199.85	54.82	0.39	0.44	0.13	0.25
EX_HEC_CL	625.72	BKF	24.90	124.46	125.94		126.05	0.002958	2.70	9.57	10.42	0.46	0.19		0.05
EX_HEC_CL	625.72	2 YR	63.90	124.46	126.49		126.77	0.004862	4.32	16.22	13.84	0.62	0.42		0.14
EX_HEC_CL	625.72	5 YR	148.00	124.46	126.98	126.95	127.70	0.010029	7.13	23.79	17.14	0.92	1.08		0.44
EX_HEC_CL	625.72	10 YR	233.00	124.46	127.54	127.54	128.41	0.009859	8.00	34.20	19.61	0.93	1.28		0.65
EX_HEC_CL	625.72	50 YR	545.00	124.46	129.31	129.30	130.28	0.006160	9.01	86.29	44.39	0.80	1.36	0.20	0.52
EX_HEC_CL	625.72	100 YR	755.00	124.46	128.49	128.49	132.10	0.028737	16.66	54.52	23.51	1.67	5.01	0.29	2.99
EX_HEC_CL	616.25	BKF	24.90	124.64	125.66	125.66	125.98	0.013335	4.70	5.95	10.14	0.94	0.62		0.22
EX_HEC_CL	616.25	2 YR	63.90	124.64	126.24	126.24	126.68	0.011689	5.74	13.35	14.94	0.93	0.81		0.43
EX_HEC_CL	616.25	5 YR	148.00	124.64	126.92	126.92	127.57	0.012399	7.18	24.52	18.26	1.01	1.15		0.83
EX_HEC_CL	616.25	10 YR	233.00	124.64	127.42	127.42	128.23	0.012423	8.02	34.27	20.72	1.03	1.36		1.08
EX_HEC_CL	616.25	50 YR	545.00	124.64	128.29	128.29	130.10	0.018113	12.18	55.02	27.17	1.32	2.79	0.35	2.09
EX_HEC_CL	616.25	100 YR	755.00	124.64	129.52	129.52	130.60	0.007713	10.25	113.19	55.23	0.92	1.74	0.46	0.82
EX_HEC_CL	605	BKF	24.90	124.49	125.34	125.34	125.61	0.016823	4.21	5.92	11.00	1.01	0.56		
EX_HEC_CL	605	2 YR	63.90	124.49	125.82	125.82	126.25	0.014469	5.28	12.11	14.56	1.01	0.75		0.05
EX_HEC_CL	605	5 YR	148.00	124.49	126.48	126.48	127.14	0.011953	6.56	23.26	18.89	0.99	0.99		0.28
EX_HEC_CL	605	10 YR	233.00	124.49	126.99	126.99	127.79	0.010244	7.29	34.18	24.39	0.96	1.12	0.12	0.40
EX_HEC_CL	605	50 YR	545.00	124.49	128.13	128.13	129.42	0.009169	9.57	67.39	33.12	0.98	1.64	0.51	0.67
EX_HEC_CL	605	100 YR	755.00	124.49	129.12	129.12	130.13	0.005407	8.91	119.20	62.80	0.79	1.29	0.48	0.34
EX_HEC_CL	593.35	BKF	24.90	124.18	125.10	125.10	125.33	0.012094	3.98	7.26	17.64	0.88	0.47	0.13	0.11
EX_HEC_CL	593.35	2 YR	63.90	124.18	125.50	125.50	125.87	0.011489	5.37	14.89	20.70	0.93	0.73	0.37	0.25
EX_HEC_CL	593.35	5 YR	148.00	124.18	126.19	126.09	126.65	0.007982	6.30	31.79	27.61	0.85	0.85	0.49	0.33
EX_HEC_CL	593.35	10 YR	233.00	124.18	127.09		127.42	0.003601	5.60	60.02	35.11	0.61	0.58	0.32	0.28
EX_HEC_CL	593.35	50 YR	545.00	124.18	128.63		129.08	0.003024	6.98	132.68	69.82	0.60	0.77	0.45	0.20
EX_HEC_CL	593.35	100 YR	755.00	124.18	129.33		129.76	0.002589	7.16	185.23	80.60	0.57	0.77	0.46	0.24
EX_HEC_CL	547.57	BKF	24.90	122.73	124.24		124.28	0.001798	1.94	16.23	18.24	0.34	0.10	0.09	
EX_HEC_CL	547.57	2 YR	63.90	122.73	125.15		125.20	0.001263	2.15	35.56	23.66	0.30	0.11	0.12	
EX_HEC_CL	547.57	5 YR	148.00	122.73	126.36		126.43	0.001118	2.59	69.47	38.49	0.30	0.14	0.15	0.01
EX_HEC_CL	547.57	10 YR	233.00	122.73	127.19		127.28	0.000914	2.87	103.46	43.09	0.29	0.15	0.16	0.05
EX_HEC_CL	547.57	50 YR	545.00	122.73	128.74		128.91	0.001131	4.17	180.08	65.83	0.34	0.28	0.29	0.08
EX_HEC_CL	547.57	100 YR	755.00	122.73	129.39		129.62	0.001324	4.92	226.29	73.81	0.38	0.37	0.38	0.12
EX_HEC_CL	524.43	BKF	24.90	122.80	124.05		124.20	0.005553	3.15	7.91	9.52	0.61	0.27		
EX_HEC_CL	524.43	2 YR	63.90	122.80	124.96		125.14	0.003565	3.44	18.55	13.86	0.52	0.28		
EX_HEC_CL	524.43	5 YR	148.00	122.80	126.16		126.38	0.002584	3.79	39.50	23.07	0.48	0.30		0.03
EX_HEC_CL	524.43	10 YR	233.00	122.80	126.99		127.23	0.002005	4.01	61.92	29.72	0.44	0.30		0.09
EX_HEC_CL	524.43	50 YR	545.00	122.80	128.40		128.85	0.002386	5.57	111.83	43.12	0.51	0.52	0.04	0.20
EX_HEC_CL	524.43	100 YR	755.00	122.80	128.90		129.53	0.002915	6.69	136.09	54.16	0.57	0.72	0.10	0.23
EX_HEC_CL	482.79	BKF	24.90	121.76	124.01		124.07	0.001405	1.91	13.05	10.90	0.31	0.09		
EX_HEC_CL	482.79	2 YR	63.90	121.76	124.92		125.02	0.001684	2.52	25.32	16.09	0.35	0.15		
EX_HEC_CL	482.79	5 YR	148.00	121.76	126.13		126.28	0.001518	3.10	47.81	20.54	0.36	0.19		
EX_HEC_CL	482.79	10 YR	233.00	121.76	126.95		127.14	0.001534	3.55	65.68	23.01	0.37	0.24		
EX_HEC_CL	482.79	50 YR	545.00	121.76	128.34		128.74	0.002185	5.17	120.98	60.79	0.46	0.46	0.02	0.09
EX_HEC_CL	482.79	100 YR	755.00	121.76	128.89		129.38	0.002405	5.92	155.77	67.66	0.50	0.57	0.06	0.16
EX_HEC_CL	471.62	BKF	24.90	122.15	123.95		124.04	0.002922	2.48	10.05	10.27	0.44	0.16		
EX_HEC_CL	471.62	2 YR	63.90	122.15	124.84		124.99	0.002530	3.13	20.41	12.88	0.44	0.22		
EX_HEC_CL	471.62	5 YR	148.00	122.15	126.00		126.25	0.002536	3.96	37.36	16.32	0.46	0.32		
EX_HEC_CL	471.62	10 YR	233.00	122.15	126.79		127.11	0.002694	4.55	51.16	18.90	0.49	0.40		
EX_HEC_CL	471.62	50 YR	545.00	122.15	127.98	127.05	128.67	0.004453	6.85	92.45	55.82	0.65	0.83		0.14
EX_HEC_CL	471.62	100 YR	755.00	122.15	128.22	128.22	129.28	0.006482	8.59	106.41	61.22	0.79	1.28	0.02	0.27

HEC-RAS Plan: NDF_Ex_Plan1 River: EX_HEC_NDF Reach: EX_HEC_CL (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear LOB	Shear ROB
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
EX_HEC_CL	460.12	BKF	24.90	122.21	123.93		124.01	0.002154	2.33	10.71	9.69	0.39	0.14		
EX_HEC_CL	460.12	2 YR	63.90	122.21	124.81		124.96	0.002338	3.12	20.48	12.40	0.43	0.22		
EX_HEC_CL	460.12	5 YR	148.00	122.21	125.97		126.22	0.002530	4.02	36.86	15.94	0.47	0.32		
EX_HEC_CL	460.12	10 YR	233.00	122.21	126.74		127.08	0.002734	4.65	50.14	18.31	0.49	0.41		
EX_HEC_CL	460.12	50 YR	545.00	122.21	127.14	127.02	128.53	0.010337	9.47	57.64	23.16	0.97	1.66		0.01
EX_HEC_CL	460.12	100 YR	755.00	122.21	128.18	128.18	129.17	0.006206	8.43	113.05	63.79	0.78	1.23	0.01	0.31
EX_HEC_CL	420.34	BKF	24.90	122.18	123.85		123.92	0.002184	2.24	11.13	11.02	0.39	0.13		
EX_HEC_CL	420.34	2 YR	63.90	122.18	124.75		124.87	0.002011	2.78	22.99	15.31	0.40	0.18		
EX_HEC_CL	420.34	5 YR	148.00	122.18	125.94		126.11	0.001850	3.29	44.94	21.68	0.40	0.22		
EX_HEC_CL	420.34	10 YR	233.00	122.18	126.75		126.95	0.001678	3.61	67.44	41.51	0.40	0.25		0.02
EX_HEC_CL	420.34	50 YR	545.00	122.18	127.57		128.04	0.003267	5.79	115.76	68.46	0.57	0.60		0.15
EX_HEC_CL	420.34	100 YR	755.00	122.18	127.89		128.54	0.004242	6.91	138.49	72.44	0.66	0.83		0.26
EX_HEC_CL	372.54	BKF	24.90	121.74	123.77		123.83	0.001529	2.04	12.19	10.35	0.33	0.10		
EX_HEC_CL	372.54	2 YR	63.90	121.74	124.66		124.77	0.001837	2.77	23.03	14.06	0.38	0.17		
EX_HEC_CL	372.54	5 YR	148.00	121.74	125.82		126.01	0.001912	3.58	41.31	17.31	0.41	0.25		
EX_HEC_CL	372.54	10 YR	233.00	121.74	126.60		126.86	0.001993	4.12	63.24	68.11	0.43	0.32		0.02
EX_HEC_CL	372.54	50 YR	545.00	121.74	127.26	127.09	127.85	0.004199	6.70	113.45	86.43	0.63	0.79	0.05	0.19
EX_HEC_CL	372.54	100 YR	755.00	121.74	127.70	127.53	128.34	0.004217	7.28	152.92	91.84	0.65	0.90	0.12	0.30
EX_HEC_CL	361.5	BKF	24.90	121.93	123.75		123.82	0.001567	2.07	12.02	10.19	0.34	0.11		
EX_HEC_CL	361.5	2 YR	63.90	121.93	124.63		124.75	0.001898	2.86	22.31	13.25	0.39	0.18		
EX_HEC_CL	361.5	5 YR	148.00	121.93	125.78		125.99	0.002108	3.73	39.66	16.85	0.43	0.28		
EX_HEC_CL	361.5	10 YR	233.00	121.93	126.58		126.84	0.002098	4.17	67.11	73.46	0.42	0.33	0.05	0.03
EX_HEC_CL	361.5	50 YR	545.00	121.93	127.26	127.09	127.78	0.004092	6.48	123.42	89.90	0.60	0.75	0.21	0.20
EX_HEC_CL	361.5	100 YR	755.00	121.93	127.73		128.26	0.003940	6.89	166.95	95.93	0.60	0.81	0.26	0.30
EX_HEC_CL	350.02	BKF	24.90	122.01	123.74		123.80	0.001387	1.92	12.98	11.32	0.32	0.09		
EX_HEC_CL	350.02	2 YR	63.90	122.01	124.62		124.73	0.001567	2.64	24.16	13.92	0.35	0.15		
EX_HEC_CL	350.02	5 YR	148.00	122.01	125.78		125.96	0.001970	3.35	44.38	21.46	0.39	0.23		0.02
EX_HEC_CL	350.02	10 YR	233.00	122.01	126.60		126.80	0.001765	3.65	77.19	78.09	0.38	0.26	0.02	0.03
EX_HEC_CL	350.02	50 YR	545.00	122.01	127.30		127.70	0.003277	5.65	135.71	89.06	0.52	0.58	0.08	0.19
EX_HEC_CL	350.02	100 YR	755.00	122.01	127.75		128.19	0.003351	6.18	177.60	96.56	0.54	0.66	0.12	0.27
EX_HEC_CL	313.25	BKF	24.90	121.80	123.43		123.67	0.008385	3.97	6.28	6.82	0.73	0.43		
EX_HEC_CL	313.25	2 YR	63.90	121.80	124.14		124.58	0.009816	5.34	11.98	9.31	0.83	0.69		
EX_HEC_CL	313.25	5 YR	148.00	121.80	125.03	124.88	125.76	0.010758	6.85	21.60	12.24	0.91	1.03		
EX_HEC_CL	313.25	10 YR	233.00	121.80	125.57	125.57	126.58	0.012814	8.06	28.92	14.77	1.01	1.38		
EX_HEC_CL	313.25	50 YR	545.00	121.80	126.94	126.90	127.53	0.006061	7.17	113.78	88.00	0.75	0.96	0.06	0.36
EX_HEC_CL	313.25	100 YR	755.00	121.80	127.64		128.06	0.003638	6.43	178.61	96.20	0.60	0.72	0.15	0.36
EX_HEC_CL	274.76	BKF	24.90	121.56	123.21		123.37	0.006215	3.22	7.74	9.73	0.64	0.29		
EX_HEC_CL	274.76	2 YR	63.90	121.56	124.09		124.27	0.003960	3.45	18.53	14.93	0.55	0.29		
EX_HEC_CL	274.76	5 YR	148.00	121.56	125.18		125.42	0.002915	3.90	37.97	20.08	0.50	0.32		
EX_HEC_CL	274.76	10 YR	233.00	121.56	125.88		126.13	0.002429	4.18	67.73	71.52	0.47	0.34	0.02	0.05
EX_HEC_CL	274.76	50 YR	545.00	121.56	127.03		127.31	0.002003	4.92	161.32	91.43	0.46	0.41	0.07	0.17
EX_HEC_CL	274.76	100 YR	755.00	121.56	127.64		127.93	0.001749	5.12	221.28	102.75	0.44	0.42	0.09	0.20
EX_HEC_CL	263.26	BKF	24.90	120.92	123.26		123.31	0.001070	1.83	13.58	9.70	0.27	0.08		
EX_HEC_CL	263.26	2 YR	63.90	120.92	124.10		124.22	0.001745	2.78	22.98	12.69	0.36	0.17		
EX_HEC_CL	263.26	5 YR	148.00	120.92	125.15		125.38	0.002417	3.87	38.23	16.41	0.45	0.30		
EX_HEC_CL	263.26	10 YR	233.00	120.92	125.78		126.10	0.002878	4.60	58.41	62.15	0.50	0.41		0.04
EX_HEC_CL	263.26	50 YR	545.00	120.92	126.96		127.28	0.002397	5.28	154.91	95.43	0.48	0.48	0.08	0.18
EX_HEC_CL	263.26	100 YR	755.00	120.92	127.62		127.91	0.001897	5.24	221.18	104.56	0.44	0.45	0.11	0.21
EX_HEC_CL	251.74	BKF	24.90	121.10	123.24		123.30	0.001268	1.94	12.85	9.77	0.30	0.09		
EX_HEC_CL	251.74	2 YR	63.90	121.10	124.07		124.20	0.001922	2.92	21.86	12.06	0.38	0.19		
EX_HEC_CL	251.74	5 YR	148.00	121.10	125.08		125.35	0.002748	4.17	35.46	14.79	0.48	0.35		
EX_HEC_CL	251.74	10 YR	233.00	121.10	125.63	124.56	126.05	0.003692	5.23	49.13	59.34	0.56	0.53		0.03
EX_HEC_CL	251.74	50 YR	545.00	121.10	126.93		127.26	0.002518	5.48	154.48	95.50	0.49	0.51	0.09	0.20
EX_HEC_CL	251.74	100 YR	755.00	121.10	127.60		127.88	0.001959	5.37	221.88	106.18	0.44	0.47	0.11	0.23
EX_HEC_CL	214.51	BKF	24.90	121.36	123.09		123.22	0.003976	2.89	8.61	8.94	0.52	0.22		
EX_HEC_CL	214.51	2 YR	63.90	121.36	123.86		124.09	0.004320	3.83	16.70	11.97	0.57	0.34		
EX_HEC_CL	214.51	5 YR	148.00	121.36	124.88		125.21	0.004479	4.66	31.73	17.51	0.61	0.47		
EX_HEC_CL	214.51	10 YR	233.00	121.36	125.50	124.81	125.89	0.004326	5.12	53.95	65.89	0.62	0.53	0.02	0.06
EX_HEC_CL	214.51	50 YR	545.00	121.36	126.91		127.15	0.001853	4.68	177.89	104.22	0.44	0.38	0.09	0.17
EX_HEC_CL	214.51	100 YR	755.00	121.36	127.58		127.80	0.001461	4.67	251.19	114.29	0.40	0.35	0.11	0.19
EX_HEC_CL	179.09	BKF	24.90	121.07	123.02		123.10	0.002049	2.31	10.80	9.30	0.38	0.13		
EX_HEC_CL	179.09	2 YR	63.90	121.07	123.76		123.94	0.003215	3.42	18.66	12.35	0.49	0.27		
EX_HEC_CL	179.09	5 YR	148.00	121.07	124.75		125.06	0.003833	4.51	32.83	16.39	0.56	0.43		
EX_HEC_CL	179.09	10 YR	233.00	121.07	125.42		125.74	0.002971	4.79	64.05	68.52	0.52	0.44	0.03	0.08
EX_HEC_CL	179.09	50 YR	545.00	121.07	126.88		127.08	0.001417	4.43	197.38	102.13	0.38	0.32	0.10	0.15
EX_HEC_CL	179.09	100 YR	755.00	121.07	127.56		127.75	0.001194	4.50	268.43	108.37	0.36	0.32	0.12	0.17
EX_HEC_CL	168.14	BKF	24.90	121.19	122.98		123.08	0.002555	2.52	9.90	8.79	0.42	0.16		
EX_HEC_CL	168.14	2 YR	63.90	121.19	123.67		123.90	0.004325	3.85	16.59	11.39	0.56	0.35		
EX_HEC_CL	168.14	5 YR	148.00	121.19	124.64		125.01	0.004614	4.90	30.54	17.94	0.61	0.51	0.07	0.01
EX_HEC_CL	168.14	10 YR	233.00	121.19	125.36	124.61	125.71	0.003274	5.03	62.78	69.68	0.54	0.48	0.07	0.08
EX_HEC_CL	168.14	50 YR	545.00	121.19	126.86		127.06	0.001488	4.57	191.86	96.35	0.40	0.34	0.12	0.16
EX_HEC_CL	168.14	100 YR	755.00	121.19	127.53		127.73	0.001281	4.68	259.14	103.94	0.38	0.34	0.13	0.19
EX_HEC_CL	156.87	BKF	24.90	121.24	122.95		123.05	0.002624	2.57	9.68	8.41	0.42	0.17		
EX_HEC_CL	156.87	2 YR	63.90	121.24	123.57		123.84	0.004629	4.16	15.39	10.14	0.58	0.40	0.01	
EX_HEC_CL	156.87	5 YR	148.00	121.24	124.31	123.99	124.92	0.007410	6.36	24.51	14.82	0.77	0.84	0.19	
EX_HEC_CL	156.87	10 YR	233.00	121.24	125.03	125.03	125.64	0.005692	6.65	47.62	53.14	0.70	0.84	0.27	0.11
EX_HEC_CL	156.87	50 YR	545.00	121.24	126.80		127.04	0.001815	5.21	175.29	84.66	0.43	0.44	0.16	0.21
EX_HEC_CL	156.87	100 YR	755.00	121.24	127.46		127.71	0.001650	5.44	236.30	98.73	0.42	0.46	0.16	0.25
EX_HEC_CL	118.82	BKF	24.90	121.08	122.90		122.96	0.001522	1.93	12.93	12.35	0.33	0.09		
EX_HEC_CL	118.82	2 YR	63.90	121.08	123.55		123.68	0.002316	2.96	21.59	14.58	0.43	0.20		
EX_HEC_CL	118.82	5 YR	148.00	121.08	124.35		124.64	0.003303	4.29	34.58	18.38	0.53	0.38	0.02	
EX_HEC_CL	118.82	10 YR	233.00	121.08	124.94		125.35	0.003491	5.14	47.62	28.93	0.57	0.51	0.08	0.03
EX_HEC_CL	118.82	50 YR	545.00	121.08	126.40		126.92	0.002911	6.36	117.40	62.82	0.56	0.67	0.18	0.21

HEC-RAS Plan: NDF_Ex_Plan1 River: EX_HEC_NDF Reach: EX_HEC_CL (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear LOB	Shear ROB
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
EX_HEC_CL	118.82	100 YR	755.00	121.08	127.05		127.60	0.002694	6.77	160.60	69.33	0.55	0.72	0.25	0.26
EX_HEC_CL	69	BKF	24.90	121.48	122.68		122.82	0.005864	3.01	8.29	11.43	0.62	0.26		
EX_HEC_CL	69	2 YR	63.90	121.48	123.21		123.48	0.007210	4.16	15.36	15.12	0.73	0.44		
EX_HEC_CL	69	5 YR	148.00	121.48	123.94		124.39	0.007035	5.41	27.36	17.44	0.76	0.65		
EX_HEC_CL	69	10 YR	233.00	121.48	124.45		125.08	0.007357	6.36	36.61	18.60	0.80	0.84		
EX_HEC_CL	69	50 YR	545.00	121.48	126.01	125.63	126.73	0.004456	7.19	94.69	49.95	0.68	0.89	0.20	0.29
EX_HEC_CL	69	100 YR	755.00	121.48	126.53	126.22	127.40	0.004716	8.12	122.29	57.01	0.72	1.09	0.29	0.42
EX_HEC_CL	58.59	BKF	24.90	121.52	122.65		122.76	0.004154	2.69	9.25	11.58	0.53	0.20		
EX_HEC_CL	58.59	2 YR	63.90	121.52	123.15		123.41	0.006179	4.09	15.64	13.96	0.68	0.41		
EX_HEC_CL	58.59	5 YR	148.00	121.52	123.79		124.31	0.008446	5.78	25.59	17.03	0.83	0.76		
EX_HEC_CL	58.59	10 YR	233.00	121.52	124.30	124.10	124.99	0.008605	6.71	34.81	19.30	0.87	0.95	0.07	
EX_HEC_CL	58.59	50 YR	545.00	121.52	125.62	125.62	126.63	0.006814	8.37	77.90	46.65	0.84	1.25	0.27	0.27
EX_HEC_CL	58.59	100 YR	755.00	121.52	126.21	126.21	127.31	0.006247	9.01	107.81	54.04	0.83	1.36	0.37	0.42
EX_HEC_CL	47.77	BKF	24.90	121.52	122.39	122.39	122.66	0.017001	4.17	5.97	11.33	1.01	0.55		
EX_HEC_CL	47.77	2 YR	63.90	121.52	122.87	122.87	123.29	0.014725	5.20	12.30	14.98	1.01	0.74		
EX_HEC_CL	47.77	5 YR	148.00	121.52	123.76		124.19	0.007591	5.28	28.04	20.02	0.79	0.64		
EX_HEC_CL	47.77	10 YR	233.00	121.52	124.34		124.86	0.006540	5.76	40.44	22.68	0.76	0.70		
EX_HEC_CL	47.77	50 YR	545.00	121.52	125.67	125.34	126.39	0.004975	7.08	91.31	54.92	0.71	0.90	0.28	0.13
EX_HEC_CL	47.77	100 YR	755.00	121.52	126.33		127.07	0.004229	7.43	130.26	62.78	0.68	0.93	0.33	0.25
EX_HEC_CL	20.65	BKF	24.90	120.51	121.99	121.59	122.12	0.004003	2.83	8.81	9.64	0.52	0.21		
EX_HEC_CL	20.65	2 YR	63.90	120.51	122.77	122.21	122.97	0.004000	3.63	17.60	13.07	0.55	0.31		
EX_HEC_CL	20.65	5 YR	148.00	120.51	123.69	123.03	124.02	0.004007	4.63	33.91	23.22	0.58	0.45		0.09
EX_HEC_CL	20.65	10 YR	233.00	120.51	124.28	123.67	124.69	0.004004	5.33	48.85	28.51	0.60	0.55	0.01	0.18
EX_HEC_CL	20.65	50 YR	545.00	120.51	125.63	125.04	126.25	0.004002	6.85	101.50	49.28	0.64	0.81	0.16	0.37
EX_HEC_CL	20.65	100 YR	755.00	120.51	126.24	125.66	126.96	0.003999	7.60	134.53	59.68	0.65	0.94	0.24	0.43



CONTOUR INTERVAL = 1.0 FOOT

Not to Scale

Professional Certification
I hereby certify that these documents were prepared or approved by me, and that I am a duly licensed professional engineer under the laws of the State of Maryland, License No. 20945, Expiration Date: 2015-08-21.

(Signature) (Date)

STATE OF MARYLAND
BRIAN HOFFMAN
No. 20945
PROFESSIONAL ENGINEER

U.S. FISH & WILDLIFE SERVICE

U.S. Fish & Wildlife Service
Chesapeake Bay Field Office
Stream Habitat Assessment and Restoration Program

177 Admiral Cochrane Drive
Annapolis, Maryland 21401

Tel. (410) 573-4581

NAVY DAIRY FARM
ANNE ARUNDEL CO, MD

REVISIONS DATE	BY	PROPOSED CONDITIONS	
		PROJECT MANAGER: BH	DRAFTING: CAC
		DESIGN: BH	CHECKED BY:
		DATE: 12/2015	SCALE: AS SHOWN

SHEET
4 of 11

PC - 1

HEC-RAS Plan: NDF_Ex_Plan1 River: PROPOSED CL Reach: PROP_CL

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear LOB	Shear ROB
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
PROP_CL	905.35	BKF	24.90	129.03	130.18		130.23	0.004878	1.95	12.77	23.46	0.47	0.16		
PROP_CL	905.35	2 YR	63.90	129.03	130.66		130.76	0.003825	2.52	25.91	30.91	0.45	0.22		0.04
PROP_CL	905.35	5 YR	148.00	129.03	131.28		131.45	0.003573	3.36	47.97	38.72	0.47	0.34	0.03	0.12
PROP_CL	905.35	10 YR	233.00	129.03	131.72		131.95	0.003622	3.98	65.50	41.98	0.50	0.44	0.07	0.19
PROP_CL	905.35	50 YR	545.00	129.03	132.74		133.20	0.004346	5.75	113.22	52.84	0.58	0.80	0.20	0.35
PROP_CL	905.35	100 YR	755.00	129.03	133.28		133.84	0.004464	6.49	143.60	59.60	0.61	0.97	0.26	0.42
PROP_CL	872.33	BKF	24.90	128.83	129.99		130.08	0.004119	2.47	10.09	11.02	0.45	0.22		
PROP_CL	872.33	2 YR	63.90	128.83	130.42		130.60	0.005499	3.68	22.07	30.18	0.56	0.43	0.05	0.13
PROP_CL	872.33	5 YR	148.00	128.83	131.02		131.29	0.005817	4.84	42.12	45.59	0.61	0.66	0.03	0.30
PROP_CL	872.33	10 YR	233.00	128.83	131.53		131.81	0.004661	5.06	66.71	49.88	0.57	0.67	0.15	0.36
PROP_CL	872.33	50 YR	545.00	128.83	132.64		133.03	0.004464	6.36	127.29	58.69	0.59	0.94	0.38	0.58
PROP_CL	872.33	100 YR	755.00	128.83	133.21		133.66	0.004384	6.96	161.85	62.64	0.60	1.07	0.48	0.68
PROP_CL	840.18	BKF	24.90	128.93	129.84		129.92	0.005929	2.23	11.19	19.76	0.52	0.21		
PROP_CL	840.18	2 YR	63.90	128.93	130.24		130.40	0.006722	3.20	20.17	24.48	0.60	0.37	0.05	0.04
PROP_CL	840.18	5 YR	148.00	128.93	130.73		131.07	0.007984	4.68	33.13	28.38	0.70	0.68	0.18	0.16
PROP_CL	840.18	10 YR	233.00	128.93	131.13	130.84	131.59	0.008089	5.58	46.94	42.83	0.74	0.89	0.20	0.13
PROP_CL	840.18	50 YR	545.00	128.93	132.21		132.84	0.006567	6.90	99.92	53.33	0.72	1.16	0.48	0.43
PROP_CL	840.18	100 YR	755.00	128.93	132.77		133.47	0.006104	7.48	130.76	57.52	0.71	1.29	0.59	0.54
PROP_CL	796.7	BKF	24.90	128.00	129.20	129.20	129.46	0.022042	4.09	6.26	13.58	0.98	0.72		0.12
PROP_CL	796.7	2 YR	63.90	128.00	129.74	129.66	130.02	0.010885	4.52	17.58	28.24	0.77	0.70	0.18	0.24
PROP_CL	796.7	5 YR	148.00	128.00	130.53		130.76	0.005132	4.49	45.83	39.92	0.58	0.57	0.25	0.30
PROP_CL	796.7	10 YR	233.00	128.00	131.00		131.27	0.004789	5.03	65.35	44.00	0.58	0.67	0.32	0.38
PROP_CL	796.7	50 YR	545.00	128.00	132.10		132.53	0.004926	6.61	118.96	52.57	0.63	1.02	0.53	0.65
PROP_CL	796.7	100 YR	755.00	128.00	132.66		133.18	0.005033	7.38	149.34	56.96	0.65	1.21	0.63	0.79
PROP_CL	746.71	BKF	24.90	127.25	128.96		129.02	0.001655	1.96	12.68	8.57	0.28	0.13		
PROP_CL	746.71	2 YR	63.90	127.25	129.54		129.72	0.003294	3.44	21.59	23.43	0.42	0.34	0.06	0.05
PROP_CL	746.71	5 YR	148.00	127.25	130.26		130.53	0.004098	4.69	45.51	39.36	0.50	0.58	0.18	0.17
PROP_CL	746.71	10 YR	233.00	127.25	130.71		131.03	0.004524	5.44	63.92	43.47	0.53	0.74	0.30	0.27
PROP_CL	746.71	50 YR	545.00	127.25	131.79		132.27	0.005286	7.13	115.57	51.35	0.61	1.16	0.63	0.56
PROP_CL	746.71	100 YR	755.00	127.25	132.36		132.91	0.005344	7.79	145.79	54.46	0.62	1.33	0.77	0.70
PROP_CL	687.71	BKF	24.90	127.00	128.92		128.95	0.000719	1.43	17.45	10.49	0.19	0.06		
PROP_CL	687.71	2 YR	63.90	127.00	129.45		129.56	0.001810	2.70	26.35	25.14	0.32	0.21	0.02	0.03
PROP_CL	687.71	5 YR	148.00	127.00	130.07		130.31	0.003120	4.19	47.97	42.06	0.44	0.46	0.10	0.11
PROP_CL	687.71	10 YR	233.00	127.00	130.47		130.78	0.003885	5.11	64.92	44.61	0.50	0.65	0.18	0.23
PROP_CL	687.71	50 YR	545.00	127.00	131.25		131.90	0.006821	7.82	101.65	49.52	0.69	1.42	0.50	0.69
PROP_CL	687.71	100 YR	755.00	127.00	131.57	131.44	132.48	0.008787	9.36	118.04	51.41	0.80	1.98	0.75	1.03
PROP_CL	653.52	BKF	24.90	127.84	128.80		128.89	0.005301	2.38	10.45	15.17	0.51	0.22		
PROP_CL	653.52	2 YR	63.90	127.84	129.24		129.44	0.006918	3.63	18.39	24.39	0.62	0.45	0.05	0.05
PROP_CL	653.52	5 YR	148.00	127.84	129.66	129.61	130.11	0.010615	5.60	31.62	38.79	0.81	0.96	0.21	0.22
PROP_CL	653.52	10 YR	233.00	127.84	130.06	130.06	130.57	0.009396	6.20	50.26	51.93	0.79	1.08	0.28	0.33
PROP_CL	653.52	50 YR	545.00	127.84	130.83	130.83	131.61	0.010607	8.26	92.65	58.34	0.89	1.72	0.69	0.80
PROP_CL	653.52	100 YR	755.00	127.84	131.25	131.25	132.14	0.010575	9.09	117.51	61.29	0.91	1.98	0.87	1.02
PROP_CL	644.91	BKF	24.90	127.91	128.62	128.57	128.80	0.017599	3.41	7.29	15.36	0.87	0.52		
PROP_CL	644.91	2 YR	63.90	127.91	128.96	128.96	129.33	0.020379	4.84	13.28	19.71	1.01	0.91	0.08	0.06
PROP_CL	644.91	5 YR	148.00	127.91	129.58	129.58	130.00	0.011314	5.45	33.48	47.08	0.83	0.94	0.22	0.22
PROP_CL	644.91	10 YR	233.00	127.91	129.93	129.93	130.40	0.010309	6.07	51.81	58.48	0.82	1.07	0.31	0.34
PROP_CL	644.91	50 YR	545.00	127.91	130.64	130.64	131.35	0.011140	7.97	95.79	64.51	0.91	1.65	0.73	0.80
PROP_CL	644.91	100 YR	755.00	127.91	131.00	131.00	131.85	0.011404	8.86	119.61	66.86	0.94	1.95	0.95	1.04
PROP_CL	633.75	BKF	24.90	127.57	128.39	128.37	128.58	0.023094	3.52	7.07	17.40	0.97	0.58		
PROP_CL	633.75	2 YR	63.90	127.57	128.73	128.73	129.04	0.021234	4.42	14.57	26.93	1.00	0.80		0.06
PROP_CL	633.75	5 YR	148.00	127.57	129.22	129.22	129.60	0.013880	5.15	33.26	49.59	0.88	0.90	0.09	0.29
PROP_CL	633.75	10 YR	233.00	127.57	129.50	129.50	129.97	0.013124	5.88	48.54	57.35	0.90	1.09	0.22	0.48
PROP_CL	633.75	50 YR	545.00	127.57	130.24	130.24	130.90	0.011601	7.40	97.50	72.92	0.91	1.49	0.53	0.83
PROP_CL	633.75	100 YR	755.00	127.57	130.58	130.58	131.36	0.011672	8.22	122.81	75.53	0.93	1.75	0.76	1.02
PROP_CL	624.5	BKF	24.90	127.01	128.11	128.11	128.37	0.020132	4.11	6.24	14.53	0.96	0.71		0.07
PROP_CL	624.5	2 YR	63.90	127.01	128.57	128.57	128.86	0.014415	4.66	17.33	31.89	0.87	0.79		0.28
PROP_CL	624.5	5 YR	148.00	127.01	129.06	129.06	129.41	0.013035	5.49	36.56	68.76	0.87	0.98	0.02	0.50
PROP_CL	624.5	10 YR	233.00	127.01	129.36	129.36	129.73	0.011504	5.96	58.57	76.67	0.85	1.08	0.22	0.59
PROP_CL	624.5	50 YR	545.00	127.01	129.94	129.94	130.52	0.013184	7.92	106.23	86.80	0.96	1.70	0.68	1.01
PROP_CL	624.5	100 YR	755.00	127.01	130.46		130.96	0.008991	7.57	152.76	92.92	0.82	1.45	0.71	0.90
PROP_CL	583.81	BKF	24.90	125.00	127.97		127.97	0.000018	0.27	93.32	51.53	0.03	0.00		
PROP_CL	583.81	2 YR	63.90	125.00	128.47		128.47	0.000053	0.54	120.93	60.49	0.06	0.01	0.00	0.00
PROP_CL	583.81	5 YR	148.00	125.00	129.01		129.03	0.000137	0.99	157.15	73.73	0.10	0.02	0.00	0.00
PROP_CL	583.81	10 YR	233.00	125.00	129.37		129.40	0.000219	1.36	187.47	89.97	0.13	0.04	0.00	0.01
PROP_CL	583.81	50 YR	545.00	125.00	130.23		130.31	0.000486	2.37	268.96	100.81	0.21	0.12	0.03	0.04
PROP_CL	583.81	100 YR	755.00	125.00	130.66		130.78	0.000623	2.87	314.44	106.26	0.24	0.17	0.05	0.07
PROP_CL	562.71	BKF	24.90	125.00	127.97		127.97	0.000024	0.30	83.68	48.11	0.04	0.00		0.00
PROP_CL	562.71	2 YR	63.90	125.00	128.46		128.47	0.000068	0.59	109.71	58.04	0.07	0.01	0.00	0.00
PROP_CL	562.71	5 YR	148.00	125.00	129.01		129.02	0.000170	1.09	144.36	69.69	0.11	0.03	0.01	0.01
PROP_CL	562.71	10 YR	233.00	125.00	129.36		129.40	0.000272	1.49	169.69	72.29	0.15	0.05	0.01	0.01
PROP_CL	562.71	50 YR	545.00	125.00	130.19		130.29	0.000628	2.64	232.65	80.00	0.23	0.15	0.04	0.05
PROP_CL	562.71	100 YR	755.00	125.00	130.61		130.76	0.000825	3.24	267.01	83.36	0.27	0.22	0.06	0.09
PROP_CL	523.64	BKF	24.90	126.99	127.91		127.96	0.003203	1.84	14.56	35.81	0.39	0.13	0.02	0.00
PROP_CL	523.64	2 YR	63.90	126.99	128.39		128.46	0.002311	2.23	37.23	53.97	0.37	0.17	0.07	0.05
PROP_CL	523.64	5 YR	148.00	126.99	128.89		129.00	0.002640	3.04	67.30	66.21	0.42	0.27	0.15	0.11
PROP_CL	523.64	10 YR	233.00	126.99	129.21		129.36	0.002986	3.64	89.59	70.73	0.46	0.37	0.21	0.17
PROP_CL	523.64	50 YR	545.00	126.99	129.92		130.22	0.004398	5.41	141.70	77.23	0.58	0.73	0.45	0.41
PROP_CL	523.64	100 YR	755.00	126.99	130.28		130.67	0.004998	6.26	169.69	80.18	0.63	0.94	0.58	0.55
PROP_CL	513.13	BKF	24.90	126.93	127.66	127.66	127.88	0.023752	3.71	6.71	15.65	1.00	0.63		
PROP_CL	513.13	2 YR	63.90	126.93	128.08	128.08	128.38	0.016733	4.38	15.21	35.79	0.91	0.74	0.05	0.05
PROP_CL	513.13	5 YR	148.00	126.93	128.54	128.54	128.92	0.012519	5.27	35.87	54.11	0.86	0.91	0.24	0.30
PROP_CL	513.13	10 YR	233.00	126.93	128.88	128.88	129.28	0.010383	5.69	57.15	70.12	0.81	0.98	0.31	0.36

HEC-RAS Plan: NDF_Ex_Plan1 River: PROPOSED CL Reach: PROP_CL (Continued)

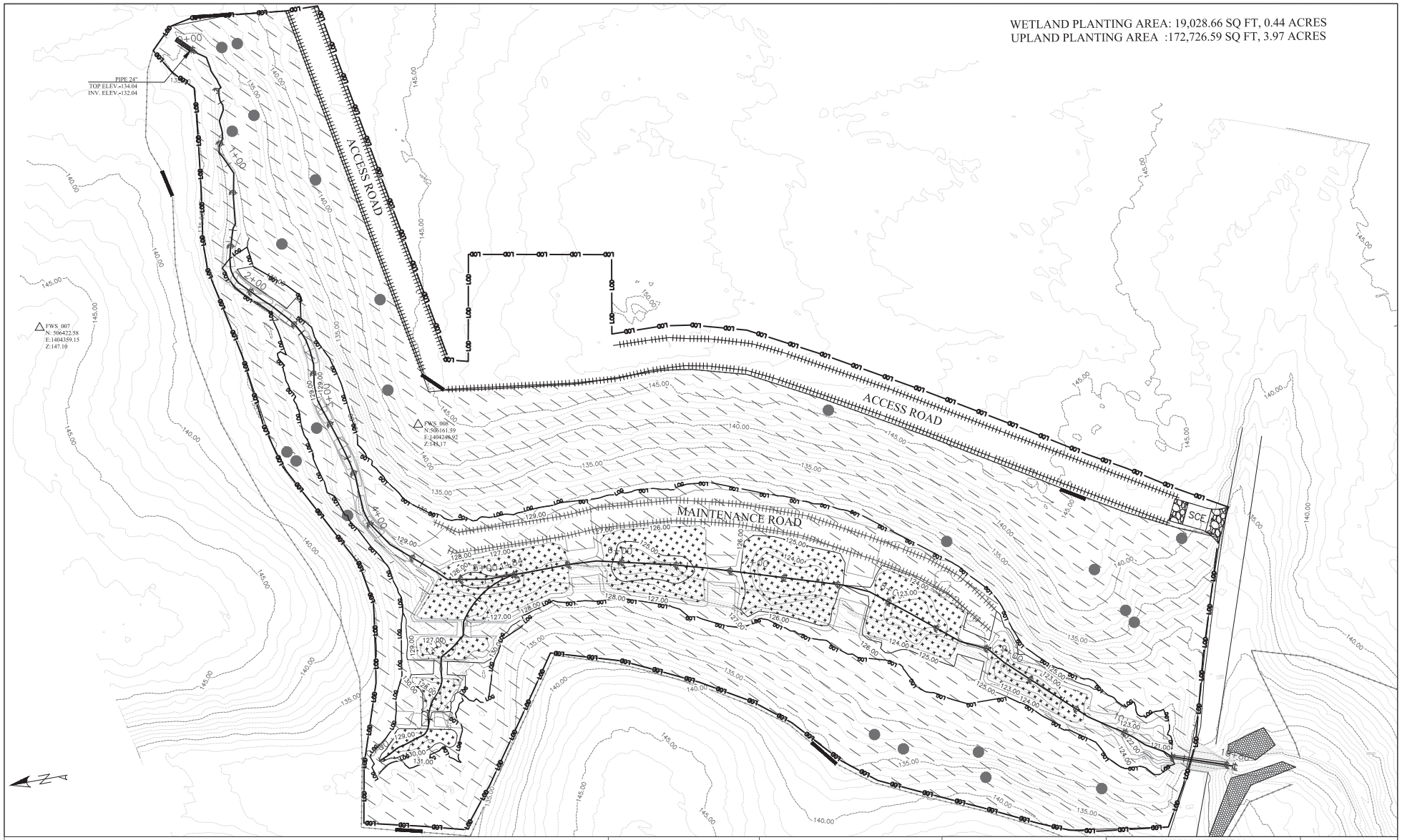
Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear LOB	Shear ROB
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
PROP_CL	513.13	50 YR	545.00	126.93	129.49	129.49	130.12	0.011947	7.63	101.62	76.65	0.92	1.57	0.71	0.81
PROP_CL	513.13	100 YR	755.00	126.93	129.81	129.81	130.56	0.012156	8.46	126.95	79.66	0.95	1.84	0.90	1.04
PROP_CL	501.78	BKF	24.90	126.56	127.29	127.29	127.52	0.023505	3.81	6.54	14.53	1.00	0.66		
PROP_CL	501.78	2 YR	63.90	126.56	127.69	127.69	127.93	0.015744	4.07	18.41	44.78	0.88	0.66	0.08	0.29
PROP_CL	501.78	5 YR	148.00	126.56	128.10	128.10	128.40	0.012649	4.99	40.34	64.90	0.85	0.84	0.34	0.31
PROP_CL	501.78	10 YR	233.00	126.56	128.32	128.32	128.71	0.013521	5.84	54.97	67.92	0.90	1.09	0.50	0.50
PROP_CL	501.78	50 YR	545.00	126.56	128.92	128.92	129.55	0.014082	7.69	97.63	73.65	0.98	1.66	0.97	0.96
PROP_CL	501.78	100 YR	755.00	126.56	129.23	129.23	130.00	0.014317	8.58	121.07	76.38	1.02	1.96	1.19	1.21
PROP_CL	464.25	BKF	24.90	123.99	126.97		126.97	0.000013	0.24	105.53	54.23	0.03	0.00		
PROP_CL	464.25	2 YR	63.90	123.99	127.36		127.37	0.000046	0.50	128.66	62.70	0.06	0.01	0.00	0.00
PROP_CL	464.25	5 YR	148.00	123.99	127.74		127.75	0.000148	0.99	153.69	71.18	0.11	0.02	0.00	0.00
PROP_CL	464.25	10 YR	233.00	123.99	128.01		128.04	0.000261	1.41	174.04	77.73	0.14	0.05	0.01	0.01
PROP_CL	464.25	50 YR	545.00	123.99	128.70		128.80	0.000672	2.60	230.28	86.12	0.24	0.15	0.03	0.04
PROP_CL	464.25	100 YR	755.00	123.99	129.04		129.19	0.000929	3.24	260.26	90.27	0.29	0.23	0.05	0.07
PROP_CL	421.21	BKF	24.90	125.94	126.90		126.96	0.004349	1.99	15.33	56.70	0.45	0.16	0.02	0.03
PROP_CL	421.21	2 YR	63.90	125.94	127.31		127.36	0.002371	2.08	45.77	83.08	0.36	0.15	0.06	0.06
PROP_CL	421.21	5 YR	148.00	125.94	127.64		127.73	0.003269	2.95	74.49	89.63	0.45	0.27	0.14	0.14
PROP_CL	421.21	10 YR	233.00	125.94	127.88		128.00	0.003852	3.57	96.46	94.19	0.50	0.38	0.20	0.22
PROP_CL	421.21	50 YR	545.00	125.94	128.48		128.72	0.005091	5.09	155.80	102.06	0.61	0.69	0.41	0.45
PROP_CL	421.21	100 YR	755.00	125.94	128.78		129.09	0.005680	5.85	186.81	105.52	0.65	0.88	0.54	0.59
PROP_CL	410.05	BKF	24.90	125.93	126.63	126.63	126.85	0.023691	3.76	6.62	15.08	1.00	0.65		
PROP_CL	410.05	2 YR	63.90	125.93	127.10	127.10	127.29	0.011036	3.69	22.63	73.47	0.75	0.52	0.03	0.12
PROP_CL	410.05	5 YR	148.00	125.93	127.39	127.39	127.65	0.012059	4.77	45.52	84.21	0.82	0.78	0.21	0.33
PROP_CL	410.05	10 YR	233.00	125.93	127.57	127.57	127.91	0.013614	5.64	61.21	88.64	0.90	1.03	0.36	0.51
PROP_CL	410.05	50 YR	545.00	125.93	128.08	128.08	128.60	0.014551	7.36	109.87	100.28	0.98	1.57	0.72	0.93
PROP_CL	410.05	100 YR	755.00	125.93	128.34	128.34	128.97	0.014899	8.17	136.02	103.32	1.02	1.84	0.93	1.16
PROP_CL	398.55	BKF	24.90	125.47	126.10	126.10	126.28	0.026146	3.45	7.21	20.14	1.02	0.58		
PROP_CL	398.55	2 YR	63.90	125.47	126.48	126.48	126.67	0.012600	3.65	22.16	71.01	0.78	0.53	0.12	0.09
PROP_CL	398.55	5 YR	148.00	125.47	126.78	126.78	127.03	0.012233	4.59	45.10	81.04	0.82	0.74	0.33	0.27
PROP_CL	398.55	10 YR	233.00	125.47	126.96	126.96	127.29	0.014159	5.52	59.64	85.06	0.91	1.01	0.53	0.43
PROP_CL	398.55	50 YR	545.00	125.47	127.71		128.07	0.008500	5.98	128.00	95.99	0.77	1.00	0.65	0.58
PROP_CL	398.55	100 YR	755.00	125.47	128.09		128.49	0.007613	6.39	165.57	100.73	0.75	1.08	0.73	0.66
PROP_CL	361.68	BKF	24.90	123.00	125.93		125.93	0.000008	0.20	126.77	61.61	0.02	0.00		
PROP_CL	361.68	2 YR	63.90	123.00	126.44		126.44	0.000026	0.40	160.63	73.24	0.04	0.00	0.00	0.00
PROP_CL	361.68	5 YR	148.00	123.00	126.85		126.86	0.000083	0.80	193.54	83.84	0.08	0.02	0.00	0.00
PROP_CL	361.68	10 YR	233.00	123.00	127.15		127.17	0.000148	1.13	218.93	89.86	0.11	0.03	0.00	0.01
PROP_CL	361.68	50 YR	545.00	123.00	127.87		127.94	0.000389	2.09	287.94	99.85	0.18	0.10	0.02	0.03
PROP_CL	361.68	100 YR	755.00	123.00	128.25		128.35	0.000531	2.60	326.76	104.85	0.22	0.14	0.03	0.05
PROP_CL	321.74	BKF	24.90	124.90	125.92		125.93	0.000954	0.84	29.66	57.77	0.21	0.03		
PROP_CL	321.74	2 YR	63.90	124.90	126.42		126.43	0.000632	1.07	61.80	71.91	0.19	0.04	0.01	0.01
PROP_CL	321.74	5 YR	148.00	124.90	126.81		126.85	0.001069	1.73	92.33	84.11	0.26	0.09	0.03	0.03
PROP_CL	321.74	10 YR	233.00	124.90	127.07		127.15	0.001410	2.23	115.75	91.40	0.31	0.15	0.05	0.05
PROP_CL	321.74	50 YR	545.00	124.90	127.72		127.89	0.002272	3.53	178.58	103.00	0.41	0.33	0.12	0.15
PROP_CL	321.74	100 YR	755.00	124.90	128.06		128.30	0.002591	4.14	214.76	108.52	0.45	0.43	0.16	0.21
PROP_CL	310.79	BKF	24.90	124.96	125.66	125.66	125.88	0.024192	3.78	6.58	15.09	1.01	0.66		
PROP_CL	310.79	2 YR	63.90	124.96	126.15	126.15	126.39	0.012142	3.98	18.39	60.41	0.79	0.60	0.06	0.04
PROP_CL	310.79	5 YR	148.00	124.96	126.51	126.51	126.80	0.011296	4.91	43.23	76.41	0.81	0.80	0.27	0.24
PROP_CL	310.79	10 YR	233.00	124.96	126.73	126.73	127.08	0.011712	5.64	61.27	83.88	0.85	0.99	0.41	0.37
PROP_CL	310.79	50 YR	545.00	124.96	127.29	127.29	127.81	0.012555	7.33	112.47	97.93	0.93	1.50	0.76	0.73
PROP_CL	310.79	100 YR	755.00	124.96	127.76		128.22	0.008721	7.07	160.70	105.60	0.80	1.30	0.72	0.71
PROP_CL	299.67	BKF	24.90	124.68	125.33	125.33	125.53	0.024112	3.66	6.80	16.36	1.00	0.62		
PROP_CL	299.67	2 YR	63.90	124.68	125.71	125.71	125.92	0.015664	3.83	19.62	54.20	0.86	0.60	0.19	0.00
PROP_CL	299.67	5 YR	148.00	124.68	126.04	126.04	126.33	0.013987	4.83	40.20	74.15	0.87	0.82	0.43	0.16
PROP_CL	299.67	10 YR	233.00	124.68	126.25	126.25	126.62	0.014288	5.59	56.70	79.26	0.91	1.03	0.57	0.34
PROP_CL	299.67	50 YR	545.00	124.68	127.22		127.52	0.005852	5.36	143.85	99.00	0.65	0.78	0.47	0.43
PROP_CL	299.67	100 YR	755.00	124.68	127.84		128.10	0.003919	5.20	207.89	109.37	0.55	0.67	0.40	0.40
PROP_CL	261.49	BKF	24.90	122.00	125.14		125.14	0.000006	0.19	128.20	55.54	0.02	0.00	0.00	0.00
PROP_CL	261.49	2 YR	63.90	122.00	125.53		125.54	0.000025	0.43	152.68	68.46	0.04	0.00	0.00	0.00
PROP_CL	261.49	5 YR	148.00	122.00	125.97		125.98	0.000083	0.85	185.44	83.78	0.08	0.02	0.00	0.00
PROP_CL	261.49	10 YR	233.00	122.00	126.28		126.30	0.000147	1.21	213.03	90.66	0.11	0.03	0.01	0.01
PROP_CL	261.49	50 YR	545.00	122.00	127.36		127.42	0.000294	2.03	322.23	111.91	0.16	0.09	0.02	0.03
PROP_CL	261.49	100 YR	755.00	122.00	127.93		128.01	0.000352	2.39	388.85	118.83	0.18	0.11	0.03	0.04
PROP_CL	224.58	BKF	24.90	124.08	125.11		125.13	0.003049	1.28	19.42	47.85	0.35	0.08		
PROP_CL	224.58	2 YR	63.90	124.08	125.49		125.53	0.002266	1.59	41.05	65.60	0.33	0.10	0.02	0.00
PROP_CL	224.58	5 YR	148.00	124.08	125.88		125.96	0.002565	2.28	70.43	83.79	0.38	0.17	0.06	0.04
PROP_CL	224.58	10 YR	233.00	124.08	126.17		126.28	0.002691	2.73	95.98	91.54	0.41	0.23	0.09	0.07
PROP_CL	224.58	50 YR	545.00	124.08	127.25		127.39	0.001687	3.17	203.09	105.87	0.36	0.26	0.13	0.14
PROP_CL	224.58	100 YR	755.00	124.08	127.83		127.98	0.001461	3.40	265.91	111.07	0.34	0.28	0.15	0.16
PROP_CL	214.11	BKF	24.90	123.99	124.84	124.82	125.05	0.020963	3.64	6.83	14.85	0.95	0.60		
PROP_CL	214.11	2 YR	63.90	123.99	125.27	125.27	125.47	0.011010	3.84	22.13	56.57	0.75	0.55	0.15	0.13
PROP_CL	214.11	5 YR	148.00	123.99	125.58	125.58	125.89	0.013156	5.20	41.35	69.14	0.87	0.91	0.35	0.35
PROP_CL	214.11	10 YR	233.00	123.99	125.97		126.22	0.007972	4.95	71.54	84.55	0.71	0.74	0.34	0.33
PROP_CL	214.11	50 YR	545.00	123.99	127.19		127.36	0.002817	4.37	184.42	99.56	0.47	0.48	0.28	0.31
PROP_CL	214.11	100 YR	755.00	123.99	127.78		127.96	0.002337	4.54	245.02	105.84	0.44	0.48	0.29	0.33
PROP_CL	202.83	BKF	24.90	123.80	124.56	124.56	124.80	0.023305	3.95	6.31	13.16	1.00	0.69		
PROP_CL	202.83	2 YR	63.90	123.80	124.97	124.97	125.24	0.014737	4.41	18.44	44.72	0.87	0.73	0.22	0.14
PROP_CL	202.83	5 YR	148.00	123.80	125.38	125.35	125.67	0.011479	5.13	42.21	63.77	0.82	0.86	0.36	0.33
PROP_CL	202.83	10 YR	233.00	123.80	125.95		126.13	0.004673	4.24	82.44	76.36	0.56	0.51	0.25	0.27
PROP_CL	202.83	50 YR	545.00	123.80	127.15		127.33	0.002674	4.51	181.56	92.94	0.46	0.49	0.27	0.32
PROP_CL	202.83	100 YR	755.00	123.80	127.73		127.93	0.002370	4.79	238.58	101.41	0.45	0.52	0.29	0.35
PROP_CL	162.59	BKF	24.90	121.00	124.29		124.30	0.000047	0.44	56.44	29.28	0.06	0.01		

HEC-RAS Plan: NDF_Ex_Plan1 River: PROPOSED CL Reach: PROP_CL (Continued)

Reach	River Sta	Profile	Q Total	Min Ch El	W.S. Elev	Crit W.S.	E.G. Elev	E.G. Slope	Vel Chnl	Flow Area	Top Width	Froude # Chl	Shear Chan	Shear LOB	Shear ROB
			(cfs)	(ft)	(ft)	(ft)	(ft)	(ft/ft)	(ft/s)	(sq ft)	(ft)		(lb/sq ft)	(lb/sq ft)	(lb/sq ft)
PROP_CL	162.59	2 YR	63.90	121.00	124.81		124.83	0.000153	0.88	72.51	32.43	0.10	0.02		
PROP_CL	162.59	5 YR	148.00	121.00	125.52		125.55	0.000334	1.53	99.07	45.24	0.16	0.06	0.01	0.01
PROP_CL	162.59	10 YR	233.00	121.00	125.99		126.05	0.000483	2.04	122.72	55.82	0.20	0.10	0.01	0.01
PROP_CL	162.59	50 YR	545.00	121.00	127.11		127.26	0.000870	3.32	193.66	69.81	0.28	0.23	0.07	0.05
PROP_CL	162.59	100 YR	755.00	121.00	127.65		127.87	0.001047	3.94	233.30	74.78	0.31	0.32	0.11	0.08
PROP_CL	114.15	BKF	24.90	123.18	124.21		124.28	0.008099	2.11	11.78	28.48	0.58	0.21		
PROP_CL	114.15	2 YR	63.90	123.18	124.71		124.80	0.003899	2.38	27.15	33.03	0.45	0.21		0.05
PROP_CL	114.15	5 YR	148.00	123.18	125.37		125.51	0.003023	3.01	51.23	41.00	0.44	0.28	0.03	0.09
PROP_CL	114.15	10 YR	233.00	123.18	125.80		125.99	0.003067	3.59	70.03	46.96	0.46	0.36	0.08	0.13
PROP_CL	114.15	50 YR	545.00	123.18	126.79		127.17	0.003572	5.13	123.35	59.81	0.53	0.64	0.20	0.27
PROP_CL	114.15	100 YR	755.00	123.18	127.28		127.76	0.003774	5.85	154.07	65.24	0.56	0.79	0.28	0.35
PROP_CL	104.15	BKF	24.90	123.04	123.89	123.89	124.13	0.023794	3.94	6.32	13.43	1.01	0.69		
PROP_CL	104.15	2 YR	63.90	123.04	124.33	124.33	124.70	0.016940	4.95	13.76	21.65	0.94	0.90	0.17	0.17
PROP_CL	104.15	5 YR	148.00	123.04	124.91	124.91	125.42	0.012668	6.06	30.02	34.05	0.89	1.13	0.36	0.36
PROP_CL	104.15	10 YR	233.00	123.04	125.31	125.31	125.90	0.011368	6.76	45.31	41.47	0.88	1.30	0.45	0.49
PROP_CL	104.15	50 YR	545.00	123.04	126.24	126.24	127.06	0.010589	8.57	90.19	54.35	0.91	1.82	0.71	0.90
PROP_CL	104.15	100 YR	755.00	123.04	126.67	126.67	127.65	0.010906	9.56	114.40	60.02	0.94	2.16	0.85	1.14
PROP_CL	92.92	BKF	24.90	122.56	123.51	123.51	123.78	0.023061	4.21	5.92	11.02	1.01	0.76		
PROP_CL	92.92	2 YR	63.90	122.56	123.99	123.99	124.40	0.020124	5.14	12.44	15.51	1.01	0.99		
PROP_CL	92.92	5 YR	148.00	122.56	124.67	124.67	125.21	0.012558	6.08	28.14	31.83	0.88	1.13	0.25	0.26
PROP_CL	92.92	10 YR	233.00	122.56	125.13	125.13	125.71	0.010167	6.57	45.69	42.93	0.83	1.21	0.37	0.34
PROP_CL	92.92	50 YR	545.00	122.56	126.08	126.08	126.86	0.009554	8.29	94.59	60.22	0.86	1.69	0.75	0.57
PROP_CL	92.92	100 YR	755.00	122.56	126.50	126.50	127.41	0.009645	9.13	121.18	64.68	0.88	1.95	0.92	0.77
PROP_CL	65.93	BKF	24.90	120.88	122.16	121.73	122.24	0.004001	2.26	11.02	13.76	0.44	0.19		
PROP_CL	65.93	2 YR	63.90	120.88	122.79	122.25	122.94	0.004002	3.10	20.90	17.86	0.48	0.31	0.01	0.05
PROP_CL	65.93	5 YR	148.00	120.88	123.59	122.89	123.86	0.004002	4.27	37.43	23.38	0.52	0.50	0.10	0.14
PROP_CL	65.93	10 YR	233.00	120.88	124.19	123.40	124.56	0.004000	5.05	52.88	29.38	0.54	0.64	0.14	0.20
PROP_CL	65.93	50 YR	545.00	120.88	125.60	124.83	126.17	0.004001	6.68	108.47	48.43	0.58	0.98	0.26	0.37
PROP_CL	65.93	100 YR	755.00	120.88	126.29	125.47	126.95	0.004000	7.41	146.89	63.68	0.60	1.15	0.32	0.39

APPENDIX M

Proposed Planting Plan



Professional Certification
I hereby certify that these document were prepared or approved by me, and that I am a duly licensed professional engineer under the laws of the State of Maryland, License No. 20346, Expiration Date: 2017-01-21

(Signature) (Date)

STATE OF MARYLAND
BRIAN HOLLAND
No. 20346
PROFESSIONAL ENGINEER

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U.S. FISH & WILDLIFE SERVICE

U.S. Fish & Wildlife Service
Chesapeake Bay Field Office
Stream Habitat Assessment and Restoration Program

177 Admiral Cochrane Drive
Annapolis, Maryland 21401

Tel. (410) 573-4581

NAVY DAIRY FARM
ANNE ARUNDEL CO, MD

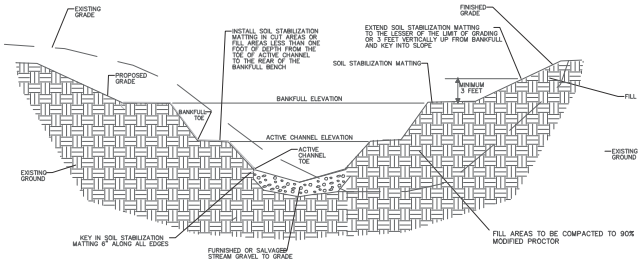
REVISIONS		
DATE	BY	

PLANTING PLAN

PROJECT MANAGER: BH	DRAFTING: CAC
DESIGN: BH	CHECKED BY: KM
DATE: 02/11/2016	SCALE: AS SHOWN

SHEET
11 of 12

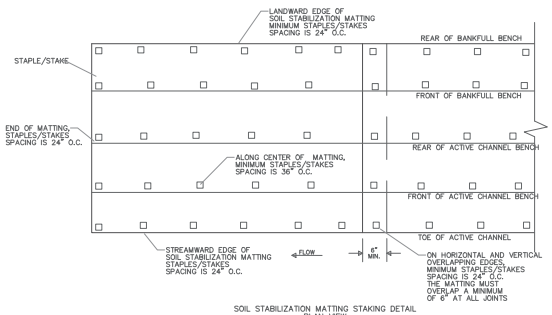
PP - 1



USE OF SOIL STABILIZATION
CROSS SECTION VIEW
NOT TO SCALE

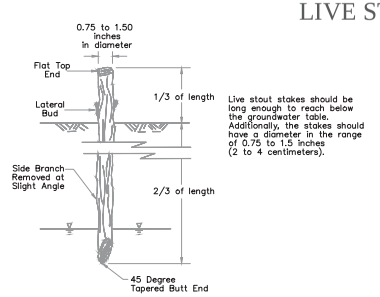
SOIL STABILIZATION MAT STAKING NOTES:

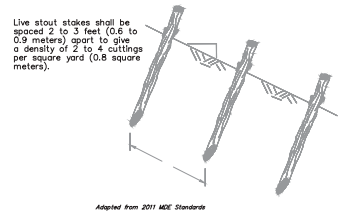
1. AT A MINIMUM, THE MATTING MUST BE STAPLED/STAKED AT THE:
   - ACTIVE CHANNEL TOE
   - FRONT OF THE ACTIVE CHANNEL BENCH
   - REAR OF THE ACTIVE CHANNEL BENCH
   - FRONT OF THE BANKFULL BENCH
   - REAR OF THE BANKFULL BENCH
2. THE 36" O.C. SPACING FOR THE CENTER OF THE MATTING MUST ALSO BE MAINTAINED



SOIL STABILIZATION MATTING STAKING DETAIL
PLAN VIEW
NOT TO SCALE

LIVE STAKES





POOL PLANTING				
BOTANICAL NAME	**COMMON NAME**	**ITEM**	**AMOUNT**	**SPACING**
Herbaceous				
Andropogan virginicus	Broomsedge		150	2'
Aster novae-angliae	New England aster		150	2'
Eupatorium purpureum	Joe-pye weed		150	2'
Iris veriscolor	Blue Flag		75	2'
Juncus effusus	Soft rush		100	2'
Panicum virgatum	Switchgrass		25	2'
Vernonia noveborecensis	New York Ironweed		100	2'
This will cover 50% of areas between 0' and 1' pool depth. All areas to be seeded with temp seed mix.				
Shrubs				
Ilex, laevigata	Winterberry		15	12'
Cornus amomum	Silky dogwood		15	12'
Clethra alnifolia	Sweet pepperbush		10	12'
Morella cerifera	Wax myrtle		25	12'
Sambucus canadensis	Elderberry		15	12'
Viburnum dentatum	Arrowood viburnum		50	12'
The pool area plant list will be adjusted based on the observation the duration/depth of ponding and soil saturation, post contruction				

UPLAND PLANTING				
BOTANICAL NAME	**COMMON NAME**	**ITEM**	**AMOUNT**	**SPACING**
Tree				
Amelanchier canadensis	Shadbush		75	60'
Betula nigra	River Birch		100	60'
Diospyros virginiana	Persimmon		25	60'
Liriondendron tulipifera	Tulip poplar		100	60'
Quercus falcata	Southern Red Oak		150	60'
Quercus palustris	Pin Oak		150	60'
Quercus prinus	Chestnut oak		150	60'

LIVE STAKE PLANTING				
BOTANICAL NAME	**COMMON NAME**	**LENGTH**	**AMOUNT**	**SPACING**
Tree				
Betula nigra	River Birch	2' MIN	25	6'
Cephalanthus occidentalis	Buttonbush	2' MIN	25	6'
Cornus amomum	Silky Dogwood	2' MIN	25	6'
Cornus stolonifera	Red Osier Dogwood	2' MIN	25	6'
Salix Nigra	Black Willow	2' MIN	50	6'

Professional Certification
I hereby certify that these document were prepared or approved by me, and that I am a duly licensed professional engineer under the laws of the State of Maryland, License No. 20346, Expiration Date: 201 7-01-27

(Signature) (Date)

STATE OF MARYLAND BRIAN HOLDER 20346 PROFESSIONAL ENGINEER

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U.S. FISH & WILDLIFE SERVICE

U.S. Fish & Wildlife Service
Chesapeake Bay Field Office
Stream Habitat Assessment and Restoration Program

177 Admiral Cochrane Drive
Annapolis, Maryland 21401

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NAVY DAIRY FARM
ANNE ARUNDEL CO, MD

REVISIONS DATE	BY	PLANTING PLAN	
		PROJECT MANAGER: BH	DRAFTING: CAC
		DESIGN: BH	CHECKED BY: KM
		DATE: 02/11/2016	SCALE: AS SHOWN

SHEET
12 of 12

PP - 2

APPENDIX N

Function-based Stream Restoration Project Process Review Checklist

Function-based Stream Restoration Project Process Review Checklist

Function-based Stream Restoration Project Process Review Checklist

Reviewer: _____

Date: _____

Project: Navy Dairy Farm Stream Restoration - USFWS

Assessor: _____

Item	Submitted (Y/N)	Acceptable (Y/N)	Page #	Comments
1.0 Programmatic Goals				
1.0a Are the project purpose and need(s) described?			6	
1.0b Does the project have clear programmatic goals?			6	
2.0 Site Selection				
2.0a Was a description/rationale provided stating how the site was selected?			1	
2.0b Was some level of assessment completed to justify the site selection?			1	
2.0c Did the assessment(s) accurately document watershed and reach conditions?			1	
2.0d Have project goals been developed based on the site selection assessment?			6	
2.0e Are the project goals appropriate for the site?			6	
2.0f Have watershed and reach level assessment parameters been identified for the detailed function-based assessments?			5	
2.0g Are the watershed and reach level assessment parameters appropriate to determine whether the proposed site will meet project goals?			6	
2.0h Overall site selection comments.				
3.0 Watershed Assessment				
3.0a Was the watershed assessment methodology described?			3-5	
3.0b Did the watershed assessment accurately document the existing and potential future health of the watershed?			6-8, 13-14	
3.0c Did the watershed assessment accurately describe the existing and potential future influence of the watershed on the proposed site?			6-8, 13-14	
3.0d Overall watershed assessment comments.				
4.0 Reach Level Function-based Assessment				
4.0a Was the reach level assessment methodology described?			3,4,6	
4.0b Were the measurement methods appropriate to document exsiting conditions?			9-12	

Function-based Stream Restoration Project Process Review Checklist

Item	Submitted (Y/N)	Acceptable (Y/N)	Page #	Comments
4.0c Did the reach level assessment accurately document the existing and potential future "without-project" function-based conditions?			9-12	
4.0d Did the reach level assessment accurately identify the "cause and effect" relationship(s) of the reach level conditions?			9-12	
4.0e Did the reach level assessment determine channel evolution?			13	
4.0f Overall reach level assessment comments.				
5.0 Restoration Potential and Constraint Analysis				
5.0a Was the restoration potential described?			14-15	
5.0b Was the restoration potential based on the results of the watershed and reach level assessments and constraints analysis?			14-15	
5.0c Did the restoration potential accurately identify which impaired functions can be restored and not restored?			14-15	
5.0d Did the restoration potential determine whether the site can still meet the project goals and if not, describe how the project will proceed?			14-15	
5.0e Was a constraints analysis completed?			13	
5.0f Did the constraints analysis accurately identify constraints and stressors?			13	
5.0g Overall restoration potential comments.				
6.0 Design Objectives				
6.0a Were design objectives provided?			15	
6.0b Were design objectives developed based on the restoration potential?			15	
6.0c Are the design objectives quantifiable and measurable?			15	
6.0d Are the design objectives appropriate and achievable for the site?			15	
6.0e Do the design objectives meet the project goals and if not, is it described how the project will proceed?			15	
6.0f Overall design objectives comments.				
7.0 Design Alternatives Analysis				

Function-based Stream Restoration Project Process Review Checklist

Item	Submitted (Y/N)	Acceptable (Y/N)	Page #	Comments
7.0a Was a design alternatives analysis performed?			16-17	
7.0b Did the alternatives analysis evaluate appropriate design solutions that could meet project goals and deisgn objectives?			16-17	
7.0c Were the alternatives analysis screening criteria provided and based on the results of the restoration potential, project goals and deisgn objectives?			16-17	
7.0d Did the alternatives analysis accurately document potential uplift and impacts (including access and construction impacts)?			16-17	
7.0e If there are potential project impacts, is there a description on how the impacts will be addressed?			16-17	
7.0f Was the most appropriate alternative selected based on the screening criteria?			16-17	
7.0g Overall design alternatives analysis comments.				
8.0 Design Development				
8.0a Were design criteria provided and explained in ralation to the project goals and design objectives?			18-22	
8.0b Does the final plan set met the project goals and design objectives			12-22 & 28-33	
9.0 Monitoring Plan				
8.0a Was a monitoring plan provided?			33	
8.0b Does it state who is required to conduct the monitoring?			33	
8.0c Does it have measurable and quantifiable performance standards?			33	
8.0c Are the performance standards based on the project goals and objectives?			33	
8.0d Is the monitoring period and frequency appropriate based on the time required for uplift to occur?				
10.0 Overall Assessment Review				
9.0a Does the project assessment address the project goals and objectives?				
9.0b Are there any assessment components that are missing or could adversely affect the success of the project?				
9.0c Does the project have a high potential for success?				

APPENDIX O

Natural Channel Design Review Checklist

NATURAL CHANNEL DESIGN REVIEW CHECKLIST

Project Design Checklist **Reviewer:** _____
Date: _____

Project: Navy Dairy Farm Stream Restoration Reach 1 (USFWS)
Engineer: _____

Item	Submitted (Y/N/P)	Acceptable (Y/N/P)	Page #	Comments
1.0 Basemapping and Hydraulic Assessment				
1.1 Basemapping				
1.1a Does the project include basemapping?			8 & plan set 3	
1.2 Hydraulic Assessment				
1.2a Was the project drainage area provided?			6	
1.2b Was a hydraulic assessment completed?			28-32 & App K & L	
1.2c Was stream velocity, shear stress and stream power shown in relation to stage and discharge?			28-32 & App K & L	
1.3 Bankfull Verification				
1.3a Were bankfull verification analyses completed?			28-30	
1.3b Were USGS gages or regional curves used to validate bankfull discharge and cross sectional area?			28-30	
1.3c If a regional curve was used, were the curve data representative of the project data?			28-30	
1.3d If gages or regional curves were not available, were other methods, such as hydrology and hydraulic models used?			28-31	
2.0 Preliminary Design				
2.1 Sediment Transport				
2.1a Did the sediment transport analysis include an evaluation of sediment supply (i.e., sediment supply amount and source(s))?			32	
2.1b Was a model used to calculate sediment transport described, including assumptions and applicability to project reach conditions?			7 & 32 & App C	
2.1c Was SAM, HEC-RAS modelling or other tools used to determine stable channel and floodplain dimensions based on sediment transport and/or resistance to shear stress?			28-32 & App C, K, L	
2.1d Was a sediment transport analysis completed upstream (supply) and within project reach using a range of sediment transport rates?			7 & 32 & App C	
2.1e Was sediment transport measured?				Measurement of sediment transport was not since the only source was associated with surface runoff
2.1f Were multiple discharges used to evaluate channel and floodplain stability?			28-32 & App C, K, L	
2.1g Did the sediment analysis show the potential for the stream channel and floodplain to aggrade or degrade after analyzing multiple discharges?			28-32	
2.1h If the reach has a sediment supply, does the design state how it will be addressed?			32	

Project Design Checklist **Reviewer:** _____
Date: _____

Project: Navy Dairy Farm Stream Restoration Reach 1 (USFWS)
Engineer: _____

Item	Submitted (Y/N/P)	Acceptable (Y/N/P)	Page #	Comments
2.2 Goals and Restoration Potential				
2.2a Does the project have clear goals and measurable objectives?			6 & 15	
2.2b Was the restoration potential based on the assessment data provided?			13-14	
2.2c Was a restoration strategy developed and explained based on the restoration potential?			16-23	
2.3 Design Criteria				
2.3a Were design criteria provided and explained?			19-22	
2.3b Were multiple methods used to prepare design criteria?			19-22	
2.3c Are the design criteria appropriate given the site conditions and restoration potential?			19-22	
2.4 Conceptual Design				
2.4a Was the conceptual channel alignment provided and developed within the design criteria?			N/A	
2.4b Were typical bankfull cross sections provided and developed within the design criteria?			N/A	
2.4c Were typical drawings of in-stream structures provided and their use and location explained?			N/A	
2.4d Was a draft planting plan provided?				
2.4e Overall Conceptual Design Comment(s)				
3.0 Final Design				
3.1 Natural Channel Design				
3.1a Was a proposed channel alignment provided and developed within the design criteria?			N/A	Rosgen B4c does not required planform design criteria
3.1b Were proposed channel dimensions provided and developed within the design criteria?			plan set 6	
3.1c Do the proposed channel dimensions show the adjacent floodplain or flood prone area?			plan set 4 & 6	only typicals are should. Limts of grading are shown.
3.1d Was a proposed channel profile provided and developed within the design criteria?			plan set 5	
3.1e If there is limited to no sediment supply, was an analysis done to show that the stream bed would not degrade during multiple flood flows?			30-32 & App K & L	
3.1f Did project constraints like right-of-ways or flood control requirements affect the width/depth/slope section? If so, was the risk of instability described?			13 & 23	
3.1g Will the project tie-ins have no change to upstream and downstream existing stability conditions?			23-27	
3.1h Were specifications for materials and construction procedures provided and explained for the project (i.e., in-stream structures and erosion control measures)?				Plan Specifications Report

Project Design Checklist

Reviewer: _____
Date: _____

Project: Navy Dairy Farm Stream Restoration Reach 1 (USFWS)
Engineer: _____

Item	Submitted (Y/N/P)	Acceptable (Y/N/P)	Page #	Comments
3.2 In-Stream Structures				
3.2a Based on the assessment and design, were in-stream structures necessary for lateral stability?			23-27	
3.2b Based on the assessment and design, were in-stream structures needed for vertical stability?			23-27	
3.2c If needed, was the reason for their location and use explained?			23-27	
3.2d Will the in-stream structures provide the intended stability?			23-27	
3.2e Were in-stream structures (or changes to geometry) needed to provide stability at tie-in locations with the existing channel?			23-27	
3.2f Were detail drawings provided for each type of in-stream structure?				
3.3 Vegetation Design				
3.3a Was a vegetation design provided?			33	
3.3b Does the design address the use of permanent vegetation for long term stability?			33	
3.3c Overall Final Design Comment(s)				
4.0 Overall Design Review				
4.0a Does the design address the project goals and objectives?				
4.0b Are there any design components that are missing or could adversely affect the success of the project?				
4.0c Does the project have a high potential for success?				

APPENDIX P

Regenerative Storm Conveyance Design Review Checklist

REGENERATIVE STORM CONVEYANCE DESIGN REVIEW CHECKLIST

Project Design Checklist **Reviewer:** _____
Date: _____

Project: Navy Dairy Farm Stream Restoration Reach 2 (USFWS)
Engineer: _____

Item	Submitted (Y/N/P)	Acceptable (Y/N/P)	Page #	Comments
1.0 Basemapping and Hydraulic Assessment				
1.1 Basemapping				
1.1a Does the project include basemapping?			8 & plan set 3	
1.2 Hydraulic Assessment				
1.2a Was the project drainage area provided?			6	
1.2b Was a hydraulic assessment completed?			28-32 & App K & L	
1.2c Was stream velocity, shear stress and stream power shown in relation to stage and discharge?			28-32 & App K & L	
2.0 Preliminary Design				
2.1 Sediment Transport				
2.1a Did the sediment transport analysis include an evaluation of sediment supply (i.e., sediment supply amount and source(s))?			32	
2.1b Was a model used to calculate sediment transport described, including assumptions and applicability to project reach conditions?			7 & 32 & App C	
2.1c Was SAM, HEC-RAS, 2-D modelling or other tools used to determine stable channel and floodplain dimensions based on sediment transport and/or resistance to shear stress?			28-32 & App C, K, L	
2.1d Was a sediment transport analysis completed upstream (supply) and within project reach using a range of sediment transport rates?			7 & 32 & App C	
2.1e Was sediment transport measured?				Measurement of sediment transport was not since the only source was associated with surface runoff
2.1f Were multiple discharges used to evaluate channel and floodplain stability?			28-32 & App C, K, L	
2.1g Did the sediment analysis show the potential for the stream channel and floodplain to aggrade or degrade after analyzing multiple discharges?			28-32	
2.1h If the reach has a sediment supply, does the design state how it will be addressed?			32	
2.2 Goals and Restoration Potential				
2.2a Is the proposed design approach appropriate given the size of the DA?			6, 16-17	
2.2b Does the project have clear goals and measurable objectives?			6 & 15	
2.2c Was the restoration potential based on the assessment data provided?			13-14	
2.2d Was a restoration strategy developed and explained based on the restoration potential?			16-23	

Item	Submitted (Y/N/P)	Acceptable (Y/N/P)	Page #	Comments
2.3 Design Criteria				
2.3a Were design criteria provided and explained?			19 & 22	
2.3b Was the method used to determine riffle and/or weir widths and depths described?			19 & 30-31 & App K & L	
2.3c Were fluvial geomorphic principles used to select the dependent variable, e.g., width?			19 & 30-31	
2.3d Were hydrology and hydraulic models used to determine the riffle and/or weir design width, depth and slope?			28-31	
2.3e Was the method used to determine cascade height (if part of design) described?			23	
2.3f Was design criteria for sand seepage berms (if part of design) provided?			N/A	no sand berms proposed
2.3g Were hydrology and hydraulic models used to determine and test stability of berm heights and widths (if part of design)?			N/A	no sand berms proposed
2.3h Were the methods used to design the plan form and bed forms described?			N/A	SISD does not require plan and bed form design criteria
2.3i Was the design discharge compared to bankfull discharge from appropriate regional curve?			28-30	
2.3j Were any other design criteria provided and explained?			22	
2.3k Are the design criteria appropriate given the site conditions and restoration potential?			22	
2.4 Conceptual Design				
2.4a Was the conceptual channel alignment provided and developed within the design width and slope range and follow the natural drainage path of the valley?			N/A	
2.4b Were typical riffle, weir and floodplain cross sections provided and developed within the design width, depth and slope ranges?			N/A	
2.4c Were typical cascade drawings provided and developed within the design criteria?			N/A	
2.4d Were typical berm height and width cross sections and profiles provided and within the design criteria?			N/A	
2.4e Were typical drawings of in-stream and floodplain structures provided and their use and location explained?			N/A	
2.4f Was a draft planting plan provided?				
2.4g Overall Conceptual Design Comment(s)				
3.0 Final Design				
3.1 RSC Restoration Design				
3.1a Were final cross sections, profile and planform provided?			plan set 4, 5, 7	
3.1b Was the rationale for selecting a final riffle and/or weir width, depth and slope combinations provided and within the design criteria?			30-32 & App K & L	
3.1c Does the final riffle and/or weir width, depth and slope convey the design year storm?			30-32	
3.1d Does the final design provide adequate storage volume for the design year storm event?			30-32	
3.1e Are the d_0 cobble size of the riffle and/or weir adequate to accommodate the design year storm velocities and shear stress?			30-32	

Item	Submitted (Y/N/P)	Acceptable (Y/N/P)	Page #	Comments
3.1f Are the boulders forming the riffle and/or weir 3 - 4 times larger than the calculated riffle d_0?			plan set 7	
3.1g Were potential pool scour depth provided and are weir and/or cascade footers 2 feet below the potential scour?			plan set 5 & 7	
3.1h If potential pool scour depths are greater than 2 feet below footers, are the pools lined with boulders?			N/A	
3.1i Were final berm (if part of design) drawings and specifications provided and within the design criteria?			N/A	no sand berms are proposed
3.1j Was the rationale for providing a final project alignment provided and within the design criteria?			N/A	SISD does not require plan form design criteria
3.1k Will the project tie-ins have no change to upstream and downstream existing stability conditions?			28-30 & plan set 4 & 5	
3.1l Did project constraints like right-of-ways or flood control requirements affect the channel width/depth/slope section? If so, was the risk of instability described?			13-23	
3.1m Were specifications for materials and construction procedures provided and explained for the project (i.e., in-stream structures and erosion control measures)?			Plan Specifications Report	
3.2 In-Stream and Floodplain Structures				
3.2a Based on the assessment and design, were in-stream structures necessary for lateral stability?			23-27	
3.2b Based on the assessment and design, were in-stream structures needed for vertical stability?			23-27	
3.2c If needed, was the reason for their location and use explained?			23-27	
3.2d Will the in-stream structures provide the intended stability?			23-27	
3.2e Were in-stream structures (or changes to geometry) needed to provide stability at tie-in locations with the existing channel?			23-27	
3.2f Were detail drawings provided for each type of in-stream and/or floodplain structure?			plan set 7	
3.3 Vegetation Design				
3.3a Was a vegetation design provided?			33	
3.3b Does the design address the use of permanent vegetation for long term stability?			33	
3.3c Overall Final Design Comment(s)				
4.0 Overall Design Review				
4.0a Does the design address the project goals and objectives?				
4.0b Are there any design components that are missing or could adversely affect the success of the project?				
4.0c Does the project have a high potential for success?				