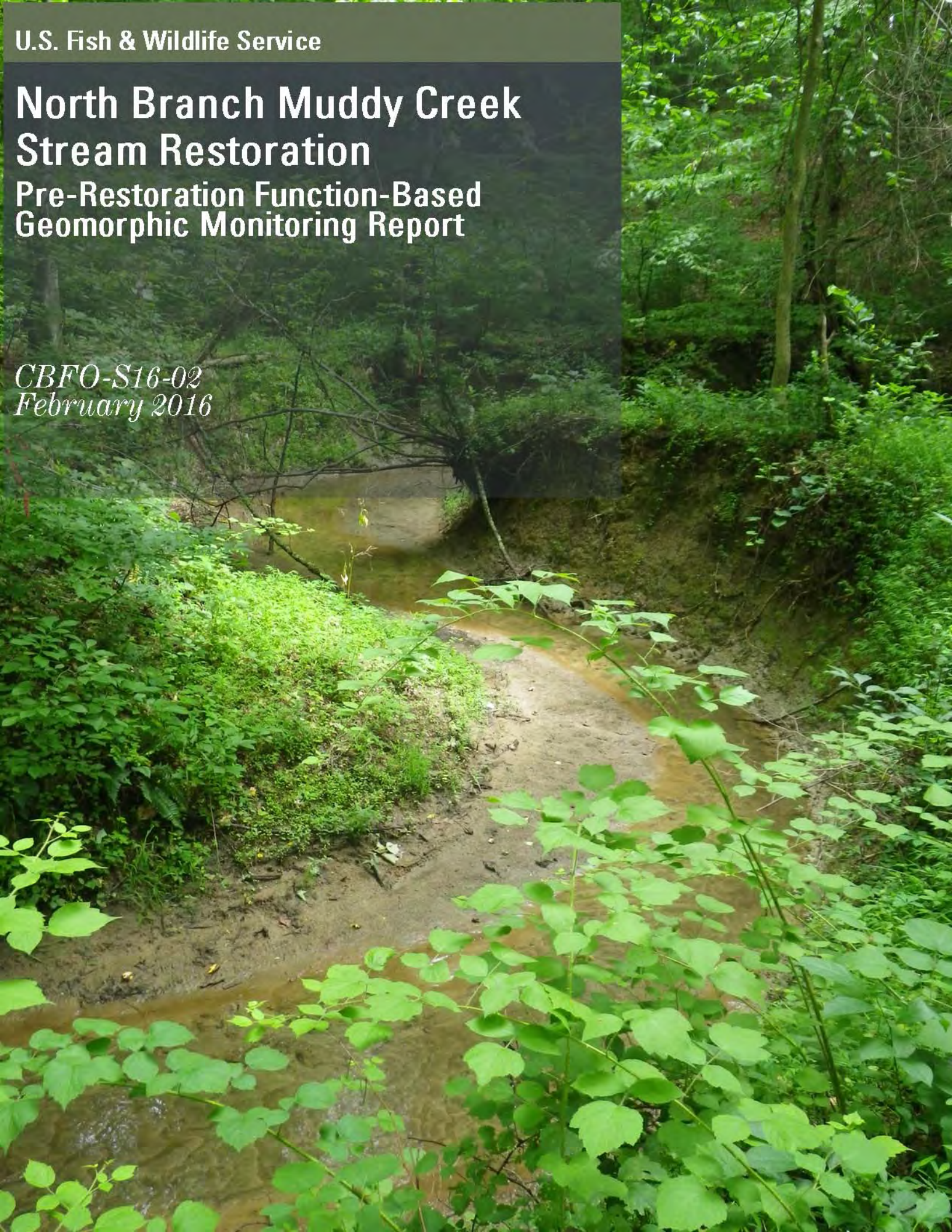
U.S. Fish & Wildlife Service

North Branch Muddy Creek Stream Restoration

Pre-Restoration Function-Based Geomorphic Monitoring Report

CBFO-S16-02
February 2016



NORTH BRANCH MUDDY CREEK STREAM RESTORATION: PRE-RESTORATION FUNCTION-BASED GEOMORPHIC MONITORING REPORT

By: Richard R. Starr and Kathleen Cullen

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

CBFO – S16 - 02

Annapolis, MD
February 2016

TABLE OF CONTENTS

LIST OF FIGURES AND TABLES

APPENDICES

Appendix A. North Muddy Creek Function-Based Assessment Monitoring Table

I. INTRODUCTION

The U.S. Fish and Wildlife Service (USFWS), Maryland Department of Natural Resources (MD DNR), and Smithsonian Environmental Research Center (SERC) have entered into a partnership to monitor various physical, chemical and biological parameters of the North Muddy Creek stream restoration project. This collaborative project will involve the partners collecting monitoring data based on their particular expertise. The project is located on the Smithsonian Environmental Research Center property in Edgewater, Maryland.

The project will be restored using an innovative design approach, Regenerative Stormwater Conveyance, which has been used for many projects in the last decade. However, there is limited comprehensive, detailed, long-term monitoring for these types of projects. In order to provide the best quality monitoring data, each group in the collaboration will be collecting data based on their field of expertise. SERC will collect water quality data and riparian vegetation, MD DNR will collect biological data, and USFWS will collect physical/geomorphic data. The project site is scheduled to be monitored for at least three continuous years post-restoration, with additional years of monitoring possible. Pre-restoration monitoring data was collected to help establish a baseline and validate restoration potential prediction. This report details the findings of the pre-restoration monitoring performed by the USFWS and focuses specifically on the data collected by the Service. See Appendix A for a list of all parameters assessed, measurement methods associated with data collection, and parties responsible for collection.

II. ASSESSMENT METHODOLOGY

This section presents a brief summary of the methods used by the Service to conduct the geomorphic monitoring.

A. WATERSHED ASSESSMENT

For this project, the Service performed a brief watershed assessment that focused on determining sources and amount of sediment supplied by the watershed. This was done through a visual inspection of the watershed. Approximately 85% of the stream reaches upstream of the project area were walked to identify potential sources of sediment. The condition of stream reaches not walked was determined based on the condition of streams assessed that had similar adjacent land cover. Through these observations, the Service determined the potential sediment supply being delivered to the project area. Results of the watershed assessment are found below, in Section III.

B. REACH ASSESSMENT

The Service conducted a limited function-based assessment of Muddy Creek. This function-based assessment approach is based on the Stream Functions Pyramid Framework (SFPF) (Harman et. al, 2012). The SFPF focuses on the hierarchical relationship of stream functions to determine the overall functional condition of a stream reach. It includes measurement methods,

performance standards and goal setting criteria for function-based stream restoration. The framework outlines five critical categories that evaluate stream functions (**Figure 1**).

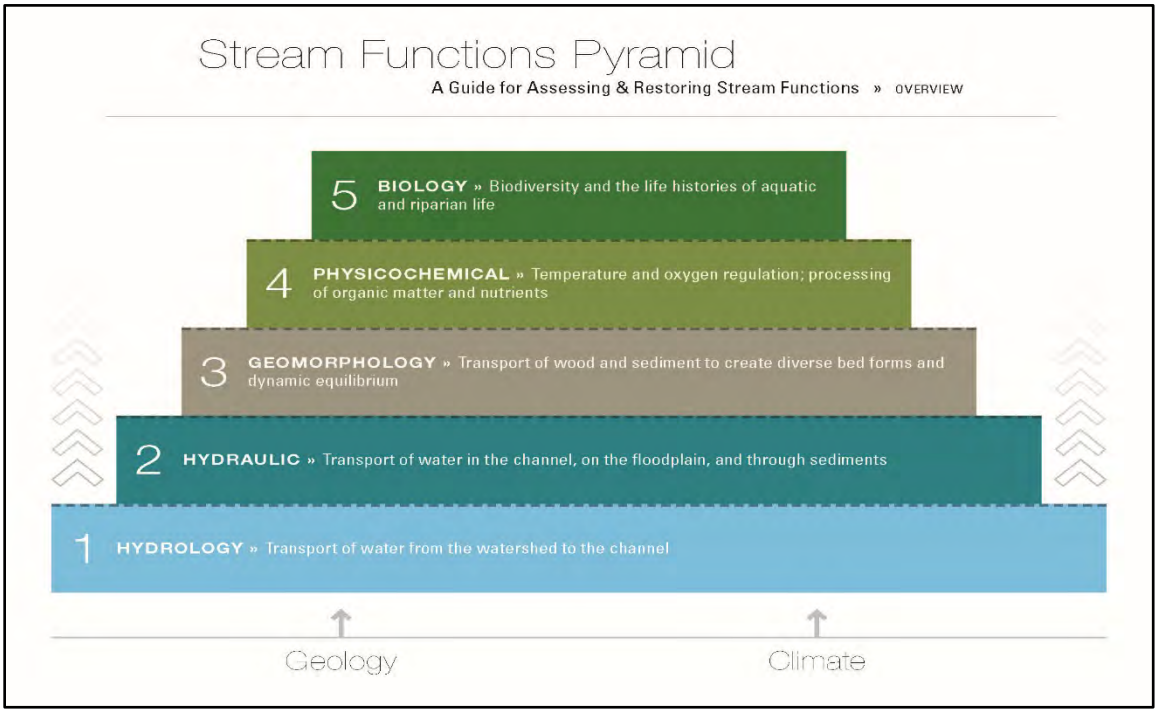


Figure 1. Stream Functions Pyramid (Harman et al., 2012)

The majority of the Service's limited assessment focused on Pyramid Level 3 – Geomorphology. A limited assessment of Level 1 – Hydrology and Level 2 – Hydraulics was also performed. The Service evaluated only the critical assessment parameters that supported the project goals and objectives. **Table 1** shows an example of the critical parameters and measurement methods used to evaluate the parameters for Levels 1 and 2. An overall reach rating was based on an accumulation of ratings at two different levels. First, each pyramid level is rated based on the individual measurement method and assessment parameter ratings (**Table 1, Column Pre-Restoration Condition Reach 1 –Overall Category Rating**). Second, the overall reach rating is based on the individual pyramid level ratings (**Table 2, Column Pre-Restoration Condition Reach 1– Overall Reach/Project Rating**).

FUNCTION-BASED ASSESSMENT MONITORING TABLE- MUDDY CREEK

Level and Category	Parameter	Measurement Method	Responsible Party	Pre-Restoration Condition- Reach 1			
				Value	Rating	Overall Category Rating	Overall Reach/Project Rating
1 - Hydrology	Flow Duration Curve	Crest Gage	SERC				
		Field Measured Velocities	SERC				
		TR55	SERC				
	Time and Concentration	Hydrograph	SERC				
	Concentrated Flow	USFWS Function-based Rapid Assessment	USFWS				
	Land use Change	USFWS Function-based Rapid Assessment	USFWS				
	Flashiness	USFWS Function-based Rapid Assessment	USFWS				
2- Hydraulics	Floodplain Connectivity	BHR	USFWS				
		ER	USFWS				
	Floodplain Drainage	USFWS Function Based Rapid Assessment	USFWS				
	Ground/Surface Water Exchange	Peizometers	SERC				
		Tracers	SERC				
		Seepage Meters	SERC				

Table 1. Function-based Assessment Parameters and Measurement Methods

III. WATERSHED ASSESSMENT

The land use in the watershed is primarily forested (50.9%), with some agriculture and low density residential. Impervious area covers 4.96%. The vegetation includes a dense canopy, with trees approximately 40 to 60 years old. Species include sweet gum, sycamore, box elder, tulip poplar, and maple. There is minimal understory, and the groundcover consists of wild multiflora rose and other annual vegetation.

The dominant stream type within the watershed is a Rosgen E5. These reaches are well connected to the floodplain, have a low width-depth ratio, low sinuosity, and are laterally stable. However, there are some stream reaches where the channel is slightly incised, but not entrenched and has some active lateral erosion. Observed bedform diversity was poor; this is possibly due to the small drainage area (0.78 sq mi), intermittent flow regime, and the lack of large woody debris in the channel.

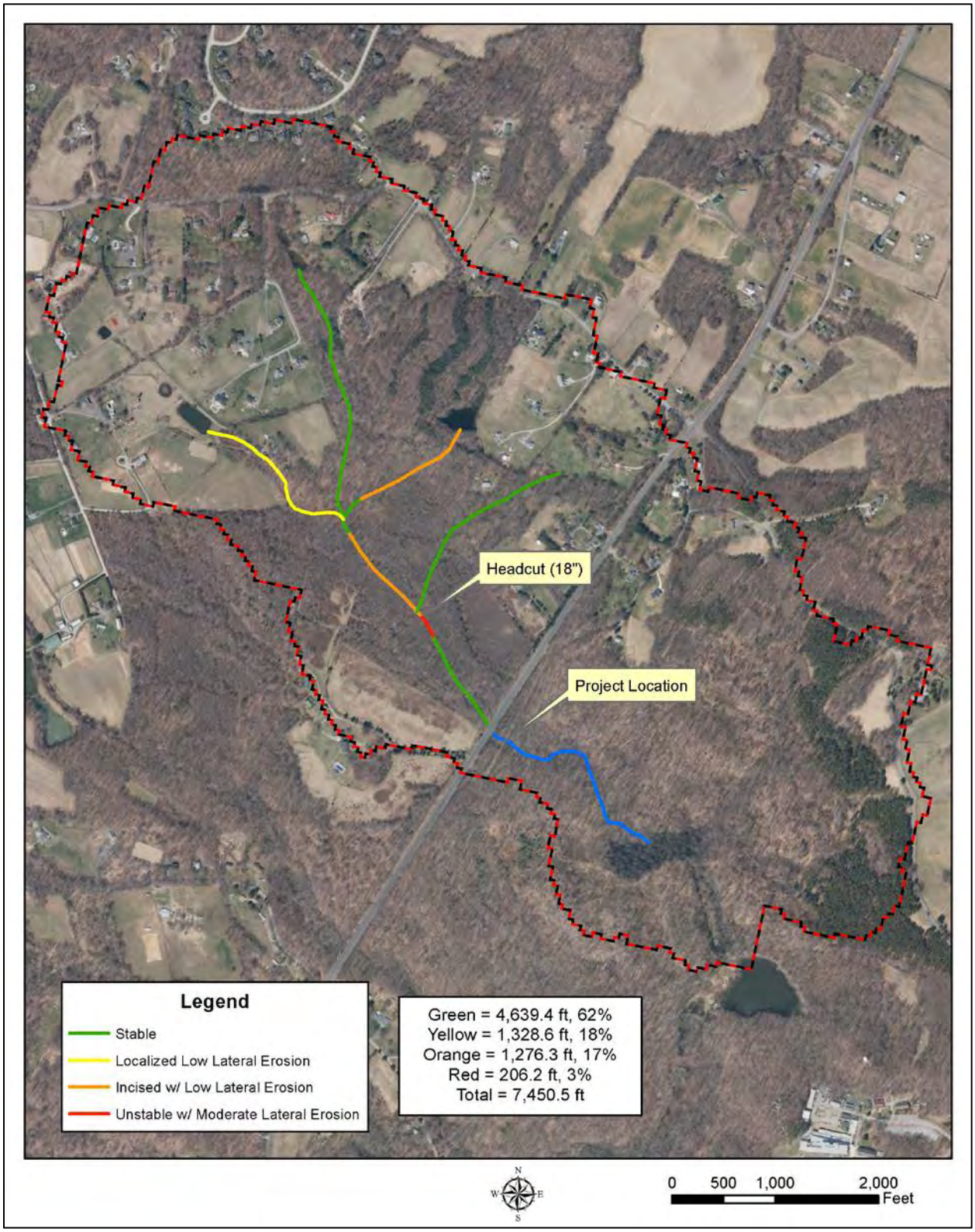


Figure 2 - Muddy Creek Watershed, showing areas of sediment supply

The lack of undercut banks, trees falling into the stream channel, high clay content in the bank, well established roots, intermittent flow and a low width-depth ratio suggests that rate of lateral erosion is low. Furthermore, the Service estimates that approximately only 38% of the drainage network (Figure 2) has eroding banks. However, the Service did observe one 18" headcut on the main channel, approximately 1000' upstream from the culvert at Muddy Creek Road. While there is active lateral and vertical erosion at this spot, the rate of erosion appears to be slow due to the high clay content in the stream bed and banks, as well as the roots associated with the riparian buffer vegetation. Given the low erosion rate and low percentage of eroding banks, the Service estimates that the sediment supply being delivered to the project area is low and should not adversely impact the proposed project

IV. REACH ASSESSMENT

The Service identified two stream reaches with different, distinct function-based conditions within the project area (**Figure 3**). A brief description of the function-based conditions for each reach is described below.

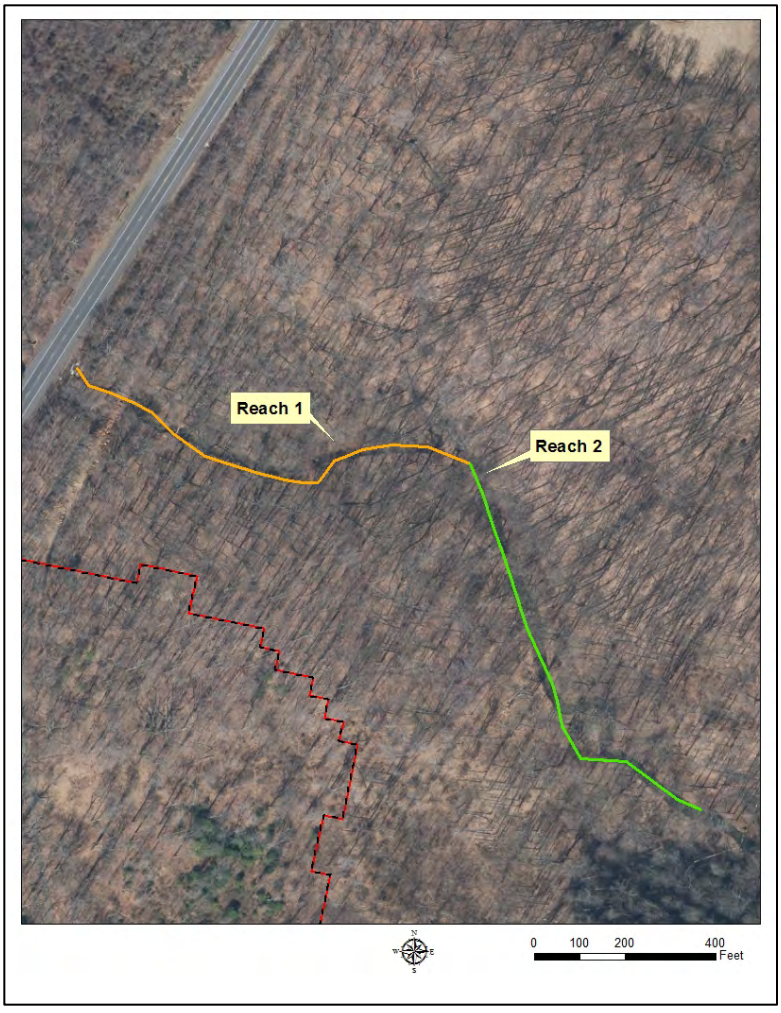


Figure 3- Muddy Creek Reach Locations

1. Reach 1

Level and Category	Parameter	Measurement Method	Responsible Party	Pre-Restoration Condition- Reach 1			
				Value	Rating	Overall Category Rating	Overall Reach/Project Rating
1- Hydrology	Concentrated Flow	USFWS Function-based Rapid Assessment	USFWS	No potential for conc. flow	F	F	NF
	Land use Change	USFWS Function-based Rapid Assessment	USFWS	50.9% forest, low density residential	F		
	Flashiness	USFWS Function-based Rapid Assessment	USFWS	Non-flashy flow regime	F		
2- Hydraulics	Floodplain Connectivity	BHR	USFWS	5.7	NF	NF	
		ER	USFWS	1.29	NF		
	Floodplain Drainage	USFWS Function Based Rapid Assessment	USFWS		F		
3 – Geomorphology	Lateral Stability	BANCS (BEHI/NBS)	USFWS	High/ Mod	NF	NF	
		MWR	USFWS	0 - 3.0	NF		
		$W/D_{proj}/W/D_{ref}$	USFWS	1	F		
		Wavelength to Riffle Width	USFWS	0	NF		
	LWD Transport and Storage	Large Woody Debris Index (Harman)	USFWS	621	NA**		
	Bed Form Diversity	% Riffle/Pool,	USFWS	40.7/59.3	FAR		
		Pool to pool Spacing	USFWS	7.64	NF		
		Pool Depth Variability	USFWS	1.98	F		
	Bed Material Characterization	Representative Reach Pebble Count	USFWS	Sand bed stream	NA		
		Facies Mapping	USFWS	Sand bed stream	NA		
	Riparian Vegetation		SERC				
	Shelter for Fish and Macro-invertibrates	USFWS Function Based Rapid Assessment	USFWS	39.3% shelter	FAR		

Table 2- Muddy Creek Reach 1 Function-Based Assessment Existing Conditions

The Service determined that the overall function-based condition for Category Levels 1 through 3 of Muddy Creek Reach 1 is Not Functioning (**Table 2)**. The reach is disconnected from its floodplain. There is a high rate of active lateral erosion. However, the ratio of Width/Depth of the project reach to the Width/Depth of the reference is functioning which indicates that bed degradation has most likely halted and active lateral erosion has just begun. Large woody debris (LWD) is moderately well represented (based on best professional judge from performance

standards currently under development). Bedform diversity is poor, with the exception of Pool Depth Variability, which is functioning but just within the functioning performance standard. This is largely in part due to the scour pools which have formed as a result of the LWD. Moreover, shelter for macroinvertebrates and fish limited.

The ability of the reach to evolve back to some level of quasi-equilibrium is unlikely to occur anytime in the near future without intervention. Reach 1 has already undergone downcutting, as evidenced by high incision and lateral erosion that is now occurring below the tree roots along the streambank. The reach will continue to widen, which will slowly lead to aggradation, allowing a new floodplain to form. The low gradient of this reach means that the stream needs to meander in order to disperse energy, and as the new floodplain is established, sinuosity will also begin to establish through deposition and lateral erosion. The watershed has an intermittent flow regime, low slope (and therefore, low energy), and moderately high clay content in the reach banks. These factors will slow down the recovery process of the stream. This could take several years or even possibly decades to complete and during this time could adversely affect downstream resources.

2. Reach 2

Level and Category	Parameter	Measurement Method	Responsible Party	Pre-Restoration Condition- Reach 2			
				Value	Rating	Overall Category Rating	Overall Reach/Project Rating
1- Hydrology	Concentrated Flow	USFWS Function-based Rapid Assessment	USFWS	No potential for conc. flow	F	F	NF
	Land use Change	USFWS Function-based Rapid Assessment	USFWS	50.9% forest, low density residential	F		
	Flashiness	USFWS Function-based Rapid Assessment	USFWS	Non-flashy flow regime	F		
2- Hydraulics	Floodplain Connectivity	BHR	USFWS	3.1	NF	NF	
		ER	USFWS	1.7	NF		
	Floodplain Drainage	USFWS Function Based Rapid Assessment	USFWS		F		
3 – Geomorphology	Lateral Stability	BANCS (BEHI/NBS)	USFWS	High/ Mod	NF	NF	
		MWR	USFWS	0 - 6.5*	NF		
		$W/D_{proj}/W/D_{ref}$	USFWS	1.8	NF		
		Wavelength to Riffle Width	USFWS	0 - 8.9*	NF		
	LWD Transport and Storage	Large Woody Debris Index (Harman)	USFWS	154	NA**		
	Bed Form Diversity	% Riffle/Pool,	USFWS	56.7/43.3	FAR		
		Pool to pool Spacing	USFWS	8.46	NF		
		Pool Depth Variability	USFWS	1.99	F		
	Bed Material Characterization	Representative Reach Pebble Count	USFWS	Sand bed stream	NA		
		Facies Mapping	USFWS	Sand bed stream	NA		
	Riparian Vegetation		SERC				
	Shelter for Fish and Macro-invertibrates	USFWS Function Based Rapid Assessment	USFWS	12.5% shelter	NF		

Table 3- Muddy Creek Reach 2 Function-Based Assessment Existing Conditions

The Service determined that the overall function-based condition for Category Levels 1 through 3 of Muddy Creek Reach 2 is Not Functioning (**Table 3**). The reach is disconnected from its floodplain. There is a high rate of active lateral erosion. The high rate of lateral erosion is supported by the ratio of Width/Depth of the project reach to the Width/Depth of the reference, which is not functioning. This suggests that bed aggradation has already begun. Large woody

debris (LWD) is poorly represented (based on best professional judge from performance standards currently under development). Bedform diversity is poor, with the exception of Pool Depth Variability, which is functioning but just within the functioning performance standard. This is largely in part due to the scour pools which have formed as a result of the LWD. Moreover, shelter for macroinvertebrates and fish limited.

The ability of the reach to evolve back to some level of quasi-equilibrium is unlikely to occur anytime in the near future without intervention. Reach 2 is furtherer along in the recovery process than Reach 1. It is most likely no longer downcutting and is actively widening. As a result, channel bed aggradation is occurring throughout the reach, and a new floodplain, at a lower elevation, is beginning to form. The low gradient of this reach means that the stream needs to meander in order to disperse energy, and as the new floodplain is established, sinuosity will also begin to establish through deposition and lateral erosion. Stabilization of this stream reach is likely decades away, for various interacting reasons. The watershed has an intermittent flow regime, low slope (and therefore, low energy), and moderately high clay content in the reach banks. These factors will slow down the recovery process of the stream. This could take several years or even possibly decades to complete and during this time could adversely affect downstream resources.

3. Overall Project Summary

The Service determined that the overall function-based condition of the Muddy Creek project area is ***Not Functioning***, for Levels 1 to 3**.**

The Hydrology level, Level 1, is currently ***Functioning*** mostly because current land uses within the watershed (i.e., mostly forested) have not significantly influenced the amount and rate of flood flows reaching the project area, resulting in a non-flashy flow regime. A non-flashy flow regime will produce lower stream shear stresses and improve ground water recharge. Lower stream shear stresses will reduce lateral and vertical degradation. Improved ground water recharge will better maintain stream base flows during the drier times of the year and support aquatic species. However, there is still some analysis needed for the Hydrology level- specifically Flow Duration Curves as well as Time and Concentration, both of which are to be completed by SERC.

The Hydraulics level, Level 2, is overall currently ***Not Functioning*** mostly due to high bank height ratio, which shows that the stream is not well connected to the floodplain for the majority if the project area. When a stream becomes disconnected from the floodplain, stream energy increases because flow depths increase while channel widths do not (Leopold et al., 1992). Increased stream energy increases stream shear stresses and promotes vertical and lateral stream degradation, which adversely affects riparian vegetation, bedform diversity, turbidity, and macroinvertebrate and fish communities. However, there is still some analysis needed for the Hydraulic level, specifically Ground/Surface Water Exchange which is to be completed by SERC.

The Geomorphology level, Level 3, is overall currently ***Not Functioning*** mostly due to high lateral instability and limited bed form diversity. As stated above in Level 2 – Hydraulics, these not functioning conditions are because of increased stream energies associated with a disconnected floodplain. Limited geomorphic functions adversely affect macroinvertebrate and fish communities due to the loss of available quality habitat structure. However, there is still some analysis needed for the Geomorphic level, specifically Riparian Vegetation which is to be completed by SERC.

4. Channel Evolution

The ability of the proposed project area to evolve back to some level of quasi-equilibrium is unlikely to occur anytime in the near future without intervention. The current geomorphic functions are still undergoing significant adjustments. As stated above, the stream is deeply incised and entrenched, causing it to be disconnected from the floodplain. Now that the stream is disconnected from the floodplain, it will actively erode stream banks to build a new floodplain at a lower level than the original floodplain.

Based on the current meander width ratio, the stream does not have the required beltwidth needed for lateral stability (aside from one artificial meander found in reach 2). A BANCS assessment found that both reaches had a high Bank Erosion Hazard Index (BEHI) and a moderate Near Bank Stress (NBS). These values mean that the stream is more susceptible to lateral erosion. The bedform diversity is also lacking, with the exception of pool depth variability, which is performing well for being a sand bed stream. The high amount of lateral erosion seen in these reaches will continue as the stream tries to create a new floodplain. However, this evolutionary process could take decades to complete and can adversely impact downstream resources.

V. Restoration Potential

Restoration potential is the highest level of restoration or functional lift that can be achieved given the site constraints and health of the watershed (Harman et al., 2012). Using watershed conditions, function-based assessment results, and constraints and stressors, the Service was able to determine the highest level of restoration that could be achieved at the Muddy Creek restoration site. Based on these factors, the Service determined that pyramid Levels 2 - Hydraulics and 3 – Geomorphology can be restored to fully functional. Restoration of Levels 2 and 3 functions are typically the easiest to achieve since they involve direct, physical manipulation of stream channel dimension, pattern, and profile. Stream channel parameters such as beltwidth, bank heights, wave lengths, facet feature lengths, slopes and depths can be constructed to specifications considered functioning upon completion of construction.

The potential for lift in Levels 4 – Physicochemical and 5 – Biology is unknown at this time, because data collection for these levels is the responsibility of MD DNR and SERC, as mentioned above. Even though this is the responsibility of other partners, the Service wants to note that levels 4 and 5 functions cannot be constructed and rely on the functionality of lower level functions and watershed health. Therefore, it takes time for levels 4 and 5 functions to respond to changes in lower level functions and watershed health. Research has shown that it

can take up to 10 to 15 years to see biological lift (Orzetti, 2010). For example, riparian vegetation needs to mature in order to provide shade to reduce stream temperature and to provide detritus for aquatic species. Then aquatic species need to migrate in to the newly created habitat to repopulate the stream. While there is potential for water quality and biological lift, it is uncertain at this time what the lift could be because assessment of water quality and biological functions were not included as a project goal in the Service's SOW.

LITERATURE CITED

1. Harman, W., R. Starr, M. Carter, K. Tweedy, M. Clemmons, K. Suggs, C. Miller. 2012. A Function-Based Framework for Stream Assessment and Restoration Projects. U.S. Environmental Protection Agency, Office of Wetlands, Oceans, and Watersheds, Washington, D.C. EPA 843-K-12-006.
2. Leopold, L.B., M.G. Wolman, and J. Miller, 1992. Fluvial Processes in Geomorphology, W.H. Freeman Company, San Francisco.
3. Orzetti, L.L., R.C. Jones, and R.F. Murphy, 2010. Stream Condition in Piedmont Streams with Restored Riparian Buffers in the Chesapeake Bay Watershed. Journal of the American Water Resources Association 46(3):474-485.

APPENDIX A

FUNCTION-BASED ASSESSMENT MONITORING TABLE- MUDDY CREEK

Level and Category	Parameter	Measurement Method	Responsible Party
1 - Hydrology	Flow Duration Curve	Crest Gage	SERC
		Field Measured Velocities	SERC
		TR55	SERC
	Time and Concentration	Hydrograph	SERC
	Concentrated Flow	USFWS Function-based Rapid Assessment	USFWS
	Land use Change	USFWS Function-based Rapid Assessment	USFWS
	Flashiness	USFWS Function-based Rapid Assessment	USFWS
2- Hydraulics	Floodplain Connectivity	BHR	USFWS
		ER	USFWS
	Floodplain Drainage	USFWS Function Based Rapid Assessment	USFWS
	Ground/Surface Water Exchange	Peizometers	SERC
		Tracers	SERC
		Seepage Meters	SERC
3 – Geomorphology	Lateral Stability	BANCS (BEHI/NBS)	USFWS
		MWR	USFWS
		$W/D_{proj}/W/D_{ref}$	USFWS
		Wavelength to Riffle Width	USFWS
	LWD Transport and Storage	Large Woody Debris Index (Harman)	USFWS

Level and Category	Parameter	Measurement Method	Responsible Party
3 – Geomorphology continued	Bed Form Diversity	% Riffle/Pool,	USFWS
		Pool to pool Spacing	USFWS
		Pool Depth Variability	USFWS
	Bed Material Characterization	Representative Reach Pebble Count	USFWS
		Facies Mapping	USFWS
	Riparian Vegetation		SERC
	Shelter for Fish and Macro-invertibrates	USFWS Function Based Rapid Assessment	USFWS
4 – Physicochemical	Temperature	Temperature Probe	SERC
	Water Quality	Temp, DO, Conductivity, pH and Turbidity	SERC
	Nitrogen	Laboratory Analysis	SERC
	Phosphorus	Laboratory Analysis	SERC
5 – Biology	Microbial Communities	Taxonomic Methods, Non-Taxonomic Methods, Bio Indicies	MD DNR MBSS
	Macrophyte Communities	Taxonomic Methods, Non-Taxonomic Methods, Bio Indicies	MD DNR MBSS

Level and Category	Parameter	Measurement Method	Responsible Party
5 – Biology continued	Benthic Macro-invertebrates	Taxonomic Methods, Non-Taxonomic Methods, Bio Indicies	MD DNR MBSS
	Fish Communities	Taxonomic Methods, Non-Taxonomic Methods, Bio Indicies	MD DNR MBSS