# South Muddy Creek Stream Restoration Project
# Year 5 Monitoring Report

## McDowell County, North Carolina

**NCDMS Project Number – 737**

Project Info:
Monitoring Year: 5 of 5
Year of Data Collection: 2016
Year of Completed Construction: 2011
NCDMS Project Manager: Matthew Reid
Submission Date: January 17, 2017

Submitted To:
NCDEQ – Division of Mitigation Services
1625 Mail Service Center
Raleigh, NC 27699
NCDEQ Contract ID No. 004522

**FINAL**

# South Muddy Creek Stream Restoration Project
# Year 5 Monitoring Report

## McDowell County, North Carolina

Report Prepared and Submitted by Michael Baker Engineering, Inc.

NC Professional Engineering License # F-1048

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**Table of Contents**



**Appendices**

# 1.0 EXECUTIVE SUMMARY

The South Muddy Creek Restoration Project (Project) was restored by Michael Baker Engineering, Inc. (Baker) through an on-call design and construction services contract with the North Carolina Division of Mitigation Services (NCDMS). This report documents and presents Year 5 monitoring data as required during the five-year monitoring period.

The specific goals for the South Muddy Creek Restoration Project were as follows:

- Create geomorphically stable conditions on the Project site,
- Improve and restore hydrologic connections between the streams and their floodplains,
- Improve water quality in the South Muddy Creek watershed, and
- Improve aquatic and terrestrial habitat along the Project corridor.

To accomplish these goals the following objectives were implemented:

- Excavate a wide floodplain bench and construct a new channel with stable dimension and pattern,
- Restore channel access the floodplain during bankfull or larger storm events to increase hydrologic connections and alleviate erosive shear stresses,
- Incorporate bedform diversity with varied in-stream structures to provide a variety of aquatic habitats,
- Treat the floodplain for invasive species vegetation, and
- Reestablish a riparian buffer with native vegetation to improve terrestrial habitat and eliminate excessive sedimentation from erosion.

The Project site is located approximately nine miles southeast of Marion in McDowell County, North Carolina, as shown in Figure 1 in Appendix A. The Project is situated in the Catawba River Basin, within the United States Geologic Survey (USGS) hydrologic unit 03050101040-020. Directions to the Project site can be found in Figure 1 of Appendix A.

South Muddy Creek lies within the Piedmont physiographic province. Its watershed is predominately forested, supporting some isolated rural residential housing, chicken farms, agricultural lands, nurseries, and several small rural residential developments. In the early 1960's the McDowell County Natural Resource Conservation Service (NRCS) constructed a flood control structure within South Muddy Creek approximately three miles upstream from the Project area. This structure controls flows from approximately 12.4 square miles of the watershed and is located on privately-owned land that is maintained by the NRCS.

The land surrounding the Project site has been used predominantly for crop cultivation. Impacts from past channelization of the stream have allowed the channel to incise over time and become disconnected from its floodplain; thereby, promoting excessive shear stress forces on the bed and banks which led to subsequent erosion. The Project involved the restoration of 2,787 linear feet (LF) of stream along South Muddy Creek at Sain Road using a Rosgen Priority 2 restoration approach. The Priority 2 channel design approach included the excavation of bankfull benches to alleviate shear stress on stream banks and to re-establish channel pattern to dissipate flow velocities in meander bends while creating in-stream habitat with riffle-pool sequences and allowing for the strategic placement of in-stream structures. Approximately 14.1 acres of associated riparian buffer were restored or enhanced throughout the Project area and a conservation easement consisting of 17.1 acres will protect and preserve all stream reaches and riparian buffers in perpetuity.

An existing overhead utility easement and corresponding power line bisect South Muddy Creek just downstream of the Sain Bridge Crossing. Due to this encroachment across the Project site, a fifty percent (50%) credit reduction has been applied to 20 linear feet of the Project that lies within the utility easement. This

reduction is reflected in the total number of Stream Mitigation Units (SMUs) outlined in Table 1. A depiction of the utility line and the easement offset is included in Sheet 2 of Figure 2.

Table 6a in Appendix B summarizes the vegetation condition of the Project site. The planted acreage performance categories were functioning at 100%. Treatment control applications for exotic invasive species have been conducted on multiple occasions throughout monitoring Years 2, 3, 4, and 5. (See Table 2 in Appendix A.) These applications have significantly reduced invasive species densities and resulted in only individual stems and/or localized populations of invasive species throughout the easement. These species consist primarily of young saplings of *Pyrus calleryana* (Braford pear), *Ligustrum sinese* (Chinese Privet), and *Rosa multiflora* (multiflora rose). No Vegetation Problem Areas (VPAs) exceeding the mapping threshold were documented in Year 5; however, the effects from an herbicidal maintenance application of an overhead utility line, which bisects Reach 2, was observed. Negative affects to the vegetative health of the easement plantings were limited to those that lie directly within the utility easement, some overspray from the maintenance activity has negatively affected the health of a few trees in Vegetation Plots 9 and 10. See Appendix B Figure 2 Sheet 2 for the location of the utility easement. Photos of the utility maintenance areas are included in the VPA Photolog in Appendix B.

The average density of total planted stems per plot ranges from 283 – 647 stems per acre with a tract mean (not including volunteers) of 462 stems per acre; therefore the Project site has met the Year 5 vegetative success criteria of 260 trees per acre. Volunteer species continue to thrive throughout the vegetation plots and include planted species, as well as, other native species such as: *Pinus virginiana*, *Prunus serotina*, and *Rubus* sp. Vegetation stem counts are summarized in Tables 7 and 9 of Appendix C.

Table 5a in Appendix B, indicates the South Muddy Creek site is generally geomorphically stable overall and performing at 90 - 100% for the majority of parameters evaluated within the lateral/vertical stability and in-stream structure performance categories. The five sub-categories receiving scores of less than 100 percent correspond to the twelve Stream Problem Areas (SPAs) that are documented and summarized in Table 5b. SPA4-2, which was previously documented in the mid-year site assessment, has re-stabilized and is no longer included in Tables 5a and 5b. Bank stabilization work conducted in November of 2015, from Station 28+00 to 29+50, has remained stable and woody vegetation is actively growing within the area. One beaver dam was not noted at Station 15+50 during the Year 5 monitoring. See Appendix B for additional SPA information.

Permanent cross-sections monitored throughout the Project Site show that there has been little adjustment to stream dimension throughout the majority of the Project site since construction. Though cross-section four had previously exhibited evidence of lateral bank erosion in Monitoring Year 4 due to large beaver dam, repair work conducted in November 2015 has reestablished the cross-sectional dimension similar to as-built conditions, and it is remaining stable. Therefore, as currently indicated in Figure 3, all four cross-sectional measurements are geomorphically similar to as-built conditions and do not indicate any stream bank or channel stability issues.

The longitudinal profiles show that bed features are stable. Riffle material along cross-section X4 has normalized and also shows that the channel bed is maintaining bed form stability. The majority of pools are well maintained with only minimal downstream migrations occurring. These adjustments are likely do the natural movement of sediment through the system, do not indicate stability issues. Grade control structures (constructed riffles, j-hooks, and log vanes) continue to help maintain the overall profile desired. As depicted in Figure 4, overall longitudinal profile has remained geomorphically stable throughout the post-construction five year monitoring period.

The USDA Animal and Plant Health Inspection Service (APHIS) was contracted to remove any beavers and their dams and to monitor the site on a monthly basis for beaver activity. Two beavers and two dams were removed by APHIS between February and March 2016. APHIS will continue to monitor beaver activity through Project close-out and will remove any subsequent colonies and/or dams as needed.

One bankfull event was observed and documented during MY5. Overall the site has experienced at least four documented bankfull events during the five year monitoring period. With at least two of the events occurring in separated monitoring years, the site has met its hydrologic success criteria. Information on bankfull events is provided in Table 12 of Appendix E.

A more detailed summary of the results for the vegetation condition assessment and the visual stream stability assessment can be found in Appendix B which includes a technical memorandum, current condition plan view (CCPV) figures, supporting data tables, and photo logs. Except for the VPA Photolog, the remaining contents of Appendix B were submitted to NCDMS in May 2016 and served as the interim visual site assessment report.

Summary information and statistic related data to the performance of various project and monitoring elements can be found in the tables and figures in the report appendices. Narrative background and supporting information formerly found in these reports can be found in the Baseline Monitoring Report (formerly Mitigation Plan) and in the Mitigation Plan (formerly Restoration Plan) documents available on DMS's website. *It should be noted that the Baseline Monitoring Report and Mitigation Plan for this Project includes the summary of constructed design approaches for South Fork Hoppers Creek (DMS Project No. 92251), a nearby project site that was designed and constructed in conjunction with the South Muddy Creek project as part of the same DMS on-call design and construction services contract.* All raw data supporting the tables and figures in the appendices is available from DMS upon request.

# 2.0 METHODOLOGY

The five-year monitoring plan for the Project site includes criteria to evaluate the success of the vegetation and stream components of the project. The methodology and report template used to evaluate these two components adheres to the DMS monitoring guidance document dated November 7, 2011 of which continued to serve as the template for subsequent monitoring years. The specific locations of monitoring features, such as vegetation plots, permanent cross-sections, reference photo stations and crest gauges, are shown on the CCPV sheets found in Figure 2 of Appendix B.

The majority of Year 5 monitoring data was collected in May and October 2016. All visual site assessment data contained in Appendix B was collected on May 25th except for the vegetation plot data and corresponding plot photos which were collected on October 4th and 5th. All stream survey (channel dimension and profile) and sediment data were collected between October 5th and October 11th. Stream survey data was collected to a minimum of Class C Vertical and Class A Horizontal Accuracy using Leica TS06 Total Station and was geo-referenced to the NAD83 State Plane Coordinate System, FIPS3200 in US Survey Feet, which was derived from the South Muddy Creek As-built Survey.

## 2.1 Stream Assessment

Geomorphic monitoring of restored stream reaches was conducted for five years to evaluate the effectiveness of the restoration practices installed. Monitored stream parameters include channel dimension (cross-sections), profile (longitudinal survey), bed composition, bank and channel stability, bankfull flows, and reference sites documented by photographs. A crest gauge, as well as high flow marks, were used to document the occurrence of bankfull events. The methods used and any related success criteria are described below for each parameter. For monitoring stream success criteria, 4 permanent cross-sections, 1 crest gauge, and 20 photo identification points were installed.

### 2.1.1 Morphologic Parameters and Channel Stability

#### 2.1.1.1 Dimension

Four permanent cross-sections were installed throughout the entire project area. Cross-sections selected for monitoring were located in representative riffle and pool facets and each cross-section was marked on both banks with permanent pins to establish the exact transect used. The two pairs of riffle and pool cross-sections are all located upstream of the Sain Road bridge crossing. A common benchmark was used for cross-sections and consistently referenced to facilitate comparison of year-to-year data. The cross-sectional surveys included points measured at major breaks in slope, including top of bank, bankfull, inner berm, edge of water, and thalweg, if the features are present. Riffle cross-sections were classified using the Rosgen Stream Classification System (Rosgen, 1994), and all monitored cross-sections should fall within the quantitative parameters defined for channels of the design stream type.

There should be little change in as-built cross-sections. If changes do take place, they will be evaluated to determine if they represent a movement toward a more unstable condition (e.g., down-cutting or erosion) or a movement toward increased stability (e.g., settling, vegetative changes, deposition along the banks, or decrease in width/depth ratio). Cross-sectional data is presented in Figure 3 of Appendix D.

#### 2.1.1.2 Longitudinal Profile

One longitudinal profile was surveyed for the entire project length of the Project reach and is provided in Figure 4 of Appendix D. Longitudinal profiles were replicated annually during the five year monitoring period.

Measurements taken during longitudinal profiles include thalweg, water surface, and the top of low bank. All measurements were taken at the head of each feature (e.g., riffle, run, pool, glide) and the maximum pool depth. Elevations of grade control structures were also included in the longitudinal profiles surveyed. Surveys were tied to a permanent benchmark.

The pools should remain relatively deep with flat water surface slopes, and the riffles should remain steeper and shallower than the pools. Bed form observations should be consistent with those observed for channels of the design stream type as well as other design information.

#### 2.1.1.3 Substrate and Sediment Transport

Bed load material analysis consists of a pebble count taken in the same constructed riffle (at cross-section X4) during annual geomorphic surveys of the Project site. This sample, combined with evidence provided by changes in cross-section and profile data will reveal changes in sediment gradation that occur over time as the stream adjusts to upstream sediment loads. Significant changes in sediment gradation were evaluated with respect to stream stability and watershed changes. Bed material distribution data is located in Figure 5 of Appendix D.

### 2.1.2 Hydrology

#### 2.1.2.1 Streams

The occurrence of bankfull events within the monitoring period were documented by the use of crest gauges and photographs. One crest gauge was installed on the floodplain at the bankfull elevation along the left top of bank at station 22+00. The bottom of the crest gauge coincides with the top of bank (bankfull) elevation. The crest gauge records the highest watermark between site visits, and is checked at each site visit to determine if a bankfull event has occurred. Photographs are used to document the occurrence of debris lines and sediment deposition on the floodplain during monitoring site visits.

Two bankfull flow events must be documented at the crest gauge within the 5-year monitoring period. The two bankfull events must occur in separate years; otherwise, the stream monitoring will continue until two bankfull events have been documented in separate years or until the monitoring period ends. If two bankfull events have not been documented at the end of 5 years the Interagency Review Team (IRT) will have to decide on an appropriate course of action.

### 2.1.3 Photographic Documentation of Site

Photographs were used to document restoration success visually. Reference stations were photographed during the as-built survey; this was repeated for the five years following construction. Reference photos are taken once a year, from a height of approximately five to six feet. Permanent markers ensure that the same locations (and view directions) are utilized during each monitoring period. Selected site photographs are shown in Appendix B.

#### 2.1.3.1 Lateral Reference Photos

Reference photo transects were taken of the right and left banks at each permanent cross-section. A survey tape, which was captured in the cross section photographs, represents the cross-section line located perpendicular to the channel flow. The water line was located in the lower edge of the frame in order to document bank and riparian conditions. Photographs were consistently taken from the same area to maintain continuity for each photo over time.

#### 2.1.3.2 Structure Photos

Photographs of primary grade control structures (i.e. vanes and weirs), along the restored streams are included within the photographs taken at reference photo stations. Photographs were consistently taken from the same area to maintain continuity for each photo over time.

Lateral and structure photographs are used to evaluate channel aggradation or degradation, bank erosion, success of riparian vegetation, structure function, and stability, and effectiveness of erosion control measures subjectively. Lateral photos should not indicate excessive erosion or degradation of the banks. A series of photos over time should indicate successive maturation of riparian vegetation and consistent structure function.

### 2.1.4 Visual Stream Morphological Stability Assessment

The visual stream morphological stability assessment involves the qualitative evaluation of lateral and vertical channel stability, and the integrity and overall performance of in-stream structures throughout the Project reach as a whole. Habitat parameters, such as riffle embeddedness and pool depth maintenance, are also measured and scored. The entire project reach was walked, noting geomorphic conditions of the stream bed profile (riffle/pool facets), both stream banks, and engineered in-stream structures. Photos were taken at every stream photo reference station as discussed in the previous section, and in locations of potential SPAs which were documented in the field for subsequent mapping on the CCPV figures. A more detailed summary of the methodology and results for the visual stream stability assessment can be found in Appendix B which includes a technical memorandum, supporting data tables, and SPA photos.

## 2.2 Vegetation Assessment

Successful restoration of the vegetation on a mitigation site is dependent upon hydrologic restoration, active planting of preferred canopy species, and volunteer regeneration of the native plant community. In order to determine if the criteria are achieved, twelve vegetation monitoring quadrants were installed across the project site. The total number of quadrants was calculated using the CVS-NCEEP Entry Tool Database version 2.2.7 (CVS-NCEEP, 2007). The size of individual quadrants varies from 100-square meters for tree species to 1-square meter for herbaceous vegetation. Level 1 CVS vegetation monitoring was documented between spring, after leaf-out has occurred, and fall, prior to leaf fall. At the end of the first growing season during baseline surveys, species composition, density, and survival were evaluated. Individual quadrant data provided during subsequent monitoring events include diameter, height, density, and coverage quantities. Relative values were calculated, and importance values were determined. Individual trees were marked to ensure that they can be found in succeeding monitoring years. Mortality was determined from the difference between the previous year's living, planted trees and the current year's living, planted trees.

The interim measure of vegetative success for the site is the survival of at least 320, 3-year old, planted trees per acre at the end of Year 3 of the monitoring period. The final vegetative success criteria is the survival of 260, 5-year old, planted trees per acre at the end of the Year 5 monitoring period.

Photographs are used to visually document vegetation success in sample plots. Reference photos of tree and herbaceous condition within plots are taken at least once per year. As part of the visual site assessment conducted on May 25, 2016, the vegetation condition of planted vegetation along stream banks, floodplains, and terraces were qualitatively evaluated for performance; this also included the documentation of invasive species and potential VPAs which were recorded in the field for subsequent mapping on the CCPV figures. A more detailed summary of the methodology and results for the vegetation condition assessment can be found in Appendix B which includes a technical memorandum, supporting data tables, and photo logs.

# 3.0 REFERENCES

Carolina Vegetation Survey (CVS) and NC Ecosystem Enhancement Program (NCEEP). 2007. CVS-NCEEP Data Entry Tool v. 2.2.7. University of North Carolina, Raleigh, NC.

Lee, M., Peet R., Roberts, S., Wentworth, T. 2007. CVS-NCEEP Protocol for Recording Vegetation, Version 4.1.

Rosgen, D. L. 1994. A Classification of Natural Rivers. Catena 22:169-199.

# APPENDIX A

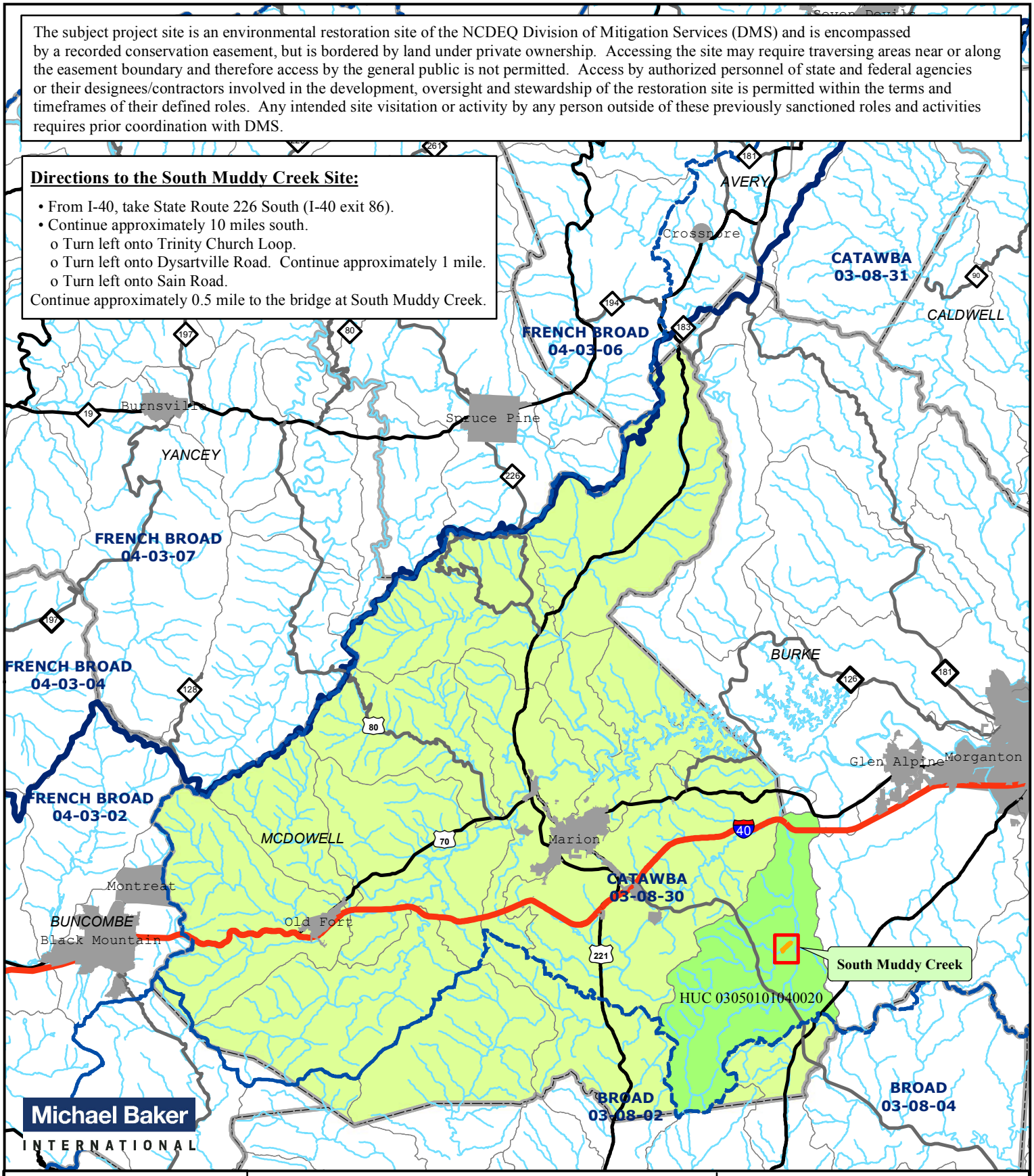
# PROJECT VICINITY MAP AND BACKGROUND TABLES

The subject project site is an environmental restoration site of the NCDEQ Division of Mitigation Services (DMS) and is encompassed by a recorded conservation easement, but is bordered by land under private ownership. Accessing the site may require traversing areas near or along the easement boundary and therefore access by the general public is not permitted. Access by authorized personnel of state and federal agencies or their designees/contractors involved in the development, oversight and stewardship of the restoration site is permitted within the terms and timeframes of their defined roles. Any intended site visitation or activity by any person outside of these previously sanctioned roles and activities requires prior coordination with DMS.

**Directions to the South Muddy Creek Site:**

- From I-40, take State Route 226 South (I-40 exit 86).
- Continue approximately 10 miles south.
  - o Turn left onto Trinity Church Loop.
  - o Turn left onto Dysartville Road. Continue approximately 1 mile.
  - o Turn left onto Sain Road.

Continue approximately 0.5 mile to the bridge at South Muddy Creek.




**Map Vicinity**

McDowell County, NC

# Figure 1. Vicinity Map

**South Muddy Creek Stream Restoration Project**

*McDowell County, NC*

NCDMS Project No.: 737
2017

**LEGEND:**

- Project Area
- NC River Basins
- USGS Hydrologic Unit
- Counties

0 2.5 5 Miles

**Table 1. Project Components**
**South Muddy Creek Stream Restoration Project: DMS Project No. 737**

| Project Segment or Reach ID | Existing Feet/Acres* | Mitigation Type | Approach | Linear Footage or Acreage* | Mitigation Ratio | Mitigation Units*** | Stationing | Comment |
|---|---|---|---|---|---|---|---|---|
| South Muddy Creek | 2,593 | R | P2 | 2,787 | 1:1 | 2,777 | 10+00 - 38+77** | Installed in-stream structures to protect the stream bank from erosion and to provide aquatic habitat. Priority 2 was implemented to connect the channel to a newly evacated floodplain bench. |

* Existing reach breaks and design reach breaks varied based on initial geomorphic differences and design requirements.
** Stationing includes 20 ft. of farm crossing above Sain Rd. and 70 ft. of Sain Rd. bridge crossing, but is not reflected in the reach length.
*** Mitigation unit reduction of 50% for 20 LF of the project that is located within the utility easement.

Component Summations

| Restoration Level | Stream (LF) | Riparian Wetland (Ac) | | Non-Ripar (Ac) | Upland (Ac) |
|---|---|---|---|---|---|
| | | Riverine | Non-Riverine | | |
| Restoration | 2,787 | - | - | - | - |
| Enhancement | | - | - | - | - |
| Enhancement I | - | | | | |
| Enhancement II | - | | | | |
| Creation | | - | - | - | - |
| Preservation | - | - | - | - | - |
| HQ Preservation | - | - | - | - | - |
| | | - | - | | |
| Totals | 2,787 | - | | - | - |
| Total Project Mitigation Units | 2,777 | | | | |

| Table 2. Project Activity and Reporting History<br>South Muddy Creek Stream Restoration Project: DMS Project No.737 | | | |
|---|---|---|---|
| **Elapsed Time Since Grading/Planting Complete: 5 Years 6 Months<br>Number of Reporting Years: 5** | | | |
| **Activity or Report** | **Scheduled Completion** | **Data Collection Complete** | **Actual Completion or Delivery** |
| Restoration Plan Prepared | N/A | N/A | Jul-07 |
| Restoration Plan Amended | N/A | N/A | Jan-08 |
| Restoration Plan Approved | N/A | N/A | Aug-08 |
| Final Design – (at least 90% complete) | N/A | N/A | Jun-09 |
| Construction Begins | Jun-10 | N/A | Jun-10 |
| Temporary S&E mix applied to entire project area | N/A | N/A | N/A |
| Permanent seed mix applied to entire project area | Nov-10 | N/A | Jan-11 |
| Planting of live stakes | Mar-11 | N/A | Mar-11 |
| Planting of bare root trees | Mar-11 | N/A | Mar-11 |
| End of Construction | Mar-11 | N/A | Jun-11 |
| Survey of As-built conditions (Year 0 Monitoring-baseline) | Nov-10 | N/A | Jun-11 |
| | | | |
| | | | |
| Year 1 Monitoring | Dec-12 | Sep-12 | Nov-12 |
| Invasive Treatment | N/A | N/A | Oct-13 |
| Year 2 Monitoring | Dec-13 | Sep-13 | Nov-13 |
| Year 3 Monitoring | Dec-14 | Sep-14 | Nov-14 |
| Invasive Treatment | N/A | N/A | Aug-14 |
| Beaver / Dam Removal | N/A | N/A | Sep-15 |
| Year 4 Monitoring | Dec-15 | Oct-15 | Dec-15 |
| Maintenance - Bank Repair & Planting | N/A | N/A | Nov-15 |
| Invasive Treatment | N/A | N/A | Nov-15 |
| Beaver / Dam Removal | N/A | N/A | Mar-16 |
| Invasive Treatment | N/A | N/A | Jun-16 |
| Invasive Treatment | N/A | N/A | Aug-16 |
| Year 5 Monitoring | Dec-16 | Oct-16 | Jan-17 |

| Table 3. Project Contacts Table<br>South Muddy Creek Stream Restoration Project: DMS Project No. 737 | |
|---|---|
| **Designer** | |
| Michael Baker Engineering, Inc. | 9716-B Rea Road #56<br>Charlotte, NC 28277<br>Contact:<br>Kristi Suggs, Tel. 704-665-2206 |
| **Construction Contractor** | |
| Carolina Environmental Contracting, Inc. | 150 Pine Ridge Road<br>Mount Airy, NC 27030<br>Contact:<br>Joanne Cheatham, Tel. 336-320-3849 |
| **Planting Contractor** | |
| Carolina Environmental Contracting, Inc. | 150 Pine Ridge Road<br>Mount Airy, NC 27030<br>Contact:<br>Joanne Cheatham, Tel. 336-320-3849 |
| **Seeding Contractor** | |
| Carolina Environmental Contracting, Inc. | 150 Pine Ridge Road<br>Mount Airy, NC 27030<br>Contact:<br>Joanne Cheatham, Tel. 336-320-3849 |
| Seed Mix Sources | Green Resources, Tel. 336-855-6363 |
| Nursery Stock Suppliers | Foggy Mountain Nursery, Tel. 336-384-5323 |
| **Profession Land Surveyor** | |
| Turner Land Survey, PLLC. | 3201 Glenridge Drive<br>Raleigh, NC 27604<br>Contact: |
| Profession Land Surveyor | David Turner, Tel. 919-875-1378 |
| As-Built Plan Set Production | Lissa Turner, Tel. 919-875-1378 |
| **Monitoring Performers** | |
| Michael Baker Engineering, Inc. | 9716-B Rea Road #56<br>Charlotte, NC 28277<br>Contact: |
| Stream Monitoring Point of Contact: | Kristi Suggs, Tel. 704-665-2206 |
| Vegetation Monitoring Point of Contact: | Kristi Suggs, Tel. 704-665-2206 |

| Table 4. Project Attribute Table<br>South Muddy Creek Stream Restoration Project: DMS Project No. 737 | |
|---|---|
| **Project County** | McDowell County, NC |
| **Physiographic Region** | Piedmont |
| **Ecoregion** | Inner Piedmont Belt |
| **Project River Basin** | Catawba |
| **USGS HUC for Project and Reference sites** | Project: 03050101040020; References: 03040103050 -090 (Spencer Creek), -080 (Barnes Creek); 03030002060 -070 (Morgan Creek); 03020201080 -020 (Sal's Branch) |
| **NCDWR Sub-basin for Project and Reference** | Project: 03-08-30; References: 03-07-09 (Spencer Creek and Barnes Creek); 03-06-06 (Morgan Creek); 03-04-02 (Sal's Branch) |
| **Within extent of EEP Watershed Plan ?** | Muddy Creek Local Watershed Plan (LWP), 2003 |
| **WRC Class (Warm, Cool, Cold)** | Warm |
| **% of project easement fenced or demarcated** | 100% |
| **Beaver activity observed during design phase ?** | None |
| | |
| **Restoration Component Attribute Table** | |
| | South Muddy |
| **Drainage area (sq. mi.)** | 18.8 |
| **Stream order** | 4th |
| **Restored length** | 2,787 |
| **Perennial or Intermittent** | Perennial |
| **Watershed type (Rural, Urban, Developing etc.)** | Rural |
| **Watershed LULC Distribution (e.g.)** | |
| **Developed Low-Medium Intensity** | 3.7 |
| **Ag-Cultivated Crops** | 0.6 |
| **Ag-Pasture/Hay** | 10.5 |
| **Forested** | 77.4 |
| **Other (Open water, Grassland, Etc.)** | 7.8 |
| **Watershed impervious cover (%)** | U |
| **NCDWR AU/Index number** | 03-08-30 |
| **NCDWQ classification** | C |
| **303d listed ?** | No |
| **Upstream of a 303d listed segment?** | No |
| **Reasons for 303d listing or stressor** | N/A |
| **Total acreage of easment** | 17.1 |
| **Total planted arceage as part of the restoration** | 14.1 |
| **Rosgen classification of pre-existing** | G4c |
| **Rosgen classification of As-built** | C4 |
| **Valley type** | Alluvial |
| **Valley slope** | 0.0017 ft/ft |
| **Valley side slope range (e.g. 2-3%)** | U |
| **Valley toe slope range (e.g. 2-3%)** | U |
| **Cowardin classification** | Riverine, Upper Perennial, Unconsolidated Bottom, Cobble-Gravel |
| **Trout waters designation** | No |
| **Species of concern, endangered etc.? (Y?N)** | No |
| **Dominant soil series and characteristics** | |
| **Series** | IoA |
| **Depth** | 10 |
| **Clay %** | 18 |
| **K** | 0.15 |
| **T** | 5 |

# APPENDIX B

## VISUAL ASSESSMENT DATA

# Site Assessment Report – Monitoring Year 5

South Muddy Creek (Randolph/Duncan Properties) Stream Restoration Project
McDowell County, North Carolina
May 2016

| | |
|---|---|
| Submitted To: | NCDEQ – Division of Mitigation Services<br>1625 Mail Service Center<br>Raleigh, NC 27699<br>NCDENR Contract ID No. 004522 |
| Submitted By: | Michael Baker Engineering, Inc.<br>5550 Seventy-Seven Center Dr., Ste. 320<br>Charlotte, NC 28217<br>License: F-1084, Baker Project No. 128221 |

Michael Baker
INTERNATIONAL

# 1. Introduction

## 1.1 Purpose

This report summarizes overall stream and vegetation conditions as part of an interim site assessment conducted in conjunction with the Year 5 monitoring services for the South Muddy Creek Stream Restoration Project site located in McDowell County, NC. This site assessment will be included as part of a more comprehensive annual monitoring report to be completed and submitted later this year (Fall 2016). The report describes project objectives, discusses the assessment methodology, summarizes assessment results, and documents potential stream and vegetation problem areas (SPAs and VPAs respectively).

## 1.2 Objectives

The objectives of the site assessment were to:

- Provide a general overview of stream morphological stability;
- Provide a general overview of vegetation conditions;
- Identify and document potential SPAs and VPAs.

## 1.3 Supporting Data

Supporting data and information are provided following the narrative portion of this report and include:

- Current condition plan view (CCPV) figures (Figure 2, sheets 1 and 2);
- Visual stream morphology stability assessment table (Table 5a);
- SPA inventory table (Table 5b);
- Vegetation condition assessment table (Table 6a);
- VPA inventory table (Table 6b);
- Stream station photos;
- SPA photos.

There are no VPA photos associated with this document.

# 2 Methodology

The methodology used for assessing overall stream and vegetation conditions at the South Muddy Creek Stream Restoration Project site adhered to the NCDEQ DMS monitoring guidance documents (dated November 7, 2011). The site assessment was comprised of two components, a visual stream morphology stability assessment and a vegetation condition assessment, both of which are described in more detail in the following sections of this report. The assessment was strictly qualitative. Vegetation monitoring plot counts were excluded from this assessment but will be conducted after July 2016. Vegetation monitoring plot data will be summarized in Appendix C and the CCPV figure of the Year 5 Annual Monitoring Report to be submitted in late November of this year.

The South Muddy Creek Stream Restoration Project site was evaluated as one project reach for each of the two components (SPA and VPA). This was done since the stream and riparian corridor are contained within one contiguous section along the mainstem of South Muddy Creek. Site conditions appeared uniform allowing for an assessment as one reach and the project was

assessed as one reach for the Final Baseline Monitoring Document/As-Built Report. Baker performed the visual site assessment on May 25, 2016.

### 2.1 Visual Stream Morphology Stability Assessment

The visual stream morphology stability assessment involved the evaluation of lateral and vertical channel stability, and the integrity and overall performance of in-stream structures throughout the project reach as a whole. Habitat parameters, such as riffle embeddedness and pool depth maintenance, were also measured and scored. The entire 2,787 linear foot reach was walked, noting geomorphic conditions of the stream bed profile (riffle/pool facets), both stream banks, and engineered in-stream structures. Photos were taken at every existing stream photo point station (from the as-built) and in locations of potential SPAs which were recorded in the field for subsequent mapping on the CCPV figures.

### 2.2 Vegetation Condition Assessment

The vegetation condition assessment involved the evaluation of vegetation within the 17.1 acre conservation easement and included assessing the performance of planted vegetation along stream banks, floodplains, and terraces as well as the documentation of invasive species. The assessment of planted vegetation was confined to the 14.1 acres of riparian buffer planting zones within the easement boundary as part of the restoration design whereas invasive vegetation and encroachment areas of invasive species were evaluated for the entire 17.1 acre easement boundary.

### 2.3 Post-processing of Field Data

The post-processing of field data consisted of the download and organization of photos into respective photo logs (stream and vegetation), creating the CCPV figures in GIS using the field-mapped SPAs and VPAs, populating the SPA and VPA tables, and finally scoring the performance of the reach in terms of stream morphology stability and vegetation condition using assessment forms provided by NCDEQ DMS.

## 3 Summary of Results

### 3.1 Visual Stream Morphology Stability Assessment

Table 5a summarizes the performance of the South Muddy Creek Stream Restoration Project reach in terms of lateral (stream bank) and vertical (channel bed) stability while evaluating the functionality and integrity of in-stream structures. Engineered in-stream structures evaluated for the assessment of this project reach consisted of constructed riffles, rock/log j-hooks, log vanes, root wads, geolifts, and brush mattresses. Constructed riffles were justified for inclusion in the evaluation of structures since they are the predominant grade control structure used throughout the site; however, they were only assessed for the ‘overall integrity’ and ‘grade control’ parameter categories in Table 5a.

As Table 5a indicates, the South Muddy Creek site was generally geomorphically stable overall within the lateral/vertical stability and in-stream structure performance categories. The seven sub-categories receiving scores of less than 100 percent correspond to the thirteen SPAs that were documented and summarized in Table 5b. Bank stabilization work conducted in November of

2015 from Station 28+00 to 29+50 has remained stable and woody vegetation is actively growing within the area. Beaver activity was not noted during the Year 5 monitoring assessment.

All thirteen SPAs were either characterized or the result from localized areas of bank erosion. One of the thirteen SPAs documented in Table 5b, SPA1-1, has persisted from the Year 1 monitoring assessment, two are from Year 2, one is from Year 3, and two are from Year 4. (Each is referenced as such by the first number in the SPA naming convention). Seven new SPAs were identified during the Year 5 monitoring assessment.

SPA1-1 consists of a portion of undermined brush mattress along the right bank in an outer meander bend that has resulted in bank erosion with the potential for bank slump. The length of undercut and eroded bank along SPA1-1 is currently active and migrating downstream. The current length of scour and active erosion is approximately 110 LF, where as it was documented as 80 LF in Year 4. It is likely that lateral instability along this outer meander bend will continue migrating downstream, over time, and potentially lead to downstream structure failure.

SPA2-2 consists of approximately 100 LF length of bank erosion from Station 16+30 and 17+30 along the right bank, beginning at the tail of the upstream riffle and continuing through the apex of the downstream outer meander bend. Though the downstream section of the meander bend is reestablishing some woody vegetative growth, the area in the upstream portion is actively eroding and has the potential to result in bank slump. This area is currently unstable and will likely continue to migrate downstream and undermine any stability that has developed in the downstream portion of the bend.

SPA2-3 consists of an area of localized scour along the right bank located downstream of an outer meander bend between station 17+95 and 18+50. Bank scour could potentially be a result of the lack of centering of the thalweg immediately downstream of the upstream meander bend (and was noted accordingly in Table 5a). As a result, some velocity vectors within the riffle have been redirected toward the right bank instead of being centered in the riffle, thereby increasing near bank stress and causing the bank to erode. The bank is vertical, exposed, devoid of vegetation and matted protection.

SPA3-2 is an area of localized scour along an outside meander bend on the right bank located downstream of the Sain Road bridge between station 31+90 and 32+10. This scour is a result of high water velocity from the steep riffle directly upstream. There are no bank protection structures in the meander, and the erosion has left the bank vertical with very little vegetative protection. It is actively eroding and is likely to migrate downstream.

SPA4-1 is a localized area of bank erosion behind a rootwad on the right bank. The erosion is likely caused by overbank flows scouring the area behind the rootwad. Erosion in this area has migrated upstream and caused separation of the root wad and log sill from the bank tie-in. Structure failure of the rootwad and log sill have occurred and are discussed in SPA5-2.

SPA4-2 is a localized area of bank erosion behind a rootwad on the right bank. The erosion appears to be caused by overbank flows scouring the area behind the rootwad. However, because of the uniform nature of the problem and the historic presence of beavers within the area, this SPA is likely a relic beaver den. The rootwad is still functioning as bank protection. Filling the void and mounding behind the rootwad would remedy the issue.

SPA5-1 is a small area of localized bank scour located on the left bank, downstream of a log sill / rootwad complex at the end of the meander bend. Upon review of the area, no distinct cause for the scour could be determined; however, due to its location along the bend, it has a potential to negatively impact the integrity of upstream structures if the area does not re-stabilize.

As previously discussed, scour from SPA4-1 has led to structure failure of both the rootwad and the log sill at SPA5-2. The root wad is no longer functioning and has separated from bank; however, it still seems to be tied into the bank. The log sill has separated completely from the bank and is now resting entirely upon the bed of the channel.

SPA5-3 is located on the right bank just downstream of rock j-hook boulder tie-in. Scour in this area has caused the boulder/bank tie-in to be breached. Currently flow velocities are skirting around the tie-in boulder and are directed toward the bank instead of flowing over the structure.

SPA5-4 is a localized scour pocket located on the inside of the meander bend at Station 24+00 to 24+35. Erosion in the area has resulted in the loss of woody vegetation into the stream. Though the area is actively eroding, no direct cause could be determined.

SPA5-5 is located along the left bank of a riffle around Station 25+60 to 25+75. Erosion is this area, likely due to the thalweg direction toward the left bank instead of the center of the riffle, has resulted in bank slump. Stream bank vegetation within this section is lacks woody vegetation.

SPA5-6 consists of bank slump on right bank along riffle downstream of Sain Rd. Bridge. Cause is likely due to high water velocities created by steep riffle just downstream of bridge, as well as, the lack of vegetation along the bank and poor soil compaction.

SPA5-7 consists of localized bank scour on right bank just downstream of a remnant beaver dam and the bank tie-in of rock J-hook. Cause unknown, but likely due to flow velocities being shifted towards right bank due to persisting debris along left bank from remnant beaver dam. Currently the boulder tie-in of the J-hook is not compromised.

## 3.2 Vegetation Condition Assessment

Table 6a summarizes the vegetation condition of the South Muddy Creek Stream Restoration site. The planted acreage performance categories were functioning at 100 percent with no low stem density areas or areas of poor growth rates/vigor that exceeded the mapping threshold of 0.1 acres or 0.25 acres respectively. In addition, no areas of invasive species concern were observed that exceeded the mapping threshold of 1000 square feet in size.

Multiple treatment control applications for exotic invasive species have been conducted throughout Monitoring Year 3 and Year 4 for *Ligustrum sinese*, *Rosa multiflora*, *Lonicera japonica*, *Sorghum halepense*, and *Pueraria montana var. lobata* by a NCDMS licensed contractor. Additionally, a subsequent treatment control application was conducted in November 2015 to further treat areas where invasive species had continued to persist.

Though invasive species density has been reduced and currently there were no VPAs which exceeded the mapping threshold, individual stems and/or localized populations of invasive species were observed throughout the assessment area. These species consisted primarily of young saplings of *Pyrus calleryana* (Braford pear). Additional treatment will be necessary to control invasive species within the Conservation Easement.

AS-BUILT CHANNEL

AS-BUILT CENTERLINE

AS-BUILT TOP OF BANK

CROSS SECTION

FENCE

CONSERVATION EASEMENT

PHOTO ID POINT

VEGETATION PLOT

VEGETATION PROBLEM AREA (VPA) INVASIVE SPECIES PRESENT

VEGETATION PROBLEM AREA (VPA) SPARSE HERBACEOUS COVER

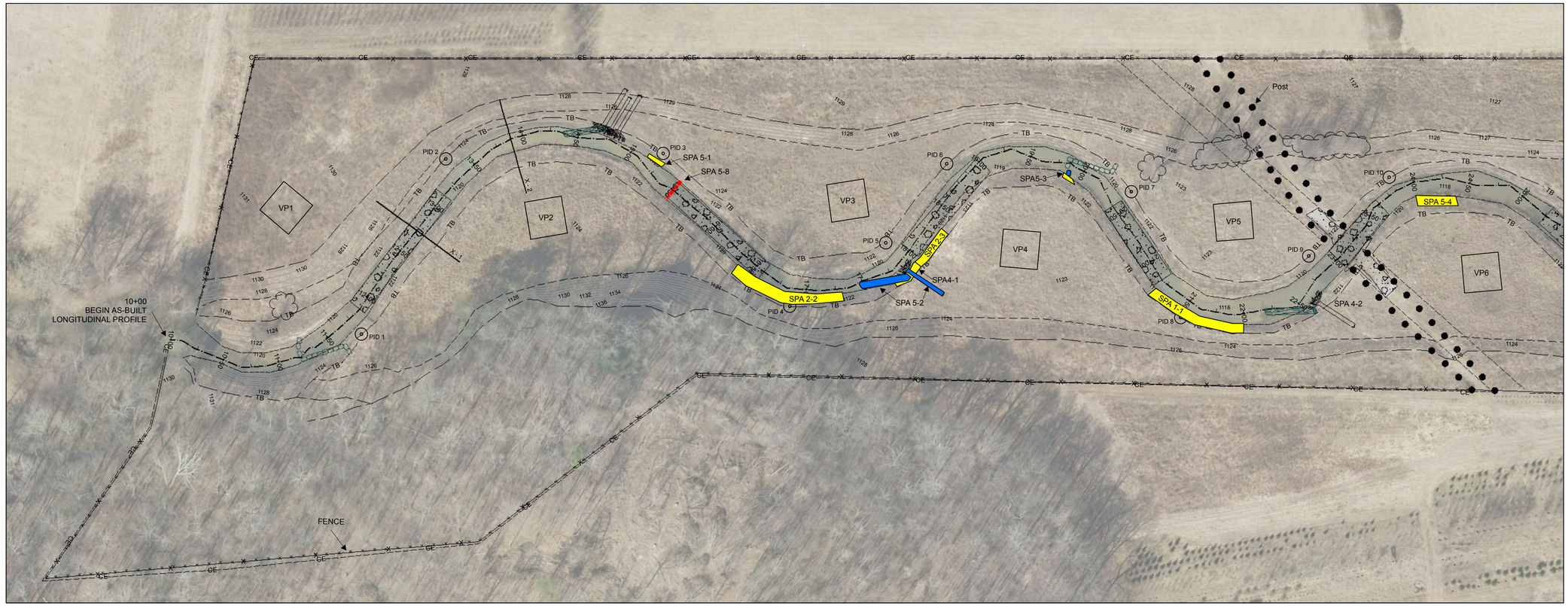
STREAM PROBLEM AREA (SPA) BANKS WITH EVIDENT SCOUR / EROSION

STREAM PROBLEM AREA (SPA) UNDERCUT BANKS

STREAM PROBLEM AREA (SPA) STRUCTURE PROBLEM

STREAM PROBLEM AREA (SPA) BANK SLUMP / COLLAPSE

BEAVERDAM




NC OneMap, NC Center for Geographic Information and Analysis, NC 911 Board (2010, 2012, & 2013)

N

50 25 0 50 100 Feet

# SOUTH MUDDY CREEK
# CURRENT CONDITION PLAN VIEW
# YEAR 5 MONITORING
# STA. 10+00 - 25+00


Michael Baker Engineering, Inc.
NC Engineering License F-1084
9716-B Rea Road #56
Charlotte, North Carolina 28277
Phone: 704.665.2206


Michael Baker INTERNATIONAL

SOUTH MUDDY CREEK
STREAM RESTORATION PROJECT
MCDOWELL COUNTY, NORTH CAROLINA
FIGURE 2

Prepared For:
North Carolina Department of Environmental Quality
Division of Mitigation Services
1625 Mail Service Center
Raleigh, NC 27699
Phone: 919-707-8976

DMS Project No. 00737

Baker Project No. 128221

Date: 2017

DESIGNED: -----
DRAWN: KLS
APPROVED: JB

Monitoring Year: 5 of 5

Sheet: 1 of 2

CONSERVATION EASEMENT

AS-BUILT CENTERLINE

AS-BUILT TOP OF BANK

AS-BUILT CHANNEL

FENCE

CROSS SECTION

UTILITY POLE

UTILITY EASEMENT EXTENTS

UTILITY LINE

VEGETATION PROBLEM AREA (VPA) INVASIVE SPECIES PRESENT

VEGETATION PROBLEM AREA (VPA) SPARSE HERBACEOUS COVER

PHOTO ID POINT

VEGETATION PLOT

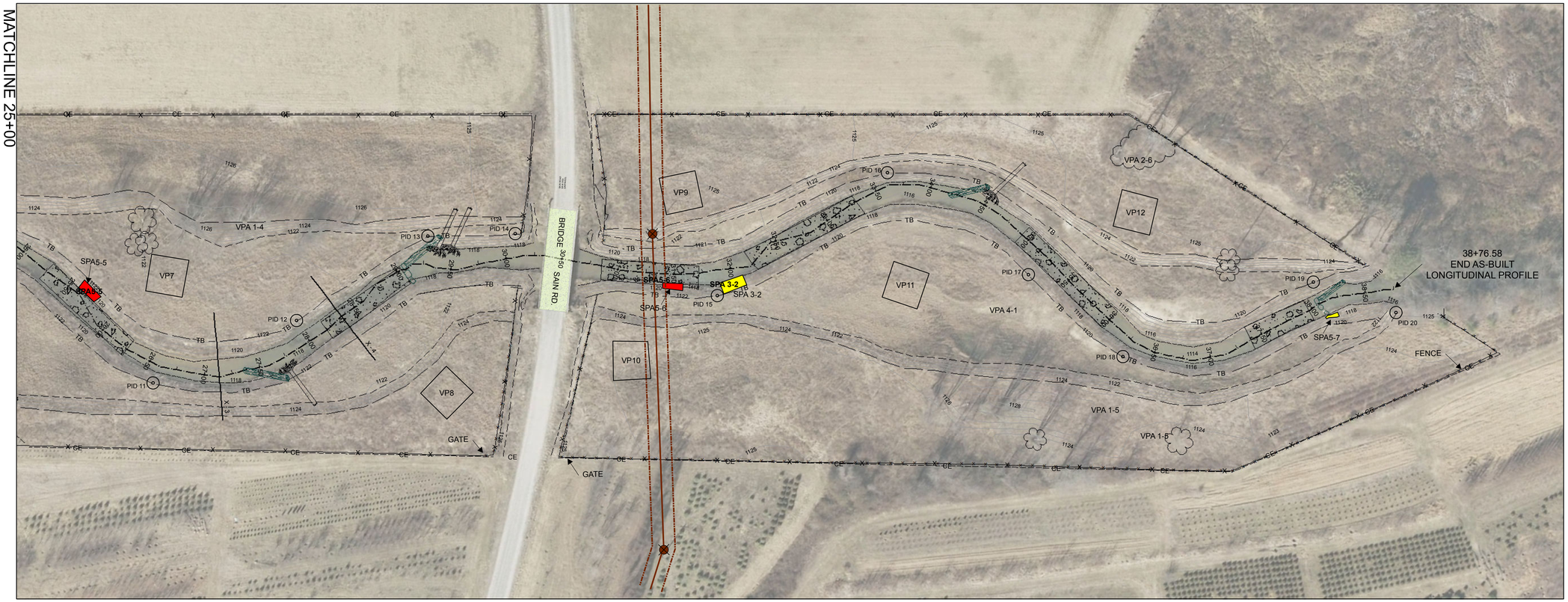
STREAM PROBLEM AREA (SPA) BANKS WITH EVIDENT SCOUR / EROSION

STREAM PROBLEM AREA (SPA) UNDERCUT BANKS

STREAM PROBLEM AREA (SPA) STRUCTURE PROBLEM

STREAM PROBLEM AREA (SPA) BANK SLUMP / COLLAPSE

MATCHLINE 25+00




NC OneMap, NC Center for Geographic Information and Analysis, NC 911 Board (2010, 2012, & 2013)

50 25 0 50 100 Feet

# SOUTH MUDDY CREEK
# CURRENT CONDITION PLAN VIEW
# YEAR 5 MONITORING
# STA. 25+00 - 38+77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SOUTH MUDDY CREEK
STREAM RESTORATION PROJECT
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FIGURE 2

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Date: 2017

DESIGNED: -----
DRAWN: KLS
APPROVED: JB

Monitoring Year: 5 of 5

Sheet: 2 of 2

**Table 5a. Visual Stream Morphology Stability Assessment**
**South Muddy Creek Stream Restoration Project: Project No. 737**

**Reach ID:** South Muddy Creek
**Assessed Length (LF)** 2787

| Major Channel Category | Channel Sub-Category | Metric | Number Stable, Performing as Intended | Total Number per As-Built | Number of Unstable Segments | Amount of Unstable Footage | % Stable, Performing as Intended | Number with Stabilizing Woody Veg. | Footage with Stabilizing Woody Veg. | Adjusted % for Stabilizing Woody Veg. |
|---|---|---|---|---|---|---|---|---|---|---|
| 1. Bed | 1. Vertical Stability | 1. Aggradation | | | 0 | 0 | 100% | | | |
| | | 2. Degradation | | | 0 | 0 | 100% | | | |
| | 2. Riffle Condition | 1. Texture/Substrate | 11 | 11 | | | 100% | | | |
| | 3. Meander Pool Condition | 1. Depth | 12 | 12 | | | 100% | | | |
| | | 2. Length | 12 | 12 | | | 100% | | | |
| | 4. Thalweg position | 1. Thalweg centering at upstream of meander bend (Run) | 12 | 12 | | | 100% | | | |
| | | 2. Thalweg centering at downstream of meander (Glide) | 9 | 11 | | | 82% | | | |
| | | | | | | | | | | |
| 2. Bank | 1. Scoured/Eroding | Bank lacking vegetative cover resulting simply from poor growth and/or scour and erosion | | | 8 | 325 | 94% | 0 | 0 | 94% |
| | 2. Undercut | Banks undercut/overhanging to the extent that mass wasting appears likely | | | 0 | 0 | 100% | 0 | 0 | 100% |
| | 3. Mass Wasting | Bank slumping, calving, or collapse | | | 2 | 30 | 99% | 1 | 15 | 100% |
| | | | | **Totals** | 10 | 355 | 94% | 1 | 15 | 94% |
| | | | | | | | | | | |
| 3. Engineering Structures | 1. Overall Integrity | Structures physically intact with no dislodged boulders or logs | 35 | 38 | | | 92% | | | |
| | 2. Grade Control | Grade control structures exhibiting maintenance of grade across the sill. | 11 | 11 | | | 100% | | | |
| | 2a. Piping | Structures lacking any substantial flow underneath sills or arms | 9 | 9 | | | 100% | | | |
| | 3. Bank Protection | Bank erosion within the structures extent of influence does not exceed 15% | 27 | 27 | | | 100% | | | |
| | 4. Habitat | Pool forming structures maintaining ~ Max Pool Depth | 9 | 9 | | | 100% | | | |

| Table 5b. Stream Problem Areas<br>South Muddy Creek Restoration Project: Project No. 737 | | | |
|---|---|---|---|
| **South Muddy Creek (2,787 LF)** | | | |
| **Feature Issue** | **Station No.** | **Suspected Cause** | **Photo Number*** |
| Bank Scour | 21+20 to 22+00 | The right bank is experiencing high flow velocities directed at the outer meander bend and is causing a significant area of erosional scour with the potential for bank slump. This area has persisted since Year 1. | SPA1-1 |
| | 16+30 to 17+30 | The right bank is experiencing high flow velocities directed at the outer meander bend and is migrating upstream along the bank face into the tail of the riffle. Currently the downstream portion of the meander bend seems to be slowly stabilizing with native vegetation. | SPA2-2 |
| | 17+95 to 18+50 | Localized scour along the right bank of a riffle resulting in raw, vertical bank, devoid of vegetation and matted protection. Appears to be caused by high near bank stress and poorly compacted soil. Vegetation and rootmass along that portion of bank is sparse. | SPA2-3 |
| | 31+90 to 32+10 | Localized scour along right bank downstream of Sain Rd. Bridge. Cause is due to high water velocites created by steep riffle just downstream of bridge. | SPA3-2 |
| | 17+75 to 17+95 | Localized scour behind rootwad has migrated upstream and caused separation of the root wad and log sill from the bank tie-in. Erosion appears to be caused by high near bank stress during high water. | SPA4-1 |
| | 15+15 to 15+30 | Localized area of bank scour on left bank. Cause unknown. | SPA5-1 |
| Engineered Structures - Log Sill & Rootwad Failure | 17+75 to 17+95 | Scour from SPA4-1 has led to structure failure of both the rootwad and the log sill. The root wad is no longer functioning and has separated from bank; however, it still seems to be tied into the bank. The log sill has separated completely from the bank and is now resting entirely upon the bed of the channel. | SPA5-2 |
| Bank Scour and Engineered Structures - Rock J-Hook | 19+80 to 19+95 | Scour pocket on right bank just downstream of rock j-hook boulder tie-in has caused the boulder/bank tie-in to be breached. | SPA5-3 |
| Bank Scour | 24+00 to 24+35 | Scour pocket causing a loss of stream bank vegetation on the right bank along the inside of the meander bend. Cause unknown. | SPA5-4 |
| Bank Slump | 25+60 to 25+75 | Bank slump on left bank along riffle, likely due to thalweg direction into the left bank, as well as, the lack of vegetation along the bank and poor soil compaction. | SPA5-5 |
| | 31+40 to 31+55 | Bank slump on right bank along riffle downstream of Sain Rd. Bridge. Cause is due to high water velocites created by steep riffle just downstream of bridge, as well as, the lack of vegetation along the bank and poor soil compaction. This area was noted during Year 5 monitoring as beginning to revegetate. | SPA5-6 |
| Bank Scour | 38+10 to 38+20 | Localized bank scour on right bank just downstream of a remnant beaver dam and the bank tie-in of rock J-hook. Cause unknown, but likely due to flow velocities being shifted towards right bank due to persisting debris along left bank from remenant beaver dam. | SPA5-7 |
| Beaver dam | 15+50 | Beaver dam | SPA5-8 |
| *Note: The first digit in the Photo Number column references the monitoring year and the second digit references the problem area or photo (which would be identical to a prior years | | | |

**Table 6a. Vegetation Condition Assessment**
**South Muddy Creek Stream Restoration Project: Project No. 737**

| | |
|---|---|
| **Reach ID:** | **South Muddy Creek** |
| **Planted Acreage:** | **14.1** |

| Vegetation Category | Definitions | Mapping Threshold | CCPV Depiction | Number of Polygons | Combined Acreage | % of Planted Acreage |
|---|---|---|---|---|---|---|
| **1. Bare Areas** | Very limited cover of both woody and herbaceous material. | 0.1 acres | see figure | 0 | 0.00 | 0% |
| **2. Low Stem Density Areas** | Woody stem densities clearly below target levels based on MY3, 4, or 5 stem count criteria. | 0.1 acres | NA | 0 | 0.00 | 0% |
| | | | **Total** | 0 | 0.00 | 0.0% |
| **3. Areas of Poor Growth Rates or Vigor** | Areas with woody stems of a size class that are obviously small given the monitoring year. | 0.25 acres | NA | 0 | 0.00 | 0% |
| | | | **Cumulative Total** | 0 | 0.00 | 0.0% |

| | |
|---|---|
| **Easement Acreage** | **17.1** |

| Vegetation Category | Definitions | Mapping Threshold | CCPV Depiction | Number of Polygons | Combined Acreage | % of Easement Acreage |
|---|---|---|---|---|---|---|
| **4. Invasive Areas of Concern** | Areas or points (if too small to render as polygons at map scale). | 1000 SF | see figure | 0 | 0.00 | 0.0% |
| | | | | | | |
| **5. Easement Encroachment Areas** | Areas or points (if too small to render as polygons at map scale). | none | NA | 0 | 0.00 | 0.0% |

**Table 6b. Vegetation Problem Areas**
**South Muddy Creek Restoration Project: Project No. 737**

**South Muddy Creek**

| Feature Issue | Station No. | Suspected Cause | Photo Number* |
|---|---|---|---|
| None | - | - | - |

*Note: The first digit in the Photo Number column references the monitoring year and the second digit references the problem area or photo (which would be identical to a prior years problem area/photo number when persisting from a previous monitoring year).

# South Muddy Creek
# Stream Station Photos

South Muddy Creek PID 1 – J-Hook near upstream end of project

South Muddy Creek PID 2 –Constructed Riffle,

South Muddy Creek PID 3 – Log Vane in Meander

South Muddy Creek PID 4 – Constructed Riffle

South Muddy Creek PID 5 – Log Vane in Meander

South Muddy Creek PID 6 – Constructed Riffle

South Muddy Creek PID 7 – J-Hook in Meander

South Muddy Creek PID 8 – Constructed Riffle

South Muddy Creek PID 9 – Log Vane in Meander

South Muddy Creek PID 10 – Stream Crossing

South Muddy Creek PID 11 – Constructed Riffle

South Muddy Creek PID 12 – Log Vane and Root Wad in Meander

South Muddy Creek PID 13 – Constructed Riffle

South Muddy Creek PID 14 – Immediately upstream of Sain Road crossing

South Muddy Creek PID 15 – Constructed Riffle downstream of Sain Road crossing

South Muddy Creek PID 16

South Muddy Creek PID 17 – Log Vane in Meander

South Muddy Creek PID 18 – Constructed Riffle

South Muddy Creek PID 19

South Muddy Creek PID 20 – J-Hook near downstream end of project

# South Muddy Creek
# Stream Problem Area (SPA) Photos

SPA1-1 – Right bank scour is migrating downstream along the outer meander bend (5-25-16).

SPA2-2 – Right bank scour is migrating upstream from the outer meander bend up the tail of the upstream riffle. The downstream section of the meander bend seems to be slowly stabilizing with native vegetation (5-25-16).

SPA2-3 – Localized scour along right bank along riffle from the lack of thalweg re-centering (5-25-16).

SPA3-2 – Localized scour along right bank downstream of Sain Rd. Bridge (5-25-26).

SPA4-1 – Localized scour along right bank behind rootwad and compromising the structures (5-25-16).

SPA 5-1 – Localized area of scour on left bank (5-25-16))

SPA5-2 – Scour from SPA4-1 has led to structure failure of both the rootwad and the log sill. The root wad is no longer functioning and has separated from bank; however, it still seems to be tied into the bank. The log sill has separated completely from the bank and is now resting entirely upon the bed of the channel (5-26-16).

SPA 5-3 – Scour pocket on right bank just downstream of rock j-hook boulder tie-in has caused the boulder/bank tie-in to be breached (5-25-16)

SPA 5-4 – Scour pocket causing a loss of stream bank vegetation on the right bank along the inside of the meander bend (5-25-16)

SPA 5-5 – Scour and bank slumping along left bank (5-25-16)

SPA 5-6 – Scour and bank slumping along right bank downstream of Sain Rd. Bridge (5-25-16).

SPA 5-7 – Scour on right bank just downstream of SPA 4-5, a remnant beaver dam (5-25-16)

SPA 5-8 – Beaver dam located approximately at Station 15+50 (11-28-16)

# South Muddy Creek
# Vegetation Problem Area (VPA) Photos

# South Muddy Creek – Vegetation Problem Area Photolog

Isolated areas of *Pyrus calleryana* (Bradford pear) trees

Herbicidal spray evidence from utility easement

Herbicidal spray evidence under utility line

# APPENDIX C

## VEGETATION PLOT DATA

| Table 7. Vegetation Plot Criteria Attainment<br>South Muddy Creek Restoration Project: DMS Project No. 737 | | | |
|---|---|---|---|
| **Vegetation Plot ID** | **Vegetation Survival Threshold Met?** | **Planted/Total Stem Count*** | **Tract Mean** |
| 1 | Yes | 324/324 | 462/553 |
| 2 | Yes | 647/728 | |
| 3 | Yes | 647/1052 | |
| 4 | Yes | 405/526 | |
| 5 | Yes | 486/688 | |
| 6 | Yes, but barely | 283/405 | |
| 7 | Yes | 486/647 | |
| 8 | Yes | 405/405 | |
| 9 | Yes | 486/486 | |
| 10 | Yes | 526/526 | |
| 11 | Yes | 364/364 | |
| 12 | Yes | 486/486 | |
| Note: *Planted/Total Stem Count reflects the changes in stem density based on the density of stems at the time of the As-Built Survey (Planted) and the current total density of planted stems including volunteers (Total). | | | |

**Table 8. CVS Vegetation Plot Metadata**
**South Muddy Creek Restoration Project: DMS Project No. 737**

| | |
|---|---|
| **Report Prepared By** | Kristi Suggs |
| **Date Prepared** | 11/18/2016 13:41 |
| **Database name** | 00737_S.Muddy_Yr2-5_cvs-eep-entrytool-v2.3.1.rwm.mdb |
| **Database location** | C:\My Documents\Baker\CVS\S.Muddy |
| **Computer name** | CHABLKSUGGS |
| **File size** | 49057792 |
| **DESCRIPTION OF WORKSHEETS IN THIS DOCUMENT** | |
| **Metadata** | Description of database file, the report worksheets, and a summary of project(s) and project data. |
| **Proj, planted** | Each project is listed with its PLANTED stems per acre, for each year. |
| **Proj, total stems** | Each project is listed with its TOTAL stems per acre, for each year. This includes live stakes, all planted stems, and all natural/volunteer stems. |
| **Plots** | List of plots surveyed with location and summary data (live stems, dead stems, missing, etc.). |
| **Vigor** | Frequency distribution of vigor classes for stems for all plots. |
| **Vigor by Spp** | Frequency distribution of vigor classes listed by species. |
| **Damage** | List of most frequent damage classes with number of occurrences and percent of total stems impacted by each. |
| **Damage by Spp** | Damage values tallied by type for each species. |
| **Damage by Plot** | Damage values tallied by type for each plot. |
| **Planted Stems by Plot and Spp** | A matrix of the count of PLANTED living stems of each species for each plot; dead and missing stems are excluded. |
| **PROJECT SUMMARY** | |
| **Project Code** | 737 |
| **Project Name** | South Muddy Creek Restoration Project |
| **Description** | The project involved the Priority II Restoration of 2,787 linear feet of stream along South Muddy Creek at Sain Rd. |
| **River Basin** | Catawba |
| **Length(ft)** | 2787 |
| **Stream-to-edge width (ft)** | 70 |
| **Area (sq m)** | 36245.24 |
| **Required Plots (calculated)** | 10 |
| **Sampled Plots** | 12 |

**Table 9. CVS Stem Count Total and Planted by Plot and Species (with Annual Means)**

**South Muddy Creek Restoration Project: DMS Project No. 737**

| Tree Species | Common Name | Type | Current Data (MY5 2016) | | | | | | | | | | | | | | | | | | | | | | Annual Means | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | | | Plot 1 | | Plot 2 | | Plot 3 | | Plot 4 | | Plot 5 | | Plot 6 | | Plot 7 | | Plot 8 | | Plot 9 | | Plot 10 | | Plot 11 | | Plot 12 | | Current Mean | | AB (2011) | | MY1 (2012) | | MY2 (2013) | | MY3 (2014) | | MY4 (2015) | |
| | | | P | T | P | T | P | T | P | T | P | T | P | T | P | T | P | T | P | T | P | T | P | T | P | T | P | T | P | T | P | T | P | T | P | T |
| *Betula nigra* | River Birch | Tree | 2 | 2 | 2 | 2 | | | 2 | 2 | 3 | 3 | 4 | 4 | 4 | 5 | | | | | | | 3 | 3 | | | 3 | 3 | 3 | 3 | 3 | 2 | 2 | 2 | 1 | 1 | 3 | 3 |
| *Carpinus caroliniana* | American Hornbeam | Tree | | | | | | | | | | | | | | | 2 | 2 | | | | | | | | | 2 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 1 | 1 | 2 | 2 |
| *Celtis laevigata* | Sugarberry | Shrub | 1 | 1 | | | | | | | | | | | | | 2 | 2 | 1 | 1 | | | | | 1 | 1 | 1 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 |
| *Diospyros virginiana* | Persimmon | Tree | | | 3 | 3 | | | | | 3 | 3 | | | 1 | 1 | | | 1 | 1 | 1 | 1 | | | 1 | 1 | 2 | 2 | 2 | 2 | 0 | 3 | 2 | 2 | 2 | 2 | 2 | 2 |
| *Fraxinus pennsylvanica* | Green Ash | Tree | | | 4 | 4 | 1 | 1 | | | | | | | 2 | 2 | | | 2 | 2 | 5 | 5 | 1 | 1 | 2 | 2 | 2 | 2 | 2 | 2 | 2 | 3 | 3 | 3 | 2 | 2 | 2 | 2 |
| *Juglans nigra* | Black Walnut | Tree | | | | | | | | | | | | | 1 | 1 | | | | | | | 1 | 1 | | | 1 | 1 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 |
| *Liriodendron tulipfera* | Tulip Poplar | Tree | 3 | 3 | 3 | 3 | 6 | 6 | 3 | 3 | 1 | 1 | 2 | 2 | | | | | 3 | 3 | | | 1 | 1 | 1 | 1 | 3 | 3 | 4 | 4 | 4 | 3 | 3 | 3 | 2 | 2 | 2 | 2 |
| *Nyssa sylvatica* | Blackgum | Tree | | | | | | | | | | | | | | | | | 1 | 1 | | | | | 1 | 1 | 0 | 0 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 1 | 0 | 0 |
| *Platanus occidentalis* | Sycamore | Tree | 1 | 1 | 4 | 4 | 5 | 5 | 2 | 2 | 3 | 3 | | | 2 | 2 | 4 | 4 | | | 4 | 4 | 3 | 3 | 6 | 6 | 3 | 3 | 4 | 4 | 4 | 3 | 4 | 4 | 3 | 3 | 4 | 4 |
| *Quercus pagoda* | Cherrybark Oak | Tree | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 0 | 0 | 0 | 3 | 0 | 0 | 1 | 1 | 0 | 0 |
| *Quercus palustris* | Pin Oak | Tree | | | | | | | | | | | | | | | | | | | | | | | | | 0 | 0 | 2 | 2 | 2 | 1 | 2 | 2 | 1 | 1 | 1 | 1 |
| *Quercus phellos* | Willow Oak | Tree | | | | | 4 | 4 | 3 | 3 | 2 | 2 | | | 1 | 1 | | | | | | | | | | | 3 | 3 | 1 | 1 | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 |
| *Quercus rubra* | N. Red Oak | Tree | 1 | 1 | | | | | | | | | 1 | 1 | 1 | 1 | 2 | 2 | 3 | 3 | 3 | 3 | | | | | 2 | 2 | 4 | 4 | 3 | 2 | 3 | 3 | 2 | 2 | 1 | 1 |
| *Vaccinium corymbosum* | highbush blueberry | Shrub | | | | | | | | | | | | | | | | | 1 | 1 | | | | | | | | 1 | | | | | | | | | | 1 |
| **Volunteers** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Acer rubrum* | Red Maple | Tree | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Betula nigra* | River Birch | Tree | | | | | | 2 | | | | 5 | | 2 | | 3 | | | | | | | | | | | | 3 | | | | | | | | 5 | | |
| *Diospyros virginiana* | Persimmon | Tree | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Fraxinus pennsylvanica* | Green Ash | Tree | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| *Juglans nigra* | Black Walnut | Tree | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | | | | | |
| *Liriodendron tulipfera* | Tulip Poplar | Tree | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | 1 | | | | |
| *Nyssa sylvatica* | Blackgum | Tree | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 | | | | |
| *Pinus virginiana* | Virginia pine | Tree | | | | 1 | | | | | | | | 1 | | | | | | | | | | | | | | 1 | | | | | | | | | | |
| *Platanus occidentalis* | Sycamore | Tree | | | | 1 | | 8 | | 3 | | | | | | | | | | | | | | | | | | 4 | | | | | | 7 | | 4 | | |
| *Prunus serotina* | Black Cherry | Tree | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 5 | | | | |
| *Quercus rubra* | N. Red Oak | Tree | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 2 | | 2 | | | | |
| *Vaccinium corymbosum* | highbush blueberry | Shrub | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | 1 |
| | Plot area (acres) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| | Species Count | | 5 | 5 | 5 | 7 | 4 | 6 | 4 | 5 | 5 | 6 | 3 | 5 | 7 | 8 | 4 | 4 | 7 | 7 | 4 | 4 | 5 | 5 | 6 | 6 | 5 | 6 | 6 | 6 | 6 | 6 | 5 | 5 | 6 | 6 | 5 | 5 |
| | Planted Stems/Plot | | 8 | 8 | 16 | 16 | 16 | 16 | 10 | 10 | 12 | 12 | 7 | 7 | 12 | 13 | 10 | 10 | 12 | 12 | 13 | 13 | 9 | 9 | 12 | 12 | 11 | 12 | 16 | 16 | 16 | 13 | 12 | 12 | 10 | 10 | 11 | 11 |
| P=Planted | Total Stems/Plot | | 8 | 8 | 16 | 18 | 16 | 26 | 10 | 13 | 12 | 17 | 7 | 10 | 12 | 16 | 10 | 10 | 12 | 12 | 13 | 13 | 9 | 9 | 12 | 12 | 11 | 14 | 16 | 16 | 16 | 18 | 12 | 16 | 10 | 13 | 11 | 11 |
| T=Total | Planted Stems Per Acre | | 324 | 324 | 647 | 728 | 647 | 1052 | 405 | 526 | 486 | 688 | 283 | 405 | 486 | 647 | 405 | 405 | 486 | 486 | 526 | 526 | 364 | 364 | 486 | 486 | 462 | 553 | 627 | 627 | 627 | 523 | 482 | 651 | 411 | 509 | 449 | 452 |
| | (including volunteers) | | 324 | | 728 | | 1052 | | 526 | | 688 | | 405 | | 647 | | 405 | | 486 | | 526 | | 364 | | 486 | | 553 | | 627 | | 725 | | 651 | | 509 | | 452 | |

Notes: CVS Level 1 Survey performed. In most cases, the volunteers observed were approximately 50 - 150 cm in height but not counted.

**Color for Density**

Exceeds requirements by 10%

Exceeds requirements, but by less than 10%

Fails to meet requirements, by less than 10%

Fails to meet requirements by more than 10%

# South Muddy Creek
# Vegetation Plot Photos

**South Muddy Creek Stream Restoration Project**
**Year 5 Monitoring - Vegetation Plot Photo Log**

10/05/2016 - Veg Plot 1

11/28/2016 - Veg Plot 2

10/04/2016 - Veg Plot 3

10/04/2016 - Veg Plot 4

10/04/2016 - Veg Plot 5

10/04/2016 - Veg Plot 6

**South Muddy Creek Stream Restoration Project**
**Year 5 Monitoring - Vegetation Plot Photo Log**

10/04/2016 - Veg Plot 7

10/04/2016 - Veg Plot 8

10/05/2016 - Veg Plot 9

10/05/2016 - Veg Plot 10

10/05/2016 - Veg Plot 11

10/05/2016 - Veg Plot 12

# APPENDIX D

## STREAM SURVEY DATA

**Figure 3. Cross-sections with Annual Overlays**

## South Muddy Creek

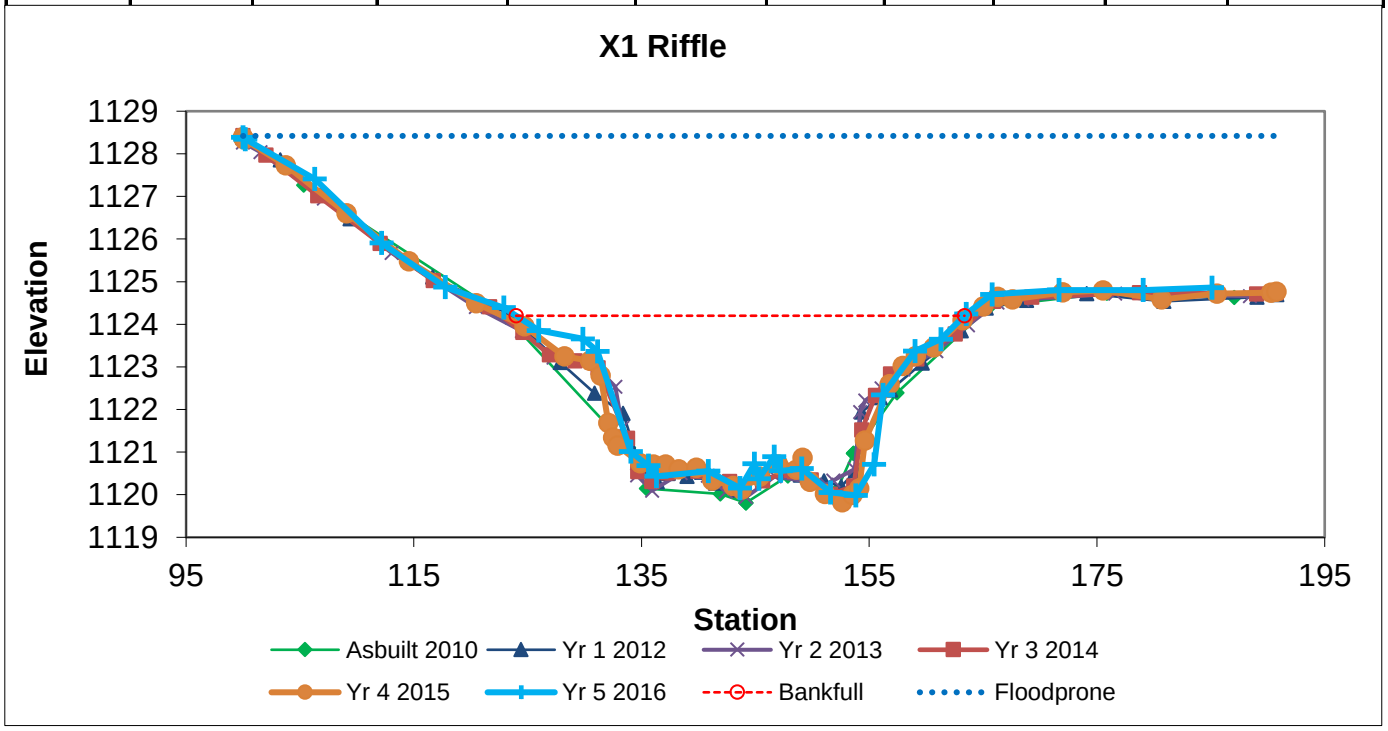
### Permanent Cross Section X1

(Year 5 Monitoring - October 2016)

**LEFT BANK**

**RIGHT BANK**

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | | 97.08 | 39.37 | 2.47 | 4.22 | 16 | 1 | 2.08 | 1124.2 | 1123.65 |



# South Muddy Creek

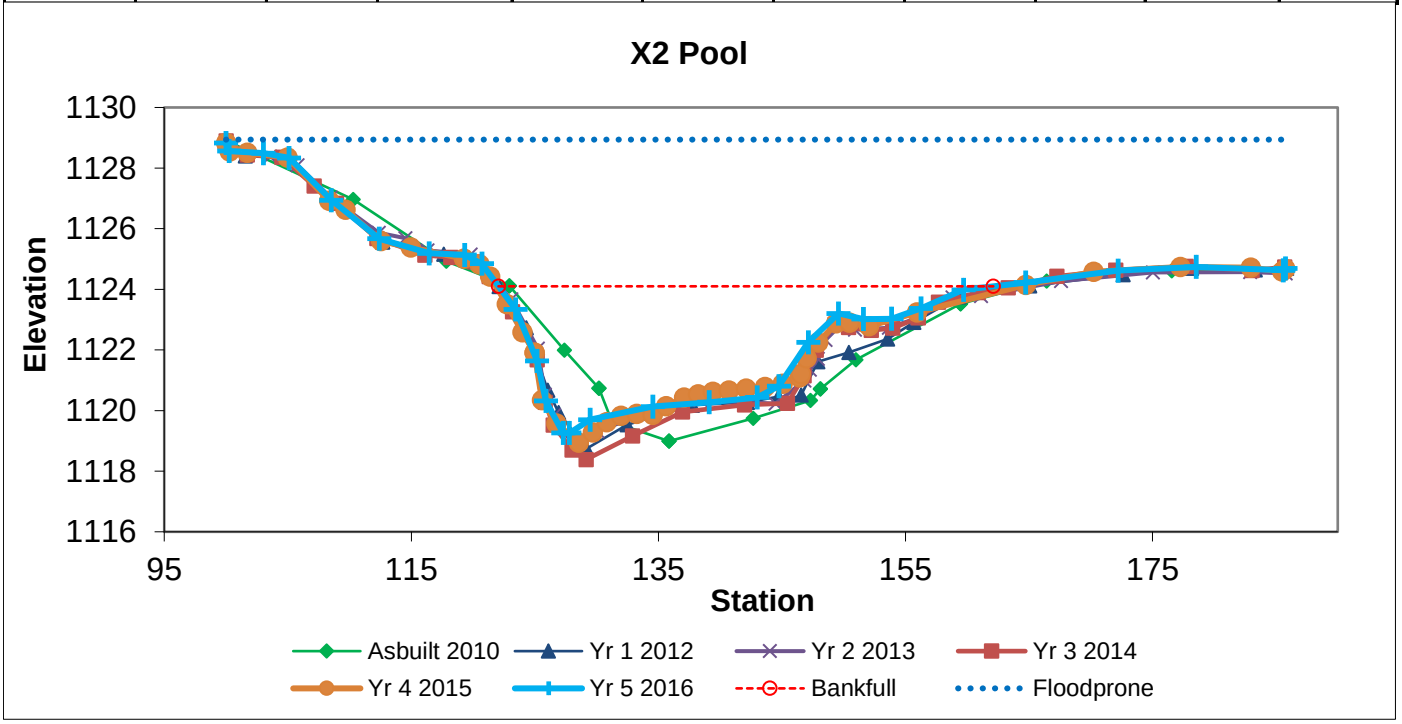
## Permanent Cross Section X2

(Year 5 Monitoring - October 2016)

**LEFT BANK**

**RIGHT BANK**

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Pool | | 99.2 | 40.05 | 2.48 | 4.84 | 16.18 | 1 | 2.1 | 1124.1 | 1124.22 |



# South Muddy Creek

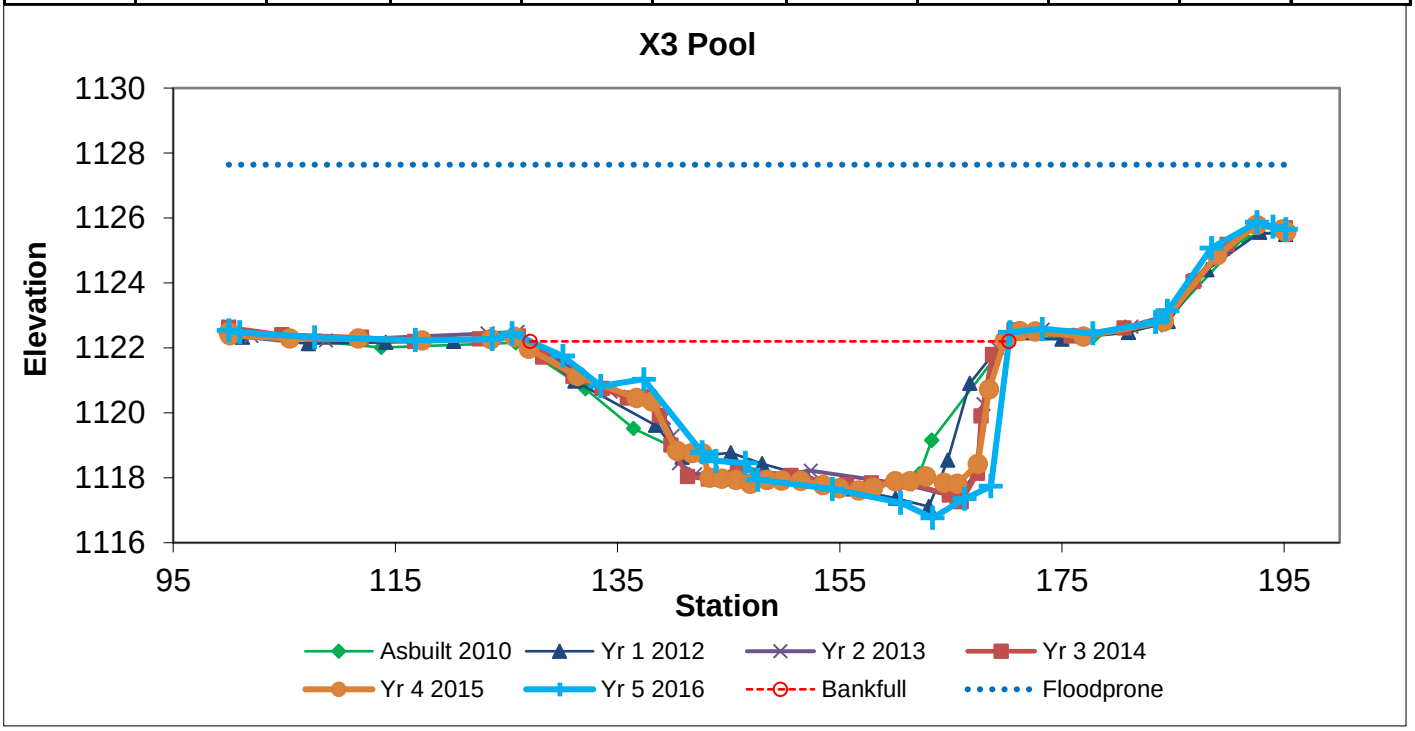
## Permanent Cross Section X3

(Year 5 Monitoring - October 2016)

**LEFT BANK**

**RIGHT BANK**

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Pool | | 142.7 | 43.09 | 3.31 | 5.44 | 13.01 | 1 | 2.2 | 1122.2 | 1122.45 |



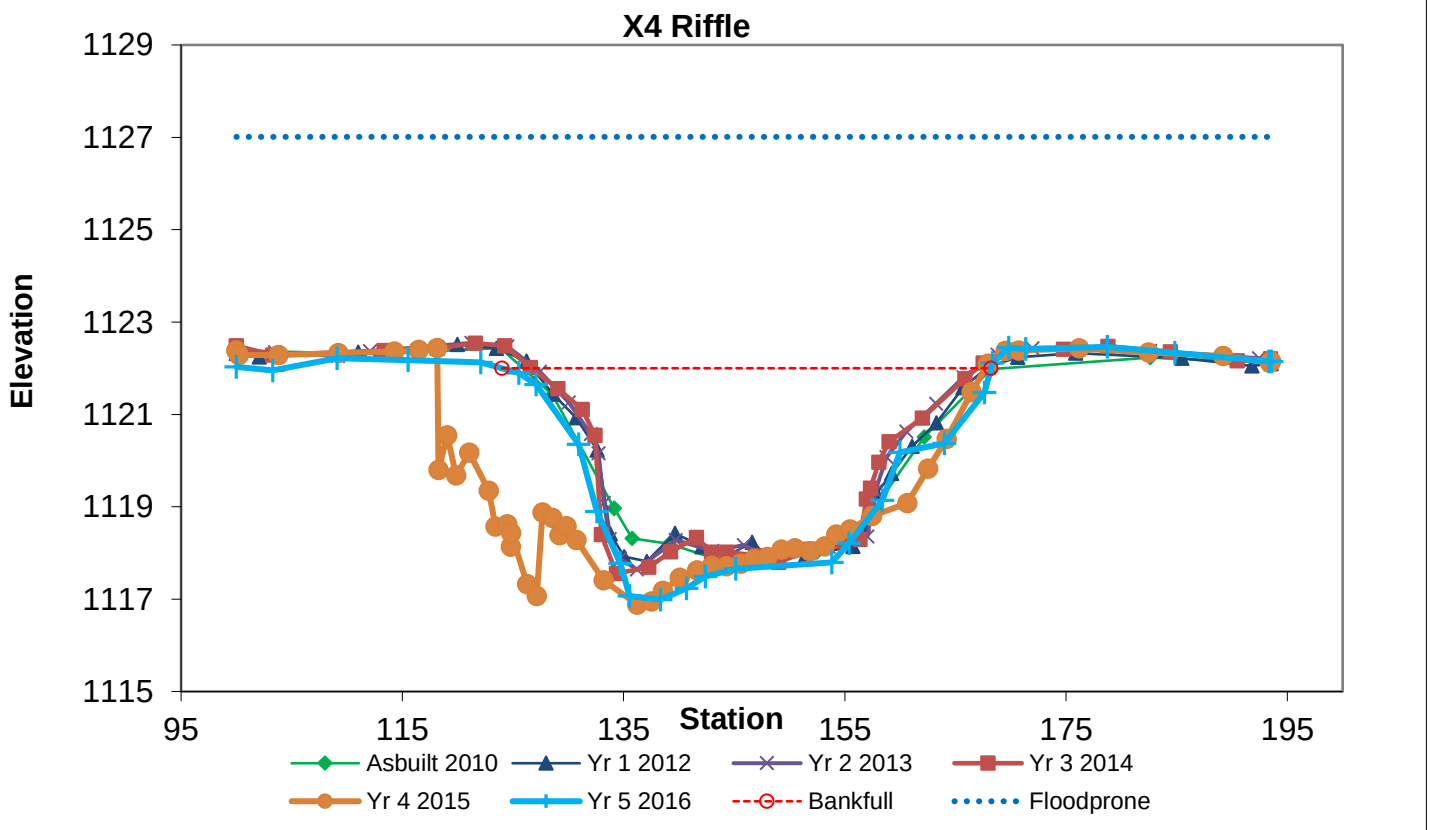
# South Muddy Creek

## Permanent Cross Section X4

(Year 5 Monitoring - October 2016)

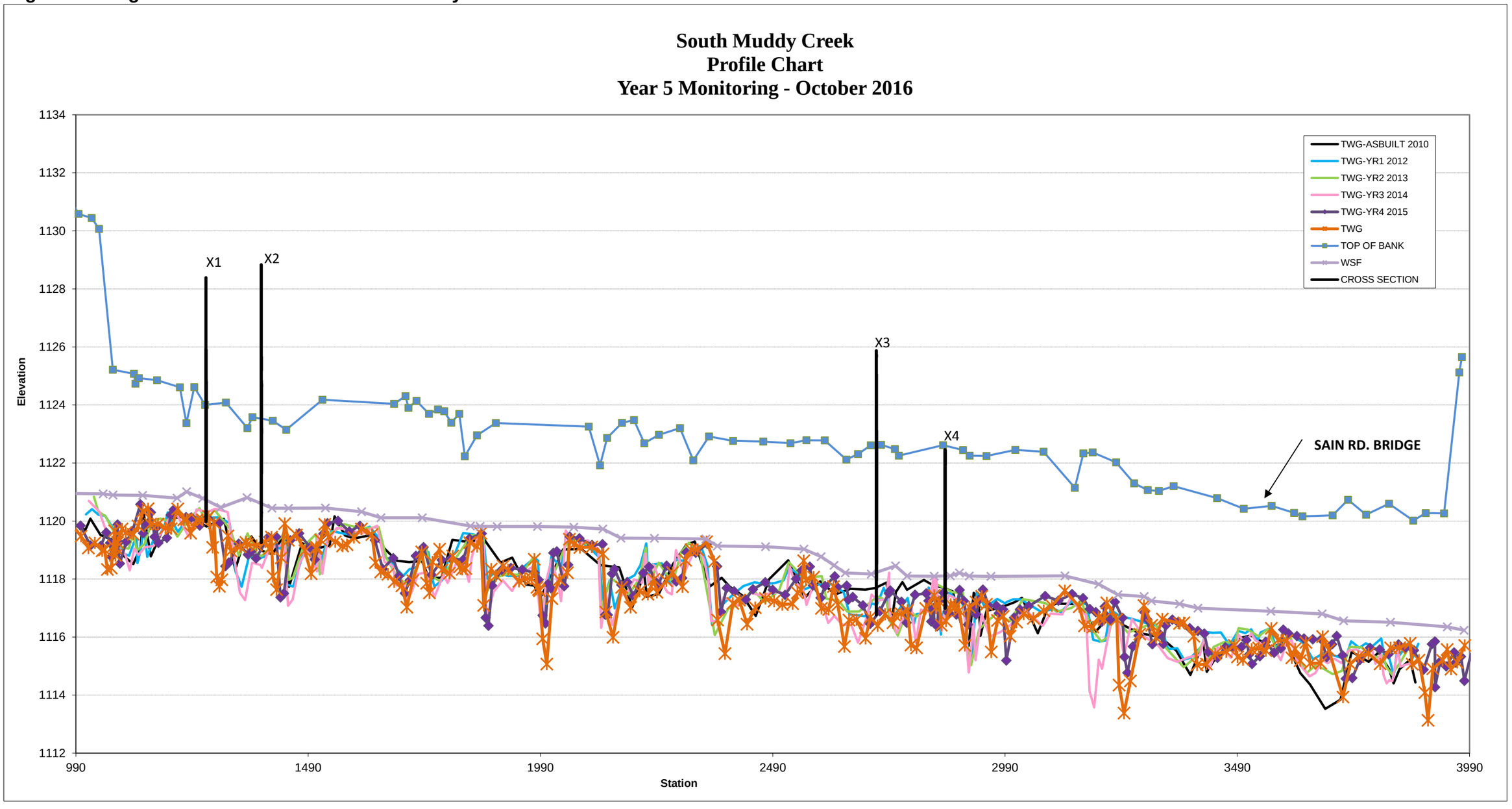
**LEFT BANK** **RIGHT BANK**

| Feature | Stream Type | BKF Area | BKF Width | BKF Depth | Max BKF Depth | W/D | BH Ratio | ER | BKF Elev | TOB Elev |
|---|---|---|---|---|---|---|---|---|---|---|
| Riffle | | 133.3 | 44.21 | 3.01 | 5.01 | 14.67 | 1 | 2.1 | 1122 | 1122.12 |




Note: Cross-section X4 was surveyed in September 2015 prior to the repairs, which were completed in November 2015.

**Figure 4. Longitudinal Profile with Annual Overlays**

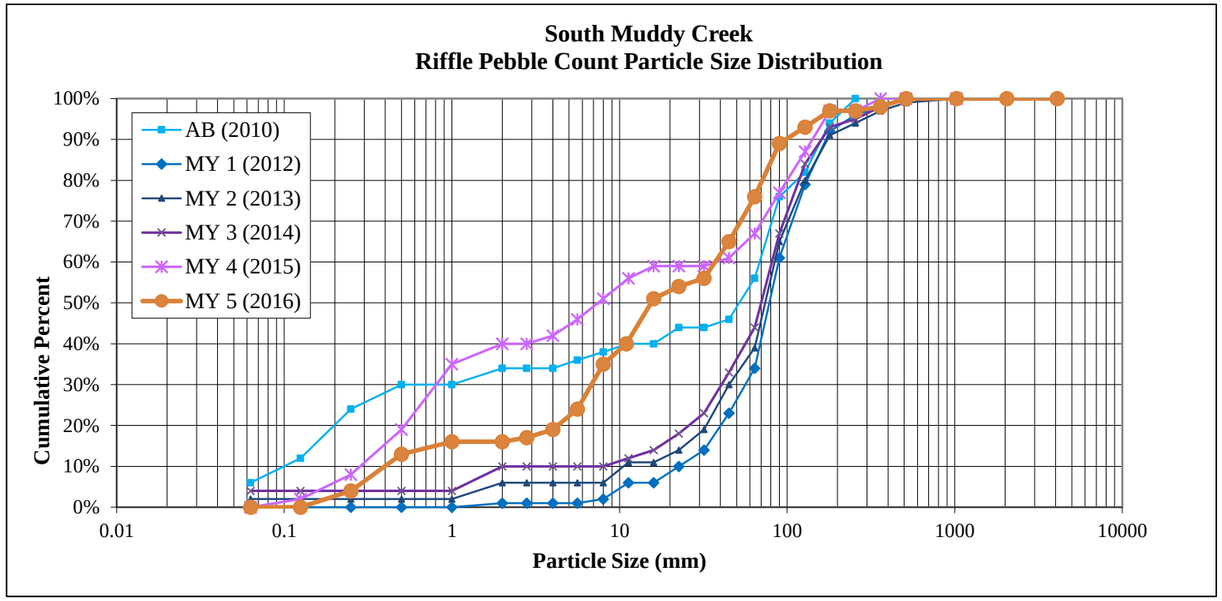


## Figure 5. Riffle Pebble Count Size Class Distribution with Annual Overlays

| | |
|---|---|
| BAKER PROJECT NO. | 128221 |
| SITE OR PROJECT: | South Muddy Creek Stream Restoration Project |
| REACH/LOCATION: | South Muddy Creek - Cross-section 4 (Riffle) |
| DATE COLLECTED: | 10/4/2016 |
| FIELD COLLECTION BY: | RM and KS |
| DATA ENTRY BY: | RM |

| | | | PARTICLE CLASS COUNT | Summary | |
|---|---|---|---|---|---|
| MATERIAL | PARTICLE | SIZE (mm) | Riffle | Class % | % Cum |
| SILT/CLAY | Silt / Clay | < .063 | | | 0% |
| SAND | Very Fine | .063 - .125 | | | 0% |
| | Fine | .125 - .25 | 4 | 4% | 4% |
| | Medium | .25 - .50 | 9 | 9% | 13% |
| | Coarse | .50 - 1.0 | 3 | 3% | 16% |
| | Very Coarse | 1.0 - 2.0 | | | 16% |
| GRAVEL | Very Fine | 2.0 - 2.8 | 1 | 1% | 17% |
| | Very Fine | 2.8 - 4.0 | 2 | 2% | 19% |
| | Fine | 4.0 - 5.6 | 5 | 5% | 24% |
| | Fine | 5.6 - 8.0 | 11 | 11% | 35% |
| | Medium | 8.0 - 11.0 | 5 | 5% | 40% |
| | Medium | 11.0 - 16.0 | 11 | 11% | 51% |
| | Coarse | 16.0 - 22.6 | 3 | 3% | 54% |
| | Coarse | 22.6 - 32 | 2 | 2% | 56% |
| | Very Coarse | 32 - 45 | 9 | 9% | 65% |
| | Very Coarse | 45 - 64 | 11 | 11% | 76% |
| COBBLE | Small | 64 - 90 | 13 | 13% | 89% |
| | Small | 90 - 128 | 4 | 4% | 93% |
| | Large | 128 - 180 | 4 | 4% | 97% |
| | Large | 180 - 256 | | | 97% |
| BOULDER | Small | 256 - 362 | 1 | 1% | 98% |
| | Small | 362 - 512 | 2 | 2% | 100% |
| | Medium | 512 - 1024 | | | 100% |
| | Large-Very Large | 1024 - 2048 | | | 100% |
| BEDROCK | Bedrock | > 2048 | | | 100% |
| | | Total | 100 | 100% | 100% |

| Cummulative | |
|---|---|
| Channel materials (mm) | |
| $D_{16}$ = | 2 |
| $D_{35}$ = | 8 |
| $D_{50}$ = | 15 |
| $D_{84}$ = | 79 |
| $D_{95}$ = | 152 |
| $D_{100}$ = | 362 - 512 |



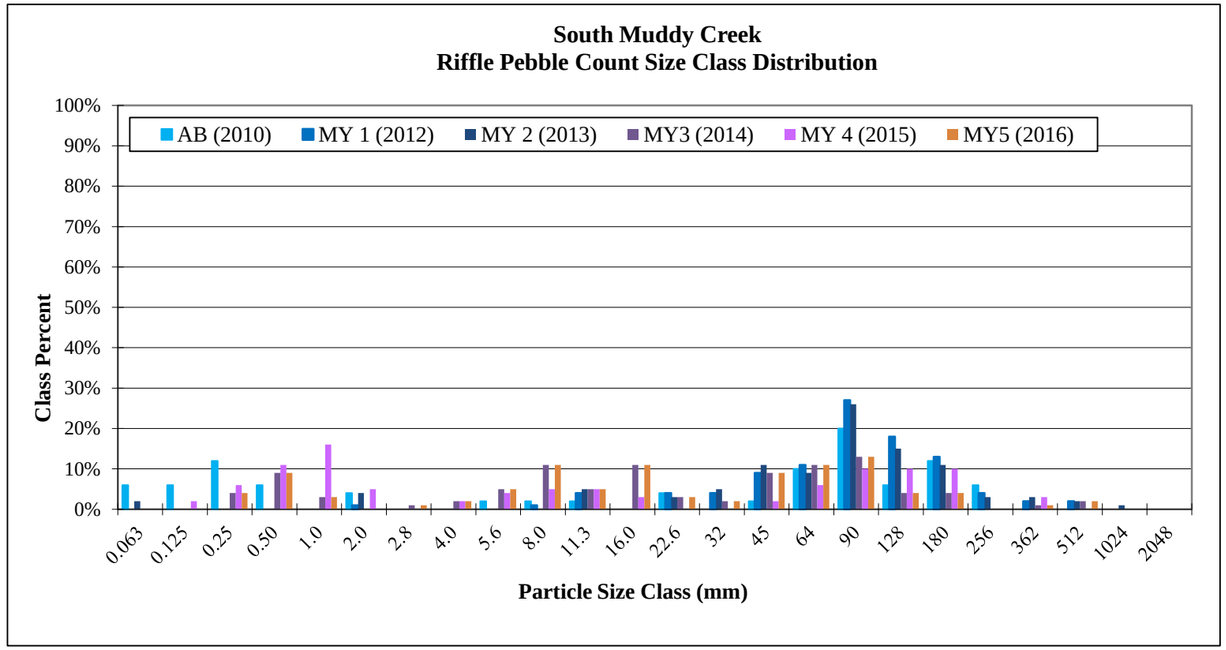



**Table 10. Baseline Stream Summary**
**South Muddy Creek Restoration Project: DMS Project No. 737**

| South Muddy Creek (2,787 LF) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **USGS Gauge** | **Regional Curve Interval (Harman et al, 1999)[1]** | | | **Pre-Existing Condition** | | | | | | **Reference Reach(es) Data** | | | | | | | | | | | | **Design** | | | | | | **Monitoring Baseline (As-built)** | | | | | |
| | | | | | | | | | | | **Morgan Creek** | | | | | | **Barnes Creek** | | | | | | | | | | | | | | | | | |
| | | LL | UL | Eq. | Min | Mean | Med | Max | SD | n | Min | Mean | Med | Max | SD | n | Min | Mean | Med | Max | SD | n | Min | Mean | Med | Max | SD | n | Min | Mean | Med | Max | SD | n |
| **Dimension and Substrate - Riffle** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| BF Width (ft) | ----- | 23.0 | 80.0 | 42.0 | 24.1 | 32.3 | ----- | 51.2 | ----- | 5 | 33.2 | ----- | ----- | 33.5 | ----- | 2 | 60.7 | ----- | ----- | 69 | ----- | 2 | ----- | 43.2 | ----- | ----- | ----- | 1 | 41.4 | ----- | ----- | 42.2 | ----- | 2 |
| Floodprone Width (ft) | ----- | ----- | ----- | ----- | 29.6 | 44.8 | ----- | 72.7 | ----- | 5 | 77.5 | ----- | ----- | 86.8 | ----- | 2 | 219 | ----- | ----- | 220 | ----- | 2 | ----- | 210+ | ----- | ----- | ----- | 1 | 90.7 | ----- | ----- | 93.6 | ----- | 2 |
| BF Mean Depth (ft) | ----- | 2.3 | 5.8 | 3.8 | 1.9 | 2.7 | ----- | 3.0 | ----- | 5 | 2.3 | ----- | ----- | 2.4 | ----- | 2 | 2.9 | ----- | ----- | 3.8 | ----- | 2 | ----- | 3.0 | ----- | ----- | ----- | 1 | 2.7 | ----- | ----- | 2.8 | ----- | 2 |
| BF Max Depth (ft) | ----- | ----- | ----- | ----- | 3.3 | 3.6 | ----- | 4.0 | ----- | 5 | 2.8 | ----- | ----- | 2.9 | ----- | 2 | 3.9 | ----- | ----- | 5.2 | ----- | 2 | ----- | 4.2 | ----- | ----- | ----- | 1 | 4.2 | ----- | ----- | 4.4 | ----- | 2 |
| BF Cross-sectional Area ($ft^2$) | ----- | 80.0 | 300.0 | 157.6 | 72.8 | 83.8 | ----- | 97.2 | ----- | 5 | 75.1 | ----- | ----- | 79.8 | ----- | 2 | 199 | ----- | ----- | 288 | ----- | 2 | ----- | 128.5 | ----- | ----- | ----- | 1 | 110.8 | ----- | ----- | 115.9 | ----- | 2 |
| Width/Depth Ratio | ----- | ----- | ----- | ----- | 8.1 | 12.9 | ----- | 26.9 | ----- | 5 | 14.1 | ----- | ----- | 14.7 | ----- | 2 | 16 | ----- | ----- | 23.8 | ----- | 2 | ----- | 14.4 | ----- | ----- | ----- | 1 | 15.4 | ----- | ----- | 15.5 | ----- | 2 |
| Entrenchment Ratio | ----- | ----- | ----- | ----- | 1.1 | 1.4 | ----- | 1.7 | ----- | 5 | 2.3 | ----- | ----- | 2.6 | ----- | 2 | 3.2 | ----- | ----- | 3.6 | ----- | 2 | ----- | 4.9+ | ----- | ----- | ----- | 1 | 2.2 | ----- | ----- | 2.2 | ----- | 2 |
| Bank Height Ratio | ----- | ----- | ----- | ----- | 2.4 | 2.8 | ----- | 2.8 | ----- | 5+ | ----- | 1.0 | ----- | ----- | ----- | 2 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 1.0 | ----- | ----- | ----- | 1 | 1.0 | ----- | ----- | 1.0 | ----- | 2 |
| d50 (mm) | ----- | ----- | ----- | ----- | ----- | 4.0 | ----- | ----- | ----- | 1 | ----- | 3.0 | ----- | ----- | ----- | 1 | ----- | 60 | ----- | ----- | ----- | 1 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Pattern** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Channel Beltwidth (ft) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 128.0 | ----- | ----- | 209.0 | ----- | 9 | 143.0 | 168.3 | 164.0 | 244.0 | 32.2 | 8 |
| Radius of Curvature (ft) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 84.0 | ----- | ----- | 138.0 | ----- | 9 | 96.0 | 121.2 | 114.0 | 152.0 | 18.9 | 9 |
| Rc:Bankfull width (ft/ft) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 1.9 | ----- | ----- | 3.2 | ----- | 9 | 2.3 | 2.9 | 2.7 | 3.6 | 0.5 | 9 |
| Meander Wavelength (ft) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 345.0 | ----- | ----- | 506.0 | ----- | 6 | 387.0 | 400.8 | 396.5 | 418.0 | 12.9 | 6 |
| Meander Width Ratio | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 3.0 | ----- | ----- | 4.8 | ----- | 9 | 3.4 | 4.0 | 3.9 | 5.8 | 0.8 | 8 |
| **Profile** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Riffle Length (ft) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 61 | 80 | 88 | 122 | 23 | 3 |
| Riffle Slope (ft/ft) | ----- | ----- | ----- | ----- | 0.003 | 0.004 | ----- | 0.006 | ----- | 3 | 0.01 | ----- | ----- | 0.02 | ----- | 2 | | ----- | ----- | ----- | ----- | ----- | 0.0034 | ----- | ----- | 0.0054 | ----- | 7 | 0.000 | 0.006 | 0.005 | 0.011 | 0.004 | 3 |
| Pool Length (ft) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Pool Spacing (ft) | ----- | ----- | ----- | ----- | 80 | 163 | ----- | 240 | ----- | 4 | 46 | ----- | ----- | 277 | ----- | 2 | | ----- | ----- | ----- | ----- | ----- | 154.0 | ----- | ----- | 327.0 | ----- | 10 | 167 | 272 | 257 | 335 | 53 | 3 |
| Pool Max Depth (ft) | ----- | ----- | ----- | ----- | 3.8 | 4.8 | ----- | 5.8 | ----- | 4 | ----- | 4.1 | ----- | ----- | ----- | 1 | ----- | ----- | ----- | ----- | ----- | ----- | 6.2 | ----- | ----- | 10.3 | ----- | 11 | | ----- | ----- | ----- | ----- | ----- |
| Pool Volume ($ft^3$) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Substrate and Transport Parameters** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Ri% / Ru% / P% / G% / S% | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ---- |
| SC% / Sa% / G% / B% / Be% | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ---- |
| d16 / d35 / d50 / d84 / d95 | ----- | ----- | ----- | ----- | | | <0.06 / 0.2 / 4 / 25 / 44 | | | | | | N/A / 1.2 / 3 / 77 / 800 | | | | | | 0.4 / 11 / 60 / 512 / >2048 | | | | ----- | ----- | ----- | ----- | ----- | ----- | | | 0.15 / 5 / 52 / 135 / 190 | | | |
| Reach Shear Stress (competency) lb/$ft^2$ | ----- | ----- | ----- | ----- | 0.18 | ----- | ----- | 0.3 | ----- | 5 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 0.28 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Max part size (mm) mobilized at bankfull (Rosgen Curve) | ----- | ----- | ----- | ----- | ----- | 95.0 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 90.0 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Stream Power (transport capacity) W/$m^2$ | ----- | ----- | ----- | ----- | 10.8 | ----- | ----- | 24 | ----- | 5 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 12.6 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Additional Reach Parameters** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Drainage Area (SM) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 18.8 | ----- | ----- | ----- | ----- | ----- | 8.4 | ----- | ----- | ----- | ----- | ----- | 23.0 | ----- | ----- | ----- | ----- | ----- | 18.8 | ----- | ----- | ----- | ----- | ----- | 18.8 | ----- | ----- |
| Impervious cover estimate (%) | ----- | ----- | ----- | ----- | | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Rosgen Classification | ----- | ----- | ----- | ----- | ----- | G4c | ----- | ----- | ----- | ----- | ----- | C4 | ----- | ----- | ----- | ----- | ----- | C4 | ----- | ----- | ----- | ----- | ----- | C4 | ----- | ----- | ----- | ----- | ----- | C5 | ----- | ----- | ----- | ----- |
| BF Velocity (fps) | ----- | ----- | ----- | ----- | 4.1 | ----- | ----- | 5.5 | ----- | 5 | ----- | 7 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 3.1 | ----- | ----- | ----- | ----- | ----- | 3.0 | ----- | ----- | ----- | ----- |
| BF Discharge (cfs) | ----- | 290.0 | 2000.0 | 741.1 | ----- | 400 | ----- | ----- | ----- | ----- | ----- | 524.0 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 400.0 | ----- | ----- | ----- | ----- | ----- | 340.0 | ----- | ----- | ----- | ----- |
| Valley Length | ----- | ----- | ----- | ----- | | 2446 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 2409 | ----- | ----- | ----- | ----- |
| Channel length (ft) | ----- | ----- | ----- | ----- | ----- | 2593 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 2842 | ----- | ----- | ----- | ----- | ----- | 2787 | ----- | ----- | ----- | ----- |
| Sinuosity | ----- | ----- | ----- | ----- | ----- | 1.06 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 1.20 | ----- | ----- | ----- | ----- | ----- | 1.18 | ----- | ----- | ----- | ----- |
| Water Surface Slope (Channel) (ft/ft) | ----- | ----- | ----- | ----- | | 0.0016 | ----- | ----- | ----- | ----- | ----- | 0.0070 | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | 0.0017 | ----- | ----- | ----- | ----- | ----- | 0.0016 | ----- | ----- | ----- | ----- |
| BF slope (ft/ft) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Bankfull Floodplain Area (acres) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| BEHI VL% / L% / M% / H% / VH% / E% | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Channel Stability or Habitat Metric | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Biological or Other | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |

* Harman, W.A., G.D. Jennings, J.M. Patterson, D.R. Clinton, L.O. Slate, A.G. Jessup, J.R. Everhart, and R.E. Smith. 1999. Bankfull hydraulic geometry relationships for North Carolina streams. Wildland Hydrology. AWRA Symposium Proceedings. D.S. Olsen and J.P. Potyondy, eds. American Water Resources Association. June 30-July 2, 1999. Bozeman, MT.

**Table 11a. Cross-section Morphology Data Table**
**South Muddy Creek Restoration Project: DMS Project No. 737**

| South Muddy Creek (2,787 LF) | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| | Cross-section 1 (Riffle) | | | | | | Cross-section 2 (Pool) | | | | | | Cross-section 3 (Pool) | | | | | | Cross-section 4 (Riffle) | | | | | |
| **Dimension and substrate** | Base | MY1 | MY2 | MY3 | MY4 | MY5 | Base | MY1 | MY2 | MY3 | MY4 | MY5 | Base | MY1 | MY2 | MY3 | MY4 | MY5 | Base | MY1 | MY2 | MY3 | MY4* | MY5 |
| **Based on fixed baseline bankfull elevation** | | | | | | | | | | | | | | | | | | | | | | | | |
| Record Elevation (Datum) Used (ft) | 1124.2 | 1124.2 | 1124.2 | 1124.2 | 1124.2 | 1124.2 | 1124.1 | 1124.1 | 1124.1 | 1124.1 | 1124.1 | 1124.1 | 1122.2 | 1122.2 | 1122.2 | 1122.2 | 1122.2 | 1122.2 | 1122.0 | 1122.0 | 1122.0 | 1122.0 | 1122.0 | 1122.0 |
| BF Width (ft) | 41.4 | 40.8 | 42.9 | 41.7 | 37.8 | 39.4 | 42.1 | 43.1 | 43.5 | 42.3 | 42.7 | 40.1 | 44.2 | 43.1 | 42.5 | 43.2 | 43.4 | 43.1 | 42.2 | 40.9 | 39.9 | 40.3 | 49.5 | 44.2 |
| BF Mean Depth (ft) | 2.7 | 2.5 | 2.4 | 2.4 | 2.4 | 2.5 | 2.8 | 2.7 | 2.5 | 2.8 | 2.5 | 2.5 | 2.9 | 3.0 | 3.2 | 3.2 | 3.1 | 3.3 | 2.8 | 2.8 | 2.8 | 2.8 | 3.5 | 3.0 |
| Width/Depth Ratio | 15.5 | 16.5 | 18.2 | 17.4 | 15.8 | 16.0 | 15.3 | 16.0 | 17.2 | 15.3 | 17.4 | 16.2 | 15.4 | 14.4 | 13.4 | 13.5 | 13.9 | 13.0 | 15.4 | 14.8 | 14.3 | 14.6 | 14.3 | 14.7 |
| BF Cross-sectional Area ($ft^2$) | 110.8 | 100.5 | 101.1 | 100.0 | 90.5 | 97.1 | 115.8 | 115.8 | 109.8 | 116.9 | 104.9 | 99.2 | 126.5 | 129.0 | 134.8 | 137.8 | 135.6 | 142.7 | 115.9 | 113.3 | 111 | 111.5 | 171.2 | 133.3 |
| BF Max Depth (ft) | 4.4 | 4.1 | 4.3 | 4.2 | 4.1 | 4.2 | 5.1 | 5.4 | 5.3 | 5.73 | 5.2 | 4.8 | 4.5 | 5.1 | 4.8 | 4.9 | 4.6 | 5.4 | 4.2 | 4.2 | 4.4 | 4.4 | 5.1 | 5.0 |
| Width of Floodprone Area (ft) | 90.7 | 89.8 | 90.7 | 90.6 | 89.0 | 90.8 | 85.6 | 85.9 | 85.8 | 85.7 | 85.8 | 85.8 | 95.3 | 95.1 | 95.2 | 95.1 | 95.2 | 95.2 | 93.6 | 93.5 | 93.5 | 93.5 | 93.5 | 93.6 |
| Entrenchment Ratio | 2.2 | 2.2 | 2.1 | 2.2 | 2.4 | 2.3 | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | N/A | 2.2 | 2.3 | 2.3 | 2.3 | 1.9 | 2.1 |
| Bank Height Ratio | 1.0 | 1.0 | 1.1 | 1.1 | 1.0 | 1.0 | 1.0 | 1.1 | 1.0 | 1.0 | 1.1 | 1.0 | 1.0 | 1.0 | 1.1 | 1.0 | 1.0 | 1.0 | 1.0 | 1.0 | 1.1 | 1 | 1.1 | 1.0 |
| Wetted Perimeter (ft) | 46.8 | 45.7 | 47.6 | 46.5 | 42.6 | 44.3 | 47.6 | 48.4 | 48.6 | 47.8 | 47.6 | 45.0 | 49.9 | 49.1 | 48.8 | 49.6 | 49.7 | 49.7 | 47.7 | 46.4 | 45.5 | 45.9 | 56.4 | 50.2 |
| Hydraulic Radius (ft) | 2.4 | 2.2 | 2.1 | 2.1 | 2.1 | 2.2 | 2.4 | 2.4 | 2.3 | 2.4 | 2.2 | 2.2 | 2.5 | 2.6 | 2.8 | 2.8 | 2.7 | 2.9 | 2.4 | 2.4 | 2.4 | 2.4 | 3.0 | 2.7 |

* MY4 Cross-section X4 is located where the damage from the beaver dam was located, and was surveyed prior to the completion of the repair that was completed in November 2015.

**Table 11b. Baseline Stream Summary**
**South Muddy Creek Restoration Project: DMS Project No. 737**

| South Muddy Creek (2,787 LF) | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| **Parameter** | **Monitoring Baseline (As-built)** | | | | | | **MY-1** | | | | | | **MY-2** | | | | | | **MY-3** | | | | | | **MY-4** | | | | | | **MY-5** | | | | | |
| **Dimension and Substrate - Riffle** | Min | Mean | Med | Max | SD | n | Min | Mean | Med | Max | SD | n | Min | Mean | Med | Max | SD | n | Min | Mean | Med | Max | SD | n | Min | Mean | Med | Max | SD | n | Min | Mean | Med | Max | SD | n |
| BF Width (ft) | 41.4 | ----- | ----- | 42.2 | ----- | 2 | 40.8 | ----- | ----- | 40.9 | ----- | 2 | 39.9 | ----- | ----- | 42.9 | ----- | 2 | 40.3 | ----- | ----- | 41.7 | ----- | 2 | 37.8 | ----- | ----- | 49.5 | ----- | 2 | 39.4 | ----- | ----- | 44.2 | ----- | 2 |
| Floodprone Width (ft) | 90.7 | ----- | ----- | 93.6 | ----- | 2 | 89.8 | ----- | ----- | 93.5 | ----- | 2 | 90.7 | ----- | ----- | 93.5 | ----- | 2 | 90.6 | ----- | ----- | 93.5 | ----- | 2 | 89.0 | ----- | ----- | 93.5 | ----- | 2 | 90.8 | ----- | ----- | 93.6 | ----- | 2 |
| BF Mean Depth (ft) | 2.7 | ----- | ----- | 2.8 | ----- | 2 | 2.5 | ----- | ----- | 2.8 | ----- | 2 | 2.4 | ----- | ----- | 2.8 | ----- | 2 | 2.4 | ----- | ----- | 2.8 | ----- | 2 | 2.4 | ----- | ----- | 3.5 | ----- | 2 | 2.5 | ----- | ----- | 3.0 | ----- | 2 |
| BF Max Depth (ft) | 4.2 | ----- | ----- | 4.4 | ----- | 2 | 4.1 | ----- | ----- | 4.2 | ----- | 2 | 4.3 | ----- | ----- | 4.4 | ----- | 2 | 4.2 | ----- | ----- | 4.4 | ----- | 2 | 4.1 | ----- | ----- | 5.1 | ----- | 2 | 4.2 | ----- | ----- | 5.0 | ----- | 2 |
| BF Cross-sectional Area (ft²) | 110.8 | ----- | ----- | 115.9 | ----- | 2 | 100.5 | ----- | ----- | 113.3 | ----- | 2 | 101.1 | ----- | ----- | 111 | ----- | 2 | 100.0 | ----- | ----- | 111.5 | ----- | 2 | 90.5 | ----- | ----- | 171.2 | ----- | 2 | 97.1 | ----- | ----- | 133.3 | ----- | 2 |
| Width/Depth Ratio | 15.4 | ----- | ----- | 15.5 | ----- | 2 | 14.8 | ----- | ----- | 16.5 | ----- | 2 | 14.3 | ----- | ----- | 18.2 | ----- | 2 | 14.6 | ----- | ----- | 17.4 | ----- | 2 | 14.3 | ----- | ----- | 15.8 | ----- | 2 | 14.7 | ----- | ----- | 16.0 | ----- | 2 |
| Entrenchment Ratio | 2.2 | ----- | ----- | 2.2 | ----- | 2 | 2.2 | ----- | ----- | 2.3 | ----- | 2 | 2.1 | ----- | ----- | 2.3 | ----- | 2 | 2.2 | ----- | ----- | 2.3 | ----- | 2 | 1.9 | ----- | ----- | 2.4 | ----- | 2 | 2.1 | ----- | ----- | 2.3 | ----- | 2 |
| Bank Height Ratio | 1.0 | ----- | ----- | 1.0 | ----- | 2 | 1.0 | ----- | ----- | 1.0 | ----- | 2 | 1.1 | ----- | ----- | 1.1 | ----- | 2 | 1 | ----- | ----- | 1.1 | ----- | 2 | 1.0 | ----- | ----- | 1.1 | ----- | 2 | 1.0 | ----- | ----- | 1.0 | ----- | 2 |
| **Pattern** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Channel Beltwidth (ft) | 143.0 | 168.3 | 164.0 | 244.0 | 32.2 | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Radius of Curvature (ft) | 96.0 | 121.2 | 114.0 | 152.0 | 18.9 | 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Rc:Bankfull width (ft/ft) | 2.3 | 2.9 | 2.7 | 3.6 | 0.5 | 9 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Meander Wavelength (ft) | 387.0 | 400.8 | 396.5 | 418.0 | 12.9 | 6 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Meander Width Ratio | 3.4 | 4.0 | 3.9 | 5.8 | 0.8 | 8 | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| **Profile** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Riffle Length (ft) | 61 | 80 | 88 | 122 | 23 | 3 | 72 | 101 | 98 | 133 | 31 | 3 | 71 | 101 | 106 | 125 | 27 | 3 | 70 | 97 | 91 | 131 | 31 | 3 | 66 | 86 | 81 | 109 | 15 | 9 | 25 | 87 | 95 | 157 | 40 | 10 |
| Riffle Slope (ft/ft) | 0.000 | 0.006 | 0.005 | 0.011 | 0.004 | 3 | 0.002 | 0.005 | 0.005 | 0.009 | 0.004 | 3 | 0.003 | 0.006 | 0.005 | 0.009 | 0.003 | 3 | 0.002 | 0.006 | 0.005 | 0.009 | 0.004 | 3 | 0.003 | 0.006 | 0.005 | 0.008 | 0.002 | 9 | 0.002 | 0.006 | 0.005 | 0.010 | 0.003 | 10 |
| Pool Length (ft) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Pool Spacing (ft) | 167 | 272 | 257 | 335 | 53 | 3 | 209 | 251 | 253 | 290 | 41 | 3 | 219 | 255 | 262 | 285 | 34 | 3 | 204 | 251 | 257 | 293 | 45 | 3 | 119 | 220 | 238 | 321 | 69 | 12 | 142 | 221 | 206 | 341 | 63 | 13 |
| Pool Max Depth (ft) | | ----- | ----- | | ----- | ----- | | ----- | ----- | | ----- | ----- | | ----- | ----- | | ----- | ----- | | ----- | ----- | | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Substrate and Transport Parameters** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| d16 / d35 / d50 / d84 / d95 | | | 0.15 / 5 / 52 / 135 / 190 | | | | | | 34.5 / 64.8/78.3 / 145.9 / 234.4 | | | | | | | | 26.0 / 54.7 / 73.9 / 144.9 / 287.3 | | | | | | | | 24.2 / 52.6 / 74.2 / 154.1 / 304.4 | | | | | | | | 0.4 / 1.0 / 7.5 / 125.0 / 165.0 | | | | | | | | 2.0 / 8.0 / 15.5 / 78.9 / 151.8 / 362.0 - 512.0 | | | | | |
| Reach Shear Stress (competency) lb/f² | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| Stream Power (transport capacity) W/m² | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |
| **Additional Reach Parameters** | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | | |
| Drainage Area (SM) | ----- | ----- | ----- | 18.8 | ----- | ----- | ----- | ----- | ----- | 18.8 | ----- | ----- | ----- | ----- | ----- | 18.8 | ----- | ----- | ----- | ----- | ----- | 18.8 | ----- | ----- | ----- | ----- | ----- | 18.8 | ----- | ----- | ----- | ----- | ----- | 18.8 | ----- | ----- |
| Rosgen Classification | ----- | C5 | ----- | ----- | ----- | ----- | ----- | C5 | ----- | ----- | ----- | ----- | ----- | C5 | ----- | ----- | ----- | ----- | ----- | C5 | ----- | ----- | ----- | ----- | ----- | C4* | ----- | ----- | ----- | ----- | ----- | C4 | ----- | ----- | ----- | ----- |
| BF Velocity (fps) | ----- | 3.0 | ----- | ----- | ----- | ----- | ----- | 3.0 | ----- | ----- | ----- | ----- | ----- | 3.0 | ----- | ----- | ----- | ----- | ----- | 3.0 | ----- | ----- | ----- | ----- | ----- | 3.0 | ----- | ----- | ----- | ----- | ----- | 3.0 | ----- | ----- | ----- | ----- |
| BF Discharge (cfs) | ----- | 340.0 | ----- | ----- | ----- | ----- | ----- | 318.0 | ----- | ----- | ----- | ----- | ----- | 318.0 | ----- | ----- | ----- | ----- | ----- | 318.0 | | ----- | ----- | ----- | ----- | 392.6 | ----- | ----- | ----- | ----- | ----- | 345.5 | ----- | ----- | ----- | ----- |
| Valley Length | ----- | 2409 | ----- | ----- | ----- | ----- | ----- | 2409 | ----- | ----- | ----- | ----- | ----- | 2409 | ----- | ----- | ----- | ----- | ----- | 2409 | ----- | ----- | ----- | ----- | ----- | 2409 | ----- | ----- | ----- | ----- | ----- | 2409 | ----- | ----- | ----- | ----- |
| Channel length (ft) | ----- | 2787 | ----- | ----- | ----- | ----- | ----- | 2787 | ----- | ----- | ----- | ----- | ----- | 2787 | ----- | ----- | ----- | ----- | ----- | 2787 | ----- | ----- | ----- | ----- | ----- | 2864 | ----- | ----- | ----- | ----- | ----- | 3088 | ----- | ----- | ----- | ----- |
| Sinuosity | ----- | 1.18 | ----- | ----- | ----- | ----- | ----- | 1.18 | ----- | ----- | ----- | ----- | ----- | 1.18 | ----- | ----- | ----- | ----- | ----- | 1.18 | ----- | ----- | ----- | ----- | ----- | 1.28 | ----- | ----- | ----- | ----- | ----- | 1.27 | ----- | ----- | ----- | ----- |
| Water Surface Slope (Channel) (ft/ft) | ----- | 0.0016 | ----- | ----- | ----- | ----- | ----- | 0.0016 | ----- | ----- | ----- | ----- | ----- | 0.0016 | ----- | ----- | ----- | ----- | ----- | 0.0016 | ----- | ----- | ----- | ----- | ----- | 0.0017 | ----- | ----- | ----- | ----- | ----- | 0.0016 | ----- | ----- | ----- | ----- |
| BF slope (ft/ft) | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- | ----- |

*Rosgen Classification was revised for MY4 to reflect stream type after maintenance work was completed.

# APPENDIX E

## HYDROLOGIC DATA

| Table 12. Verification of Bankfull Events<br>South Muddy Creek Restoration Project: Project No. 737 | | | | |
|---|---|---|---|---|
| Location | Date of Data Collection | Date of Occurence of Bankfull Event | Method of Data Collection | Gage Height (feet) |
| South Muddy (Station 22+00) | 5/18/2012 | Unknown | Crest Gauge | 0.13 |
| South Muddy (Station 22+00) | 5/11/2015 | Unknown | Crest Gauge | 1.00 |
| South Muddy (Station 22+00) | 11/16/2015 | Unknown | Crest Gauge | 1.08 |
| South Muddy (Station 22+00) | 10/4/2016 | Unknown | Crest Gauge | 0.25 |

# South Muddy Creek
# Bankfull Photo Documentation

# South Muddy Creek – Bankfull Photolog

Crest Gauge Photo (10/04/16)